Adopted by the TCEQ: June 13, 2007
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Seventeen Total Maximum Daily Loads for Bacteria, Dissolved Oxygen, and pH in Adams Bayou, Cow Bayou, and Their Tributaries

For Segment Numbers 0508, 0508A, 0508B, 0508C, 0511, 0511A, 0511B, 0511C, and 0511E

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This TMDL document is based in large part on the following technical reports prepared by Parsons Inc.:

- "Water Quality Modeling of Adams and Cow Bayous: WASP Model Report" (Parsons 2006)
- "Nonpoint Source Modeling of the Watersheds of Adams and Cow Bayous: HSPF Model Report" (Parsons 2006)

Contents

Figures

Tables

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Executive Summary

This document describes total maximum daily loads for bacteria, dissolved oxygen and pH in the tidal and above-tidal portions of Adams and Cow Bayous, Hudson Gully, Gum Gully, Cole Creek, Terry Gulley, and Coon Bayou (Segments 0508, 0508A, 0508B, 0508C, 0511, 0511A, 0511B, 0511C, and 0511E). Adams and Cow Bayous and their tributaries are a mixture of above-tidal and tidally influenced bayous, with a 244-square-mile watershed. Uses were identified as impaired in the 2004 *Texas Water Quality Inventory and 303(d) List*. Concentrations of dissolved oxygen are lower than the criterion to support the aquatic life use in eight segments, and concentrations of bacteria do not support the contact recreation use in eight segments. In one segment, there is an impairment to the general use due to low pH.

The sources of pollution contributing to the impairments in Adams and Cow Bayous and their tributaries are a combination of point and nonpoint sources. Sources include municipal wastewater treatment facilities (WWTFs), failing onsite sewage facilities (OSSFs), and other nonpoint pollution.

Based on existing loadings for Adams Bayou, both tidal and above tidal, and its tributaries, meeting the water quality standard would require a 56 percent reduction of the constituents that contribute to the dissolved oxygen impairment. A 62 percent reduction in bacterial loading is required for Adams Bayou, both tidal and above tidal, and its tributaries, to comply with the *Escherichia coli* (*E. coli*) criterion. Based on existing loadings for Cow Bayou, both tidal and above tidal, and its tributaries, compliance with the water quality standards would require a 48 percent reduction of the constituents that contribute to the dissolved oxygen impairment. The reduction required for attainment of the dissolved oxygen standard will eliminate the pH impairment. A 52 percent reduction in bacterial loading is required for Cow Bayou, both tidal and above tidal, and its tributaries, to comply with the *E. coli* criterion.

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 total maximum daily load (TMDL) for each pollutant that contributes to the impairment of a listed water body. The Texas Commission on Environmental Quality (TCEQ) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

In simple terms, a TMDL is like a budget that determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. In other words, TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time, but may be expressed in other ways. TMDLs must also estimate how much the pollutant load must be reduced from current levels in order to achieve water quality standards.

The TMDL Program is a major component of Texas' overall process for managing surface water quality. 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, contact recreation, support of aquatic life, or fish consumption—of impaired or threatened water bodies.

This report describes a total of 17 TMDLs:

- Eight TMDLs address impairments to the contact recreation use due to elevated fecal coliform in Adams Bayou Tidal, Adams Bayou Above Tidal, Gum Gully, Hudson Gully, Cow Bayou Tidal, Coon Bayou, Cole Creek, and Terry Gully.
- Eight TMDLs address impairments to the aquatic life use due to low dissolved oxygen in Adams Bayou Tidal, Adams Bayou Above Tidal, Gum Gully, Hudson Gully, Cow Bayou Tidal, Cow Bayou Above Tidal, Coon Bayou, and Cole Creek.
- One TMDL addresses an impairment to general uses from low pH in Cow Bayou Tidal.

Section 303(d) of the Clean Water Act and the implementing regulations of the U.S. Environmental Protection Agency (EPA) (Title 40 Code, of Federal Regulations, Part 130) describe the statutory and regulatory requirements for acceptable TMDLs. The EPA provides further direction for developing TMDLs in its *Guidance for Water Quality-Based Decisions: The TMDL Process* (USEPA 1991). This TMDL document has been prepared in accordance with those regulations and guidelines. 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
- Margin of Safety
- Pollutant Load Allocation
- Seasonal Variation
- Public Participation
- Implementation and Reasonable Assurance

The commission adopted this document on June 13, 2007. Upon EPA approval, the TMDL will become an update to the state's Water Quality Management Plan.

Problem Definition

Adams Bayou was first added to the Texas 303(d) List in 1996 because it did not support the aquatic life use due to low dissolved oxygen concentrations, nor the contact recreation use due to elevated fecal coliform concentrations. The report cited “sluggish flow coupled with organic loading” from municipal and industrial sources as contributing to the impairment.

The Sabine River Authority of Texas (SRA-TX) conducted water quality surveys on Adams and Cow Bayous and their tributaries, summarizing their findings in two reports released in 1999. The data from these studies were used by the TCEQ in compiling the 2000 *Texas Water Quality Inventory and 303(d) List* (TCEQ 2000). Adams Bayou still did not support the contact recreation and aquatic life uses. Other segments were added to the 303(d) List:

- Adams Bayou Above Tidal and Gum Gully did not support contact recreation and aquatic life uses.
- Cow Bayou Tidal did not support contact recreation and aquatic life uses and only partially supported the general use due to low pH.
- Cow Bayou Above Tidal and Coon Bayou did not support the contact recreation and aquatic life uses.
- Cole Creek did not support the contact recreation use and only partially supported the aquatic life use.

In 2002, new assessment procedures were implemented that resulted in changes to the 303(d) list. Cow Bayou Tidal was found to support the contact recreation use, based upon the new assessment methodology, and was removed from the 303(d) list for contact recreation. All other 303(d) listings remained the same for the water bodies discussed in this document (TCEQ 2002). Also in 2002, five small tributaries of Adams and Cow Bayous were added to the 303(d) list as a result of additional data collection initiated by the SRA-TX. Table 1 summarizes the affected uses and the support status of each of the segments considered in this document, as listed on the 2004 303(d) List.

Adams Bayou Tidal and Cow Bayou Tidal are classified tidal segments described in the *Texas Surface Water Quality Standards*. Adams Bayou above Tidal, Cow Bayou above Tidal, Hudson Gully, Gum Gully, Cole Creek, Terry Gully, and Coon Bayou are unclassified water bodies. Unclassified water bodies are those smaller water bodies that are not designated as segments with specific uses and criteria in *Texas Surface Water Quality Standards*. Cole Creek, Hudson Gully, and Coon Bayou are considered tidal water bodies. Adams Bayou above Tidal, Gum Gully, and Cow Bayou above Tidal are considered intermittent streams with perennial pools. Intermittent streams are defined as having a period of zero flow for at least one week during most years. Where flow records are available, a stream with a the 7-day, 2-year minimum flows (7Q2) of less than 0.1 cfs is considered intermittent.

The *Texas Surface Water Quality Standards* include several different subcategories of aquatic life use: exceptional, high, intermediate, and limited. The aquatic life uses are assigned based on the characteristics of the water bodies. Table 2 summarizes the stream types, designated uses, and subcategory of aquatic life use for the segments considered in this document. Perennial water bodies and tidal streams are assumed to have a high aquatic life use and corresponding dissolved oxygen criteria. Intermittent streams not specifically assigned an aquatic life use are considered to have no significant aquatic life use. When water is present in intermittent streams, a 24-hour dissolved oxygen (DO) mean/minimum criterion of 2.0/1.5 mg/L applies. Intermittent streams with perennial pools are assigned a limited aquatic life use. The contact recreation use is applied to all water bodies, except where contact recreation is considered unsafe for reasons unrelated to water quality. General uses are applied to all classified water bodies, but not to unclassified water bodies.

Table 1. Affected uses and support status by segment

Segment Number	Segment Name	Aquatic Life Use	Contact Recreation	General Use	Parameter(s)
0508	Adams Bayou Tidal	Not supporting	Not supporting	Fully supporting	Bacteria, dissolved oxygen
0508A	Adams Bayou Above Tidal	Not supporting	Not supporting	Fully supporting	Bacteria, dissolved oxygen
0508B	Gum Gully	Not supporting	Not supporting	Fully supporting	Bacteria, dissolved oxygen
0508C	Hudson Gully	Not supporting	Not supporting	Fully supporting	Bacteria, dissolved oxygen
0511	Cow Bayou Tidal	Not supporting	Not supporting	Not supporting	Bacteria, dissolved oxygen, pH
0511A	Cow Bayou Above Tidal	Not supporting	Fully supporting	Fully supporting	Dissolved oxygen
0511B	Coon Bayou	Not supporting	Not supporting	Fully supporting	Bacteria, dissolved oxygen
0511C	Cole Creek	Not supporting	Not supporting	Fully supporting	Bacteria, dissolved oxygen
0511E	Terry Gully	Fully supporting	Not supporting	Fully supporting	Bacteria

Description of the Watershed

Adams and Cow Bayous are sluggish streams that flow into the Sabine River just upstream of Sabine Lake in Orange County, Texas. Adams Bayou extends from its confluence with the Sabine River in a northerly direction across Orange County to near the Newton County line. Adams Bayou previously extended into southern Newton County, but the flow has been redirected eastward through a ditch to the Sabine River. This diversion serves as an upstream boundary for this project. Cow Bayou extends from its confluence with the Sabine River in a northerly direction, roughly parallel to but west of Adams Bayou, across Orange County to Buna in southern Jasper County.

Turbidity is high in the bayous most of the year, giving them a muddy or chocolate color (Figure 1). Decaying organic matter and suspended sediments are just two possible contributors that give the bayous their unique color. The lower portions of both bayous have been channelized, straightened, and dredged for navigation, creating numerous oxbows in what were formerly more sinuous natural channels. Both bayous are under tidal influence below and a short distance above Interstate Highway 10. The tidal portions of Adams and Cow Bayous extend approximately 8 and 20 miles, respectively, above their confluences with the Sabine River.

A U.S. Geological Survey (USGS) gauging station measured flow in Cow Bayou at the State Highway 12 Bridge near Mauriceville from 1952 to 1986, and was reactivated in October 2002. The annual average, the maximum, and the 7Q2 at this site were 104.4 cubic feet per second (cfs), 4600 cfs, and 0.05 cfs, respectively, over the period of record.

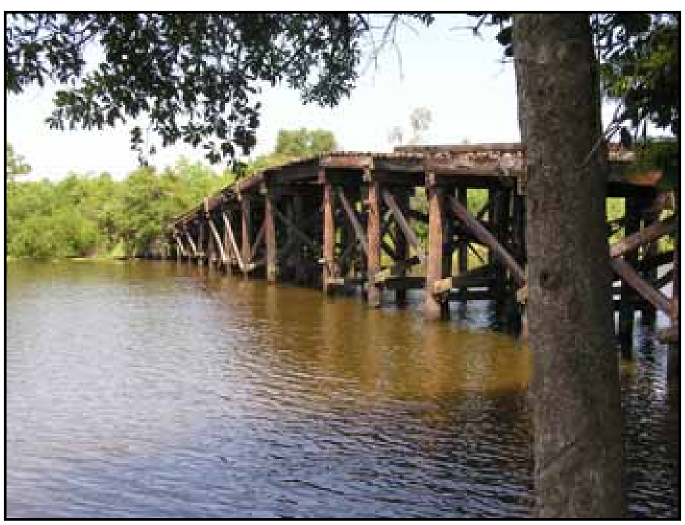

Figure 1. Cow Bayou

There is no flow gauging station on Adams Bayou, but field surveys indicate that under extended dry weather conditions there is essentially no base flow in the bayou (TWC 1986). Under these conditions, water movement occurs due to tidal ebb and flow, downstream water diversions, and wastewater discharges to the bayou. The upper reaches of Adams Bayou and its above-tidal tributaries are intermittent streams (Table 2).

The 51-square-mile watershed of Adams Bayou lies almost entirely within Orange County, though it includes a small portion of southern Newton County. The Cow Bayou watershed stretches 193 square miles across substantial portions of Orange and Jasper Counties, as well as a small corner of Newton County. The combined watersheds cover 41 percent of Orange County, 8 percent of Jasper County, and 0.3 percent of Newton County (Figure 2).

Table 2. Stream types, designated uses, and subcategory of aquatic life use

Segment	Description	Type	Aquatic Life Use Subcategory	Designated Uses
0508	Adams Bayou Tidal	Tidal	High	Aquatic life use; contact recreation; general use; fish consumption
0508A	Adams Bayou Above Tidal	Intermittent with pools freshwater	Limited	Aquatic life use; contact recreation; fish consumption
0508B	Gum Gully	Intermittent with pools freshwater	Limited	Aquatic life use; contact recreation; fish consumption
0508C	Hudson Gully	Tidal	High	Aquatic life use; contact recreation; fish consumption
0511	Cow Bayou Tidal	Tidal	High	Aquatic life use; contact recreation; general use; fish consumption
0511A	Cow Bayou Above Tidal	Intermittent with pools freshwater	Limited	Aquatic life use; contact recreation; fish consumption
0511B	Coon Bayou	Tidal	High	Aquatic life use; contact recreation; fish consumption
0511C	Cole Creek	Tidal	High	Aquatic life use; contact recreation; fish consumption
0511E	Terry Gully	Perennial freshwater	High	Aquatic life use; contact recreation; fish consumption

Most of the nine segments have varying levels of tidal influence. Bayous are unique water bodies that do not have a conventional flow pattern like most perennial streams. During certain times of the year, flow may not even be measurable as the bayou becomes stagnant. Negative flow, or reversing flow, has been observed and recorded due to the tidal influence. This back and forth flow pattern could even be responsible for carrying constituents from a normally “downstream” location to an “upstream” location. The net flow is from the bayou headwaters to the confluence with the Sabine River, but the tidal action of the alternating forward-reverse flows slows the overall travel time considerably, further compounding the complexity of assessing these impairments.

A runoff event, if occurring during a time of a reverse flow, may actually contribute to low dissolved oxygen and elevated bacteria concentrations. If a rainfall event is not sufficiently heavy to create enough flow to flush the system, it may simply add storm water containing bacteria and substances that have a high biological oxygen demand (BOD). These constituents would be dispersed very slowly throughout the system.

Endpoint Identification

TMDL projects must identify a quantifiable water quality endpoint for each constituent that causes a body of water to appear on the state’s 303(d) list. These endpoints are indicators of the desired water quality condition and provide a measurable goal for the TMDL. The endpoint also serves to focus the technical work to be accomplished during TMDL development and serves as a criterion against which to evaluate future conditions.

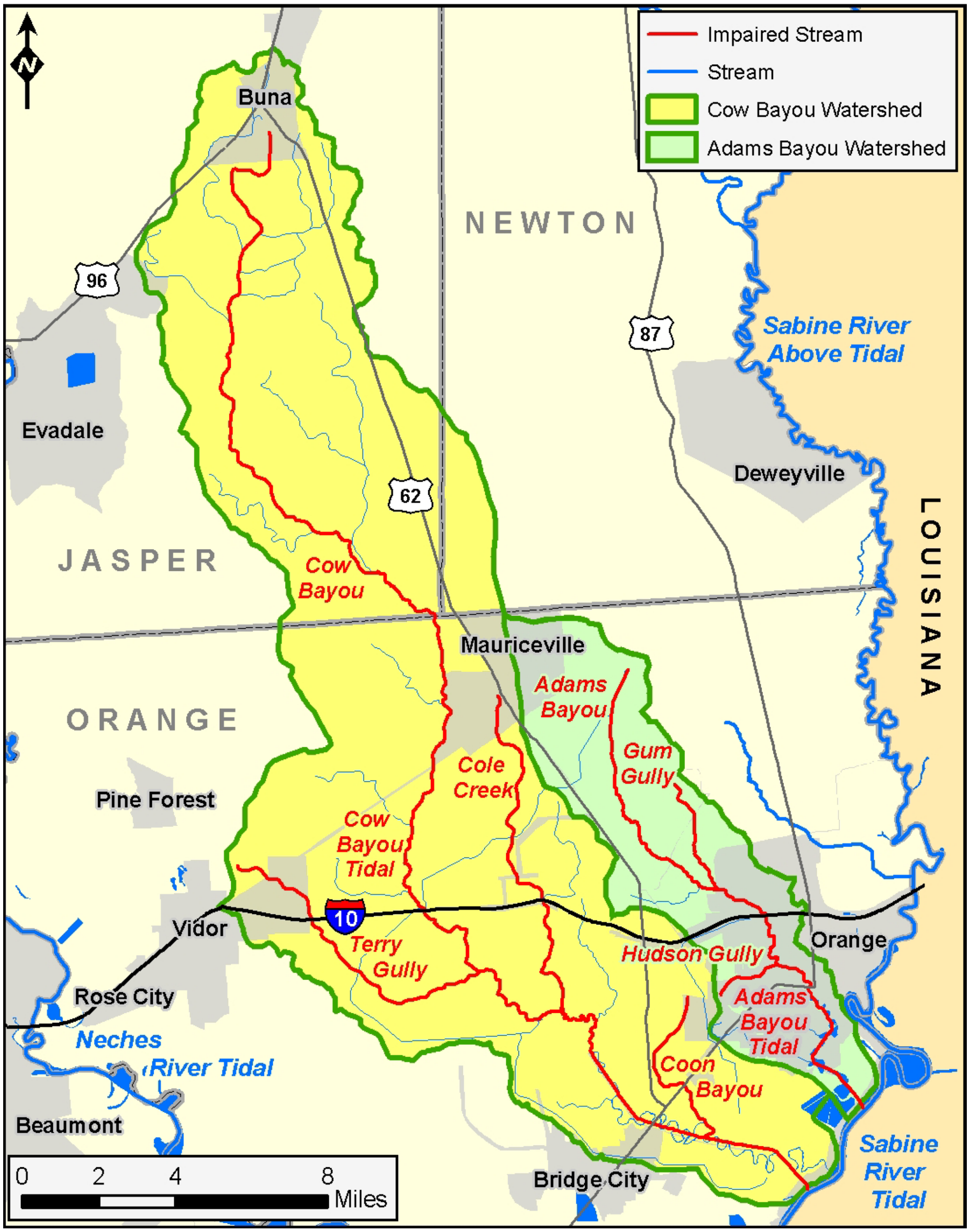

Figure 2. Study area

The establishment of the endpoint for the TMDL is an integral part of the TMDL process itself, and manifests many of the same complexities as the development of TMDLs.

