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# One Total Maximum Daily Load for Bacteria in the Lower San Antonio River

For Segment 1901

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This document is based in large part on the report titled
"*E. Coli* TMDL Development for the Lower San Antonio River, Segment 1901"
by James Miertschin & Associates, Inc.

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## Executive Summary

This document describes development of a total maximum daily load (TMDL) for the Lower San Antonio River (LSAR), where concentrations of indicator bacteria exceed the criteria used to evaluate attainment of the contact recreation use. The LSAR, Segment 1901, is 153 miles long and has a watershed of 1,210 square miles. It is located primarily in Karnes and Goliad counties. The segment receives flows from two upstream segments: the Upper San Antonio River (USAR), Segment 1911, and Lower Cibolo Creek, Segment 1902. The LSAR was first identified as impaired for recreational use in the 2000 *Texas Water Quality Inventory and 303(d) List.*

The goal for this TMDL project is to determine the maximum bacterial loading the stream can receive and still allow support of the contact recreation use. Elevated levels of indicator bacteria such as Escherichia coli (*E. coli*), although not generally pathogenic, indicate the potential for risk to public health. The criteria for support of the contact recreation use are based on indicator bacteria rather than direct measurements of pathogens.

The standards for water quality are defined in the *Texas Surface Water Quality Standards* (Texas Administrative Code, Title 30, Chapter 307). The criteria for assessing attainment of the contact recreation use are expressed as the number of colony-forming units (cfu) of bacteria per hundred milliliters (100 mL) of water. For *E coli*, the number of colony-forming units may not exceed 394 cfu/100 mL in a single sample, nor a geometric mean of 126 cfu/100 mL for all samples over a range of time.

The Texas Commission on Environmental Quality (TCEQ) used analyses of flow and load duration curves (LDCs) to develop this TMDL. Although not used to calculate the TMDL, bacterial source tracking (BST) methods were used in source identification.

Based on the load allocation analysis, a TMDL to meet the water quality standards requires a:

- 0 to 51 percent reduction of nonpoint source loading under wet-weather conditions (upper/middle range flows);
- and a reduction in point source loads of 63 percent in order to comply with discharge permits.

## 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. For each high priority impairment ranked as Category 5a, states must develop a TMDL for each pollutant that contributes to the impairment. The TCEQ is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

In simple terms, a TMDL is like a budget—it determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. 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. For bacteria TMDLs, loads are typically expressed as the number of organisms (or colony-forming units) per period of time. TMDLs must also estimate how much the pollutant load must be reduced from current levels in order to achieve water quality standards.

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

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

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

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

This TMDL document was prepared based upon the report titled "*E. Coli* TMDL Development for the Lower San Antonio River, Segment 1901" prepared for the TCEQ by James Miertschin & Associates, Inc. (JMA 2006).

In accordance with the *Memorandum of Agreement between the TCEQ and the Texas State Soil and Water Conservation Board (TSSWCB) Regarding TMDLs, Implementation Plans (I-Plans), and Watershed Protection Plans*, the Board will consider approval of this TMDL at a future date. The Commission adopted this document on August 20, 2008. Upon EPA approval, the TMDL will become an update to the state's Water Quality Management Plan.

# Problem Definition

This document describes a project developed to address a water quality impairment related to bacterial indicators for pathogens in the LSAR. The LSAR was first identified as impaired for bacteria in the 2000 *Texas Water Quality Inventory and 303(d) List* (TCEQ 2000).

The watershed is depicted in detail in Figure 1. According to the 2006 *Texas Water Quality Inventory and 303(d) List*, the impaired reaches, highlighted in red, extend from the upstream end of the segment to 25 miles downstream of the confluence with Manahuilla Creek. Six Assessment Units (AUs) which are the smallest geographic area of use support reported in a surface water quality assessment (see Figure 5) define segment 1901. Descriptions of the AUs, from upstream to downstream, are as follows:

- AU 1901_05, from upstream end of segment to Escondido Creek;
- AU 1901_04, 9 miles downstream of Escondido Creek;
- AU 1901_03, from 25 miles upstream of Manahuilla Creek to 9 miles downstream of Escondido Creek;
- AU 1901_02, 25 miles upstream of Manahuilla Creek;
- AU 1901_01, 25 miles downstream of the confluence with Manahuilla Creek; and
- AU 1901_06, lower 31 miles of segment.

In total, 122 miles of the LSAR are designated as impaired. In response to the listing, the TCEQ initiated an investigation to identify possible point and nonpoint sources of bacteria, and to quantify the appropriate reductions necessary to comply with established standards for water quality (see the following section). Possible sources and/or causes of contamination include:

- discharges from wastewater treatment facilities (WWTFs)
- storm water runoff from both the urban and non-urban landscapes
- wildlife and other warm-blooded animal deposition
- pet and livestock deposition
- leaking sewer infrastructure
- failing septic systems

# Designated Uses and Water Quality Standards

The *Texas Surface Water Quality Standards* (TCEQ 2000) provide numeric and narrative criteria to evaluate attainment of designated uses. *E. coli* is the preferred indicator bacteria for assessing the contact recreation use in freshwater. The numeric criteria defined in the Standards for support of the contact recreation use are as follows:

- *E. coli*
  - The geometric mean of *E. coli* should not exceed 126 colony-forming units per 100 milliliters (126 cfu/100 mL)
  - Single samples of *E. coli* should not exceed 394 cfu/100 mL more than 25 percent of the time

The LSAR's designated uses are contact recreation and high-quality aquatic life.

# Description of Watershed

The LSAR is 153 miles long, flows through Karnes and Goliad counties, and forms the boundary between Refugio and Victoria counties before reaching its confluence with the Guadalupe River near San Antonio Bay. The LSAR receives flows from two upstream segments: the USAR, Segment 1911, and Lower Cibolo Creek, Segment 1902.

A TMDL for bacteria in the USAR was adopted by the TCEQ on July 25, 2007, and approved by the EPA on September 25, 2007. A USAR Watershed Protection Plan (WPP) was completed in December of 2006, and will serve as a template for control/management measures that may be incorporated in the subsequent TMDL I-Plan. Implementation of the WPP to achieve required bacteria reductions is underway. Though the USAR is listed as impaired on the 2006 *Texas Water Quality Inventory and 303(d) List*, the lower 6 miles of the USAR, AU 1911_01, are unimpaired and meeting the contact recreation standard. The division between the Upper and Lower San Antonio rivers is at Mays Crossing near the Wilson/Karnes county line.

Cibolo Creek meets the LSAR a few miles upstream of State Highway 80 in north-central Karnes County. The lower ten miles of Cibolo Creek, AU 1902_01 and 02, are listed on the 2006 *Texas Water Quality Inventory and 303(d) List* as impaired for contact recreation. The watershed of the LSAR is approximately 1,210 square miles. It is located predominantly in Karnes and Goliad counties, but also includes portions of Refugio, Dewitt, Wilson, Victoria, and Guadalupe counties. A map of the project area is presented in Figure 1.

## Climate

The study area is located within the south-central Texas climatic division. The Gulf of Mexico is the principal source of moisture that drives precipitation in the area. The average annual precipitation typically decreases with distance from the coast. As with the rest of the interior of the state, maximum precipitation periods in the study area are typically late spring (May and June) and early autumn (September and October). Winter and summer periods are typically low precipitation periods. The precipitation period in late spring is driven by the buildup of water vapor from the Gulf of Mexico due to the prevailing winds from the south. Precipitation is caused by late-season cold air migrations, warm-season thunderstorms, and low-pressure troughs. In September, cold air converges with moisture-laden southerly winds, and late-season convective thunderstorms drive the precipitation. It is not unusual for hurricanes to affect rainfall in the early autumn period. Summer drought conditions are common, due to strong high-pressure cells that result in lengthy dry spells.

Annual precipitation in the LSAR Basin varies with distance from the Gulf of Mexico. For the period 1995-2004, annual average rainfall was 39.4 inches at Goliad and 33.5 inches at Runge, though rainfall patterns can vary widely from year to year. For example, it rained 0.1 inches in July of 2001, and 12.4 inches in July of 2002.

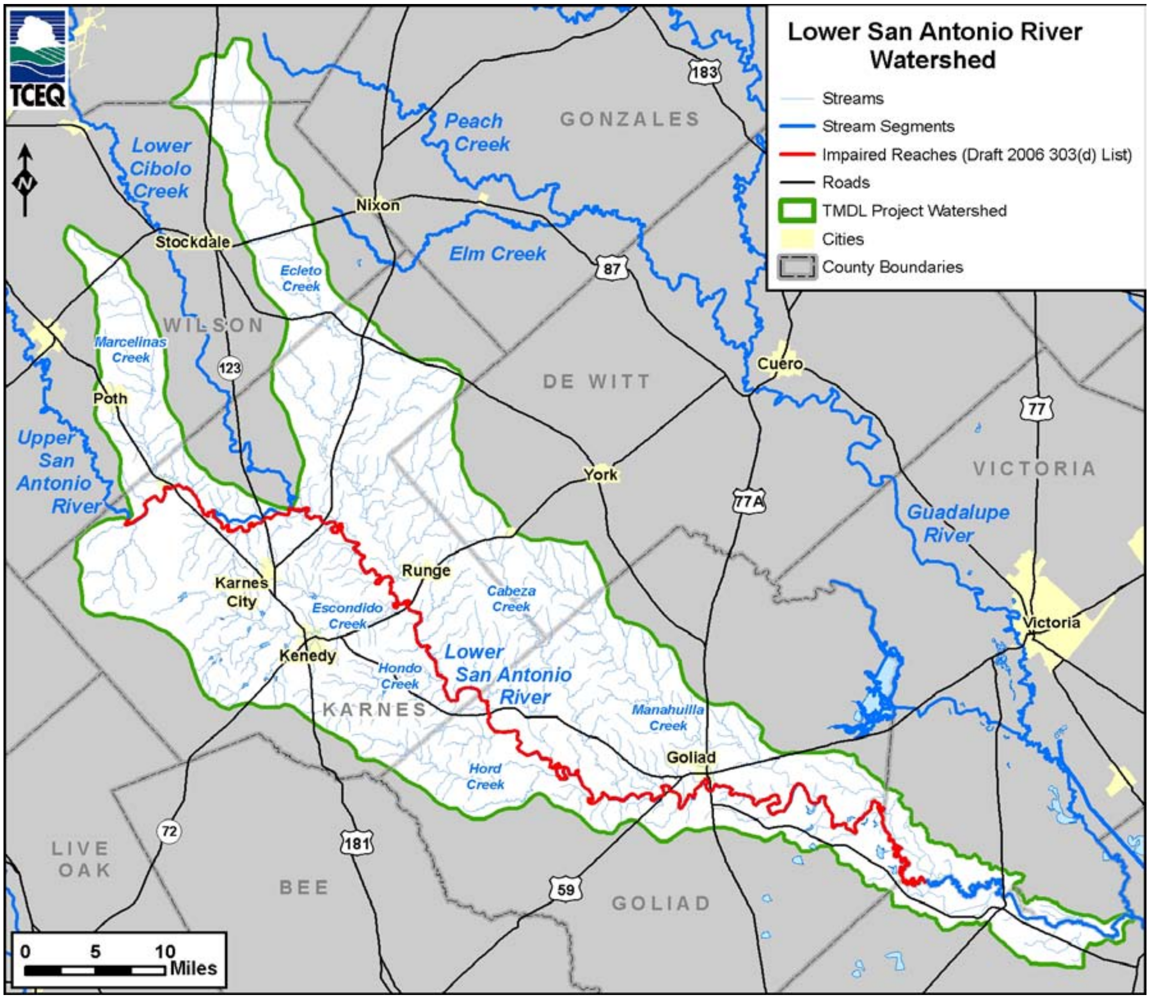


Figure 1: LSAR Watershed

# Economy

## Goliad County

Goliad County covers 854 square miles and had a population (year 2000) (US Census Bureau 2006) of 7,192. The population has increased by 19 percent since 1990. Approximately 28 percent of the population lives in urban areas. The largest urban area is the city of Goliad, which is the county seat, with a population of 2,042 (TAC 2006). The county's economy includes agribusiness, tourism, and oil and gas production (TSHA 2001).

Agribusiness is an important component of the county economy. There are 984 farms in the county with an average size of 514 acres (USDA 2002). Total land area for farms has increased by 13 percent from 1997 to 2002. Cattle are the primary type of livestock raised in the county. Harvested crops account for only a small portion of the county's agribusiness, and just 5 percent of the county's total farmland.

