Approved April 6, 2016

Implementation Plan for Three Total Maximum Daily Loads for Bacteria in the Upper San Antonio Watersheds

Segments: 1910, 1910A, 1911

Water Quality Planning Division, Office of Water

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

This plan was produced by the Upper San Antonio River Watershed Stakeholder Coordination Committee and the Technical Subcommittee.

In compliance with the Americans with Disabilities Act, this document may be requested in alternate formats by contacting the TCEQ at 512/239-0028, Fax 239-4488, or 1-800-RELAY-TX (TDD), or by writing P.O. Box 13087, Austin, TX 78711-3087.

Distributed by the
Total Maximum Daily Load Team
Texas Commission on Environmental Quality
MC-203
P.O. Box 13087
Austin, Texas 78711-3087
E-mail: tmdl@tceq.texas.gov

TMDL Implementation Plans are also available on the TCEQ website at:
www.tceq.texas.gov/waterquality/tmdl/

Implementation Plan for Three Total Maximum Daily Loads for Bacteria in the Upper San Antonio River Watersheds

Segments:

1910 – Salado Creek

1910A – Walzem Creek

1911 – Upper San Antonio River

This plan is based in part on technical reports prepared for the TCEQ by:

James Miertschin & Associates, Inc., "Modeling Report for Bacteria TMDL Development: Salado Creek, Segment 1910; Walzem Creek, Segment 1910A; Upper San Antonio River, Segment 1911" and James Miertschin & Associates, Inc., "Upper San Antonio River Watershed Protection Plan" December 2007, for the San Antonio River Authority and Bexar Regional Watershed Management Partnership, and in large part on the recommendations of the Upper San Antonio River Watershed Stakeholder Technical Subcommittee, a subcommittee of the Coordination Committee responsible for developing the implementation plan for total maximum daily loads for bacteria in the Upper San Antonio Watershed.

Organizations and individuals that participated in the development of this document include:

Texas Commission of Environmental Quality
San Antonio River Authority
San Antonio Water System
City of San Antonio
Bexar County
Wilson County
Texas State Soil and Water Conservation Board
Texas Parks and Wildlife Department
Texas Farm Bureau
CPS Energy
Texas A&M AgriLife Research
Trinity University
Pape-Dawson Engineers, Inc.
Mark E. Kellmann, Architect, NCARB
CDS Muery
The Real Estate Council of San Antonio

On January 15, 2015, the members of the Coordination Committee approved this document for submission to the Texas Commission on Environmental Quality.

The members of the Coordination Committee understand that this Implementation Plan puts the total maximum daily load into action by outlining the steps necessary to reduce pollutant loads through voluntary activities.

Responsible Parties:

San Antonio River Authority
City of San Antonio
San Antonio Water System
Bexar County
Wilson County
Texas State Soil and Water Conservation Board

Contents

Figures

Abbreviations

ACS	Animal Care Services Department (City of San Antonio)
BRWM	Bexar Regional Watershed Management
BMP	best management practice
CCDO	Center City Development & Operations Department (City of San Antonio)
CCTV	closed-circuit television
CoSA	City of San Antonio
CRP	Clean Rivers Program
CWA	Clean Water Act
DMR	discharge monitoring reports
DO	dissolved oxygen
E. coli	*Escherichia coli*
EARZ	Edwards Aquifer Recharge Zone
EDMR	electronic discharge monitoring report
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FOG	fats, oils, and grease
FOTG	field office technical guide
FSP	field screen points
GIS	geographic information system
HSPF	hydrologic simulation program - FORTRAN
I-Plan	implementation plan

KSAB	Keep San Antonio Beautiful
LEED	Leadership in Energy & Environmental Design
LID	low impact development
LSHS	Lone Star Healthy Streams
mL	milliliter
MS4	municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NRCS	Natural Resources Conservation Service
O&M	operation and maintenance
OSSF	on-site sewage facility
PRD	Parks and Recreation Department (City of San Antonio)
RWWA	River Walk Watershed Alliance
SARA	San Antonio River Authority
SARIP	San Antonio River Improvements Project
SAWS	San Antonio Water System
SORP	Sanitary Sewer Overflow Response Plan
SSO	sanitary sewer overflow
SWCD	soil and water conservation district
SWI	student water investigators
TCEQ	Texas Commission on Environmental Quality
TCI	Transportation and Capital Improvements Department (City of San Antonio)
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TSS	total suspended solids
TSSWCB	Texas State Soil and Water Conservation Board
TSWQS	Texas Surface Water Quality Standards
TxDOT	Texas Department of Transportation
UDC	unified development code
USDA	United States Department of Agriculture
UV	ultraviolet

WCTS	Wastewater Collection and Transmission System
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan

Background Summary

On July 25, 2007, the Texas Commission on Environmental Quality (TCEQ) adopted *Three Total Maximum Daily Loads for Bacteria in the San Antonio Area* (Segments 1910 – Salado Creek, 1910A – Walzem Creek, and 1911 – Upper San Antonio River). The total maximum daily loads (TMDLs) were approved by the U.S. Environmental Protection Agency (EPA) on September 25, 2007. Appendix I of this document contains the entire TCEQ report *Three Total Maximum Daily Loads for Bacteria in the San Antonio Area*.

A TMDL is a technical analysis that:

- determines the amount of a particular pollutant that a water body can receive and still meet applicable water quality standards

The final TCEQ TMDL report was based in large part on the modeling report by James Miertschin & Associates, Inc. (2006) for bacteria TMDL development for Salado Creek, Walzem Creek, and the Upper San Antonio River. This work included data collection, analysis, supplemental sampling, mathematical modeling of water quality, load allocations, and report preparation. Fecal coliform was selected as the key modeling parameter in work associated with the TMDL, but final TMDL load allocations were assessed using *Escherichia coli (E. coli)*. Historical fecal coliform measurements were converted to *E. coli* using a ratio of 0.63 *E. coli* per fecal coliform.

At the time the San Antonio Area TMDLs were under development by TCEQ in 2006, the standard to support contact recreation was in transition, so both *E. coli* and fecal coliform recreational standards were in place. At the February 12, 2014, TCEQ Commission Agenda meeting, the Commissioners adopted revisions to the Texas Surface Water Quality Standards (TSWQS). *E. coli* are now the preferred bacteria for indicating the level of pathogens in freshwater streams.

The current TCEQ standards for contact recreation (Texas Administrative Code, Title 30, Chapter 307) that are applicable to freshwater streams in Texas are:

- **Primary contact recreation 1:**
  - *E. coli* geometric mean criterion ≤126 per 100 milliliters (mL)
  - Single sample criterion for *E. coli* is 399 per 100 mL (not being used in current assessments)
- **Primary contact recreation 2:** (for non-federal projects only) (EPA has not yet acted on this standard)
  - *E. coli* geometric mean criterion <206 per 100 mL
- **Secondary contact recreation 1:**
  - *E. coli* geometric mean criterion <630 per 100 mL
- **Secondary contact recreation 2:**
  - *E. coli* geometric mean criterion <1,030 per 100 mL
- **Noncontact recreation:**
  - *E. coli* geometric mean criterion < 2,060 per 100 mL

Introduction

To improve water quality in impaired waterways, stakeholders develop an Implementation Plan (I-Plan) for each TMDL in cooperation with the TCEQ.

This I-Plan is designed to guide activities that will improve water quality for the Salado Creek, Walzem Creek, and Upper San Antonio River watersheds. It is a flexible tool that governmental and nongovernmental organizations voluntarily use to guide their activities to improve water quality. The participating partners may accomplish the management measures described in the plan through activities, guidance, or other action.

This I-Plan contains the following components:

- description of management measures[1] that will be implemented to improve water quality.
- follow-up tracking and monitoring plans to determine the effectiveness of the management measures undertaken.
- identification of outcomes and other considerations that stakeholders will use to determine whether the current I-Plan improves water quality, or whether the plan needs to be modified.
- identification of the communication strategies that TCEQ or their subcontractors will use to disseminate information to stakeholders.
- the strategy that stakeholders will use to periodically review and revise the plan to ensure there is continued progress in improving water quality.
- recommendations for further analysis.

This 5-year I-Plan also includes:

- possible causes and sources of the impairment
- management measure descriptions
- a schedule of implementation
- measurable milestones for years 2 and 5
- indicators to measure progress
- monitoring components
- responsible entities

[1] Management measures refer to strategies for reducing unregulated pollutants.

Projects developed to implement nonpoint source (NPS) (unregulated) elements of this plan may be eligible for funding under the EPA's Clean Water Act (CWA) Section 319(h) grant program.

This I-Plan:

- describes steps that watershed stakeholders will take toward improving water quality
- outlines the schedule for implementation activities

The ultimate goal of this I-Plan is to meet primary contact recreation uses in Salado Creek (Segment 1910), Walzem Creek (Segment 1910A), and the Upper San Antonio River (Segment 1911), by reducing concentrations of *E. coli* bacteria to levels established in the TMDLs.

The TMDLs identified regulated and unregulated sources of *E. coli* in the watershed that could contribute to water quality impairment. Regulated sources identified include point sources as well as municipal separate storm sewer systems (MS4s). There are several regulated municipal point-source outfalls in the watershed. Within the impaired segments, San Antonio Water System (SAWS) has two permitted Water Recycling Centers and six discharge locations. Three of these locations provide dry-weather base flow for the upper San Antonio River and dry-weather base flow for Salado Creek. SAWS achieves disinfection of effluents by chlorination and de-chlorinates all water just prior to discharge. As such, bacteria concentrations are orders of magnitude below the Water Quality Standard. The TMDL for bacteria in the San Antonio area assigned a Waste Load Allocation for these discharges based on actual flow and bacteria concentrations.

Both point and nonpoint sources have been identified as contributing to the bacteria impairment. One substantial point source of *E. coli* to the Upper San Antonio River is the San Antonio Zoo. Other point sources identified as potentially contributing to bacteria levels are stormwater from MS4 Phase II dischargers, sanitary sewer overflows, and dry weather discharges. Nonpoint sources that could contribute to the *E. coli* load in the watershed include stormwater outside MS4 areas, failing septic systems, leaking wastewater infrastructure, livestock, and wildlife such as egret rookeries.

This I-Plan includes 30 management measures that will be used to improve water quality and reduce *E. coli* in Salado Creek, Walzem Creek, and the Upper San Antonio River watersheds.

Historically, the San Antonio Zoo discharged substantial concentrations of bacteria to the Upper San Antonio River. The Zoo waterway has one primary and one secondary outfall, both of which discharge directly to the San Antonio River. In 2011, monitoring of the primary outfall was added to the City of San Antonio MS4 permit as Outfall 008, which requires testing for *E.coli* and Total Suspended Solids (TSS). The discharge flow rate for the primary outfall (averaging 1,700 gallons per minute) was characterized using data reported annually to the Edwards Aquifer Authority.

Bacteria concentrations in the discharge were characterized using grab sampling data available from several sources, including recent sampling by SAWS and San Antonio River Authority (SARA). As of June 15, 2015, the primary outfall waters entering the ultraviolet (UV) facility located between the Zoo and the San Antonio River had a geometric mean of 9,554 org/100 mL. The geometric mean concentration leaving the UV system is approximately 5 org/100 mL for both treatment channels (1 and 2).

Implementation Strategy

This 5-year plan provides 30 management measures to improve water quality. Management measures were selected based on feasibility, costs, support, and timing. Activities may be implemented in phases based on the needs of the stakeholders, availability of funding, and the progress made in improving water quality.

Adaptive Implementation

All I-Plans are implemented using an adaptive management approach in which measures are periodically assessed for efficiency and effectiveness. This adaptive management approach is one of the most important elements of the I-Plan. The iterative process of evaluation and adjustment ensures continuing progress toward achieving water quality goals, and expresses stakeholder commitment to the process.

At annual meetings, the stakeholders will assess progress using the schedule of implementation, interim measurable milestones at 2 and 5 years, water quality data, and the communication plan included in this document. If annual assessments find that insufficient progress has been made or that implementation activities have not improved water quality, the implementation strategy will be adjusted. Adaptive management will be especially important in implementing this plan, since the TCEQ TMDL report containing the modeling results used was developed close to 10 years ago and many factors have changed since then.

Activities and Milestones

The Upper San Antonio River Watershed Stakeholder Coordination Committee directing this I-Plan formed a subcommittee to determine appropriate activities and schedules to accomplish the management measures in the plan. This Technical Committee advised the Coordination Committee about technical matters and wrote the Implementation Plan under the direction of the Coordination Committee. Collectively, the Upper San Antonio River Watershed Stakeholder Coordination Committee and Technical Committee held 22 meetings to develop this I-Plan.

Early meetings were held for the purpose of selecting a Coordination Committee. These meetings were held on May 20, June 24, and July 25, 2013. The third meeting was open to the public. The first meeting of the Coordinating Committee was held August 15, 2013, where a chairman was elected and one of the committee members was appointed to form a Technical Subcommittee. That committee member co-chaired the Technical Subcommittee alongside a co-chair elected from the subcommittee. The Coordination Committee also met again on September 19 and December 13 in 2013. In 2014, they met on March 27 and June 24.

The first meeting of the Technical Subcommittee was held on September 19, 2013, where a co-chair was elected. Subsequently, the committee met again on October 3 and 17, November 7 and 21, and December 5 of 2013. In 2014, they met on January 16, February 20, March 20, April 17, May 15, June 19, July 17, August 21, and November 20. The two committees met in joint sessions on December 13 of 2013, September 24 and December 4 of 2014, and January 15, 2015.

Additional meetings were held with SARA, SAWS, City of San Antonio (CoSA), Bexar County, Wilson County, and Alamo Area Council of Governments with presentations to Wilson County Farm Bureau and Alamo and Wilson Soil and Water Conservation Districts (SWCD), as well as Bexar County mayors.

The Technical Subcommittee developed detailed, consensus-based management measures for the Coordination Committee to approve. The planned management measures are described in the following sections.

Management Measures

In 2006, a strategy for reducing bacteria levels in the Upper San Antonio River resulted in the development of a watershed protection plan (WPP). A "Nine Key Elements Table," which is a listing of the identified Best Management Practices (BMPs), was developed and included in the WPP. This table was used by the stakeholders as a framework for the development of the management measures found in this I-Plan.

Stakeholders wanted to document the activities that have been accomplished since the TMDL adoption in 2007, as well as current and future work. Therefore, the following management strategies have been organized into the three categories of completed, on-going, or recently identified:

- SAWS Implementation Strategy: Wastewater Collection and Transmission System Operation and Maintenance Programs to Reduce Sanitary Sewer Overflows (SSOs)
- San Antonio Zoo UV Treatment System Implementation
- Advancement of Low Impact Development (LID)
- MS4 Related Activities
- Avian Management for the River Walk and Other Riparian Areas
- Expansion of the Pooper Scooper Program
- Increased Awareness and Enforcement of Pet Control Ordinance
- BMP Assessment, Pilot Studies, and Mission Drive-In Redevelopment

- Feral Hog Management
- Livestock Management
- Inspection of New Construction Sites
- Evaluation of Restoration of Westside Creeks
- Mission Reach Ecosystem Restoration and Recreation
- Environmental Investigators
- "Be Watershed Wise" Campaign
- Homeless and Vagrant Population: Cleaning, and Control of Brush and Dumping at Encampments
- Inspection and Repair of Septic Systems
- Specially Designed Boat (Lady Eco)
- Implementation of Measures to Improve Maintenance and Cleaning Operations for the River Loop Area
- Street Sweeping Activities
- San Antonio River Loop Sediment Removal
- Urban Horse Stable Assessment
- Creek Book
- BMP Assessment Report, 2010
- Providing Illegal Dumping Signs for Existing Vegetated Swales/Filter Strips (70.5 miles of earthen channel on Alazan, Apache, Martinez, Olmos, 6-Mile Creek, and Upper San Antonio River)
- Animal Pound Wash-down
- Wildlife Management at the Bat Colony Under the Houston Street Bridge

- SAWS' Recycled Water Program and Streamflow Augmentation Discharges
- Connection of 117 Homes to SAWS' Sanitary Sewer Collection System in the Espada Community Located in Southwest Bexar County
- San Antonio River Walk Implementation Project and Plan

Management Measure 1. Implement Wastewater Collection and Transmission System Operation and Maintenance Programs to Reduce Sanitary Sewer Overflows

SAWS has implemented programs to provide for the operation and maintenance (O&M) of the Wastewater Collection and Transmission System (WCTS) that will minimize system failures, malfunctions and line blockages that could contribute to SSOs. SAWS will continue to improve its practices through a proactive use of information and data obtained from operational experience.

Sanitary Sewer Overflow Response Plan (SORP)

SAWS has implemented a SORP designed to respond to and halt SSOs as rapidly as technically feasible consistent with safety and legal requirements. The SORP includes a plan describing the standard operating procedures to be followed by SAWS personnel responding to SSOs.

System Cleaning Program

Materials such as fats, oils, and grease (FOG), rags, roots and other foreign objects can create blockages within the WCTS. Regular maintenance and cleaning regimens can reduce these occurrences. The purpose of cleaning is to remove FOG, debris, roots and any other obstructions from the WCTS that may contribute to an SSO.

SAWS' Small Diameter (<24-inch) Cleaning Program provides a cleaning maintenance frequency for each main segment (asset) based upon the main type, condition, date installed, and operating history. Assets identified as critical are cleaned more frequently. SAWS anticipates that it will clean a minimum of 400 miles of small diameter pipe each year.

SAWS' Large Diameter Cleaning Program (≥24-inch) is designed to make a determination of whether cleaning is required based on inspection results. SAWS will clean large diameter sewer mains that are determined to contain debris in a quantity that may cause insufficient flow capacity to exist in the main.

Lift Station Operation and Maintenance Program

SAWS' Lift Station O&M Program is designed to maintain functionality and restore system components. SAWS periodically reviews and updates its Lift Station O&M Program as needed. Any defective conditions that might contribute to an SSO that are discovered during an inspection will be repaired.

Fats, Oil and Grease Control Program

The FOG Control Program is designed to reduce the amount of grease, which is a significant cause of SSOs, being discharged into the WCTS. The discharge of FOG is regulated by the CoSA Code of Ordinances that are administered and enforced by SAWS' FOG Control Program. The Program includes FOG control device management, routine compliance inspections to ensure compliance, public education and an enforcement program. SAWS intends to inspect all food service establishments for ordinance compliance at least once every two years. In addition, updates to Chapter 34 of the City Code have included a provision to prohibit additional items that contribute to stoppages in the WCTS. Items such as medical sharps, regulated medical waste, used health care products (cleaning wipes, articles of clothing, bedding) or any materials which can be disposed of as trash were all added as prohibited items.

Condition Assessment and Remedial Measures Program

SAWS' Condition Assessment Program consists of performing an inspection and assessment of the structural condition of gravity sewer mains and manholes within the WCTS through a series of investigative steps. These activities are designed to identify structural defects in the WCTS that have caused or significantly contributed to previous SSOs or, that are likely to cause or significantly contribute to the future occurrence of SSOs.

Condition assessment activities determine those structural defects that warrant remedial measures alternatives analysis and possibly remedial measures, in contrast to those defects that can be addressed via monitoring or maintenance activities. If a remedial measure is

required to correct a structural defect, SAWS will implement a variety of corrective actions including a point repair, slip lining, cured in place lining, or the installation of new pipe.

Capacity Assessment and Remedial Measures Program

SAWS' Capacity Assessment Program consists of conducting an assessment to identify sewer mains that are not large enough to carry the flow within the WCTS, that have caused or significantly contributed to previous SSOs, or are likely to cause or significantly contribute to the future occurrence of SSOs.

Capacity assessment evaluates the capacity of the WCTS through activities that may include flow monitoring, hydraulic modeling and investigative steps which may include both field and office activities.

Capacity assessment activities determine those mains that are not large enough to carry flows within the WCTS that warrant remedial measures alternative analysis and possibly remedial measures.

Lift Station Rehabilitation and Elimination Program

SAWS initiated a phased Lift Station Rehabilitation and Elimination Program to assess the condition of lift stations in order to determine whether improvements were necessary to improve a lift station and whether a facility could be eliminated. For lift stations that will not be eliminated, an assessment is conducted to determine what repairs or rehabilitation may be warranted. The assessment process considers a wide variety of factors to determine the condition and operating performance of a lift station and, when necessary, identifies measures to improve condition or operating performance. Not all considerations are applicable to each lift station, nor does each consideration apply to each lift station in the same way, since each lift station is unique.

Force Main Assessment Program

SAWS' Force Main Assessment Program consists of creating an inventory of each force main in SAWS' WCTS that includes a description of the force main construction material, age or installation date, diameter, length, and special corrosion protection measures, if any. The inventory also includes any redundant or standby force main and the typical operating mode (i.e., emergency standby, wet weather standby or other). SAWS assesses each force main by

reviewing past maintenance records, physically examining the air release valves, and visually inspecting the ground surface over the entire length of the force main to the extent practicable.

SAWS performs inspections of lift stations and force mains located over the Edwards Aquifer Recharge Zone (EARZ) that are reported in an annual report that is submitted to the TCEQ.

Edwards Aquifer Recharge Zone Program

Regulations adopted by the State of Texas require that SAWS perform inspection and testing of various components of the WCTS that are located within the EARZ. In accordance with these regulations SAWS performs closed-circuit television (CCTV) inspections of sewer system mains and performs smoke testing of sewer laterals. SAWS also repairs defects that could result in exfiltration of sewage.

Water Quality Program

The Water Quality Program was implemented to determine water quality in the Upper San Antonio River, Salado Creek, and Medio Creek watersheds. The scope includes submitting up to 120 water samples obtained from two dry and two wet weather events sampled at 29 selected stormwater outfalls over a two year period. The condition and age of the WCTS up-gradient of the respective field screen points (FSPs) and stormwater outfalls were taken into consideration for the selection process. In addition, SAWS chose neighborhoods that were nearest to measured historical high bacteria levels. These samples will be submitted for laboratory analysis to determine the existence of a human Bacteroides marker using the Quantitative Polymerase Chain Reaction method and *E. coli*.

Responsible Party: SAWS

Timeline: Ongoing

Measurable Milestones

Year 2:

- As year 2 unfolds, SAWS will continue its mission as an integrated team to develop durable BMPs that improve program management; capacity assessment; remedial

measures; capacity, management, operation, and maintenance; and information services. These combined efforts with a focus on proactive planning and maintenance, will aid in the continued reduction of SSOs through appropriate completion of capital projects and O&M activities.

Year 5:

- SAWS will perform the same SSO reduction principals listed in year 2 with an increased focus from planning to the implementation of projects. These combined efforts will continue to reduce SSOs through timely completion of capital projects and O&M activities to reduce *E. coli* quantity and volume of SSOs.

Management Measure 2. San Antonio Zoo UV Treatment System Implementation

The San Antonio Zoo (Zoo), located in Brackenridge Park, has been identified as the major point source contributor of bacteria in the Upper San Antonio River during dry weather. The bacteria originate from resident and nonresident animals, principally waterfowl and other birds, that are located along the internal waterway that traverses the Zoo. The internal waterway is fed by a well, withdrawing water from the Edwards Aquifer at a rate of approximately 1700 gallons per minute. There exists one primary and one secondary outfall from the internal waterway to the Upper San Antonio River. Flows from the secondary outfall are generally negligible, except under rainfall runoff conditions.

According to water quality modeling, disinfection (99.9 percent bacteria removal) of the Zoo's discharge will bring most of the Upper San Antonio River (within the impaired river segment) into compliance with the state criteria, except under periods of prolonged wet weather. Under periods (months) of prolonged wet weather, bacteria concentrations are heavily influenced by loads from urban runoff, and Zoo controls alone are not sufficient.

The most cost-effective BMP for reducing bacteria loads to the Upper San Antonio River is to disinfect the dry weather flow leaving the Zoo, the primary cause of impairment from Brackenridge Park through downtown San Antonio under base-flow conditions. CoSA installed a UV treatment system (May 2014) with an anticipated three log (99.9 percent) disinfection removal in bacteria density. The UV disinfection process is a non- chemical

method for destroying microorganisms by altering their genetic material, and rendering them unable to reproduce. Optimal treatment effectiveness of a UV system is achieved when the transmissivity (low turbidity/water clarity) of the treated water approaches 100 percent. Turbidity governs the effectiveness of UV (Klotz Associates, 2008); the UV system is designed to accept 5 mg/L of TSS. The UV system has been designed to have a total of 96 bulbs (three banks of 32) of low pressure lamps.

The water quality modeling projected that once the base flow from the Zoo has been controlled, there should be an observable improvement in water quality in the upper reach of the impaired river segment. With disinfection, concentrations at the Zoo outfall should be significantly reduced. Concentrations downstream of the outfall should also decrease substantially. According to the water quality model, concentrations as far downstream as Loop 410 should drop substantially (geometric means drop by about half). Due to all of the variability associated with bacteria sampling, this can only be validated through long-term sampling.

Responsible Party: CoSA Transportation and Capital Improvements Department (TCI)

Timeline: UV System became operational in May, 2014.

Measurable Milestones

Year 2:

- CoSA is responsible for on-going operations and maintenance of the UV system.
- SAWS will continue with monitoring of UV treatment efficiency and effectiveness which is a requirement of the MS4 permit.

Year 5:

- CoSA is responsible for on-going operations and maintenance of the UV system.
- SAWS will continue with monitoring of UV treatment efficiency and effectiveness which is a requirement of the MS4 permit.