Through the analysis of water quality data and modeling exercises, it becomes possible, at least to some degree, to define quantitative values of various parameters that can serve as target conditions. The TMDL is, by definition, the set of external loadings that result in a predicted concentration in the water body equal to the target condition. The TMDL determination and the endpoint specification are coordinated, parallel activities.

Specification of endpoint conditions implies a corresponding set of critical conditions. There is not necessarily one unique set of these critical conditions. The parameter for which an endpoint condition is defined may not be the parameter that characterizes pollutant loading, and may not be sufficient, in itself, to ensure attainment of the desired use of the water body.

Dissolved Oxygen

Compliance with the appropriate 24-hour dissolved oxygen criterion is determined through the collection and analysis of diel (24-hour) dissolved oxygen data. Numerical endpoints for dissolved oxygen that signify full support of aquatic life use may be expressed as:

- a probability of less than 10 percent that the average 24-hour dissolved oxygen measured in the mixed surface layer during the index periods will be below the standard (i.e., 90 percent compliance rate).
- a probability of less than 10 percent that the 24-hour minimum dissolved oxygen concentration in the mixed surface layer of the segment will be below the standard over a consecutive 8-hour period.

The water quality standards for dissolved oxygen require that daily average dissolved oxygen concentrations at any site in Cow Bayou Tidal or Adams Bayou Tidal must be at least 4 milligrams per liter (mg/L), and daily minimum dissolved oxygen concentrations must be above 3 mg/L. These same criteria also apply to Coon Bayou and Cole Creek in the Cow Bayou system and to Hudson Gully in the Adams Bayou system.

In Adams Bayou Above Tidal, Cow Bayou Above Tidal, and Gum Gully, the criteria are 3 mg/L and 2 mg/L for daily average and daily minimum dissolved oxygen concentrations, respectively. The endpoint of the TMDL for the dissolved oxygen impairment will be attainment of the dissolved oxygen criteria.

Bacteria

Initially, the segments listed as impaired for the contact recreation use were evaluated using fecal coliform as the indicator bacteria. However, just as the TMDL project was being initiated, the TCEQ changed to using *E. coli* as the indicator bacteria. Therefore, sampling for the project and the subsequent TMDL equation used in this report uses *E. coli*. Even though the water bodies in the project have varying levels of tidal influence, they are mostly freshwater. Therefore, *E. coli* is the indicator bacteria they are assessed against, and not Enterococcus, which is the indicator for marine waters.

The water quality standards state that the geometric mean of *E. coli* should not exceed 126 colony forming units/100 milliliters (cfu/mL), and single samples should not exceed

394 cfu/100 mL more than 25 percent of the time. Failure to meet either the single-sample or geometric-mean criterion is sufficient for a determination that water quality standards are not supported. Data collected at flows below the 7Q2 are eliminated from the assessment in accordance with the standards. The reductions required to meet the geometric mean criterion are in all cases greater than those required to meet the single sample criterion. Therefore, the TMDLs and the load reductions necessary are based upon attainment of the geometric mean criterion.

pH

The general use is not met in Cow Bayou Tidal due to observed pH levels below the acceptable range of criteria (6.0–8.5) for this segment. Twelve of fifty-seven measurements (21 percent) fell below the criteria in samples taken from 1998 to 2003 from the upper tidal reaches of Cow Bayou. The endpoint for pH will be attainment of the acceptable range for pH in Cow Bayou Tidal.

Source Analysis

Pollutants may come from several sources, both point and nonpoint. Point source pollutants come from a single definable point, such as a pipe, and are regulated by permit under the Texas Pollutant Discharge Elimination System (TPDES). Storm water discharges from industries, wastewater treatment facility bypasses and collection system overflows construction, and the separate storm sewer systems of urbanized areas identified as subject to TPDES are considered point sources of pollution. Nonpoint source pollution originates from multiple locations, usually carried to surface waters by rainfall runoff, and is not regulated by permit under the TPDES.

The sources of pollution contributing to the impairments in Adams and Cow Bayous and their tributaries are a combination of point and nonpoint sources. Elevated *E. coli* concentrations are observed during low flow periods, and increase dramatically as a result of runoff events. This situation implies that the bayous could be receiving a small point or nonpoint source loading during low flow periods, and a large contribution from either/both point or nonpoint sources during runoff events.

Point Sources

In the Adams Bayou watershed, there are currently five point source wastewater discharges from four facilities. Three of the facilities in the Adams Bayou watershed are domestic wastewater treatment facilities (WWTFs) that have a total permitted discharge of 8.72 million gallons per day (MGD) (Table 3). One industrial facility is permitted to discharge about 0.06 MGD of process wastewater and storm water (Table 4). In 2000, actual reported discharges averaged approximately 9.1 MGD for the five dischargers combined. Most of the dischargers are located in the lower reaches of the bayou. There are no concentrated animal feeding operations (CAFOs) in the Adams and Cow Bayou watersheds.

Cow Bayou has 20 point-source wastewater discharges from 15 facilities. Five of the discharges are storm water from permitted industries. Total permitted domestic and industrial wastewater flow is approximately 2.2 and 9.1 MGD, respectively. In 2000, actual reported discharges averaged 10.5 MGD. All of the permitted domestic WWTF discharges are less than 0.1 MGD, except for the City of Bridge City and Jasper WCID #1, which are larger than 0.1 MGD (Table 3). Industries such as Bayer, Chevron, Firestone, and Honeywell all have major industrial wastewater discharges to Cow Bayou (Table 4). Most of the major discharges of wastewater are located in the lower stretch of Cow Bayou.

Table 3. Permitted Domestic WWTF discharges in the Adams and Cow Bayou watersheds

	WWTF Discharges and TCEQ Permit Number	Maximum Permitted Flow (MGD)
Adams Bayou Watershed	Orange County WQ0010240-001	1.22
	City of Pinehurst WQ0010597-001	0.5
	City of Orange WQ0010626-001	7.0
Cow Bayou Watershed	City of Bridge City WWTP 001 WQ0010051.001	1.6
	Jasper WCID #1 WQ0010808-001	0.41
	Bayou Pines Park WQ0011315-001	0.009
	TXDOT Orange Co. Comfort Station WQ0011457-001	0.011
	Orangefield ISD WWTP WQ0011607-001	0.032
	PCS Development Co. WQ0011916-001	0.09
	Sabine River Authority of Texas 1 Plant WQ0012134-001	0.003
	Sunrise East Apartments WQ0013488-001	0.01
	Waterwood Estates WQ0013691-001	0.02

Table 4. Permitted Industrial Discharges in the Adams and Cow Bayou watersheds

	Industrial Discharges and TCEQ Permit Number	Maximum Permitted Flow (MGD)
Adams Bayou Watershed	A. Schulman, Inc. WQ0000337-000	0.06
Cow Bayou Watershed	Chevron Phillips Chemical. Orange Plant WQ0000359-000	3.15
	Firestone Polymers. Orange Plant WQ0000454-000	1.0
	Honeywell International Inc. Orange WQ0000670-000	1.4
	Bayer Corp. WQ0001167-000	3.5
	Texas Polymer Services, Inc. WQ0002835-000	Not Applicable
	Printpak, Inc. Orange County Plant WQ0002858-000	0.085

In recent years, total BOD loading from point sources to Adams and Cow Bayous averaged 170 and 280 lbs/day, respectively, based on effluent data collected and self-reported by the dischargers. Total point source loading of total suspended solids (TSS) to Adams and Cow Bayous have averaged 390 and 835 lbs/day, respectively, in recent years.

In Cow and Adams Bayous, the dissolved oxygen, bacteria, and pH impairments are more prevalent in the middle and upper reaches of the segments. However, it is in the lower reaches of the bayous, closer to the Sabine River, where most of the major wastewater dischargers are located.

Nonpoint Sources

Probable nonpoint pollution sources in the Adams and Cow Bayous watersheds include malfunctioning septic tanks, storm sewer overflows, runoff from urban areas, pet and wildlife waste, and other natural sources. The magnitude of some of these suspected sources was reported in the 1980-1981 Southeast Texas Nonpoint Source Study (Plummer and Associates 1982). Urban runoff was the single most significant source of fecal coliforms, followed by sewer overflows, wastewater treatment plant bypasses, agricultural and rural runoff, and wastewater treatment facility discharges in order of decreasing magnitude.

Land Use and Land Cover

Overall, 14 percent of the Adams Bayou watershed and 6 percent of the Cow Bayou watershed are considered developed or built-up land (residential, commercial, industrial, or transportation) (Table 5). More than 65 percent of the Cow Bayou watershed, and one third of the Adams Bayou watershed, is covered by forest, primarily evergreen and mixed evergreen/deciduous forest. Approximately 15 percent of the Cow Bayou watershed, and 27 percent of the Adams Bayou watershed, is used for pasture or hay production for grazing animals. Water and wetlands comprise approximately 10 percent and 22 percent, respectively, of the Cow and Adams Bayou watersheds. Land use is illustrated in Figure 3, from the Multi-Resolution Land Cover Consortium's National Land Cover Dataset (USGS 1999a). This land use classification is based on Landsat Thematic Mapper satellite imagery from the early 1990s.

On-Site Sewage Facilities

On-site sewage facilities (OSSFs), such as septic tanks, can serve as nonpoint sources of pollutants. Malfunctioning septic tanks are those that have been improperly engineered or installed, poorly maintained, or are located where soils do not permit the sanitary absorption of septic effluent. In rural and some suburban areas of Adams and Cow Bayou watersheds, conventional septic tanks serve as the primary mechanism for sewage disposal. The most recent available data on the abundance of septic tanks in the watersheds comes from the 1990 decennial federal census. In the Adams Bayou watershed, 6,754 housing units (88 percent) were connected to a public sewer, 888 units (12 percent) used septic tanks or cesspools for sewage disposal, and 20 units reported "other means" of sewage disposal method. In the Cow Bayou watershed, 2,205 housing units (28 percent) were connected to a public sewer, 5,582 units (71 percent) used septic tanks or cesspools, and 108 units (1 percent) reported an "other means" sewage disposal method.

In the 2000 census, the questionnaire did not include a question on sewage disposal. Since 1991, when Orange County adopted its OSSF program, it has been a requirement that a soil survey must be performed before installation of an OSSF. Given that almost all soils in the watersheds are unsuitable for conventional septic systems, in most cases an aerobic OSSF must be installed. Thus, since 1991, new housing in areas not served by public sewers has generally required aerobic OSSF systems, and the number of housing units utilizing conventional septic systems has likely remained steady.

Figure 4 displays the density of septic tanks in the Adams and Cow Bayou watersheds, based on the 1990 federal census. The absolute highest densities of septic tanks at that time appear to have occurred near Vidor and between Bridge City and West Orange. A previous report (Hydroscience 1978) cited the Maple Crest neighborhood near Vidor, the Westlawn area near I-10, Orangefield, the Bridge City area along Cow Bayou, and Mauriceville as areas with dense concentrations of conventional septic systems.

Table 5. Land use/land cover in the Adams and Cow Bayou watersheds

Land Use Category	Adams Bayou	Cow Bayou
Open water	4.0%	1.0%
Low density residential	7.8%	2.8%
High density residential	3.0%	1.6%
Commercial, industrial, & transportation	3.6%	2.0%
Bare rock, sand, or clay	0.1%	0.1%
Quarries, strip mines, and gravel pits	0.0%	0.2%
Transitional	0.0%	1.8%
Deciduous Forest	9.3%	10.6%
Evergreen forest	14.5%	21.3%
Mixed forest	9.9%	33.2%
Grasslands/ herbaceous	0.5%	0.1%
Pasture/hay	27.1%	15.4%
Row crops	0.0%	0.0%
Small grains	0.4%	0.4%
Urban & recreational grasses	2.0%	0.8%
Woody wetlands	11.5%	6.3%
Emergent herbaceous wetlands	6.5%	2.6%

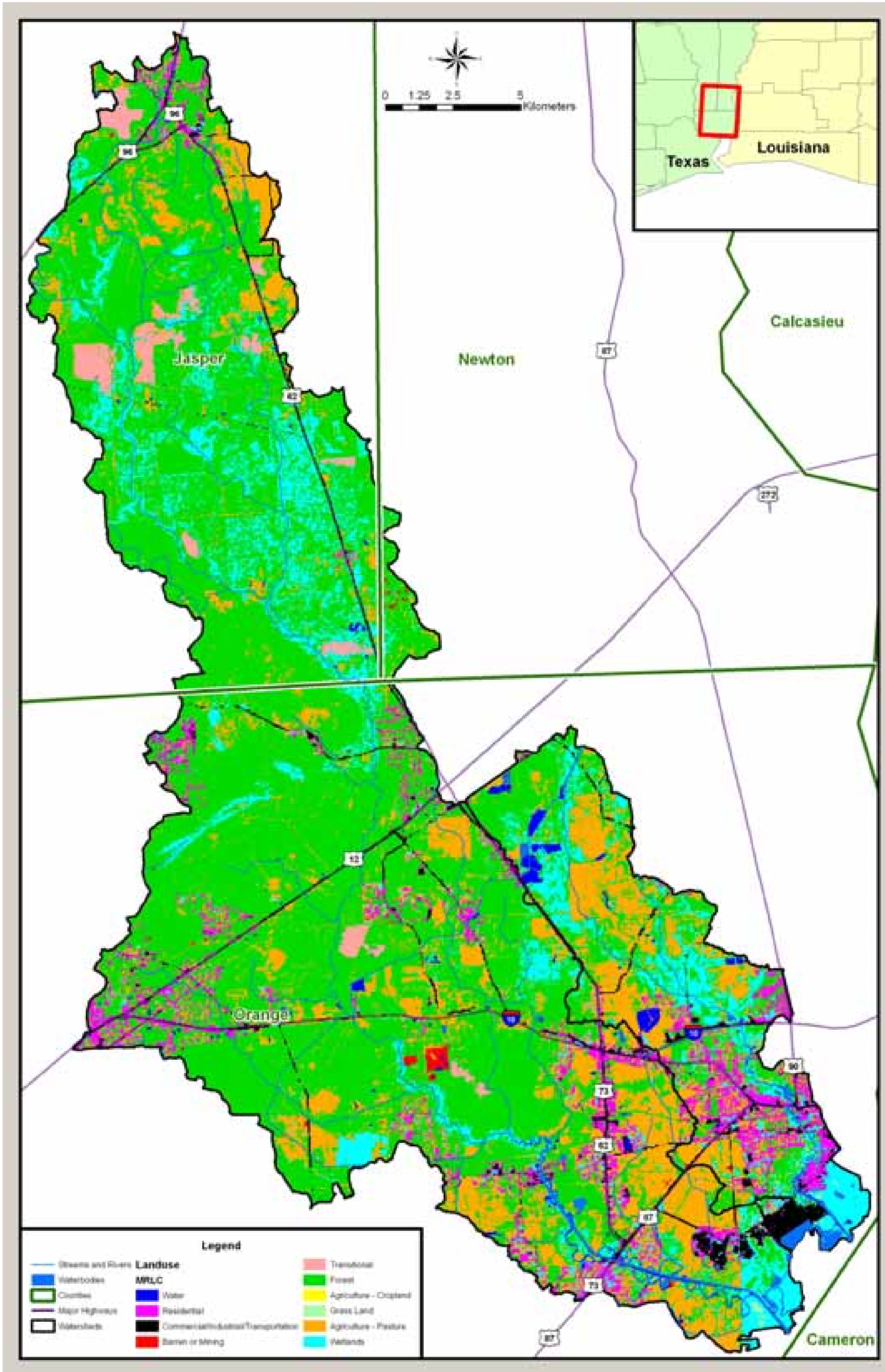

Figure 3. Land use in the project watershed

Conventional septic tank systems rely on absorption fields to disperse liquid components of sewage into the soil after solids have settled into the tank. Several factors affect the suitability of soils for septic tank absorption fields (NRCS 2004), as follows:

1) **Frequency and Duration of Flooding**

   Flooding in this context indicates the temporary inundation of an area caused by overflowing streams, tides, or runoff from adjacent slopes. Flooding may allow the widespread contamination of surface waters with septic tank effluent.