### Karnes County

Karnes County covers 753 square miles and had a population (year 2000) (US Census Bureau 2006) of 15,270. The population has increased by 23 percent since 1990. Approximately 48 percent of the population lives in urban areas. The largest urban area is Karnes City with a population of 3,406 (TAC 2006). The county's economy includes agribusiness, oil and gas, uranium mining and milling, guar processing, and fiberglass production (TSHA 2001).

Agribusiness is an important component of the Karnes County economy. There are 1,157 farms in the county with an average size of 410 acres (USDA 2002). Total land area for farms has increased by 16 percent from 1997 to 2002. Cattle are the primary type of livestock raised in the county. Harvested crops account for only a small portion of the county's agribusiness, and just 11 percent of the county's total farmland.

## Geology and Hydrogeology

The age of geologic formations in the study area ranges from the Eocene to the Quaternary period. The formations dip toward the Gulf of Mexico with the youngest formations located near the Gulf coast. These formations are typically fluvial in origin and include layers of sandstone and caliche. The formations are typically overlain with younger fluvial and eolian deposits (NRCS 1999).

Groundwater in the area is primarily associated with the Gulf Coast and Carrizo-Wilcox aquifer systems. The Gulf Coast Aquifer outcrop dominates the central and eastern portions of the study area. The maximum sand thickness of this aquifer ranges from 700 feet to 1,300 feet. The Carrizo-Wilcox downdip zone covers the northwestern border of Karnes County. Sand and gravel layers in this aquifer range from less than 200 feet to 3,000 feet in thickness (Ashworth 1995).

### Soils

Soil conditions vary throughout the study area based on geological and topographical characteristics. The terrain of Goliad County is level to gently rolling and consists of dark calcareous clays and sandy loams. In the northeastern portion, the soils consist of sandy loams and sands. In Karnes County, soils are gently sloping and consist of loamy, clayey, and sandy soils (TSHA 2001).

### Land Use

Land use data for the watershed were based on the 1992 U.S. Geological Survey (USGS) National Land Cover Dataset (NLCD). Urban areas (residential, commercial, and industrial) account for less than 1 percent of the watershed. Forests and shrublands account for about 46.4 percent of the watershed, and pastures and grasslands account for 38.9 percent of the watershed. Agricultural row crops and grains account for only 10.2 percent of the watershed. The remaining 4.4 percent of the watershed is made up of wetlands, barren earth, and mining operations. A map of these land uses is shown in Figure 2.

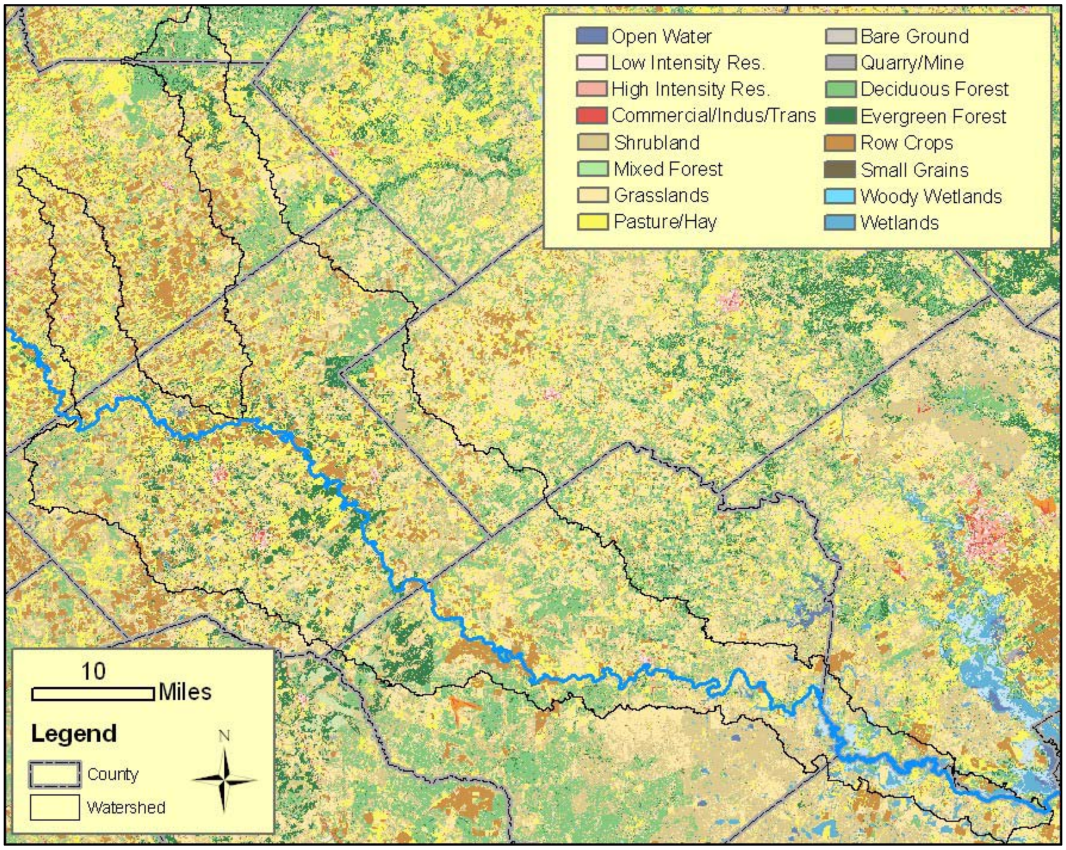


Figure 2: USGS Land Use for Study Area

# Assessment of Pollutant Sources

The data used to assess sources affecting the impaired stream segment are discussed in the following sections. The inventory of data and information is outlined, along with monitoring, water quality, and streamflow data.

## Data and Information Inventory

A wide range of data and information were used in the development of the TMDL. Categories of data used include the following:

- Hydrographic data that describe the physical conditions of the stream, such as the stream reach network and connectivity, and the stream channel depth, width, slope, and elevation.
- Physiographic data that describe the watershed's physical conditions such as topography, soils, and land use.
- Data that describe land uses and activities in the watershed that can be used to identify potential bacterial sources.
- Environmental monitoring data that describe stream flow and water quality conditions in the stream.

## Water Quality Monitoring

The San Antonio River Authority (SARA) is responsible for coordinating the Texas Clean Rivers Program's monitoring activities in the San Antonio River basin. Data collected by SARA and other entities were used by the TCEQ's Surface Water Quality Monitoring (SWQM) program to assess the segment for compliance with water quality standards. This assessment determined that the segment was not meeting its contact recreation use due to elevated levels of indicator bacteria. Table 1 lists the monitoring stations and WWTFs in upstream-to-downstream order.

Table 1: LSAR Stations and WWTFs

| Station/WWTF | Assessment Unit ID | Stream | Location |
|---|---|---|---|
| 16580 | 1901-05 | San Antonio River | FM 791 |
| 17862 | 1901-05 | San Antonio River | US 181 |
| 12796 | 1901-05 | San Antonio River | FM 81 |
| WWTF-1 | 1901-05 | SA River Tributary | Karnes City - Milam St. |
| 17861 | 1901-05 | San Antonio River | SH 123 |
| 12797 | 1902-01 (1901-05) | Cibolo Creek | FM 81 |
| 12795 | 1901-05 | San Antonio River | SH 80 |
| 17860 | 1901-05 | San Antonio River | CR 326 |
| WWTF-2 | Unclassified (1901-04) | Dry Escondido Creek | Karnes City - Main St. |
| WWTF-3 | Unclassified (1901-04) | Escondido Creek | Kennedy |
| 18402 | Unclassified (1901-04) | Escondido Creek | CR 331 |
| 12794 | 1901-04 | San Antonio River | SH 72 |
| 12793 | 1901-03 | San Antonio River | SH 239 |
| 17859 | 1901-03 | San Antonio River | Riverdale |
| 17858 | 1901-02 | San Antonio River | US 59 |
| WWTF-4 | 1901-02 | San Antonio River | Goliad |
| 12791 | 1901-02 | San Antonio River | US 77A/183 |
| 12790 | 1901-01 | San Antonio River | FM 2506 |
| 12789 | 1901-06 | San Antonio River | US 77 |

### Water Quality Data

Review of the available data reinforced earlier assessments, which concluded that the segment contains elevated levels of bacteria. Table 2 summarizes the available *E. coli* data collected for the LSAR. The table includes the number of routine samples collected, the number of samples that exceeded the grab-sample criterion, and the geometric mean of the sampled concentrations. Rows shaded in gray are LDC stations.

Table 2: *E. coli* Data for LSAR (1998-2005)

| Historic Database 1998-2005 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Station** | **# Samples** | **# Exceed** | **Geo Mean** | **Station** | **# Samples** | **# Exceed** | **Geo Mean** |
| 16580 | 20 | 1 | 89 | 12793 | 93 | 22 | 132 |
| 17862 | 60 | 5 | 125 | 17859 | 82 | 23 | 171 |
| 12796 | 83 | 13 | 141 | 17858 | 60 | 16 | 182 |
| 17861 | 61 | 9 | 138 | 12791 | 112 | 31 | 219 |
| 12795 | 84 | 15 | 142 | 12790 | 135 | 31 | 147 |
| 17860 | 61 | 10 | 125 | 12789 | 89 | 17 | 103 |
| 12794 | 109 | 24 | 158 | — | — | — | — |

Rows shaded in gray are LDC stations.

Figure 3 shows the locations, names, and numbers for stations where significant bacteria sampling was done throughout the period 1998-2005. The figure also includes the locations of WWTFs that discharge directly to the LSAR or one of its tributaries, and the reaches that are identified as impaired on the TCEQ's 303(d) List for 2006.

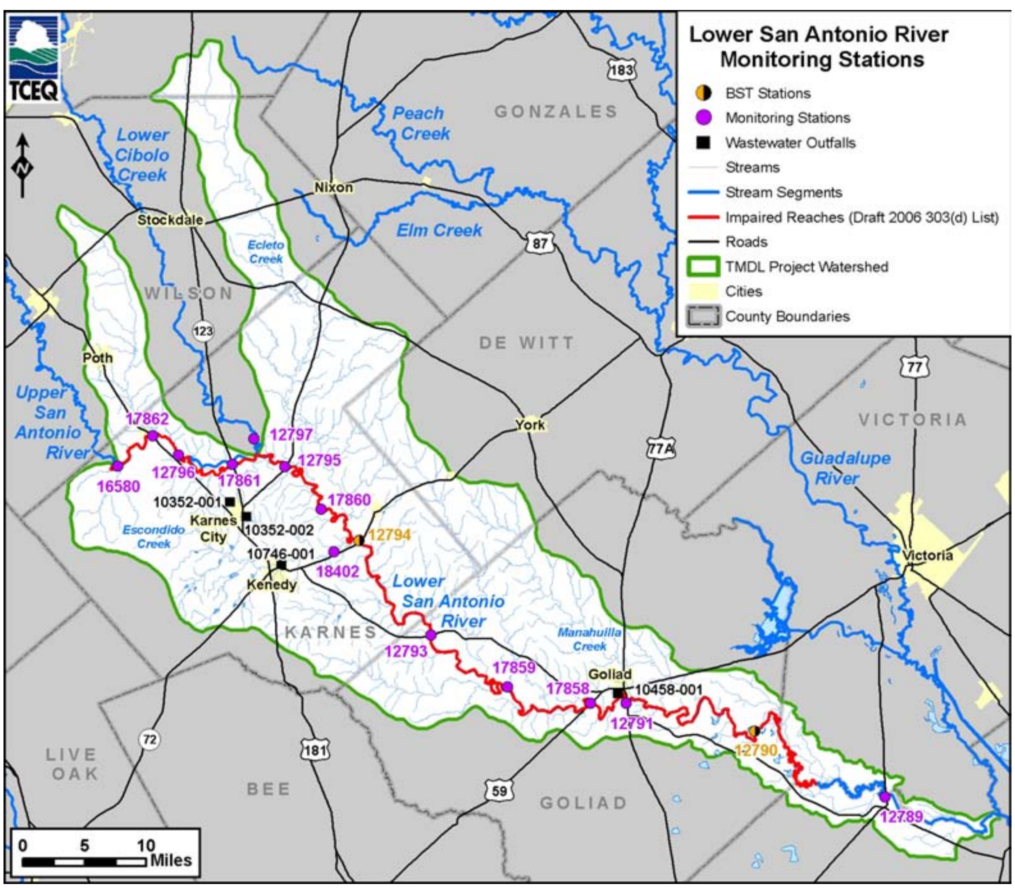

Figure 3: LSAR Sampling Stations

Table 3 summarizes assessment results, 1999 through 2004 for the LSAR, and includes assessment units, number of samples, number of samples exceeded, and the geometric mean of those respective samples. Figure 4 shows monitoring results (1998-2005) for each station, including the geometric mean, upper quartile (75th percentile), and lower quartile (25th percentile) of samples at each station. Figure 5 is a map of respective LSAR AUs.