Management Measure 3. Advancement of Low Impact Development

SARA will contribute to the I-Plan by working to advance LID in the following areas;

- Continued promotion of LID through education and training
- Continue work to reduce barriers to LID – modification of CoSA Unified Development Code (UDC)
- Continue efforts to meet SARA's SA2020 goal to have 20 percent of development using LID by the year 2020
- Continue LID BMP monitoring to document load reductions

Modeling

SARA will contribute water quality modeling and analysis throughout the five year time frame of the I-Plan. Water quality modeling efforts will include modeling the Upper San Antonio River watershed at a sub-watershed scale using the Hydrologic Simulation Program - FORTRAN (HSPF) for existing conditions and a future scenario. These models will then help determine the bacterial load reductions at the sub-watershed scale required to meet the regulatory standard for each scenario. In addition, a selection of BMPs will be evaluated for their impact on bacterial loads and recommendations for allocation of BMP resources developed.

Watershed Master Plans

SARA will contribute water quality components to watershed master plans for the Upper San Antonio River watershed and the Salado Creek watershed. SARA began developing watershed master plans for these two watersheds in 2009. SARA with support of the CoSA and Bexar County, as partners in the Bexar Regional Watershed Management (BRWM) group, collectively worked to develop regional flood control solutions. In 2011, SARA began to develop more holistic watershed master plans and include additional project opportunities that would address water quality issues, LID, stream restoration, nature based park planning, mitigation banking, and conservation banking. These additional components are being added to the existing plans.

The plans will continue to be updated on an annual basis with projects that have been constructed, projects being implemented, new projects that have been identified, and projects that are no longer feasible to complete. A geographic information system (GIS) platform has been developed to map all components of the master plans, which will be utilized to score new projects and prioritize them. The platform will help to ensure the projects developed are more comprehensive and have multi-benefit components, i.e. flood control, water quality, stream restoration, and LID.

Master plans for Leon Creek, Medina River, Lower San Antonio River, and Cibolo Creek watersheds have been completed or are being developed.

Long-Term Monitoring

SARA will contribute surface water quality monitoring data to the I-Plan through its long-term monitoring programs. These efforts currently incorporate 31 river and tributary sites and one site on the discharge channel from the San Antonio Zoo (Figure 1). Data is used to identify trends and assess surface water quality standard compliance (excluding zoo discharge). Monitoring sites are evaluated annually; based on analysis of data and resource availability, sites may be added or deleted. In addition to routine surface water sampling, SARA has initiated a long-term, in-stream, stormwater monitoring program that currently has one automated site within the I-Plan area. SARA's long-term monitoring programs are:

1) Clean Rivers Program (CRP)

2) SARA Stream Monitoring Program

3) In-Stream Stormwater Monitoring Program

Responsible Party: SARA

Timeline: On-going

Measurable Milestones

LID Education & Training

Year 2:

- Audience-targeted workshops and field trips, annual LID training, and LID website.

- 2 trainings, lunch and learn sessions upon request.

Years 3-5:

- Annual LID training and LID website.
- 2 trainings, lunch and learn sessions upon request.

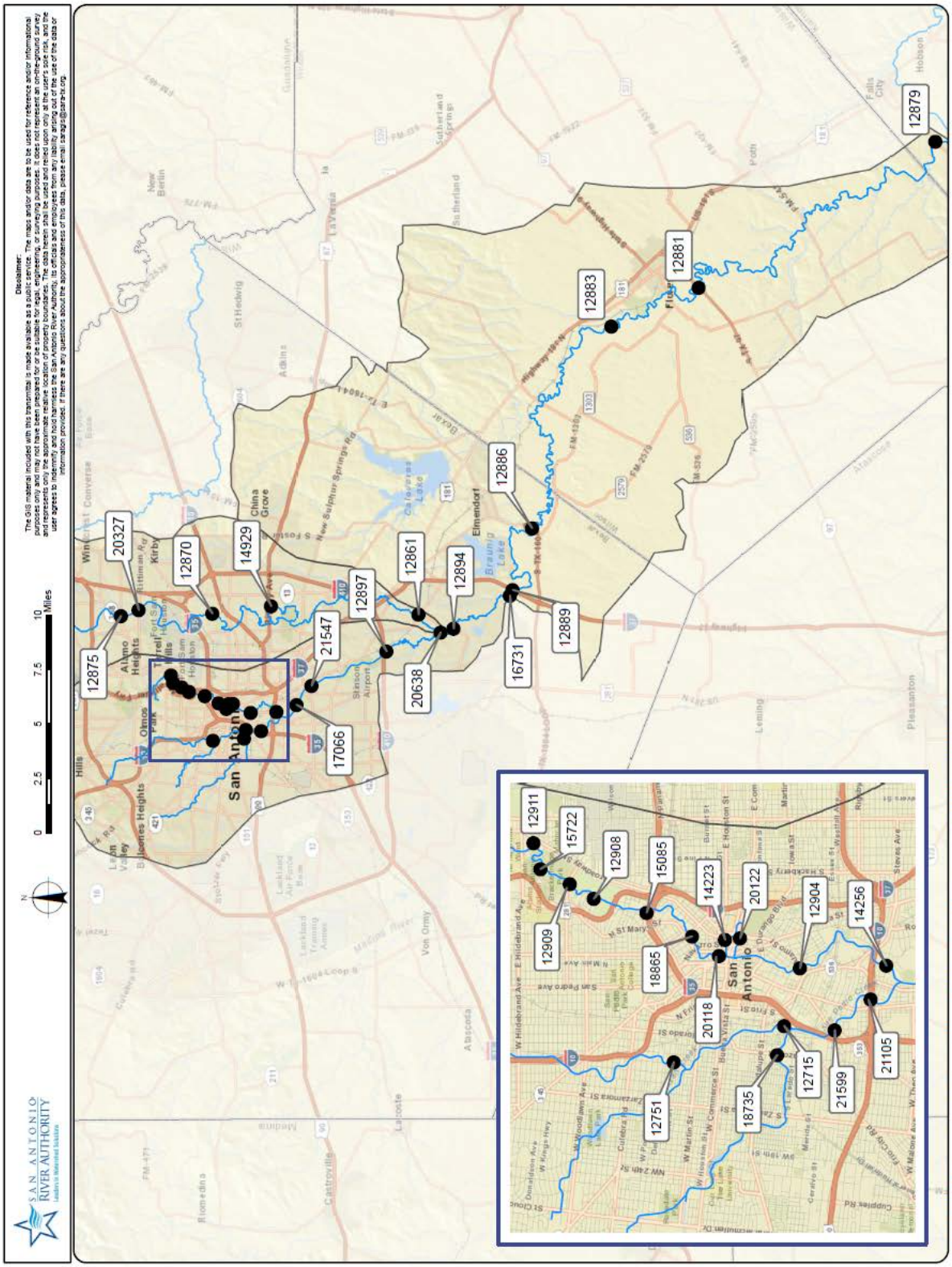

Figure 1. 2014-2015 San Antonio River Authority Monitoring Within I-Plan Area.

Unified Development Code

Year 2:

- SARA project management has presented to City Council a voluntary LID option under the UDC (12/15). The code is being drafted through input from a multi-agency Agency Advisory Panel and a Development Community Stakeholder Committee. The Agency Advisory Panel represents all departments within CoSA whose work affects or will be affected by LID as well as representatives from Bexar County, SARA, SAWS, City Public Service Energy (CPS Energy), and the Texas Department of Transportation (TxDOT). The Development Community Stakeholder Committee consists of representatives from the design, development, building, and realty industries, as well as representatives from the Watershed Improvement Advisory Committee of the BRWM group. Early guidance regarding representatives for this committee was sought from, and provided by, the CoSA's Development Process Task Force.

Years 2-5:

- SARA attends the CoSA's Master Development Plan meetings, Preliminary Plan Review meetings, and meetings of the Historic Design Review Commission, and under an Interlocal agreement with the City, identifies upcoming developments within the River Improvements Overlay District and offers LID assessments and stormwater BMP options to the developers and their designers.
- SARA also provides LID assessment assistance in coordination with the CoSA on development plans that are self-identified as having LID components.

SA2020

Years 2-4:

- SARA will continue LID advocacy and promotion to development and design community, government agencies, and others to implement LID projects.
- SARA's promotion of LID to developers and project engineers on a minimum of eight significant development projects annually.

- SARA's promotion of LID through the SARA website.

Year 5:

- Work to implement further UDC amendments in 2020, if necessary, such as continued investigations into and implementation of effective LID incentives.

LID BMP Monitoring

Years 2-5:

SARA will continue current BMP water quality monitoring at its Guenther Street and Euclid Avenue properties. SARA has conducted pre-construction stormwater monitoring at several CoSA street projects. As these projects are completed SARA will conduct post-implementation monitoring to gauge the effectiveness of the BMP's.

Modeling

Year 5:

Amend appropriate watershed master plans with recommendations based upon the described modeling efforts.

Watershed Master Plans

Years 2-5:

The Upper San Antonio River and Salado Creek Watershed Master Plans will be updated annually.

Long-Term Water Quality Monitoring

The routine monitoring component is primarily long-term and designed to identify trends – no end date.

Years 2-5:

SARA will review monitoring annually with TCEQ and other monitoring partners in a coordinated monitoring process which allows for a more effective use of limited resources. The outcome of the meetings could be an increase or decrease in sites being monitored. SARA will provide the TMDL I-Plan group, at its annual meeting, an updated monitoring map, and

a summary of changes in *E. coli* concentrations at all on-going routine monitoring sites in the I-Plan area. CRP and SARA routine surface water monitoring sites can be accessed at <https://cms.lcra.org/>.

Management Measure 4. MS4 Related Activities and MS4 Phase I Water Quality Protection Activities

Permittees: SAWS, CoSA, TxDOT

Most of the urbanized area in the greater San Antonio metropolitan area is covered by an MS4 permit issued by the TCEQ. According to EPA guidelines, stormwater regulated by an MS4 permit is considered a point source for TMDL allocation. CoSA Transportation and Capital Improvements Department, TxDOT District 15, and SAWS are co-permittees under Texas Pollutant Discharge Elimination System (TPDES) Permit No. WQ0004284000 (2007). The MS4 permit describes numerous tasks and activities that are required of the permittees. For example, a comprehensive Stormwater Management Program and Annual Report are required from each permittee.

Under the existing permit, the permittees are responsible for many facets of the Federal Stormwater Program. Associated responsibilities, especially those under the EPA National Pollutant Discharge Elimination System (NPDES) permit are outlined below.

- Structural controls and stormwater collection system operation
- Areas of new development and significant redevelopment
- Illicit discharges and improper disposal
- Spill prevention and response
- Industrial and high risk runoff
- Construction site runoff
- Public education
- Monitoring programs (including wet and dry weather screening programs and industrial and high risk runoff monitoring programs)

Understanding that there are numerous small municipalities within Bexar County that have water quality protection activities as part of their MS4 Phase II permit, the permittees will focus on the largest MS4 in Bexar County, which is the only Phase I permit in the area of impairment, for this first period of implementation. The other MS4 Phase II entities which will be considered in future implementation periods are: Hollywood Park, Hill Country Village, Castle Hills, Windcrest, Selma, Universal City, Live Oak, Shavano Park, Helotes, Schertz, Converse, Terrell Hills, Alamo Heights, Olmos Park, Balcones Heights, Leon Valley, Somerset, Elmendorf, China Grove, and Bexar County.

The MS4 Phase I permit issued to CoSA, SAWS, and TxDOT on February 1, 1996 was the second permit issued in Texas by the EPA Region 6. The three agencies are co-permittees on the permit. During initial discussion between the permittees, tasks were identified and program responsibilities were agreed upon with an inter-local agreement.

SAWS' Stormwater Management Programs include the Industrial & High Risk Runoff Inspection Program, the Construction Site Runoff Program, Technical Spill Response, Public Education of Youth, and the Illicit Connection Inspection Program. Within SAWS, the Resource Compliance Division is responsible for the implementation of the Stormwater Management Program (except for Education), which addresses many of the components of the TPDES stormwater permit. The permit includes requirements to implement a water quality permit program to improve the quality of surface water flowing through the MS4, which discharges to the Edwards Aquifer Recharge Zone and into local streams.

Almost all the required activities under the permit aid in the reduction of overall pollution, however, only a select number of requirements address bacteria, these items will be focused on exclusively within this document.

Public Education Program - CoSA

The City's campaign, *Remember the River*, specifically focuses on educating residents and audiences about adverse stormwater runoff impacts to natural waterways which are directly and indirectly affected by the following human/domestic animal activities:

- illegal dumping
- household hazardous waste product storage/application/disposal

- lawn maintenance and automotive maintenance
- illicit pet waste (*E. coli* and hazardous bacteria)
- commercial activities and maintenance (businesses, industrial facilities, construction, municipal operations)

Educational outreach is simultaneously conducted through the following outlets:

- Campaign Website Resource Outreach: *Remember the River* website offers one-stop information, downloadable educational literature and Web resources pertaining to stormwater runoff pollution prevention tips, knowledge, and awareness for multiple local audiences. The website also links residents with information on campaign-sponsored volunteer programs and activities, as well as staff contacts for educational presentations.
- Community Event Information Exhibitions: Campaign coordinator and department staff disseminate educational literature and promote awareness of stormwater runoff pollution prevention knowledge (stormwater runoff awareness, household hazardous waste disposal, lawn/automotive maintenance, illegal dumping reporting, pet waste pickup) and volunteer opportunities (Adopt-A-Spot Right-Of-Way Maintenance and Beautification Program, Stormwater Inlet Marking Program, Pet Waste Pickup Education/Free Pet Waste Pickup Tool Incentive Program) through interactive resource booths at various City-sponsored and external community outreach events held throughout the year.
- Community Presentations: Campaign coordinator and department staff offer and conduct free educational presentations on stormwater runoff pollution prevention topics and promote volunteer programs to residents, commercial groups, and general audiences by invitation and coordinated through various City-sponsored/external opportunities during the year.

Public participation volunteer programs designed to increase resident/group awareness and interactive investment in stormwater runoff pollution prevention include:

- Adopt-A-Spot Right-Of-Way Maintenance/Beautification Program: Residents and groups are encouraged to adopt CoSA-managed rights-of-way (street medians, creek channels, drainage channels) for volunteer-based trash pickup and beautification maintenance throughout the year. Campaign coordinator, department staff, and Keep San Antonio Beautiful (KSAB) partners coordinate right-of-way adoptions, recruit volunteer groups, and support/highlight Adopt-A-Spot progress.

- Storm Drain Inlet Marking Program: Residents and groups are encouraged to support public awareness (discouraging pollutants entering storm drains through runoff or illegal dumping) by voluntarily placing stencil markings on inlets as visual public deterrents throughout the year. Campaign coordinator and department staff coordinate stencil marking activities, recruit volunteers from residents in the community, and support/highlight inlet marking progress.

- Pet Waste Pickup Education/Free Pet Waste Pickup Tool Incentive Program: Residents who are pet owners are offered free pet waste pickup tools as incentives to promote pet waste pickup as part of pet waste outreach/education activities. Campaign coordinator and department staff distribute free pickup tools through community events/presentations throughout the year, and through pet adoption educational support from Animal Care Services (ACS) Department. The program also offers campaign yard signs for home, park, and property use to encourage pet owners walking their dogs to pick up pet waste (visual deterrents).

Additionally, the *Remember the River* outreach campaign heightens public awareness about stormwater runoff pollution prevention through an annual public service announcement advertising campaign focusing on volunteer opportunities and website information resources.

Public Education Program - SAWS

SAWS offers an environmental education program that provides valuable learning opportunities for children through adults utilizing classroom curriculum, interactive activities, and special events and programs outside of the school setting. SAWS' education program takes a holistic approach to water focusing on stormwater, groundwater, wastewater treatment, and

drinking water issues for the education of teachers, students, and the general public from pre-kindergarten through adults.

From an effective communications standpoint, it is essential that the stormwater quality message be a component of the overall water education program. SAWS' education program combines all water messages/information into one program to reach more citizens each year with a comprehensive water message as opposed to teaching each program separately. In addition, it is also more cost effective to run a comprehensive program than individual efforts. In 2013, SAWS targeted stormwater education included:

Rain to Drain Experience Community Field Trips:

During these 8 eight-hour field trips, 400 adult community leaders were introduced to water-related topics including the hazards of pesticides, herbicides and household hazardous waste, their proper use and disposal, and the infrastructure operations and demands of the stormwater system in San Antonio.

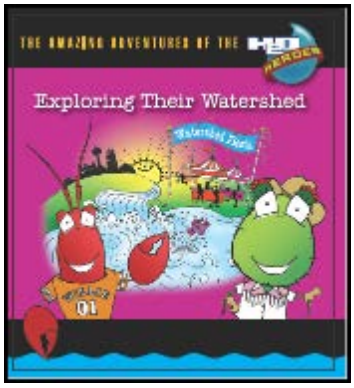

Figure 2. Example of environmental education program, "The Adventures of the H2O Heroes."

The Adventures of the H_2O Heroes:

All Kindergarten through 5th grade students (approximately 48,000) in the Northside Independent School District (the 3rd largest district in Texas) and all Kindergarten through 5th grade students (6,864) in the Harlandale Independent School District, participated in a week-long curriculum project (Figure 2) introducing them to watershed, stormwater, and pollution prevention concepts.

Enviroscape:

This stormwater runoff model (Figure 3) was available for schools to check out and use for classroom presentations.

Figure 3. Enviroscape model

Waterwheel Distribution:

The water wheel (Figure 4) educational product (created in-house by SAWS staff) includes ten tips for protecting water quality. In 2013, the product was distributed at school presentations, community festivals, and environmental events.

Figure 4. SAWS Waterwheel.

Student Water Investigators (SWI):

The Student Water Investigators curriculum (Figure 5) is a hands-on investigation of water in our local environment. Using the skills of a detective, middle school aged students investigate water properties, explore groundwater and examine the community water cycle.

Figure 5. SWI program materials.

Monitoring Programs

The Instream Monitoring and Illicit Connection programs are two separate monitoring programs that operate under the requirements of the permit where different types of samples are collected and reported for MS4 permit compliance and to gather data to monitor trends in pollutant levels.

Instream Monitoring is performed at sampling station sites in which the collection of samples and storm data is done from a fixed location during qualified rain events. Flow weighted samples are collected (as well as grab samples when appropriate) and field data is recorded. SAWS samples storm events from stations at outfalls:

- 001 - San Pedro Ave and Olmos Creek
- 002 - South Flores Street and Six Mile Creek
- 003 - Alderete Park and Zarzamora Creek
- 004 - Bandera Road and Zarzamora Creek
- 005 - Bitters Road into a tributary of Salado Creek

- 006 - Business Park into a tributary of Salado Creek.

SAWS has made use of the Electronic Discharge Monitoring Report (EDMR) system that is on the TCEQ website to submit the information electronically. A copy of the data submitted will be attached in a section marked Discharge Monitoring Reports (DMRs). TxDOT contracts out the sampling at outfall 007 Ingram Road and Leon Creek with SARA. Pollutant loadings from the various land uses in each of the watersheds were calculated and documented. In addition to the samples being taken for the pollutant loading calculations and for reporting on the DMRs, individual grab samples are taken as part of the Wet Weather Monitoring Program at in-stream locations to check the pollutant parameters in the various stream segments for evaluation during individual storm events. This gives SAWS a snapshot of the individual storm to see what influence it may have had and if there is a need to investigate further a particular pollutant parameter in that watershed. Sampling of outfall 008 will be performed at the San Antonio Zoo Water Quality Treatment Facility for TSS and *E. coli*.

Illicit Connection Program

The program involves investigating individual complaints of illicit discharges, checking the dry weather flow from over 425 MS4 outfalls (36" and larger), conducting visual surveys of 435 miles of open MS4 channels, participating in the draining of the downtown River Walk (investigation and sampling of all MS4 outfalls normally underwater); and responding to SSOs to ensure adequate cleanup and assess the impact to the receiving water body.

Figure 6. shows the locations of designated FSP that SAWS investigates. When there is a discharge from the outfall it is checked for ammonia, free and residual chlorine, surfactants, copper and phenols; the dissolved oxygen (DO) and pH levels are monitored; and visual indicators such as color, smells, and biological diversity in the immediate area of the discharge are checked. *E.coli* is tested when further water quality characterization is needed to address the issue.

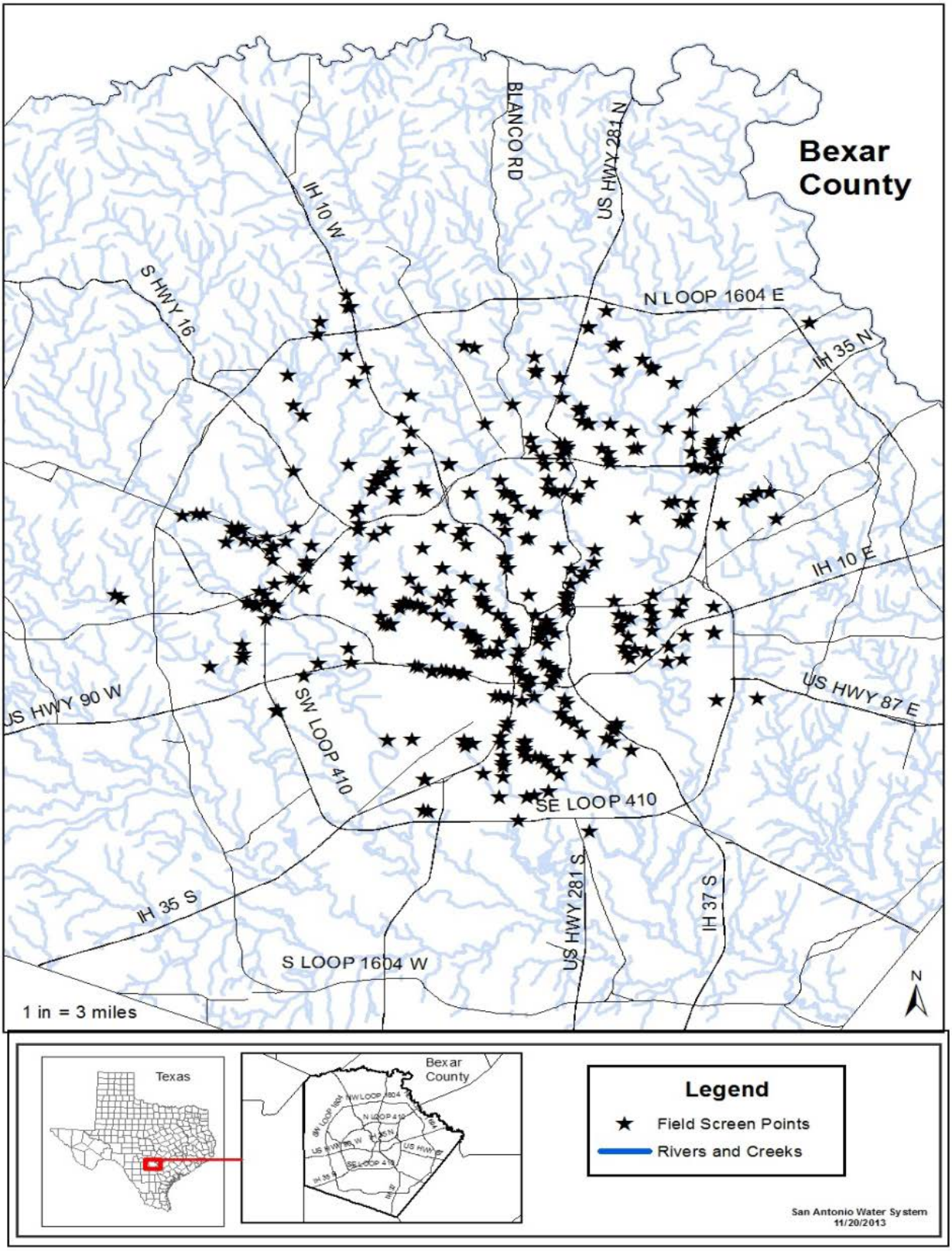

Figure 6. Map of SAWS FSP locations.

Illicit Discharge Investigations

Illicit discharge investigations are done by SAWS staff to investigate complaints on an individual basis. The complaint can include industrial type discharges, noncompliant construction sites, accidental discharges, as well as discharges from other individual private properties. In addition, SAWS staff can provide technical assistance (sampling, spill containment, field measurements), to assist various agencies such as the San Antonio Fire Department or CoSA Transportation and Capital Improvements, in the event of a spill or hazardous material situation.

Responsible Parties: SAWS, CoSA, TxDOT

Timeline: Long Term, On-going

Annually CoSA submits a report to TCEQ outlining the functions which assist with meeting the MS4 permit requirements. These functions include street sweeping, debris removal from channels and out tunnel facilities, restoration and silt removal from drainage channels, BMP inspection, wet and dry sampling, industrial and high risk inspections, illicit discharge and improper disposal programs, education, and stormwater construction site runoff program.

- **Year 2:** In concurrence with CoSA, SAWS and TxDOT, manage the MS4 permit in compliance with its requirements. As mentioned earlier, the MS4 permit describes numerous tasks and activities that the permittees are required to implement. For the purpose of the I-Plan, only bacteria reduction related activities were listed. Entities will strive to implement the required measures with a consideration of the potential bacteria loading contributions to the impaired waterways and identify BMPs to meet the I-Plan objectives.
- **Year 5:** Continue the same MS4 compliance related and bacteria reduction activities outlined for year 2. An increased focus of identifying bacteria reduction related BMPs will occur with plans to suggest to stakeholders to implement certain BMPs that could ultimately aid in lowering bacteria load contributions to the impaired waterways.