2) **Frequency and Duration of Ponding**

   Ponding is standing water in a closed depression. Ponding may allow the localized contamination of surface waters with septic tank effluent.

3) **Soil Water Permeability**

   Soil water permeability limits the rate at which the septic field can absorb and transmit septic effluent. The soil hydrologic group indicates the soil water permeability.

4) **Depth to the Saturated Zone**

   The saturated zone refers to the depth from the land surface down to where the soil is saturated with ground water. Shallow saturated zones may lead to contamination of ground water. Most of the soils in the Adams and Cow Bayou watersheds tend to be saturated near the surface at least part of the year, which makes them unsuitable for septic fields.

5) **Tendency for Subsidence**

   Soil subsidence may cause leaks or other malfunctions in the septic tank. Subsidence is not a major problem for many of the soils in these watersheds.

Based on one or more of these factors, almost all of Adams and Cow Bayou watersheds are very limited in their utility for septic tank absorption fields (Figure 5), according to the Soil Survey Geographic Database (SSURGO) developed by the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS). Extensive site engineering may minimize the effects of some of these factors.

A survey of septic tank failure in Texas (Reed Stowe and Yanke 2001) estimated that the overall chronic malfunction rate of OSSF systems in east Texas was 19 percent, more than any other region in the state. The estimated chronic malfunction rate rose to 54 percent for systems installed in the fine-textured, clayey soils common in the Adams and Cow Bayou watersheds. In this region, the factor reported to have the highest impact on malfunction was unsuitable soils, followed by the high water table, then system age.

Project stakeholders with knowledge of the watersheds, including septic system inspectors, believe that the actual rate of malfunction of conventional septic systems in these watersheds is close to 100 percent. They cited observations that on almost all conventional systems, the cap had been removed from the septic field drain line, essentially

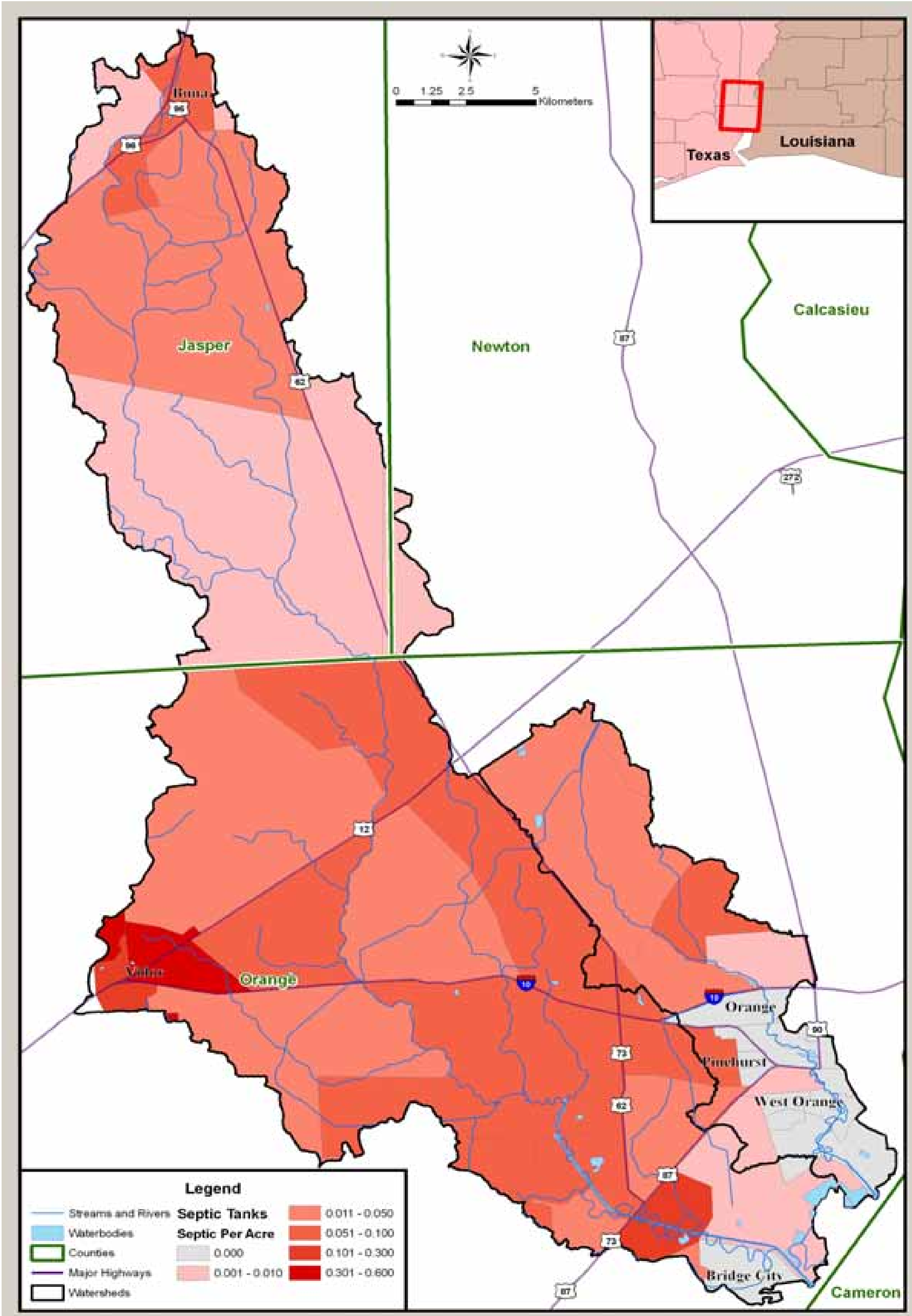

Figure 4. Septic tank density

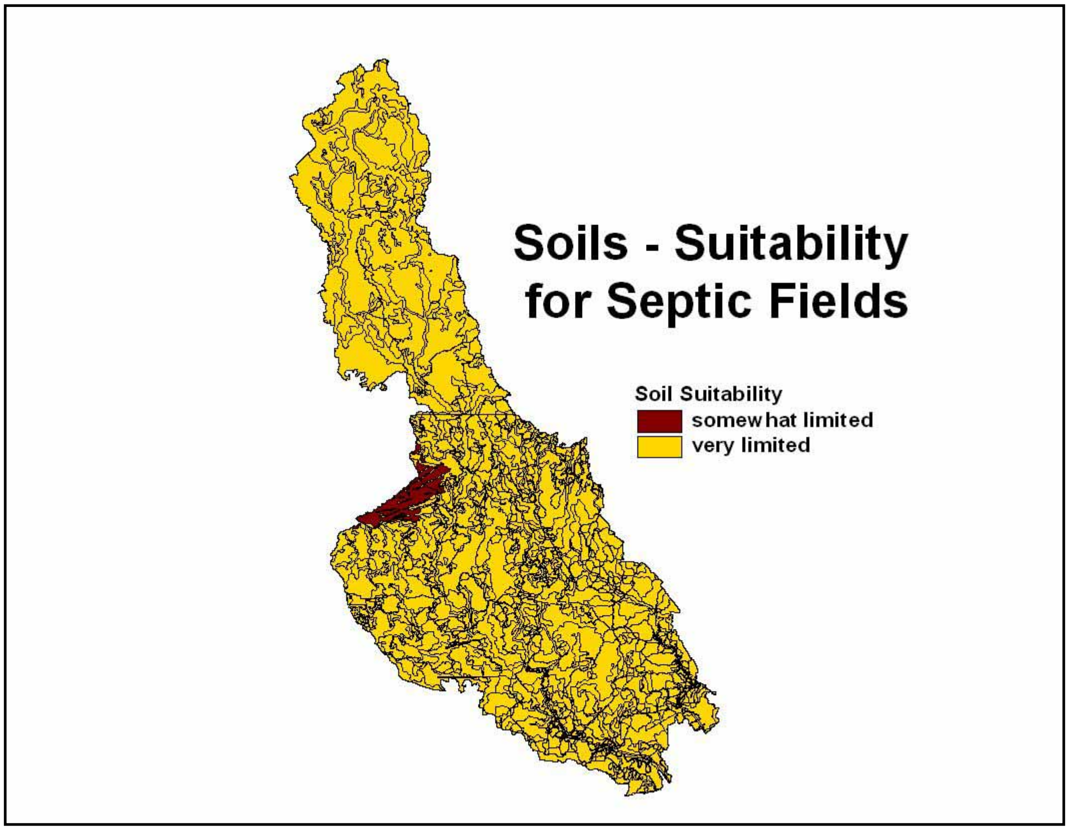

Figure 5. Soil suitability for septic fields

conveying the septage directly from the tank to the ditch. In accordance with these estimates, it was assumed in the model that 95 percent of the conventional septic systems in these watersheds are malfunctioning.

Properly functioning conventional septic tank systems and aerobic systems were assumed to produce no pollutant loads to the bayous, while loads from malfunctioning septic tank systems were included in the model as sources of loading to the bayous. Flows from septic systems were estimated based on an average of 2.5 persons per household and 70 gallons of water use per person per day (Horsely and Whitten 1996). Pollutant concentrations in septic tank effluent were estimated (Table 6) as the approximate average concentrations from a number of published reports (Metcalf and Eddy 1991, Canter and Knox 1985, Cogger and Carlile 1984, Brown et al. 1984).

Prior to publication of the Southeast Texas Nonpoint Source Study, a report titled *An Assessment of Nonpoint Sources of Pollution in the Southeast Texas Designated 208 Planning Area* (Hydroscience 1978) investigated the impact of failing OSSFs in southeast Texas. Their conclusion was that soils in the entire study area were generally unsuitable for operating a standard trench-bed septic tank. The three main soil groups found in the area, as determined by the NRCS, are: Harris/Veston/Ijam, Morey/Crowley/Waller, and Acadia/Waller/Splendor. These combinations of soil types result in low permeability, high shrink/swell capacity, and slow percolation rates. As a result, the report estimated that, depending upon the exact location in the study area, from 50 to 90 percent of the septic systems “discharge directly into roadside ditches and/or into water bodies.” These failing septic systems are certainly a major component of the nonpoint source loading.

Table 6. Estimated Concentrations of Septic Tank Effluent

Parameter	Concentration
E. coli	100,000 cfu/100 ml[†]
BOD	170 mg/L
Total Suspended Solids	70 mg/L
Ammonia nitrogen	35 mg/L as N
Phosphate phosphorus	15 mg/L as P

cfu = colony forming unit

[†] includes 10x attenuation factor to account for *E. coli* death between end of pipe and stream

Livestock

Fecal waste from livestock may become a nonpoint source pollutant through runoff of fecal matter deposited on land by grazing animals on pasture or rangeland, from direct deposition by animals into water, or by application of manure from confined animals to fields as fertilizer. Manure production by livestock was estimated based on the animal population figures in the 2002 USDA Census of Agriculture (Table 7) multiplied by the estimated average daily manure production rate (Table 8) from the American Society of Agricultural Engineers (ASAE 1998). The *E. coli*, ammonia nitrogen, and phosphorus production estimates were also derived from published ASAE estimates.

Manure from cattle, horses, sheep, and goats was assumed to be directly deposited to pastureland. A portion of the manure from grazing cattle was assumed to be deposited directly in water as the animals drank from streams. It was assumed for modeling purposes, based on the best estimates of watershed stakeholders, that only 5 percent of cattle in Adams Bayou subwatersheds above I-10 drink from the bayous, and 1 percent of cattle in subwatersheds below I-10 drink from the bayous, due to alternate water sources. In the Cow Bayou watershed, it was assumed that 5 percent of cattle below I-10 and 10 percent of cattle above I-10 drink from Cow Bayou or its tributaries. It was also estimated by stakeholders that, on average, the cattle drinking water from the bayous spend 10 minutes per day in the stream during June, July, August, or September, and five minutes per day in March, April, May, October, and November, and do not stand in the bayous to drink from December through February. The fecal deposition to the stream was assumed to be directly proportional to the time spent in the streams. On average, only 0.01 percent of the total fecal load from grazing cattle in the Adams Bayou watershed was assumed to be deposited directly into Adams Bayou or its tributaries, and 0.03 percent of the total fecal load from grazing cattle in the Cow Bayou watershed was deposited to the bayous.

Table 7. Livestock and wildlife populations by county: 2002 agricultural census

Type	Orange	Jasper	Newton
Cattle/calves*	10,402	15,006	6,492
Hogs/pigs	120	380	89
Horses/ponies	1,125	1,152	631
Sheep/lamb	117	76	27
Goats	580	585	572
Mules/burros/donkeys	94	20	20
Rabbits	64	0	16
Deer	130	503	0
Chickens/layers& pullets	1,150	2,448	802
Chickens/broilers	D	402	436
Turkeys	27	55	60
Pheasants	D	110	16
Pigeons/squab	257	0	D
Quail	D	284	D
Ducks	688	147	156
Geese	80	40	148
Other poultry	D	D	516

* All were beef cattle except 13 dairy cows in Orange County

D: Withheld to avoid disclosing data from individual farms

Table 8. Pollutant production rates of manure from livestock

Animal	**E. coli production** (billion CFU/animal/day)	**BOD Production** (lb/animal/day)	**Ammonia Nitrogen Production** (lb/animal/day)	**Phosphate Phosphorus Production** (lb/animal/day)
Beef cow	104	1.28	0.069	0.074
Hog	10.8	0.42	0.039	0.024
Sheep	12.0	0.07	0.005	0.005
Horse	0.42	1.70	0.079	0.071
Goat	1.0#	0.07#	0.005#	0.005#
Chicken	0.14	0.02	0.001	0.001
Turkey	0.09	0.03	0.001	0.004

All values from ASAE (1998) except where otherwise noted.

[#] Best professional judgment—no data exist.

Because there are few if any dairy cattle in the watershed and other cattle in the watershed are not confined, it was assumed that no cattle manure was collected and spread on cropland as fertilizer. Stakeholders confirmed that land application of manure was not practiced in the watershed. However, it was assumed that manure from swine and poultry within the watershed was collected and applied to cropland as fertilizer.

Urban Runoff

Potential pollutant sources in residential areas that were considered in the model include malfunctioning septic systems, dog and cat fecal waste, wildlife fecal waste, and lawn fertilizer. Malfunctioning septic systems were described previously. The populations of dogs and cats were estimated based on the number of households in each subwatershed, along with the national average numbers of 0.58 dogs and 0.66 cats per household, from the American Veterinary Medicine Association (AVMA 2002). Pollutant loadings in pet fecal waste are summarized in Table 9. It was assumed that 100 percent of dog feces and 50 percent of cat feces were applied outdoors, and that 20 percent of dog waste was collected and removed to a landfill.

Table 9. Pollutant production rates of manure from dogs and cats

Animal	**E. coli production** (Billion cfu/animal/day)	**BOD Production** (lb/animal/day)	**Ammonia Nitrogen Production** (lb/animal/day)	**Phosphate Phosphorus Production** (lb/animal/day)
Dog	4.1	0.10	0.0065	0.0063
Cat	0.54	0.028	0.0018	0.0018

All values from ASAE (1998).

To estimate the amount of commercial fertilizer applied to turf grass, it was assumed that 50 percent of the residential land was covered by turf grasses, nitrogen was applied to turf at the rate of 4 pounds of ammonia nitrogen per 1,000 square feet per year, and phosphate phosphorus was applied at a rate of 2 pounds per 1,000 square feet per year, in line with the low end of Texas Agricultural Extension recommendations for St. Augustine and Bermuda grass lawns in East Texas. It was assumed that the BOD content of fertilizer was 5 times the ammonia nitrogen content to account for the oxidation of ammonia. It was also assumed that 49 percent of the applied nutrients were collected and removed to the landfill each year as grass clippings and other yard waste (Baker et al. 2001).

Wildlife

Very few data exist on the population of wildlife species in the watersheds. The whitetail deer population in Jasper County has hovered around 50 per 1,000 acres over the last few years, and that in Newton County has stayed closer to 30 per 1,000 acres, according to information on the Texas Parks and Wildlife Department's web site <www.tpwd.state.tx.us/landwater/land/habitats/pineywood/regulatory/>. No deer population estimates were found for Orange County, which has less forest and a greater urban influence.

