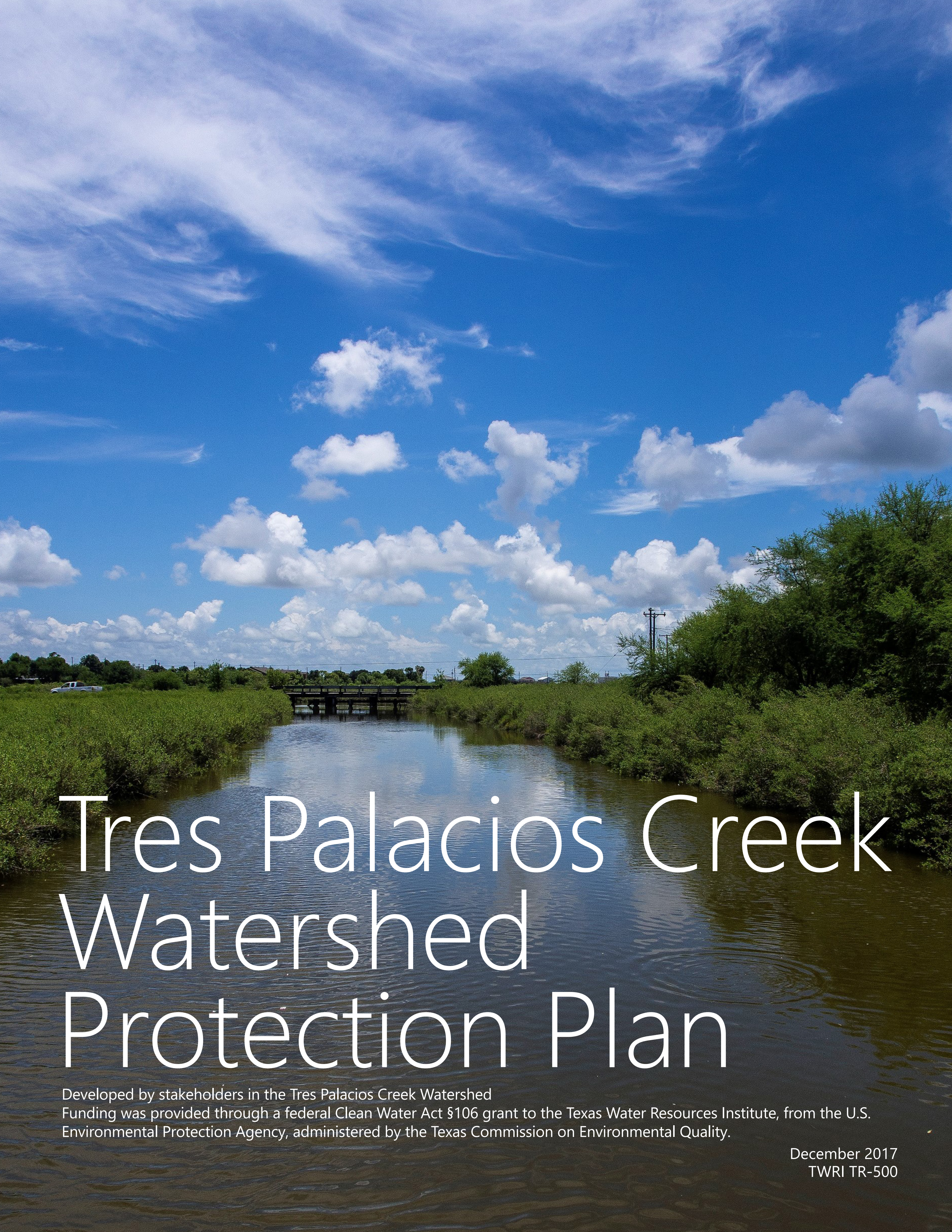

Tres Palacios Creek Watershed Protection Plan

Developed by stakeholders in the Tres Palacios Creek Watershed

Funding was provided through a federal Clean Water Act §106 grant to the Texas Water Resources Institute, from the U.S. Environmental Protection Agency, administered by the Texas Commission on Environmental Quality.

December 2017
TWRI TR-500

Tres Palacios Creek Watershed Protection Plan

Developed by the stakeholders in the Tres Palacios Creek watershed

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Funding was provided through a federal Clean Water Act §106 grant to the Texas Water Resources Institute, from the U.S. Environmental Protection Agency, administered by the Texas Commission on Environmental Quality.

Cover photo: Unnamed tributary to Tres Palacios Bay, by Michael Schramm, TWRI

Acknowledgments

The Tres Palacios Creek Watershed Protection Plan (WPP) presents the strategy developed by the stakeholders of the Tres Palacios Creek watershed to restore water quality in Tres Palacios Creek such that it meets applicable water quality standards. The Tres Palacios Creek watershed stakeholders dedicated considerable time and effort in discussing the watershed, its influences on water quality, potential means to improve the watershed and water quality, and in selecting management strategies appropriate for inclusion in the watershed plan.

Special appreciation is extended to the many landowners and residents of the watershed who attended the many meetings and events to provide direct input to the plan. With the rural nature of the watershed, input from private landowners and residents was critical to ensure the plan included recommendations that not only address the issues facing the watershed, but that those measures could also feasibly be implemented by landowners and residents. The time and efforts of these landowners is greatly appreciated and is reflected in the contents of this plan.

Agency support and input was an integral part of the Tres Palacios Creek WPP development process. The technical guidance and willingness to provide specialized knowledge of many subjects is very much appreciated. Agencies contributing to the development of the Tres Palacios Creek WPP include:

- Texas A&M AgriLife Extension Service
- Texas A&M AgriLife Research
- Texas Commission on Environmental Quality
- Texas Institute for Applied Environmental Research
- Texas Parks and Wildlife Department
- Texas State Soil and Water Conservation Board
- USDA Natural Resources Conservation Service

Local government organizations also played a key role in plan development. Representatives provided insight regarding their specific focus areas and ensured inclusion of content in the plan is appropriate for the watershed. These organizations include:

- AgriLife Extension County Agents
- El Campo City Manager
- El Campo Public Works Department
- El Campo Utilities Department
- Matagorda County Judge
- Matagorda County SWCD Board Members
- Wharton County Judge and Commissioners
- Wharton County SWCD Board Members

Wilson Creek at FM 1095.

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List of Abbreviations

Acronym	Meaning
ac	Acre
AgriLife Extension	Texas A&M AgriLife Extension Service
AI	Adaptive Implementation
AU	Assessment Units
An.U	Animal Units
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
CCN	Certificate of Convenience and Necessity
cfu	Colony Forming Unit
cfs	Cubic Feet Per Second
CHAMP	County Hog Abatement Matching Program
CIG	Conservation Innovation Grants
CRP	Clean Rivers Program
CSP	Conservation Stewardship Program
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund
CZM	Coastal Zone Management Program
CZMA	Coastal Zone Management Act
DO	Dissolved Oxygen
ECHO	Enforcement and Compliance History Online
EDAP	Economically Distressed Areas Program
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FBMB	Farm Business Management and Benchmarking
ft	Feet
FDC	Flow Duration Curve
Gal	Gallon
GIS	Geographic Information System
I/I	Inflow and Infiltration
in	Inch
LDC	Load Duration Curve
LULC	Land Use and Land Cover
MGD	Million Gallons per Day
mg/L	Milligrams per Liters
ml	Milliliter
MS4	Municipal Separate Storm Sewer System
MSL	Mean Sea Level

Acronym	Meaning
NASS	National Agricultural Statistics Service
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NIFA	National Institute of Food and Agriculture
NIWQP	National Integrated Water Quality Program
NLCD	National Land Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
OSSF	On-Site Sewage Facility
PUC	Public Utility Commission of Texas
RCPP	Regional Conservation Partnership Program
RUS	Rural Utilities Service
SARE	Sustainable Agriculture Research & Education
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SEP	Supplemental Environmental Projects
SSO	Sanitary Sewer Overflow
SWCD	Soil and Water Conservation District
SWMP	Stormwater Management Plan
TCEQ	Texas Commission on Environmental Quality
TDA	Texas Department of Agriculture
TEEX	Texas A&M Engineering Extension Service
GLO	Texas General Land Office
TPWD	Texas Parks and Wildlife Department
TRWA	Texas Rural Water Association
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
TMDL	Total Maximum Daily Load
TWON	Texas Well Owners Network
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility
yr	Year

Executive Summary


Tres Palacios Creek at County Road 438.

Tres Palacios Creek is a rural coastal Texas water body that drains a watershed that is home to generations of farmers, ranchers, small businesses, and various communities. The Tres Palacios Creek watershed drains approximately 268 square miles of mainly rural and agricultural land. Tres Palacios Creek, which starts near the town of El Campo, meanders generally south through Wharton and Matagorda counties before draining into Tres Palacios Bay and the Matagorda Bay System. Along the way, Tres Palacios Creek provides an important water resource for agriculture, livestock, wildlife, businesses, and residents.

Problem Statement

Water quality monitoring conducted by the Texas Commission on Environmental Quality (TCEQ) indicated that fecal indicator bacteria levels are often above the state's recreational water quality standard. Furthermore, 24-hour dissolved oxygen (DO) monitoring indicated that average and minimum DO levels fall below state water quality standards. As a result, the tidal portion of Tres Palacios Creek was listed as impaired for elevated bacteria and depressed DO in the 2014 Texas 303(d) List. With the impairment listing comes a need to plan and implement corrective actions to restore instream water quality and ensure a safe, healthy Tres Palacios Creek for residents and visitors. To meet this need, an assessment and planning project was undertaken to develop the Tres Palacios Creek Watershed Protection Plan (WPP).

Action Taken

An extensive review of the watershed's land and water resources was carried out, enabling stakeholders to be provided with up-to-date information on watershed characteristics and uses. Potential sources of bacteria pollution were identified and quantified based on data from local, state, and federal databases as well as local stakeholder knowledge. Data were integrated into several simplistic watershed models to determine the types and sources of impairment-causing pollutants in the watershed with the highest potential to impact water quality.

Tres Palacios Creek Watershed Protection Plan Overview

This document is a culmination of an extensive stakeholder process to identify sources of pollution in the watershed and to develop a plan to mitigate loadings through the voluntary implementation of management measures described within. By comprehensively considering the multitude of potential pollutant sources in the watershed, this plan describes management strategies that, when implemented, will reduce pollutant loadings in the most cost effective manner available at the time of planning. Despite the extensive amounts of information gathered during the development of this WPP, a better understanding of the watershed and the effectiveness of management measures will undoubtedly develop. As such, this plan is a living document that will evolve as needed through the adaptive management process.

Pollutant Sources

Stakeholder input, backed by credible science, was used to identify potential sources of fecal-derived bacteria pollutants and DO depressing nutrient pollutants. Sources of bacteria loadings identified in the watershed, in decreasing order of their relative estimated contributions, include: cattle, household pets, deer, on-site sewage facilities (OSSFs), feral hogs, horses, wastewater treatment facilities (WWTFs), and urban runoff. While other sources of fecal-derived bacteria are likely present in the watershed, available information was not sufficient to reliably estimate loadings. The nutrient loading potential from these sources were also quantified.

Recommended Actions

To mitigate pollutant loadings from the identified sources, nine primary recommended actions were made. Individual recommendations are crafted to deal with bacteria and nutrient pollution but in many cases will have ancillary effects on other pollutants as well. Briefly, these actions are as follows:

Cattle

The management of bacteria and nutrient loadings from cattle and other livestock sources rely on the voluntary implementation of site-specific conservation plans. These plans include technical assistance to aid in better managing resources while also protecting water quality and, in some cases, can provide financial assistance. These plans can include a variety of best management practices (BMPs), such as brush management, critical area planting, range and pasture planting, livestock water wells, shade structures for livestock, cross fencing, rotational grazing, and others. Education and outreach are also needed to deliver pertinent information to producers on the water quality impacts of good resource management. Education and outreach not only imparts knowledge but promotes the increased implementation of BMPs.

Feral Hogs

Feral hog management in the watershed will consist of both active and passive controls. Management of water, shelter, and food resources can modify hog behavior and encourage them to move elsewhere. However, feral hogs are a nuisance throughout the watershed. Therefore, watershed landowners will continue to trap and remove hogs voluntarily with assistance from various agencies through their control actions. Education also provides critical support in the efforts to control feral hogs and aid in the tracking of the number of hogs removed.

OSSFs

Failing OSSFs, in particular those in close proximity to water bodies, have been known to contribute to water quality impairments in watersheds all over the state. OSSF management measures seek to identify, document, and prioritize the replacement of failing OSSFs in critical areas within the watershed. The delivery of education and outreach programs will assist residents in the proper operation and maintenance of OSSFs and provide information on available financial assistance options.

Illicit Dumping

Although not quantified, stakeholders identified illicit dumping as a potential concern at bridges and stream crossings throughout the watershed. The goal is to reduce illicit dumping by working with Matagorda County to identify useful resources and equipment, and outreach and education efforts and programs for residents that would ultimately decrease the amount of dumping throughout the watershed.

Urban Stormwater

Urbanized areas make up a relatively small portion of the total watershed. However, with expected increases in population within municipalities in counties throughout Texas, prioritization of stormwater management planning, BMPs, and strategies is needed to control bacteria runoff in the future. By working with municipalities in the watershed with the preparation of stormwater planning and strategies, the plan can ensure bacteria and nutrient loadings are adequately addressed. Planning and prioritizing areas where urban stormwater demonstration projects can be implemented can directly reduce bacteria and nutrient loadings from reaching Tres Palacios Creek. The delivery of education programs to residents can also increase the adoption of BMPs at private residences and educate home owners about the connection between urban runoff and water quality.

Pet Waste

The reduction of bacteria and nutrients reaching Tres Palacios Creek from unmanaged pet waste relies on the delivery of education and outreach materials to pet owners and by providing pet waste stations and clean-up bags to pet owners in areas of high pet density. Reductions from this management measure are difficult to quantify due to the dependence on changes in behavior by pet owners. However, because pet waste can potentially contribute a relatively high amount of loading, minor changes in behavior might result in significant reductions.

Wastewater Treatment Facilities

WWTFs are subject to regulatory discharge requirements issued by the TCEQ. However, voluntary measures from municipalities and WWTFs can result in direct reductions in bacteria and nutrient loadings. The goal of WWTF management measures are to assist the City of El Campo with implementing wastewater reuse with effluent from the municipal WWTF and to work with area WWTFs to identify and replace aging infrastructure that contribute to sanitary sewer overflows (SSOs).

Education and Outreach

Providing continued education and outreach to watershed stakeholders is a continual need. These events provide critical platforms for the delivery of new or improved information to stakeholders that will enable them to improve aspects of their operations and land management while simultaneously enhancing instream water quality. As evidenced by the integration of education into the recommended actions described above, education will be a mainstay of implementing the Tres Palacios Creek WPP. Stakeholder meetings held as needed and supplemented with topically relevant education and outreach events will be critical in maintaining local interest in WPP implementation and provide a needed local platform for conveying and illustrating implementation successes.

Tracking Progress

Effectively tracking and communicating WPP implementation progress and success is also critical. Periodic water quality monitoring conducted at selected sites will be gaged against water quality benchmarks established in the plan. This monitoring will serve as the primary measure of WPP implementation success. The numbers of practices implemented, events held, people in attendance at events and other measures described in the plan will also document success. Collectively, this information will feed into the adaptive management process and be used to redirect the WPP should implemented practices not produce anticipated water quality improvements.

Goals of the Plan

The goal of the WPP and purpose for implementing recommended practices is to restore water quality in the tidal portion of Tres Palacios Creek through long-term conservation and stewardship of the watershed's resources. Bacteria reduction goals [water quality target of 33 colony forming units (cfu)/100 milliliters (mL)], increases in average DO concentration [water quality target of 5 mg/L (milligrams per liter)] and increases in minimum DO concentration (water quality target of 4 mg/L) were developed to be achieved after a five-year implementation phase. Interim reduction and programmatic goals were developed to serve as milestones and progress indicators after implementation begins. Ultimately, this plan sets forth an approach to improve stewardship of the watershed resource that allows stakeholders to continue relying on the watershed as their livelihood while also restoring the quality of its water resources.

The plan also hopes to help meet outstanding conditions for the state's Coastal Nonpoint Source Pollution Control Program as set forth in Section 6217 of the Coastal Zone Management Act. Since the majority of the impairment on Tres Palacios Creek falls within the coastal zone, the plan will also work to mitigate malfunctioning OSSFs and reduce runoff pollutant concentration and volumes from entering into the creek and coastal zone.

Chapter 1
Watershed Management

Trull Marsh, Palacios, Texas.

Objective

Enterococcus bacteria are found in the intestinal tract and waste of warm-blooded animals and are used as an indicator for the presence of disease-causing pathogens in the water body. The TCEQ *Enterococcus* standard for waters classified as primary contact recreation is 35 cfu/100 mL. Water quality sampling in the tidal portion of Tres Palacios Creek indicated geometric mean *Enterococcus* bacteria concentrations over 67 cfu/100mL.

Fish, shellfish and the benthic macro- and micro-organisms that feed larger fauna all require sufficient DO. DO refers to the amount of oxygen available for aquatic organisms to use for respiration within water. The current TCEQ standard for average 24-hour DO in the tidal portion of Tres Palacios Creek is 5 mg/L and the standard for minimum 24-hour DO is 4 mg/L. Water quality sampling from September 2003 through November 2004 indicates that Tres Palacios Creek fell below these criteria in at least 10 percent of the assessed data.

The objective of the Tres Palacios Creek WPP is to reduce bacteria loadings, increase DO levels, and attain water quality standards established by the state of Texas for Tres Palacios Creek. The WPP, developed by stakeholders in the watershed, identifies pollutant sources, the types and amount of management measures estimated as needed to meet the water quality standards, prioritizes sections of the watershed to implement management measures, identifies sources of financial and technical assistance needed to implement the plan, and outlines how progress will be tracked.

Definition of a Watershed

A watershed is composed of a "land area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ocean." Any land surface surrounding the water body is considered a part of the watershed. These land surfaces, ranging in size from small geological features to large portions of a country, contribute to the water system during runoff and rainfall events. For example, several smaller watersheds combine to form the Tres Palacios Creek watershed, which is a part of the Colorado-Lavaca River Basin.

Watershed and Water Quality

Water quality and quantity within a watershed is affected by both natural processes and human activities. Runoff initially begins as surface or subsurface water flow from a rainfall event in a land area ranging from agricultural, industrial and urban to undeveloped. Runoff water may contain pollutants from different land management practices it crossed as it flowed to the creek. A WWTF can also release directly into a water body, emitting contaminants. To effectively identify and manage different pollutants entering a watershed and water body, potential contaminants are classified as either originating from point or nonpoint source pollution.

Point Source Pollution

Point source pollution is discharged from a defined point or location, such as a pipe or a drain, and can be traced to a single point of origin. Such pollution is typically directly discharged into a water body and contributes to the water body's flow. Point sources of pollution that are permitted to discharge their effluent within specific pollutant limits must hold a permit through the Texas Pollutant Discharge Elimination Systems.

Nonpoint Source Pollution

Pollution that comes from a source that does not have a single point of origin is defined as nonpoint source (NPS) pollution. The pollution is generally composed of pollutants that are carried by runoff in stormwater during rain events. Runoff traveling across land can pick up natural and human-related pollutants. The types and concentrations of pollutants that are found in a water body will indicate the water quality and suitable uses for the water, such as for irrigation, drinking, or recreational contact.

Benefits of a Watershed Approach

The watershed approach is widely accepted by both state and federal water resource management and environmental protection agencies to facilitate water quality management. Assessing the sources and causes of water quality impairments in a watershed assists in developing and implementing watershed management plans. By determining a watershed based on landscape boundaries rather than political boundaries, potential pollution sources can be better identified and targeted. It is critical and necessary for the success of a watershed management plan to involve watershed stakeholders in this process. Watershed stakeholders are defined as individuals who live, work, or engage in recreation in the watershed and are affected by efforts to address water quality issues. The continuous involvement and efforts of stakeholders can assist in selecting, designing, and implementing management methods to improve the water quality of the targeted water body.

Watershed Protection Planning

The United States Environmental Protection Agency (EPA) developed nine key elements, which are designed to provide guidance for the development of an effective WPP. Plans are developed by watershed stakeholders to ultimately restore and/or protect water quality by voluntary, non-regulatory water resources management. The Tres Palacios Creek WPP describes the measures and opportunities for stakeholders to collaborate and for individuals to implement voluntary management efforts and programs to restore and protect the water quality of the water body.

Adaptive Management

Adaptive management consists of developing a natural resource management strategy to facilitate decision-making based on an ongoing, science-based process. Such an approach includes results of continual testing, monitoring, evaluating applied strategies, and revising management approaches continuously to incorporate new information, science, and societal needs (EPA 2000). Adaptive management promotes flexibility for the stakeholders in their decision-making process to account for uncertainty and to improve the performance of specific management measures (Williams et al. 2009). Using the process of adaptive management will help to implement strategies to address pollutant loadings and to promote efforts to understand further uncertainties in the watershed.

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Williams, B.K., Szaro, R.C., Shapiro, C.D. 2009. Adaptive management: the U.S. Department of the Interior Technical Guide. Washington D.C.: The U.S. Department of the Interior, Adaptive Management Working Group. Retrieved September 7, 2011, from: <https://www2.usgs.gov/sdc/doc/DOI-%20Adaptive%20ManagementTechGuide.pdf> .

Chapter 2
Watershed Characterization

Cotton field, Matagorda County.

Introduction

This chapter describes the current conditions of the Tres Palacios Creek watershed. A comprehensive characterization of the watershed's current land uses and land cover, soil types, climate, surface water and groundwater resources, and potential pollutant sources are required to reliably assess pollutant loads and potential management measures to address pollutant sources. Development of the information presented within this chapter relied heavily on state and federal data resources as well as local stakeholder knowledge.