Management Measure 5.
Avian Management for the River Walk and Other Riparian Areas

Within the context of this plan and associated management measures it is important to identify and address potential native and exotic wildlife bacterial load contributors. Native wildlife species (herons, egrets, native waterfowl, bats, etc.) are managed and protected by state and federal laws, are desirable, and provide a natural aesthetic appreciated by the public. Wildlife (exotic waterfowl) are not protected by state or federal laws and are considered a detriment to the natural ecosystem.

Wild birds such as ducks, geese, egrets, and pigeons are a source of nonpoint source bacteria loads. However, the complete exclusion of these animals is unrealistic and undesirable. Instead, limited actions can be taken at key locations to reduce the number of birds present.

Native and Exotic Waterfowl

Waterfowl populations (ducks and geese) have taken advantage of urban fragmented habitats, human feeding, and human refuse along the urban watersheds. Many waterfowl are descendants of domestic stock or have lost natural behaviors. These waterfowl do not migrate and remain within the urban watersheds year round.

CoSA has hired falconers to routinely fly a bird of prey in the vicinity of known nesting areas during peak nesting periods in order to deter birds from nesting and roosting in those locations. Lasers are also used as a method to reduce the nesting of grackles along the River Walk. These BMPs will also reduce nonpoint bacteria source loads because birds often deposit fecal material directly into the river.

CoSA encourages visitors to refrain from feeding the wildlife on the river. Accompanying signage at the River Walk and City Parks that front the San Antonio River, including Brackenridge Park and Roosevelt Park, helps to relay this message. The River Walk Watershed Alliance (RWWA) website also has helpful information about feeding wildlife.

Egret and Heron Rookeries

Texas is a major route for migratory birds and serves as a breeding site for egrets and herons. During nesting season, most egrets and herons gather in large colonies to nest (rookeries). Rookeries can consist of dozens or even hundreds of nesting birds in a concentrated area and can include 2-5 species of egrets and herons. The cattle egret, little blue heron, snowy egret, great egret, and yellow crowned night herons are the most common species found in a rookery. Concentrated fecal matter can lead to water quality concerns when rookeries are associated with streams and rivers.

Egrets and herons are protected by state and federal laws. Under the Migratory Bird Treaty Act, it is illegal to kill or harass the birds in any way that would cause nest abandonment or the death of eggs or hatchlings. Nesting season starts when the first egg is laid in the nest. Up to that point, it is legal to deter birds from an area where a rookery is not desirable. Once the first bird lays an egg, all harassment and scare techniques must stop.

The best way to prevent the establishment of an urban rookery is through public awareness and early detection. When birds first arrive in the spring, they are somewhat nervous and more easily scared away. Scaring devices can be used to deter the birds. These techniques must not injure or kill the birds. CoSA has applied for and been granted a permit from the United States Fish and Wildlife Service to eradicate 10 to 15 egrets along the River Walk Loop area above several restaurants. This work is scheduled annually in the fall months.

Modifying the habitat around water bodies can also help to minimize the attractiveness of the area to waterfowl. Vegetation in the watershed can be managed to minimize the attractiveness of the habitat to wildlife. In the winter months, creating openings within the canopy and removing overlapping branches makes the area less desirable for the birds and can deter rookeries from returning to previous locations. Other available techniques include turf maintenance and planting of agricultural species that do not provide food for migrating birds and other species. However, these methods can have adverse aesthetic impacts that may not be desirable. It is also uncertain how effective these habitat modification methods might be when buildings are available as alternative locations in which birds may roost.

Another technique that has been used at both airports and landfills for controlling nuisance avian fauna is the use of one or more falconers. This action would be well served by a public

awareness program explaining the purpose of the efforts to address the potential native and exotic wildlife bacterial load contributions. Other bird deterrent practices, such as the removal of bird nesting locations and the use of lasers, have been considered.

Because birds and other wildlife may deposit fecal material on the land's surface as well as the river, these BMPs are also expected to reduce stormwater runoff loads.

Responsible Party: CoSA Center City Development & Operations Department (CCDO)

Timeline: Long Term, Ongoing

Measurable Milestones
Years 2-5:

A falconer is used 6 months of the year and a laser device is used for the other six months to reduce the grackle population in the downtown area. It is difficult to measure the reduction of birds and wastes as a result of the implementation of this BMP, however, this management measure will continue to be utilized. There will also be a continued effort through public awareness and early detection to aid in the reduction of avian load contributions.

Management Measure 6.
Expansion of Pooper Scooper Program

Pet waste deposited on the yard, sidewalk, or gutter, can easily end up in the storm drain, and eventually enter into local waterways. Many people do not realize the harm that the careless disposal of pet wastes may have on water quality. However, despite their apparent inconsequence, pet wastes can be a major source of nutrients and bacteria in urban streams.

While most localities have some form of pet waste ordinance, many put little effort into enforcement (EPA, 2004). CoSA has expanded the Pooper Scooper Program enforcement and public outreach (see below) which are vital elements that complement the rules outlined in the ordinance. This element is used in conjunction with the Pooper Scooper Program that involves public outreach, signage, and the placement of stations for pet waste pick-up and disposal.

Local Ordinances

Local ordinances can be used to require that pet owners pick up after their pets and then dispose of the pet waste correctly. CoSA already has such an ordinance in place. Section 5-19 of the San Antonio City Code (2006) requires that

> "*an animal owner or keeper shall not walk his/her animals without a leash restraint, and shall not guide or take animals onto the yards or driveways of property not owned, leased or occupied by the animal owner for the purpose of allowing the animal to defecate, but shall keep his/her animal in the public right-of-way, and shall carry a container and scooper for the sanitary removal of his/her animal's fecal matter from the public sidewalk and public right-of-way adjacent to any property with a structure or other improvements thereon.*"

With regard to disposal of the waste, the ordinance states that "animal owners shall collect and dispose of animal waste by flushing it down a commode, by burial at least six inches below the surface of the ground, or by placing it in a disposable container, sealing the container, and disposing of it as household garbage." Violation of this ordinance is considered to be a health and safety related misdemeanor crime, and is punishable by a fine of up to $2,000. Clearly, to be fully effective such ordinances must be enforced.

Pooper Scooper Program

The Pooper Scooper Program uses a combination of public outreach and provision of pet waste pick-up materials to encourage owners to pick up after their pets. This kind of pet waste reduction program can result in fewer bacteria from domestic pets finding its way into the City's waterways and storm drains. Multiple vendors supply pet waste pick-up products. Currently, the City Parks and Recreation Department (PRD) uses Mutt Mitts.

Mutt Mitts <www.pickupmitts.com/muttmitt> are double-ply, degradable, mitten-like plastic bags that can be used to pick up pet waste. As well as the mitts, the manufacturer also sells dispensers that can be pole- or wall-mounted in public places, along with signs encouraging pet owners to use them to pick up after their pets (Figure 7). Mutt Mitt dispensers were first installed by the PRD in McAllister Park in 2002 using funds from a TCEQ grant. To date, the PRD has installed 161 dispensers in 75 public parks and more are likely to be added, though there is no fixed schedule for the expansion of this program.

The capital cost for each Mutt Mitt dispenser is approximately $62, with optional accompanying waste cans costing $160 each, and signs costing $30 each. While signs in parks can have a higher cost than other printed outreach materials, they can last for many years and can also be more effective as they act as on-site reminders to dog owners to clean up after their pets.

There is additional labor cost for installation of these items, which is performed by PRD staff. PRD maintenance personnel replenish dispensers as part of their regular duties while they are emptying trash cans around the City parks. Refill cases of Mutt Mitts, each containing 2000 bags, cost approximately $77.76 per case. The City expects to use over 350 cases during fiscal year 2014, at a total cost of over $21,700.

Figure 7. Pooper Scooper Dispenser and Signage.

Dog Parks

Dog parks provide enclosed areas where owners can let their pets run off-leash and typically include signage reminding the owners to remove waste. In addition to providing a public amenity, these dog parks also help to transfer the conscientious behavior of responsible pet owners who pick up after their pets to less conscientious owners, which, in turn, helps to establish a social norm (EPA, 2004). These parks can be designed to further mitigate stormwater impacts. For example, using vegetated buffers, pooper scooper stations, and siting away from drainage-ways, streams, and steep slopes will help to minimize impacts.

There are currently five dog parks in San Antonio. The first one was opened in June 2004, and is located in Pearsall Park <www.sanantonio.gov/sapar/dogpark.asp>. Seventy-five out of 230 city parks are participating in the Pooper Scooper Program.

Responsible Party: CoSA PRD

Timeline: On-going

Measurable Milestones

Contingent upon the receipt of proposed project funding, the measureable milestones are as follows.

CoSA will continue installing pet stations to allow citizens to pick-up after their pet with future development of linear creekway trail projects. CoSA is also increasing community outreach to educate citizens about the importance of picking up their animal's waste.

Year 2:

- CoSA has installed Mutt Mitt Stations along 46 miles of linear creekways. Approximately 14.4 miles of creekways are anticipated to be constructed during this two year period. CoSA will continue the installation of Mutt Mitt Stations along these future linear creekway trail projects. This management measure will also be further enhanced through education at many events that are provided within the community and planned for the coming years.

Year 5:

- Continue installation of Mutt Mitt Stations with future linear creekway trail projects and community outreach, depending on budget approval.

Management Measure 7. Increase Awareness and Enforcement of Pet Control Ordinance

In conjunction with the other programs, public education and outreach has been used to expand the Pooper Scooper Program resulting in the increase of the public awareness of the issue. While passing local ordinances and setting up pooper scooper programs provide the opportunity for people to be "good citizens," public education campaigns help to inform pet

owners about the importance of cleaning up after their pets. Many communities implement pet waste management programs by posting signs in parks or other pet-frequented areas, by mass mailings, and by broadcasting public service announcements. Some develop brochures that instruct pet owners about the proper disposal of pet waste or that describe the problems associated with pet waste and how to properly dispose of it.

Sign posting is one of the most common outreach strategies. Signs can designate areas where dog walking is prohibited, where waste must be recovered, or where dogs can roam freely. Many communities post neighborhood signs that ask pet owners to "Curb Your Dog." The rationale behind this request is that dogs walked along the curb are more likely to defecate on the road, where the waste can be captured by street sweeping. However, waste deposited in the road is also more likely to be washed down storm drains so this tactic has limited usefulness.

Responsible Party: CoSA ACS Department

Timeline: On-going

Measurable Milestones

Contingent upon the receipt of proposed project funding the measureable milestones are:

CoSA ACS Department provides outreach and education to the citizens on various topics such as vaccination and spay and neutering programs. CoSA TCI also provides education on pet waste and its hazards.

Year 2:

- Continue education and outreach programs. This goal will be measured by the services determined to be impactful to the community, based on ACS Department performance measures and funding.

Year 5:

- Continue education and outreach programs. This goal will be measured by the services determined to be impactful to the community, based on ACS Department performance measures and funding.

Management Measure 8.
BMP Assessment, Pilot Studies and Mission Drive-In Redevelopment

SARA and CoSA are currently planning and implementing many new projects aimed at enhancing understanding of watershed sustainability locally, elevating the profile of watershed sustainability in the community, and improving the quality of stormwater flowing off of agency property.

Sustainability-focused projects to be conducted by SARA which began in 2012 include:

- A stormwater audit of SARA's facilities was completed in January 2012 and is available on SARA's website.
- A rain garden project at SARA's Environmental Center was completed in the spring of 2014. In addition to the rain garden, a series of educational videos and website materials are in development.
- An erosion control project at SARA's Environmental Center will use the triple bottom line approach (which provides an objective matrix by which sustainable initiatives can be evaluated using the three criteria areas of economics, environment, and quality of life) to determine the best BMP to install to reduce erosion.
- A stormwater improvement project at SARA's main office utilizing low impact design techniques. Stormwater monitoring is currently being done, to help determine which type of low impact design should be used at this site to reduce pollutants entering the river.
- SARA completed a new maintenance facility in November 2014. This building utilizes low impact design techniques such as tree wells, rainwater harvesting and vegetative strips. It is anticipated that the building will be Leadership in Energy and Environmental Design (LEED) certified.
- Sustainability training sponsored by SARA has been completed for both in-house and external audiences. SARA continues to support subsistence education through their website and presentations to the community. The SARA organized a LID Competition

in partnership with the San Antonio Land/Water Sustainability Forum with the winners announced July 10, 2013, to promote LID throughout the larger San Antonio community.

Stormwater capital projects to be conducted by CoSA include:

- Mission Drive-In LID project:
  - SARA in partnership with CoSA is monitoring two stormwater sites at the Mission Drive-In LID project. One site monitors runoff from a series of rain gardens installed on the Mission Drive-In Library grounds. The other site samples stormwater runoff from a grass swale and permeable pavement parking lot. There is another sample site near the Mission Drive-In Library which is a control site (non-LID) that monitors the runoff from the Pan American Branch Library.
- Hausman Road and Ray Ellison Drive LID components:
  - SARA in partnership with CoSA is monitoring sites at both Hausman Road and Ray Ellison Drive prior to the installation of LID components. Once the LID components are installed, it is anticipated that post construction monitoring will occur.
- Hemisfair Park LID components:
  - SARA in partnership with CoSA is monitoring two sites at Hemisfair Park prior to the installation of LID components. Once the LID components are installed, it is anticipated that post construction monitoring will occur.

Responsible Party: SARA & CoSA TCI

Timeline: On-going

Measurable Milestones

Year 2:

- CoSA is responsible for on-going operations and maintenance at the Mission Drive-In project.

- SARA will complete monitoring on Mission Drive-In Library.
- SARA will complete the erosion control project at SARA's Environmental Center.
- SARA will complete the rain garden educational videos and educational website.
- LEEDs certification for SARA's new maintenance facility.
- SARA will complete pre-construction monitoring on Hausman Road, Ray Ellison Drive, and at Hemisfair Park.

Year 5:

- CoSA is responsible for on-going operations and maintenance at the Mission Drive-In project.
- SARA will complete the stormwater improvement project at SARA's main office.
- SARA will complete post-construction monitoring on Hausman Road, Ray Ellison Drive and at Hemisfair Park.

Management Measure 9. Feral Hog Management

In the rural areas of the San Antonio River watershed, feral hogs are abundant. Their wallow areas are evident along the San Antonio River and its tributaries. Statewide, control of feral hog populations is a challenging topic. The potential bacteria loading from this specific source has not been quantified.

Feral hogs have been identified as significant contributors of pollutants to water bodies across Texas. As feral hogs congregate around water sources to drink and wallow, this concentration of high numbers of feral hogs in small riparian areas poses a threat to water quality. Fecal matter deposited directly in streams by feral hogs contributes bacteria and nutrients, polluting the state's water bodies. In addition, extensive rooting activities of groups of feral hogs can cause extreme erosion and soil loss. The destructive habits of feral hogs cause an estimated $52 million worth of agricultural crop and property damage each year in Texas. Stakeholders in watersheds across the state, including the Upper San Antonio River, have recommended that efforts to control feral hogs be undertaken to reduce the

population, limit the spread of these animals, and minimize their effects on water quality and the surrounding environment.

Texas Wildlife Services, through cooperative agreements between Texas A&M AgriLife Extension Service and the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service, provides statewide leadership in the science, education, and practice of wildlife and invasive species (feral hogs) management to protect the state's agricultural, industrial and natural resources, as well as the public's health, safety, and property (Texas Health and Safety Code Chapter 825).

Prevention and management of wildlife conflicts is an essential and responsible part of wildlife management. The complex wildlife-damage management environment includes a combination of biological, legal, socio-political, financial, and technical considerations. Texas Wildlife Services accomplishes this through cooperation with federal, state, and private entities, servicing both rural and urban areas, utilizing technical assistance and direct control services in this specialized field of wildlife management.

Texas Wildlife Services has always been available to provide assistance with addressing feral hogs and will remain available to all citizens of the state. While direct control will be limited to availability of personnel in cooperative association areas, technical assistance can be provided to individuals on how to best resolve feral hog problems. Since 2008, the Texas Department of Agriculture has awarded grants (state general revenue) to Texas Wildlife Services for feral hog abatement programs where control efforts can be measured. Certain areas of the state have been targeted due to the contributions from feral hogs to impaired water quality and bacteria loading.

Responsible Parties: Landowners, Texas Wildlife Services, Texas A&M AgriLife Extension, and Texas State Soil and Water Conservation Board (TSSWCB)

Timeline: Ongoing

Measurable Milestones

Contingent upon the receipt of proposed project funding, the measureable milestones are as follows.

Year 2:

- Host feral hog workshops in the watershed - Texas A&M AgriLife Extension, TSSWCB, SARA.
- Promote feral hog abatement activities in different stakeholder meetings in the watershed – TSSWCB, SARA.

Year 5:

- Host feral hog workshops in the watershed - Texas A&M AgriLife Extension, TSSWCB, SARA.
- Promote feral hog abatement activities in different stakeholder meetings in the watershed – TSSWCB, SARA.

Management Measure 10. Livestock Management

In the rural portions of the watershed, livestock are a potential contributor of fecal bacteria loadings. Fecal material produced by livestock can enter surface waters through several pathways, including: wash-off of waste deposited on the land surface, direct deposition of waste material in the stream, and potential runoff from animal feeding operations. In the San Antonio River watershed, the majority of livestock populations are grazing animals rather than animals in confined feeding operations.

For grazing livestock, waste material is deposited directly on the ground surface. Management measures would generally consist of maintenance of adequate grass cover that would serve to reduce runoff velocities and provide some treatment of runoff waters.

The purpose of this management measure is for the stakeholders to explore a range of existing nonprofit and governmental (local, regional, state, and federal) programs that will work with landowners to accomplish the overall goal of protecting priority areas within the watershed. The programs for consideration are described below.

Texas State Soil and Water Conservation Board

The TSSWCB is the lead agency in Texas responsible for planning, implementing, and managing programs and practices for preventing and abating agricultural and silvicultural (forestry-related) nonpoint source pollution (Texas Agriculture Code Section 201.026). In accordance with this responsibility, the TSSWCB administers a certified Water Quality Management Plan (WQMP) Program that provides, through local SWCDs, for the development, implementation, and monitoring of individual WQMPs for agricultural and silvicultural lands. Each WQMP is developed, maintained, and implemented under rules and criteria adopted by the TSSWCB. A WQMP achieves a level of pollution prevention or abatement consistent with the state's water quality standards.

A WQMP is a site-specific plan designed to assist landowners in managing NPS pollution from agricultural and silvicultural activities. WQMPs are traditional conservation plans based on the criteria outlined in the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) Field Office Technical Guide (FOTG). The FOTG is the best available technology and is tailored to meet local needs.

A WQMP includes appropriate land treatment practices, production practices, management measures, technologies, or combinations thereof. WQMPs are developed in cooperation with the landowner with assistance from the NRCS and approved by the local SWCD. The WQMPs are certified by the TSSWCB. This approach to preventing and abating NPS pollution uses a voluntary approach while affording the landowner a mechanism for compliance with the state's water quality standards.

The TSSWCB regularly performs status reviews on WQMPs to ensure that the producer is implementing the measures prescribed in the WQMP. The TSSWCB administers technical and cost-share assistance programs to assist producers in implementing their WQMPs. The TSSWCB utilizes both state general revenue and federal grants to fund the WQPM Program. Several essential practices from the NRCS FOTG included in a WQMP are of specific applicability to the bacteria reduction goals of this TMDL and I-Plan. A grazing management system is a vital component of a WQMP for livestock operations.

Grazing management examines the intensity, frequency, duration and season of grazing to promote ecologically and economically stable relationships between livestock and forage

species. The distribution of grazing animals is managed to maintain adequate and desired vegetative cover, including on sensitive areas like riparian corridors. Livestock distribution is managed through cross-fencing, alternate water sources, supplemental feed placement, and shade or cover manipulation. The expected forage quality, quantity, and species are analyzed to plan for an appropriate forage-animal balance. Grazing management systems plan for contingencies such as severe drought, wildfires, or flooding in order to protect the resource, protect grazing animals, and reduce economic risk.

The TSSWCB, in collaboration with NRCS and the Alamo SWCD #330 and the Wilson County SWCD #301, will continue to provide technical assistance to landowners in developing and implementing WQMPs. TSSWCB will develop WQMPs on livestock operations in the Upper San Antonio River watershed who request planning assistance through the SWCD. TSSWCB will annually perform status reviews on WQMPs in the Upper San Antonio River watershed. Currently, there are six certified WQMPs in the watershed, with practices that cover grazing management. All of these plans are located within the Wilson County SWCD.

Since the beginning of the TSSWCB WQMP Program in 1995, cost-share (state general revenue) has been allocated to SWCDs in priority areas across the state and obligated by the SWCDs to individual producers. In 2013, the TSSWCB updated the WQMP priority areas across the state to be consistent with water bodies that appear on the CWA Section 303(d) List and could potentially have pollution sources from various agricultural or silvicultural practices. The Alamo SWCD #330 and the Wilson County SWCD #301 are both priority SWCDs, and are eligible for state general revenue funding to implement WQMPs. Requests for financial assistance are subject to priority ranking and are not guaranteed funding through the program.

Soil and Water Conservation Districts

A SWCD, like a county or school district, is a subdivision of state government. SWCDs are administered by a board of five directors who are elected by their fellow landowners. There are 216 individual SWCDs organized in Texas. Through decades old agreements, SWCDs offer agricultural landowners and operators technical assistance through a partnership with the NRCS and the TSSWCB. Through this conservation partnership, local SWCDs furnish

technical assistance to farmers and ranchers in the preparation of a complete soil and water conservation plan to meet each land unit's specific capabilities and needs. The Upper San Antonio River watershed encompasses portions of the Alamo SWCD #330 and Wilson County SWCD #301.

U.S. Department of Agriculture Natural Resources Conservation Service

The NRCS is a federal agency that works hand-in-hand with Texans to improve and protect their soil, water and other natural resources. For decades, private landowners have voluntarily worked with NRCS specialists to prevent erosion, improve water quality, and promote sustainable agriculture. The NRCS provides conservation planning and technical assistance to landowners, groups, and units of government to develop and implement conservation plans that protect, conserve, and enhance their natural resources. When providing assistance, NRCS focuses on the sound use and management of soil, water, air, plant, and animal resources. NRCS ensures sustainability, allows for productivity, and respects the customers' needs. Conservation planning can make improvements to livestock operations, crop production, soil quality, water quality, and pastureland, forestland, and wildlife habitats. The NRCS also integrates ecological and economic considerations in order to address private and public concerns.

The NRCS administers numerous Farm Bill programs authorized by the U.S. Congress that provide financial assistance for many conservation activities:

- Conservation Innovation Grants
- Conservation Stewardship Program
- Environmental Quality Incentives Program
- Regional Conservation Partnership Program
- Agricultural Conservation Easement Program
- Conservation Reserve Program administered by USDA Farm Service Agency

The Environmental Quality Incentives Program (EQIP) and other programs were reauthorized in the federal Agricultural Act of 2014 (Farm Bill) to provide a voluntary

conservation program for farmers and ranchers that promotes agricultural production and environmental quality as compatible national goals. People who are engaged in livestock or agricultural production on eligible land may participate in EQIP. EQIP offers financial and technical assistance to eligible participants for installation or implementation of structural and management practices on eligible agricultural land.

EQIP also provides incentive and cost-share payments to implement conservation practices. EQIP activities are carried out according to a plan of operations developed in conjunction with the producer that identifies the appropriate conservation practice(s) to address resource concerns. All practices are subject to NRCS technical standards described in the FOTG and adapted for local conditions. The local SWCD approves the plan.

Local Work Groups provide recommendations to NRCS on allocating EQIP county base funds and on resource concerns for other USDA Farm Bill programs. Upper San Antonio River stakeholders are encouraged to participate in the Local Work Group in order to promote the goals of this management measure as compatible with the resource concerns and conservation priorities for EQIP.

Texas A&M AgriLife Extension Service

AgriLife Extension, an agency of The Texas A&M University System, provides quality, relevant, outreach and continuing education programs and services to Texans. AgriLife Extension serves every county in Texas; its information is provided by scientists and researchers at Texas A&M and other universities, and is made practical and relevant by Extension educators or agents who work in each county. AgriLife Extension continually assesses and responds to educational needs identified by community residents, advisory committee members, volunteers, stakeholder groups, and representatives of organizations and agencies. Extension education encompasses the broad areas of agriculture and natural resources, community economic development, family and consumer sciences, and youth development programs such as 4-H.

Among other goals and priority objectives pursued by AgriLife Extension, the following relate to agriculture and natural resources:

- Consumers, homeowners, agricultural producers, communities, and irrigation districts understand and adopt BMPs to protect water quality and enhance conservation so water supplies will meet future water needs in Texas that are essential for expanding agricultural growth, jobs, and the economy in both rural and urban areas.

- Landowners, professional ecosystem managers, community planners, and other interest groups become more knowledgeable, make informed decisions, and adopt BMPs that ensure the proper management of rural and urban natural ecosystem resources through stewardship education in order to support the biological, sociological, and economic sustain-ability of those resources.

- Advance the planning and management of natural resource-based recreation opportunities in Texas.