Wildlife were assumed to contribute pollutants to all land use categories and subwatersheds. The assumed populations of wildlife are shown in Table 10. Pollutant production rates of wildlife (Table 11) were estimated based on Schueler (2001) and other references in the Bacterial Indicator Tool (USEPA 2000). In cases where pollutant production rates from wildlife species were not available, they were estimated by multiplying the manure production rate estimate for the animal by the average pollutant concentration in manure for other animal species. While the levels of uncertainty in the wildlife populations and pollutant production rates are very large, sensitivity analyses showed that varying these numbers had little effect on the model outcome since wildlife were a relatively minor source.

Table 10. Assumed wildlife population densities for various land use categories

Species	**Population Density (animals/ square mile)**					
	Cropland	**Wetlands**	**Pasture**	**Forest**	**Grassland**	**Residential**
Deer	20	50	20	50	10	40
Waterfowl	10	128	10	0	0	0
Other birds	100	1,500	1,000	1,500	1,500	1,500
Opossum	20	100	50	100	20	50
Raccoon	4	100	4	100	20	50
Rodents	2,000	2,000	2,000	2,000	2,000	2,000

Table 11. Pollutant production rates of manure from wildlife

Animal	***E. Coli* Production** (billion cfu/animal/day)	**BOD Production** (lb/animal/day)	**Ammonia Nitrogen Production** (lb/animal/day)	**Phosphate Phosphorus Production** (lb/animal/day)
Deer	0.5	0.050	0.0033	0.0032
Waterfowl	2.43	0.011	0.00074	0.00071
Other birds	0.1	0.0006	0.000037	0.000035
Opossum	0.1	0.028	0.0018	0.0018
Raccoon	0.1	0.10	0.0065	0.0063
Rodents	0.005	0.0027	0.00018	0.00017

Forest Leaf Litter

Deposition of forest leaf litter can be a nonpoint source of nitrogen, phosphorus, and BOD to waters. An estimated 30 pounds of nitrogen and 2 pounds of phosphorus are deposited in leaf litter per acre of forest per year, based on the measurements of Finzi et al. (2001) for a mature loblolly pine/hardwood forest, similar to the dominant type in the Adams and Cow Bayou watersheds. The nitrogen was assumed to be ammonia nitrogen, phosphorus assumed to be phosphate, and a BOD/nitrogen ratio of 5 was used to estimate the BOD content. Evergreen forests were assumed to deposit leaf litter evenly throughout the year, while litter fall from deciduous forests was assumed to occur primarily in October and November.

Human Population

The Adams and Cow Bayou watersheds cover portions of Orange, Jasper, and Newton counties. Portions of the cities of Orange, West Orange, Pinehurst, and Mauriceville lie within the Adams Bayou watershed, while portions of Bridge City, Vidor, Mauriceville, Evadale, and Buna lie within the Cow Bayou watershed. In 2000, the population of the Cow Bayou watershed (~23,900) was slightly higher than that of Adams Bayou (~17,500). Between 1990 and 2000, the population of the Adams Bayou watershed increased only 2 percent, while it grew by 17 percent in the Cow Bayou watershed.

Unauthorized Discharges

Some common types of unauthorized discharges are leaks and overflows from the sanitary sewer system to surface water and illicit cross-connections between the sanitary and storm sewer systems. Unlawful discharges by septic tanks and grease trap cleaners and haulers are also possible. These discharges are episodic and may affect the bayous in the vicinity of the discharge a great deal for a short period of time until the pollutants are dispersed. It is difficult to gage the magnitude of unauthorized discharges, since very few data exist. Inspection of permit files revealed only a few instances where unauthorized discharges were reported to state authorities, and these reports were only made since 2004, from two facilities where TCEQ inspectors noted that the facilities had not been reporting known sewage leaks.

There is no reason to expect that problems with sewer systems are limited to these two facilities, so the magnitude of the problem is probably underestimated. Since only an estimate of the volume of the unauthorized discharge was reported, the concentrations of pollutants were estimated as the reported typical domestic sewage of medium concentration (Metcalf and Eddy 1991). It was also assumed that all of the nutrients and BOD discharged ultimately made it into the bayou, but that the loads of *E. coli* bacteria were diminished by one order of magnitude due to die-off before they entered the bayou. To estimate annual loadings, the reported discharges from the years in which discharges were reported were assumed to be representative of other years. However, the model only utilized the estimated annual loadings from these two facilities, and did not make estimated annual loads of this type for every permitted facility.

Linkage Analysis

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

Point Sources of Pollutants

Point source loadings were estimated based on a combination of self-reported effluent data (from January 2000 through March 2005) and effluent measurements made during the intensive surveys of the summer of 2004. Most facilities with permitted discharges to the bayous are required to report, each month, the average measured flow rate of their discharges. Most facilities are also required to report monthly either the monthly total loads or the average concentrations of one or more specific parameters in their wastewater discharges. In cases where the facility did not self-report a pollutant concentration or load, that load was estimated using the self-reported monthly average flow and the average concentration measured during the intensive surveys.

During some storm events, domestic wastewater treatment facilities receive more flow than they are able to treat. This is typically caused by inflow and infiltration into the sewers, as well as storm drains connected to the sanitary sewers. Facilities will typically disinfect but not otherwise treat the sewage flows that exceed capacity before discharging them to the bayou. Also, full disinfection under these conditions may be compromised due to inadequate detention time. Many facilities have made extensive efforts to reduce inflow and infiltration to sanitary sewers to minimize these untreated or partially treated storm-related discharges. The extent of the remaining problem is not known. However, the City of Bridge City has reported the volume and the BOD and TSS content of their excess storm flows to the TCEQ. This information was used in the modeling effort.

Nonpoint Sources of Pollutants

A nonpoint pollutant source inventory was developed for each watershed and sub-watershed using a system of linked Microsoft Excel spreadsheets. This tool was adapted from the Bacterial Indicator Tool developed by the EPA (2000). The tool provides monthly and annual loading estimates of indicator bacteria for modeling based on land use, livestock, and wildlife populations, the number and failure rate of septic systems, and other watershed properties. This tool was modified to address watershed-specific conditions and sources, as well as the nitrate and ammonia nitrogen, phosphate phosphorus, and BOD.

Modeling

Following their determination that the water quality standards of Adams and Cow Bayous were not supported, in 2002 the TCEQ selected Parsons and SRA-TX as contractors to assist in developing TMDLs. An assessment of existing water quality data (Parsons 2002) concluded with a high degree of confidence that water quality in Adams and Cow Bayou did not meet water quality standards. However, the assessment also concluded that the sources of pollutants were not adequately quantified, and the impacts of sources were not known with sufficient confidence to develop TMDLs without additional investigation and analysis. The assessment also indicated that both nonpoint sources and in-stream hydrology probably contributed to the impairments, so it was advisable to develop and calibrate both a watershed model and an in-stream model to aid in developing the TMDLs.

The Hydrologic Simulation Program-Fortran (HSPF) was recommended for its capacity to simulate watershed-loading processes in both urban and rural areas (Parsons 2003a). The Water Quality Analysis Simulation Program (WASP) water quality model, coupled with the hydrodynamic program, DYNHYD, and the HSPF watershed model, was recommended as the best available model system to simulate water quality processes in the bayous. It was later discovered that DYNHYD was not able to accurately simulate the tidal cycles occurring during the intensive surveys of May through August of 2004. Consequently, hydrodynamic models of Adams and Cow Bayou were developed using RMA2, a more full-featured hydrodynamic model developed by the U.S. Army Corps of Engineers. Overall, HSPF modeled the loads coming off the land surfaces and was coupled with WASP to simulate the instream water quality conditions.

A water quality monitoring plan (Parsons 2003b) and quality assurance project plan (Parsons 2003c) were then developed to collect the data necessary to build and calibrate the water quality and watershed models. This data was collected by Parsons and the SRA-TX between January and November 2004. The data collection effort consisted of runoff sampling to calibrate pollutant-loading factors for the watershed model, and several intensive surveys of flow and the quality of water and effluent in Adams and Cow Bayous, along with sediment oxygen demand surveys, to calibrate the instream hydrodynamic and water quality models.

Intensive Surveys

Two 48-hour intensive surveys were performed on each bayou during the summer of 2004, to provide data for calibration and verification of the hydrodynamic and water quality models. Summer is the season when dissolved oxygen levels have historically been very low. The surveys were performed approximately one month apart. The Adams Bayou intensive surveys were performed from May 26–28 and June 29–July 1. The Cow Bayou intensive surveys were performed from July 20–22 and from August 24–26. Ambient monitoring sites from the intensive surveys are depicted in Figure 6.

Each ambient monitoring site was visited five to nine times over the course of each 48-hour intensive survey for measurement of flow, water depth and velocity, dissolved oxygen, salinity/conductivity, water temperature, and pH. Flow and velocity measurements were made using acoustic Doppler current profilers and Marsh-McBirney electronic current meters. Water surface elevations were continuously monitored and recorded at a few locations using tide gages. Multi-parameter sondes were deployed at one or two depths at many sites to record water depth, salinity/conductivity, temperature, dissolved oxygen, and pH every 15 minutes over the course of each survey.

Additional water quality samples were collected three to five times from each ambient monitoring site during each survey. Samples were analyzed for chlorophyll *a* (ChlA), nitrate nitrogen (NO_3N), ammonia nitrogen (NH_3N), total Kjeldahl nitrogen (TKN), orthophosphate phosphorus (PO_4P), five-day carbonaceous biochemical oxygen demand (cBOD5), total dissolved solids, TSS, volatile suspended solids (VSS), *E. coli*, and alkalinity. Additional water quality samples were collected daily from the permitted water quality discharges to the bayous and analyzed for the same suite of parameters.

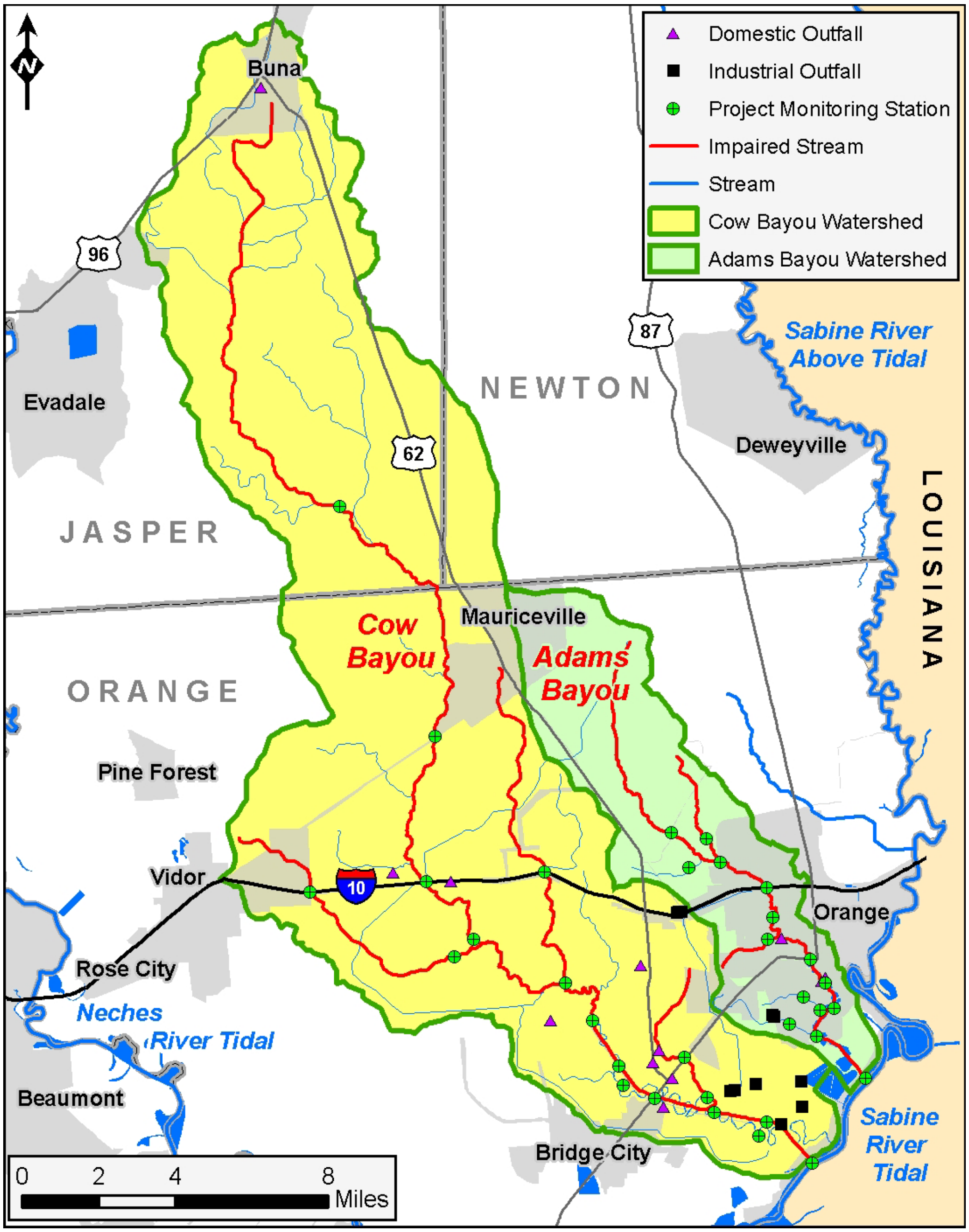

Figure 6. Monitoring sites

The cBOD is typically measured as cBOD5, the oxygen demand from oxidation of organic matter over a five-day period. However, the WASP model simulates ultimate cBOD, the oxygen demand from biochemical oxidation of essentially all organic matter. In order to estimate ultimate cBOD from cBOD5, cBOD was measured after 5, 15, and 20 days in fourteen ambient samples from various locations in each bayou. The 20-day cBOD measurements were considered to represent ultimate cBOD. The ratio of ultimate cBOD to cBOD5 ranged from 1.0 to 3.9 with an overall average of 2.3 and a standard deviation of 0.7. This ratio was not significantly different between bayous or intensive survey periods. Therefore, for the WASP model input, all cBOD5 measurements were multiplied by 2.3 to represent ultimate cBOD.

Model output determined the amount of contribution from various land uses or sources for particular constituents. Figure 7 summarizes *E. coli* sources to the Adams Bayou system. For the purpose of determining contributions from each source, Adams and Cow Bayou systems were evaluated separately and were also separated into subwatersheds divided by Interstate 10. The reason for using Interstate 10 as a dividing line is two-fold. First, it is roughly the point at which tidal influence ends or decreases substantially. Second, the area north of the Interstate is more rural, while the bulk of urban land use is south of the interstate. Above I-10, failing septic systems are the largest contributor, followed by pasture. Below I-10, the main three contributors are failing septic systems, urban residential areas, and pasture.

Sensitivity analysis determined that cBOD and ammonia nitrogen loadings have the most effect on instream dissolved oxygen concentrations. As cBOD and ammonia nitrogen loadings increase, dissolved oxygen concentrations decrease. In Adams Bayou, the main contributors of both constituents above I-10 are failing septic systems (Figures 8 and 9). Below I-10, the main contributions are from point sources.

In Cow Bayou, the main source of bacteria loading, both above and below I-10, appears to be from failing septic systems (Figure 10). Pasture and forest are the other main contributors, but comprise less than 25 percent of the total *E. coli* loading. Cattle in streams and residential land uses contribute only a minor fraction of the whole.

In Cow Bayou above I-10, cBOD loading comes mainly from failing septic systems and forests (Figure 11). Below I-10, cBOD loading comes mainly from failing septic systems, point sources, forests, and pasture, in decreasing order. Ammonia nitrogen loading is due in large part to failing septic systems both above and below I-10 (Figure 12). Point sources, forest, and pasture make only minor contributions.

Sediment oxygen demand (SOD) was believed to be a key factor controlling dissolved oxygen levels in the bayous, based on the QUAL-TX modeling reports of the Texas Water Commission from the 1980s (TWC 1986, 1988). Therefore, SOD was measured at a number of sites in each bayou using *in situ* respirometers. The respirometer, or SOD chambers, monitored the dissolved oxygen depletion in a confined volume of water overlying bed sediments over the course of one to three hours. Field measurements revealed only average to slightly above average SOD levels.