Watershed Boundaries

Tres Palacios Creek is located along the Texas Gulf Coast, midway between the cities of Victoria and Houston. It is comprised of two segments: the upstream segment is designated as "Above Tidal (Segment 1502)" and the downstream segment is designated as "Tidal (Segment 1501)" (Figure 2.1). Segment 1502 flows from the crossing of US Highway 59 in Wharton County to a point 1.0 km (0.6 miles) upstream of the confluence of Wilson Creek in Matagorda County, where Segment 1501 begins and flows to the outlet into Tres Palacios Bay (TCEQ 2012a). At its mouth, Tres Palacios Creek drains approximately 268 square miles in Matagorda (64 percent of the watershed) and Wharton (36 percent of the watershed) counties (Table 2.1).

Table 2.1. County area within the Tres Palacios Creek watershed.

County	Area within watershed (sq mi)	Percent of watershed
Wharton	96.48	36%
Matagorda	171.52	64%
Total	268	100%

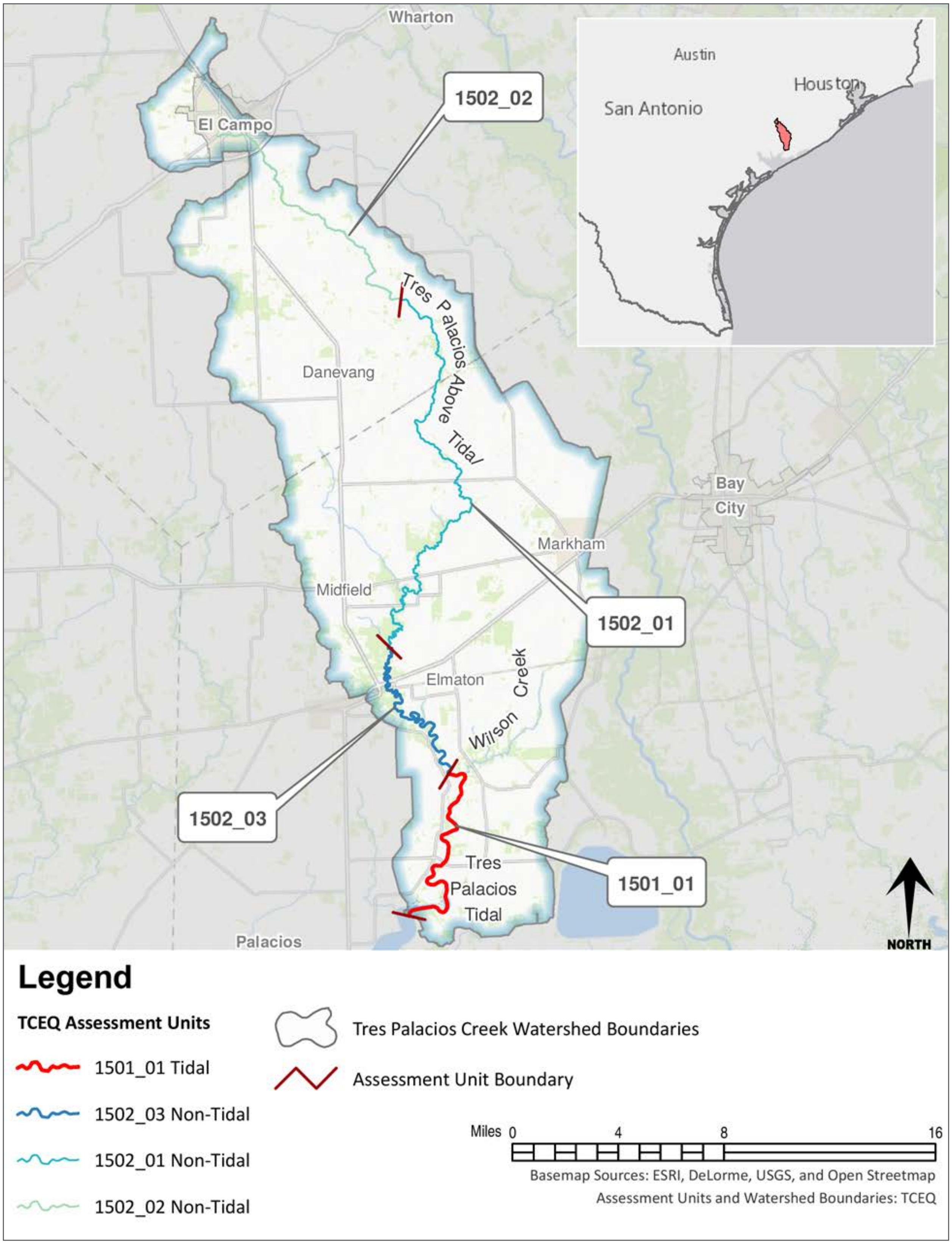

Figure 2.1. Overview map of the Tres Palacios Creek watershed and TCEQ assessment units (AUs) within Tres Palacios Creek. Sources: Assessment units (TCEQ 2011).

Topography

The watershed is characterized by low relief. Elevation ranges from approximately 115 feet (ft) above mean sea level (MSL) in the upper portions of the watershed to near sea level at the watershed outlet. The mean elevation of the watershed is approximately 55 ft above MSL. Slope ranges from 0 to approximately 22 percent with a mean average slope of less than 1 percent. Figure 2.2 depicts the elevation of the Tres Palacios Creek watershed as derived from USGS National Elevation Dataset (NED) images (2013).

Soils

Soils within the Tres Palacios Creek watershed, categorized by their Hydrologic Soil Group, are shown in Figure 2.3. Within the Tres Palacios Creek watershed, approximately 98 percent of the soils are high in clay and classified in Hydrologic Soil Group D, and therefore have the following characteristics: a high runoff potential when thoroughly wet, restricted water movement though the soil, and a high shrink-swell potential [Natural Resources Conservation Service (NRCS) 2007]. Along portions of the Tres Palacios Creek tidal segment (1501_01) occur soils classified within Hydrologic Soil Group C; these soils have a moderately high runoff potential when thoroughly wet (NRCS 2007).

Climate

This watershed lies within the subtropical humid sub-climate in Wharton and Matagorda counties. Measurements taken at the Danevang 1W weather station note that daily peak average high temperatures occur in August where they reach 93.5°F. Daily low averages bottom out in January at 41.5°F. In Danevang, the wettest month is typically September (average of 5.1 inches (in) for the month), while the driest month is generally February (average 2.8 in for the month), though rainfall typically occurs year-round [National Oceanic and Atmospheric Administration (NOAA 2015)]; (Figure 2.4). Annual pan evaporation within the watershed averages 50.1 in.

Ecoregions

Ecoregions are land areas with ecosystems that contain similar quality and quantity of natural resources (Griffith et. al. 2004). Ecoregions have been delineated into four separate levels; level I is the most unrefined classification, while level IV is the most refined. The Tres Palacios Creek watershed is located in the Level III Ecoregion 34, known as the Western Gulf Coastal Plain. It is subdivided into the Level IV ecoregion 34a, known as the Northern Humid Gulf Coastal Prairie (Figure 2.5). The Northern Humid Gulf Coastal Prairie ecoregion spreads through coastal portions of Louisiana and Texas. Landscape in the area is mostly flat with some gently rolling slopes. Soils are predominantly clay, causing poor drainage in this ecoregion. Grassland is the predominant vegetation type; however, much of the prairie grasslands have been converted to ranchland, cropland, and urban and industrial areas.

Tres Palacios Creek.

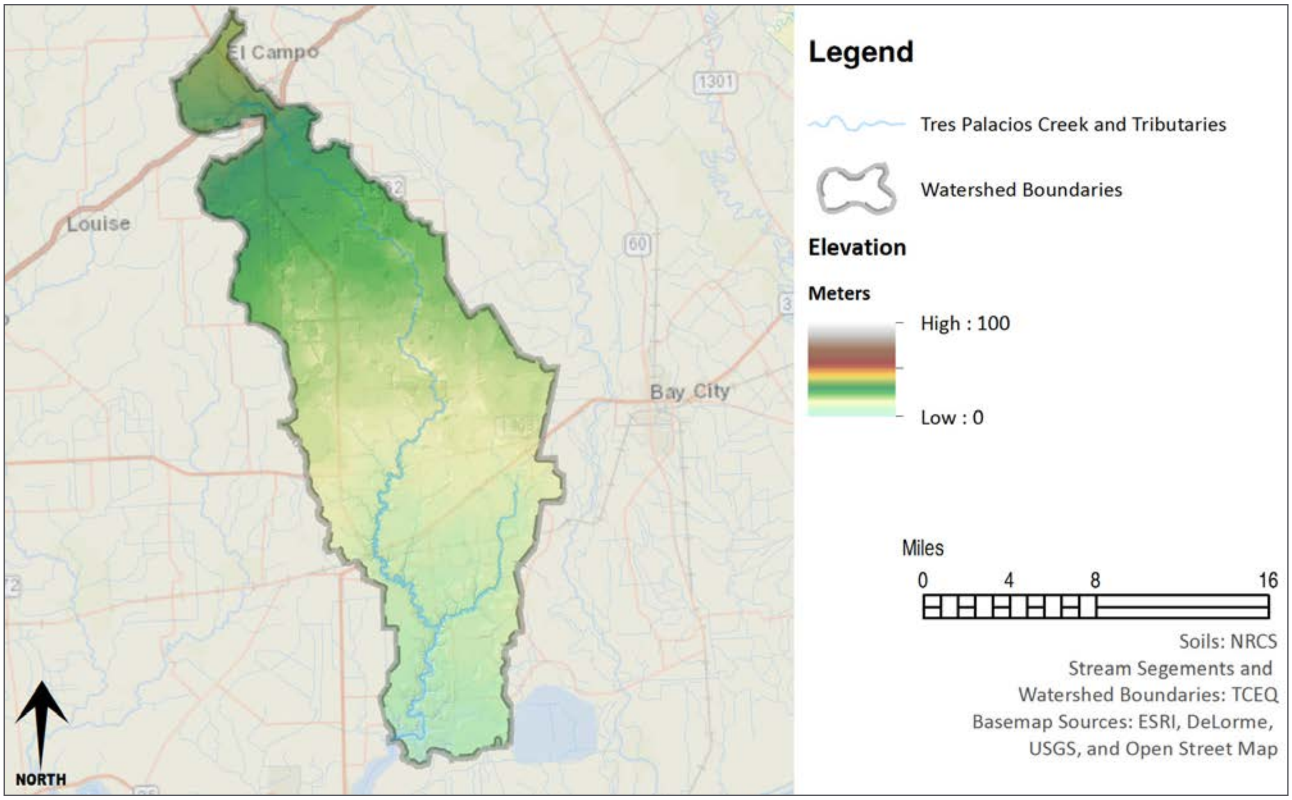

Figure 2.2. Elevation of the Tres Palacios Creek watershed. Source: 1/3 arc second NED (USGS 2013).

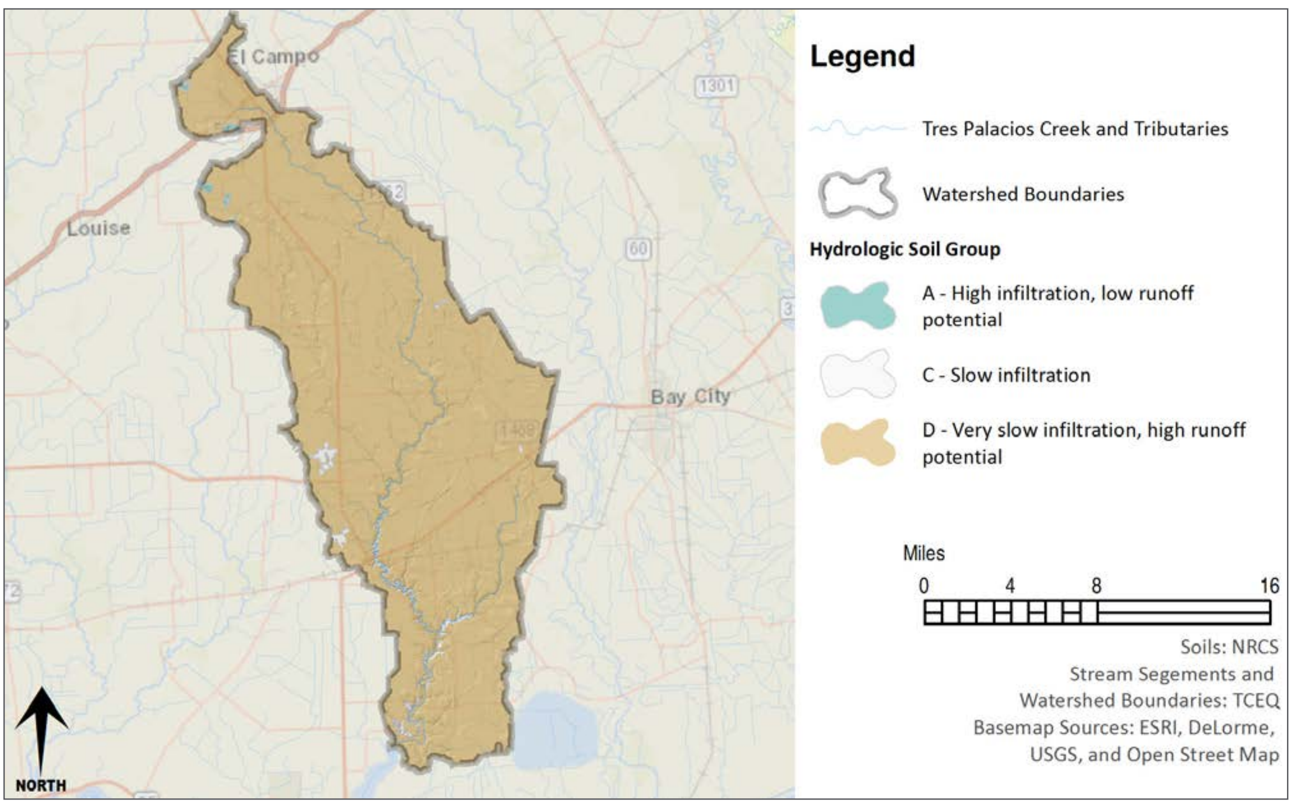

Figure 2.3. Hydrologic Soil Groups in the Tres Palacios Creek watershed. Source: (NRCS 2013a; NRCS 2013b).

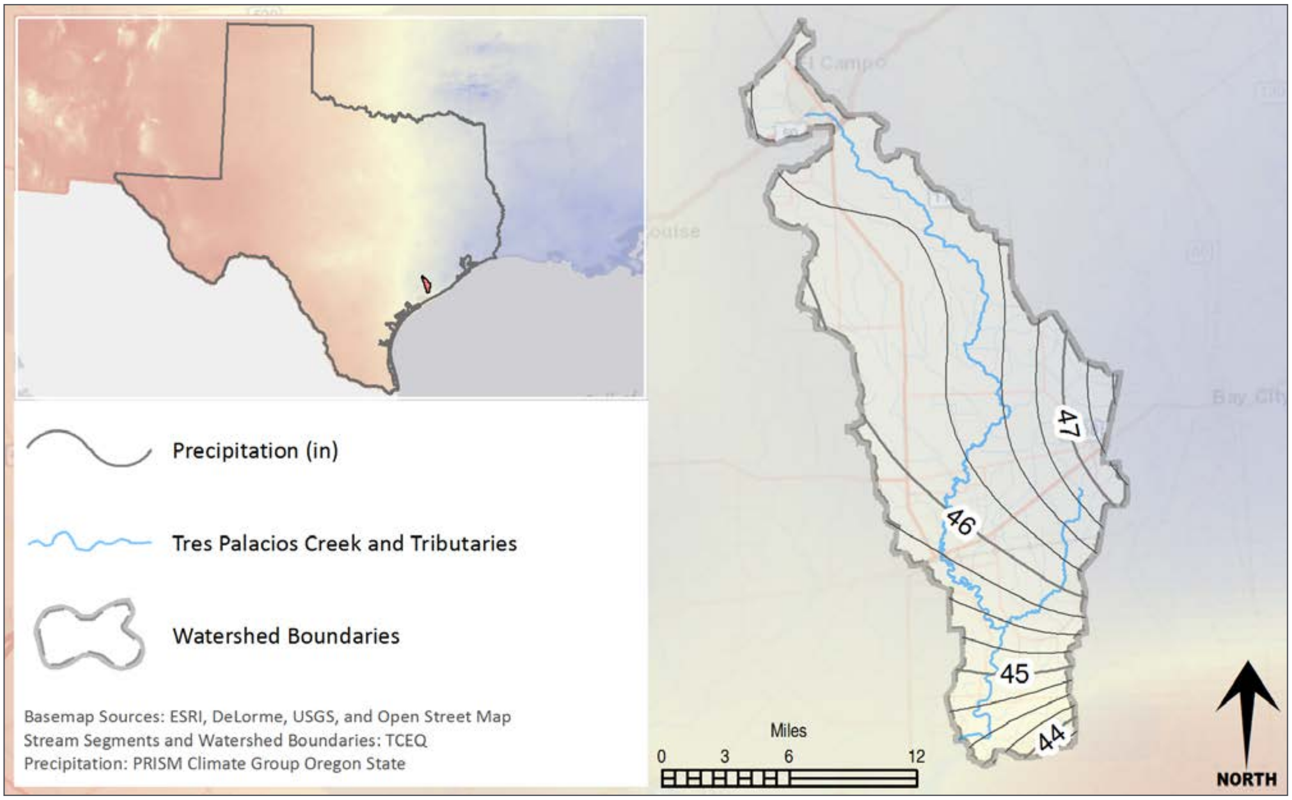

Figure 2.4. Annual average precipitation (in) in the Tres Palacios Creek watershed from 1981 through 2010. Source: (PRISM Climate Group 2016).

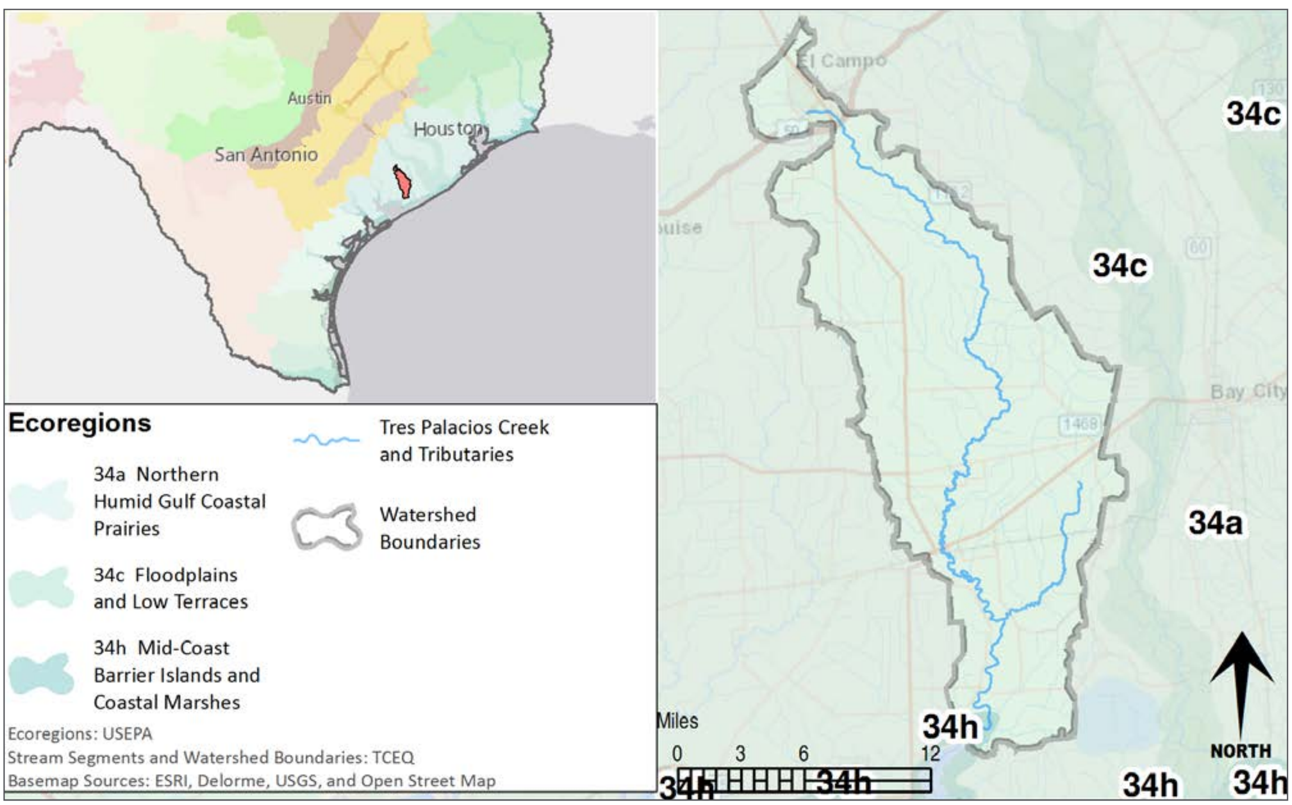

Figure 2.5. Ecoregions of the Tres Palacios Creek watershed. Source: (EPA 2012).

Land Use and Land Cover

The land use/land cover (LULC) data for the Tres Palacios Creek watershed were obtained from the U.S. Geological Survey (USGS) 2011 National Land Cover Database (NLCD) and are displayed in Figure 2.6. The NLCD determined that Cultivated Crops (52.5 percent) is the predominant land use in Above Tidal and Tidal segments of the watershed. The watershed is predominantly rural in land-use; around 6 percent of the area is classified as Developed (open space, low intensity, medium intensity, and high intensity). Table 2.2 illustrates the type of land uses within the watershed, as well as their corresponding percentage of land that each land use covers.

Unregulated Nonpoint Sources

Unregulated sources of indicator bacteria and nutrients are generally nonpoint and can emanate from wildlife, feral hogs, various agricultural activities, agricultural animals, land application fields, urban runoff not covered by a permit, failing OSSFs, and domestic pets.