Lone Star Healthy Streams (LSHS) was developed by AgriLife Extension with support from the Texas Water Resources Institute and funding from the TSSWCB through a CWA Section 319(h) nonpoint source grants. The primary goal of the program is to protect Texas waterways from bacterial contamination originating from livestock operations and feral hogs that may pose a serious health risk to Texas citizens. To achieve this important goal, the program's objective is the education of Texas farmers, ranchers, and landowners about proper grazing, feral hog management, and riparian area protection to reduce the levels of bacterial contamination in streams and rivers. Program resources include a manual and a series of species-specific publications focused on management and control of NPS pollution <http://lshs.tamu.edu/publications/>. The program is delivered as face-to-face training events, and through an on-line course <http://campus.extension.org/course/ view.php?id=728/>. The curriculum promotes the adoption of BMPs and participation in federal and state cost-share programs and should be delivered in these watersheds. Recommended BMPs for livestock can be found at <http://lshs.tamu.edu/bmps/>.

In concert with curriculum development, AgriLife Extension has evaluated the effectiveness of selected BMPs in reducing bacteria loading from grazing cattle to streams. BMPs evaluated include grazing management, shade, fencing, alternative water source development, riparian buffers, and combinations thereof. Results to date show significant

impacts to animal behavior and subsequent fecal loading thus substantiating the use of these practices to mitigate pollutant loading.

The LSHS program also addresses feral hogs with a specific manual on management and control <http://lshs.tamu.edu/media/340450/feral_hogs.pdf>. In addition, AgriLife Extension has produced a comprehensive series of 11 publications addressing management strategies and techniques for feral hog control, and an on-line feral hog activity reporting system to support identification of target areas for implementation of feral hog control activities. This program is currently available to watersheds impacted by feral hogs, including the Upper San Antonio River.

The intent of these programs is for the agencies listed under Management Measure #10 to work with landowners to voluntarily reduce NPS pollution. Technical assistance to agricultural producers in developing WQMPs provided through the TSSWCB WQMP Program is funded through state general revenue. It is not anticipated that any new sources of funding will be required to implement this management measure; however, this is dependent on continued appropriations from the Texas Legislature.

TSSWCB and NRCS will continue to provide appropriate levels of cost-share assistance to agricultural producers that will facilitate the implementation of BMPs and WQMPs in the watershed, as described in this management measure. Historically, WQMP development and implementation in this watershed has been low; as such, it is anticipated that current funding levels available in the watershed may be sufficient to meet implementation needs.

NRCS expects that existing levels of financial assistance available through multiple Farm Bill programs may be sufficient, depending on continued appropriations from the U.S. Congress, to satisfy demand and need in the watershed.

Responsible Party: TSSWCB, Alamo SWCD #330, Wilson County SWCD #301, NRCS, Texas A&M AgriLife Extension

Timeline: On-going

Measurable Milestones

Contingent upon the receipt of proposed project funding, the measureable milestones are as follows.

Year 2:

- Promote programs that help implement BMPs for grazing livestock –TSSWCB, Alamo SWCD, Wilson County SWCD, NRCS, and SARA.
- Develop WQMPs on livestock operations in the watershed - TSSWCB, Alamo SWCD, Wilson County SWCD, NRCS, and SARA.
- Perform annual status reviews on existing WQMPs in the watershed – TSSWCB, Alamo SWCD, and Wilson SWCD.

Year 5:

- Promote programs that help implement BMPs for grazing livestock - TSSWCB, Alamo SWCD, Wilson County SWCD, NRCS, and SARA.
- Develop WQMPs on livestock operations in the watershed - TSSWCB, Alamo SWCD, Wilson County SWCD, and NRCS.
- Perform annual status reviews on existing WQMPs in the watershed - TSSWCB, Alamo SWCD, and Wilson SWCD.

Management Measure 11. Inspection of New Construction Sites

Bexar County has started inspecting construction sites under the Federal Phase II Storm-water regulations. Required by the CWA, stormwater discharges from “small” MS4s must be covered by a discharge permit. Bexar County originally obtained Phase II MS4 coverage in June 2009 (TXR040031) and renewed coverage in October 2014. MS4s are defined as any conveyance including roads with bar ditches owned by a political subdivision.

Part of the MS4 Permit requires Bexar County to maintain an acceptable erosion and sedi-ment control program. Construction sites lacking adequate stormwater controls can

contribute significant amounts of sediment to streams and rivers. To reduce the water quality impacts of active construction sites, regulations require that many construction projects install and maintain appropriate erosion and sediment control, stormwater management, and housekeeping BMPs. In addition, the regulations require many municipalities to implement programs to control runoff from construction sites. These regulations include reviewing construction plans, conducting site inspections, and enforcing control measures necessary to minimize water quality impacts. Bexar County now inspects construction sites to make sure they are adhering to the appropriate rules. Bexar County regulates outside of CoSA's and SAWS' geographic zones of jurisdiction, in the unincorporated areas of Bexar County. Bexar County as part of the MS4 permit has a construction inspection and permitting regulation that requires issuance of a Stormwater Site Development Permit prior to any land disturbing activity of 1 acre or more.

Bexar County Stormwater Inspectors are assigned sections and are responsible for inspecting all permits within their section. Bexar County has implemented a Stormwater Quality Court Order, identified in the Bexar County Regulations For Stormwater Pollution Prevention document Section 6.0 (Texas Local Government Code Section 423.002(a)(5)) which gives Bexar County the authority to write Notices of Violations.

Responsible Party: Bexar County

Timeline: On-going

Measurable Milestones

Year 2:

- Ensure that all construction sites over 1 acre are permitted.
- Inspect all permitted construction sites at regular intervals.

Year 5:

- Ensure that all construction sites over 1 acre are permitted.
- Inspect all permitted construction sites at regular intervals.

Management Measure 12.
Evaluate Restoration of Westside Creeks

The Westside Creeks Restoration Project is a community-based planning effort initiated in 2008 by SARA. Its mission is to 1) develop concepts for restoring the environmental condition of the Alazán, Apache, Martínez, and San Pedro Creeks; 2) maintain the current flood control components of these creeks; and 3) provide increased opportunities for people to enjoy these urban creeks.

The project focuses on restoring the creeks in such a way that keeps with and enhances the rich historical and cultural background of the community. The project seeks to incorporate key historical cultural features into the design of the project in order to reflect the community and frame the project.

Elmendorf Lake, situated along Apache Creek, is a tributary to the Upper San Antonio River watershed (Segment 1911). A July 2012 study on Elmendorf Lake concluded the primary water quality concerns for the lake are DO concentrations during certain seasons or rainfall events, *E. coli* concentrations above the State water quality standard for contact recreation, and sediment accumulation in the lake leading to reports of high turbidity during rain events which exacerbate anoxic conditions. Bexar County and CoSA are funding BMP improvements to the lake and surrounding park land. Improvements include rain gardens, bio-retention swales, a constructed wetland, and lake aeration. The improvements design and construction will be managed by SARA.

Responsible Party: SARA, City of San Antonio, and Bexar County

Timeline: On-going

Measurable Milestones

Year 2:

- Elmendorf Lake Park improvements (Apache Creek) – Construction is anticipated to be completed by February 2016. Improvements include:
    - Rain gardens – Filters runoff from adjacent streets and park parking lots.

- Bio-Retention Swales – Intercept runoff from adjacent streets and park parking lots.
- Constructed Wetland – Capture water from adjacent site.
- Lake Aeration – Increase oxygen levels in the lake.
- Post construction BMP monitoring – SARA.

Construction will be managed by SARA. Maintenance of these improvements will be managed by the CoSA.

Management Measure 13. Mission Reach Ecosystem Restoration and Recreation Project

The San Antonio River Improvements Project (SARIP) is a $384.1 million investment by CoSA, Bexar County, SARA, the U.S. Corps of Engineers, and the San Antonio River Foundation in flood control, amenities, ecosystem restoration, and recreational improvements along 13 miles of the San Antonio River. SARIP is comprised of four distinctive reaches: The Museum Reach, a four-mile segment of the river from Hildebrand Avenue south to Lexington Avenue; the Downtown Reach, a segment of the original River Walk from Lexington Avenue to South Alamo Street; the Eagleland Reach, a one-mile segment from South Alamo Street to Lonestar Boulevard; and the Mission Reach, an eight-mile section of the river extending from Lonestar Boulevard south to Loop 410 South. Throughout the project, SARA will provide project and technical management, as well as overall project coordination between the project partners. SARA will also conduct on-going operations and maintenance activities along the Museum Reach – Urban Segment, Eagleland, and Mission Reach sections of the River Walk when the project is completed. The City will continue operations and maintenance activities along the Museum Reach – Park Segment and the Downtown Reach.

The Mission Reach Ecosystem Restoration and Recreation Project will increase the quality, quantity, and diversity of plants and animals (flora and fauna) along the eight-miles of the San Antonio River Mission Reach area. The ecosystem restoration process will be accomplished over several years through many steps including construction on the river to reconfigure the channel and create improved aquatic habitat, which concluded in October

2013, and reestablishing hundreds of acres of native grasses, wildflowers, trees, and shrubs. It will take approximately 50 years for the entire ecosystem restoration process to be completed. The Mission Reach project restores two types of habitats: riparian woodland habitat and aquatic habitat. The culmination of these steps will result in the transformation of the river into a more natural state. The Mission Reach project includes the restoration of approximately 334 acres of riparian woodland habitat planted with over 10,000 pounds of native grasses and wildflower seeds of over 60 different species. It is anticipated that over 23,000 native trees and shrubs, of over 40 different species, will be reestablished over time. Native plants will be used on the Mission Reach not only for their beauty, but also because they play a crucial role in ecosystem restoration. They do this in several ways. First, native plants provide food and habitat for native wildlife, which will lead to increased wildlife diversity in the area. Many native plants have long root systems that hold soil in place which helps to control erosion on the banks of the river. Additionally, native plants aid in improving water quality by filtering out stormwater runoff before it enters the river.

A healthy river contains a variety of aquatic features that combine to create a healthy habitat for the fish, insect and plant species that inhabit the river. The Mission Reach project will restore approximately 113 acres of aquatic habitat. This includes the creation of riffle-run-pool sequences and approximately 13 acres of embayment (wetland) habitat in the river. Improvements along the Mission Reach will focus on ecosystem restoration using a technique known as fluvial geomorphology, which is the study of the processes and pressures operating on river systems. This technique will transform the straightened river by adding sinuosity where possible while maintaining flood control, reducing erosion, re-introducing native aquatic vegetation and creating an environment more suitable for recreation and wildlife.

Along the Eagleland and Mission Reach sections of the River Walk, SARA has had an internal goal since 2010 to clean up significant floatable debris within 14 days following a river level rise. SARA conducts this work with its own staff as well as with the occasional assistance of contractors. Tons of trash have been collected from the river since this goal was instituted. For example, from July 2013 to June 2014, it is estimated that SARA staff removed a total of 22.6 tons of trash on Mission Reach and an additional estimated 21.7 tons

of trash was removed by SARA contractors. This work will not be listed as a measurable milestone because it is on-going following each river level rise.

However, to better address floatables, SARA has already conducted its "Trash and Floatables Best Management Practice Study" with the assistance of HDR Engineering. The study helped to identify the sub-watersheds that drain into the Mission Reach area and the potential sources of trash and floatables associated with those sub-watersheds. Recommendations were made by the study for collections systems to be installed at major stormwater outfalls and tributaries to capture trash and floatables during rain events. Efforts are underway to implement the study recommendations where feasible.

Additionally, SARA completed a mapping project in coordination with the City to identify all the stormwater inlets that drain to the River Walk. This will allow for better identification of sources of trash and contaminates along the project. The project also includes marking each inlet with a tag to discourage citizens from dumping trash, floatables, and other contaminants into the stormwater inlets (Figure 8).

Figure 8. River Walk stormwater inlet tag.

Further public outreach will be required to effectuate positive change and reduce trash, floatables, and bacteria levels along the Mission Reach and other sections of the River Walk. SARA will continue to conduct watershed awareness outreach and education as identified in Management Measure 15. However, specific to the Mission Reach and other sections of the River Walk, SARA has recently opened a dialog with KSAB to jointly promote the KSAB "Adopt a Spot" program to the neighborhoods and communities within the River Walk watershed. The intent of the Adopt-a-Spot program is to provide civic-minded individuals, organizations, and businesses the opportunity to participate in creating a cleaner, more beautiful San Antonio by "adopting" a portion of a city street or several blocks to keep clean. SARA is working with KSAB to target areas that drain to the River Walk to encourage local residents, organizations, and businesses to help keep the streets clean,

which in turn will help keep trash and floatables from entering the river through stormwater outfalls.

The extent to which the River Improvements Project might help to reduce bacteria in the watershed is not quantifiable. However, the addition of wetland habitat to certain storm-water outfalls may help to treat runoff entering the river to some degree. Additionally, some sedimentation might be affected by the riffle structures and weirs constructed along the river as part of the project.

Responsible Party: SARA, Bexar County, and CoSA

Timeline: On-going - Major construction activities have been completed and the project opened to the public in 2013. Vegetation and natural resources management including planting of trees and shrubs is ongoing.

Measurable Milestones

Year 2:

- SARA will provide project and technical management, as well as overall project coordination between the project partners. SARA will also conduct on-going operation and maintenance activities when the project is completed. These activities include planting and maintaining native dominated vegetation cover including grasses, forbs, shrubs, and trees with a goal of achieving at least 50 percent coverage by native vegetation.
- SARA and KSAB will promote the "Adopt a Spot" program and seek to secure at least five Adopt a Spot sponsors in areas that drain to the Mission Reach.

Year 5:

- SARA will provide project and technical management, as well as overall project coordination between the project partners. SARA will also conduct on-going operation and maintenance activities when the project is completed. These activities include planting and maintaining native dominated vegetation cover including grasses, forbs, shrubs, and trees with a goal of achieving at least 70 percent coverage by native vegetation.

- SARA and KSAB will promote the "Adopt a Spot" program and seek to secure at least Adopt a Spot sponsors in areas that drain to the Mission Reach.
- SARA and KSAB will promote the "Adopt a Spot" program and seek to secure at least five Adopt a Spot sponsors in areas that drain to the Museum Reach.
- SARA will implement trash collection systems at outfalls along the Mission Reach as technically feasible and as appropriate funding allows.

Management Measure 14. Environmental Investigators

SARA has created positions called Environmental Investigators whose job is to proactively respond to and follow up on water quality concerns and incidents, illegal dumping activities in the flood plain, and property encroachment violations which include the following:

- Supervises, coordinates, and orchestrates environmental compliance within the San Antonio River basin in order to protect public health, and natural resources and preserve SARA's property rights in accordance with the River Authority's mission, enabling statute, ordinances, and the laws of the State of Texas.
- Identifies activities in the basin adjacent to the rivers, creeks, and waterways that have the potential for adverse environmental impact or that threaten public health and safety. Investigates conditions that may be hazardous to the aquatic ecology of the basin, pose threats to public health and safety, and or infringe on SARA's property rights and or violate SARA ordinances. Coordinates and collaborates with other SARA departments and other agencies on plans and BMPs to remedy pollution, material spills, habitat destruction, property encroachment, permit violations, illegal dumping or discharge; potential and real abuse of the flood plain within the San Antonio River basin and any other environmental issues or violation of SARA ordinances.
- Responds to and follows up on emergency situations regarding the San Antonio River Basin streams. Patrols the San Antonio River Basin in search of all unauthorized activities (as described above). Designs and implements a regular patrol schedule to

ensure maximum coverage of the river basin. Works with other agencies on environmental compliance, flood plain alteration, fish kill, hazardous material spills, and pollution investigations; responds to public complaints.

Responsible Party: SARA

Timeline: On-going, hired first investigator in 2009, and second investigator in 2013. Additional investigators may be hired as needed.

Measurable Milestones

Years 2-5:

Environmental Investigators will continue to investigate activities and conditions in the San Antonio River Basin adjacent to rivers, creeks, and waterways that have the potential for adverse environmental impact or that threaten public health and safety.

Management Measure 15. "Be Watershed Wise" Campaign

SARA has developed an environmental awareness initiative called the "Be Watershed Wise" initiative. It is designed to provide education to the community and inform citizens about ways that they can help protect and preserve the environment of the San Antonio River and its tributaries. The goal is to increase community knowledge of and interest in sustainable watershed solutions. This environmental awareness initiative encourages residents to "Be Watershed Wise" through a series of messages addressing issues such as general watershed education, prevention of illegal dumping and littering, encouraging recycling, reducing the use of plastic bags, picking up pet waste, proper lawn care and vehicle maintenance techniques, and implementation of sustainable land use techniques, such as LID. Since 2008, SARA has used various outreach methods to distribute "Be Watershed Wise" information to the public including, but not limited to: educational outreach; advertisements; promotional materials; Creek Book; production of an award-winning documentary movie about the San Antonio River; and development of a volunteer program called Watershed Wise Warriors. There is also a "Be Watershed Wise" poster available for children to learn simple lessons designed to protect watersheds.

Figure 9. San Antonio River Watershed model.

The "Be Watershed Wise" in-class presentation is an interactive, hands-on lesson that addresses the geography of the river, landforms, watersheds, NPS, and take-home actions that can protect our water resources. SARA's watershed lesson provides in-depth learning and active participation by using a large 4 foot by 2 foot model (Figure 9). This model is a three-dimensional 1:250,000 scale replica of the San Antonio River Watershed representing all of Bexar, Wilson, Karnes, and Goliad Counties (Figure 10) and a significant portion of the other counties that make up the watershed. The lesson activities allow students to simulate rainfall in the watershed by spraying water on the model. By sprinkling colored powder to simulate land-based NPS pollution, students can discover how rain events and stormwater carry pollutants to the waterways. Students evaluate their voluntary actions that can positively and negatively affect the San Antonio River's water quality and the subsequent impact on the San Antonio Bay and estuary system.

Figure 10. Close up of counties from the San Antonio River Watershed model.

The "Be Watershed Wise" lesson can be extended to include a rigorous lesson on measuring the abiotic and biotic factors associated with determining water quality. Studying these abiotic factors, such as DO, nitrates, phosphates, and pH can help students discover that human impact on the river's water quality is measurable in a real-time, highly relevant way. By collecting and identifying biotic factors, such as aquatic insects, students investigate how these abiotic factors play a critical role in supporting eco-systems.

To add to its educational outreach capabilities, SARA recently acquired a unique, one-of-a-kind model to demonstrate how to take a home property and turn it into a beautiful landscape that naturally filters pollutants from stormwater. Citizens can learn from SARA's LID model (Figure 11) by considering their current actions in dealing with stormwater off their home's roofs and driveways and then discovering ways that they can keep rain water where it is naturally meant to stay, which is on their property. This highly interactive and hands-on model works by allowing citizens to simulate rain events on a traditional property, which is often described by turf grasses, raised garden beds, and hard surfaces such as driveways. The model demonstrates that the stormwater flows across these traditional home properties, into the street, and eventually into area waterways. A participant can then

Figure 11. SARA's LID model.

transform the landscape of the model property to feature rain barrels, rain gardens, and pervious driveway surfaces. Once the rainfall is simulated again, citizens can see that the water stays on the property, infiltrating and percolating into the ground. The water gets clean and stays clean, never traveling to the San Antonio River, and with the added benefit that the salvaged water can be used to beautify their homes.

The newest component of this public awareness initiative is the Watershed Wise Warriors (2014). Watershed Wise Warriors serve as community defenders of the flora and fauna, giving their time and energy to advance the sustainability of the watershed. Watershed Wise Warriors will be invited to participate in a variety of activities such as cleanups, ecosystem restoration projects, and watershed education opportunities throughout the San Antonio River Watershed. The watershed education opportunities offered to the Watershed Wise

Warriors will include topics to promote sustainable development and other stormwater related issues, such as how to build a rain garden or how to implement other LID BMPs.

An important component of the new Watershed Wise Warriors program is the creation of the citizen scientist program. SARA aims to gather scientific data on the organisms calling the San Antonio River's riparian area their home. Wildlife species can be a useful indicator of the quality of water and the environment around a river. SARA's citizen science program, within the Watershed Wise Warriors initiative, invites the public to help SARA to learn more about our wildlife along the river with the goals of capturing long-term data on rare sightings, migratory species such as birds and butterflies, pollinators, population dispersal, seasonal emergences, and nonnative species. Additional and highly valuable benefits include public engagement, increased awareness, more eyes on the San Antonio River, and an increased relevant connection between citizens and their water resource.

Responsible Party: SARA

Timeline: On-going - started 2008

Measurable Milestones

Year 2:

- Between years 1 and 2, use the "Be Watershed Wise" initiative and related stormwater educational outreach to cumulatively reach over 30,000 individuals (adults and children) via direct educational outreach.
- By the end of year 2, have over 500 citizens signed up to be Watershed Wise Warriors/Citizen Scientists.
- Conduct a statistically valid public survey and compare results with surveys conducted in 2008, 2012, and 2014, to determine if trends indicate a growing appreciation of the San Antonio River Watershed and knowledge of sustainability issues.
- Offer and promote a training opportunity in association with the Paseo del Rio Association for restaurant operators to train staff on "Don't feed the wildlife" and other water quality BMPs associated with the River Walk area.

Year 5:

- Between years 1 and 5, use the "Be Watershed Wise" initiative and related stormwater educational outreach to cumulatively reach over 75,000 individuals (adults and children) via direct educational outreach.
- By the end of year 5, have over 1,500 citizens signed up to be Watershed Wise Warriors/Citizen Scientists.
- Conduct a statistically valid public survey and compare results with previous surveys to determine if trends indicate a growing appreciation of the San Antonio River Watershed and knowledge of sustainability issues.
- Offer and promote a training opportunity in association with the Paseo del Rio Association for restaurant operators to train staff on "Don't feed the wildlife" and other water quality BMPs associated with the River Walk area.

Management Measure 16. Homeless and Vagrant Population: Cleaning and Control of Brush and Dumping at Encampments

A population of homeless/transients is common in urban areas. The transient population is often encamped under street bridges and other similar areas that provide some amount of shelter from the elements. Another potential source of human waste in the study area could be untreated waste from transients or homeless people. Several encampments were observed at locations in the San Antonio urban area. There is evidence that this transient population is affecting bacteria concentrations in some of the smaller watercourses in the study area.

These individuals do not always have access to centralized plumbing and restroom facilities. They may deposit waste directly into or in close proximity to the area's waterways. This is a plausible source, since bridges along the waterway may provide temporary or semi-permanent shelter. To help reduce this potential load, CoSA provided restroom facilities and adequate maintenance cleaning in areas with concentrated homeless populations. A control measure for this source of bacteria would be an increased effort for provision of sanitary restroom facilities at strategic locations throughout the City. In the past, there were few, if

any, public restroom or shower facilities within the City, except for those that are located near various public places, such as the Brackenridge Park.

A new Haven for Hope Campus is located adjacent to the Central Business District, on the west side. This facility may alleviate some, but not all of the transient problem. Haven for Hope is a private nonprofit organization dedicated to transforming the lives of homeless men, women, and families in the San Antonio/Bexar County area by addressing the root causes of homelessness through job training, education, and behavioral health services.

Responsible Parties: CoSA: CCDO, TCI, Code Department, Police Department

Timeline: On-going

Measurable Milestones

CoSA has a crew that removes debris from their infrastructure, which will include encampments along their drainage structures.

Years 2-5:

CoSA will continue to coordinate with the Code and Police Departments and document through their annual report to TCEQ the amount of debris removed by this management measure.

Efforts to curb the impact of vagrants and homeless people on the environment will continue for the next 5 years. Since it is difficult to measure the size of the homeless population and their impact on the environment, there is not a measurable milestone other than the reporting of refuge removal by CoSA.

Management Measure 17. Inspection and Repair of Septic Systems

Bexar County, as part of its On-site Sewage Facility (OSSF) Program, investigates all failed systems and resolves the issues. The county Environmental Department of Public Works investigates illicit discharges that may be septic in origin. The department participates in any investigations that have environmental impacts in the un-incorporated areas of Bexar County and within the cities where the County provides the OSSF permitting.

Septic systems can act as sources of nutrients and pathogens for reasons related to inadequate design, inappropriate installation, neglectful operation, or exhausted lifetime. In terms of system operation, many system failures can be attributed to hydraulic overloading. Also, the regular inspection and maintenance required to keep the systems operating effectively is often not performed. Finally, all septic systems require maintenance and, if this is not performed, the design life of the system components will be shortened and the likelihood of sewage discharges increases. For this reason, all aspects of permitting, planning, construction, operation, and maintenance should be conducted in accordance with Title 30 Texas Administrative Code, Chapter 285.

Public Education

Many of the problems involved with improper use of septic systems can be attributed to a lack of user knowledge concerning the operation and maintenance of the system. Making educational materials available to homeowners and providing training courses for septic system installers and inspectors can reduce the incidence of pollution from these systems. Education is most effective when used as part of a BMP system which involves other source reduction practices such as the use of low-volume plumbing fixtures, as well as mitigating BMPs, such as upgrading and maintenance.

Inspection and Maintenance

Inspections and certifications of septic systems are performed by Bexar County. Regular system inspections are essential for monitoring system performance and, while homeowners can be provided with educational materials and can monitor their own systems, inspection programs should also be developed by local governments. A lower cost, though less reliable alternative, is for local governments to distribute reminders to septic system owners to let them know when inspection or maintenance is due for their systems (e.g., a reminder on a tax statement). Utilities or other agencies can sometimes be utilized at reduced expense to implement a program like this. At a minimum, requirements should be established for inspection during change of property ownership.

Septic tanks need to be pumped to remove accumulated bio-solids approximately every 3 to 5 years, though this required frequency may vary based on the size of the tank, the number of users in the home, and whether or not a garbage disposal is being used. Failure to remove

bio-solids periodically will likely result in reduced tank settling capacity and eventual overloading of the soil absorption system, which is more expensive to remedy.