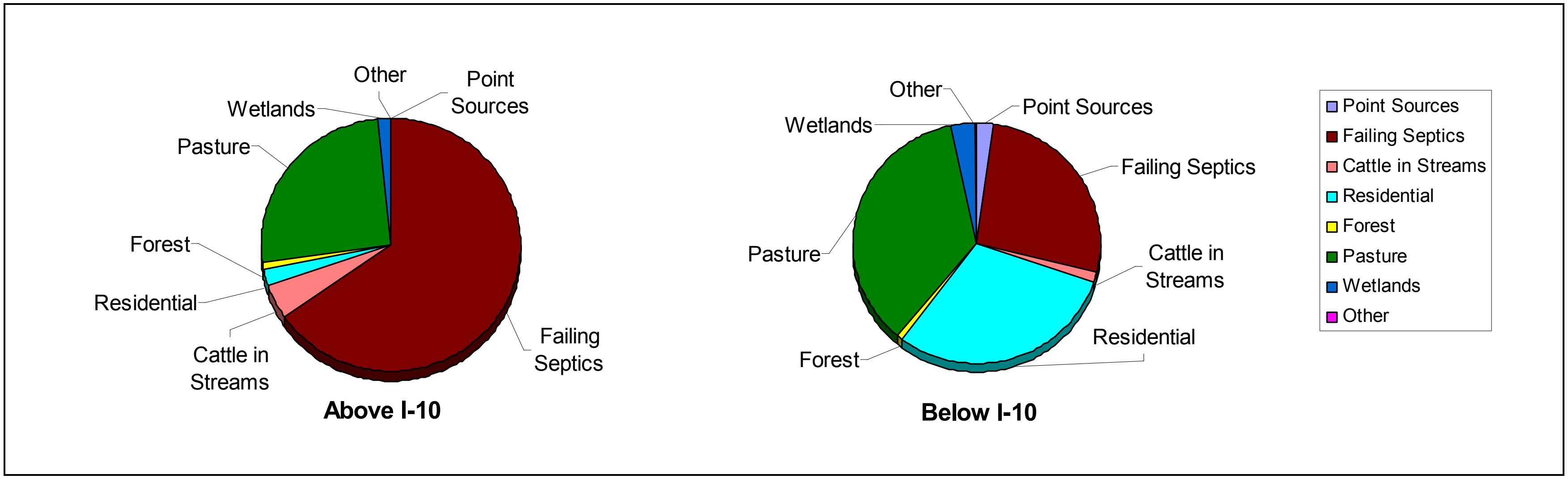

Figure 7. Sources of *E. coli* to Adams Bayou

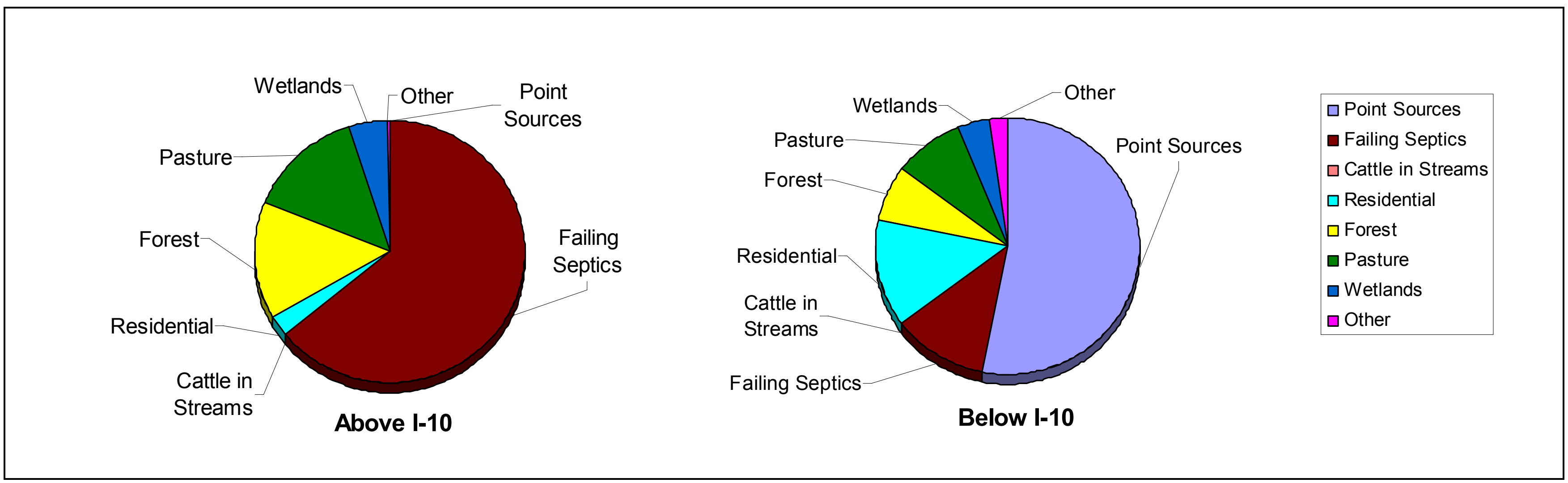

Figure 8. Sources of cBOD to Adams Bayou

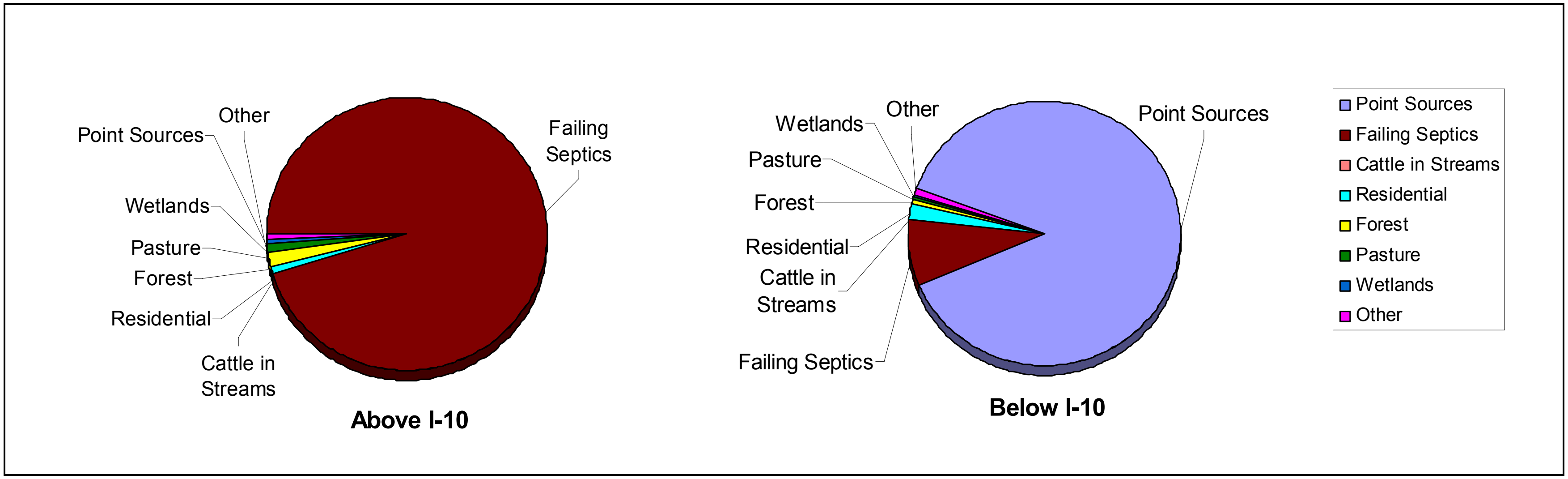

Figure 9. Sources of ammonia nitrogen to Adams Bayou

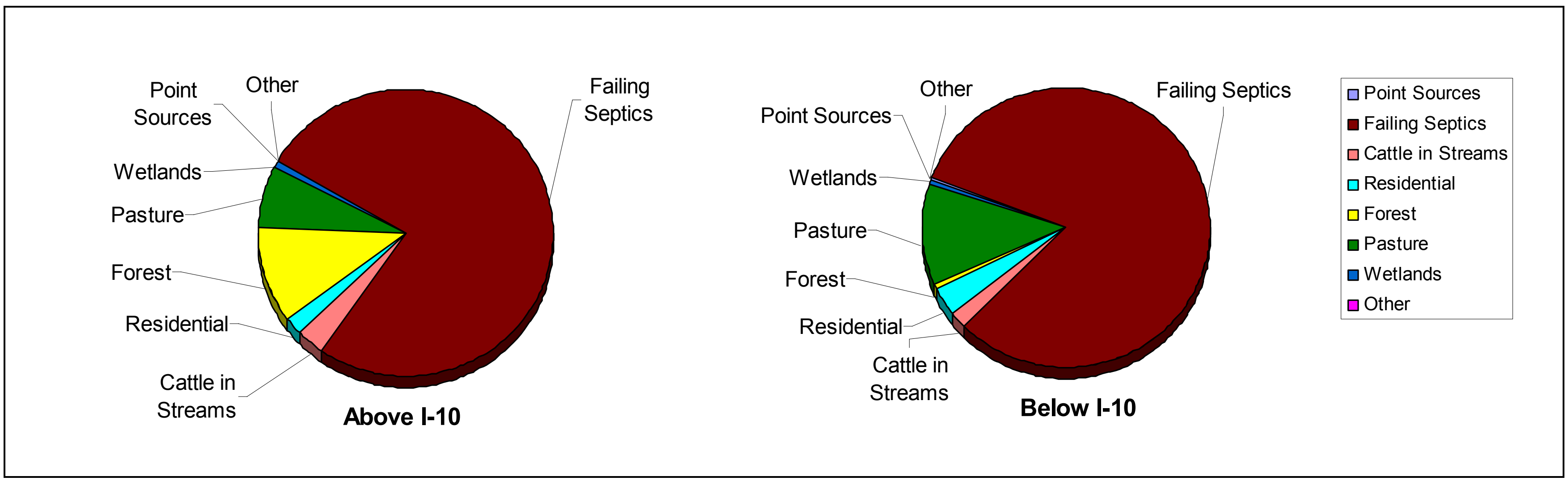

Figure 10. Sources of *E. coli* to Cow Bayou

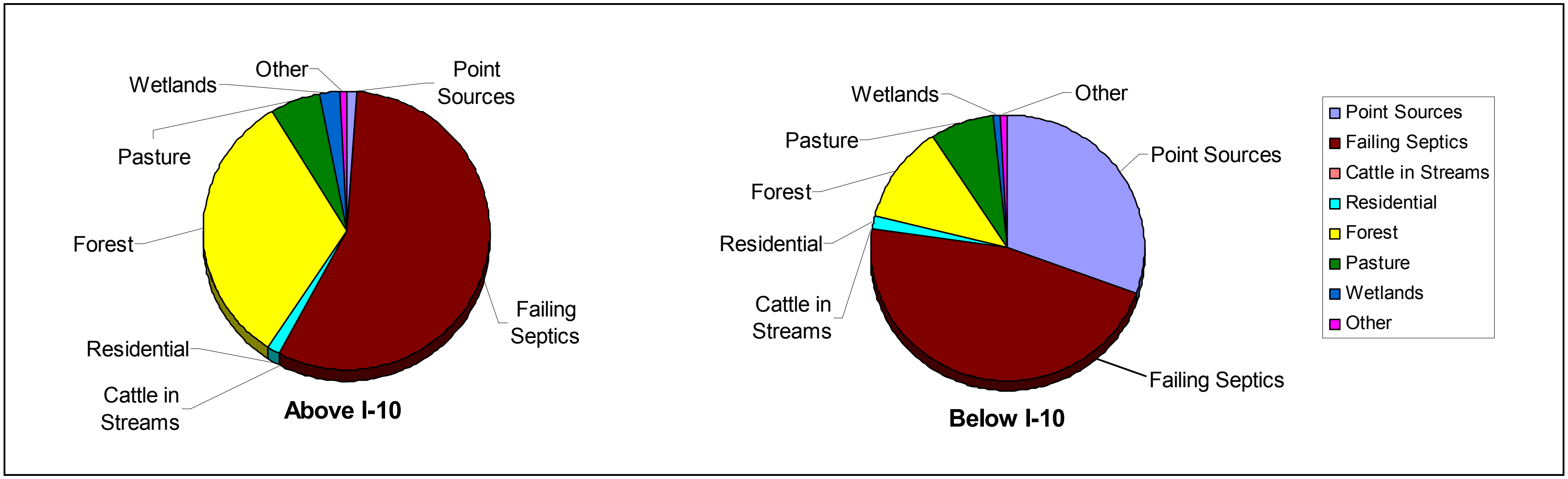

Figure 11. Sources of cBOD to Cow Bayou

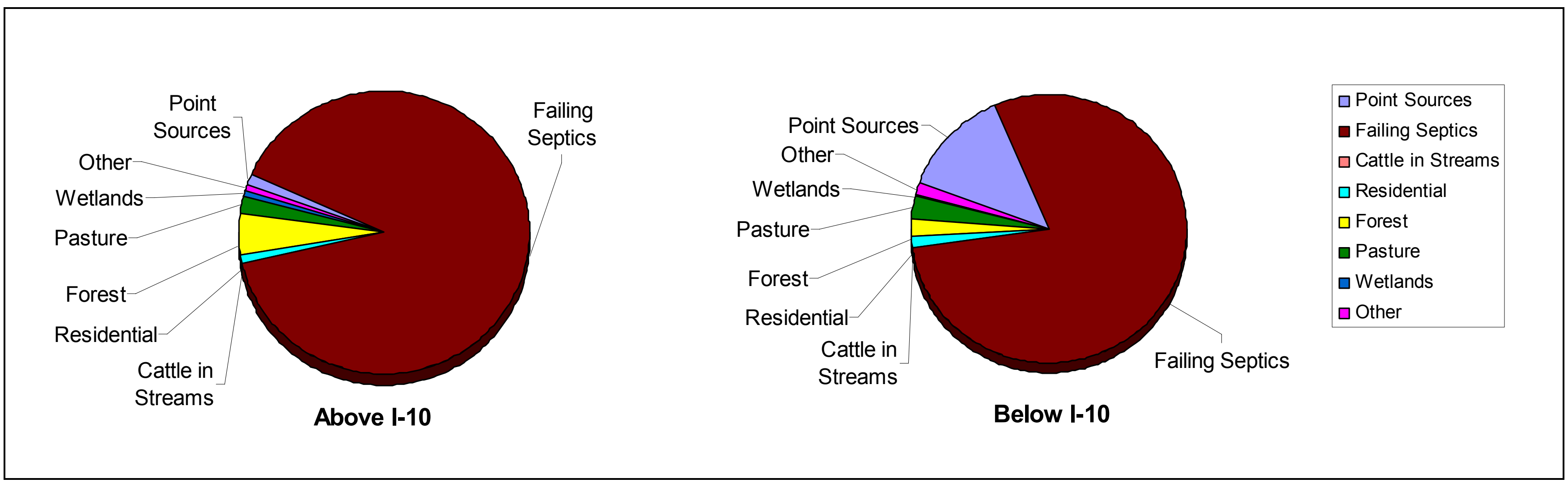

Figure 12. Sources of ammonia nitrogen to Cow Bayou

Seasonal Variation

An investigation of the historical data from both bayou systems revealed that there is a consistent springtime peak and summertime decline in bacteria concentrations. At some sample stations there was also a secondary autumn peak in bacteria concentrations. These peaks and declines may be related to stream flow, temperature, predation by other micro-organisms, or other unknown factors. Interestingly, counter to expectations, normal monthly precipitation at Port Arthur, just south of the study area, peaks in summer, when stream flow and bacteria concentrations are lowest. It is commonly expected that the highest bacteria levels occur in the season with the most frequent rainfall, because runoff washes fecal matter built up on land into waterways, as well as contributing to sewer overflows and WWTF bypasses. It appears that the critical seasonal conditions for bacteria differ from those for dissolved oxygen, which tend to occur in late summer.

Bacteria levels have been measured for over thirty years at one monitoring site in each of Cow Bayou and Adams Bayou. These stations are in the lower tidal reaches of each bayou. The variability in geometric mean concentrations is higher in the 1970's and 1980's because fewer measurements were made in these years. However, fecal coliform concentrations have not varied significantly in either bayou over the thirty year period examined. Bacteria levels have declined slightly in the last few years; this may be simply due to natural inter-annual variability.

Margin of Safety

The margin of safety (MOS) should 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. The margin of safety may be incorporated into the analysis using two methods:

- implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- explicitly assigning a loading amount for the MOS.

The TMDLs for Orange County use an implicit of MOS for the dissolved oxygen, bacteria, and pH impairments. The implicit MOS used in these TMDLs is embodied in the assessment methods, as well as in the way the modeling was conducted.

In an effort to be conservative in development of the TMDLs for *E. coli*, the load reductions were calculated using the geometric mean as the target. In all cases, attainment of the geometric mean criterion required a higher load reduction than attainment of the single sample criterion. Also, the failure rate of septic systems used a higher percentage than most published values, based upon input by local stakeholders, OSSF inspectors, and the report titled, *An Assessment of Non-Point Sources of Pollution in the Southeast Texas Designated 208 Planning Area.* This high failure rate used could possibly overestimate the magnitude of the impairment. Furthermore, no flow regimes, such as high flow events, were excluded from model analysis.