Table 3: 2006 Assessment Results for LSAR (1999-2004)

| AU ID | # Samples | # Exceeded | Geo Mean |
|---|---|---|---|
| 1901-01 | 122 | 30 | 152 |
| 1901-02 | 156 | 46 | 226 |
| 1901-03 | 152 | 41 | 142 |
| 1901-04 | 95 | 25 | 185 |
| 1901-05 | 140 | 21 | 142 |
| 1901-06 | 87 | 20 | 108 |

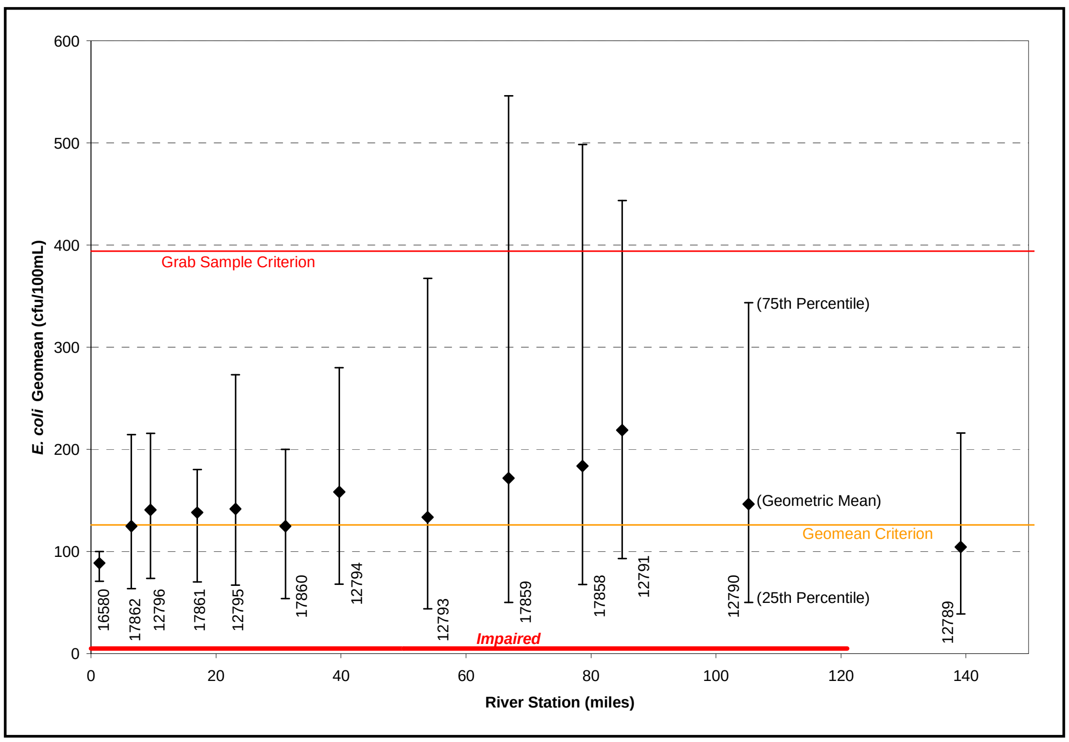


Figure 4: *E. Coli* Sampling Results for the LSAR

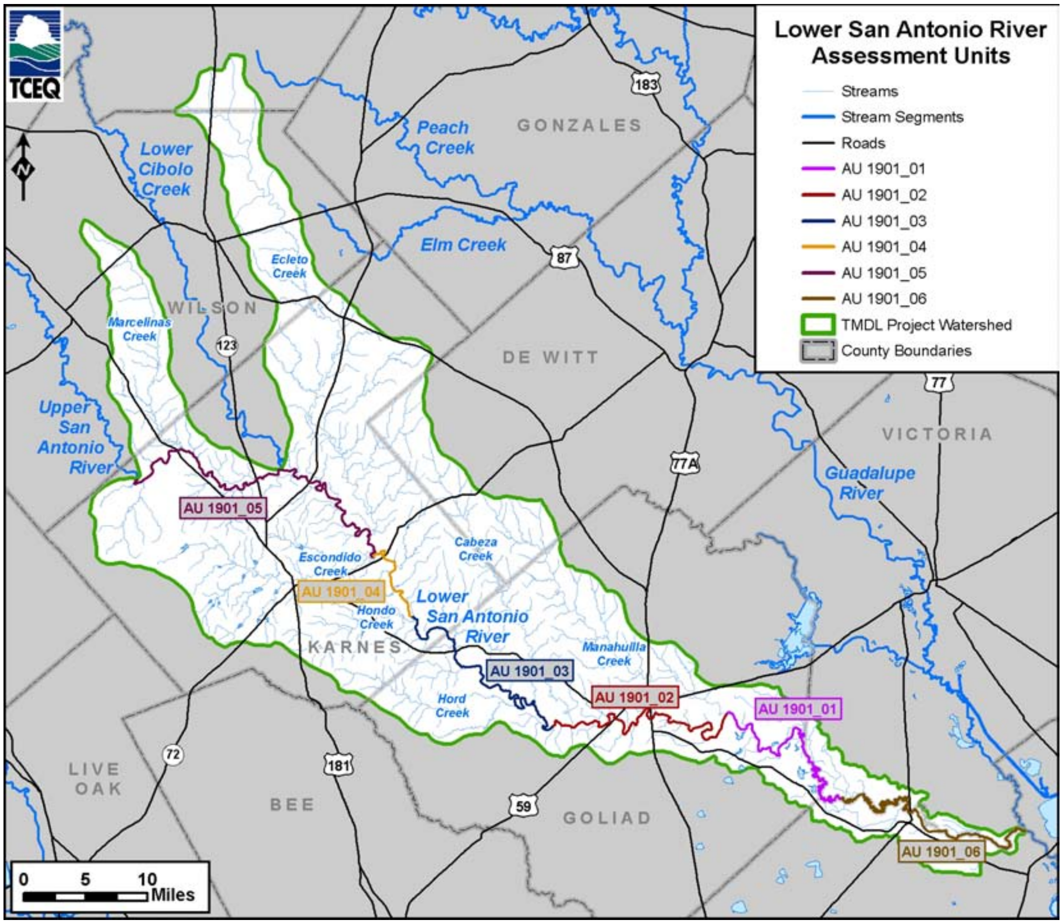


Figure 5: LSAR Assessment Units

## Stream Flow Data

Together with water quality sampling data, stream-flow data were important for analyzing existing conditions and determining required loading reductions. Flows in the LSAR could be characterized based on a series of four USGS gages shown in Figure 6. Based on these gages and adjustment factors for the drainage area, flows could be estimated at any point along the LSAR.

# Critical Condition

Federal regulations in 40 CFR 130.7(c)(1) require TMDLs to take into account critical conditions for stream flow, loadings, and water quality parameters. The intent of this requirement is to ensure that the water quality is protected during times when the attainment of the use is most vulnerable. The critical condition is considered the "worst case scenario" of environmental conditions for the study segments. If the TMDL is developed so that the water quality targets are met under the critical condition, then the water quality targets are most likely to be met under other conditions as well. Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and help in identifying the actions that may have to be undertaken to meet the water quality standards.

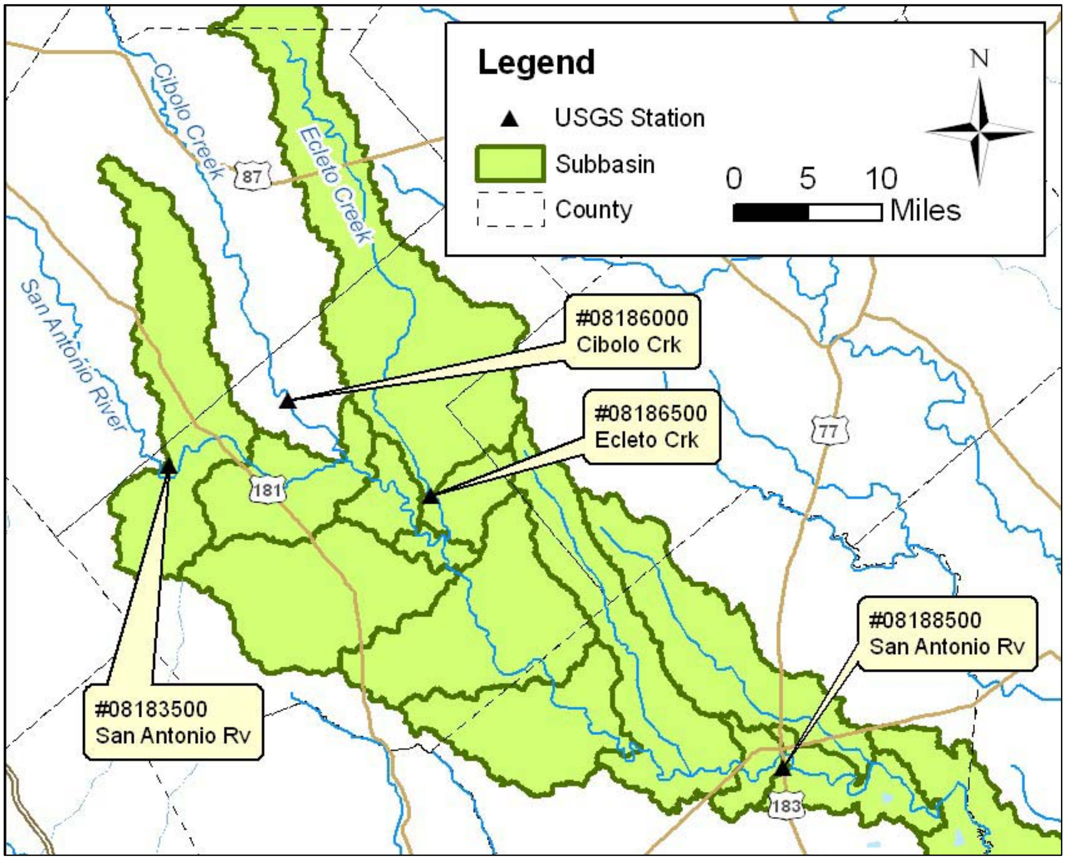


Figure 6: USGS Flow Gaging Stations

Bacteria data for the impaired segment were analyzed for seasonal and climatic trends. Seasonal trends were consistent with climatic trends. However, bacteria levels were found to vary significantly based on climatic conditions. Bacteria concentrations were observed to be highest typically under runoff conditions. Therefore, periods of frequent rainfall (high flow) were found to be the periods with the highest average bacteria concentrations. Critical conditions were determined by considering different flow regimes. The "High Flow" regime was not selected to represent the critical loading condition because contact recreation is rare and physically dangerous under the highest of stream discharge events. Instead, the "Upper/Middle Flow" regime was determined to be the critical condition, and is more appropriate for determining compliance with state criteria because it represents general wet-weather conditions, which may persist over longer periods (seasonally) when contact recreation is likely.

## Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality because of hydrologic and climatic patterns. Seasonal variations were evaluated for this TMDL. This allowed the consideration of temporal variability in bacteria loadings within the study area. Typically, spring and fall are the wettest seasons and therefore have relatively high average bacteria levels. Concentrations were typically lower in the dryer summer and winter seasons. Bacteria levels in summer and winter months were not found to be significantly different.

# Endpoint Identification

TMDLs must identify a quantifiable water quality target for each constituent that causes a water body to appear on the 303(d) List. These water quality targets are based on the *Texas Surface Water Quality Standards* (TCEQ 2000). The numerical criteria defined in the Standards for support of the contact recreation use in freshwater are as follows.