Table 2.2. Land Use Land Cover (LULC) within the Tres Palacios Creek watershed. Source: NLCD (USGS 2014).

2011 NLCD	**Tres Palacios Creek**	
Classification	**mi²**	**% of Total**
Open Water	1.5	0.6%
Developed, Open Space	11.8	4.4%
Developed, Low Intensity	3.0	1.1%
Developed, Medium Intensity	1.1	0.4%
Developed, High Intensity	0.4	0.1%
Barren Land	0.2	0.1%
Deciduous Forest	2.8	1.0%
Evergreen Forest	5.8	2.2%
Mixed Forest	2.3	0.8%
Shrub/Scrub	10.1	3.8%
Herbaceous	3.0	1.1%
Hay/Pasture	78.6	29.3%
Cultivated Crops	140.9	52.5%
Woody Wetlands	4.6	1.7%
Emergent Herbaceous Wetlands	2.4	0.9%
Total	**268.5**	***100%***

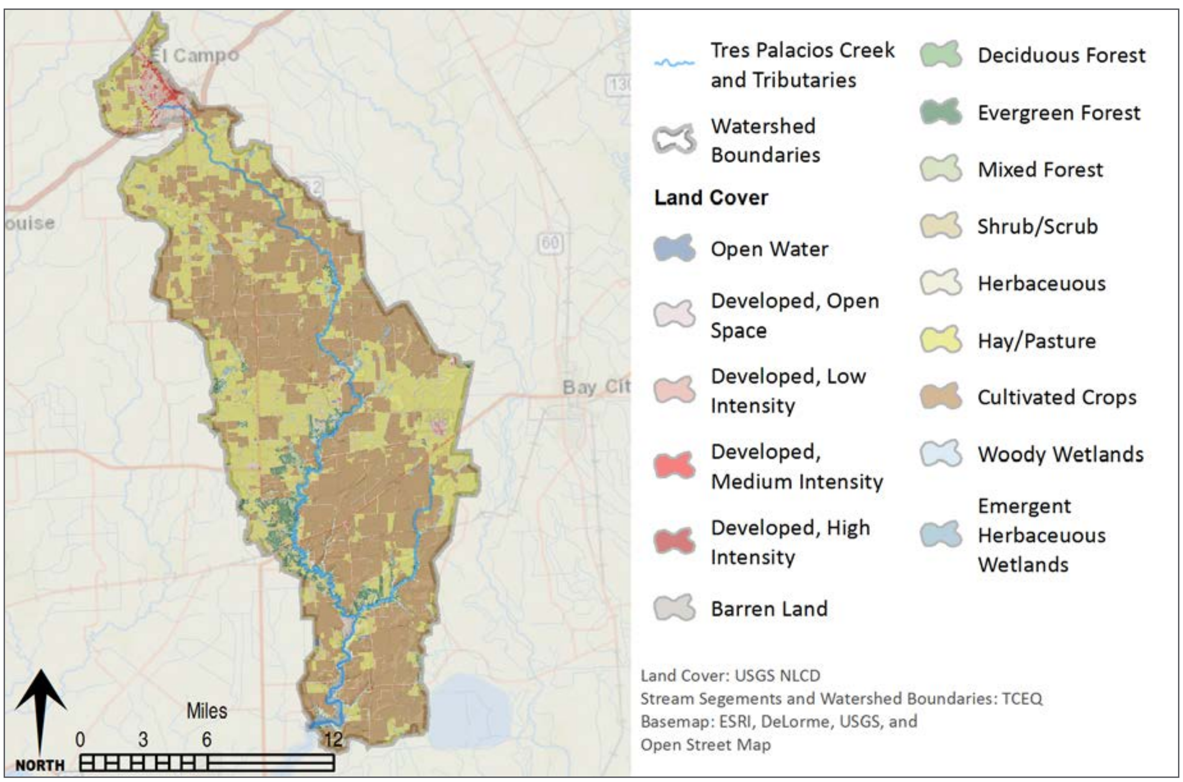

Figure 2.6. LULC within the Tres Palacios Creek watershed. Source: NLCD (USGS 2014).

Wildlife and Unmanaged Animal Contributions

Fecal indicator bacteria such as *Enterococci* and *E. coli* are common inhabitants of the intestines of all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria Total Maximum Daily Loads (TMDLs), it is important to identify by watershed the potential for bacteria contributions from wildlife. Fecal wastes can also contribute nutrients in the form of ammonia, nitrite, nitrogen, and phosphorus. Wildlife are naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria and nutrient loading to a water body. Fecal bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff.

Quantitative estimates of wildlife are rare, inexact, and often limited to discrete taxa groups or geographical areas of interest so that even county-wide approximations of wildlife numbers are difficult or impossible to acquire; however, population estimates for feral hogs and deer, as well as many species of birds, are readily available for the Tres Palacios Creek watershed.

A population estimate for feral hogs was derived using a density rate of 33.3 acres (ac)/hog, an estimate used by Wagner and Moench (2009) in the proximate Copano Bay watershed. When applied to the total acreage of hay/pasture, cultivated crops, shrub/scrub, herbaceous, deciduous forest, evergreen forest, mixed forest, woody wetlands, and emergent herbaceous wetlands identified in 2011 NLCD data, an estimate of 4,856 feral hogs was generated for the watershed.

For deer, local Texas Parks and Wildlife Department (TPWD) biologists communicated an approximate density of 19 ac/deer for the watershed. Applying this density to hay/pasture, cultivated crops, shrub/scrub, herbaceous, deciduous forest, evergreen forest, mixed forest, woody wetlands, and emergent herbaceous wetlands resulted in an estimated 8,435 deer.

For birds, the Cornell Lab of Ornithology and the National Audubon Society maintain an online database (eBird 2015) that provides bird abundance and distribution information at a variety of spatial scales. A query of Wharton and Matagorda counties reveals that there have been 352 species of birds observed within the last five years. Querying "abundance" data by county for the last full year (2014) and summing the number of individuals by month indicates that there were over 500,000 individual birds observed in Matagorda County and over 100,000 individual birds observed in Wharton County in 2014.

Non-Permitted Agricultural Activities and Domesticated Animals

Livestock grazing, primarily cattle, occurs throughout the watershed on managed pastures and rangeland. Estimates of cattle and horse populations were derived based on stakeholder and workgroup input. For cattle, an average stocking rate of 5 ac/cattle was applied to pasture and rangelands throughout the watershed, resulting in an estimated 13,131 head of cattle within the watershed. For horses, the total number was derived from the U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) data for Matagorda and Wharton counties (USDA 2014). For each county, the total number of horses, was multiplied by the percentage of the county occupied by the watershed. This methodology resulted in an estimate of 327 horses.

Domestic Pets

Fecal matter from dogs and cats is transported to streams by runoff in both urban and rural areas and can be a potential source of bacteria loading. American Veterinary Medical Association (AVMA) estimates of 0.584 dogs per household and 0.638 cats per household were used to calculate watershed-wide pet populations (AVMA 2012). AVMA estimates were multiplied by the total number of households identified through county 911 address locations within the watershed. This resulted in an estimate of 6,370 total pets.

On-site Sewage Facilities

The Tres Palacios Creek is a predominately rural watershed. As a result, a large number of residences use an OSSF. Typical designs consist of (1) one or more septic tanks and a drainage or distribution field (anaerobic system) or (2) aerobic systems that have an aerated holding tank and often an above-ground sprinkler system for distributing the liquid. In simplest terms, household waste flows into the septic tank or aerated tank, where solids settle out. The liquid portion of the water flows to the distribution system which may consist of buried perforated pipes or an above-ground sprinkler system.

Using 911 address data filtered to remove households in incorporated or wastewater treatment service areas and visually validated to remove obvious non-residential structures, it is estimated that 1,490 OSSFs occur in the watershed (Figure 2.7). 95 percent of these systems are found on "very limited" soil types where there is a 15 percent expected failure rate.

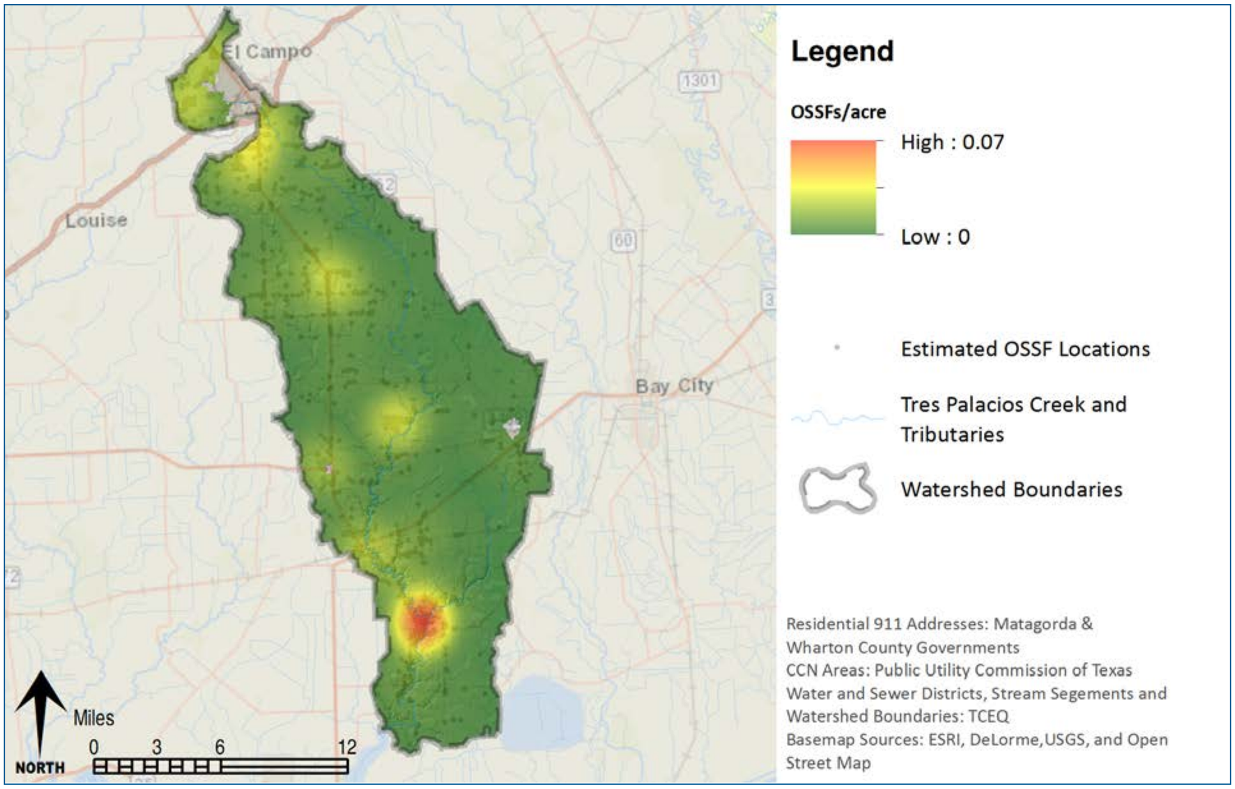

Figure 2.7. Estimated OSSF locations and density within the Tres Palacios Creek watershed. Sources: Certificate of Convenience and Necessity (CCN) Sewer Areas (Public Utility Commission of Texas (PUC) 2014), Water District Spatial Data (TCEQ 2015).

Illegal Dumping

Stakeholders identified illegal dumping as a potential source of bacteria in the watershed. Dumping of animal carcasses in or next to streams can directly contribute bacteria to the watershed. Illegal dumping of residential waste could feasibly contribute bacteria, as well as the illegal dumping of septic waste. However, locations and frequency of occurrences is currently unknown.

Permitted Discharges

Domestic and Industrial Wastewater Treatment Facilities

Four permitted WWTFs operate within the watershed (Figure 2.8). The City of El Campo WWTF, Midfield WWTF, and the Markham Municipal Utility District WWTF treat domestic wastewater. These facilities and their permitted requirements are outlined in Table 2.3. The Apex Matagorda LLC facility does not have a bacteria monitoring requirement and is not included in the table. According to EPA's Enforcement and Compliance History Online database (ECHO), one violation for elevated bacteria and two violations for exceeding daily average discharge have been reported for watershed WWTFs since 2013 (EPA 2016). However, no formal enforcement actions were taken. Generally, levels of bacteria and nitrogen are well below state standards and daily average flows are well below permitted limits.

Table 2.3. Permitted domestic and industrial WWTFs with bacteria and nutrient requirements in the Tres Palacios Creek watershed according to the EPA ECHO database (reporting period January 2013 - December 2015).

Facility Name	Permitted Flow [million gallons per day (MGD)]	Reported Flow (3-year (yr) mean MGD)	*E. coli* Limit (cfu/ 100mL)	Reported *E. coli* (cfu/ 100mL)	Nitrogen Limit (mg/L)	Phosphorus Limit (mg/L)[1]	Reported Phosphorus (mg/L)	Number of Quarters in Violation from 01/2013 – 12/2015
City of El Campo WWTF	2.62	1.03	126 Daily Avg. 399 Single Grab	3.81	2.0 Daily Avg. 7.0 Daily Max.	N/A	N/A	5 (2 reporting, 1 nitrogen exceedance, 2 dissolved oxygen (DO) exceedance, 1 *E. coli* exceedance)
Markham MUD WWTF[2]	0.3	0.08	126 Daily Avg. 399 Single Grab	1.13	N/A	N/A	N/A	1 (1 reporting)
Midfield WWTF[2]	0.03	0.01	126 Daily Avg. 399 Single Grab	N/A	N/A	N/A	N/A	4 (1 suspended solids exceedance, 2 flow exceedance, 3 residual chlorine exceedance)
Apex Matagorda Energy Center[3]	0.223	N/A	N/A	N/A	N/A	N/A	N/A	N/A

[1] Watershed facilities do not currently have phosphorus monitoring or effluent concentration requirements.
[2] The Markham MUD WWTF and Midfield WWTF do not have nitrogen effluent concentration limits in current permits.
[3] Apex Matagorda Energy was permitted to treat wastes with a compressed air energy storage facility but was never constructed.

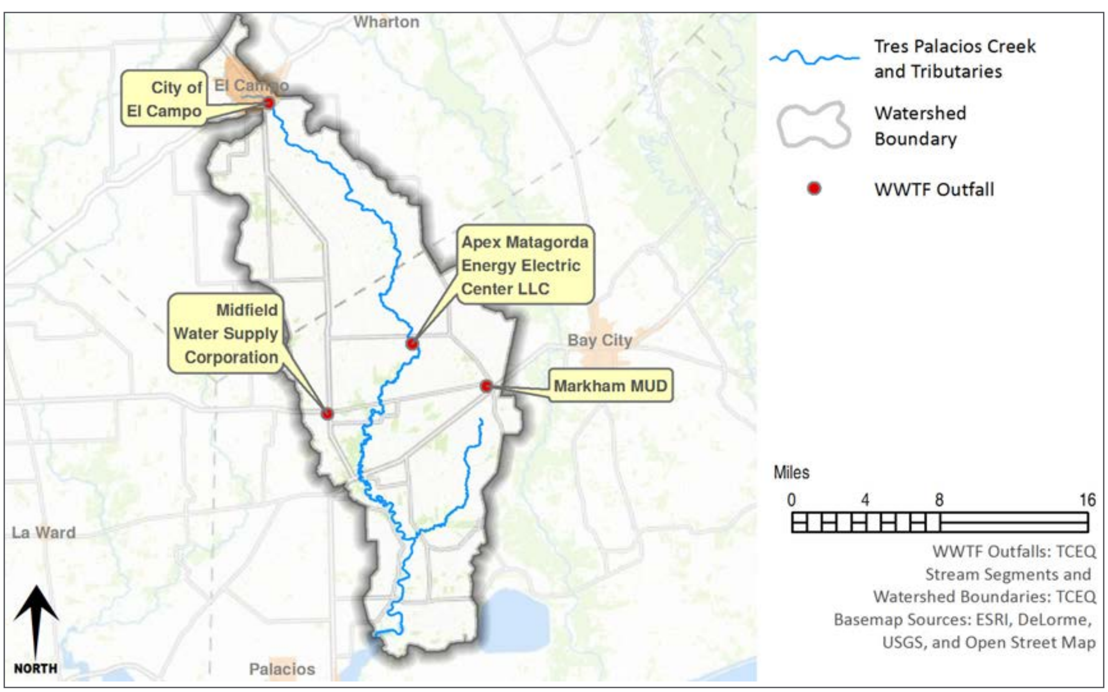

Figure 2.8. WWTF locations within the Tres Palacios Creek watershed. Source: Permitted outfalls (TCEQ 2012b).

Groundwater Resources

Part of the Gulf Coast Aquifer is located in the Tres Palacios Creek watershed (Figure 2.9). It is defined as a major aquifer by the Texas Water Development Board (TWDB). The Gulf Coast Aquifer stretches from Florida to Mexico and is an important source of water for coastal users. In Texas, it provides water to 54 counties, with the Houston metropolitan area being the largest user. Average well yields are approximately 1,600 gallons/minute (gal/min). About 90 percent of all water pumped from the aquifer is used for municipal and agricultural uses.

Due to reliance on this aquifer as a major water source, over-pumping has been an issue, particularly in the Houston area. Water levels have declined by 200 to 300 feet in areas of Harris and Galveston counties, and substantial declines have been observed in areas of Kleberg, Jefferson, Orange, and Wharton counties. Subsidence has occurred as a result. Subsidence levels are generally less than 0.5 ft, but the Harris County area has seen subsidence up to 9 ft. As a result, salt-water intrusion and flooding became a serious issue. Shifting to surface water sources has led to a decline in subsidence-related problems.

Aquifer water quality is good north of the San Antonio River Basin; dissolved solid levels are less than 500 milligrams/liters (mg/L) up to a depth of 3,200 feet in this portion of the aquifer. South of the San Antonio River Basin, water quality diminishes due to increased chloride concentrations, increased salinity, or increased alkalinity. Heavy municipal and industrial water usage in this area has influenced groundwater quality.

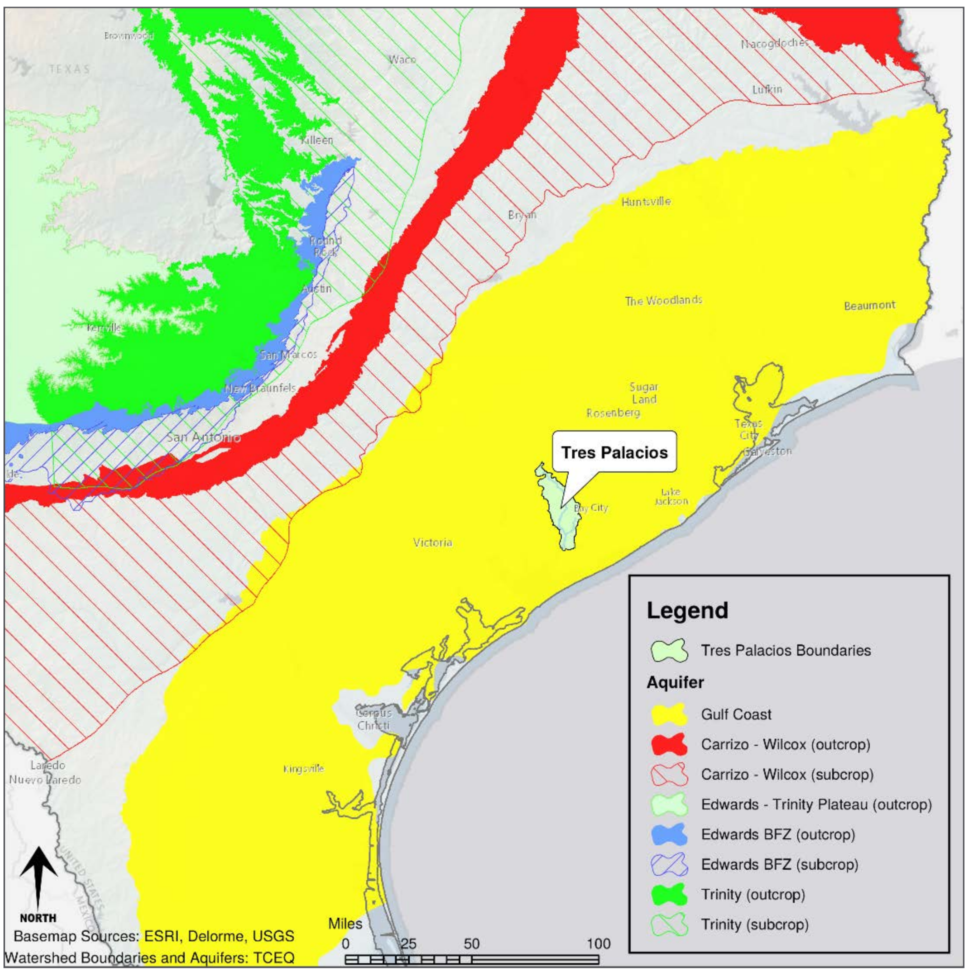

Figure 2.9. Major aquifers of east and central Texas. Source: (TWDB 2006).

Surface Water Resources

According to the USGS National Hydrography Dataset (NHD), there are approximately 372 stream miles within the Tres Palacios Creek watershed (USGS 2012). Of which, 132 miles are named perennial or intermittent streams (Figure 2.10). Tres Palacios Creek begins within El Campo and meanders south approximately 60 miles to Tres Palacios Bay. The tidal segment of Tres Palacios Creek begins approximately 0.6 miles upstream of the confluence with Wilson Creek. Major named tributaries to Tres Palacios Creek include Willow, Juanita, and Wilson creeks. Open water habitat accounts for approximately 1,020 ac of land surface area throughout the watershed. According to the NHD, there are over 500 open water impoundments, the vast majority of which are small man-made lakes and ponds under 2 ac in size (USGS 2012).