The model was used to determine the percent reduction required for each impaired segment to comply with the standard for dissolved oxygen, *E. coli*, and pH. In the WASP model, Cow Bayou tidal was broken into 20 individual reaches. The 20 reaches formed five groups of reaches that better represented the variability within the entire segment. Load reductions were then calculated for each group. Breaking up Cow Bayou tidal into five smaller reach groups reduces the possibility of utilizing one average load reduction for an entire water body that has such large variation in its loading capacity. A similar practice was utilized for Adams Bayou tidal. The segment was split into four groups of reaches, to better represent the variability within the segment. This method reduces the possibility of applying a single load reduction for an entire segment that contains varying load capacity within the segment.

Pollutant Load Allocation

The TMDL represents the maximum amount of a pollutant that the stream can receive in a single day without exceeding the water quality standard. The load allocation can be developed using the following equation:

TMDL = WLA + LA + MOS

Where:

WLA = wasteload allocation (point source contributions)
LA = load allocation (nonpoint source contributions)
MOS = margin of safety

Load Reductions and TMDLs

Table 12 summarizes the existing loads for the key parameters most closely related to water quality impairments. cBOD and ammonia nitrogen were the two parameters most important to controlling dissolved oxygen levels in the bayous, as determined during model development. Reductions in loadings of cBOD and ammonia nitrogen will result in an increase in the dissolved oxygen concentration of a water body. For that reason, their loadings are critical to the development of the TMDLs for attainment of the dissolved oxygen criteria.

Except for ammonia nitrogen, nonpoint source contributions are greater than point sources in Adams Bayou Tidal. Point sources also contribute a significant part of the total loads of cBOD in Adams Bayou Tidal and Cow Bayou Tidal.

Bacteria Load Reduction

The load reductions required to meet contact recreation standards in the Adams Bayou impaired segments are illustrated in Figures 15 and 16 and Table 17. The reductions required to meet the geometric-mean criterion for *E. coli* are in all cases greater than those required to meet the single-sample criterion. The required load reductions were calculated at each ambient monitoring site, and the load reductions for the segments are those from the site requiring the greatest load reductions. Required load reductions ranged from 15 percent in Hudson Gully to 83 percent in Gum Gully.

Table 12. Existing loads of key pollutants to Adams and Cow Bayou segments

Segment	cBOD (lbs/day)			NH_3N (lbs/day)			*E. coli* (billion cfu/day)		
	Point	Nonpoint	Total	Point	Nonpoint	Total	Point	Nonpoint	Total
Adams Bayou Above Tidal	0	137	137	0	20	20	0	350	350
Gum Gully	0	42	42	0	5.5	5.5	0	120	120
Hudson Gully	0	14	14	0	1.8	1.8	0	41	41
Adams Bayou Tidal† Group 1	0.9	21.6	22.5	0	2.1	2.1	3.8	220	224
Group 2	70.7	16.2	86.9	34.8	0.7	35.5			
Group 3	0	5.4	5.4	0	0.2	0.2			
Group 4	0	42	42	0	5.7	5.7			
Adams Bayou Tidal total	71.6	85.2	156.8	34.8	8.7	43.5			
Cow Bayou Above Tidal	20	723	743	2	75	77	2.2	1100	1100
Cole Creek	0	217	217	0	30	30	0	430	430
Terry Gully	0	660	660	0	104	104	0	1400	1400
Coon Bayou	3	114	117	0.3	18	19	0.7	300	300
Cow Bayou Tidal† Group 1	286	17	303	11.7	1.0	12.7	9.4	1900	1909
Group 2	95	160	255	8.6	24.4	33			
Group 3	1	88	89	0	14.4	14.4			
Group 4	37	277	314	0.1	45.6	45.7			
Group 5	1	192	193	1.2	45.9	47.1			
Cow Bayou Tidal total	420	734	1,154	21.6	131.3	152.9			

†Note that loads to tributaries are not included in the loads of the main tidal segment; i.e., they are not double-counted, although they also could be considered as loads to the downstream segment.

As an example of how to utilize the following tables, the *E. coli* TMDL for Hudson Gully will be explained:

Step 1. The existing *E. coli* loading is 41 billion colonies/day found in Table 12.

Step 2. A 15 percent reduction is required, found in Table 17.

Step 3. A 15 percent reduction from 41 billion colonies/day equals 35 billion colonies/day, which is the value found in Table 18 as the maximum load for the segment.

Step 4. The TMDL equation is found in Table 21 utilizing these values. Since there are no point source discharges to Hudson Gully, the WLA is 0, and the required reduction comes from the LA.

The load reductions required to support the contact recreation use in the Cow Bayou impaired segments are illustrated in Figures 17 and 18 and Table 17. Terry Gully requires a 20 percent reduction in *E. coli* loading to meet water quality standards, and Coon Bayou will require an 83 percent load reduction to meet water quality standards. Even though Cow Bayou Tidal and Cole Creek were both listed for noncompliance of the contact recreation criterion, they are projected to meet water quality standards for contact recreation without load reductions (Figure 18). It appears that they are both currently receiving a level of loading they can assimilate and still meet the contact recreation use. However, the years of data that resulted in their listing were years in which their maximum loads were exceeded. The period during which data were collected as part of the TMDL project was a time of reduced loading.

Dissolved Oxygen Load Reduction

Load reductions of cBOD and NH_3N required to meet dissolved oxygen criteria were similar throughout the Adams Bayou system (Figure 19), ranging between 51 percent in Adams Bayou Above Tidal and 60 percent in Adams Bayou Tidal. In the Cow Bayou system, Coon Bayou and Cole Creek require 27 percent and 28 percent load reductions, respectively, to meet dissolved oxygen criteria (Figure 20). Cow Bayou Tidal is predicted to require from 0 percent up to 69 percent load reduction to meet dissolved oxygen criteria, depending upon location within the segment.

WASP calculated load reductions for individual reaches within each segment. The smaller segments feeding into Cow Bayou tidal were comprised of one or two reaches (Figure 13). Cow Bayou tidal was divided into 5 reach groups of similar characteristics at points where the bayou characteristics change:

- Group 1: from FM 1442 south crossing (below oxbow 3) to confluence with Sabine River (reaches 1–7 in Figure 13)
- Group 2: from FM 1442 south crossing to SH 87 (reaches 9, 10, 12, and 13 in Figure 13)
- Group 3: from SH 87 to SH 105 (reaches 14–17 in Figure 13)
- Group 4: from SH 105 to confluence with Terry Gully (reaches 18, 20, and 23 in Figure 13)
- Group 5: Cow Bayou Tidal above confluence with Terry Gully (reaches 25 and 26 in Figure 13)

The existing loading of cBOD and ammonia nitrogen to Cow Bayou Tidal is divided among the five reach groups (Table 13 and Table 14). The percent reductions required to meet water quality standards were calculated for each reach group using the model. Thus, maximum loadings were calculated for the individual reach groups. Table 13 lists existing loads of cBOD for each reach group divided by point and nonpoint sources, as determined by modeling. The table, also, lists the percent reduction required to meet the dissolved oxygen criterion. Finally, the far right columns list the final load allocation allocated to point and nonpoint sources. These are the values used to construct the TMDL equation listed in Table 19. This demonstrates that the lower reaches of Cow Bayou have high assimilative capacity for BOD, while the upper reaches have very little. Thus, a pound of loading to the lower reaches clearly has a much lower impact on water quality impairment than a pound of loading to upper reaches.

Percent reductions for point source dischargers are based upon existing loads which are quite lower than the current full permitted load. This approach was taken because the watershed also includes a significant existing loading from nonpoint sources. It is, therefore, an important point to make that while the percent load reduction for a point source may be zero (compared for the existing waste load), a TPDES permit may need to be modified for consistency with this TMDL.

Adams Bayou Tidal was divided into four reach groups representing contiguous stretches of the bayou with similar physical properties:

- Group 1: Adams Bayou tidal below FM 1006 (reaches 1–6 in Figure 14)
- Group 2: Adams Bayou tidal between FM 1006 and Green Ave/SH 87 (reaches 8–18 in Figure 14)
- Group 3: Adams Bayou tidal between Green Ave/SH 87 and I-10 (reaches 19–21, 23–28 in Figure 14)
- Group 4: Adams Bayou tidal above I-10 (reaches 29–32 in Figure 14)

The existing loading of cBOD and ammonia nitrogen to Adams Bayou Tidal is divided among the four reach groups (Table 15 and Table 16). The percent reductions required to meet water quality standards were calculated for each reach group using the model. Thus, maximum loadings were calculated for the individual reach groups. This demonstrates the variability in the assimilative capacity for BOD within Adams Bayou tidal exists, but not on the same scale as Cow Bayou tidal.

Cow Bayou Above Tidal is an interesting case. The HSPF model used to simulate water quality in Cow Bayou above tidal predicts that dissolved oxygen criteria were not met 36 percent of the time. These violations were predicted by the model to occur when there was no flow but perennial pools were present in the bayou, a condition known to occur somewhat frequently. Reducing cBOD loads in the model, even up to 100 percent, did not predict that dissolved oxygen levels would improve. Additional field monitoring under no-flow conditions would be required to confirm the model predictions. Since load reductions could not be shown to lead to attainment of water quality standards, a TMDL cannot be established for Cow Bayou Above Tidal with the same degree of accuracy as for the other segments. Due to its direct hydraulic linkage to its tidal segment, the safest and most directly estimated load reduction would be to use the same load reduction as that for Cow Bayou Tidal reach group 5. Therefore, for Cow Bayou Above Tidal, 69 percent reductions in cBOD and NH_3N loadings are required.

Table 13. cBOD: TMDLs for meeting the dissolved oxygen standard in Cow Bayou tidal

Reach Group	Existing cBOD Loads (lbs/day)		Percent Reduction Required	TMDL	
	Point Source	Nonpoint Source		Point Source	Nonpoint Source
1	286	17	0%	286	17
2	95	160	0%	95	160
3	1	88	0%	1	88
4	37	277	60%	37	89
5	1	192	69%	1	59
Segment total	**420**	**734**		**420**	**413**

Table 14. NH_3N: TMDLs for meeting the dissolved oxygen standard in Cow Bayou Tidal

Reach Group	Existing NH_3N Loads (lbs/day)		Percent Reduction Required	TMDL	
	Point Source	Nonpoint Source		Point Source	Nonpoint Source
1	11.7	1.0	0%	11.7	1.0
2	8.6	24.4	0%	8.6	24.4
3	0	14.4	0%	0	14.4
4	0.1	45.6	60%	0.1	18.2
5	1.2	45.9	69%	1.2	13.4
Segment total	**21.6**	**131.3**		**21.3**	**71.4**

Table 15. cBOD: TMDLs for meeting the dissolved oxygen standard in Adams Bayou tidal

Reach Group	Existing cBOD Loads		Percent Reduction Required	TMDL	
	Point Source	Nonpoint Source		Point Source	Nonpoint Source
1	0.9	21.6	59%	0.4	8.9
2	70.7	16.2	60%	28.3	6.5
3	0	5.4	58%	0	2.3
4	0	42.0	56%	0	18.5
Segment total	**71.6**	**85.2**		**28.7**	**36.2**

Table 16. NH_3N: TMDLs for meeting the dissolved oxygen standard in Adams Bayou Tidal

Reach Group	Existing NH_3N Loads		Percent Reduction Required	TMDL	
	Point Source	Nonpoint Source		Point Source	Nonpoint Source
1	0	2.1	59%	0	0.9
2	34.8	0.7	60%	13.9	0.3
3	0	0.2	58%	0	0.1
4	0	5.7	56%	0	2.5
Segment total	**34.8**	**8.7**		**13.9**	**3.8**

Table 17. Summary of load reductions required to meet criteria for dissolved oxygen, *E. coli,* and pH

Segment	cBOD and NH_3N	*E. coli*
Adams Bayou Above Tidal	51%	77%
Gum Gully	58%	83%
Hudson Gully	55%	15%
Adams Bayou Tidal†	60%	73%
Cow Bayou Above Tidal	69%	NA
Cole Creek	28%	0%
Terry Gully	NA	20%
Coon Bayou	27%	83%
Cow Bayou Tidal†	69%*	0%

†Note that loads to tributaries are not included in the loads of the main tidal segment, i.e., they are not double-counted, although they also could be considered as loads to the downstream segment.
*Determined for the reach group requiring the highest reduction; some reach groups require no reduction.

pH Load Reduction

pH, a measure of the hydrogen ion content (acidity) of water, is also an impairment in Cow Bayou Tidal requiring a TMDL. General water quality uses are not met due to observed pH levels below the acceptable range of water quality criteria (6.0–8.5) for this segment. Twelve of the 57 measurements (21 percent) taken from 1998 to 2003 in the upper tidal reaches of Cow Bayou fell lower than the minimum of 6.0.

pH is a difficult parameter to simulate through water quality modeling. A large number of natural processes affect pH levels—watershed soil and bedrock type, watershed vegetation type, loading of organic matter, wastewater effluent discharges, temperature, seasonality, photosynthesis by phytoplankton and other aquatic plants, and respiration of organic matter. Algal photosynthesis consumes hydrogen ions, raising the pH. Respiration reverses this process, releasing hydrogen ions and lowering pH.