- *E. coli*
  - The geometric mean of *E. coli* should not exceed 126 cfu/100mL
  - Single samples of *E. coli* should not exceed 394 cfu/100mL, more than 25 percent of the time

For this TMDL, the endpoint will be considered achieved when the geometric mean of *E. coli* are met for the critical condition.

## Point Sources

Point sources, such as municipal and industrial WWTFs, can contribute bacteria loads to surface water through effluent discharges. These facilities are permitted through the Texas Pollutant Discharge Elimination System (TPDES) program, and are managed by the TCEQ. As shown in Table 4, there are several WWTFs and other dischargers in the LSAR watershed. The WWTFs shaded in gray discharge directly to the San Antonio River or one of its tributaries.

Table 4: Potential Point Source Summary

| Entity | Permit # | Permitted Flow (MGD)**** | Discharge Type | Average Daily Flow (MGD) |
|---|---|---|---|---|
| **Wastewater Dischargers** | | | | |
| City of Falls City | 10398-001 | 0.065 | irrigation**/ outfall* | - |
| City of Karnes City - Milam St. | 10352-001 | 0.41 | outfall** | 0.187 |
| City of Karnes City - Main St. | 10352-002 | 0.092 | outfall** | 0.049 |
| City of Karnes City (proposed permit) | 10352-003 | 0.80 | outfall*** | - |
| City of Kenedy | 10746-001 | 1.5 | outfall* | 0.755 |
| City of Goliad | 10458-001 | 0.35 | outfall* | 0.19 |
| City of Poth | 10052-001 | 0.22 | irrigation** | - |
| City of Runge | 10266-001 | 0.11 | irrigation** | - |
| City of Nordheim | 11163-001 | 0.0275 | irrigation** | - |
| Diocese of Victoria | 13362-001 | 0.0062 | irrigation** | - |
| **Other Dischargers** | | | | |
| City of Kenedy (potable water plant) | 3913-000 | - | outfall | - |

*treatment via chlorination | **treatment via 21 days of detention/exposure to solar radiation
***treatment via UV | **** Million Gallons per Day

WWTFs shaded in gray discharge directly to the San Antonio River or one of its tributaries.

Both the Karnes City Milam and Main St. WWTFs are scheduled for decommission. Karnes City Milam St. will be replaced with a new WWTF that will utilize an Ultraviolet Light (UV) system for disinfection. These WWTFs can be significant point sources of bacteria if effluent is not properly disinfected. The other WWTFs in the study area dispose of their effluent through irrigation. (The Falls City WWTF has the option to discharge directly to the stream, but typically irrigates.) These irrigation systems apply effluent slowly over the land surface. The treated effluent infiltrates into the ground or evaporates, and therefore, if operated properly, these facilities are not expected to be a significant source of bacteria. Operators irrigate under their own discretion, but typically prefer to irrigate when it is not windy or wet. Each WWTF that applies effluent via irrigation has daily average flow, effluent, and application rate limits in their permit. Monitoring is done after the final treatment unit and prior to irrigation. Application rates specific to individual permits are defined to not exceed specific acre-feet per year, per acre of land irrigated. Respective application rates are a part of a permit's general description of waste disposal systems. Records are maintained on a monthly basis and available for inspection by the TCEQ for at least three years.

Raw municipal wastewater has high levels of indicator bacteria, typically around 1,000,000 cfu/100mL. Geldreich (1978) has estimated that average human fecal coliform production is about $2x10^9$ cfu/person/day. Therefore, all municipal WWTFs are required to have some form of disinfection prior to discharge. The Kenedy and Goliad WWTFs currently utilize chlorine disinfection. If a facility is operated in accordance with TCEQ design criteria, then effluent bacteria concentrations should be negligible. During runoff events, larger chlorine doses are typically required to compensate for higher flows and larger loads of organic matter.

The Karnes City WWTFs (Milam St. and Main St.) utilize facultative or oxidation lagoons for disinfection. These treatment facilities do not include chemical disinfection processes. Instead, 21 days detention time within the pond system, where bacteria are degraded by solar radiation and other natural processes, reduce bacteria counts. This type of pond system is required to monitor effluent for fecal coliform. The *E. coli* discharge from a properly functioning facultative lagoon WWTF under normal conditions is required to be at or below the ambient water quality standard. Depending on management and design, this form of disinfection may lack the ability for precise operator control and may be less reliable than chlorine disinfection. Elevated bacteria levels have been measured in the effluents of these WWTFs, particularly at the Main Street facility (JMA 2005).

Table 4 includes one other facility that discharges effluent directly to streams in the study area. This facility is the City of Kenedy's drinking water treatment plant. This facility discharges brine resulting from reverse osmosis filtration. Bacteria levels in this discharge should be negligible.

## Nonpoint Sources

Nonpoint source (NPS) loading enters the impaired segment through distributed, unspecific locations. Some NPS pollutant sources are not regulated. NPS pollutants can enter the impaired stream through two pathways—directly through wastewater discharges, or indirectly through storm water runoff. Nonpoint sources generally include background loads, failing septic systems, animal deposition, and leaking wastewater infrastructure. Each of these sources can result in either direct or indirect NPS pollution. Figure 7 illustrates methods of NPS loading.

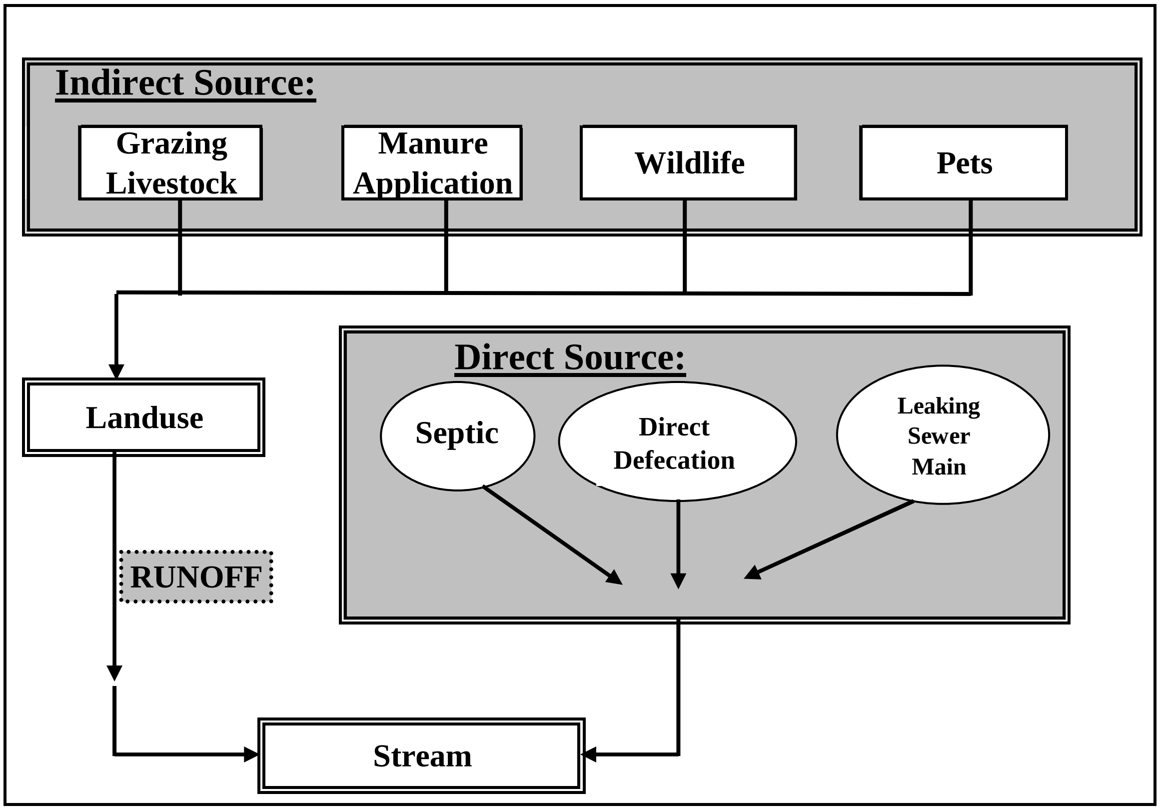


Figure 7: Mechanisms of Nonpoint Source Loading

## Failing Septic Systems

Private residential sewage treatment systems (septic systems) typically consist of a series of tanks, or a compartmented tank, followed by a drainage or distribution field. Household waste flows into the septic tank(s), where solids settle out and partial treatment occurs. The liquid portion of the waste flows to the distribution system, which may consist of perforated pipes, buried in a soil or gravel bed. Effluent in the bed may move vertically to groundwater, laterally to surface water, or upward to the ground surface. As it moves, the majority of the liquid portion is consumed by evapotranspiration of vegetation planted on top of the distribution field or adjacent to it. Properly designed, installed, and functioning septic systems would be expected to contribute virtually no fecal coliform to surface waters. The principal removal mechanism for fecal coliform would be die-off as the liquid moves through the soil. For example, it has been reported that less than 0.01 percent of fecal coliform originating in household waste moves farther than 6.5 feet downgradient from a properly functioning drainfield (Weiskel, 1996).

A septic system failure can occur via two mechanisms. First, drainfield failures, broken pipes, or overloading could result in uncontrolled, direct discharges to surface water. Such failures could occur in reaches with older homes located near a waterway or in remote areas. Second, effluent could surface above an overloaded drainfield, and the pollutants would then be available for surface accumulation and subsequent washoff under runoff conditions. According to a report by Reed, Stowe, and Yank (2001), septic systems in south Texas have a failure rate of about 3 percent.

The number of septic systems in the study area was estimated using information from the 1990 U.S. Census, which included a question regarding the means of household sewage disposal. Unfortunately, this question was not posed in the 2000 Census. Based on the 1990 data, the number of septic systems in the study area was estimated by intersecting the geographic census blocks with the study area watershed. Based on this analysis, there are an estimated 3,180 septic systems in the study area.

## Leaking Wastewater Infrastructure

Leaking wastewater sewer lines are difficult to detect, but are a potentially significant source of bacteria, especially in urbanized areas where most residences are served by a central sewage collection system. As with failing septic systems, only wastewater lines located close to streams have a high potential to act as bacterial sources. However, wastewater lines, especially large collection lines, tend to be installed along creeks and streams because the elevation profile along the waterway channel provides an economical arrangement for the gravity transport of collected sewage. In general, wastewater lines will only leak when their hydraulic grade line is higher than that of the stream to which they parallel. Also, sewers typically only leak if lines are blocked, cracked, or improperly installed.

## Livestock

Livestock and grazing animals contribute fecal coliform bacteria to the land surface that is subsequently available for washoff to surface waters during storm events. Also, livestock can deposit fecal material directly into a stream.

Livestock population estimates for the study were based upon the 2002 U.S. Department of Agriculture (USDA) Agricultural Census (USDA 2002). The census data are reported by county. These numbers were determined by intersecting county data with the watershed boundaries in a Geographic Information System (GIS). Other types of livestock in the watershed had small populations compared to the major livestock categories listed below; therefore, the fecal loads from these other animal groups were assumed to be negligible. Results are presented in Table 5. Other types of livestock may also be present in the watershed, but in small numbers. The number of chickens in the watershed is expected to be small, but this could not be confirmed since these data were not disclosed by the USDA.

Grazing animals contribute fecal coliform bacteria to the land surface that is subsequently available for washoff to surface waters during storm events. Also, livestock can deposit fecal material directly into the stream.

Table 5: Livestock Population Estimates

| | Cattle & Calves | Hogs & Pigs | Sheep & Lambs | Chickens |
|---|---|---|---|---|
| Total: | 113,528 | 527 | 589 | * |

*Not disclosed by USDA

### Wildlife and Feral Animals

Primary sources of indicator bacteria from wildlife in this watershed could include deer, raccoons, opossums, feral hogs, ducks/geese, and exotic game ranches. There is no practical method to estimate the number of each species of wildlife, or the distribution of fecal deposits. As with livestock, there are two mechanisms considered for bacteria loadings from wildlife to be transported to the stream segment. First, wildlife deposit waste on land surfaces that is subsequently available for washoff. Second, they may deposit waste directly into the stream.

# 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.

In the development of a TMDL, load relationship increases, reductions, and possible sources were defined through the use of LDCs and flow duration curves (FDCs), as summarized in the section “Load Duration Curve Development” later in this report. Two water quality stations were critical to this study—Station 12794 (LSAR at SH 72) and Station 12791 (LSAR at US 77A/183). At both stations, bacteria concentrations regularly exceeded criteria. BST was also used at two sites—Station 12794 and Station 12790—to better define sources of bacteria and will be particularly useful in implementation.