Water Quality

Data included in Texas' 2012 and 2014 Integrated Report on Surface Water Quality indicated the tidal portion of Tres Palacios Creek (Segment 1501) is impaired for bacteria and DO and there is a concern for chlorophyll-a. For water quality assessments, TCEQ uses data from the most recent seven-year period. Two separate station have been used in segment 1501: stations 20636 and 12515. Station 20636 is located 90 meters east at the intersection of Live Oak Boulevard and Riverside Drive in Matagorda County. Station 12515 is located along FM 521 (Figure 2.10).

For this watershed plan, water quality data was obtained from the TCEQ Surface Water Quality Viewer (TCEQ 2016). Water quality data collected between December 1, 2005 and November 30, 2012 for the tidal segment of the Tres Palacios Creek at stations 12515 and 20636 are shown in Figure 2.11. This data indicates that measurements for temperature, pH, ammonia, total nitrogen, and phosphorus are generally within state water quality parameters (Table 2.4). Scatterplots of total nitrogen, phosphorus, *Enterococci,* Grab DO, and chlorophyll-a concentration measurements are shown in Figure 2.11.

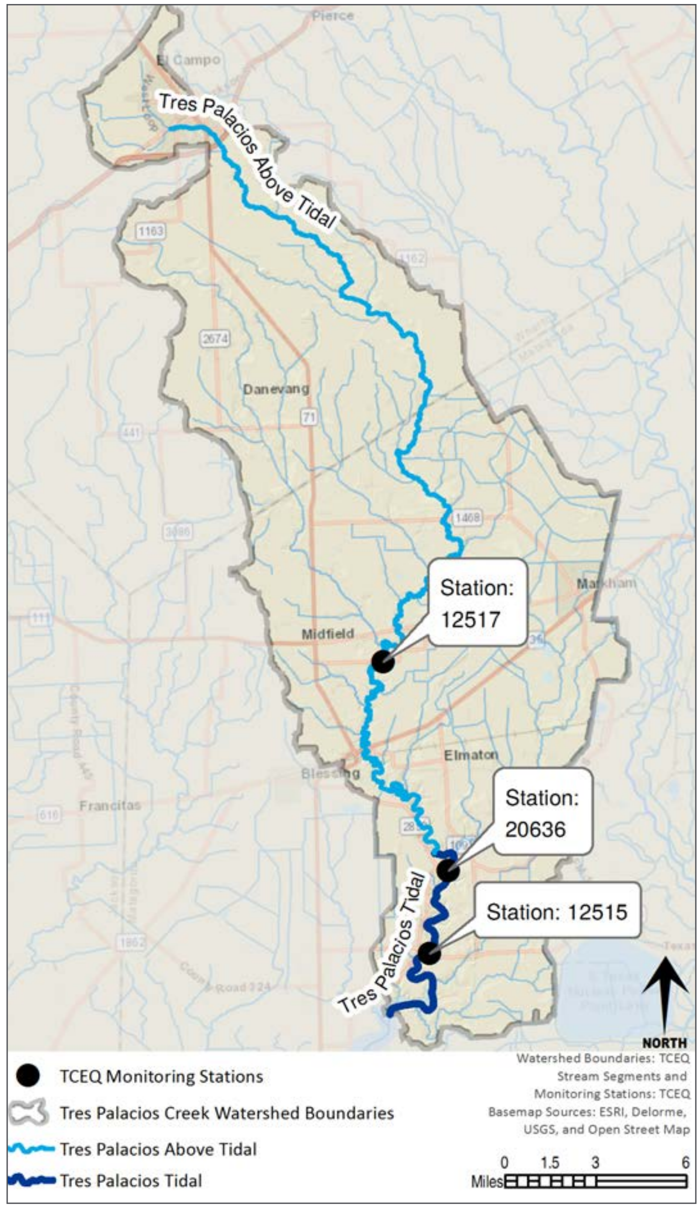

Figure 2.10. Surface water resources and water quality monitoring stations within the Tres Palacios Creek watershed. Sources: NHD (USGS 2012), Monitoring Stations (TCEQ 2016).

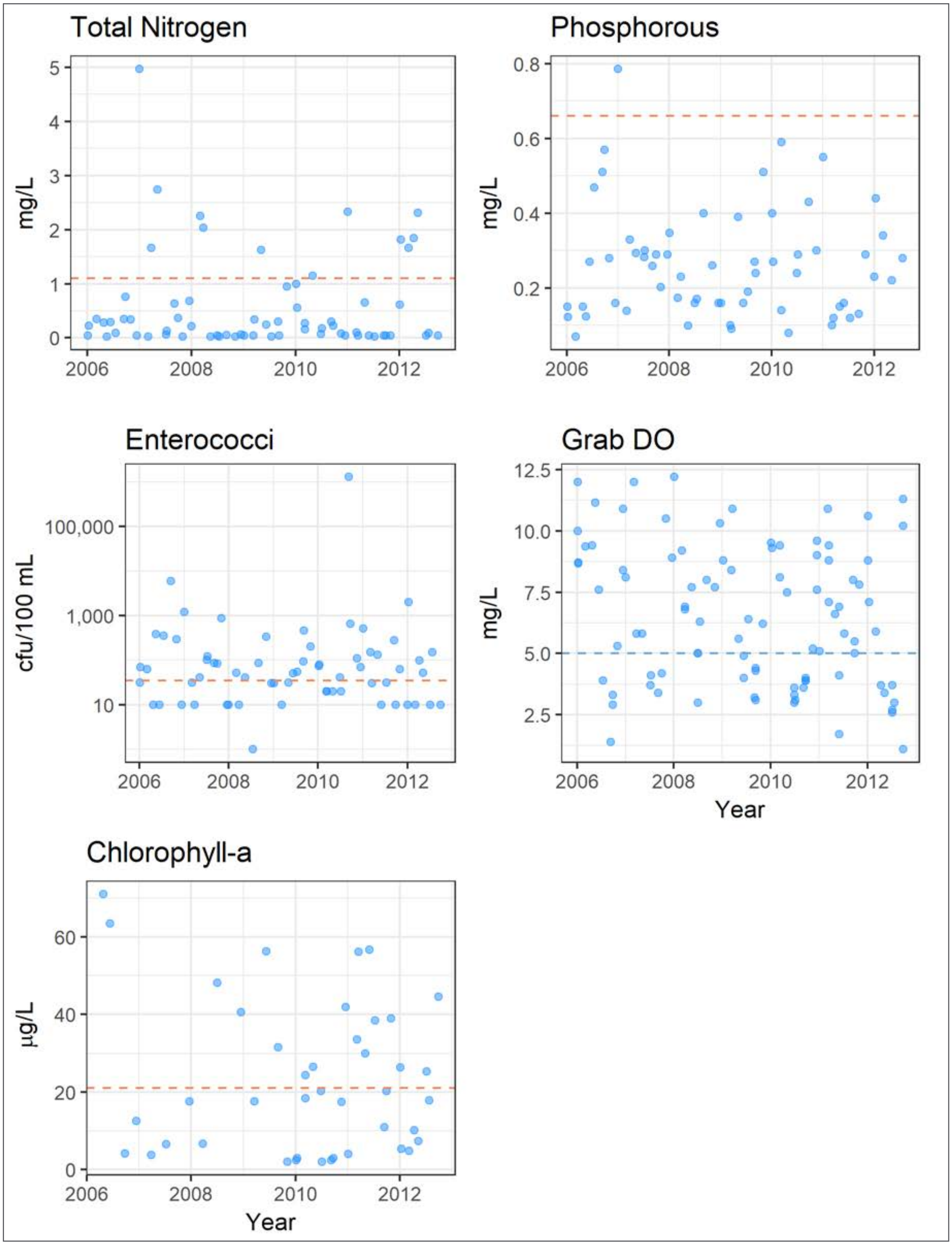

Figure 2.11. Selected water quality values from stations 12515 and 20636 in the tidal segment of Tres Palacios Creek recorded from December 1, 2005 through November 30, 2012. Dashed red lines indicate TCEQ maximum water quality standards or nutrient screening levels and dashed blue lines indicate minimum water quality standards for DO (TCEQ 2016).

Table 2.4. Summary of water quality data from segment 1501 of Tres Palacios Creek from December 2005 through November 2012. Source: TCEQ Surface Water Quality Viewer (TCEQ 2016).

Parameter	Number of Samples	Min	Max	Average	TCEQ Standard	Status
Temperature (°C)	93	9	31.4	23.32	35.00	
Dissolved Oxygen (mg/L)	93	1.1	12.2	6.4	5.0/4.0 (average/single grab)	Impaired
pH (Standard Units)	93	6.6	8.4	7.88	6.5 - 9.0	
Ammonia (mg/L)	66	0.02	0.76	0.12	0.46 (>20% exceedance)[1]	
Total Phosphorus (mg/L)	52	0.07	0.59	0.31	0.66 (>20% exceedance)[1]	
Chlorophyll-a (µg/L)	65	2	86.43	21.95	21.00 (>20% exceedance)[1]	Concern

[1]Indicates TCEQ screening levels, standards have not been established for nutrients.

Bacteria

Concentrations of fecal indicator bacteria are evaluated to assess the risk of illness during contact recreation. In marine-influenced environments, such as the tidal portion of Tres Palacios Creek, concentrations of *Enterococcus* bacteria are measured. The presence of these fecal indicator bacteria may suggest that associated pathogens from the intestinal tracks of warm-blooded animals could be reaching water bodies and potentially cause illness in people that recreate in them.

Water quality data collected between December 1, 2005 and November 30, 2012 for the tidal segment of the Tres Palacios Creek indicate a geometric mean of 67.19 cfu/100 mL for *Enterococci* bacteria (Figure 2.11). This exceeds the state established criterion for primary contact recreation of 35 cfu/100 mL.

Stakeholders helped identify potential sources of fecal bacteria within the watershed based on data presented in this chapter. The identified potential sources included wildlife, domestic livestock, pets, malfunctioning OSSFs, urban and agricultural runoff, permitted dischargers, and illicit dumping.

Dissolved Oxygen

Sufficient levels of DO are essential for the survival of aquatic species within water bodies. Consequently, if levels of DO are low, it may limit the quantity and types of aquatic species found within those bodies. When DO levels fall too low, fish and other organisms may begin to die off. Oxygen is dissolved into water through simple diffusion from the atmosphere, aeration of water as it flows over rough surfaces, and through aquatic plant photosynthesis. Typically, DO levels fluctuate throughout the day, with the highest levels occurring in mid to late afternoon due to plant photosynthesis. DO levels typically reach the lowest point just before dawn as both plants and animal respire and consume the available DO in the water column. Furthermore, seasonal fluctuations in DO are common because of decreased oxygen solubility as water temperature increases. Additional daily fluctuations occur during tidal cycles, as DO levels will decrease with increasing salinities. Therefore, it is not uncommon to observe lower DO levels during summer months.

While DO can fluctuate naturally, human activities can also cause abnormally low DO levels. Elevated amounts of organic matter (vegetative material, untreated wastewater, etc.) can result in depressed DO as bacteria breaks down organic matter and consumes oxygen. Excessive nutrients from fertilizers and manures can also reduce DO as the quantity of plants and algae increase in response to higher amounts of nutrients. The increased respiration from plants and the decay of dead plant matter can also drive decreases in DO.

The numeric criterion for DO is an indirect measure of whether the aquatic life use in a water body is being maintained. To date, the tidal segment of Tres Palacios Creek is assigned an "Exceptional" Aquatic Life Use, with a corresponding DO criteria of 5.0 mg/L minimum average over 24-hours and 4.0 mg/L minimum (Table 2.5).

In 2007, TPWD and TCEQ undertook a Use Attainability Assessment in order to determine the appropriate DO criterion of the Tres Palacios Creek tidal (Tolan et al. 2007). In essence, the study compared watershed characteristics, aquatic habitat, and the quantities and types of aquatic species in the Tres Palacios Creek tidal to a nearby reference creek. The study determined that DO was not a major driver of ecosystem health in the Tres Palacios Creek tidal. Importantly, data in the study suggests that current DO levels support healthy ecosystem function in Tres Palacios Creek, with mean DO levels from grab samples routinely above the 5.0 mg/L level (Figure 2.11). Furthermore, data also indicates total nitrogen and phosphorus are within TCEQ screening

Table 2.5 Aquatic Life Use categories and descriptive measures used to assess ecosystem health

Aquatic Live Use Category	DO Criterion (mg/L) Mean/ Minimum	Habitat Characteristics	Species Assemblage	Sensitive Species	Diversity and Species Richness	Trophic Structure
Exceptional	5.0/4.0	Outstanding natural variability	Exceptional or unusual	Abundant	Exceptionally High	Balanced
High	4.0/3.0	Highly diverse	Usual association of regionally expected species	Present	High	Balanced to slightly imbalanced
Intermediate	3.0/2.0	Moderately diverse	Some expected species	Very low in abundance	Moderate	Moderately imbalanced
Limited	<2.0	Uniform	Most regionally expected species absent	Absent	Low	Severely imbalanced

levels (Figure 2.11). However, chlorophyll-a is above current TCEQ screening levels. Elevated chlorophyll-a can be indicative of possible imbalances and nutrient loading occurring in the system.

With the most recently available assessed 24-hr DO data, 45 percent of the average 24-hour DO values were below 5.0 mg/L and 64 percent were below the minimum 24-hr DO value of 4.0 mg/L (Figure 2.12).

Attributing sources of depressed DO within the Tres Palacios Creek watershed presents certain challenges. First, ecosystem health compares well to nearby tidal streams. Second, assessment data indicates traditional contributors to depressed DO, such as nitrogen and phosphorus are below state screening levels. Third, water quality dynamics in the Tres Palacios Creek tidal system are not well studied. Because tidal systems are notoriously difficult and resource intensive to model, little information is available for what drives DO fluctuations in the tidal segment of the Tres Palacios Creek. A number of interacting processes control DO in surface waters, including: respiration, carbonaceous deoxygenation within the water column, nitrogenous deoxygenation, nitrifications, reaeration, and sediment oxygen demand.

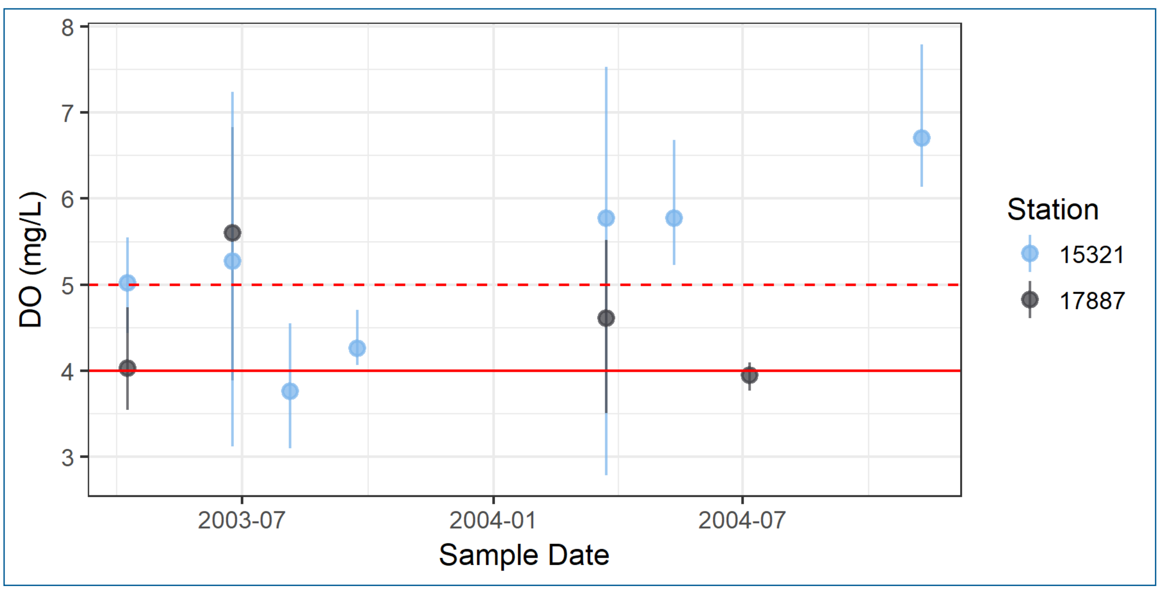

Figure 2.12. 24-hour DO measurements from two water quality monitoring stations in Tres Palacios Creek tidal. Points indicate the 24-hour mean DO concentration; vertical lines extend to the 24-hr minimum and maximum values. The dashed red line indicates the 24-hr average criterion (5mg/L) and the solid red line indicates the 24-hr minimum criterion (TCEQ 2016).

Furthermore, measuring and accounting for influence of freshwater flow and tidal influences on DO can be extraordinarily difficult. While it is likely that human-derived influences, such as nutrients and organics within agricultural runoff, effluent from failing OSSFs, and effluent from permitted dischargers contribute to DO fluctuations; there is little understanding of natural background fluctuations.

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Chapter 3 Estimates of Pollutant Source Loads and Needed Load Reductions

Tres Palacios Creek at FM 521.

Introduction

Water quality sampling outlined in Chapter 2 establishes that the tidal segment of Tres Palacios Creek is impaired for *Enterococcus* and depressed DO. To meet primary contact recreation water quality standards, the amount of bacteria entering Tres Palacios Creek needs to be reduced so concentrations are below 35 cfu/100mL. To meet standards for aquatic life use, the average 24-hour DO concentration needs to be at least 5 mg/L while the minimum 24-hour concentration needs to be at least 4 mg/L.

To calculate the pollutant load reductions needed to meet the bacteria criterion, the bacteria load capacity of Tres Palacios Creek was calculated along with the current bacteria load based on water quality samples with the Load Duration Curve (LDC) method. By taking the difference between the load capacity and the current load, the needed reduction can be reliably estimated.

The relative bacteria load contributions from different sources (i.e. cattle, household pets, OSSFs, etc.) were calculated with Geographic Information System (GIS) analysis combined with the best available data and stakeholder knowledge. By estimating the relative contributions of each source across the watershed, management measures can be prioritized within the watershed, and the number of needed management measures can be estimated.

Given the uncertainty of the appropriate water quality standard and primary factors driving depressed DO in Tres Palacios Creek, the nutrient load reductions needed to reach DO criterion were not calculated. It is generally assumed that management measures to reduce runoff and bacteria loads, outlined in Chapter 4, will also result in associated nutrient reductions that will have positive impacts of DO levels within the watershed. Chapter 3 provides estimates of potential nitrogen and phosphorus loads from livestock, feral hogs, pets, urban runoff, OSSFs, and WWTFs.

Developing mechanistic models of relative nutrient loading contributions from different sources is resource intensive and includes a considerable amount of uncertainty in estuarine systems such as Tres Palacios Creek tidal. Tidal systems, such as the Tres Palacios Creek, add additional modelling complexity due to difficulties associated with linking stream flows, tidal fluxes, and salinity with DO dynamics. Therefore, this plan relies on management measures identified for bacteria load concentrations to also reduce nutrient loading that can depress DO.

Needed Bacteria Load Reductions

Load Duration Curve

LDCs are a widely accepted methodology used to characterize water quality data across different flows. The LDC provides a visual display between streamflow, load capacity, and water quality exceedance. The LDC is first developed by constructing a Flow Duration Curve (FDC) using historical streamflow data. The FDC is constructed by ranking flow measurements from highest to lowest and determining the frequency of different flow measurements at the sampling location. A sample FDC that shows flow volume plotted against flow frequency is included in Figure 3.1. From this sample FDC, one could interpret that flows exceeded 300 cubic feet per second (cfs) for 10 percent of the days sampled (note that this is an example FDC and does not apply to the impaired segment of the Tres Palacios Creek).

This FDC is multiplied by the allowable pollutant concentration minus a margin of safety (typically between 5 and 10 percent) to identify the maximum acceptable pollutant load across flow conditions (a maximum allowable load curve). Using existing water quality and stream flow measurements, pollutant loads are plotted on the same figure. Points above the curve are out of compliance and points below the curve are within compliance. The difference between the predicted load and the allowable load is the estimated load reduction required to achieve the water quality standard. An example LDC is shown in Figure 3.2, where the blue line is the maximum allowable load curve and the red line is the actual load curve fitted to the pollutant load points plotted on the graph. On this example LDC, we can see exceedances primarily occur under the highest flow conditions (note that this is only an example LDC).

For the Tres Palacios Creek, a modified LDC analysis was conducted to illustrate relative *Enterococcus* loadings as they relate to measured stream flow levels. The modified LDC approach accounts for water diversions and tidal influences in the streamflow data used at station 12515. Further discussion of the modified LDC approach can be found in Appendix A.

The LDC was produced for tidal station 12515 (Segment 1501) on Tres Palacios Creek with data collected from January 1, 1999 through December 31, 2013 (Figure 3.3). This graph illustrates that *Enterococcus* loadings exceeding the water quality standard occur under all flow conditions. The LDC also illustrates that *Enterococcus* loadings are most elevated under the two highest flow conditions. Elevated loadings under higher flow conditions suggest loading sources are from NPS pollution or from bacteria present within stream sediments that are re-suspended under increased flows. The elevated loadings at low flow and dry conditions are generally attributed to point sources of pollution or direct fecal deposition to streams. WWTFs in the watershed have a relatively good compliance history, and SSO events are extremely rare, suggesting that direct fecal deposition and resuspension of bacteria in stream sediment are likely contributors to *Enterococcus* loadings in streams at low flow conditions. The load reductions goals under each flow category needed to achieve water quality requirements are presented in Table 3.1. To establish a numeric target for the total annual load reduction needed to meet water quality standards at station 12515, the "needed daily load reduction" for each flow category was multiplied by the number of days within each respective flow category and added together to yield an annual load reduction. The annual reduction needed to meet the water quality standard was calculated as 3.43×10^{14} cfu of *Enterococcus* per year.