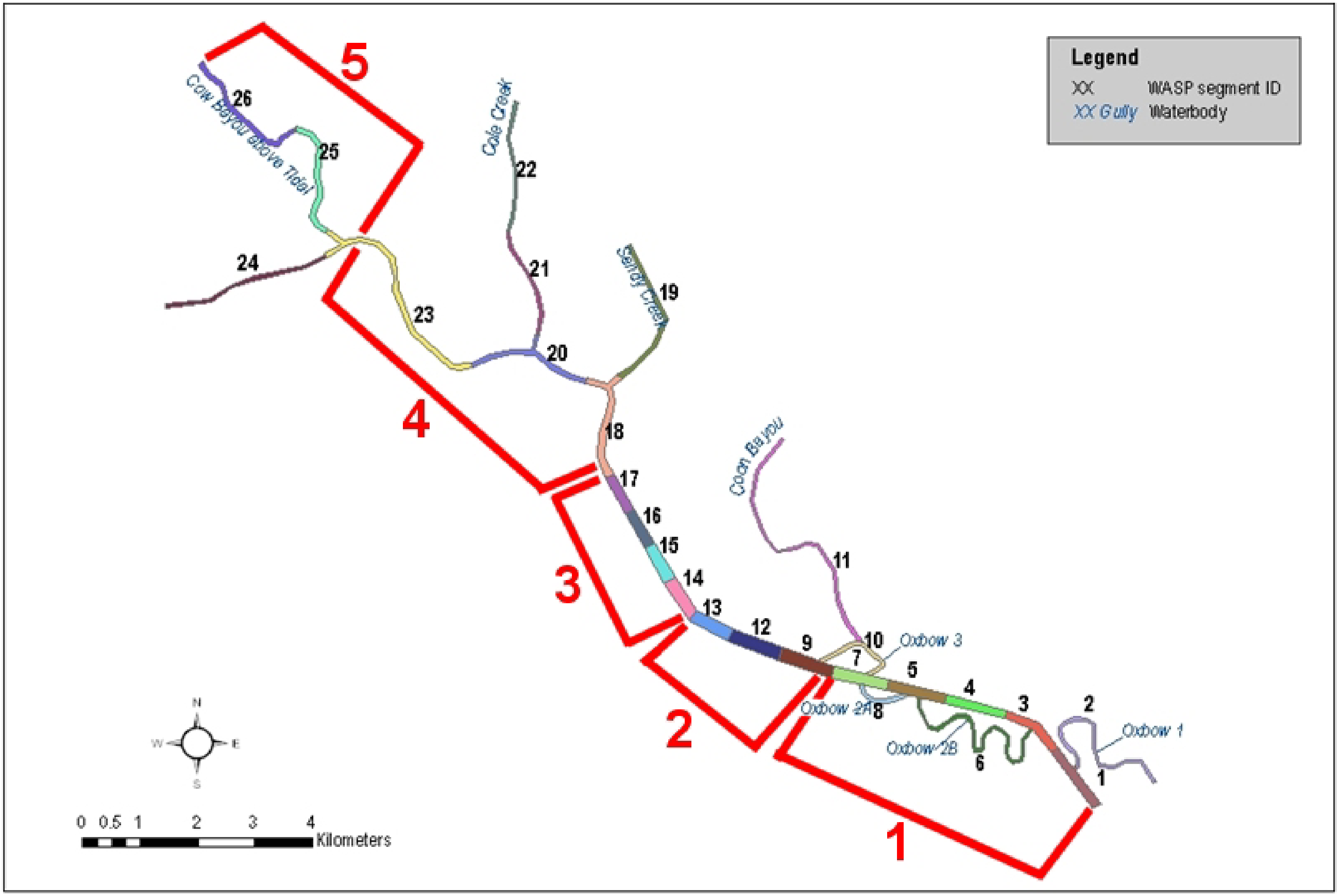

Figure 13. Cow Bayou WASP model segmentation

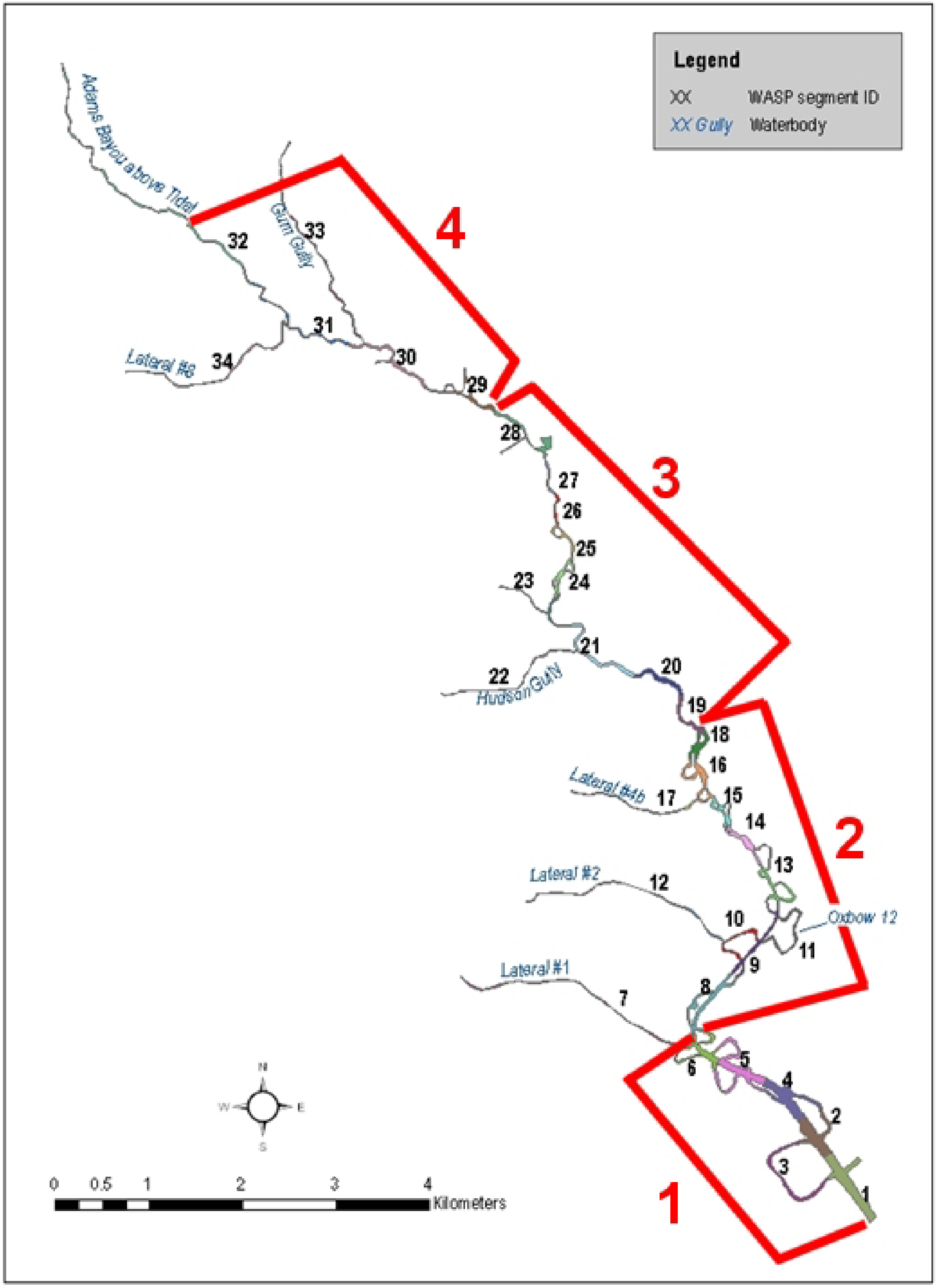

Figure 14. Adams Bayou WASP model segmentation

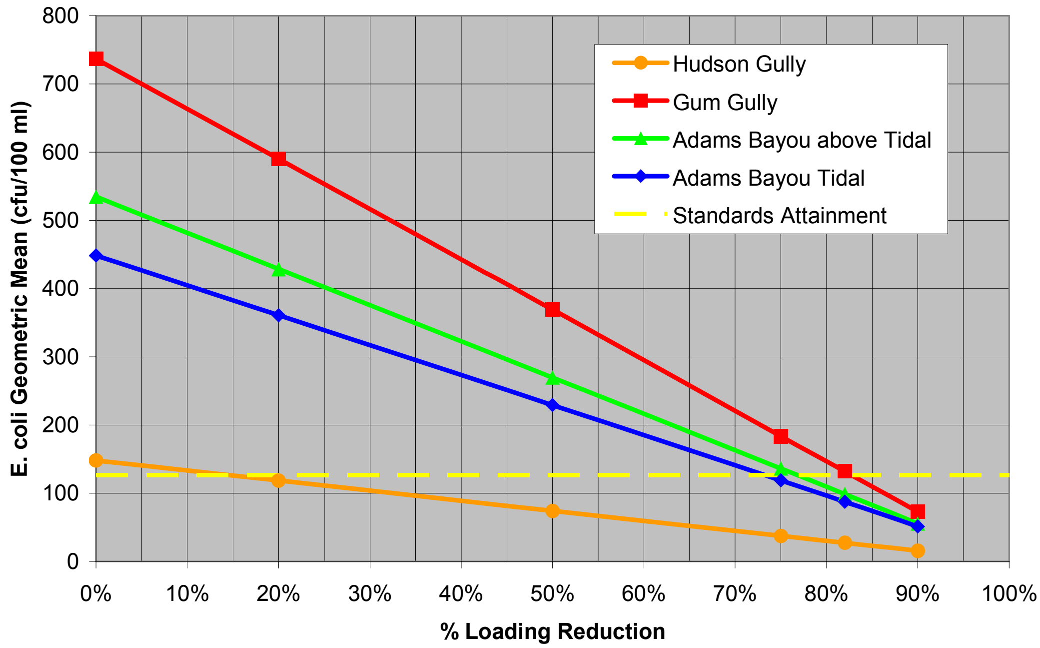

Figure 15. Adams Bayou system attainment of the *E. coli* geometric mean criterion

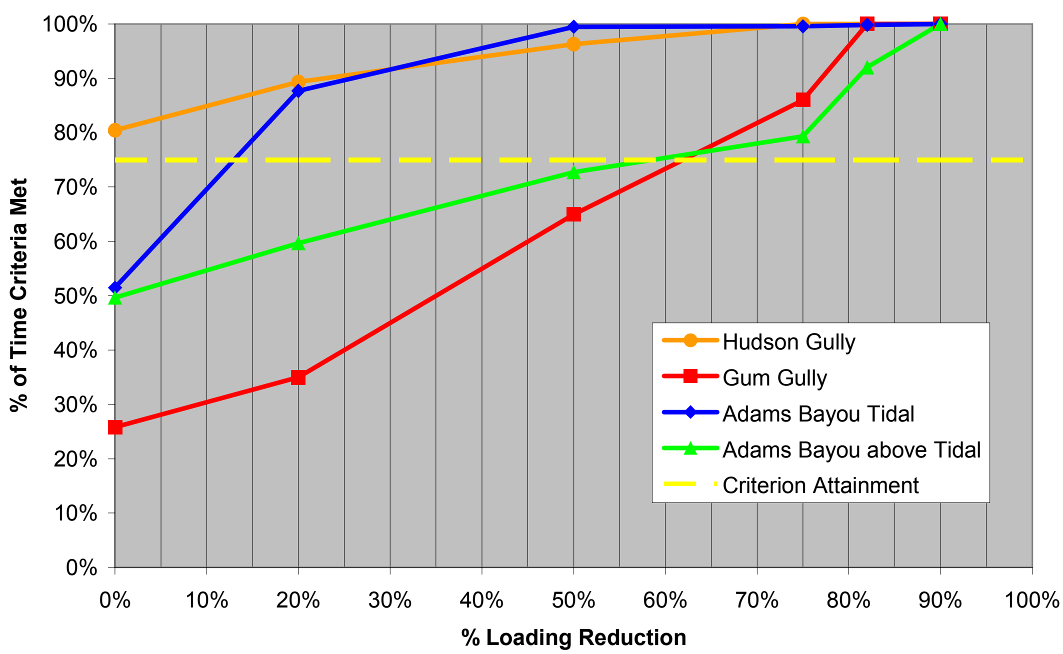

Figure 16. Adams Bayou system attainment of the *E. coli* single sample criterion

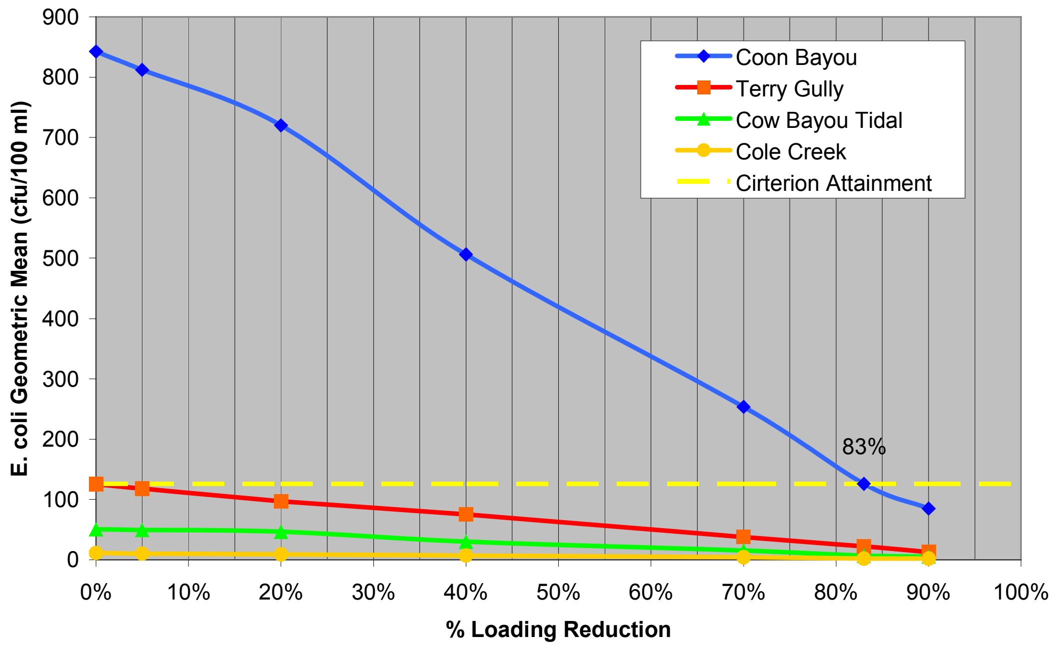

Figure 17. Cow Bayou system attainment of the *E. coli* geometric mean criterion

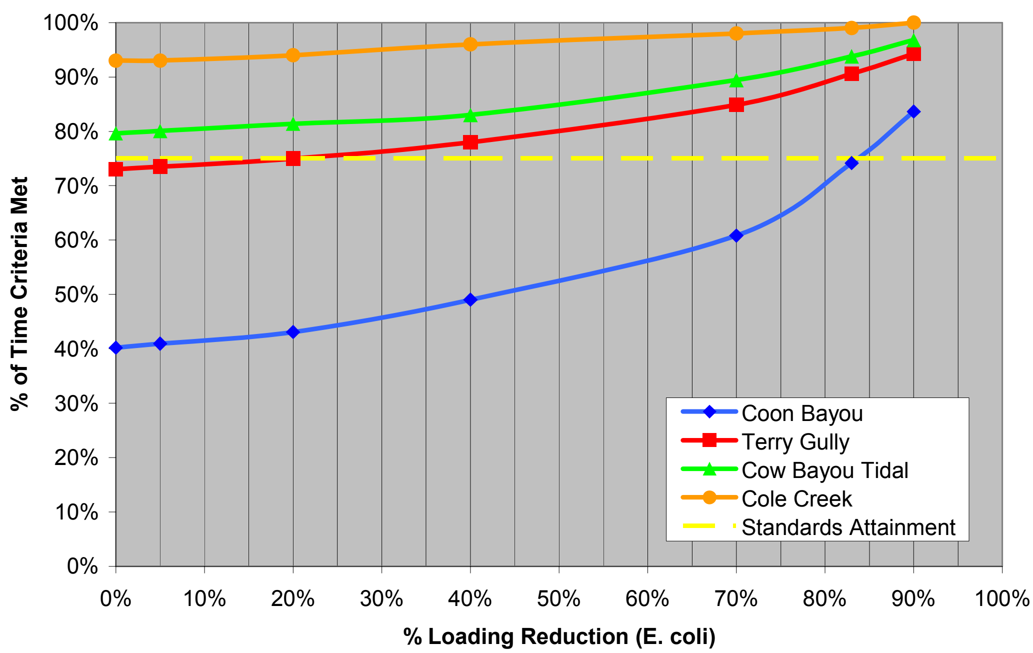

Figure 18. Cow Bayou system attainment of the *E. coli* single sample criterion

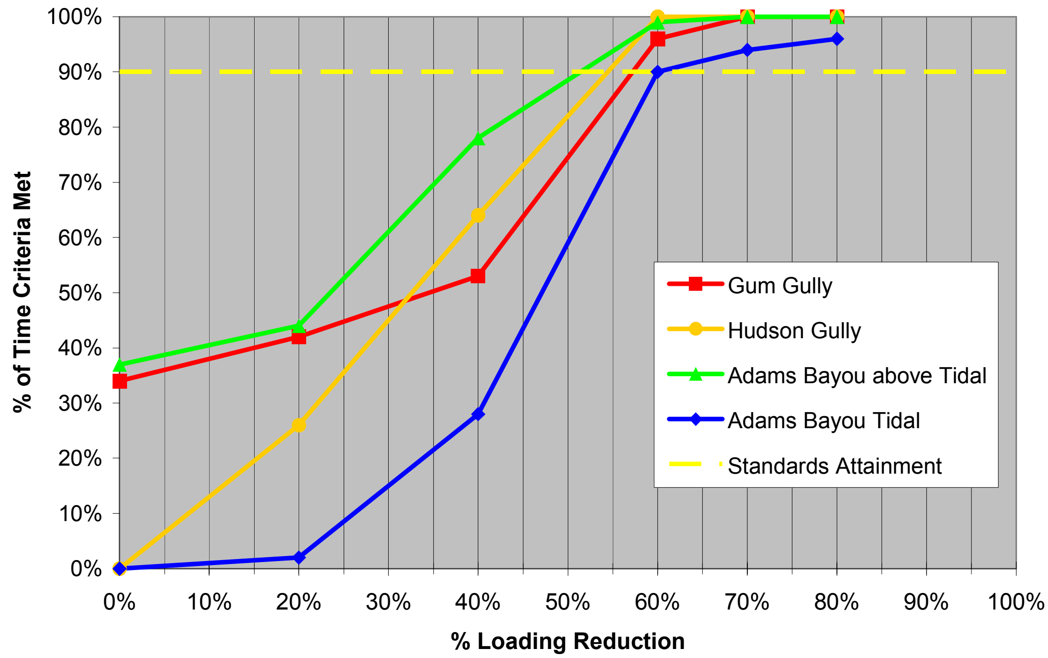

Figure 19. Adams Bayou system load reductions to attain dissolved oxygen criteria

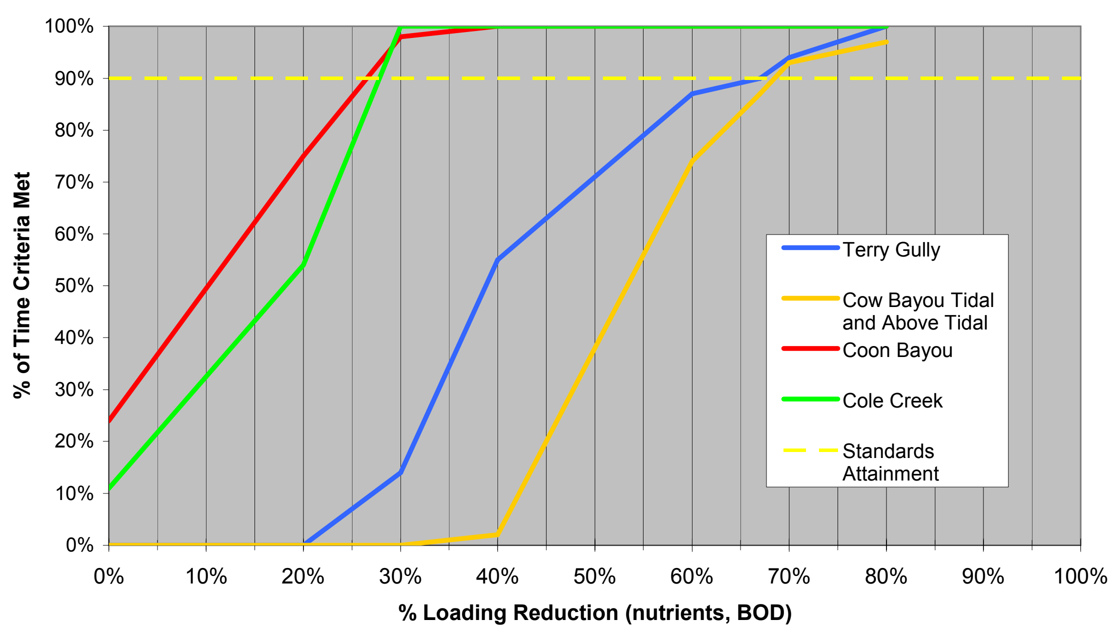

Figure 20. Cow Bayou system load reductions to attain dissolved oxygen criteria

The WASP model does not simulate pH; in fact, few water quality models attempt to simulate pH. pH varies less as alkalinity (buffering capacity) increases, but these bayous have low levels of alkalinity. In particular, at approximately 22 km upstream of the Sabine River, the median levels of total alkalinity are 20 mg/L as calcium carbonate. The lower tidal portions of both bayous are more frequently buffered by the salts found in seawater.