Septic tank maintenance can be required by using contracts, operating permits, and local ordinances or utility management. Local governments can issue renewable operating permits that require users either to have a contract with an authorized inspection/maintenance professional or to demonstrate that inspection and maintenance procedures have been performed on a periodic basis. Permit fees can be assessed to cover the program costs. Inspection and maintenance are more effective when used as parts of a BMP system which involves source reduction through low-volume plumbing fixtures.

Upgrade or Replacement of Failing Systems

Replacement of aging or inadequate systems and the repair of failing ones is an important component of an onsite wastewater management program. Typical repairs include fitting the septic system with new inflows and outlets, creating a new drain field, or the use of other alternative technologies. Complete replacement of the system may be required in the event that the original one is inadequate, incorrectly constructed or installed, or if the system deficiencies cannot be addressed by other corrective measures. If the systems are sufficiently close to an existing sewer system, connection to that system may also be an alternative.

Local governments and other programs can facilitate these remedial measures through the provision of technical assistance to septic system owners, a recommended list of licensed installers, a complaint response system, and financial assistance to low income households for performing the necessary repairs.

Several alternative technologies are available for the upgrade or replacement of failing septic systems. These include leaching chambers, drip distribution, low pressure dosing, and surface irrigation. Upgrade or replacement is more effective when used as part of a BMP system which involves source reduction through elimination of garbage disposals and use of low-volume plumbing fixtures.

Chemical Additive Restrictions

Organic solvents are advertised for cleaning septic systems and also sometimes as substitutes for sludge pumping. However, there is limited evidence that these cleaning agents

effectively achieve the intended functions, though they can inhibit microbial activity in the system and consequently result in increased discharge of pollutants. Additionally, the solvent chemicals themselves can potentially contaminate receiving waters and some common cleaner constituents are listed with EPA as priority pollutants. Therefore, restrictions on the use of these additives can prevent the worsening of poor system function. Additive restrictions are most effective when used as part of a BMP system that involves other source reduction practices such as use of low-volume plumbing fixtures, as well as mitigated BMPs such as upgrading and maintenance.

Responsible Party: Bexar County

Timeline: On-going

Measurable Milestones

Years 2-5:

Sanitary sewer providers identify older developed areas that are not served by public sanitary sewer and provide maps of those areas to Bexar County. Bexar County will continue to educate and inspect as part of its OSSF Program.

Management Measure 18. Specially Designed Boat (*Lady Eco*)

Beginning in 2006, the 'Lady Eco' has been used to remove debris from the San Antonio River in the River Walk area. The amount of debris removed from the river is estimated to be approximately 30,000 pounds per year.

Responsible Party: CoSA CCDO

Timeline: On-going

Measurable Milestones

Contingent upon the receipt of proposed project funding, the measureable milestones are as follows.

Figure 12. River Walk Implementation Plan power washer which recaptures the wastewater.

Years 2-5:

Lady Eco's efforts to remove trash and debris from the river will continue for the next 5 years. Our base line amount of trash and debris removal is 30 tons a year, a measureable milestone is to remove more; however, removing more or less has several implications such as the impact of education on less trash or a weather event that increases the removal of vegetative debris from the river. Therefore, there is not a measurable milestone.

Management Measure 19. Implement Measures to Improve Maintenance and Cleaning Operations for River Loop Area

The River Walk Implementation Plan examined the maintenance practices that were being used in the River Walk area. It was discovered that the walkways were being power washed and the wastewater was being allowed to runoff into the river. A new power washer (Figure 12) has been obtained, through the River Walk Implementation Plan, which recaptures the wastewater. The wastewater is then disposed of into a sanitary sewer where it can be properly treated. The BMPs developed as part of the River Walk implementation plan are available on the River, Life, Love It website <www.riverlifeloveit.org/index.php>.

These BMPs were developed for several different segments of the River Walk community including residents and tourists, food service providers, general merchants, hotel and motel employees, and waste management providers.

Responsible Party: CoSA CCDO

Timeline: On-going

Measurable Milestones

Contingent upon the receipt of proposed project funding, the measureable milestones are as follows.

Years 2-5:

Improve maintenance practices to reduce runoff and chemical spills will continue for the next 5 years. Since no runoff occurs and any spills are contained, a measurable milestone is to continue the zero tolerance policy.

Management Measure 20. Street Sweeping Activities

Bexar County Public Works Department provides routine and systematic street sweeping to remove loose material from un-incorporated roadways. Bexar County's street sweeping program is designed to help prevent dirt from reaching the storm sewers and waterways. Sweeping of residential streets is year round. Each service center is responsible for setting and monitoring their routes.

The CoSA TCI is responsible for street sweeping activities; these activities are performed nightly downtown (with the exception of two holidays), twice a year for residential streets, and four times year for major streets.

Responsible Parties: Bexar County, CoSA TCI

Timeline: On-going

Measurable Milestones

Years 2-5:

- Bexar County will continue to perform street sweeping within the un-incorporated area of the County.
- CoSA will continue to perform street sweeping nightly in the downtown area (with the exception of two holidays), twice a year for residential streets, and four times a year for arterial/collector streets. The number of cycles of sweeping per street is dictated by available funding.

Management Measure 21.
San Antonio River Loop Sediment Removal

The CoSA TCI is responsible for the maintenance of designed channels and natural waterways in the City. All improved drainage channels are inspected on a regular basis and re-grading, de-silting, and debris removal projects are scheduled and conducted on a priority basis. Channel de-silting helps with reducing the TSS contributed to local waterways, as well as aiding with the conveyance of stormwater by maintaining the design characteristics and conveyance capacity of the channels. TCI completed de-silting of the San Antonio River Loop over a two year period, in 2010 and 2011. The San Antonio River Main Channel was de-silted most recently in 2014.

Responsible Party: CoSA TCI

Timeline: On-going

Measurable Milestones

CoSA TCI evaluates the sediment in the river loop and upon the identification of excess accumulation staff schedules the cleaning of the loop and extension during even numbered years. Furthermore, during these clean-ups the main channel of the river is de-silted.

Years 2-5:

Since the 2010-2011 de-silting project, CoSA implemented a plan to review the River Loop every two years (even numbered years) and evaluate and clean as necessary, within the allotted budget, the River Loop, Loop Extension, and Main Channel.

Management Measure 22.
Urban Horse Stable Assessment

There are horse stables located adjacent to Salado Creek, just upstream of the Austin Highway crossing, and this potential source should be investigated. Much of the creek riparian zone is wooded and vegetated, and wildlife, particularly birds and small mammals, are probably abundant. The widespread residential areas also house numerous pets. These animal sources can deliver fecal material to the stream via direct deposition and via washoff during storm events.

Responsible Parties: CoSA ACS, AgriLife Extension LSHS Horse Manuals

Timeline: Long Term on-going

Measurable Milestones

CoSA has a livestock permitting and inspection process in place. All private livestock pens are inspected annually during the existing permit process.

Years 2-5:

- CoSA will provide the number of citations/warnings issues as well as the number of animals impounded.
- CoSA will inspect all private livestock pens annually during the existing permit process and will provide the number of citations and warnings issued as well as the number of animals impounded.

Management Measure 23. Creek Book

SARA's Creek Book promotes environmental stewardship and an appreciation of the San Antonio River and its tributaries. It is a guide for homeowners and property managers that provides information on how to manage property, dispose of waste, recycle, landscape, and conserve in order to improve aquatic ecosystem quality, stability, and sustainability. The Creek Book is distributed by SARA at booth shows, water fairs, and workshops and is publically available via the SARA website. A survey will be conducted to monitor how the Creek Book is changing behavior.

Responsible Party: SARA

Timeline: Completed 2010, Revised: 2013; next revision TBD

Measurable Milestones

Year 2:

- A new revision of the Creek Book will be scheduled with plans to enhance the content on LID and sustainability. This will include information on BMPs in LID and references to guides or handbooks SARA has created. The new version will also include pictures, references, and resource information.

Measures Completed Prior To I-Plan Development

Management Measure 24.
BMP Assessment Report - 2010

The report was developed as a component of the TMDL I-Plan for the Upper San Antonio River, and Salado and Walzem creeks. The objective of this report was to identify and assess potential sources of bacteria, and to evaluate BMPs to control those sources. Portions of this document were used to help identify management measures for this I-Plan.

Responsible Parties: SARA, BRWM Water Quality Focus Group

Timeline: Completed

Measurable Milestones

This project has been completed and no additional work is planned.

Management Measure 25.
Provide Illegal Dumping Signs for Existing Vegetated Swales/Filter Strips

(70.5 miles of earthen channel on Alazan, Apache, Martinez, Olmos, 6-mile Creek, and Upper San Antonio River)

Regular site inspections occurred to verify that refuse (including fecal matter) is no longer being dumped into buffer area. Signs were placed along some creeks to discourage dumping.

Responsible Parties: SARA / CoSA TCI

Timeline: Completed

Measurable Milestones

SARA/CoSA TCI have no activities planned during this timeframe.

Management Measure 26.
Animal Pound Wash-Down

CoSA operated an animal control center near the San Antonio Zoo. This center was believed to be a potentially significant contributor of bacteria loads because of wash-down practices that could result in fecal material reaching the river. These wash-down practices are routine

maintenance operations and not the result of rainfall. However, this facility was moved to a new location in a different watershed, resulting in a potential load reduction.

Responsible Party: CoSA ACS

Timeline: Completed

Measurable Milestones

CoSA ACS has moved their facility to 4710 State Highway 151. Cleaning of animal cages is primarily confined to animal housing areas and water is kept on property and drained into sewers. No further activity anticipated.

Management Measure 27. Wildlife–Bat Colony in Houston Street Bridge

A migratory colony of Mexican Free Tail bats was found to be roosting under the Houston Street Bridge. The waste from these animals was deposited directly into the river or onto the sidewalk and subsequently washed into the river. Once the bats returned to Mexico for the winter the bridge was examined and work performed to keep the bats from roosting there in the future. The bridge is inspected annually to verify that the bats are not roosting under the bridges in the River Walk area.

Responsible Party: CoSA CCDO

Timeline: Completed

Measurable Milestones

The Houston Street bat colony removal measure has been completed. No further bat removal programs are planned for the next 5 years; however, CoSA will continue to perform annual inspections to verify that the bats are not roosting under the bridges in the River Walk area.

Management Measure 28. SAWS' Recycled Water Program and Streamflow Augmentation Discharges

In 2000, SAWS began using its Recycled Water Program infrastructure to release high quality water for streamflow augmentation in the San Antonio River at Brackenridge Park. A

second discharge location on the San Antonio River is located at the Flood Tunnel Inlet at the southern tip of Brackenridge Park. In 2001, SAWS initiated another flow augmentation discharge on Salado Creek at Rittiman Road. In 2006, SAWS completed a fourth flow augmentation discharge structure on an extension of the San Antonio River at the Henry B. Gonzalez Convention Center.

SAWS has allocated 4,250 acre-feet/yr to augment flow in the Brackenridge Park area, 850 acre-feet/yr for Salado Creek, and 723 acre-feet/yr for the Convention Center discharge, making SAWS total annual commitment for streamflow augmentation 5,823 acre-feet/yr.

Since the highest potential for DO and fecal coliform concerns are in low flow, stagnant conditions, increasing the flow with recycled water that nearly meets drinking water standards greatly enhances the overall water quality in the Upper San Antonio River Basin.

At Brackenridge Park, in addition to the primary discharge location, SAWS also operates a pump station to convey and recirculate discharged water to the San Antonio River at Hildebrand Avenue. At the Convention Center, SAWS discharges provide flow in what would otherwise be a "dead-end" extension of the River.

In addition to direct stream flow augmentation and recirculation, SAWS' Recycled Water Program has other significant beneficial impacts to the water quality in the basin. Recycled water is also used for irrigation of golf courses, parks, and cemeteries in the City, and in numerous industrial processes. Application of recycled water for these uses decreases the amount of pumpage from the Edwards Aquifer, thereby protecting natural spring flows that are the source of much of the area's stream flow.

All these initiatives are critical to the flow of the San Antonio River and Salado Creek and are directly related to improved water quality.

Responsible Party: SAWS

Timeline: Completed

Measurable Milestones

No further activity anticipated for this project.

Management Measure 29. Connection of 117 Homes in the Espada Community Located on Southwest Bexar County

In some cases, it may be more cost-effective and practical to address an area served by failing septic systems by connecting that area to a nearby sewer system. The completed Espada Unsewered Area Project is a good example of this process. This project connected 117 homes in the Espada community north of loop 410 between the San Antonio River and Roosevelt Avenue and south of Ashley Road.

The project resulted in the installation of approximately 23,000 feet (4.35 miles) of small diameter sewer mains and two lift stations in the Espada community and cost $3.2 million. As well as addressing what had been classified by the Metropolitan Health District as a serious health risk, the project also removed a potential source of bacteria in the watershed. SAWS completed the connecting of homes in the Espada Community to sewer service in 2007. These homes were previously on septic systems.

Responsible Party: SAWS

Timeline: Completed

Measurable Milestones

No further activity anticipated for this project.

Management Measure 30. San Antonio River Walk Implementation Project and Plan (to include new sections of the River Walk)

The goal of this initiative was to educate citizens on bacteria controls and identify merchants' and patrons' behaviors that contribute to elevated bacteria levels. Workshops were conducted to educate watershed residents, tourists, and merchants to change behaviors and reduce bacteria levels in the San Antonio River. The River Walk Watershed Alliance (RWWA), a public-private entity, was organized to provide guidance on how residents, tourists, and merchants could help to improve the water quality in the river.

A public information campaign was also conducted as a part of the River Walk Implementation Plan as a list of BMPs was developed that residents, tourists, merchants, and waste management providers could adopt to improve water quality in the River Walk Watershed.

The BMPs were developed in cooperation with the RWWA and are available on the internet <www.riverlifeloveit.org/)>.

Two video public service announcements were also developed as well as print ads (Figure 13) that encourage residents and visitors to not feed the wildlife and to properly dispose of litter.

Figure 13. Examples of RWWA Advertisements.

Responsible Party: RWWA, CoSA, SARA, Bexar County

Timeline: Completed

Measurable Milestones

SARA will continue this type of messaging but will do so under the SARA Watershed Wise Program (Management Measure 15), not the RWWA. SARA will continue to monitor the water quality sample site upstream of La Villita for *E. coli* bacteria under the CRP or SARA Stream Monitoring Program.

I-Plan Progress Monitoring

Stakeholders have agreed upon a strategy to address water quality monitoring by measuring bacteria in both impaired surface waters and through specific management measures. It is understood that numerous management measures do not have a water quality monitoring component; these management measures are planned to be monitored for success by other endpoints such as productivity.

Stakeholders' Responsibilities

- SAWS Implementation Strategy: Wastewater Collection and Transmission System WCTS Operation and Maintenance Programs to Reduce Sanitary Sewer Overflows — SAWS
- San Antonio Zoo UV Treatment System Implementation — CoSA
- Advancement of Low Impact Development — SARA
- MS4 Related Activities — SAWS, CoSA, TxDOT
- Avian Management for the River Walk and Other Riparian Areas — CoSA
- Expansion of the Pooper Scooper Program — CoSA
- Increased Awareness and Enforcement of Pet Control Ordinance — CoSA
- BMP Assessment, Pilot Studies and Mission Drive-In Redevelopment — SARA, CoSA
- Feral Hog Management — TSSWCB, SARA
- Livestock Management — TSSWCB, SARA
- Inspection of New Construction Sites — Bexar County
- Evaluate Restoration of Westside Creeks — SARA, CoSA, Bexar County
- Mission Reach Ecosystem Restoration and Recreation — SARA, Bexar County, CoSA
- Environmental Investigators — SARA

- "Be Watershed Wise Campaign" — SARA
- Homeless, Vagrant Population and Cleaning, Brush Control in Encampment, and Dumping — CoSA
- Inspection and Repair of Septic Systems — Bexar County
- Specially Designed Boat (Lady Eco) — CoSA
- Implement Measures to Improve Maintenance and Cleaning Operations for River Loop Area — CoSA
- Street Sweeping Activities — Bexar County, CoSA
- San Antonio River Loop Sediment Removal — CoSA
- Urban Horse Stable Assessment — CoSA
- Creek Book — SARA
- BMP Assessment Report, 2010 — SARA, BRWM
- Provide Illegal Dumping Signs for Existing Vegetated Swales/Filter Strips— SARA, CoSA
- Animal Pound Wash-Down — CoSA
- Wildlife Management- Bat Colony in Houston Street Bridge — CoSA
- SAWS' Recycled Water Program and Streamflow Augmentation Discharges — SAWS
- Connection of 117 Homes to SAWS' Sanitary Sewer Collection System in the Espada Community Located in Southwest Bexar County — SAWS
- San Antonio River Walk Implementation Project / Plan — CoSA, SARA, Bexar County

Recommendations for Further Analysis

A significant bacteria load identified during the stakeholder meetings was the load from wildlife and invasive species, which includes warm-blooded aquatic and terrestrial organisms. Questions were raised regarding the amount of human versus wildlife bacteria, invasive species, and livestock bacterial load contributions to the impaired segments. The stakeholders discussed the challenges involved with achieving the primary contact recreation standard in certain areas. These discussions among the stakeholders identified further analysis or activities that could be useful in addressing this issue. They are:

- Keep advised of the most recent published literature of the fate and transport of *E. coli* in our particular environmental conditions.
- Consider using bacterial source tracking, which utilizes genetic fingerprinting techniques to identify bacterial strains that are host-specific.
- Continue investigating methods for controlling egret rookery populations.
- Keep advised of the most successful feral hog abatement programs.
- Continue annual inspections to verify that the bats are not roosting under the bridges in the River Walk area.

The degree to which further analysis items are pursued will be based upon funding, stakeholder input, or annual reviews of progress.

Communication Strategy

TMDLs are a requirement of the federal CWA Section 303, designed to determine the capacity of natural waterways to assimilate bacterial loadings and allocate the allowable loading to contributing sources in the watershed. A TMDL identifies possible sources and causes of water quality impairments and uses a water quality model to establish bacterial load allocations and reductions. TMDL guidance also requires the inclusion of a communications strategy to inform and educate all stakeholders of the progress and benefits of the TMDLs and I-Plan.

Communication is necessary to ensure stakeholders understand the I-Plan and its progress in restoring water quality conditions. The TCEQ will obtain information derived from tracking I-Plan activities during the annual meetings. This information will be posted on the TCEQ website for interested parties, including watershed stakeholders, state leadership, government agencies, non-governmental organizations, and individuals. At the annual meeting, the TMDL Program will summarize trends observed in the water quality data to assist in tracking the progress of implementation. Responsible parties are committed to providing appropriate information to the TCEQ to update these progress assessments and communicating information at annual meetings. Regionally, the progress and results of the I-Plan will be reported in annual reports prepared by the Upper San Antonio River Technical Subcommittee.

The TCEQ will be responsible for hosting annual meetings for up to the next five years so stakeholders may evaluate their progress. Stakeholders will continue to take part in the annual meetings over the five-year period to evaluate implementation efforts and to revise the plan as needed. At the completion of the scheduled I-Plan activities, stakeholders will assemble and evaluate the actions, overall impacts, and results of their implementation efforts.

A public participation campaign will be conducted to keep the public informed of the activities and progress of the project. The campaign will be used to enhance partner, stakeholder, and public understanding of the I-Plan and encourage their participation in implementing and maintaining appropriate control measures. The Upper San Antonio River Coordination and Technical committees have identified a stakeholder list composed of partners, special interest groups, and interested citizens to whom they will disseminate information. The basis of the stakeholder list is the stakeholder group established during I-Plan development. The current stakeholder group will meet to stay informed of the plan's progress and will help disseminate information to the public. All meetings of the I-Plan committees are open to the public. Additional meetings may be scheduled to inform a wider audience of the general public in both Bexar and Wilson counties.

Communication Objective

Support the I-Plan with wide-ranging, proactive communications that effectively inform and motivate key audiences, including the general public, the media, individual stakeholders, and decision-makers.

Desired Outcomes

- Develop a public understanding of the role of the TMDL and accompanying implementation activity in restoring and protecting the recreational use of the Upper San Antonio River watersheds.
- Foster stewardship and inspire actions to meet the goals of the I-Plan.

Strategies

- Communicate information, messages, and developments through public meetings, the TCEQ website, and a variety of communications tools and activities.
- Develop messages during phases of the plan implementation that reflect current status, ongoing activities, and future plans.

Audiences

Key Stakeholders

- Government agencies — federal, state and local
- Watershed groups and other non-profit environmental organizations
- Agriculture and agricultural organizations
- Wastewater utilities and associations

General Public

Media

- Print
- Social Media
- Website

- Radio / TV

References

City of San Antonio. 2006 Code of Ordinance, Section 5-19, Leash and pooper scooper required.

City of San Antonio. 2008. Klotz Associates, Phase "A" Report.

EPA's Section 319(h) incremental grant program. 2014.

JMA. 2006. Upper San Antonio River Watershed Protection Plan. Report to SARA and Bexar Regional Watershed Management Partnership; James Miertschin & Associates, Inc.

JMA. 2010. BMP Assessment Report Update. Report to SARA and Bexar Regional Watershed Management Partnership; James Miertschin & Associates, Inc.

Migratory Bird Treaty of 1918. U.S. Code, Volume 16, Sections 703-712.

Texas Administrative Code, Title 30, Part 1, Rule 307.7, Chapter 307.

TCEQ. 2007. Texas Pollutant Discharge Elimination System Permit No. 04284 (TXS001901) for the City of San Antonio Municipal Separate Storm Sewer System.

TCEQ. 2007. Three Total Maximum Daily Loads for Bacteria in the San Antonio Area, Segments 1910, Salado Creek, 1910A, Walzem Creek, and 1911, the Upper San Antonio River. Appendix I.

77th Texas Legislature. 2001. Texas Agriculture Code Section 210.206, Nonpoint Source Pollution. The State of Texas.

113th United States Congress. 2014. Agriculture Act of 2014, the Congress of the United States of America.

2012 Texas Nonpoint Source Management Program <www.tceq.state.tx.us/assets/public/comm_exec/pubs/sfr/068_12.pdf>.

2013 Managing Nonpoint Source Water Pollution in Texas: Annual Report.

<www.tceq.state.tx.us/assets/public/compliance/monops/nps/annualreports/066_13.pdf.

Appendix I.
TCEQ Report: Three Total Maximum Daily Loads for Bacteria in the San Antonio Area

TCEQ Adopted: July 25, 2007

Three Total Maximum Daily Loads for Bacteria in the San Antonio Area

For Segment Numbers:
1910 – Salado Creek
1910A – Walzem Creek
1911 – Upper San Antonio River

printed on recycled paper

Prepared by the:
Chief Engineer's Office, Water Programs, TMDL Section

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Three TMDLs for Bacteria in the San Antonio Area

Distributed by the
Total Maximum Daily Load Program
Texas Commission on Environmental Quality
MC-203
P.O. Box 13087
Austin, Texas 78711-3087

TMDL Project Reports are also available on the TCEQ web site at:
www.tceq.state.tx.us/implementation/water/tmdl/

The preparation of this report was financed in part through grants from
the U.S. Environmental Protection Agency.

This document is based in large part on the:
"Modeling Report for Bacteria TMDL Development: Salado Creek, Segment 1910;
Walzem Creek, Segment 1910A; Upper San Antonio River, Segment 1911,"
by James Miertschin & Associates, Inc.

Contents

Figures

Tables

Three Total Maximum Daily Loads for Bacteria in the San Antonio Area

Executive Summary

This document describes a project developed to address water quality impairments related to bacteria for three streams located in and around the City of San Antonio—Salado Creek, Segment 1910; Walzem Creek, Segment 1910A; and the Upper San Antonio River, Segment 1911. Salado Creek and the Upper San Antonio River (USAR) were first identified as impaired due to bacteria in the 2000 *Texas Water Quality Inventory and 303(d) List* (TCEQ 2000). Walzem Creek was added to the list in 2002.

Salado Creek, located in Bexar County, is approximately 45 miles long, with a drainage area of 223 square miles. Walzem Creek, located inside the Salado Creek watershed, is approximately 3.1 miles long and drains 2.8 square miles. The USAR, located in Bexar and Wilson Counties, is approximately 85 miles long, and is joined by two major tributaries—Salado Creek and the Medina River (Segment 1903). The drainage area specific to the USAR, excluding the Salado Creek watershed, is approximately 530 square miles.

The goal of this TMDL project was to determine the maximum bacteria loading the stream can receive and still allow support of the contact recreation use. Indicator bacteria such as *E. coli,* although not generally pathogenic, indicate a possible 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 Water Quality Standards* (Chapter 307 of the Texas Administrative Code, Title 30). The criteria for assessing attainment of the contact recreation use are expressed as the number of organisms (org) of bacteria per hundred milliliters (100 mL) of water. The number of organisms may not exceed certain concentrations in a single sample, nor as a geometric mean of all samples over a range of time.

Based on field assessments and analysis of load allocation scenarios, attaining the water quality standards requires:

- 90 percent reduction in nonpoint source loading to Salado and Walzem Creeks
- 60 percent reduction in urban storm water loading to Salado and Walzem Creeks
- 99.9 percent reduction in baseflow loading from the San Antonio Zoo to the USAR
- 50 percent reduction on nonpoint source loading to the USAR
- 30 percent reduction in urban storm water loading to the USAR

Overall, a 59 percent reduction in bacterial loading is required for Salado and Walzem Creeks, and a 31 percent reduction in bacterial loading is required for the USAR.