## Load Duration Curves

LDCs are graphical tools for analyzing water quality data. Many states have used the LDC methodology for better characterization of pollutant sources; point versus nonpoint contributions, and for the development of a more robust TMDL target than that achieved by less sophisticated methodologies (Nevada DEP 2003).

LDCs utilize historical flow data and water quality monitoring data to define a relationship between stream flow (volume per time) and pollutant load (mass or number of bacteria per time). The curve represents the maximum pollutant load allowable under different flow conditions, based on state criteria. This curve is then compared to actual water quality samples that are plotted as points, falling either above or below the curve.

LDCs are a simple statistical method that provides a first step in describing the water quality problem. This tool:

1. Is easily developed and explained to stakeholders;
2. Does not require any assumptions regarding loading rates, stream hydrology, land use conditions, etc.;
3. Uses the available water quality and flow data in a statistical analysis.

The U.S. EPA supports the use of this approach to characterize pollutant sources. The Texas Bacterial Task Force also identifies LDCs as a tool for TMDL development. Many other states are using LDC methods to develop TMDLs. This method separates point and nonpoint sources by looking at the flows at which high levels of bacteria occur.

Disadvantages of the LDC method include the limited information it provides regarding the magnitude or nature of the various sources. No information is gathered regarding point and nonpoint sources in the watershed. Finally, it is not apparent from analyzing a curve, whether unallowable loads happened within the same month or ten years apart.

## Load Duration Curve Development

This section describes the process used to develop LDCs for this TMDL. The LDC provides a simple way to examine loads and identify necessary reductions to meet water quality standards. The large number of samples collected along the river provides good definition of the variation in bacteria load under different flow regimes. In the Lower San Antonio River, flow regimes were estimated for key stations using analyses of drainage area ratios.

### Flow Duration Curves

A FDC is a graphical plot of daily streamflow versus the percent of days that the streamflow value is exceeded. The creation of an FDC is the first step in the LDC development process. In fact, LDCs are created through the modification of FDCs by adding pollutant criteria and pollutant sampling data.

FDCs are typically developed using daily flow data collected at USGS gaging stations. Table 6 identifies the USGS gaging stations utilized in this project, and Figure 6 shows the gage locations. It should be noted that other USGS gages were also present in the study area, but have not been used because of insufficient periods of record.

Yearly FDCs for the four USGS Stations are shown in Figure 8. Figure 8 uses a logarithmic y-axis. Use of the logarithmic axis is more typical for flow duration curves because it provides more definition for low-range flows, but it is less intuitive for most observers.

The flow distribution has been divided into five flow regimes as recommended by EPA (2007). These flow regimes are listed in Table 7, and are illustrated in all FDC and LDC figures. For the LSAR, the "High Flow" category corresponds to large storm-induced runoff events. Generally, these high flows correspond with local rainfall events. The "Upper/Mid-Range flows" typically represent smaller runoff events, periods of flow recession following large storm events, and periods of high base flows. The "Mid-Range Flows" typically represent periods of moderate base flows, but can also represent small runoff events. The "Lower Mid-Range Flows" typically represent period of moderate to low base flow conditions. The

"Low Flows" represent relatively dry conditions, resulting from extended periods of little or no rainfall.

Table 6: USGS Stations Used for FDC Development

| USGS Station | Location Description | Drainage (square miles) | Period of Record Used |
|---|---|---|---|
| 08183500 | San Antonio River near Falls City, TX | 2113 | 1986-2005 |
| 08186000 | Cibolo Creek nr Falls City, TX | 827 | 1986-2005 |
| 08186500 | Ecleto Creek near Runge, TX | 239 | 1986-2005* |
| 08188500 | San Antonio River at Goliad, TX | 3921 | 1986-2005 |

*Missing flow records: Oct 1989 - Sept 2002

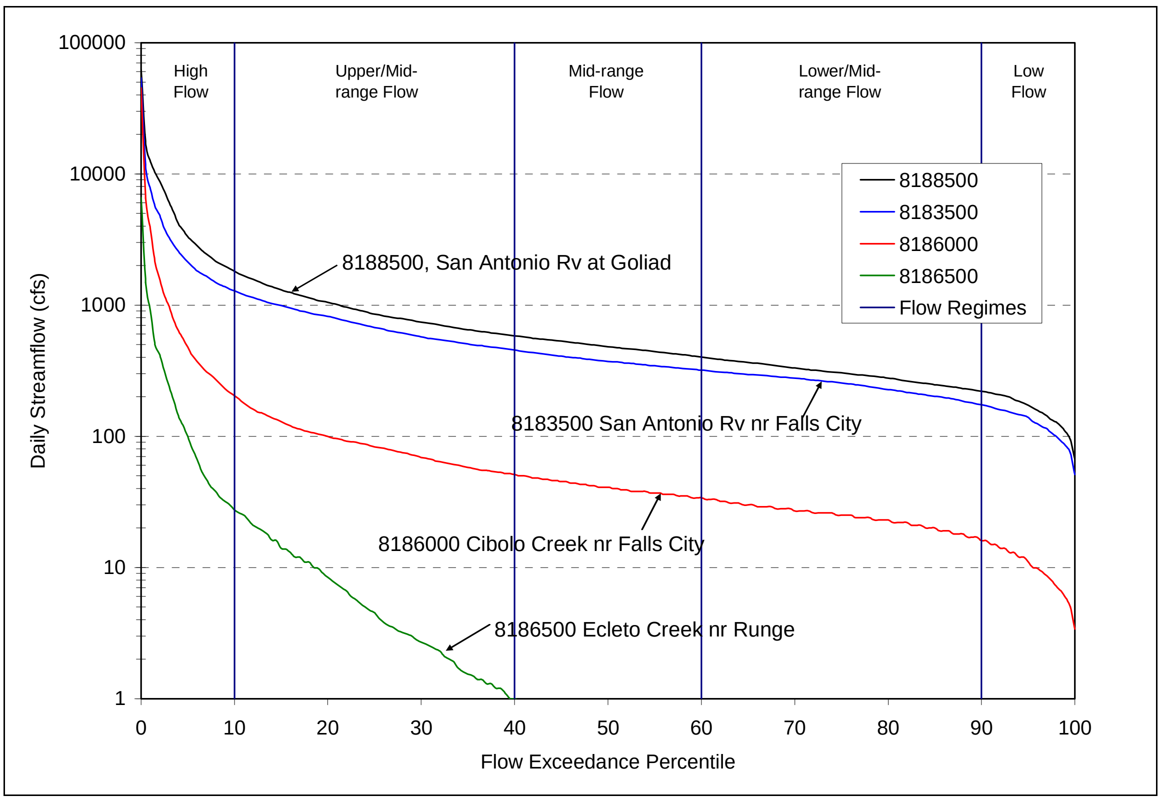


Figure 8: Flow Duration Curves for USGS Stations, Logarithmic Scale

FDCs were developed for all of the bacteria monitoring locations considered in the LDC analysis, including sites without a nearby USGS flow gage. For these ungaged locations, synthesized flow records were developed by utilizing the flow records from upstream and/or downstream USGS gaging stations. Flows were adjusted for location based on drainage area adjustment factors. Table 8 provides a list of the bacteria monitoring stations that were included in the LDC analysis, along with their total upstream drainage areas, and the USGS gages used for FDC development.

Table 7: Flow Regime Classifications

| Flow Regime Classification | Flow Duration Interval |
|---|---|
| High Flows | 0 - 10% |
| Upper/Mid-Range Flows | 10 - 40% |
| Mid-Range Flows | 40 - 60% |
| Lower/Mid-Range Flow | 60 - 90% |
| Low Flows | 90 - 100% |

Table 8: FDC Development for Bacteria Monitoring Locations

| Station | AU | Location | Drainage (square miles) | USGS Gages for FDC Development | | | |
|---|---|---|---|---|---|---|---|
| | | | | 08183500 | 08186000 | 08186500 | 08188500 |
| 12794 | 04 | SH 72 | 3577 | X | X | X | X |
| 12793 | 03 | SH 239 | 3696 | X | X | X | X |
| 12791 | 02 | US 77A/183 | 3921 | | | | X |
| 12790 | 01 | FM 2506 | 4072 | | | | X |

## Application of Water Quality Criteria

FDCs can be multiplied by pertinent water quality criteria to create LDCs. For the present study, the maximum allowable geometric mean of *E. coli* samples (126 cfu/100 mL) and the grab sample value (394 cfu/100 mL) were considered. When a flow (volume/time) is multiplied by a bacterial concentration (number/volume), the result is a pollutant loading rate (number/time).

## Integration of Water Quality Sampling Data

The next step in the development of LDCs is the plotting of existing water quality sampling data. To accomplish this, measured pollutant concentrations must be converted to daily loads. This approximates that the instantaneous sample concentration generally reflects the average (flow-weighted) concentration for the day in which it was collected. This average concentration can then be multiplied by the daily streamflow value adapted from a nearby USGS gage, in order to estimate the daily load. Comparing the streamflow used for the load estimate to the FDC reveals the exceedance percentile associated with the flow and corresponding estimated load. These loads are then plotted versus their corresponding daily streamflow exceedance percentile on the LDC.

The plotted loads can then be compared to the LDCs for water quality criteria. The degree to which a plotted load exceeds the criterion LDC reflects the degree to which the measured concentration exceeded the criterion on the day the sample was taken. For example, if a load is plotted 50 percent higher than the 394 cfu/100 mL criterion LDC, this means that the concentration sampled on that day was 591 (394x1.5) cfu/100 mL.

Figure 9 shows the LDC for Station 12791 at US 77A/183, including the sampled *E. coli* loads. A trend line is also included in this figure, demonstrating how bacteria concentrations typically vary with flow. The sampling data plotted in this figure are best represented by a trend line. Trend lines are one of several accepted procedures to determine exceedances to allow calculation of required percent reductions, which allows the allocation process to be quantified. Trend lines also serve to develop a greater understanding of water quality conditions and how they vary over time under a variety of environmental conditions. This effort is designed to accomplish several goals, including:

- define long-term water quality variability and significant relationships
- provide supplementary information for concerns and impairments
- define particular needs for water quality monitoring
- identify areas where water quality is deteriorating so that action strategies may be developed to address potential problems

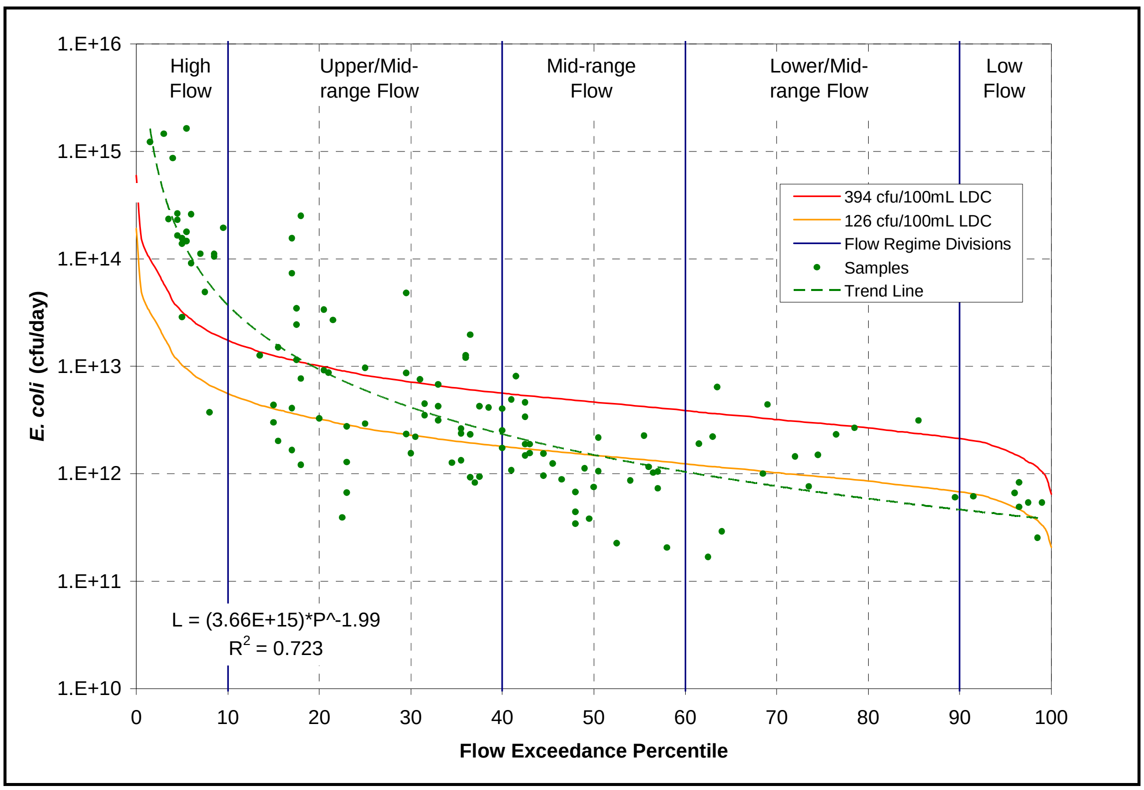


Figure 9: LDC for Station 12791 (LSAR at US 77A/183)

For bacterial data, trend lines are most suitable because concentrations can increase substantially under high flow conditions. In other words, runoff-related nonpoint (wet weather) sources seem to be the dominant method of bacterial loading in this reach. The $R^2$ value, which tests how well the data variation is explained by the trend line, is 0.723. For environmental data, this indicates a very strong correlation between flow and load. A more detailed discussion of this LDC, and the LDCs for other stations, is presented in the following section.