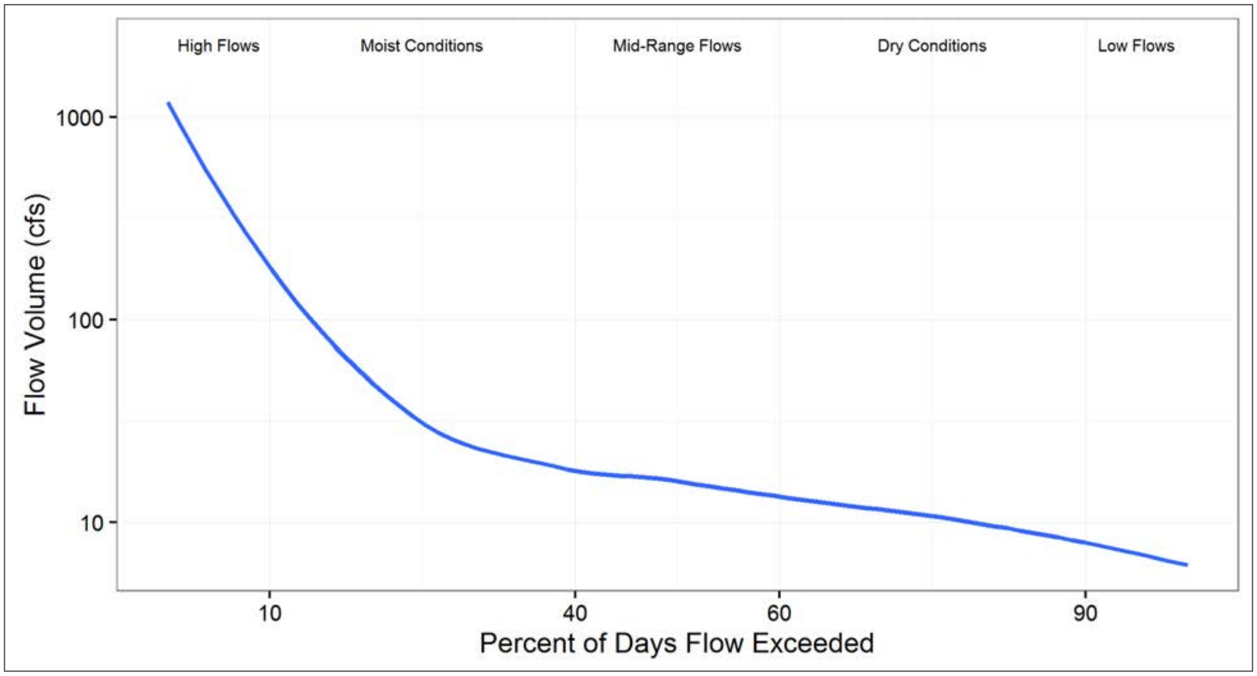

Figure 3.1. Example FDC using historical stream flow data to determine how frequently streams exceed different flow conditions.

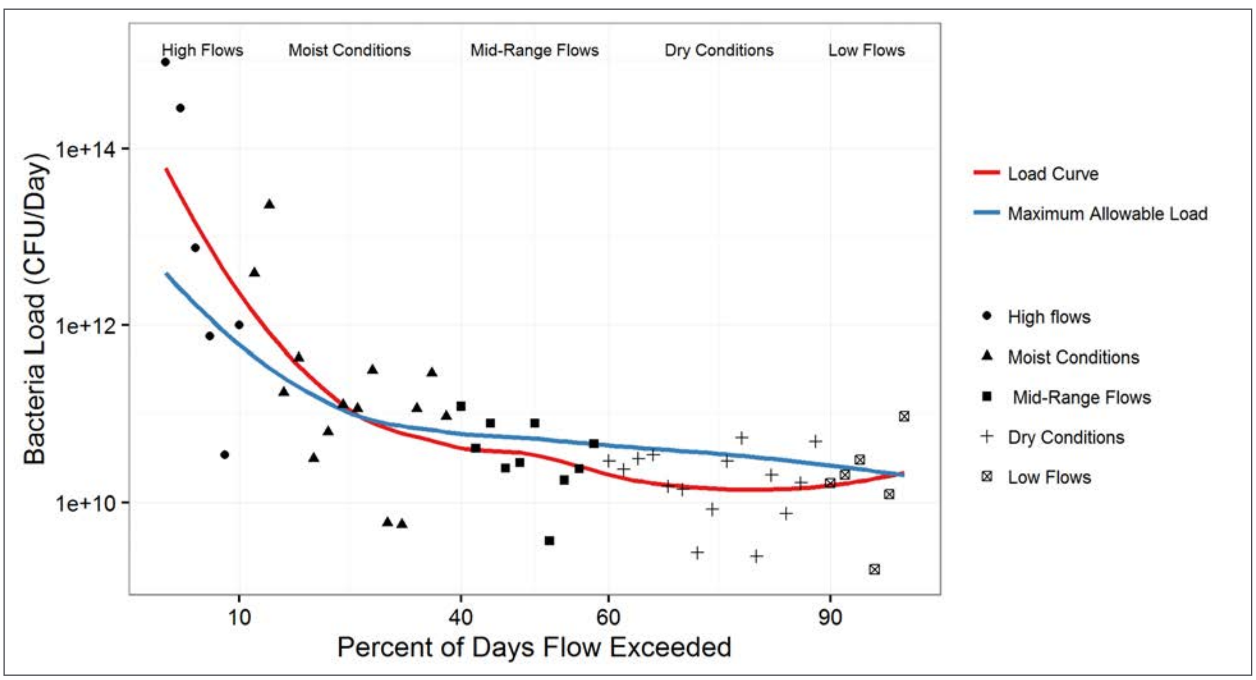

Figure 3.2. Example LDC demonstrating bacteria loading across different flow regimes. Individual points indicate individual instream measurements, points above the blue line indicate out of compliance measurements.

Table 3.1. Estimated reduction needed to meet *Enterococcus* water quality standards at station 12515 as determined by LDC analysis, including a 5% margin of safety.

Flow Condition	Percent Days Flow Exceeded	Existing Load (cfu/day)	Allowable Load (cfu/day)	Reduction Needed to Meet Allowable Load	Needed Daily Load Reduction (cfu/day)	Needed Annual Loading Reduction (cfu/yr)
High Flows	0-10	9.29×10^{12}	6.91×10^{11}	93%	8.60×10^{12}	3.14×10^{14}
Moist Conditions	10-40	2.61×10^{11}	5.62×10^{10}	79%	2.05×10^{11}	2.25×10^{13}
Mid-Range Flows	40-60	9.10×10^{10}	3.25×10^{10}	64%	5.85×10^{10}	4.27×10^{12}
Dry Conditions	60-90	3.65×10^{10}	2.20×10^{10}	40%	1.44×10^{10}	1.58×10^{12}
Low Flows	90-100	2.86×10^{10}	1.45×10^{10}	49%	1.41×10^{10}	5.15×10^{11}

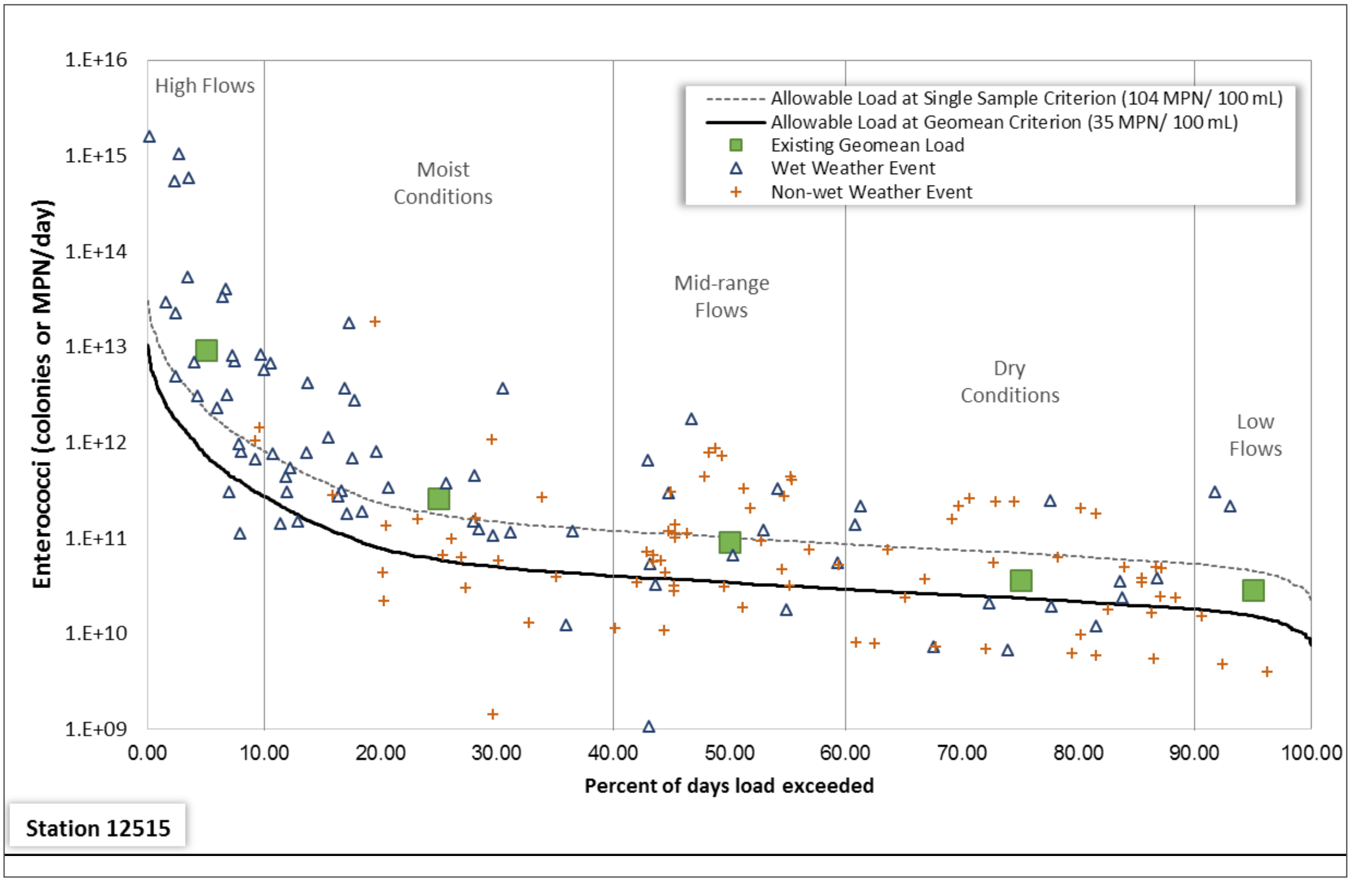

Figure 3.3. Load duration curve for Tres Palacios Creek Station 12515 for the period January 1, 1999 through December 31, 2013.

Estimates of Bacteria Source Loads

Geographic Information System Analysis

To aid in identifying potential areas of *Enterococcus* contributions within the watershed, a GIS analysis was applied using a similar methodology to the Spatially Explicit Load Enrichment Calculation Tool (SELECT) employed in Borel et al. 2012. The best available information and stakeholder input were used to estimate potential pollutant loading based on population estimates, land cover, household locations, and discharge points. These data were used to evaluate potential loadings from cattle, deer, domestic pets (dogs and cats), feral hogs, horses, OSSFs, urban runoff, and WWTFs at the subwatershed level. Populations of other livestock were not assessed based on assumptions that populations were likely very low or due to the lack of relevant population, waste, or bacteria production information.

Using GIS analysis for each source across the watershed, the relative potential for *Enterococcus* loading from each source can be compared and used to prioritize management. The loading estimates for each source are potential loading estimates that do not account for bacteria fate and transport processes that occur between the points where they originate and where they enter the water body, if at all. As such, these analyses represent a worst case scenario that do not represent the actual *Enterococcus* loadings expected to enter the creek. Loads are estimated at the subwatershed level to show the potential loadings in each of the 22 subwatersheds (Figures 3.4 – 3.9). These results suggest that subwatersheds 1, 4, 10, and 12 have the highest potential *Enterococcus* loads (Figures 3.9 and 3.10). The ranges and median potential annual *Enterococcus* loading are shown in Figure 3.11. These results indicate cattle have the highest potential for *Enterococcus* loads across the watershed, followed by household pets, deer, hogs, and OSSFs (Figure 3.11). Potential annual loads for each subwatershed and total potential loads for the entire watershed as modeled are detailed in Table 3.2.

Estimates of Nutrient Source Loads

Potential nutrient loads were calculated for cattle, domestic pets, feral hogs, OSSFs, urban runoff, and WWTFs (Figure 3.12). These loading estimates were generated across the watershed. Importantly, these values do not include all potential sources of nutrients since the information required to develop the mechanistic models needed to adequately estimate various point and NPSs of nutrients were not available. The calculations used to develop the potential nitrogen and phosphorus loading estimates are included in Appendix C.

The estimated potential loadings follow a similar trend to potential bacteria loadings suggesting unregulated NPSs are a relatively large contributor to nutrient loads in the watershed. There is general understanding that excessive nitrogen and phosphorus can drive eutrophication and depressed DO in freshwater and estuarine water bodies. However, the particular dynamics driving DO concentrations are not well understood. Therefore, instead of using nutrient potential to prioritize locations of management measures, estimates of bacteria sources loads were used to prioritize management measures. This is based on an assumption that many of the management measures limit, treat, or control runoff and reduce bacteria loads, will also reduce nutrient loads to a similar degree.

Sources

Borel, K., Gregory, L., Karthikeyan, R. 2012. Modeling Support for the Attoyac Bayou Bacteria Assessment using SELECT. College Station, TX: Texas Water Resources Institute. Technical Report 454.

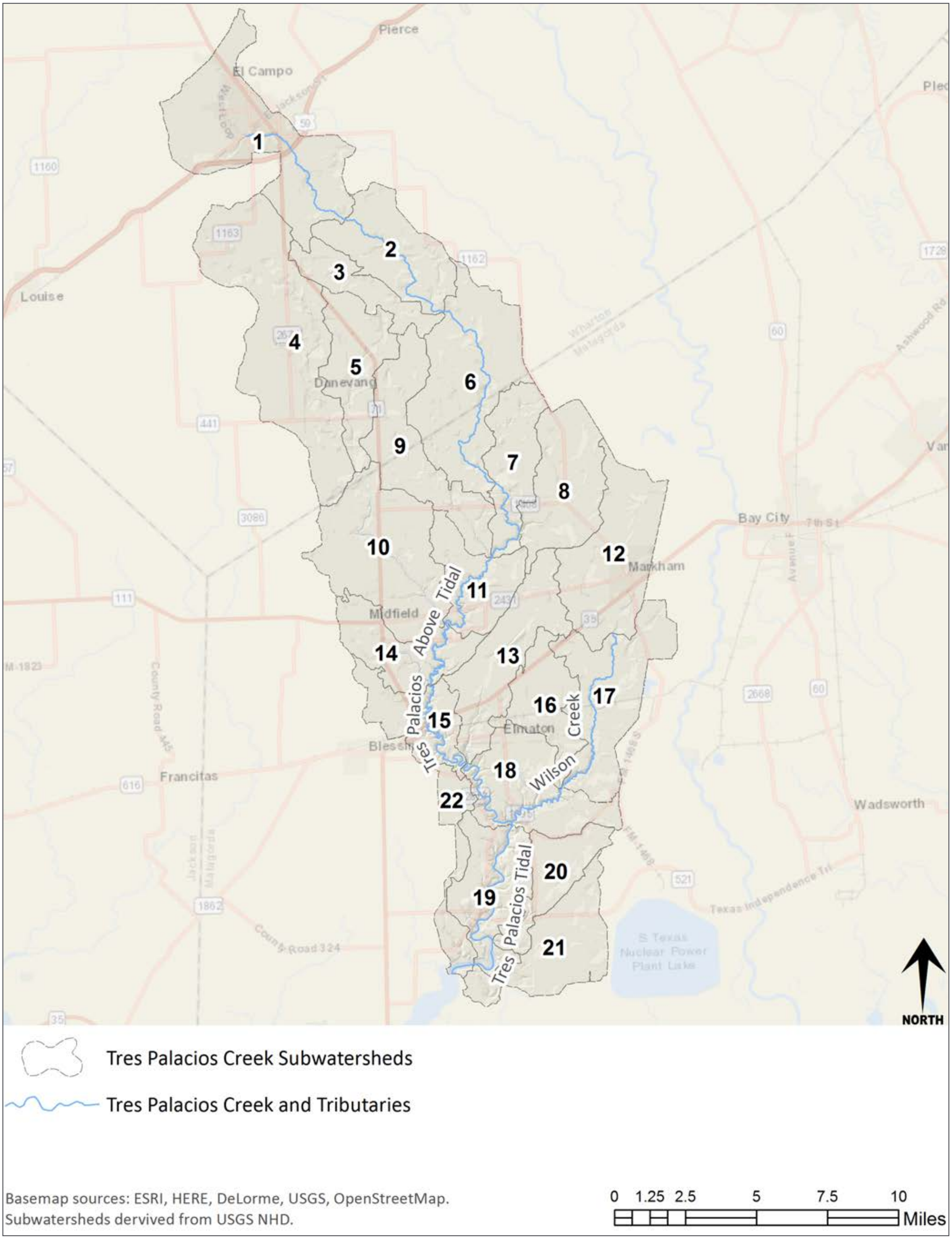

Figure 3.4. Subwatersheds within the Tres Palacios Creek watershed.

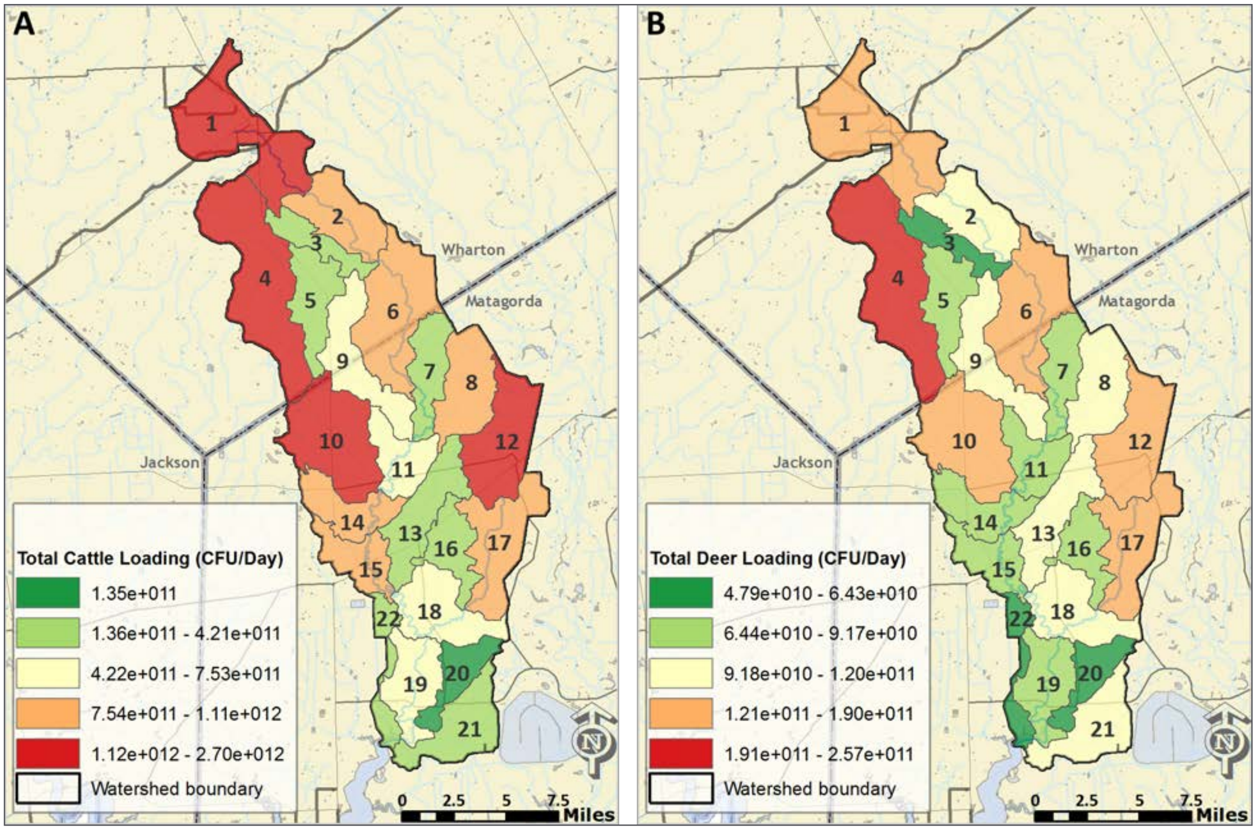

Figure 3.5. Distribution of total potential *Enterococcus* loads from (A) cattle and (B) deer across the watershed.