The primary process responsible for lower pH in many systems is the respiration of organic matter. Primary production by aquatic plants, on the other hand, is the key process raising the pH level in many systems. Low pH levels tend to occur in poorly buffered systems where respiration exceeds primary production. Other potential sources of low pH include un-neutralized point source discharges.

The source of low pH in Cow Bayou Tidal appears to be the degradation of organic matter, which is also the primary source of low dissolved oxygen levels. Figure 21 shows that the changes in average pH levels with distance downstream in Cow Bayou vary inversely with the cBOD levels. Thus, the low pH values tend to occur where cBOD levels are highest, likely due to the degradation of the organic matter comprising cBOD. For this reason, it appears that the same measures intended to raise dissolved oxygen levels will also raise pH values to meet water quality standards.

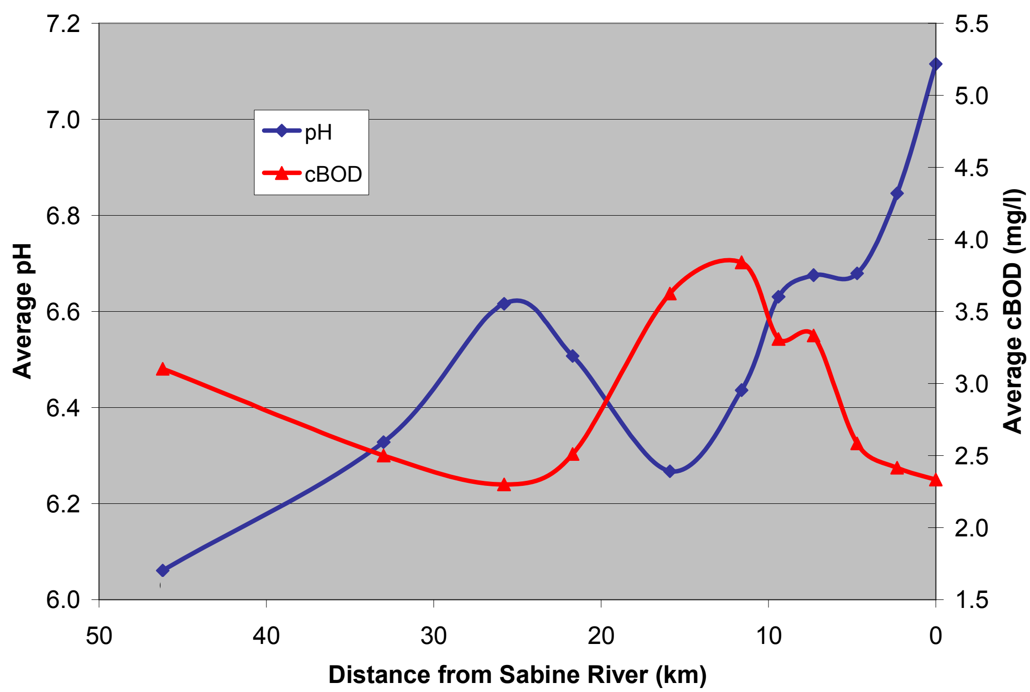

Figure 21. Average measured pH and cBOD in Cow Bayou with distance upstream during the summer 2004 intensive surveys.

Given that the dissolved oxygen criteria are not met in Cow Bayou far more frequently than the pH criteria, it follows logically that a TMDL involving sufficient reductions in oxygen demanding organic matter to meet water quality standards for dissolved oxygen will in all likelihood also lead to attainment of the pH standard. Therefore, the TMDL for attainment of the pH criteria in Cow Bayou Tidal is the same allocations for cBOD and ammonia for attainment of the dissolved oxygen criteria. Therefore, the same 69 percent reduction for attainment of the dissolved oxygen criteria will apply for attainment of the pH criteria.

Total Maximum Daily Loads

Maximum allowable loads of cBOD, NH_3N, and *E. coli* that are predicted to allow water quality standards to be met are provided in Table 18. These are calculated based on average percent reductions from total existing loading to the water body. The water quality impairments are not uniformly distributed throughout the larger water bodies such as Cow Bayou Tidal, Adams Bayou Tidal, and Cow Bayou Above Tidal. Neither are the pollutant loads mixed throughout the water bodies, and assimilative capacity may vary greatly with distance from the Sabine River. For dissolved oxygen impairments, the load reductions described apply only to the case in which a single uniform load reduction percentage is applied to both cBOD and NH_3N loadings to the water body.

For example, for Cole Creek to meet the aquatic life use, cBOD and ammonia nitrogen must be equally reduced by 28 percent. Reducing only one constituent is not likely to have the same impact as reducing both. The actual load reductions required to meet criteria will vary with the pollutant source, and reducing some specific loads may not result in improved water quality. The model may be used to evaluate the impact of varying load reductions on a source-specific basis.

The TMDLs for cBOD, NH_3N, *E. coli*, and pH are shown in Tables 18 through 22.

Table 18. Maximum allowable loads

Segment	**cBOD** (lbs/day)	**NH_3N** (lbs/day)	**E. coli** (billion cfu/day)
	Total	**Total**	**Total**
Adams Bayou Above Tidal	67	9.8	81
Gum Gully	18	2.3	20
Hudson Gully	6.3	1.8	35
Adams Bayou Tidal†	64.9	17.7	59
Cow Bayou Above Tidal	513	53	NA
Cole Creek	156	22	430
Terry Gully	NA	NA	1100
Coon Bayou	85	14	51
Cow Bayou Tidal†	833	93	1900

†Note that loads to tributaries are not included in the loads of the main tidal segment, i.e., they are not double-counted, although they also could be considered as loads to the downstream segment.

Table 19. cBOD: TMDLs for meeting the dissolved oxygen standard

Segment	TMDL (lbs/day) = WLA (lbs/day) + LA (lbs/day)
Adams Bayou Above Tidal	67 = 0 + 67
Gum Gully	18 = 0 + 18
Hudson Gully	6.3 = 0 + 6.3
Adams Bayou Tidal†	64.9 = 28.7 + 36.2
Cow Bayou Above Tidal	513 = 103 + 410
Cole Creek	156 = 0 + 156
Terry Gully	NA
Coon Bayou	85 = 3 + 82
Cow Bayou Tidal†	833 = 420 + 413

†Note that loads to tributaries are not included in the loads of the main tidal segment, i.e., they are not double-counted, although they also could be considered as loads to the downstream segment.

Table 20. NH_3N: TMDLs for meeting the dissolved oxygen standard

Segment	TMDL (lbs/day) = WLA (lbs/day) + LA (lbs/day)
Adams Bayou Above Tidal	9.8 = 0 + 9.8
Gum Gully	2.3 = 0 + 2.3
Hudson Gully	1.8 = 0 + 1.8
Adams Bayou Tidal†	17 = 14 + 3
Cow Bayou Above Tidal	53 = 5 + 48
Cole Creek	22 = 0 + 22
Terry Gully	NA
Coon Bayou	14 = 5 + 9
Cow Bayou Tidal†	93 = 21.6 + 71.4

†Note that loads to tributaries are not included in the loads of the main tidal segment, i.e., they are not double-counted, although they also could be considered as loads to the downstream segment.

Table 21. *E. coli*: TMDLs for meeting the contact recreation use

Segment	TMDL = WLA + LA*
Adams Bayou Above Tidal	81 = 0 + 81
Gum Gully	20 = 0 + 20
Hudson Gully	35 = 0 + 35
Adams Bayou Tidal†	59 = 10 + 49
Cow Bayou Above Tidal	NA
Cole Creek	430 = 0 + 430
Terry Gully	1100 = 0 + 1100
Coon Bayou	51 = 10 + 41
Cow Bayou Tidal†	1900 = 18 + 1882

*all values in the equation are expressed in billions colonies/day.

†Note that loads to tributaries are not included in the loads of the main tidal segment, i.e., they are not double-counted, although they also could be considered as loads to the downstream segment.

Table 22. TMDL for attainment of pH criteria in Cow Bayou Tidal

Parameter	TMDL = WLA + LA
cBOD	833 = 420 + 413
NH_3N	93 = 21.6 + 71.4

Public Participation

The Orange County TMDL Stakeholder Advisory Group (SAG) was formed in 2003, during the initial stages of project development. It was formed and approved according to guidance provided by HB 2912. Members represent government, permitted facilities, agriculture, business, environmental, and community interests in the Adams and Cow Bayou watersheds. The SAG met quarterly. Meetings usually consisted of a brief overview of the project, followed by a more in-depth discussion of the current project activity. Time was given for SAG members to offer advice and local insight to the project staff.

Throughout the fifteen times the SAG has met, their insight and energy contributed greatly to the success of the project. SAG member input was important from as early on as development of the sampling plan. Members offered helpful local insight regarding sample station selection. SAG members provided crucial input during the modeling phase in regards to local OSSF failure rates and cattle operations in the area. Meetings were al-ways open to the public. Sabine River Authority of Texas hosted and facilitated all SAG meetings.

Additionally, a Technical Advisory Group (TAG) composed of state and local governmental entities was formed at the same time the SAG was formed. Members served in an advisory role to the SAG.

In an effort to better inform the public in the project area, a "Clean Bayous Fair" was held in January 2005 at the Lamar State College Orange Student Center Gymnasium in Orange (Figure 22). The fair was a direct result of the efforts and enthusiasm of the SAG members. Upon entering the Fair, attendees were given a brief overview of the TMDL project, and then sent on a tour of the available activities. Highlights of the activities included: educational activities for all ages, interactive fish species "touch tank," information on reduced rate loan and grant programs for septic systems, table-top demonstrations on non-point source runoff, refreshments, games, door prizes, free give-aways for kids and adults, and an appearance by the Fair mascot "Tad the Tadpole." Approximately 400 people from the Adams and Cow Bayou watersheds attended the fair.

Figure 22. Participants at the Clean Bayous Fair, January 2005

Implementation and Reasonable Assurances

The TMDL development process involves the preparation of two documents:

1) a TMDL, which determines the amount of pollutant a water body can receive in a single day and continue to meet applicable water quality standards, and
2) an implementation plan (I-Plan), which is a detailed description and schedule of regulatory and voluntary management measures necessary to achieve the pollutant reductions identified in the TMDL.

It is the policy of the TCEQ to develop I-Plans for all TMDLs adopted by the commission, and to assure the plans are implemented; I-Plans are critical to ensure water quality standards are restored and maintained. I-Plans are not subject to EPA approval.

The TCEQ works with stakeholders to develop the strategies summarized in the I-Plan. I-Plans may use an adaptive management approach that achieves initial loading allocations from a subset of the source categories. Adaptive management allows for development or refinement of methods to achieve the environmental goal of the plan.

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

The TCEQ is working to identify funding sources to help alleviate nonpoint source pollution in the area through several routes. One such funding method, Supplemental Environmental Projects (SEPs), are a means for directing fines, fees, and penalties for environmental violations toward environmentally beneficial uses. Through a SEP, a respondent in an enforcement matter can choose to invest penalty dollars in improving the environment, rather than paying into the Texas General Revenue Fund. Orange County already has a pre-approved SEP in place that will facilitate funding in the area. In addition, the SEP is under review to better tailor it to fit the needs of the area, as identified in this TMDL document, and the resulting implementation plan.

Another route for reducing nonpoint source pollution will be through applying for 319-grant money to fund repair, replacement, or upgrades to local failing OSSFs. Failing OSSFs have been shown to be a major source of nonpoint source pollution.

A review of recent self-reported data from TPDES permit holders might be appropriate to gage the compliance history of the point sources within the watershed. Additional measures such as increased reporting and/or limits may be needed. If repeated noncompliance is a factor, the TMDL program will work with Field Operations Division to bring the noncompliant discharger(s) back into compliance with the TCEQ's permit limits.

Implementation Processes to Address the TMDL

Together, a TMDL and a TMDL I-Plan direct the correction of unacceptable water quality conditions that exist in an impaired surface water in the state. A TMDL broadly identifies the pollutant load goal after assessment of existing conditions and the impact on those conditions from probable or known sources. A TMDL identifies a total loading from the combination of point sources and nonpoint sources that would allow attainment of the established water quality standard.

A TMDL I-Plan specifically identifies required or voluntary implementation actions that will be taken to achieve the pollutant loading goals of the TMDL. Regulatory actions identified in the I-Plan could include adjustment of an effluent limitation in a wastewater permit, a schedule for the elimination of a certain pollutant source, identification of any nonpoint source discharge that would be regulated as a point source, a limitation or prohibition for authorizing a point source under a general permit, or a required modification to a storm water management program (SWMP) and pollution prevention plan (PPP). 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.

A TMDL and the underlying assumptions, model scenarios, and assessment results are not and should not be interpreted as required effluent limitations, pollutant load reductions that will be applied to specific permits, or any other regulatory action necessary to achieve attainment of the water quality standard. In simple terms, a TMDL is like a budget that determines the amount of a particular pollutant that the water body can receive and still meet a water quality standard. The I-Plan adopted by the Commission will direct implementation requirements applicable to certain sources contributing a pollutant load to the impaired water.

The I-Plan will be developed through effective coordination with stakeholders affected by or interested in the goals of the TMDL. In determining which sources need to accomplish what reductions, the I-Plan may consider factors such as cost, feasibility, the current availability or likelihood of funding, existing or planned pollutant reduction initiatives such as watershed-based protection plans, whether a source is subject to an existing regulation, the willingness and commitment of a regulated or unregulated source, and a host of additional factors. Ultimately, the I-Plan will identify the commitments and requirements to be implemented through specific permit actions and other means. For these reasons, the I-Plan that is adopted may not approximate the predicted loadings identified category by category in the TMDL and its underlying assessment, but with certain exceptions, the I-Plan must nonetheless meet the overall loading goal established by the Commission-adopted and EPA-approved TMDL.

An exception would include an I-Plan that identifies a phased implementation that takes advantage of an adaptive management approach. It is not practical or feasible to approach all TMDL implementation as a one-time, short-term restoration effort. This is particularly true when a challenging wasteload reduction or load reduction was required by the TMDL, high uncertainty with the TMDL analysis exists, there is a need to reconsider or revise the established water quality standard, or the pollutant load reduction would require costly infrastructure and capital improvements. Instead, activities contained in the first phase of implementation may be the full scope of the initial I-Plan and include strategies to make substantial progress towards source reduction and elimination, refine the TMDL analysis, conduct site-specific analyses of the appropriateness of an existing use, and monitor in stream water quality to gage the results of the first phase. Ultimately, the accomplishments of the first phase would lead to development of a phase two or final I-Plan, or revision of TMDL. This adaptive management approach is consistent with established guidance from EPA (USEPA 2006).

The TCEQ maintains an overall water quality management plan (WQMP) that directs the efforts to address water quality problems and restore water quality uses throughout Texas. The WQMP is continually updated with new, more specifically focused WQMPs, or "water quality management plan elements" as identified in federal regulations (40 CFR Part 130). Consistent with federal requirements, each TMDL is a plan element of a WQMP and Commission adoption of a TMDL is state certification of the WQMP update.

Because the TMDL does not reflect or direct specific implementation by any one pollutant discharger, the TCEQ certifies additional "water quality management plan elements" to the WQMP once the I-Plan is adopted by the Commission. Based upon the TMDL and I-Plan, the TCEQ will propose and certify WQMP updates to establish required water-quality-based effluent limitations necessary for specific TPDES wastewater discharge permits. The TCEQ would normally establish best management practices (BMPs), which are a substitute for effluent limitations in TPDES MS4 storm water permits as allowed by the federal rules where numeric effluent limitations are infeasible (USEPA 2002). Thus, TCEQ would not identify specific implementation requirements applicable to a specific TPDES storm water permit through an effluent limitation update. However, the TCEQ would revise a storm water permit, require a revised SWMP or PPP, or implement other specific revisions affecting storm water dischargers in accordance with an adopted I-Plan.

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