## Load Duration Curve Analysis

This section presents LDCs for various water quality sampling stations throughout the study area. The bacterial loads are the product of each grab-sample bacteria concentration and the corresponding mean daily streamflow rate. The LDCs are analyzed for compliance with state criteria and for source assessment. Sources are assessed by observing how bacteria levels vary under different flow conditions (flow percentile). Trend lines and data scatter are also considered, and comparisons are made between LDCs at upstream and downstream locations. This analysis does not attempt to quantify TMDL load reductions. LDCs are presented in order, from most upstream to most downstream location.

### Station 12794 – LSAR at State Highway 72

The LDC for Station 12794 is shown in Figure 10. Station 12794 is a key station at State Highway 72 in the impaired portion of the segment near Kenedy. Criteria exceedances are most typical under relatively high flow conditions. The trend line exceeds the geometric mean criterion curve throughout the High and Upper/Mid-range flow regimes. In addition, 88 percent and 33 percent of samples exceed the grab sample criterion in the High and Upper/Mid-range flow regimes, respectively. A comparison of the data at this station to the upstream station suggests that bacteria levels are typically slightly higher at this station. The $R^2$ value of 0.795 indicates a very strong correlation between flow and load.

### Station 12793 – LSAR at State Highway 239

The LDC for Station 12793 is shown in Figure 11. As with the previous station, it is clear that exceedances of water quality criteria appear to be common under relatively high flow conditions. Eighty-five percent and 20 percent of samples exceed the grab sample criterion in the High and Upper/Mid-range flow regimes, respectively. Bacteria levels at Mid-range flows generally meet state criteria. Bacteria levels at this station typically appear to be lower than bacteria levels at the upstream station.

### Station 12791 – LSAR at US Highway 77A/183

The LDC for Station 12791 was shown previously in Figure 9. Station 12791 is another key station in an impaired portion of the segment near Goliad. Exceedances of state criteria appear to be most common under high flow conditions, but unlike at the previous stations, exceedances have also been reported frequently under low flow conditions. Ninety percent and 32 percent of samples exceed the grab sample criterion in the High and Upper/Mid-range flow regimes, respectively. Under the Lower/Mid-range flow regime, 21 percent of samples exceed the grab sample criterion. In addition, numerous samples in each flow regime exceed the geometric mean criterion. The high bacteria levels measured under low flows suggest that a point source or dry-weather (direct) nonpoint source may exist upstream of this station. In general, the bacteria levels at this station are higher than at any other station within the study area.

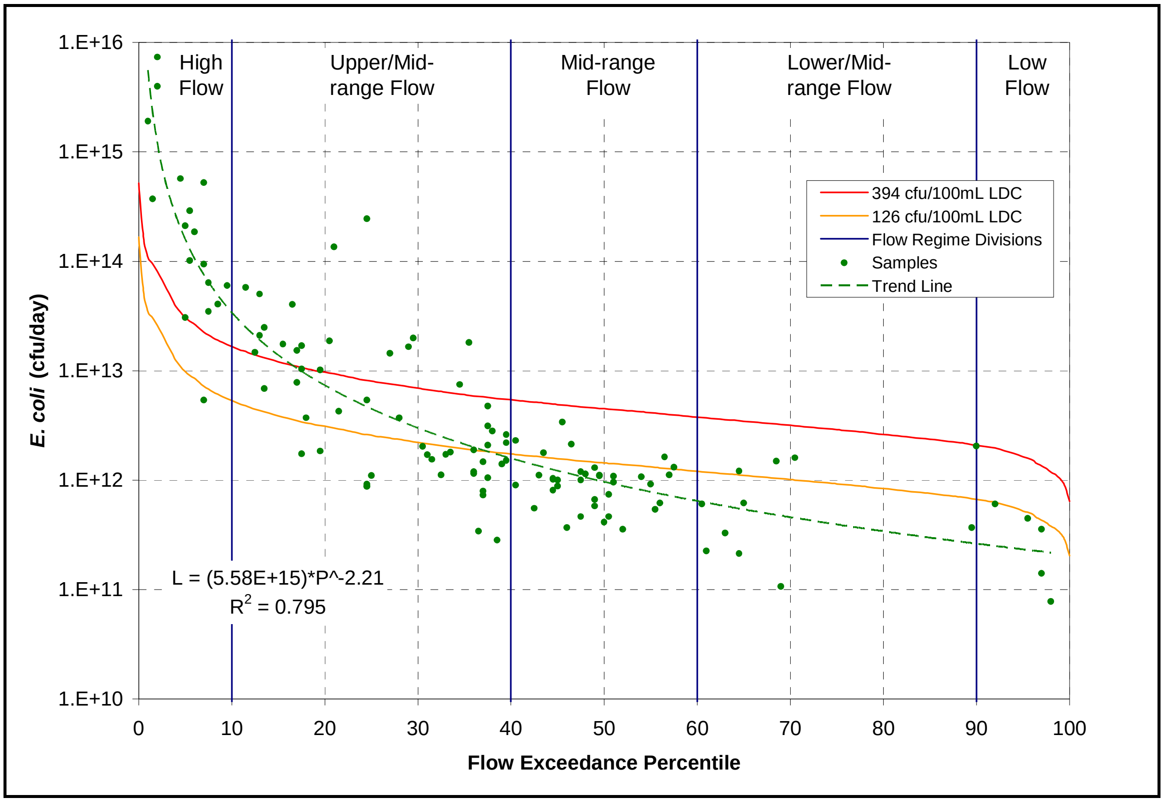


Figure 10: LDC for Station 12794 (LSAR at SH 72)

### Station 12790 –LSAR at FM 2506

The LDC for Station 12790 is shown in Figure 12. As with the previous stations, it is clear that exceedances of water quality criteria appear to be common under relatively high flow conditions. Seventy-eight percent and 19 percent of samples exceed the grab sample criterion in the High and Upper/Mid-range flow regimes, respectively. Bacteria levels at Mid-range flows and lesser flows generally meet state criteria. Bacteria levels appear to be lower at this station than at the previous upstream station (12791).

## Bacterial Source Tracking

Watersheds can be adversely affected by many different sources of microbial pollution. The primary potential sources of microbial pollution include human and animal populations. During the past decade, several methods have been proposed for identifying the sources of microbial pollution in the environment. BST was attempted as a tool to identify possible sources of bacteria. BST can be useful in the development of TMDLs as part of the source assessment, load allocation, and in the development of an implementation plan to target specific sources of bacteria entering a respective water body.

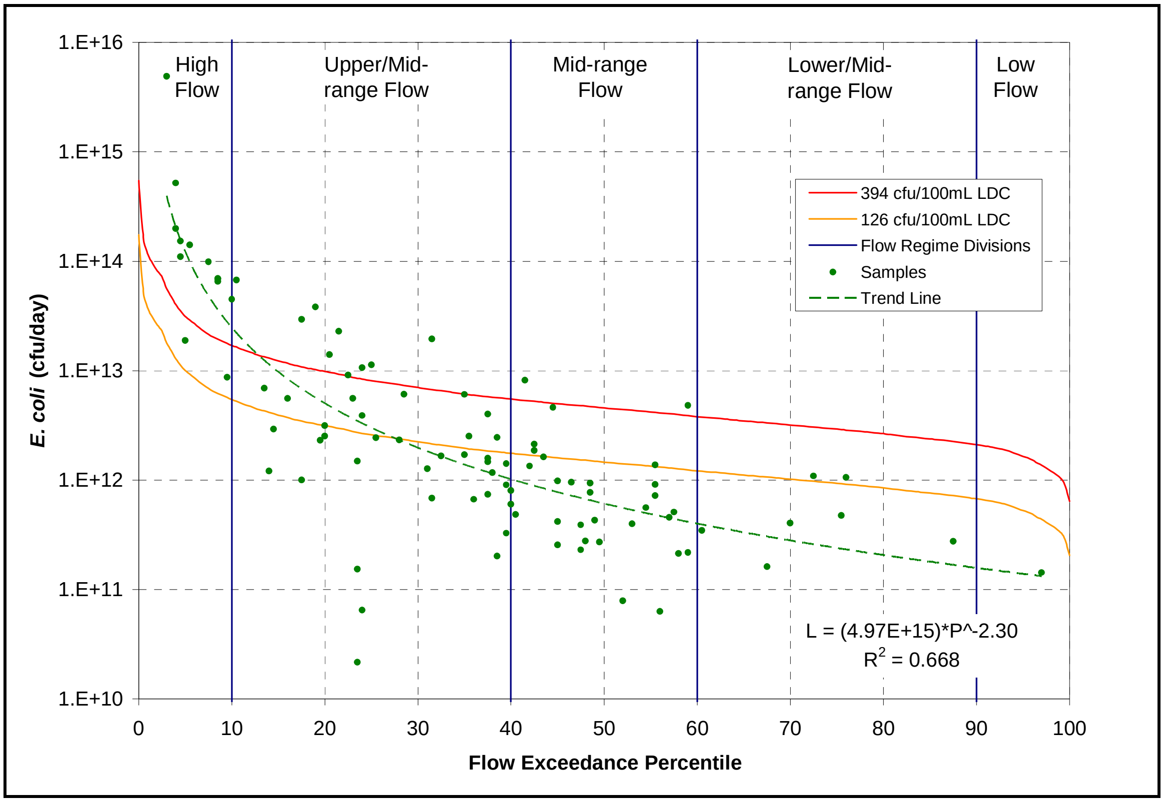


Figure 11: LDC for Station 12793 (LSAR at SH 279)