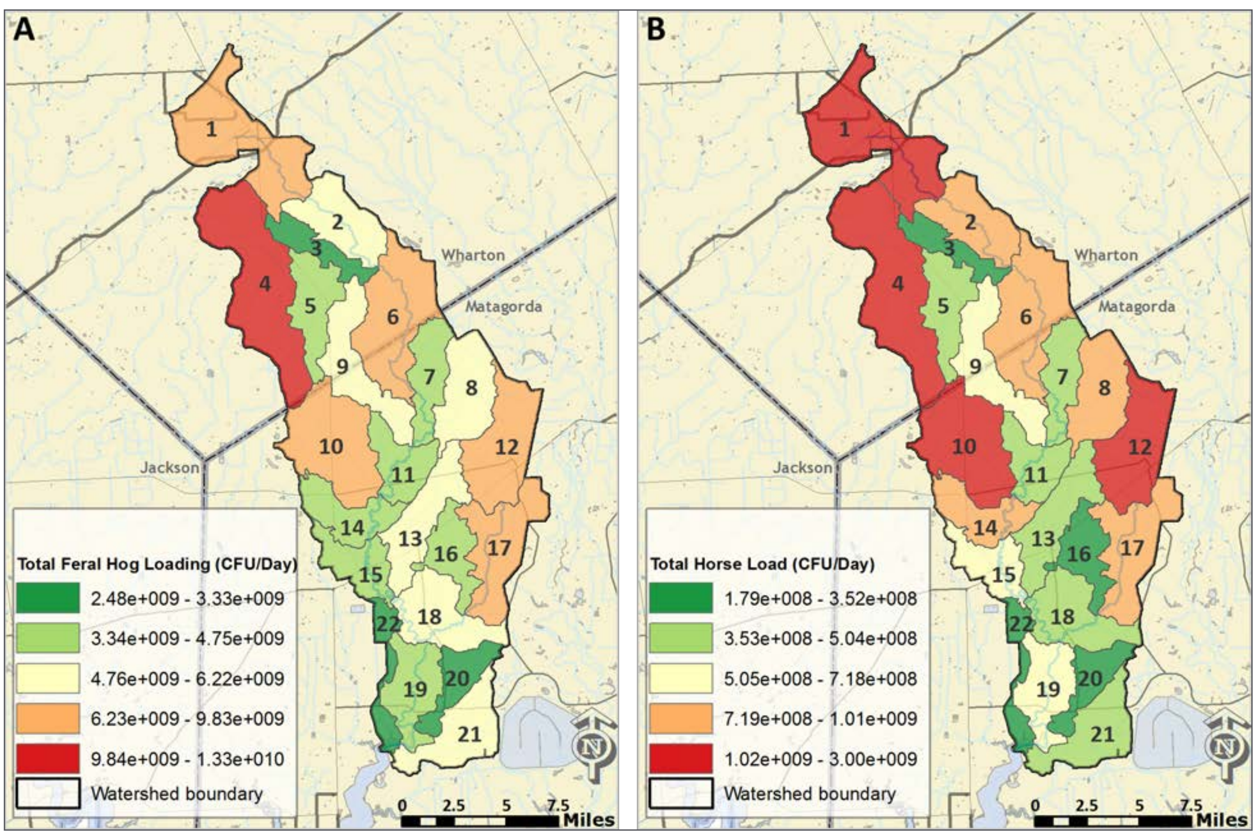

Figure 3.6. Distribution of total potential *Enterococcus* loads from (A) feral hogs and (B) horses across the watershed.

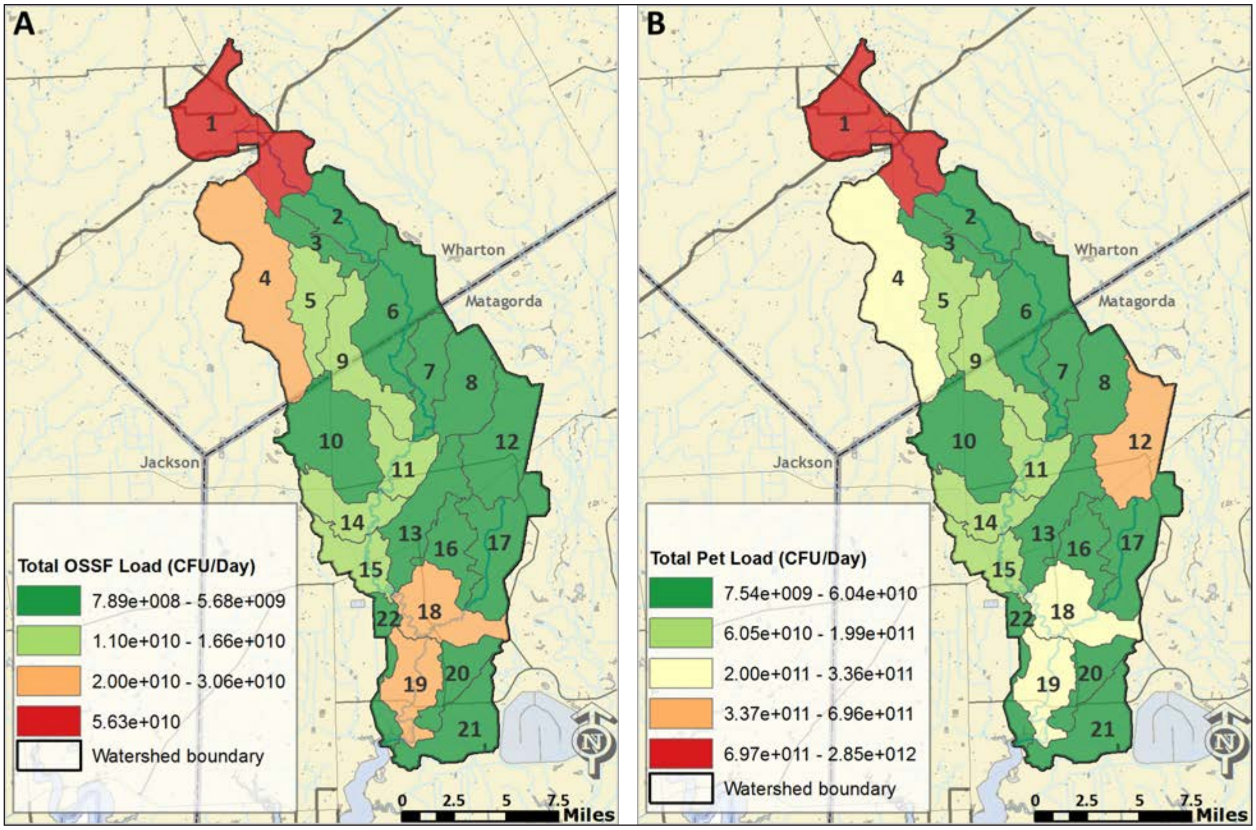

Figure 3.7. Distribution of total *Enterococcus* loads from and (A) OSSFs and (B) pets across the watershed.

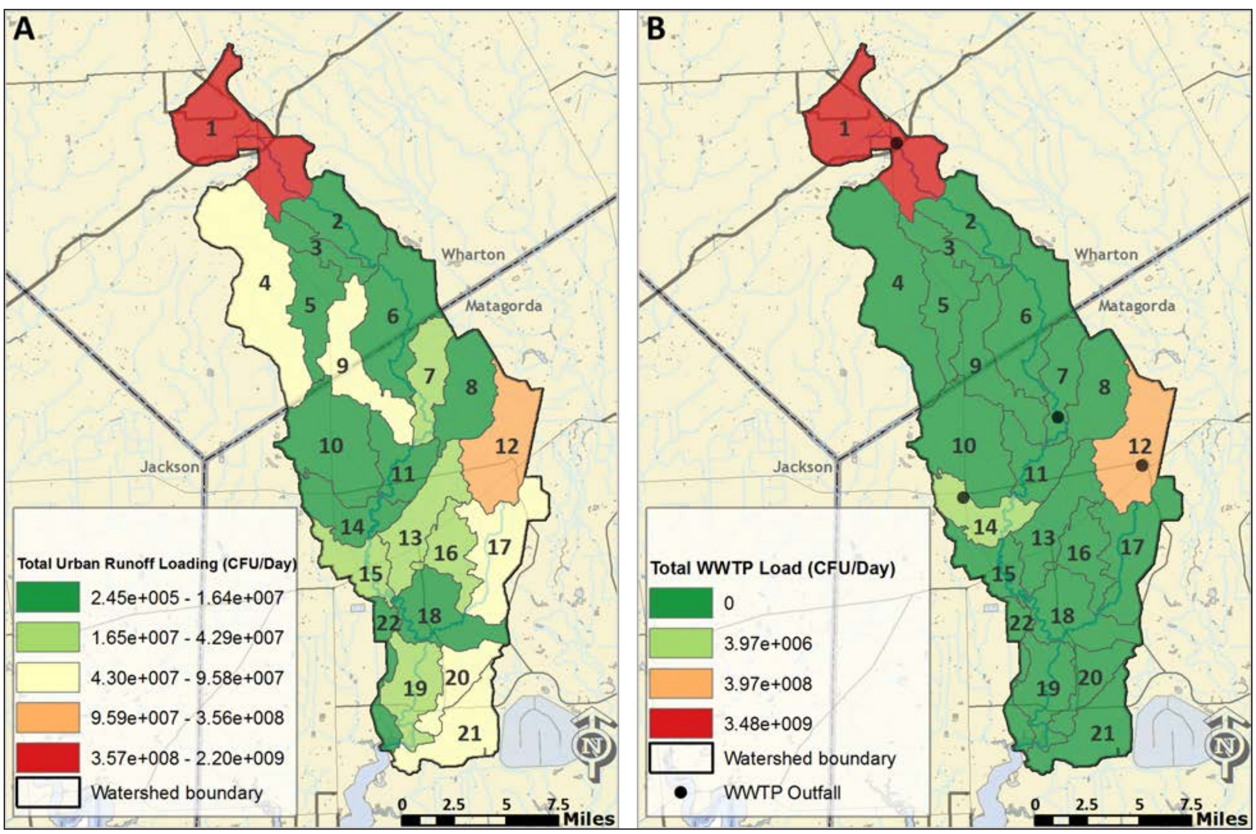

Figure 3.8. Distribution of total potential *Enterococcus* loads from (A) urban runoff and (B) WWTFs across the watershed.

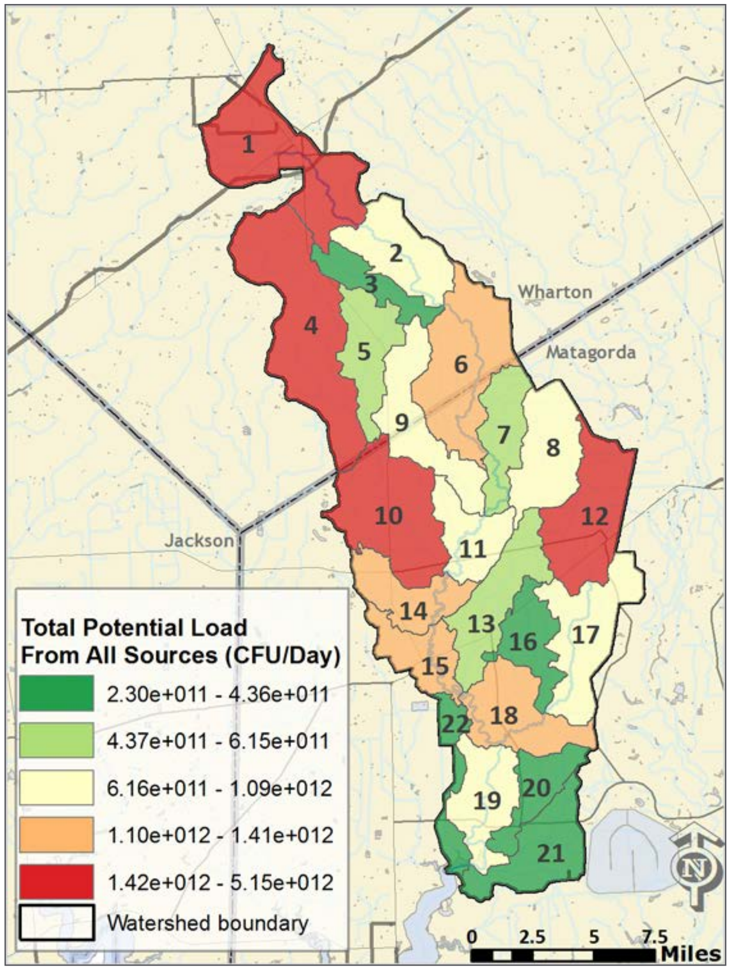

Figure 3.9. Distribution of total potential *Enterococcus* loads from all sources across the watershed.

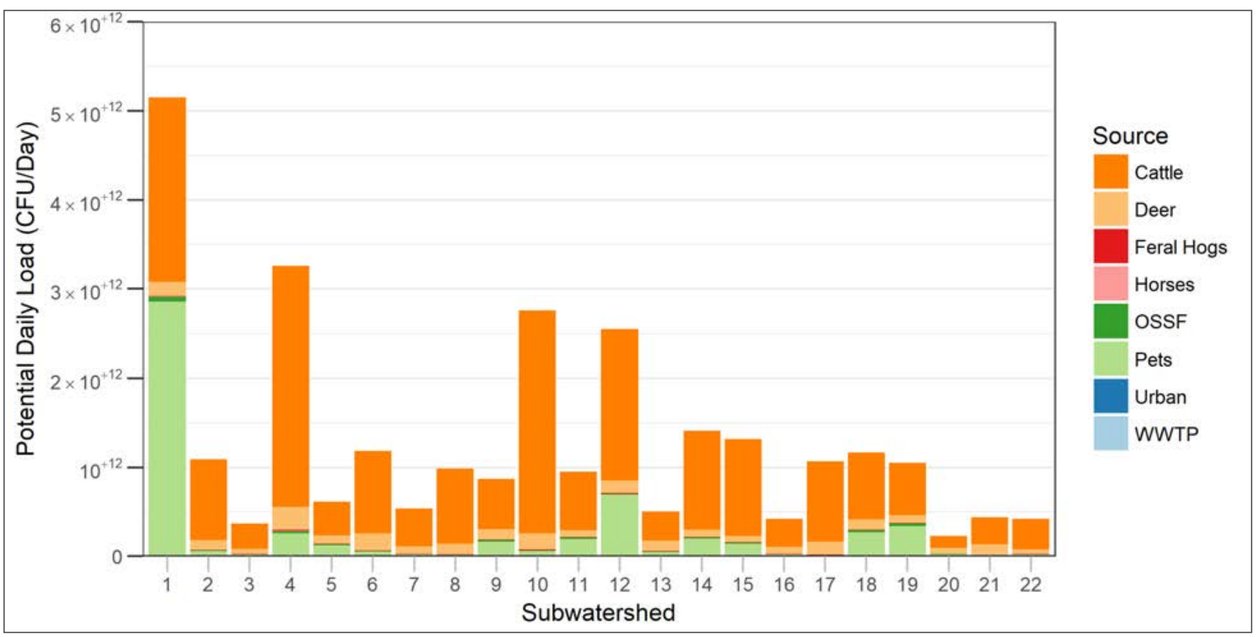

Figure 3.10. Total potential loadings by source within subwatersheds.

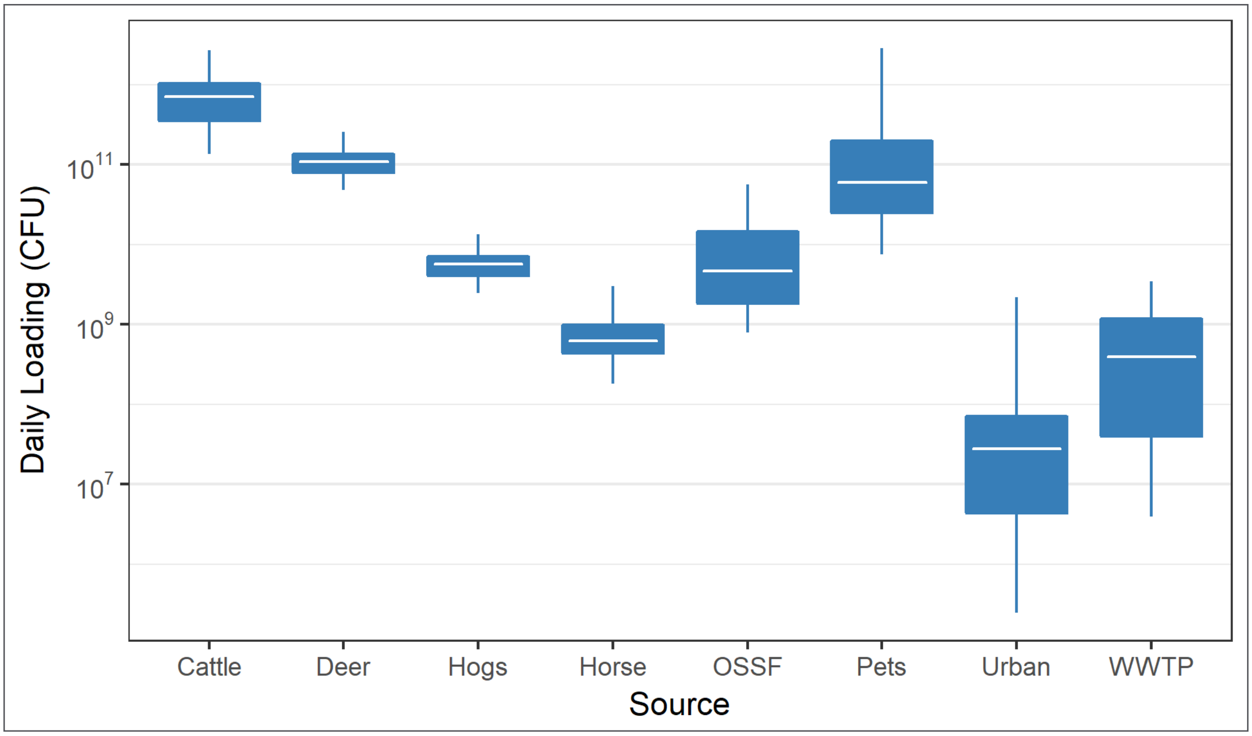

Figure 3.11. Distributions of potential *Enterococcus* loading by source as predicted across all subwatersheds. Note that the actual minimum loading for WWTFs in most subwatersheds is actually 0 cfu. Boxes indicate the interquartile range (middle 50 percent of values), whiskers extend to the minimum and maximum values, and white bars are the median values.

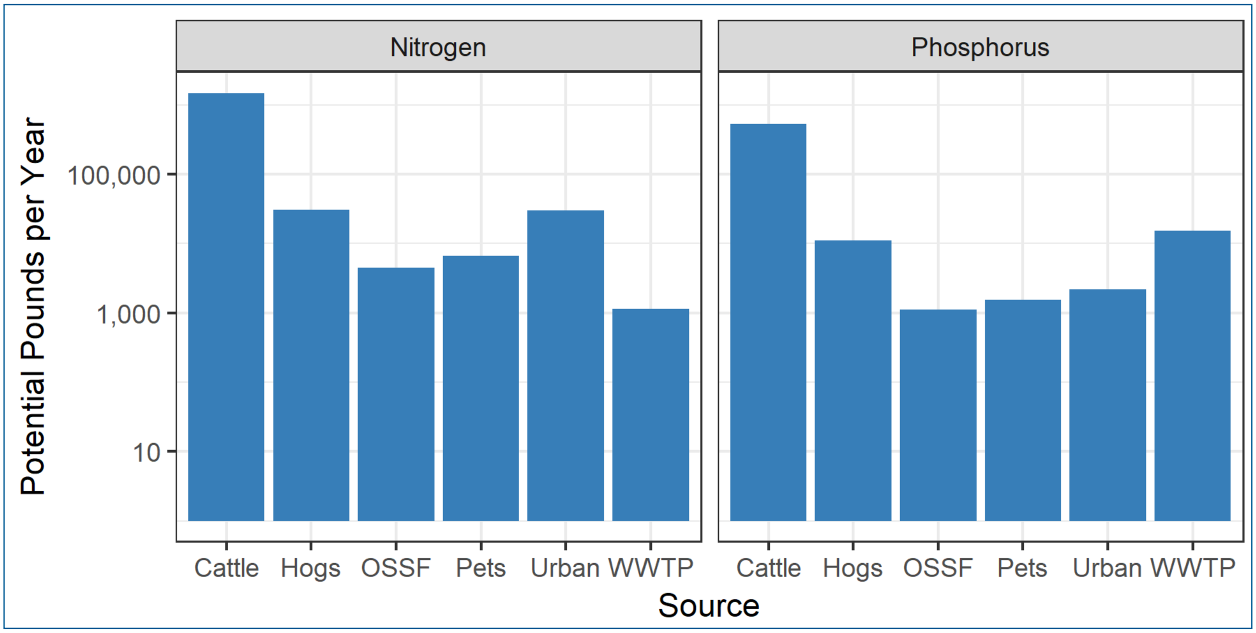

Figure 3.12. Potential watershed-wide nitrogen and phosphorus loads by source.

Table 3.2. Potential annual *Enterococcus* loads (cfu/yr) per watershed as indicated by GIS analysis.