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. The compilation of subject water bodies is known as the 303(d) list. For each listed water body, states must develop a TMDL for each pollutant that contributes to an 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 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. 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 surface water quality. The Program addresses impaired or threatened 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. These TMDLs address impairments to contact recreation from bacterial indicators for pathogens in Salado Creek, Walzem Creek, and the USAR.

Section 303(d) of the Clean Water Act and the implementing regulations of the U.S. Environmental Protection Agency (EPA) in Title 40, Code of Federal Regulations, Part 130 (40 CFR 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
- Seasonal Variation
- Linkage Analysis
- Margin of Safety
- Pollutant Load Allocation
- Public Participation
- Implementation and Reasonable Assurance

This document is based on the "Modeling Report for Bacteria TMDL Development: Salado Creek, Segment 1910; Walzem Creek, Segment 1910A; Upper San Antonio River, Segment 1911," prepared for the TCEQ by James Miertschin & Associates, Inc. (JMA 2006).

The commission adopted this document on July 25, 2007. Upon EPA approval, this TMDL will become an update to the state's Water Quality Management Plan.

Problem Definition

This document describes a project to develop TMDLs for three streams located in and around the City of San Antonio—Salado Creek (Segment 1910), Walzem Creek (Segment 1910A), and the USAR (Segment 1911). Salado Creek and the USAR were first identified as impaired for bacteria in the 2000 *Texas Water Quality Inventory and 303(d) List* (TCEQ 2000). Walzem Creek was added to this list in 2002.

The study area is depicted in Figure 1. Only the red portions were found to be impaired, as indicated in the 303(d) List and confirmed through an additional assessment of historic data (JMA and PES 2002). Salado Creek is impaired from 1.5 miles upstream of Loop 410-N to the confluence with the USAR. Walzem Creek is impaired from 1.5 miles upstream of Walzem Road to its confluence with Salado Creek. The USAR is impaired from its headwaters at San Antonio Springs to Wilson County Road 125; and from 2.5 miles upstream of FM 536 to 4 miles below FM 541. Possible sources and/or causes of contamination include:

- discharges from wastewater treatment facilities and other institutions
- discharges from urban storm sewer systems
- runoff from undeveloped lands
- wildlife deposition
- pets 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. At the time these TMDLs were under development, the standard to support contact recreation was in transition, so both *E. coli* and fecal coliform were in place. The TMDLs were developed for fecal coliform, and converted to *E. coli*. 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 organisms per 100 milliliters (126 org/100 mL)
  - Single samples of E. coli should not exceed 394 org/100 mL
- Fecal coliform
  - The geometric mean of fecal coliform should not exceed 200 org/100 mL
  - Single samples of fecal coliform should not exceed 400 org/100 mL

Salado Creek and the USAR are designated for contact recreation and high aquatic life uses. Salado Creek is also designated for domestic water supply use, and the portion of the creek located over the contributing, transition, and recharge zones of the Edwards

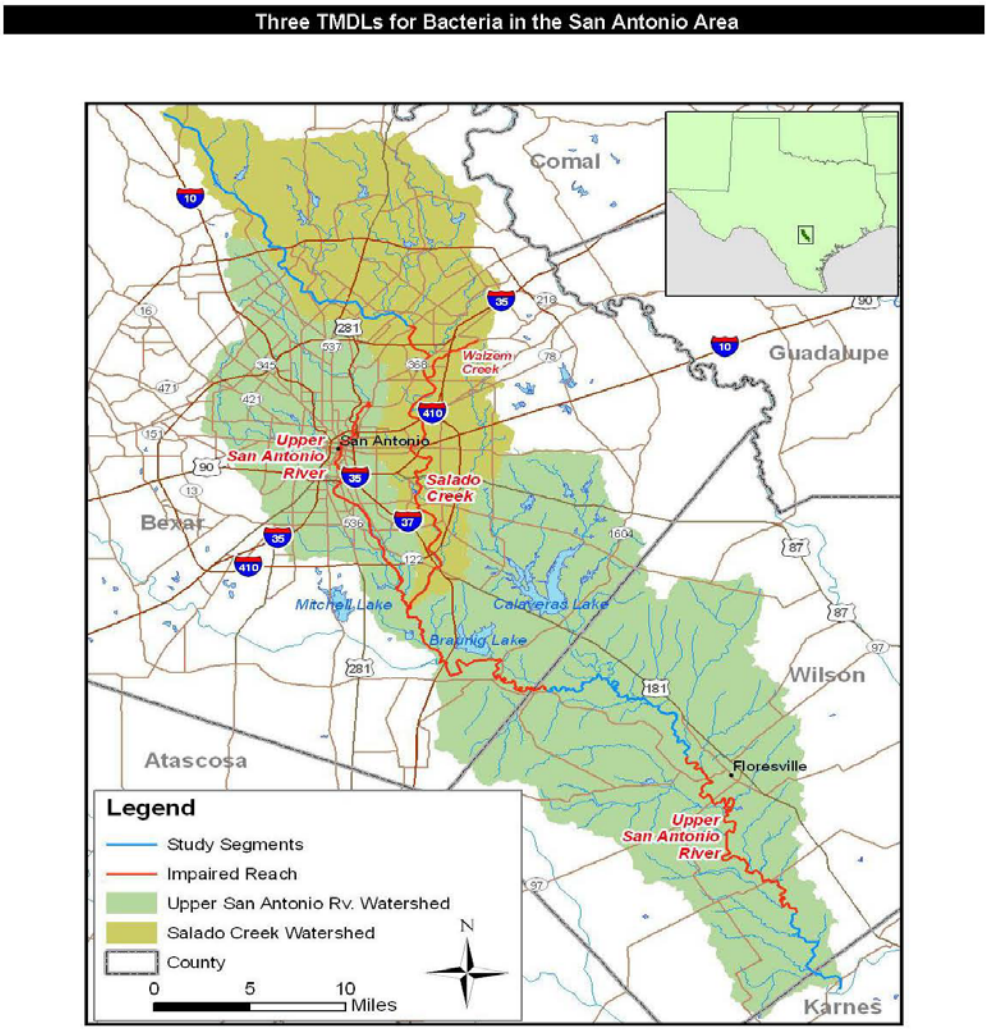

Figure 1: TMDL Watersheds

Aquifer is designated for aquifer protection use. As an unclassified intermittent stream, Walzem Creek has presumed uses for contact recreation and limited aquatic life.

Description of Watershed

The three impaired streams addressed by this study are located inside and around the greater San Antonio area. Salado Creek, located in Bexar County, is approximately 45 miles long with a drainage area of 223 square miles. Walzem Creek, located inside the Salado Creek watershed, is approximately 3.1 miles long and drains 2.8 square miles. The USAR, located in Bexar and Wilson Counties, is approximately 85 miles long, and is joined by two major tributaries—Salado Creek and the Medina River. The drainage area specific to the USAR, excluding the Salado Creek watershed, is approximately 530 square miles. The southern half of the USAR watershed is located in the largely rural Wilson County, downstream of the City of San Antonio (Figure 1).

Climate

The Gulf of Mexico is the principal source of moisture that drives precipitation in the study area. The amount of precipitation is influenced by the distance from the Gulf of Mexico and by topography. The study area is located primarily within the Edwards Plateau climatic division, though the lower portion of the San Antonio River basin is located within the south central plains province.

As with the rest of the interior of the state, maximum precipitation periods are typically late spring (May) and early autumn (September). Winter and summer periods typically have low precipitation. The maximum precipitation period in May is driven by the buildup of water vapor from the Gulf of Mexico carried by the prevailing winds from the south. Springtime precipitation is caused by late season cold air migrations, warm season thunderstorms, and spring low-pressure troughs. In September, cold air converges with moisture-laden southerly winds and late season convective thunderstorms drive the precipitation. It is also not unusual for hurricanes to affect rainfall in the early autumn period. Summer drought conditions are common in the study area, due to strong high-pressure cells that result in lengthy dry spells. For the 30-year period of 1970–2000, the annual rainfall in the study area, as measured in San Antonio, has ranged from 30.2 to 35.5 inches. The average annual rainfall for this period was 32.2 inches.

Economy

Bexar County

Bexar County covers 1,247 square miles, and has an estimated population in 2005 of 1,518,370. The population has increased by about 28 percent since 1990. Approximately 90 percent of the population lives in urban areas. The largest urban area, by far, is the City of San Antonio, with a population of 1,256,506 (TAC 2006). The county's economy includes agribusiness, tourism, oil production, manufacturing, construction, and professional services (TSHA 2001).

Tourism is an important component of the economy and is the top provider of nongovernmental jobs in Bexar County. The tourist industry is a result of the county's historical background as a battleground during the Texas Revolution. In addition, there are two major theme parks located in the county (TSHA 2001).

Agribusiness is also an important component of the county economy. There are 2,385 farms in the county with an average size of 185 acres (USDA 2002). Total land area for farms decreased by 6 percent from 1997 to 2002, but farmland still accounts for about 55 percent of the county's total area. 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 17 percent of the total farmland. Most of the county's agricultural land is located outside of the TMDL study area.

Wilson County

Wilson County covers 807 square miles, and has an estimated population in 2005 of 37,529. The population has increased by about 66 percent since 1990. Approximately 32

percent of the population lives in urban areas. The largest urban area, by far, is the city of Floresville, with a population of 7,024 (TAC 2006). The county's economy includes agribusiness, oil and gas field services, and manufacturing (TSHA 2001).

Production of crude oil is an important component of the Wilson County economy. Oil was first discovered in 1941 and production has gradually grown. In 1990, 1,973,734 barrels of crude oil were produced (TSHA 2001). Agribusiness is also an important component of the economy. There are 2,157 farms in the county with an average size of 207 acres (USDA 2002). Total land area for farms decreased by 3 percent from 1997 to 2002, but farmland still accounts for 86 percent of the county's total area. Cattle are the primary type of livestock raised in the county. As in Bexar County, harvested cropland accounts for 17 percent of the county's total farmland.

Geology and Hydrogeology

The northwest corner of Bexar County is dominated by the Cretaceous-period limestone formations of the Edwards plateau. Moving southeast, through the rest of the study area, there are a series of progressively younger formations, dating primarily from the Tertiary Period. These formations vary considerably in composition and include materials such as chalk, clay, sand, and sandstone.

Groundwater in the area is primarily associated with the Edwards and Carrizo-Wilcox aquifer systems. The Edwards Aquifer outcrop (recharge zone) cuts across the northern portion of Bexar County, and its downdip zone dominates the central portion of the county. Water bearing layers in this aquifer range from 200 feet to 600 feet in thickness. The Carrizo-Wilcox Aquifer outcrop cuts across southern Bexar and northern Wilson County. This aquifer's downdip zone is dominant in the rest of Wilson County. The thickness of sand and gravel layers in the Carrizo-Wilcox aquifer range from less than 200 feet to 3,000 feet (Ashworth 1995).

Soils

Soil conditions vary throughout the study area based on geological and topographical characteristics. The northern portion of Bexar County consists of shallow to deep loamy soils. In the remainder of the study area, the soils are generally loamy with clayey subsoils (TSHA 2001).

Land Use

The San Antonio metropolitan area dominates the northern portion of the USAR watershed and much of the Salado Creek watershed. The southern portion of the USAR watershed is dominated by farms and ranches.

Land use characterization for the TMDL study watersheds (Figure 2) was based on the most recent National Land Cover Data (NLCD) developed by the U.S. Geological Survey (USGS 1992). Where possible, the NLCD data were updated with more recent zoning and parcel data. Based on these data, the Salado Creek watershed is 36.5 percent developed (commercial, industrial, and residential). Above the confluence with Salado Creek, the

USAR watershed is 85.5 percent developed, and below the confluence it is 3.7 percent developed. Undeveloped lands in the northwestern portion of the study area are primarily forest; to the southeast, undeveloped lands are primarily agricultural (range and cropland).

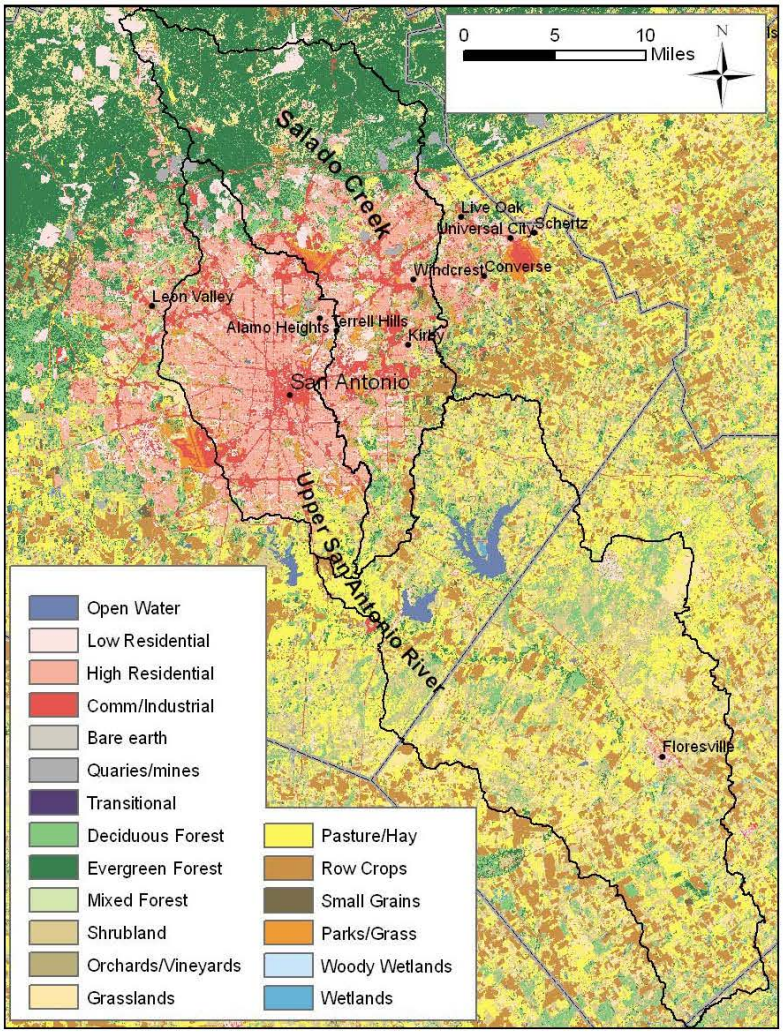

Figure 2: 1992 USGS Land Cover Data for Study Area

Data Used in the Assessment

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

Data and Information Inventory

A wide range of data and information were used in the development of these TMDLs. 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.
- Watershed physiographic data that describe the watershed's physical conditions such as topography, soils, and land use.
- Data and information related to the use of, and activities in, the watershed that can be used in the identification of 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 Clean Rivers Program monitoring activities in the San Antonio River Basin for inclusion in the TCEQ's Surface Water Quality Monitoring (SWQM) program database. The TCEQ and the USGS have also conducted water quality monitoring in the basin. Figures 3a and 3b show the locations, names, and numbers for stations at which significant bacteria sampling occurred throughout the period 1997–2004.

Water Quality Data

Review of the available water quality data reinforced earlier assessments, which concluded that the three impaired segments contain elevated levels of bacteria. Tables 1 and 2 summarize the data collected on Salado Creek (including Walzem Creek) and USAR, respectively. The tables include the number of routine samples collected, the number of samples that exceeded the grab sample criterion, and the geometric mean of the sampled concentrations. Figures 4, 5, 6, and 7 show monitoring results for select stations at which more than 10 samples were collected for *E. coli* and fecal coliform. The figures include the geometric mean, the upper quartile (or 75th percentile), and the lower quartile (or 25th percentile) of samples at each station.

Stream Flow and Weather Data

Stream flow and precipitation records are necessary to calibrate watershed and water quality models, calculate loadings of pollutants from point and nonpoint sources, characterize transport processes, and evaluate impacts of pollutant loadings.

For Salado Creek, continuous streamflow records are available at two monitoring stations. USGS station #08178700 is located at Loop 410 NE at the upper end of the study segment. USGS #08178800 is located at Loop 13 near the lower end. The station at Loop 13 was used for hydraulic calibration of the Salado Creek model.

For the USAR, there were several streamflow-gauging stations available. The key stations selected for determining hydraulic calibration were USGS #08178050 at Mitchell Street,

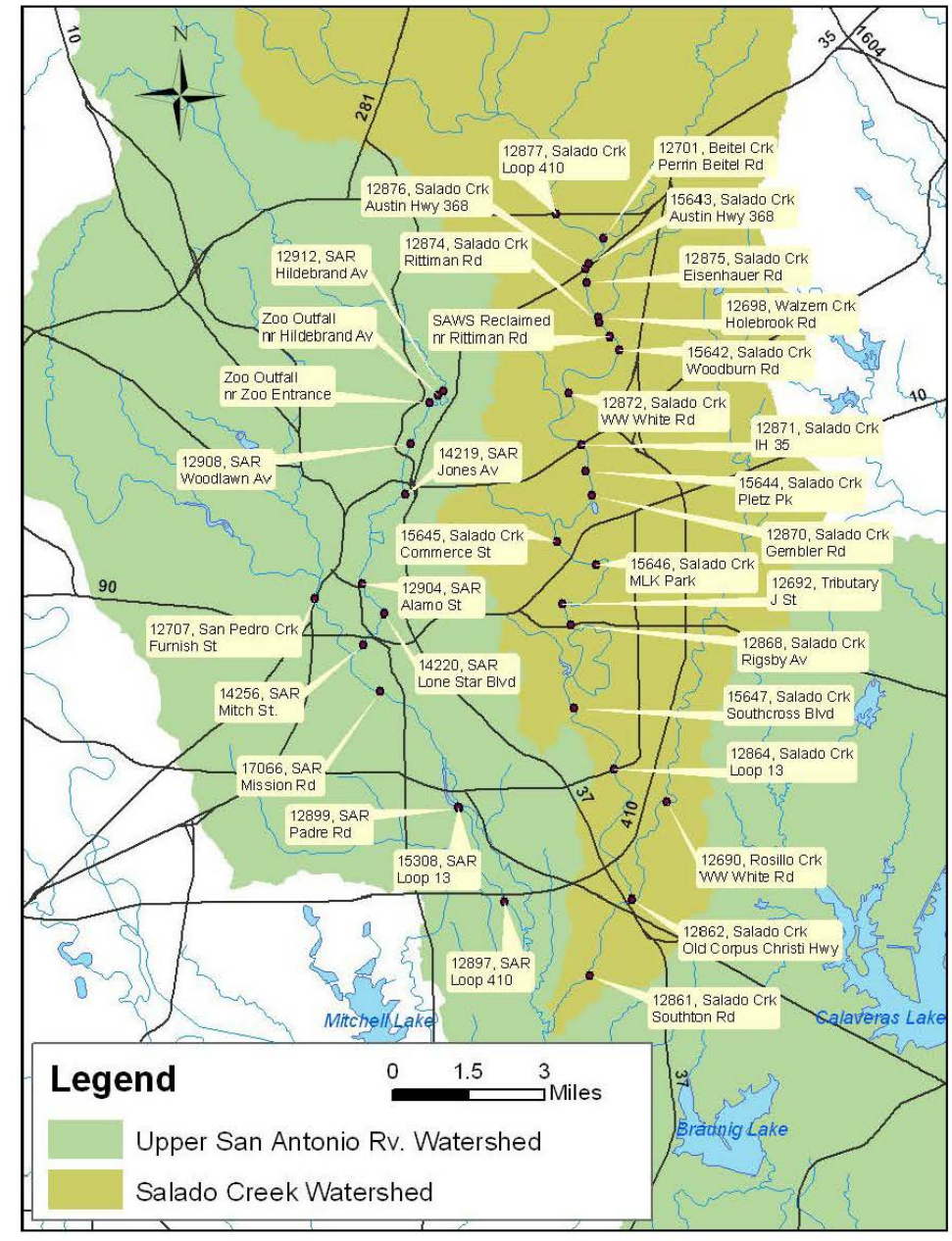

Figure 3a: Sampling Stations – Salado Creek and Northern Portion of USAR

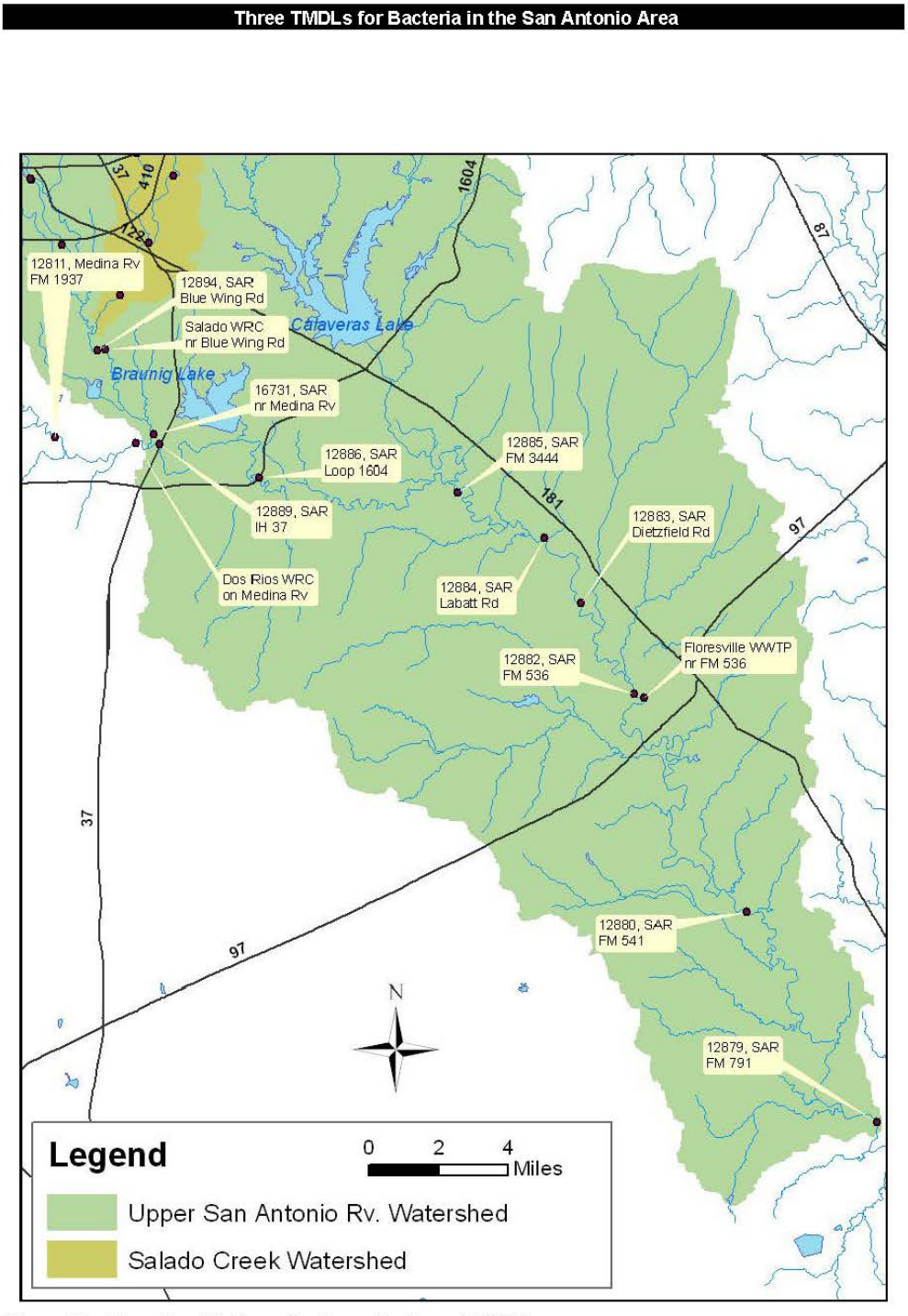

Figure 3b: Sampling Stations, Southern Portion of USAR

USGS #08178565 located at Loop 410 South, and USGS #08183500 located near Falls City. These three stations represent locations just below San Antonio's downtown business district, just below the city's southern limits, and at the downstream end of the segment, respectively.

Precipitation data were available for meteorological stations at the San Antonio International Airport (SAIA), Sea World, and Floresville. The SAIA gage, located inside the Salado Creek watershed, was used in the Salado Creek model. For the northern portion of

Table 1: Bacteria Data Collected on Salado Creek, (1997-2004)

Station	Stream	Location	Fecal Coliform Routine			*E. coli* Routine		
			# Samples	# Exceed	Geo Mean (org/ 100 mL)	# Samples	# Exceed	Geo Mean (org/ 100 mL)
12877	Salado Crk	Loop 410	10	4	249	13	5	105
15643	Salado Crk	Austin Hwy	60	29	439	58	14	225
12876	Salado Crk	Austin Hwy	8	8	3385	10	7	992
12875	Salado Crk	Eisenhauer Rd	66	26	266	64	13	138
12698	Walzem Crk	Holbrook Rd	68	50	815	68	26	263
12874	Salado Crk	Rittiman Rd	20	8	466	20	4	180
15642	Salado Crk	Woodburn Rd	62	30	509	62	16	200
12872	Salado Crk	WW White Rd	78	17	187	73	11	111
12871	Salado Crk	IH 35	62	14	204	62	9	104
15644	Salado Crk	Pletz Pk	60	22	269	59	12	143
12870	Salado Crk	Gembler Rd	40	12	255	40	8	129
15645	Salado Crk	Commerce St	65	31	388	65	11	159
15646	Salado Crk	MLK Pk	104	52	449	99	31	220
12868	Salado Crk	Rigsby Ave	75	33	427	73	24	193
15647	Salado Crk	E Southcross	60	19	311	58	9	159
12864	Salado Crk	Loop 13	80	30	366	79	16	189
12690	Rosillo Crk	WW White Rd	5	4	689	5	4	568
12862	Salado Crk	Old Corpus Rd	144	31	186	139	20	117
12861	Salado Crk	Southton Rd	13	5	258	13	3	153

the USAR, a synthesized precipitation record was developed from the SAIA and Sea World gages. The Floresville gage was used for the southern portion of the USAR model (below the confluence with Salado Creek).