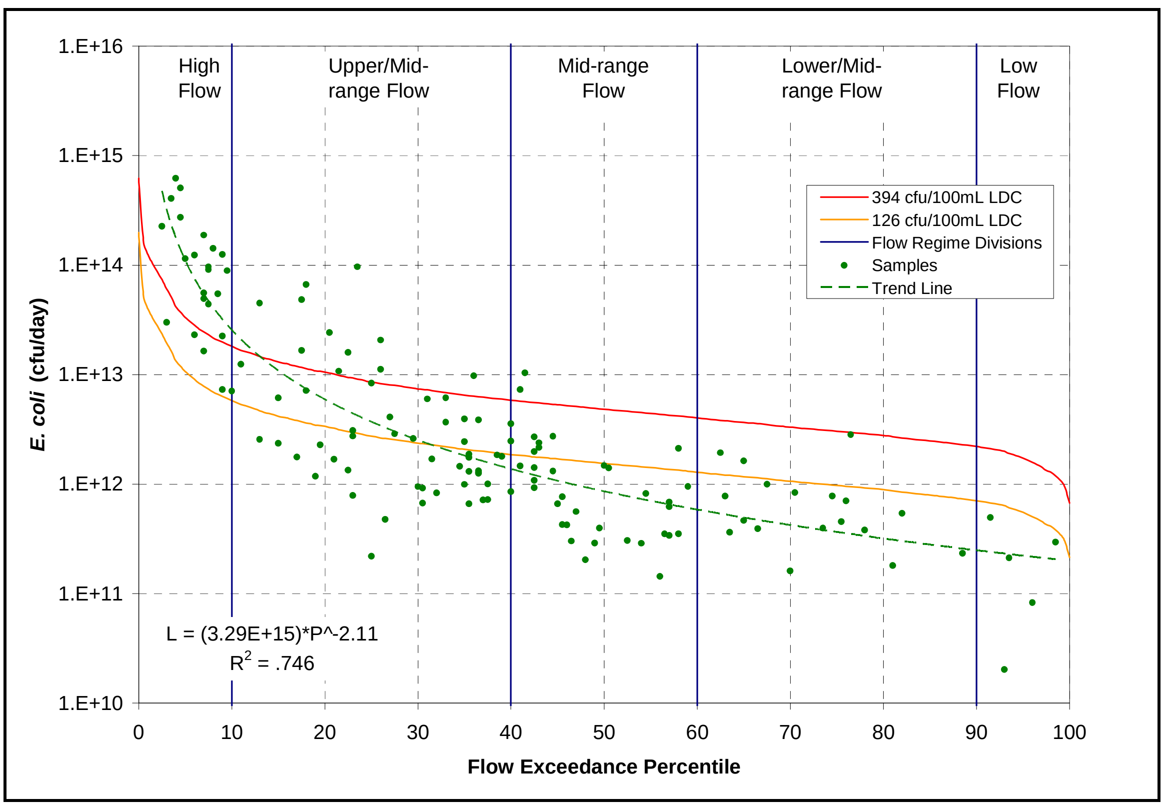


Figure 12: LDC for Station 12790 (LSAR at FM 2506)

Currently, several research groups and commercial laboratories conduct source tracking and source identification studies using a variety of different methods and target organisms (EPA 2005). The methodologies that have been used to determine the sources of microbial contamination in the environment include phenotypic-based methods such as anti-biotic resistance analysis (ARA), and genotypic-based methods such as ribotyping, pulsed field gel electrophoresis (PFGE), polymerase chain reaction (PCR) based methods, and many others. ARA and ribotyping have been used far more than other BST methods, and are more developed with respect to their application to water quality studies.

Available BST methods were evaluated and two genetic fingerprinting methods were selected to meet the needs of this study:

- enterobacterial repetitive intergenic consensus sequence polymerase chain reaction (ERIC-PCR)
- automated ribotyping (RiboPrinting).

All BST laboratory work was conducted by the Texas A&M University Agricultural Research and Extension Center (AREC) at El Paso (Di Giovanni and Casarez, 2006). The source identification portion of the method relies on generating genetic fingerprints of *E. coli* strains isolated from the contaminated sites and comparing the fingerprints to those of *E. coli* strains isolated from potential sources of fecal pollution.

The BST process involves two primary steps. First, a library of the genetic fingerprints of known sources is created. This was accomplished through the field collection of fecal matter samples from animals within the LSAR watershed. To achieve a higher rate of correct classification, a combined TCEQ-TSSWCB library utilizing *E. coli* isolates from fecal matter samples from other study watersheds was also employed. As data were gathered, they were sent to AREC to be analyzed and added to the library of genetic fingerprints. The genetic fingerprints are prepared by applying restriction enzymes to the ribosomal RNA of bacteria.

The second step required that bacteria of unknown origin (*E. coli* isolates), collected in ambient water samples, be compared to the fingerprints in the library to determine source classification. For this project, ambient samples were collected at two stations listed in Table 9 and shown on Figure 3.

Table 9: BST Sampling Stations

| Station | Location Description |
|---|---|
| 12794 | San Antonio River at SH 72 |
| 12790 | San Antonio River at FM 2506 |

AREC employed two methods for comparison and classification of DNA fingerprints. First, the Bionumerics statistics software (Applied Maths, Austin, Texas) was used to assign a probable match between each isolate from the water samples and the isolates from the fecal source library. The second method was a visual assessment of each individual band, or DNA fingerprint, generated throughout the study. Only isolate matches with a confidence level of 85 percent or more were accepted as probable matches in the classification protocol for this TMDL. This conservative cut-off criterion was designed to avoid misclassification errors.

The classification results indicate that the sources of *E. coli* in the area sampled include avian wildlife, non-avian wildlife, sewage, cattle, pet, non-avian livestock, and avian livestock. Overall results (for sampling stations 12794 and 12790 combined) for the BST are presented as follows:

- 26% of the isolates originated from avian wildlife
- 12% of the isolates originated from non-avian wildlife
- 12% of the isolates originated from sewage
- 10% of the isolates originated from cattle
- 9% of the isolates originated from other non-avian livestock
- 6% of the isolates originated from pets
- 4% of the isolates originated from zoo/exotic animals
- 21% of the isolates were unidentified

The three predominant sources identified were avian wildlife, non-avian wildlife, and sewage. However, since samples were collected within a limited timeframe from only two sampling locations within a very large geographic area (1,210 square miles), the results must be interpreted with caution.

# Pollutant Load Allocation

## TMDL Calculation

TMDLs are the sum of the individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background conditions, and a margin of safety (MOS). The TMDL equation has historically been written as follows:

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

where… $\sum$ WLA = Sum of Wasteload Allocations (Point Source Allocation)
$\sum$ LA = Sum of Load Allocations (Nonpoint Source Allocation)
MOS = Margin of Safety

In this equation, the WLA and LA represent the maximum allowable point and nonpoint source contributions, respectively. The MOS is included to account for any uncertainty concerning the relationship between effluent limitations and water quality.

## Allocation Scenario Development

Critical conditions were used to determine the load reductions required for this TMDL. Using LDCs, critical conditions are defined as the flow regime and location under which the maximum percent load reduction is required to achieve compliance with water quality standards.

For the LSAR, it is recognized that the “High Flow” regime represents only extreme runoff events, which are not persistent, and therefore not appropriate for calculating long-term bacterial statistics. Therefore, as stated previously in this report the “High Flow” regime and respective percent reduction, 94.5 percent, were not selected to represent the critical loading reduction. The “Upper/Middle Flow” regime is more appropriate for determining compliance with state criteria because it represents general wet-weather conditions, which may persist seasonally when contact recreation is likely.

The required loading reductions for stations and flow regimes are shown in Table 10. Loading reductions were calculated for geometric mean criteria. At most stations, loading reductions are only required for the “Upper/Middle Flow” regime. The critical loading reduction for the TMDL is 0-51 percent. This removal is based on compliance with the geometric mean criterion at respective stations under the “Upper/Middle Flow” regime.

Table 10: Required Load Reductions by Station and Flow Regime

| | | Flow Regime (percentile) | | | | |
|---|---|---|---|---|---|---|
| **Station** | **AU** | **0-10 High Flow** | **10-40 Upper/Middle Flow** | **40-60 Mid-range** | **60-90 Lower Mid-range** | **90-100 Low** |
| 12794 | 05 | 94.5% | 45.1% | 0.0% | 0.0% | 0.0% |
| 12793 | 04 | 91.9% | 0.0% | 0.0% | 0.0% | * |
| 12791 | 02 & 03 | 94.2% | 51.1% | 0.0% | 32.7% | 18.4% |
| 12790 | 01 | 88.6% | 17.3% | 0.0% | 0.0% | 0.0% |

*Insufficient Data (<5 samples)

## Wasteload Allocations

The TMDL WLA represents the maximum allowable contribution from point sources. As discussed previously, several WWTFs discharge directly to the LSAR or one of its tributaries. There are limited bacteria monitoring data available for these dischargers. Based on the sampling performed in conjunction with the TMDL study (JMA and Parsons, 2005), the total average load from these four dischargers has been estimated at $34.5 \times 10^9$ cfu/day, which requires an overall reduction of 63 percent to meet the WLA. Under baseflow conditions, on August 3-4, 2004, the Karnes City municipal WWTF displayed the highest counts, with a maximum value of 28,000 cfu/100 mL and a mean value of 16,709 cfu/100 mL. Under runoff conditions, on April 24-30, 2004, the City of Kenedy municipal WWTF showed measurable counts, with the highest individual grab of 41,860 cfu/100 mL. Under runoff conditions, on November 17-19, 2004, the Karnes City municipal WWTF displayed the highest counts, with a highest individual grab count of 46,400 cfu/100 mL. Overall, this load is relatively small compared to the total stream loads observed in the LSAR, but still could be significant, especially since the source is human.

According to permit requirements listed in Table 4, WWTFs must provide disinfection. If disinfection and holding time is achieved then bacteria concentrations should be negligible. To develop the WLA for this TMDL, a bacteria concentration of 126 cfu/100 mL, and the facility's total permitted flows were used. The City of Karnes City's proposed WWTF permit and respective permitted flow were used to determine the WLA, instead of the existing City of Karnes City WWTFs (Milam and Main St.) scheduled for decommission. For the entire watershed, this yielded a total WLA of $12.9\text{x}10^{9}$cfu/day. The WLAs and respective LDC stations are summarized in Table 11.

Table 11: Total Wasteload Allocation Summary (*E. coli* 10^9 cfu/day)

| Point Source | LDC Station | MGD | WLA* |
|---|---|---|---|
| City of Falls City | 12794 | 0.065 | 0.3 |
| City of Karnes City | 12794 | 0.80 | 3.8 |
| City of Kenedy | 12794 | 1.5 | 7.2 |
| City of Goliad | 12791 | 0.35 | 1.6 |
| | | **Total WLA (cfu/day) =** | **12.9** |

*permitted flow x water quality standard

It is the TCEQ's intention to implement these individual WLAs through the permitting process. However, there may be a more economical or technically feasible means of achieving the goal of improved water quality, and circumstances may warrant changes in individual WLAs after this TMDL is adopted. Therefore, these individual WLAs are non-binding until implemented via a separate TPDES permitting action, which may involve a TCEQ "Water Quality Management Plan Update." Regardless, all permitting actions will demonstrate compliance with the TMDL.

The commission understands that this TMDL is, by definition, the total of the sum of the wasteload allocation, the sum of the load allocation, and the margin of safety. Changes to individual WLAs may be necessary in the future in order to accommodate growth or other changing conditions. These changes to individual WLAs do not ordinarily require a revision of the actual TMDL and will be accommodated through the TCEQ's WQMP update process. Any future changes to effluent limitations will be addressed through the permitting process and by updating the WQMP.

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

### Load Allocations

LAs represent the maximum allowable contribution of nonpoint sources. Nonpoint sources can include both "wet weather" and "dry weather" sources. Wet weather sources include animal deposition and septic system failures that result in the buildup of bacteria at the land's surface (which is subsequently available for washoff during rainfall events). Dry weather nonpoint sources include animals in streams, wastewater infrastructure leaking directly to streams, and failing septic systems leaking directly to streams. The total LA is calculated using the TMDL equation described in the preceding section. The LAs are based on the geometric mean criterion. Existing loads were determined by calculating in each of the flow regimes, the geometric mean concentration of the historical bacteria data, the median flow, and then multiplying the concentration by the flow to determine the existing load. Total required reductions are shown in gray and bold. The calculations were performed separately for each flow regime at each LDC station. The LA is equal to the TMDL less the WLA and MOS. The median flow, existing load, total required reduction, TMDL, MOS, WLA, LA, and respective flow regime are summarized in Tables 12 through 15.

## Margin of Safety

The MOS is a required component of the TMDL to account for any uncertainty concerning the relationship between effluent limitations and water quality. According to EPA guidance (EPA 1991), the MOS can be incorporated into the TMDL using two methods:

- implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

A five percent MOS was explicitly incorporated into this TMDL. There is also an implicit margin of safety built into the established water quality standards and criteria, which were developed using a low illness rate of less that 1.0 percent.

## Future Growth

Compliance with this TMDL is based on keeping bacteria concentrations in selected waters below the water quality standard for contact recreation. Future growth for existing and new point sources is not limited by this TMDL as long as their activities do not cause bacteria to exceed the water quality standard for contact recreation. The assimilative capacity of the stream will increase as the amount of flow in the stream increases. Increases in flow will allow for increased loadings. The LDCs and respective tables will guide determination of the assimilative capacity of the stream including future growth.