					Potential Annual Load (cfu/yr)				
Subwatershed	**Cattle**	**Deer**	**Feral Hog**	**Horses**	**OSSFs**	**Pets**	**Urban**	**WWTFs**	**Total**
1	7.6×10^{14}	5.6×10^{13}	2.9×10^{12}	1.1×10^{12}	2.1×10^{13}	1.0×10^{15}	8.0×10^{11}	1.3×10^{12}	1.9×10^{15}
2	3.3×10^{14}	4.0×10^{13}	2.1×10^{12}	3.7×10^{11}	2.0×10^{12}	2.1×10^{13}	6.3×10^{8}	-	4.0×10^{14}
3	1.0×10^{14}	2.1×10^{13}	1.1×10^{12}	1.2×10^{11}	8.1×10^{11}	8.3×10^{12}	8.9×10^{7}	-	1.3×10^{14}
4	9.9×10^{14}	9.4×10^{13}	4.9×10^{12}	1.1×10^{12}	8.9×10^{12}	9.4×10^{13}	3.2×10^{10}	-	1.2×10^{15}
5	1.4×10^{14}	3.3×10^{13}	1.7×10^{12}	1.8×10^{11}	4.4×10^{12}	4.6×10^{13}	2.2×10^{9}	-	2.3×10^{14}
6	3.4×10^{14}	6.9×10^{13}	3.6×10^{12}	3.6×10^{11}	1.5×10^{12}	1.9×10^{13}	2.9×10^{9}	-	4.3×10^{14}
7	1.5×10^{14}	3.0×10^{13}	1.6×10^{12}	1.6×10^{11}	2.9×10^{11}	9.0×10^{12}	8.3×10^{9}	-	2.0×10^{14}
8	3.1×10^{14}	4.3×10^{13}	2.2×10^{12}	3.6×10^{11}	3.5×10^{11}	6.3×10^{12}	9.8×10^{8}	-	3.6×10^{14}
9	2.0×10^{14}	4.4×10^{13}	2.3×10^{12}	2.4×10^{11}	5.0×10^{12}	6.1×10^{13}	3.5×10^{10}	-	3.2×10^{14}
10	9.1×10^{14}	6.6×10^{13}	3.4×10^{12}	8.8×10^{11}	1.5×10^{12}	2.2×10^{13}	4.7×10^{9}	-	1.0×10^{15}
11	2.4×10^{14}	2.8×10^{13}	1.5×10^{12}	1.8×10^{11}	6.1×10^{12}	7.1×10^{13}	8.9×10^{9}	-	3.5×10^{14}
12	6.2×10^{14}	5.2×10^{13}	2.7×10^{12}	7.4×10^{11}	1.4×10^{12}	2.5×10^{14}	1.3×10^{11}	1.5×10^{11}	9.3×10^{14}
13	1.2×10^{14}	4.2×10^{13}	2.2×10^{12}	1.6×10^{11}	2.1×10^{12}	1.8×10^{13}	1.6×10^{10}	-	1.8×10^{14}
14	4.1×10^{14}	3.0×10^{13}	1.6×10^{12}	3.2×10^{11}	4.0×10^{12}	7.3×10^{13}	6.0×10^{9}	1.5×10^{9}	5.2×10^{14}
15	3.9×10^{14}	2.7×10^{13}	1.4×10^{12}	2.2×10^{11}	5.4×10^{12}	5.0×10^{13}	1.3×10^{10}	-	4.8×10^{14}
16	1.1×10^{14}	2.7×10^{13}	1.4×10^{12}	1.3×10^{11}	6.3×10^{11}	9.0×10^{12}	1.3×10^{10}	-	1.5×10^{14}
17	3.3×10^{14}	5.3×10^{13}	2.7×10^{12}	3.6×10^{11}	2.9×10^{11}	2.7×10^{12}	2.7×10^{10}	-	3.9×10^{14}
18	2.7×10^{14}	4.3×10^{13}	2.2×10^{12}	1.8×10^{11}	7.3×10^{12}	9.8×10^{13}	1.4×10^{9}	-	4.3×10^{14}
19	2.1×10^{14}	3.3×10^{13}	1.7×10^{12}	2.6×10^{11}	1.1×10^{13}	1.2×10^{14}	1.3×10^{10}	-	3.8×10^{14}
20	4.9×10^{14}	2.3×10^{13}	1.2×10^{12}	6.5×10^{10}	1.0×10^{12}	9.0×10^{12}	2.3×10^{10}	-	8.4×10^{13}
21	1.1×10^{14}	3.9×10^{13}	2.0×10^{12}	1.4×10^{11}	6.3×10^{11}	7.1×10^{12}	2.9×10^{10}	-	1.6×10^{14}
22	1.2×10^{14}	1.7×10^{13}	9.1×10^{11}	8.7×10^{10}	4.6×10^{11}	9.0×10^{12}	8.9×10^{8}	-	1.5×10^{14}
Total	$\mathbf{7.2\times10^{15}}$	$\mathbf{9.1\times10^{14}}$	$\mathbf{4.7\times10^{13}}$	$\mathbf{7.7\times10^{12}}$	$\mathbf{8.6\times10^{13}}$	$\mathbf{2.1\times10^{15}}$	$\mathbf{1.2\times10^{12}}$	$\mathbf{1.4\times10^{12}}$	$\mathbf{1.0\times10^{16}}$

Chapter 4
Strategies for Watershed Protection Plan Implementation

Tres Palacios Creek at Carl Park.

Introduction

Chapter 3 illustrates the diverse sources of bacteria and nutrient loading to Tres Palacios Creek. LDC analysis indicates that the bulk bacteria of loading occurs under the two highest flow categories. The GIS analysis indicates that cattle have the highest potential to contribute bacteria loading across the watershed, followed by pets, deer, and OSSFs. Livestock, wildlife, urban runoff, and pets can contribute considerable nutrient loads as well.

Estimated potential load reductions from each management measure are presented with each recommended action discussed in this chapter. Each loading estimate presented is based on a predicted worst case scenario loading. As a result, these estimates do not accurately predict real loadings that are occurring or expected load reductions that may be realized in stream. Actual reductions are dependent on a number of factors, which may trigger the need for adaptive implementation (AI). Potential annual load reductions from management measures covered in this chapter are shown in Figure 4.1 and indicate that reducing the bacteria loads entering the Tres Palacios Creek to levels that support primary contact recreation use is feasible.

Figure 4.2 shows the potential nutrient load reductions from these management measures. These nutrient load reductions should reduce risks of eutrophication and contributions to depressed DO in the tidal segment of the Tres Palacios Creek. Further work will be needed to evaluate the contributions of nutrients to existing DO concentrations.

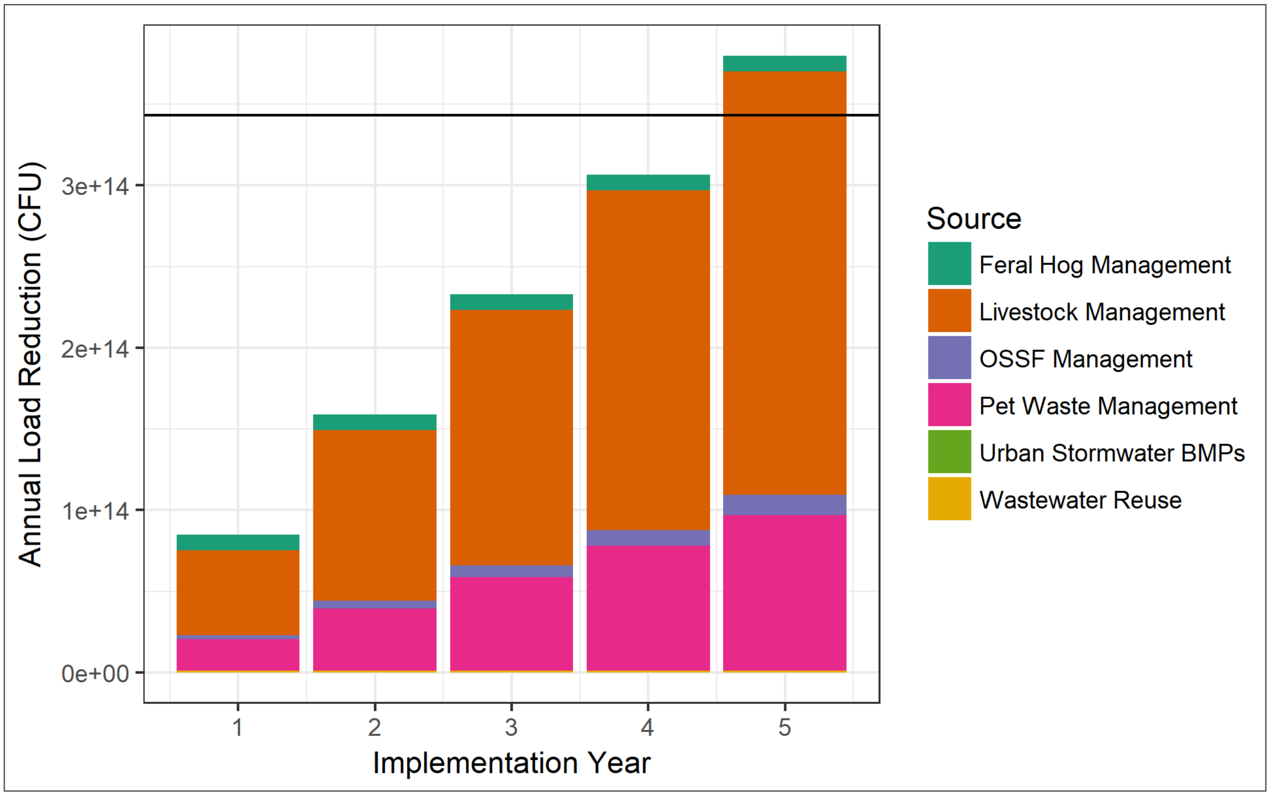

Figure 4.1. Potential bacteria load reduction based on management measure outlined in Chapter 4. Load reductions from urban stormwater BMPs are included in the figure but relative contributions are too small to discern from the larger load reductions.

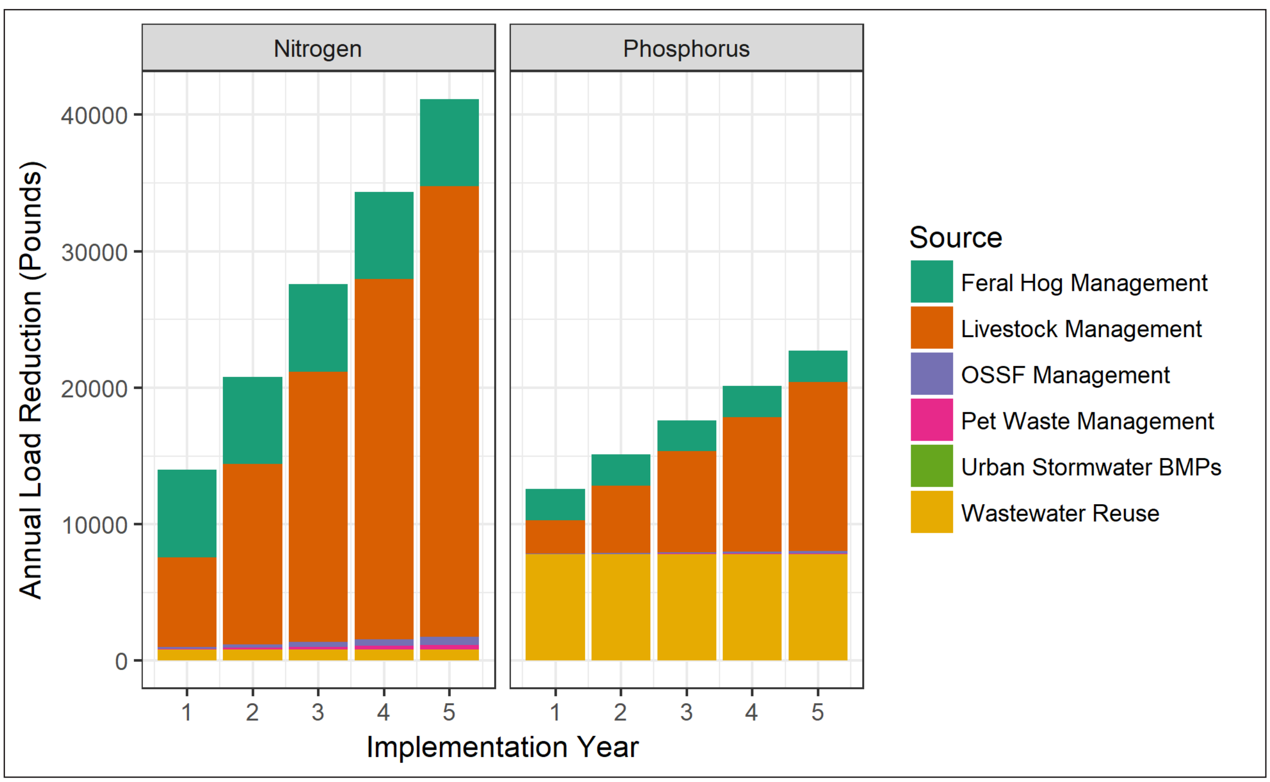

Figure 4.2. Potential nutrient load reduction based on management measure outlined in Chapter 4.

Agricultural Nonpoint Source Management Measures

Management Measure 1 – Developing and Implementing Conservation Plans in Priority Areas of the Watershed

Bacteria loadings in the Tres Palacios Creek watershed from cattle and other livestock were estimated to be relatively high compared to other evaluated sources. These sources are also considered manageable as the behavior of cattle and the areas where they spend their time can be modified through changes to food, shelter, and water availability and access. Cattle grazing is highly dependent upon proximity to these resources, especially water. Their fecal loading is also strongly tied to resource utilization as it is directly related to the amount of time an animal spends in an area. Therefore, reducing the amount of time livestock spend in riparian pastures through rotational grazing, adding alternative watering facilities, or moving supplemental feeding locations can directly reduce the potential for bacteria and nutrients from livestock to enter the creek. Actual practices needed or appropriate will vary by operation and will be determined through technical assistance from NRCS, the Texas State Soil and Water Conservation Board (TSSWCB), or local soil and water conservation districts (SWCDs), as appropriate.

The implementation of proven BMPs within priority sub-watersheds can lead to instream water quality improvements by reducing degradation and minimizing fecal deposition in the riparian area. Currently, 38 conservation plans (30 in Wharton County and 8 in Matagorda County) have been developed and implemented across the watershed. Load reductions achieved from this measure will vary depending on where and what conservation measures are implemented in the various plans. Improvements have already been shown in the Above Tidal Segment of Tres Palacios Creek, as it has recently been delisted from the 2014 Integrated Report for bacteria levels. Establishing additional acreage under management practices and additional conservation plans in this watershed is the primary goal of this management measure.

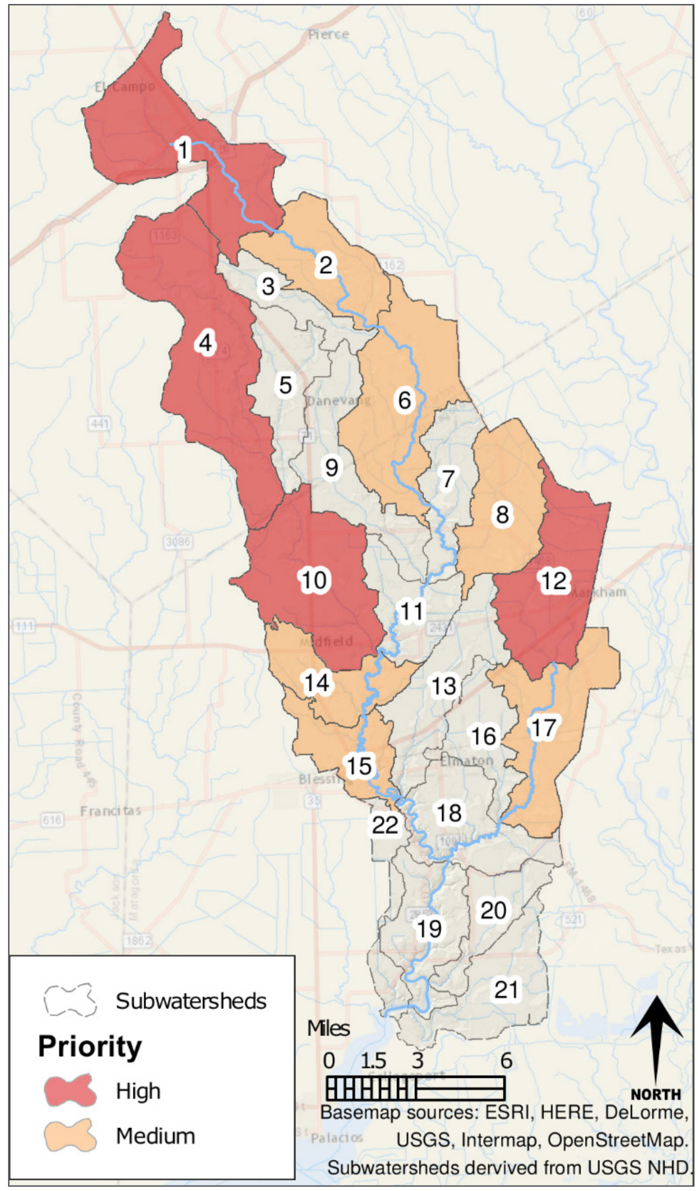

Figure 4.3. Priority areas for livestock management measures.

<table>
<tr><td colspan="4">Pollutant Source: Cattle and Other Livestock</td></tr>
<tr><td colspan="4">Problem: Direct and indirect riparian fecal and nutrient loading, riparian degradation, overgrazing</td></tr>
<tr><td colspan="4">Objectives:
• Work with ranchers, property owners with riparian/creek access to develop conservation plans
• Develop customized whole-farm plans
• Provide producers technical and financial assistance
• Reduce fecal and nutrient loadings from grazing livestock</td></tr>
<tr><td colspan="4">Critical Areas: Priority subwatersheds are 1, 4, 10, and 12 (Figure 4.3). Farms within close proximity of water bodies should also be given priority.</td></tr>
<tr><td colspan="4">Goal: Develop conservation plans focused on minimizing bacteria loadings from livestock</td></tr>
<tr><td colspan="4">Description: Conservation plans will be developed in areas that most appropriately address direct and indirect fecal deposition from cattle and other livestock and prescribe BMPs that will reduce time spent in the creek or riparian corridor, likely focusing on prescribed grazing, cross-fencing, and watering facilities.</td></tr>
<tr><td colspan="4">Implementation Strategies</td></tr>
<tr><td>Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>Critical areas above</td><td>Develop and implement nine conservation plans annually for five years</td><td>2017–2022</td><td>$15,000/ea</td></tr>
<tr><td>Texas A&M AgriLife Extension Service</td><td>Deliver various education programs including: Lone Star Healthy Streams, Riparian Education, Texas Watershed Stewards, etc.</td><td>2017–2022</td><td>N/A</td></tr>
<tr><td colspan="4">Estimated Load Reduction</td></tr>
<tr><td colspan="4">Prescribed management will most effectively reduce direct deposition but will also reduce bacteria and nutrient loads from the landscape as well. By implementing prescribed grazing, cross fencing, watering facilities, and other BMPs identified by local SWCDs on approximately 45 farms, potential annual loading reductions from livestock are estimated to be 2.61×1014 cfu Enterococcus, 3.30×10^4 pounds of nitrogen and 1.24×10^4 pounds of phosphorus annually. These estimates are further explained in Appendix B and C.</td></tr>
<tr><td>Effectiveness:</td><td colspan="3">High: Decreasing the time livestock spend in the riparian corridor and reducing surface runoff through effectively managing vegetative cover will reduce NPS contributions of bacteria and other nutrients to the creek.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: Landowners acknowledge the importance of good land stewardship practices and conservation plan objectives; however, financial incentives are needed in many cases to increase adoption of conservation plans.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Landowners are mostly willing to implement land stewardship practices that will benefit both the land and their operation; however, costs are often prohibitive and financial incentives will be needed to increase adoption of conservation plans.</td></tr>
<tr><td>Needs</td><td colspan="3">High: Financial assistance is the primary need, and conservation plan adoption will likely not occur without it. Education and outreach are needed to illustrate animal production, economic, and water quality benefits of conservation plan development and implementation.</td></tr>
<tr><td>Potential Funding Sources</td><td colspan="3">Conservation Plans: Clean Water Act (CWA) §319(h) grant program, TSSWCB Water Quality Management Plan Program (WQMP), NRCS Environmental Quality Incentives Program (EQIP), and others listed in Chapter 5
Education: CWA §319(h) grant program</td></tr>
</table>

*Funding available from listed programs varies yearly so potential contributions are unknown

Wildlife and Non-Domestic Animal Management Measures

Management Measure 2 – Feral Hog Removal and Management

Feral hogs have been identified as significant contributors of pollutants to water bodies. As feral hogs congregate around water resources to drink and wallow, this concentration of high numbers of feral hogs in riparian areas poses a threat to water quality. Fecal matter deposited directly in streams by feral hogs contributes to bacteria and nutrients, polluting the state's water bodies. In addition, extensive rooting activities 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. Also, it has been estimated that 60 percent would need to be removed annually to hold the population stable with no increase (Timmons et al. 2012). Stakeholders in watersheds across the state, including the Tres Palacios Creek watershed, 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.

The purpose of this management measure is to manage the feral hog population such that the current population does not increase, especially to an unmanageable level. Without a significant number of hogs removed from the watershed on an annual basis and sustained efforts to keep the population at a manageable level, water quality improvements may not be realized. Various control efforts are currently employed such as live trapping, shooting, hunting with dogs, aerial hunting, exclusion, and habitat management. The continuation and increased intensity of these practices, especially in priority areas, along with technical and financial assistance, is needed to reach the overall goal of this plan. Activities will be targeted toward priority areas where landowners should be contacted to discuss the economic savings of removing feral hogs, specific methods to do so, and available programs that assist in feral hog removal.

In an effort to track progress of this management measure, the AgriLife Extension Feral Hog Reporting tool will be used in addition to other tracking techniques. Also, sightings of feral hogs should be a notable indicator of a significant reduction in the feral hog population. The reporting tool can be found at http://feralhogreports.tamu.edu/.

Implementation for much of this management measure is dependent on available funding. Funding assistance will be needed for personnel, materials, supplies for feral hog management and education.