Table 2: Bacteria Data Collected on USAR, (1997-2004)

Station	Stream	Location	Fecal Coliform Routine			*E. coli* Routine		
			# Samples	# Exceed	Geo Mean (org/100 mL)	# Samples	# Exceed	Geo Mean (org/100100 mL)
12912	SAR	Hildebrand Ave	18	8	486	13	4	184
12908	SAR	Woodlawn Ave	28	22	1068	28	18	500
14219	SAR	Jones Rd	3	2	474	5	2	407
12904	SAR	Alamo St	23	13	518	11	2	181
14220	SAR	Lone Star Blvd	4	4	779	-	-	-
14256	SAR	Mitchell St	44	30	577	46	16	329
17066	SAR	Mission Rd	26	15	693	26	7	348
15308	SAR	Loop 13	4	1	297	6	2	234
12899	SAR	Padre Rd	7	3	222	-	-	-
12897	SAR	IH 410	39	12	217	31	7	117
12894	SAR	Blue Wing Rd	29	13	485	23	6	214
16731	SAR	above Medina Rv	37	9	228	37	6	104
12889	SAR	IH 37	27	7	155	23	6	93
12886	SAR	Loop 1604	21	6	237	16	2	126
12885	SAR	FM 3444	7	1	138	-	-	-
12884	SAR	Labatt Rd	15	4	170	8	1	151
12883	SAR	Dietz Rd	29	6	196	24	3	116
12882	SAR	FM 536	19	5	214	12	3	191
12880	SAR	FM 541	22	6	225	17	5	141
12879	SAR	FM 791	91	14	149	84	7	100

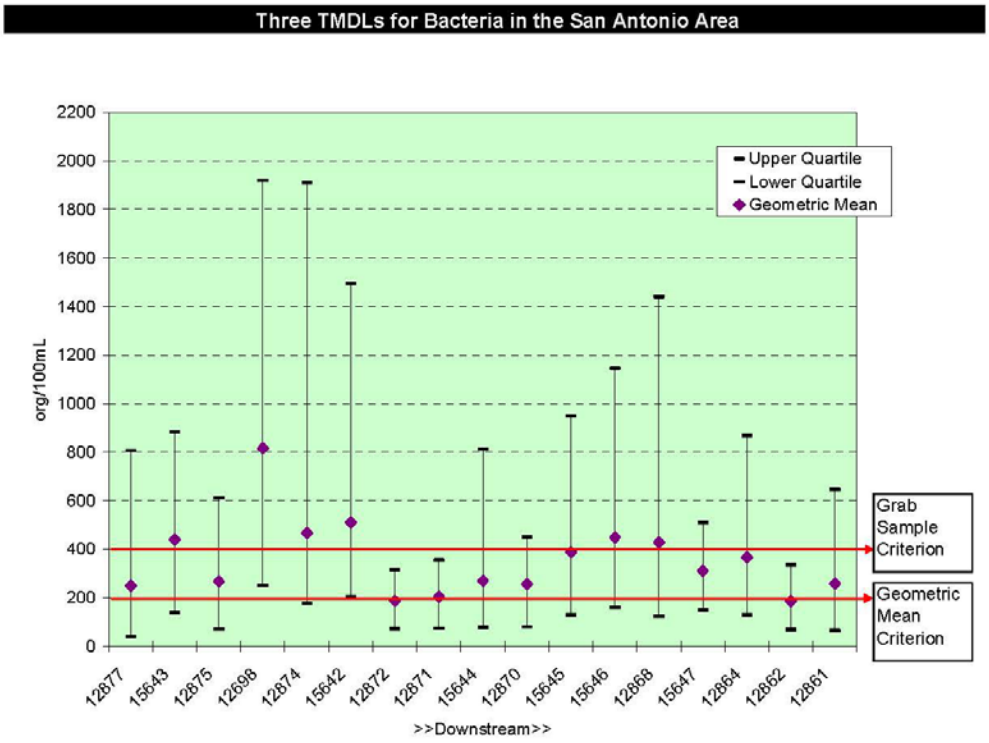

Figure 4: Fecal Coliform Sampling Results, Salado Creek

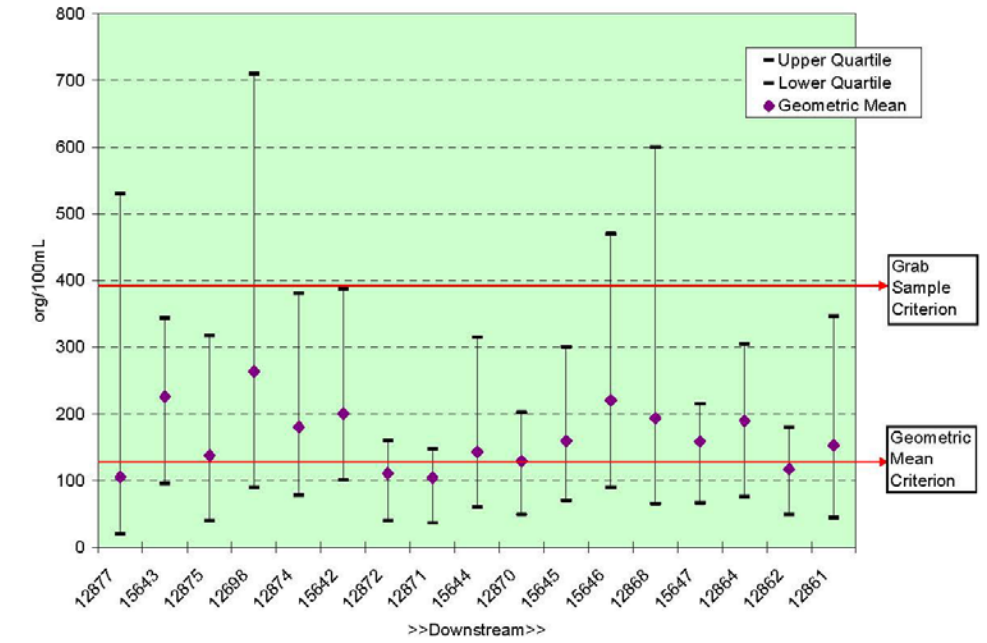

Figure 5: *E. Coli* Sampling Results, Salado Creek

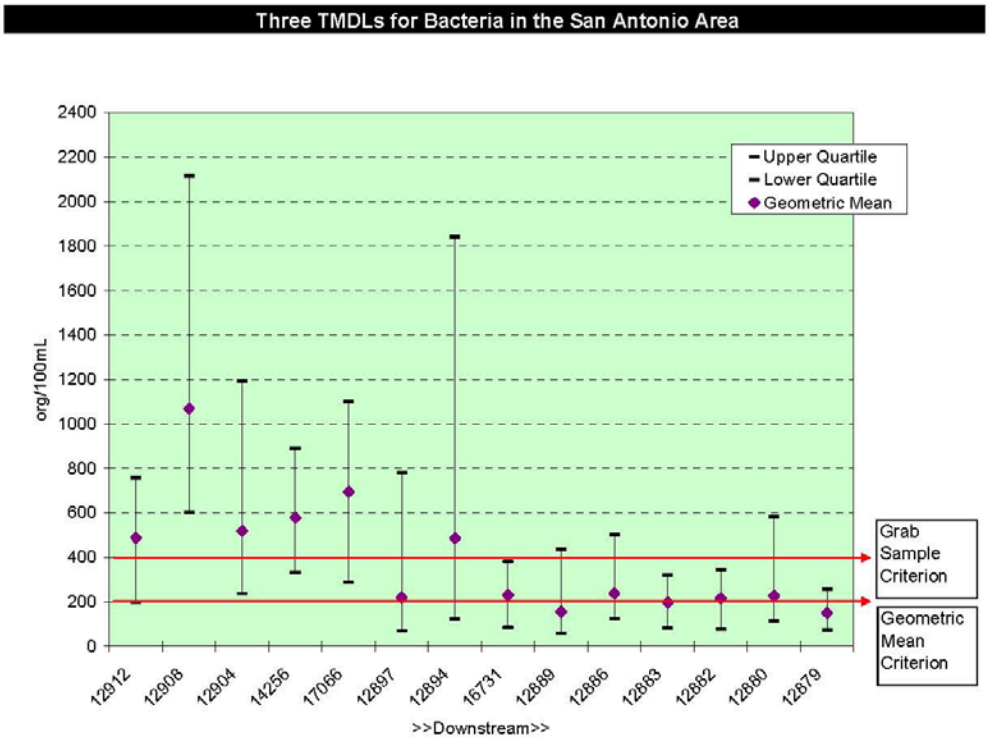

Figure 6: Fecal Coliform Sampling Results, USAR

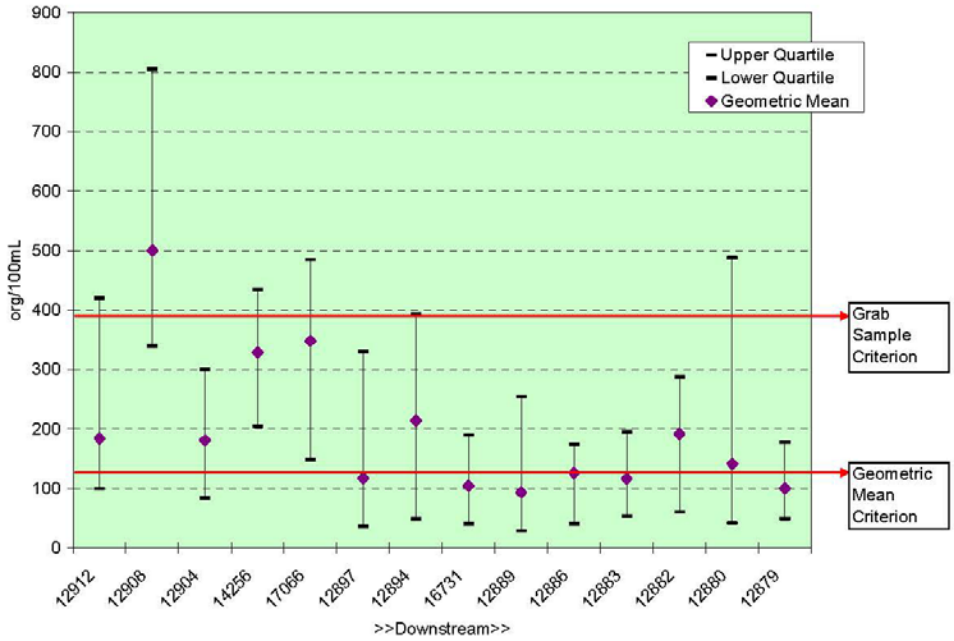

Figure 7: *E. Coli* Sampling Results, USAR

Critical Conditions

Federal law (40 CFR 130.7(c)(1)) requires that TMDLs 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 it is most vulnerable. The critical condition is considered the "worst case scenario" of environmental conditions for a particular study segment. If the TMDL is developed so that the water quality targets are met under critical conditions, then the water quality targets are very likely to be met under all other conditions.

Bacteria data for the impaired segments were analyzed for seasonal and climatic trends. In general, there were no consistent seasonal trends in the watershed. However, bacteria concentrations were found to vary significantly based on climatic conditions and were highest under runoff conditions. Therefore, periods of frequent rainfall correlated with the highest average bacteria concentrations. To quantify this effect, bacteria samples from the historical database were classified as either runoff or baseflow samples. Samples were typically classified as runoff-related if they were collected during periods of rising or rapidly receding flow. The results of this analysis are presented in Tables 3 and 4. The analysis was important for calibrating the water quality model, as well as for determining critical conditions. The analysis included fecal coliform samples, and *E. coli* samples that were converted to fecal coliform using standard multipliers.

Table 3: Hydrologic Classification of Historical Data, Salado Creek

Station	Baseflow Data		Runoff Data	
	# of Observed Data	Median of Observed Data (fecal org/100 mL)	# of Observed Data	Median of Observed Data (fecal org/100 mL)
Loop 410 - RCH 49	8	44	17	7500
SH 368 - RCH 52	39	170	21	1310
Walzem Creek - RCH 15	47	500	23	2840
Woodburn - RCH 53	40	248	26	2180
Commerce - RCH 57	42	148	27	1420
Rigsby - RCH 72	43	190	28	1760
Loop 13 - RCH 74	53	176	28	1325

Seasonal Variation

Exceedances occurred throughout the impaired segments regardless of season. Data was collected throughout various seasons. The water quality model accounts for seasonal effects by including temporal variations in climatic patterns, groundwater releases, water

temperature, and loading rates for some of the bacteria sources. Climatic variations have the greatest influence on bacteria levels in the streams, with periods of chronic wet weather typically resulting in the highest average bacteria concentrations.

Table 4: Hydrologic Classification of Historical Data, USAR

Station	Baseflow Data		Runoff Data	
	# of Observed Data	Median of Observed Data (fecal org/100 mL)	# of Observed Data	Median of Observed Data (fecal org/100 mL)
Woodlawn - RCH 62	11	820	4	4850
Mitchell - RCH 67	32	470	22	8130
Loop 410 - RCH 71	24	93	7	1140
IH 37 - RCH 78	21	90	5	1709
1604 - RCH 25	10	76	4	1010
FM 791 - RCH 28	36	95	6	1025

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, construction, and the separate storm sewer systems of cities are considered point sources of pollution. Nonpoint source pollution originates from multiple locations, usually carried to surface waters by rainfall runoff, and is not regulated by permit under the TPDES. The possible sources of bacteria in the impaired segments are discussed in this section.

Point Sources

Bacteria loading in urban storm water originates from nonpoint sources. When storm water flows into a municipal separate storm sewer system (MS4), it is then considered a point source discharge and is subject to a TPDES permit. Collective discharges from the storm sewer systems of large cities are typically considered point sources and are regulated under MS4 permits. The City of San Antonio is required to operate under such a permit, making virtually all urban runoff part of the point source load. Point sources related and unrelated to storm water are discussed in further detail in the following two sections.

Point Sources Other Than Storm Water

Point sources, such as municipal wastewater treatment facilities (WWTFs), can contribute fecal coliform bacteria loads to surface water streams through effluent discharges. These

point sources are permitted through the TPDES program managed by the TCEQ. There are several point sources located in the study watersheds that may contribute fecal coliform. These point sources are shown in Table 5, in upstream to downstream order. There may be other permitted discharges in the study area that were not included in the present analysis because of a very low likelihood that they would discharge fecal coliform bacteria. Such sources might include industrial wastewater dischargers, quarries, or facilities that operate with no-discharge permits.

In the Salado Creek watershed, there are no point sources that have a high potential for discharging bacteria. There is one discharger of reclaimed municipal effluent in the upper portion of the study area—the San Antonio Water System (SAWS) Outfall 4 in James Park. SAWS is required to maintain a chlorine disinfectant residual in releases from this distribution system, which results in very minimal bacteria concentrations. TCEQ criteria for Type I Reclaimed water require that fecal coliform concentrations do not exceed:

- 20 cfu/100 mL as a geometric mean
- 75 cfu/100 mL in single grab samples

Compliance with these criteria has been confirmed by historical monitoring data.

Table 5: Point Sources Other Than Storm Water

Point Source Description	Location
Upper San Antonio River	
SAWS Reclaimed Water Outfall #2	Breckenridge Park, near Tuleta Drive
San Antonio Zoo	Breckenridge Park, near Tuleta Drive
SAWS Reclaimed Water Outfall #3	Josephine St, near tunnel entrance
SAWS Salado Water Recycling Center	near Blue Wing Road, below Loop 410
SAWS Dos Rios Water Recycling Center	on Medina River, near confluence with SAR
Floresville WWTF	City of Floresville, near FM 536
Salado Creek	
SAWS Reclaimed Water Outfall #4	James Park, near Rittiman Road

There are several point sources in the USAR watershed. However, most of these point sources are permitted, and are required to achieve disinfection prior to discharge. There are two outfalls of reclaimed municipal effluent located in the upper portion of the watershed. A third potential outfall of reclaimed water is located near the Convention Center on the River Walk, but it has only recently been activated, and is therefore not included in this study.

Near the southern portion of the City of San Antonio, there are two municipal WWTFs—the Dos Rios and Salado facilities operated by SAWS, which have been in operation for a number of years. In the lower portion of the study segment, the Floresville WWTF discharges treated municipal effluent.

There is one facility in the USAR watershed without a permit that discharges substantial concentrations of bacteria. Representing one of the more significant existing loadings to the river, the San Antonio Zoo has an interior waterway, fed by groundwater from the Edwards Aquifer, which passes through numerous animal exhibits. This waterway has one primary and one secondary outfall, both of which discharge directly to the San Antonio River. The discharge flow rate (averaging 1700 gallons per minute) was characterized using data reported annually to the Edwards Aquifer Authority. Bacteria concentrations in the discharge were characterized using available grab sampling data from several sources, including recent sampling provided by SAWS and SARA. The average concentration leaving the Zoo was 23,100 org/100 mL from March through September 2005, and 11,800 org/100 mL from October 2005 through February 2006.

Storm Water

Much of the study area is comprised of the urban landscape of residential, commercial, and industrial areas. Storm water from urban areas is considered a point source and is regulated under TPDES permits. Bacteria from various sources build up on the land's surface and are washed off into a city's storm water system during rainfall events. These bacteria loadings may be derived from urban wildlife, pets, septic system failures, sewer system leaks, discharges of varied nature and composition, and other sources that may be present.

Nonpoint Sources

Nonpoint source (NPS) loadings enter the impaired segments from distributed, non-specific locations and are not typically regulated by permit. Nonpoint sources generally include background loads (birds and wildlife), failing septic systems, animal deposition (pets), and leaking wastewater infrastructure. Each of these sources can contribute pollutants to the stream directly or indirectly. For example, an animal may defecate over the land's surface and the resulting bacteria are available for washoff by storm water; alternatively, the animal may stand in the stream and defecate directly into the receiving water body. Figure 8 illustrates methods of nonpoint source loading.

Failing Septic Systems

Private residential sewage treatment systems (or septic systems) typically consist of one or more septic tanks and a drainage or distribution field. A septic system failure can occur in many ways. For example, drainfield failures, broken pipes, or overloading can result in uncontrolled, direct discharges to streams. Such failures would not be expected to be common in the study watershed, but they could occur in reaches with older homes located near a watercourse or in remote, undetected areas. In addition, effluent can surface from an overloaded drainfield, and the pollutants would then be available for surface accumulation and subsequent washoff under runoff conditions.

The number of septic systems in the study area was estimated using information from the 1990 US Census, which included a question regarding the means of household sewage disposal (US Census 2006). 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

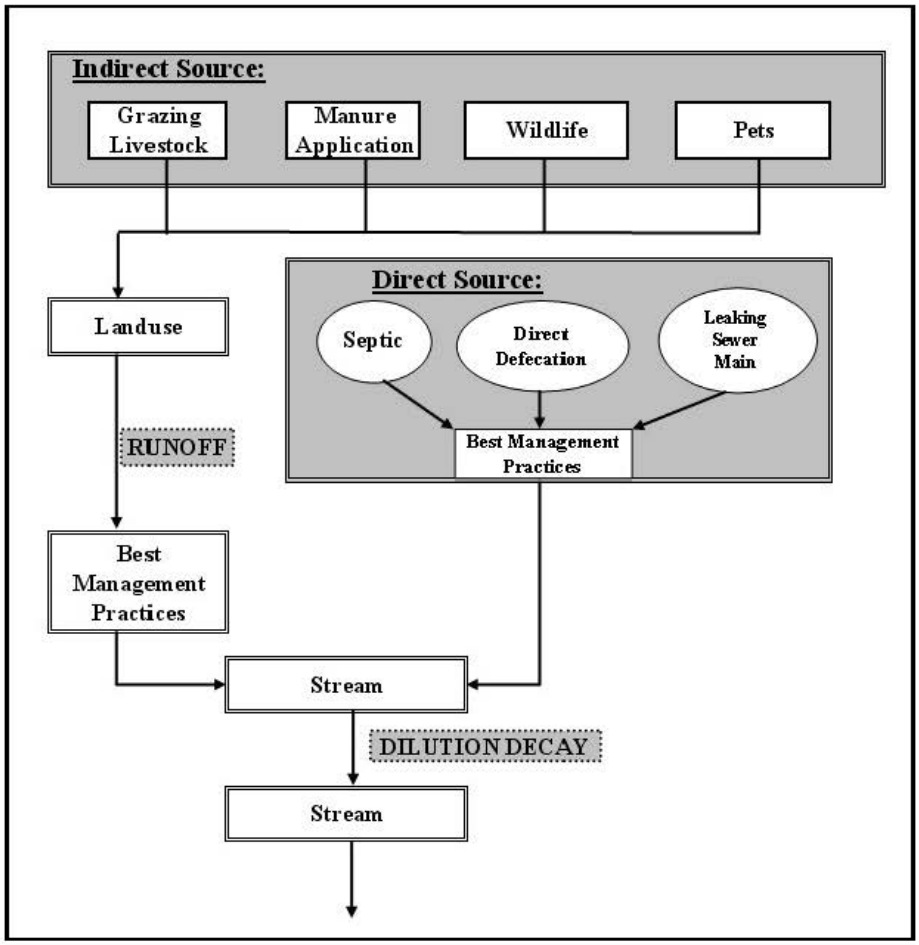

Figure 8: Methods of Nonpoint Source Loading

by intersecting the census tracts with the study area watersheds. Table 6 shows the number of septic systems in the study areas, along with the number of sewer connections and "other" types of disposal. From 1990 to 2000, the population of Bexar County grew by 17 percent and the population of Wilson County grew by 43 percent. Based on these growth rates, the number of septic systems in 2000 has been estimated at 8,910 for the USAR watershed, and 5,960 for the Salado Creek Watershed.

Table 6: Household Sewage Disposal Methods from 1990 US Census

Watershed	Septic	Sewer	Other
Salado Creek	5,094	116,662	197
USAR	7,237	208,228	874

Leaking Wastewater Infrastructure

Leaking wastewater sewer lines are difficult to detect but are potentially significant sources of bacteria, especially in highly urbanized areas where most residences are served by a central 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 are parallel. Also, sewers will typically leak if they become cracked or are improperly installed.

Livestock

Livestock population estimates for Bexar County and Wilson County were based on the 2002 Agricultural Census (USDA 2002). The types of livestock explicitly included in the present analysis included cattle, horses/donkeys, sheep/goats, and hogs. Animal population estimates are presented in Table 7. Other types of livestock had small populations compared to the major livestock species listed above; therefore, the fecal loads from these other animal groups were assumed to be negligible.

Fecal coliform bacteria production rates for livestock in the Salado Creek and Upper San Antonio River watersheds are displayed in Table 8. For the present study, all of the data regarding manure production rates and fecal coliform density were based upon values reported in the literature (EPA 2001).

Table 7: Livestock Population Estimates

Region	Cattle	Hogs	Sheep	Horses
Salado Creek	8,214	556	1,746	459
USAR	15,769	697	871	479

Table 8: Fecal Coliform Production Rates for Livestock and Wildlife

Animal	Fecal Coliform (10^9 org/day) (count/animal/day)	Animal	Fecal Coliform (10^9 org/day) (count/animal/day)
Dairy Cow	101	Turkey	0.01
Beef Cow	104	Duck	2.43
Hog	11	Opossums	0.01
Sheep	12	Deer	1
Horse	0.42	Feral Hogs	11
Chicken	0.14	Raccoon	0.13

Wildlife

Representative species of wildlife and non-indigenous pests (like feral hogs) were included in the modeling analysis as potential sources of bacteria. Of course, there are numerous other species of animals that inhabit the watershed, but the species selected in the present analysis were chosen based upon population and fecal production potential. The population of each wildlife species was developed using estimated population densities per square mile of habitat and the total area of suitable habitat available in each subwatershed. Duck habitat was based on a 300-foot riparian corridor. Habitat for other animals was based on the acreage of undeveloped land. The estimated wildlife inventory is shown in Table 9.

Table 9: Inventory of Wildlife

Region	Ducks	Deer	Raccoons	Opossums	Feral Hogs
Salado Creek	2,220	7,581	5,655	22,622	505
USAR	1,800	2,283	16,226	64,903	7,610

To support water quality modeling, a general estimate of the overall load contribution from wildlife is needed. Since wildlife populations cannot be precisely known, all loading parameters that represent wildlife were subject to adjustment in the model calibration process.

Linkage Analysis

Establishing the relationship between instream water quality targets and the source loadings of bacteria is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. The link can be established through a variety of techniques, ranging from qualitative assumptions based on scientific principles to sophisticated mathematical modeling techniques. In the development of a TMDL for Salado Creek and the USAR, the relationship was defined through computer modeling based upon data collected throughout the watershed. Monitored flow and water quality data were used to verify that the relationships developed through modeling were accurate.

The Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate existing conditions and to perform TMDL allocations. The HSPF model is a continuous simulation model for watershed hydrology and water quality. The model can account for both point source and nonpoint source loadings in the watershed. HSPF includes simulation of the receiving stream that receives mass loadings from the watershed.