Table 12: Load Allocation Summary for Station 12794 (AU 05) (*E. coli* 10^9 cfu/day)

| | Flow Regime (percentile) | | | | |
|---|---|---|---|---|---|
| | 0-10 | 10-40 | 40-60 | 60-90 | 90-100 |
| **Median Flow (cfs)** | 3,187 | 833 | 466 | 300 | 169 |
| **Existing Load** | 168,205 | 4,442 | 901 | 503 | 276 |
| **Wasteload Allocation (WLA)** | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| **Load Allocation (LA)** | 9,334.1 | 2,439.9 | 1,364.6 | 878.7 | 495.6 |
| **Margin of Safety (MOS)** | 491.3 | 128.4 | 71.8 | 46.3 | 26.1 |
| **TMDL (WLA+LA+MOS)** | 9,826 | 2,569 | 1,437 | 925 | 522 |
| **Total Required Reduction** | 94.5% | **45.1%** | 0.0% | 0.0% | 0.0% |

Total required reduction is shown in bold in gray-shaded cell.

Table 13: Load Allocation Summary for Station 12793 (AU 04) (*E. coli* 10^9 cfu/day)

| | Flow Regime (percentile) | | | | |
|---|---|---|---|---|---|
| | 0-10 | 10-40 | 40-60 | 60-90 | 90-100 |
| **Median Flow (cfs)** | 3,260 | 841 | 473 | 303 | 171 |
| **Existing Load** | 118,112 | 2,322 | 634 | 428 | * |
| **Wasteload Allocation (WLA)** | 11 | 11 | 11 | 11 | 11 |
| **Load Allocation (LA)** | 9,536.8 | 2,451.7 | 1,375.6 | 876.5 | 488.6 |
| **Margin of Safety (MOS)** | 502.5 | 129.6 | 73.0 | 46.7 | 26.3 |
| **TMDL (WLA+LA+MOS)** | 10,050 | 2,592 | 1,460 | 934 | 526 |
| **Total Required Reduction** | 91.9% | 0.0% | 0.0% | 0.0% | * |

Table 14: Load Allocation Summary for Station 12791 (AU 02 & 03) (*E. coli* 10^9 cfu/day)

| | Flow Regime (percentile) | | | | |
|---|---|---|---|---|---|
| | 0-10 | 10-40 | 40-60 | 60-90 | 90-100 |
| **Median Flow (cfs)** | 3,328 | 853 | 481 | 304 | 172 |
| **Existing Load** | 168,882 | 5,105 | 1,104 | 1,323 | 617 |
| **Wasteload Allocation (WLA)** | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| **Load Allocation (LA)** | 9,745.7 | 2,496.7 | 1,407.2 | 888.8 | 502.2 |
| **Margin of Safety (MOS)** | 513.0 | 131.5 | 74.1 | 46.9 | 26.5 |
| **TMDL (WLA+LA+MOS)** | 10,260 | 2,630 | 1,483 | 937 | 530 |
| **Total Required Reduction** | 94.2% | **51.1%** | 0.0% | 32.7% | 18.4% |

Total required reduction is shown in bold in gray-shaded cell.

Table 15: Load Allocation Summary for Station 12790 (AU 01) (*E. coli* 10^9 cfu/day)

| | Flow Regime (percentile) | | | | |
|---|---|---|---|---|---|
| | **0-10** | **10-40** | **40-60** | **60-90** | **90-100** |
| **Median Flow (cfs)** | 3,456 | 886 | 500 | 316 | 179 |
| **Existing Load** | 88,472 | 3,139 | 824 | 549 | 136 |
| **Wasteload Allocation (WLA)** | 0 | 0 | 0 | 0 | 0 |
| **Load Allocation (LA)** | 10,122.7 | 2,594.5 | 1,463 | 924.7 | 523.2 |
| **Margin of Safety (MOS)** | 532.8 | 136.6 | 77.0 | 48.7 | 27.5 |
| **TMDL (WLA+LA+MOS)** | 10,655 | 2,731 | 1,540 | 973 | 551 |
| **Total Required Reduction** | 88.6% | **17.3%** | 0.0% | 0.0% | 0.0% |

Total required reduction is shown in bold in gray-shaded cell.

# TMDL Expressions

Based on the load allocation analysis, a TMDL to meet the water quality standards requires:

- 0 to 51 percent reduction of nonpoint source loading under wet-weather conditions (upper/middle range flows);
- and a reduction in point source loads of 63 percent in order to comply with discharge permits.

The total wasteload allocations, load allocations, margins or safety, and TMDLs for each flow category at each LDC station are summarized in Tables 16 through 19.

Table 16: TMDL Allocation Summary for Station 12794 (*E. coli* 10^9 cfu/day)

| | Flow Regime (percentile) | | | | |
|---|---|---|---|---|---|
| | **0-10** | **10-40** | **40-60** | **60-90** | **90-100** |
| **Wasteload Allocation (WLA)** | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| **Load Allocation (LA)** | 9,334.1 | 2,439.9 | 1,364.6 | 878.7 | 495.6 |
| **Margin of Safety (MOS)** | 491.3 | 128.4 | 71.8 | 46.3 | 26.1 |
| **TMDL (WLA+LA+MOS)** | 9,826 | 2,569 | 1,437 | 925 | 522 |

Table 17: TMDL Allocation Summary for Station 12793 (*E. coli* 10^9 cfu/day)

| | Flow Regime (percentile) | | | | |
|---|---|---|---|---|---|
| | **0-10** | **10-40** | **40-60** | **60-90** | **90-100** |
| **Wasteload Allocation (WLA)** | 11 | 11 | 11 | 11 | 11 |
| **Load Allocation (LA)** | 9,536.8 | 2,451.7 | 1,375.6 | 876.5 | 488.6 |
| **Margin of Safety (MOS)** | 502.5 | 129.6 | 73.0 | 46.7 | 26.3 |
| **TMDL (WLA+LA+MOS)** | 10,050 | 2,592 | 1,460 | 934 | 526 |

Table 18: TMDL Allocation Summary for Station 12791 (*E. coli* 10^9 cfu/day)

| | Flow Regime (percentile) | | | | |
|---|---|---|---|---|---|
| | **0-10** | **10-40** | **40-60** | **60-90** | **90-100** |
| **Wasteload Allocation (WLA)** | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| **Load Allocation (LA)** | 9,745.7 | 2,496.7 | 1,407.2 | 888.8 | 502.2 |
| **Margin of Safety (MOS)** | 513.0 | 131.5 | 74.1 | 46.9 | 26.5 |
| **TMDL (WLA+LA+MOS)** | 10,260 | 2,630 | 1,483 | 937 | 530 |

Table 19: TMDL Allocation Summary for Station 12790 (*E. coli* 10^9 cfu/day)

| | Flow Regime (percentile) | | | | |
|---|---|---|---|---|---|
| | **0-10** | **10-40** | **40-60** | **60-90** | **90-100** |
| **Wasteload Allocation (WLA)** | 0 | 0 | 0 | 0 | 0 |
| **Load Allocation (LA)** | 10,122.7 | 2,594.5 | 1,463 | 924.7 | 523.2 |
| **Margin of Safety (MOS)** | 532.8 | 136.6 | 77.0 | 48.7 | 27.5 |
| **TMDL (WLA+LA+MOS)** | 10,655 | 2,731 | 1,540 | 973 | 551 |

# Public Participation

The TCEQ maintains an inclusive public participation process. From the inception of the investigation, the project team sought to ensure that stakeholders were informed and involved. Communication and comments from the stakeholders in the watershed strengthened the project and will support its implementation.

Notices of meetings were posted on the TMDL program's web calendar. Two weeks prior to scheduled meetings, media releases were initiated and steering committee stakeholders were formally invited to attend. To ensure that absent stakeholders and the public were informed of past meetings and pertinent material, a project Web page was established to provide meeting summaries and presentations. The project web page is available at <www.tceq.state.tx.us/implementation/water/tmdl/34-lowersanantonio_group.html>.

Throughout the term of the project, the TCEQ held four meetings. At each meeting, the project team received and responded to a number of questions and comments. The first round was held in Goliad and Karnes City, and included a discussion of water quality in the LSAR.

At the first meeting in Goliad, in April of 2006, the objectives were to:

- introduce the project goals, project team, and summarize the public participation process to stakeholders in the Goliad County area
- inform the stakeholders on the status of work being performed on the project
- provide information on data and results from BST
- discuss the next phase

At the second meeting in Karnes City, in June of 2006, the objectives were to:

- introduce the project goals, project team, and summarize the public participation process to stakeholders in the Karnes County area
- inform stakeholders on the status of work being performed on the project
- provide information on data and results from BST
- discuss the next phase

At the third meeting in Goliad, in March of 2008, the objectives were to:

- inform stakeholders on the status of work being performed on the project
- provide information and data on LDCs
- disclose allocations and TMDL endpoints
- discuss the public comment, adoption, and approval process
- discuss implementation

At the fourth meeting in Karnes City, in March of 2008, the objectives were to:

- inform stakeholders on the status of work being performed on the project
- provide information and data on LDCs
- disclose allocations and TMDL endpoints
- discuss the public comment, adoption, and approval process
- discuss implementation

# 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 and continue to meet applicable water quality standards, and
2) an I-Plan, which is a detailed description and schedule of regulatory and voluntary management measures to achieve the pollutant reductions identified in the TMDL.

The TCEQ is committed to developing I-Plans for all TMDLs adopted by the commission and to ensuring the plans are implemented. The TCEQ works in partnership with the TSSWCB to develop I-Plans for water bodies with agricultural sources of pollution. I-Plans are critical to ensure water quality standards are restored and maintained. They 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. It is the policy of the commission and of the TSSWCB to develop I-Plans for all TMDLs adopted by the State, and to assure the plans are implemented.

During TMDL implementation, the State works with stakeholders to develop the management strategies needed to restore water quality to an impaired water body. This information is summarized in the TMDL I-Plan, which is separate from the TMDL document. Preparation of the I-Plan will begin upon Commission approval of the TMDL. The I-Plan will detail any activities such as mitigation measures, permit actions, best management practices (BMP), and additional sampling and monitoring determined to be necessary to restore water quality.

Together, a TMDL and a TMDL I-Plan direct the correction of unacceptable water quality conditions that exist in an impaired surface water body 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 NPS discharge that would be regulated as a point source
- a limitation or prohibition for authorizing a point source under a general permit
- 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 monitoring and reporting of effluent discharge quality to evaluate and verify loading trends, adjustment of an inspection frequency, a response protocol to public complaints, and escalation of an enforcement remedy to require corrective action of a regulated entity contributing to impairment.

The TMDL document and the underlying assumptions, model scenarios, and assessment results should not be interpreted as absolute requirements. Effluent monitoring, limitation, or other requirements must first be incorporated into a TPDES permit as implementation for point source activities. The I-Plan developed by stakeholders, and approved by the state, will direct implementation efforts to certain sources contributing 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 and/or feasibility
- current availability or likelihood of funding
- existing or planned pollutant reduction initiatives such as watershed-based protection plans
- whether a source is subject to an existing regulation
- the willingness and commitment of a regulated or unregulated source
- 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.

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 (see August 2, 2006 memorandum from EPA relating to clarifications on TMDL revisions).

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 Code of Federal Regulations (CFR) Sec. 130.6(c)). Consistent with federal requirements, each TMDL is a plan element of a WQMP and commission adoption of a TMDL is state certification of the WQMP update.

Because the TMDL does not reflect or direct specific implementation by any one pollutant discharger, the TCEQ certifies additional "water quality management plan elements" to the WQMP after 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 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 (see November 22, 2002 memorandum from EPA relating to establishing TMDL WLAs for storm water sources). Thus, the TCEQ would not identify specific implementation requirements applicable to a specific TPDES storm water permit through an effluent limitation update. However, the TCEQ would revise a storm water permit, require a revised SWMP or PPP, or implement other specific revisions affecting storm water dischargers in accordance with an adopted I-Plan.

The TSSWCB is the lead agency in Texas responsible for planning, implementing, and managing programs and practices for preventing and abating agricultural and silvicultural nonpoint sources of water pollution (Texas Agriculture Code §201.026). In collaboration with local soil and water conservation districts, the TSSWCB works with landowners to develop and implement Water quality management plans on agricultural or silvicultural lands. A TSSWCB-certified water quality management plan is a site-specific plan that includes appropriate land treatment practices, production practices, management measures, and technologies that are based on criteria established by the USDA Natural Resources Conservation Service. Water quality management plans are designed to achieve a level of pollution prevention or abatement determined by the TSSWCB to be compliant with the state's standards for surface water quality.

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