In order to develop a representative linkage between the sources and the instream water quality response in the Salado Creek and USAR watersheds, model parameters were ad-

justed to accurately represent hydrology and streamflow as well as fecal coliform bacteria loading and instream concentrations. Hydrologic parameters in the model were set and adjusted based upon available soils, land use, topographic, and streamflow data.

Calibration of the water quality model entailed adjustment of bacteria-related parameters to achieve agreement of the observed in-stream fecal coliform measurements with the simulated model results. Several parameters were available for adjustment in the model. The model was calibrated for both baseflow and runoff conditions.

The bacterial loads associated with the model calibration can be readily examined in terms of load originating from the land use categories and point sources embodied in the analysis. For Salado Creek, these loads are compared graphically in Figure 9. It is apparent that the largest presumed source of fecal coliform bacteria originates in washoff from developed areas, making up about 93.9 percent of the average annual load. This is attributable to the fact that the Salado Creek Basin is highly developed. Typically, developed areas have higher runoff volumes and bacteria concentrations than undeveloped areas. However, runoff conditions are not persistent. Under baseflow, dry-weather conditions, direct nonpoint sources are the most significant load in the watershed. Although direct sources account for only about 2.44 percent of the annual average load, they have a disproportionately large effect on mean stream concentrations because they occur when there is less flow available for load dilution.

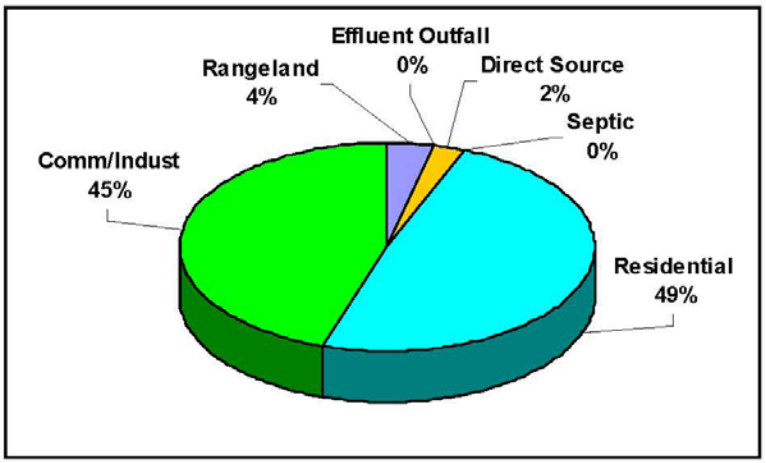

Figure 9: Comparison of Fecal Coliform Sources for Salado Creek

For the USAR, the bacterial loads associated with the model calibration are compared graphically in Figure 10. As with Salado Creek, in the USAR, it is apparent that the largest presumed source of fecal coliform bacteria is runoff from developed urban areas. The combined commercial, industrial, and residential loads account for about 68.1 percent of

the average annual load. The second largest bacterial source is the inflow from springs and streams, at about 19.4 percent of the annual load. In reality, springs account for an almost insignificant portion of this load, while loads from Salado Creek and the Medina River dominate this source category. Under baseflow conditions, the primary sources of loading are effluent outfalls at 4.3 percent and direct sources at 2.92 percent. The effluent outfall category is dominated by the load from the City Zoo.

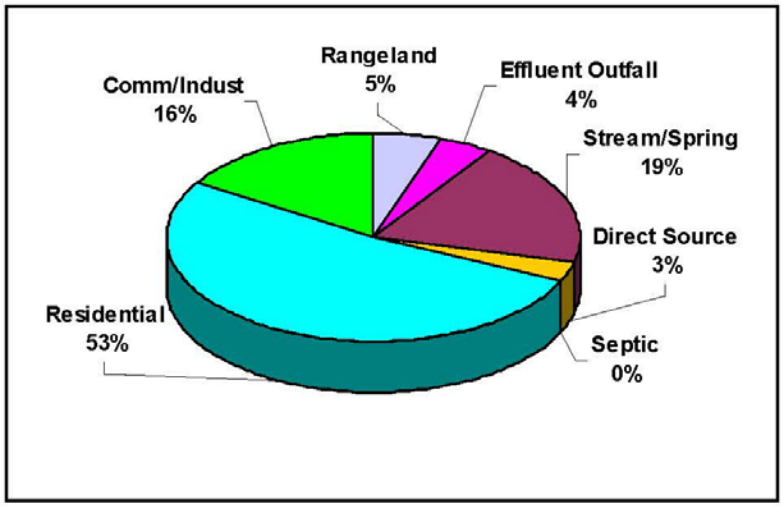

Figure 10: Comparison of Fecal Coliform Sources for the USAR

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. According to EPA guidance (EPA 1991), the MOS can be incorporated into the TMDL using two methods:

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

The TMDL target was established as a fecal coliform geometric mean value of 200 org/100 mL, based on the bacteria criterion specified in the *Texas Surface Water Quality Standards*. An explicit MOS of five percent was employed in the TMDL calculations, or 10 org/100 mL. Application of the model to the TMDL determination was therefore based on achieving an instream geometric mean of 190 org/100 mL. In addition to the explicit MOS, implicit MOS factors were incorporated into the TMDL development process through the use of conservative model assumptions and estimates of source loads.

Pollutant Load Allocation

TMDL Calculation

Total maximum daily loads (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 may be expressed as:

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

The TMDL defines the total amount of a pollutant that the receiving water body can assimilate and still support water quality standards. For fecal coliform bacteria, TMDLs are expressed in terms of bacteria counts or resulting concentrations.

The WLA portion of this equation is the total loading assigned to point sources. For the purposes of TMDL development, the WLA includes WWTFs and permitted storm water systems. Inside the City of San Antonio, virtually all storm water runoff is regulated under the City's MS4 permit.

The LA portion of this equation represents the loading assigned to nonpoint sources, which would include storm water runoff not regulated by permit (from areas outside of the City of San Antonio), direct deposition from animals, failing septic systems, and leaking wastewater infrastructure. The MOS is the portion of the loading that is assigned to represent any uncertainty in the data and the modeling process. Therefore, for development of TMDLs in areas that have regulated storm water point sources, the TMDL equation presented above would be modified as follows:

$$TMDL = \Sigma WLA_{\text{non-storm water point sources}} + \Sigma WLA_{\text{regulated storm water point sources}} + \Sigma LA_{\text{unregulated storm water and nonpoint sources}} + MOS$$

Allocation Scenario Development

Multiple applications of the HSPF model were performed to develop load reduction scenarios capable of achieving compliance with geometric mean concentration of 190 org/100 mL of fecal coliform (criterion with MOS). Results are presented below for key gauged monitoring stations in the study reaches. Results for several additional locations are presented in the TMDL modeling report (JMA 2006). Minimal exceedances (less than 1 percent of time) of the geometric mean criterion were observed at a few stations in Salado Creek under the allocation scenario. However, based on the overall results, the segment was judged to attain the contact recreation use. In the implementation phase of the TMDL, the required load reductions can be targeted toward specific locations, as determined in the I-Plan.

For Salado and Walzem Creeks, it was determined that a 90 percent reduction in direct nonpoint source loads and a 60 percent reduction in washoff loads would achieve compliance with the criterion. These reductions are prescribed only for the portion of the Salado

Creek watershed below Loop 1604 (including Walzem Creek). Figure 11 shows geometric mean results for the period of simulation at Loop 13, with and without the prescribed loading reductions.

Figure 11: 91-Day Geometric Mean Results for Salado Creek at Loop 13

Multiple applications of the HSPF model were also performed in order to develop load reduction scenarios that would result in attainment of the standards in the USAR. In the final load reduction scenario, a 99.9 percent reduction (complete disinfection) of the Zoo's discharge is prescribed. In addition, a 50 percent reduction in direct nonpoint loads from all reaches and a 30 percent reduction in washoff loads from reaches above the confluence with Salado Creek would be required to meet the criterion. Figures 12 and 13 show the geometric mean results for the period of simulation and illustrate the prescribed loading reductions for the USAR at Mitchell and at FM 541.

Wasteload Allocations

Wasteload allocations are determined for point sources. For the purposes of TMDL development, these point sources include effluent discharges from permitted wastewater treatment facilities, permitted storm water runoff, and other point sources. Wasteload allocations are summarized in Table 10.

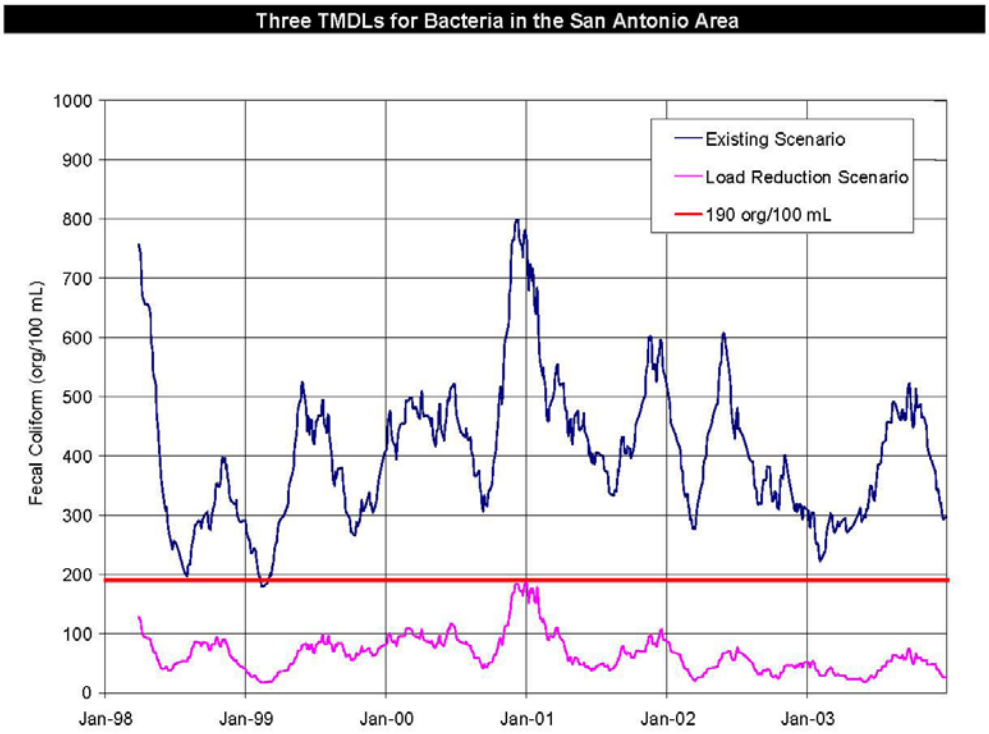

Figure 12: 91-Day Geometric Mean Results for USAR at Mitchell

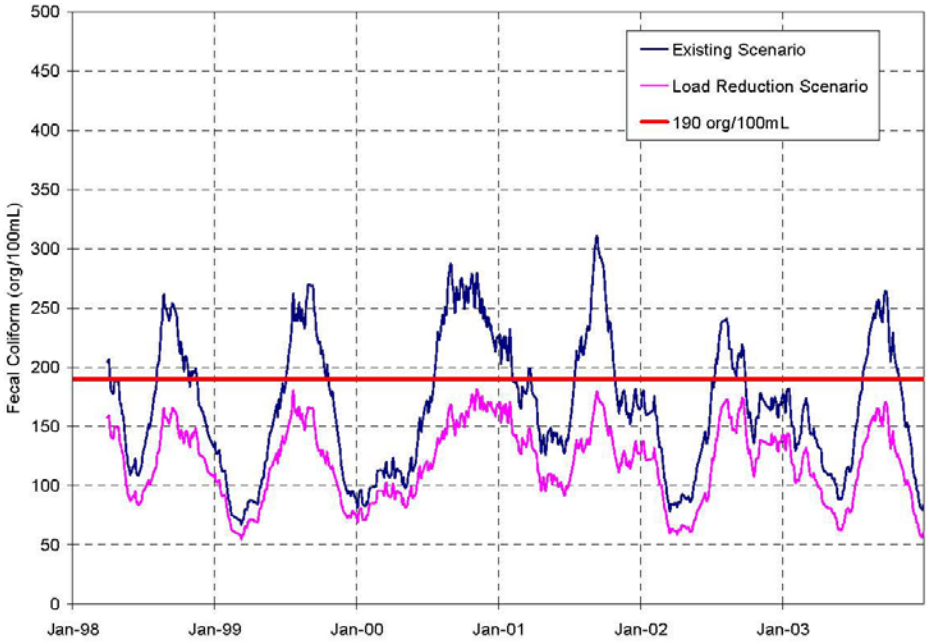

Figure 13: 91-Day Geometric Mean Results for USAR at FM 541

Salado and Walzem Creeks

For Salado and Walzem Creeks, the only significant point sources are the washoff loads from the City of San Antonio's MS4. These runoff-related loads require a 60 percent reduction. In addition, one relatively minor point source, the SAWS reclaimed water outfall #4, is located in James Park just below Rittiman Road. This discharger is required to maintain a disinfectant residual in its effluent. Therefore, the bacteria loading associated with the discharge is expected to be relatively low; this has been confirmed by historical monitoring data. Therefore, no reduction is required at this outfall.

Upper San Antonio River

As with Salado and Walzem Creek, the greatest point sources of bacteria in the USAR segment are the washoff loads from the City of San Antonio's storm sewer system (Central Zone). These runoff-related loads have been prescribed at a 30 percent reduction.

There are several municipal point sources in the watershed. Three of these outfalls are operated by SAWS. Since these outfalls are required to maintain a disinfectant residual, bacterial counts at these discharges would be expected to be relatively low; this was confirmed by available monitoring data. In the lower reaches of the study segment, there is a domestic WWTF operated by the City of Floresville. Assuming that permit effluent meets its disinfection requirements, bacterial loads should be relatively low at this location as well. Therefore, no reductions were required for municipal outfalls.

There is one other major point source in the upper reach of the San Antonio River for which a WLA reduction has been calculated. The San Antonio Zoo continually releases a large volume of water from interior water features that have high bacterial counts. The modeling analysis indicated that this point source discharge had a dramatic affect on bacterial counts in the study area under non-runoff conditions, as shown for station #12908, Woodlawn Avenue (Table 2). As a result, a substantial WLA reduction was prescribed in order to achieve the TMDL target. The calculated WLA for the zoo is based on achieving complete disinfection during baseflow conditions (99.9 percent bacteria removal).

Notably, the SAWS Dos Rios Water Recycling Center (WRC) is not included in Table 10 because it is located on the Medina River, not the USAR. This facility would be considered part of the upstream load from the Medina River, which is included as a Load Allocation. However, because the facility is required to achieve disinfection, bacteria loads are considered minimal.

Load Allocations

Load allocations for nonpoint sources generally include background loads, upstream loads, storm water runoff not subject to permit, septic loads, and other direct nonpoint sources such as direct animal deposition and leaking wastewater infrastructure. A summary of the recommended load allocations is presented in Table 11. In general, greater reductions were required in Salado and Walzem Creeks than in the USAR. This is generally a result of higher base flows in the USAR (from natural springs, zoo flows, and

SAWS reclaimed water outfalls). These higher base flows allow for more dilution of direct loads, and thus provide the USAR with a higher assimilative capacity.

Table 10: WLAs for Point Source Fecal Coliform Loads in Study Areas

Segment	Point Source	Existing Load (10^6 org/day)	Reduction %	WLA (10^6 org/day)
Salado Creek	San Antonio MS4	11,827,718	60%	4,731,088
	SAWS Reclaimed 4	19	0	19
	Subtotal	***11,827,740***		***4,731,107***
Walzem Creek	San Antonio MS4	331,611	60%	132,644
	Subtotal	**331,611**		**132,644**
USAR	San Antonio MS4	24,745,068	30%	17,321,548
	San Antonio Zoo	1,704,110	99.9%	1,704
	SAWS Salado WRC	7,562	0	7,562
	SAWS Reclaimed 2	175	0	175
	SAWS Reclaimed 3	19	0	19
	Floresville WWTF	19	0	19
	Subtotal	***26,456,953***		***17,331,027***

Salado and Walzem Creeks

For Salado Creek and Walzem Creek, a 90 percent reduction in direct nonpoint sources is required to achieve compliance with bacteria criteria, as shown in Table 11. The estimated loads from septic systems are relatively insignificant, as formulated in the modeling analysis, and have not been assigned a load allocation. However, it is possible that septic systems have been under-represented in the analysis and it could be surmised that a portion of the direct source reduction could be directed at septic loads.

The LA for Salado Creek and Walzem Creek is presented in Table 11. It includes only a portion of the bacteria available for washoff that make it to a stream. The TMDL presented in Table 12 is expressed as a gross load; it includes all quantifiable sources available for washoff in the watershed.

Upper San Antonio River

The required load reductions for the USAR are presented in Table 11. A 50 percent reduction in direct nonpoint sources is required for all reaches. No washoff reduction is required outside the Central Zone (MS4 permit area). In addition, a 60 percent reduction has been assigned to the load from Salado Creek. This reduction will be achieved if the loading reductions prescribed for the Salado Creek TMDL are achieved. Loads from the Medina River are also significant, but do not require reduction because these loads are the

result of large flow volumes, not high bacteria concentrations, and it has been determined that the Medina River is not impaired by bacteria.

As with Salado Creek, the estimated loads from septic systems are relatively insignificant, and have not been assigned a load reduction. However, it is possible that septic systems have been under-represented in the analysis and it could be surmised that a portion of the direct source reduction could be directed at septic loads.

Table 11: LAs for Nonpoint Source Fecal Coliform Loads in Study Areas

Segment	Nonpoint Source	Existing Load (10^6 org/day)	Reduction %	LA (10^6 org/day)
Salado Creek	Direct Sources	295,614	90%	29,562
	Septic Systems	1,140	0	1,140
	Subtotal	***296,753***		***30,701***
Walzem Creek	Direct Source	3,403	90%	340
	Septic Systems	8	0	8
	Subtotal	***3,411***		***348***
USAR	Washoff (outside MS4)	4,404,425	0%	4,404,425
	Direct Sources	1,162,918	50%	581,460
	Septic Systems	16,732	0	16,732
	Salado Creek	4,218,356	60%	1,705,863
	Medina River	3,501,918	0	3,501,918
	Springs	10,668	0	10,668
	Subtotal	***13,315,019***		***10,221,066***

TMDL Summary

Table 12 summarizes the TMDL fecal coliform loading allocations for Salado Creek, Walzem Creek, and the USAR. Each of these TMDLs was developed with a similar approach. The WLA includes all of the allocated point sources, including permitted urban storm water. The LA is comprised of washoff sources, direct nonpoint sources, septic sources, and various background sources. The MOS is calculated as 5 percent of the TMDL.

The proposed TMDL for fecal coliform is also expected to be protective for Texas water quality criteria related to *E. coli*. The criteria ratio of 0.63 (126/200 = 0.63) was applied to convert fecal coliform to *E. coli*. The actual ratio of observed fecal coliform to *E. coli* concentrations for stations with 10 or more pairs of data in Salado Creek (average of 0.56) and the Upper San Antonio River (average of 0.60) was reasonably close to the assumed *E. coli* to fecal coliform criteria ratio (0.63). Therefore, use of the criteria ratio (0.63) has been applied to all TMDLs. A TMDL to achieve compliance with a fecal coliform concentration of 190 org/100 mL should be protective for an *E. coli* concentration of

120 org/100 mL (190 x 0.63 = 120). This is below the corresponding *E. coli* geometric mean criterion of 126 org/100 mL. Table 13 shows the TMDL summary expressed as *E. coli* loadings.

Table 12: Summary of Fecal Coliform TMDL for Impaired Reach (10^6 org/day)

Segment #	Segment Name	WLA	LA	MOS	TMDL
1910	Salado Creek	4,731,107	30,701	250,622	5,012,430
1910A	Walzem Creek	132,644	348	7,000	139,995
1911	USAR	17,331,027	10,221,066	1,450,110	29,002,203

Table 13: Summary of *E. coli* TMDL for Impaired Reach (10^6 org/day)

Segment #	Segment Name	WLA	LA	MOS	TMDL
1910	Salado Creek	2,980,597	19,342	157,890	3,157,833
1910A	Walzem Creek	83,567	219	4,411	88,195
1911	USAR	10,918,548	6,439,271	913,570	18,271,389

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. The project team also recognized that communication and comments from the stakeholders in the watershed would strengthen the project and its implementation.

In accordance with requirements of law promulgated in 2001 under Texas House Bill 2912, an official steering committee was established and 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 members were formally invited to attend. To ensure that absent members and the public were informed of past meetings and pertinent material, a project web page was established to provide meeting summaries, presentations, ground rules, and a list of steering committee members at <www.tceq.state.tx.us/implementation/water/tmdl/34-sanantonio_group.html>.

Throughout the term of the project, from 2002 to 2005, four meetings were held in San Antonio. At each meeting the project team received and responded to a number of questions and comments. The objectives of the first meeting in September of 2002 were to:

- Introduce the project team and summarize the public participation process.
- Define what the project was intended to accomplish.
- Provide historical monitoring data, information, issues, and potential sources.

The objectives of the second stakeholders meeting in August of 2003 were to:

- Inform the stakeholders on the status of work being performed on the project.
- Provide information on prior data assessment.
- Provide information on supplemental sampling results.
- Discuss the next phases.

The objectives of the third stakeholders meeting in February of 2005 were to:

- Inform the stakeholders on the status of work being performed on the project.
- Provide information on monitoring results.
- Update stakeholders on preliminary modeling results.
- Discuss the next phase.

The objectives of the fourth stakeholders meeting in August of 2005 were to:

- Inform the stakeholders on the status of work being performed on the project.
- Provide information on modeling results.

Implementation and Reasonable Assurances

The TMDL development process involves the preparation of two documents:

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

During TMDL development, the TCEQ determines the acceptable pollutant load for impaired water bodies and apportions the load among broad categories of pollutant sources in the watershed. This information is summarized in a TMDL report such as this document.

During TMDL implementation, the TCEQ develops the management strategies needed to restore water quality to an impaired water body. This information is summarized in an implementation plan (I-Plan) which references, but is separate from, the TMDL document. The I-Plan details load reduction and other mitigation measures planned to restore water quality in an impaired water body.

The TCEQ is committed to developing I-Plans for all TMDLs adopted by the commission and to ensuring the plans are implemented. I-Plans are critical to ensure water quality standards are restored and maintained. They are not subject to EPA approval.

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.

As part of the TMDL process, a watershed protection plan (WPP) is being developed to outline actions that will be taken to reduce bacteria loading from the urban portion of the USAR (above Loop 410). The WPP, funded by EPA through the TCEQ, has provided valuable resources and information to stakeholders, including:

- a forum for stakeholders to meet and reach consensus on the measures necessary to reduce bacterial loads in the basin.
- investigation of best management practices and treatment alternatives for bacterial sources in the San Antonio area.
- additional water quality monitoring to determine the magnitude and location of sources of bacteria.
- water quality model enhancements to improve model resolution and to reflect data gathered during the WPP process.

The WPP can be used as the basis for development of the I-Plan for the USAR. Furthermore, some of the best management practices and treatment alternatives investigated for the WPP will also be applicable to Salado and Walzem Creeks.

Additional sampling at appropriate locations and frequencies will allow progress toward the targeted and primary endpoints to be tracked and evaluated. These steps will provide reasonable assurances that the regulatory and voluntary activities necessary to achieve the pollutant reductions will be implemented.

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 (EPA 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

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 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 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 (EPA 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.

References

Ashworth, J., J. Hopkins 1995. Report 345: Aquifers of Texas. Texas Water Development Board. Austin, Texas.

EPA 1991. Guidance for Water Quality-Based Decisions: The TMDL Process. <www.epa.gov/OWOW/tmdl/decisions/>.

EPA 2001. Bacterial Indicator Tool: User's Guide. EPA-823-B-01-003. Office of Water. Washington, D.C.

EPA 2002. November 22, 2002 Memorandum from EPA Relating to Establishing TMDL WLAs for Storm Water Sources.

EPA 2006. August 2, 2006 Memorandum from EPA Relating to Clarifications on TMDL Revisions.

JMA 2006. Modeling Report for Bacteria TMDL Development: Salado Creek, Segment 1910; Walzem Creek, Segment 1910A; Upper San Antonio River, Segment 1911. Work Order #4. Report to the TMDL Section, TCEQ, Austin, Texas.

JMA and PES 2002. Historical Water Quality Data Assessment, Project Area 2 - Basins Groups D&E Bacteria Impairments. Report to the TMDL Section, TCEQ, Austin, Texas.

TAC 2006. Texas Association of Counties web site: County Profiles. <www.txcip.org/tac/census/CountyProfiles.php>.

TCEQ 2000. Texas Water Quality Inventory and 303(d) List. <www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/305_303.html>.

TCEQ 2000. Texas Surface Water Quality Standards, 2000 update, 30 TAC 307. <www.tceq.state.tx.us/permitting/water_quality/wq_assessment/standards/WQ_standards_2000.html>.

TSHA 2001. The Handbook of Texas Online. Texas State Historical Association. <www.tsha.utexas.edu/handbook/online/>.

U.S. Census 2006. Online census data for 1990, 2000. US Census Bureau.

USDA 2002. Census of Agriculture. Volume 1, Chapter 2: Texas County Level Data. <www.nass.usda.gov/census/census02/volume1/tx/index2.htm>.

USEPA 2002. Memorandum. Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs. November 22, 2002 (Robert H. Wayland, III to Water Division Directors).

USEPA 2006. Memorandum. Clarification Regarding "Phased" Total Maximum Daily Loads. August 2, 2006 (Benita Best-Wong to Water Division Directors).