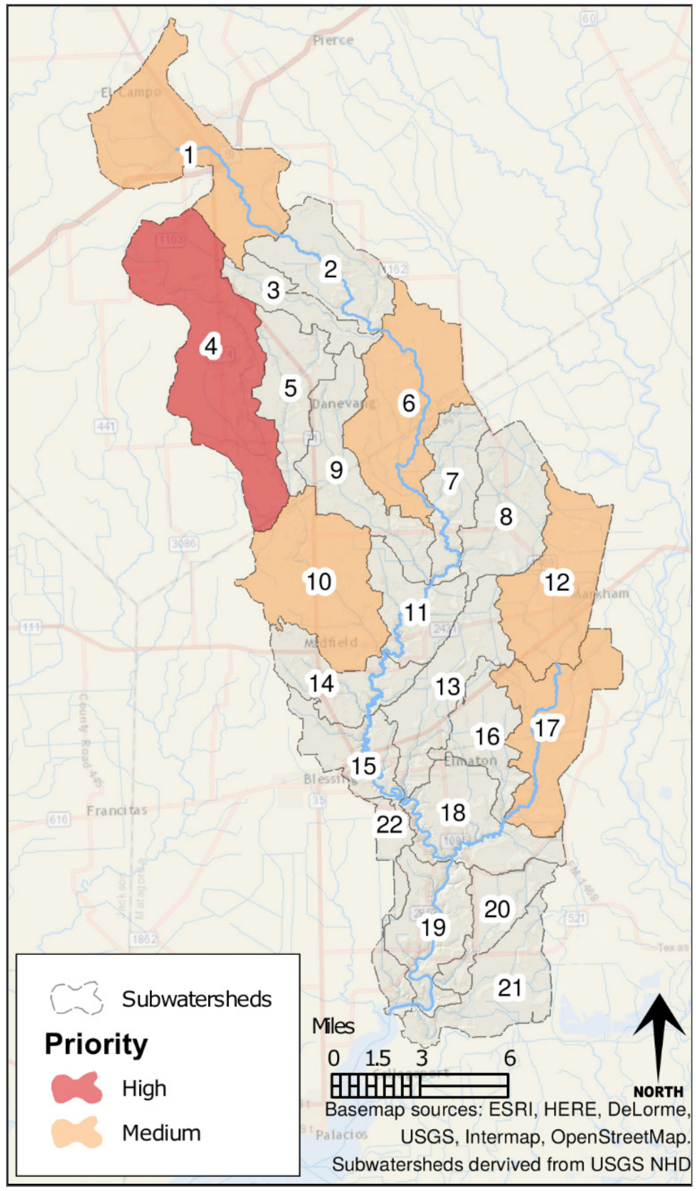

Figure 4.4. Priority areas for feral hog management measures.

Pollutant Source: Feral Hogs			
Problem: Direct and indirect fecal loading, riparian habitat destruction, and pasture and crop damage			
Objectives: • Reduce fecal and nutrient loadings from feral hogs • Reduce feral hog numbers • Reduce food supply			
Critical Areas: Priority subwatersheds include 1, 4, 6, 10, 12, 17 as well as riparian areas along water bodies (Figure 4.4).			
Goal: Manage the feral hog population through available means and efforts to reduce the total number of hogs in the watershed by 20 percent (1,000 hogs) and maintain that level of reduction annually			
Description: Voluntarily implement efforts to reduce feral hog populations throughout the watershed by reducing food supplies, removing hogs as practical, and educating landowners on BMPs for hog removal.			
Implementation Strategies			
Participation	**Recommendations**	**Period**	**Capital Costs**
Landowners, land managers, lessees	Voluntarily construct fencing around deer feeders to prevent feral hog use	2017–2022	$200 per feeder exclusion
	Voluntarily identify travel corridors and employ trapping and hunting in these areas to reduce feral hog numbers	2017–2022	N/A
	Voluntarily shoot all hogs; ensure lessees shoot all hogs on site	2017–2022	N/A
AgriLife Extension	Deliver Feral Hog Education Workshop	2017, 2019, 2021	$7,500 each
County/AgriLife Extension	Promote use of AgriLife Extension's online tracking tool to report hog harvest data	2017–2022	$10,000

Estimated Load Reduction	
Reducing the feral hog population will reduce bacteria loading to the landscape and direct deposition to the creek. This effort will primarily reduce direct deposition as these animals spend the majority of their time in the riparian corridors. By implementing this management measure, we expect annual loading reductions of 9.66×10^{12} cfu *Enterococcus*, 6.39×10^{3} pounds of nitrogen and 2.28×10^{3} pounds of phosphorus. See Appendix B and C for calculations.	
Effectiveness:	High: Reduction in feral hog population will result in a direct decrease in bacteria and nutrient loading to the stream.
Certainty	Low: Feral hogs are transient and adapt to their environment and will migrate due to hunting and trapping pressure; as such, the ability to remove 20 percent of the population each year will be difficult and is highly dependent upon the diligence of watershed landowners.
Commitment	Moderate: Landowners are actively battling feral hog populations and will continue to do so as long as resources remain available.
Needs	Moderate: Additional funds are needed to provide an additional incentive to landowners to actively remove feral hogs. Education and outreach delivery is needed to further inform landowners about feral hog management options, adverse economic impacts of feral hogs and what their options for dealing with feral hogs are.
***Potential Funding Sources**	Control: private funds, State-level feral hog control grants (full list of sources in Chapter 5) Education: CWA §319(h) grant program (this funding cannot be used for control or removal)

*Funding available from listed programs varies yearly so potential contributions are unknown

On-Site Sewage Facility Management Measures

Management Measure 3 – Identify OSSFs, Prioritize Problem Areas, and Systematically Work to Bring Systems into Compliance

Failing OSSFs are known to contribute to elevated bacteria and nutrient levels in nearby water bodies. Within the Tres Palacios Creek watershed, soils are not conducive for conventional septic systems, so aerobic systems are most commonly used. The soils are composed of clays with a very slow infiltration rate and high water table. Within Matagorda County, aerobic systems make up approximately 98 percent of permitted OSSFs due to the county's soil type; in Wharton County both aerobic and conventional systems can be found. For aerobic systems, TCEQ regulations (30 Texas Administrative Code §285.7) require the homeowners to have a maintenance contract with a licensed maintenance provider or be properly trained to provide the maintenance themselves. As a result, we assumed the vast majority of permitted aerobic systems are properly treating sewage.

The purpose of this management measure is to identify potential failing and failing OSSFs. Currently, Matagorda County maintains a database of OSSFs and their maintenance contracts, and this database can be used to identify systems not meeting their maintenance requirements. Systems identified as failing should be upgraded or replaced. This management measure will also be used to support TCEQ's Coastal Nonpoint Source Pollution Control Program by prioritizing systems in the coastal zone that are failing and/or if their system is by N-limited waters. A detailed OSSF GIS-based inventory database was completed by TCEQ in 2017, in support of the TX Coastal NPS Program. However, this has only inventoried OSSFs in the coastal boundary of Matagorda County, which reaches up to the upstream end of segment 1501. Further, education on system operation and maintenance as well as proper installation, inspection, and repair procedures should be delivered. Education and outreach events should also discuss financial assistance options available to OSSF owners.

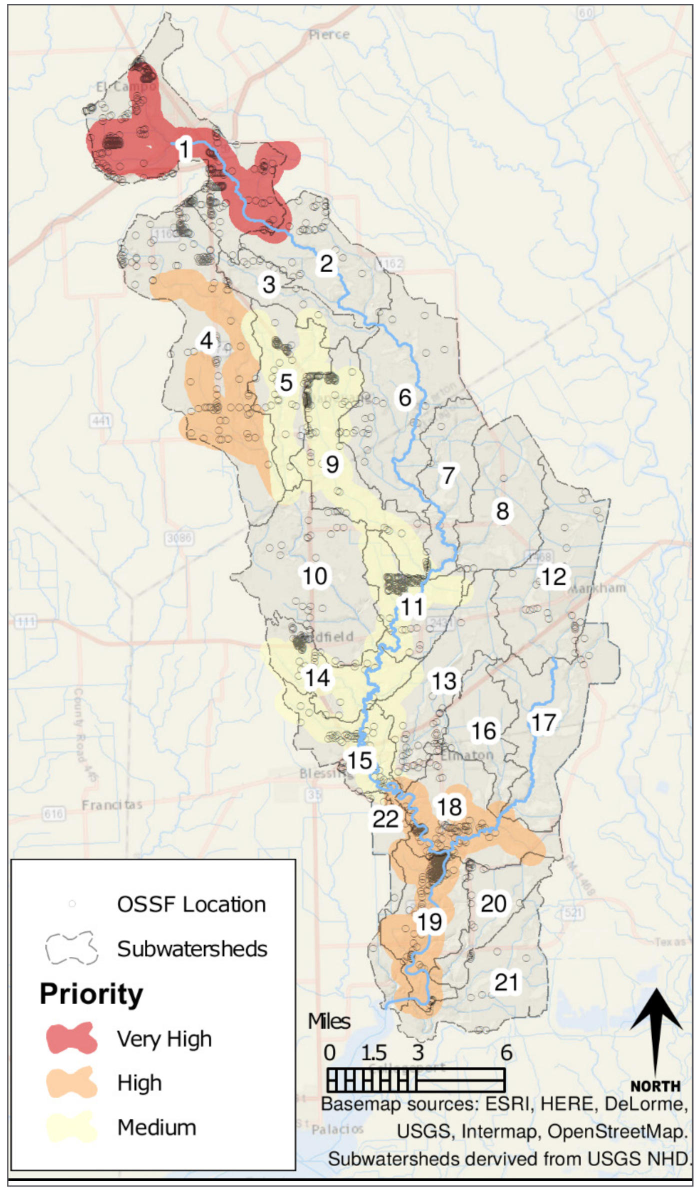

Figure 4.5. Priority areas for OSSF management measures.

Pollutant Source: Address Failing OSSFs			
Problem: Pollutant loading from failing OSSFs			
Objectives: • Identify and inspect failing OSSFs in the watershed • Determine priority areas for OSSF repair and replacement • Maintain database of OSSF systems • Repair or replace OSSFs as funding allows			
Critical Areas: Priority subwatersheds include 1, 4, 18, and 19 as well as systems within close proximity to the water body (Figure 4.5). Areas failing within the coastal zone.			
Goal: Identify, inspect, and repair or replace, as appropriate, failing OSSFs within priority subwatersheds or close proximity to a water body			
Description: Potential OSSF failures will be addressed by working with homeowners to identify and inspect all OSSFs within critical areas. Deficient systems will be repaired or replaced as appropriate to bring them into compliance with local requirements.			
Implementation Strategies			
Participation	**Recommendations**	**Period**	**Capital Costs**
Designated representative and/or contractor	Identify and inspect OSSFs in close proximity to waterways	2017–2022	$40,000/yr
	Maintain OSSF database that documents OSSF information	2017–2022	$50,000
	Administer OSSF repair/replacement program to address deficient systems identified during inspections	2017–2022	$15,000/yr
Contractor	Repair/Replace OSSFs as funding allows	2017–2022	$5,000–$10,000 ea
Estimated Load Reduction			
As planned, 25 systems will be repaired or replaced throughout the watershed. The identification and replacement of OSSFs should prioritize critical areas and areas within close proximity of water bodies. If all 25 planned OSSFs are addressed, the expected annual loading reductions are 1.22×10^{13} cfu *Enterococcus*, 6.14×10^{2} pounds of nitrogen and 1.54×10^{2} pounds of phosphorus. See Appendix B and C for calculations.			
Effectiveness:	High: Replacement and repair of failing OSSFs will yield direct fecal reductions to the waterways and nearby areas of the watershed.		
Certainty	Moderate: The level of funding available to identify, inspect, and repair or replace OSSFs is uncertain; however, funding sources are available for assistance.		
Commitment	Moderate: Local officials are currently dedicated to permitting and maintaining compliance; therefore, continued efforts should receive implementation priority.		
Needs	High: Funding to identify, inspect, and repair/replace OSSFs as well as to maintain a watershed database is limited; however, there is high need of funding for systems that are out of compliance.		
***Potential Funding Sources**	Inspections, database, administration: CWA §319(h) grant program, Texas Supplemental Environmental Projects (SEP) fund, local funds Repair/Replacements: CWA §319(h) grant program, Texas SEP fund, OSSF owners (full list of sources in Chapter 5)		

*Funding available from listed programs varies yearly so potential contributions are unknown

Illegal Dumping Management Measures

Management Measure 4 – Reduction of Illicit Dumping and Proper Disposal of Animal Carcasses

Stakeholders have identified illicit dumping as a concern. Trash, household items, waste, and animal carcasses are sometimes dumped into local creeks and then during rain events, washed downstream.

Challenges in enforcing illicit dumping can include the lack of available personnel for education and enforcement, lack of equipment necessary to reduce the ease of dumping, lack of equipment available to monitor sites for enforcement, and other challenges unique to the area. It is the purpose of this management measure to reduce the amount of dumping in and near the local water bodies. Through various types of efforts, including education (for both local officials and residents), signage at water bodies, enforcement, and other measures, illicit dumping in water bodies can be reduced. Responsible parties will develop a strategy on how to reduce illicit dumping and implement their respective strategies.

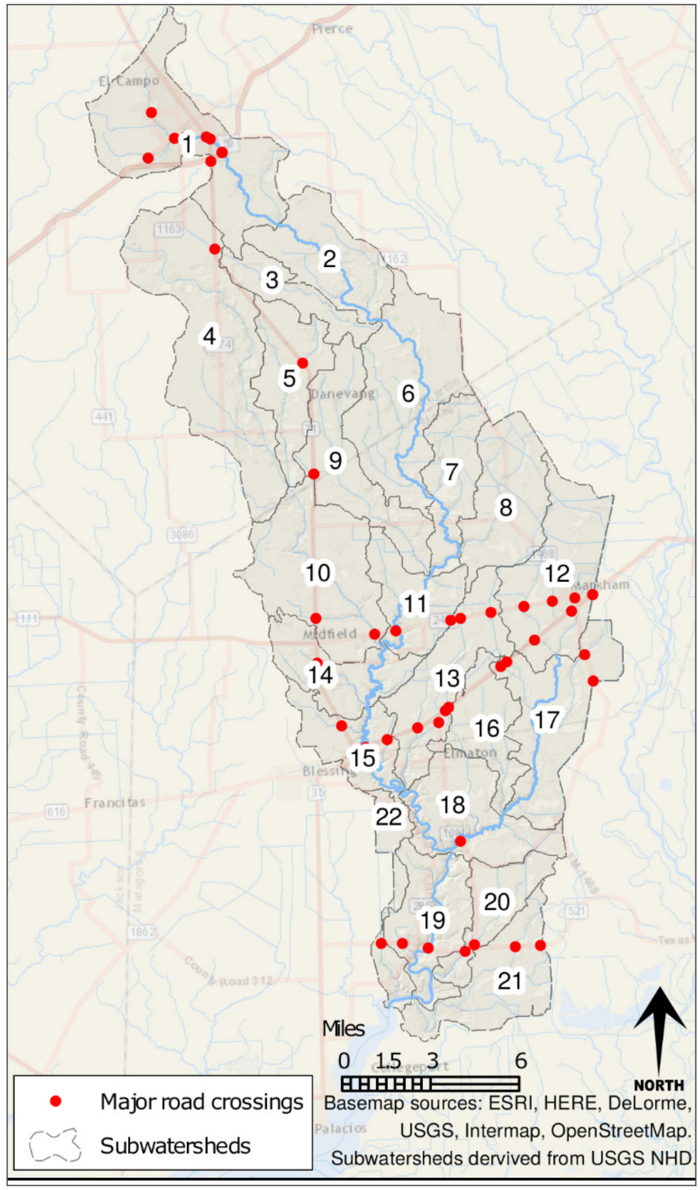

Figure 4.6. Map indicating locations of major road and stream crossings.

Pollutant Source: Illicit Dumping and Improper Disposal of Animal Carcasses			
Problem: Direct and indirect fecal loading resulting from illicit dumping and improper animal carcass disposal			
Objectives: • Work with counties to lessen the amount of illegal dumping that occurs at bridge crossings • Educate recreational hunters of how to properly dispose of animal carcasses			
Critical Areas: Primarily bridge crossings and areas with high hunting demand (Figure 4.6)			
Goal: Reduce the amount of "dumping" in and near local water bodies			
Description: To work with responsible parties to lessen the impact of illicit dumping and improper animal carcass disposal			
Implementation Strategies			
Participation	**Recommendations**	**Period**	**Capital Costs**
Designated representative	Work to acquire equipment needed to reduce illicit dumping (posting of signs at bridges warning of fines for dumping, etc.)	2017–2022	$24,000
Designated representative	Education and Outreach	2017–2022	$115,000
Estimated Load Reduction			
Loading reductions from this management measure could not be estimated.			
Effectiveness:	Low: Reducing illicit dumping and animal carcasses in water bodies can potentially reduce instream bacteria loadings.		
Certainty	Low: Difficulty in stopping illicit dumping and remote locations of hunters pose challenges in success of implementation.		
Commitment	Moderate: Local stakeholders have expressed interest in reducing the amount of "dumping" that occurs in the water body; however, it may not lead to a sizable load reduction.		
Needs	Moderate: Financial assistance is needed 1) to acquire the equipment necessary for enforcing illicit dumping and 2) to develop education programs on how to properly dispose of animal carcasses.		
***Potential Funding Sources**	Control: CWA §319(h) grant program, local funds Education: CWA §319(h) grant program (full list of sources in Chapter 5)		

*Funding available from listed programs varies yearly so potential contributions are unknown

Urban Management Measures

Urban stormwater management and mitigation measures are not likely widespread within the watershed due in most part to limited urban land use and small community sizes in this largely rural watershed. The responsibility for the implementation of structural and programmatic urban stormwater measures remains with individual entities and property owners in the watershed. The planning, design, and implementation of specific stormwater management improvements and BMPs are generally outside the scope of most municipal operations. Therefore, technical and financial assistance, and professional engineering analysis is needed to assist with the planning and implementation of urban stormwater improvements and BMPs. With access to funding and technical assistance, communities might be willing to adopt and implement BMPs to better manage stormwater runoff. Throughout this process, the continued assistance and commitment of city officials and staff is critical to the implementation of management measures.

Management Measure 5 – Urban Stormwater Planning and Management

The City of El Campo represents the prominent urbanized area within the watershed. Stormwater from El Campo is currently unregulated. However, based on recent census figures (a little over 11,000), El Campo is likely to be regulated by the Phase II Municipal Separate Storm Sewer System (MS4) stormwater permit program in the near future. This permit is required for small urbanized areas with a population density of at least 1,000 people per square mile. Under this permit, the city would be required to develop a stormwater management plan (SWMP) that includes at least the following control actions:

- public education and outreach;
- public involvement or participation;
- detection and elimination of illicit discharges;
- control for stormwater runoff from construction sites;
- post-construction stormwater management in new development and redevelopment zones; and
- pollution prevention and "good housekeeping" measures for municipal operation.

The city has expressed a desire to prepare for Phase II permit requirements. By working with the City of El Campo to assist with Phase II preparation and securing funding where possible to facilitate the transition, the WPP can assist the city in prioritizing management measures and control actions that most effectively reduce bacteria loading.

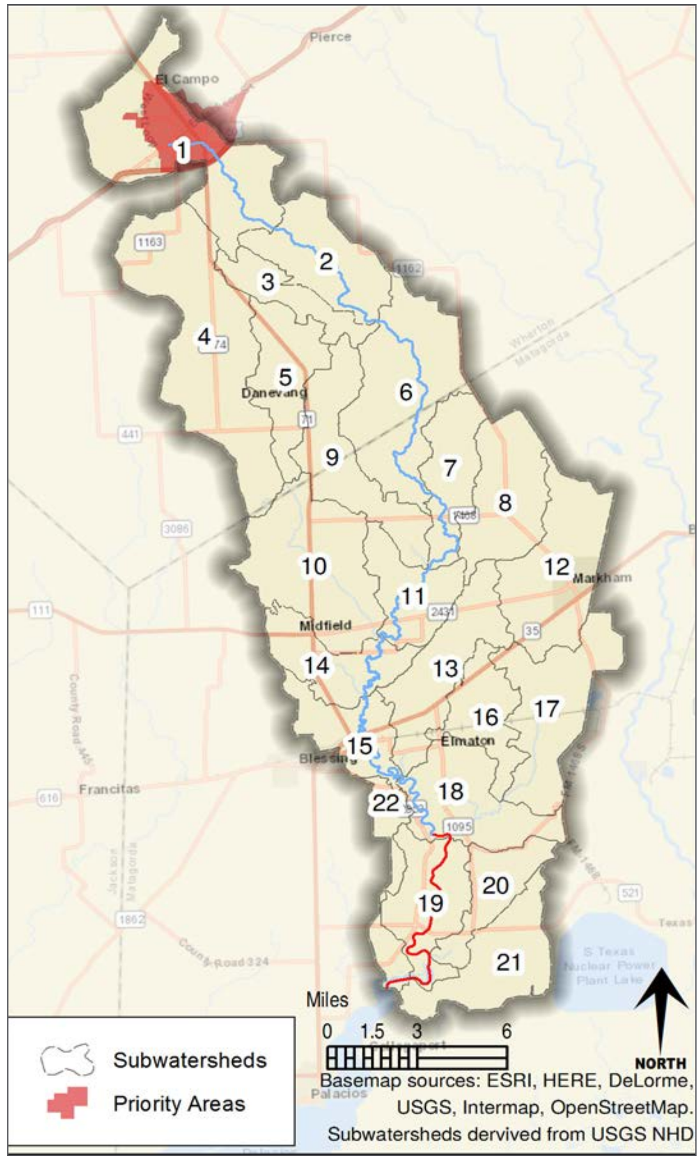

Figure 4.7. Priority areas for urban, wastewater, and SSO management measures.

<table>
<tr><td colspan="4">Pollutant Source: Urban stormwater</td></tr>
<tr><td colspan="4">Problem: Anticipated stormwater planning needs</td></tr>
<tr><td colspan="4">Objectives:
• Assist the City of El Campo with preparations for a SWMP or development of stormwater management strategies that address the six control actions required by Phase II SWMP permits</td></tr>
<tr><td colspan="4">Critical Areas: El Campo (Figure 4.7)</td></tr>
<tr><td colspan="4">Goal: Assist with preparations and funding of a SWMP or stormwater management strategies that effectively address bacteria loading in the Tres Palacios Creek</td></tr>
<tr><td colspan="4">Description: The City of El Campo anticipates MS4 Phase II permit requirements in the future. This plan can provide assistance in the development of stormwater management strategies, prioritize management practices, and recommend effective control actions to most effectively reduce bacteria loadings in the Tres Palacios Creek from urban stormwater runoff.</td></tr>
<tr><td colspan="4">Implementation Strategies</td></tr>
<tr><td>Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>City of El Campo</td><td>Initiate stormwater management planning and strategies that are anticipated as part of MS4 Phase II requirements.</td><td>2020–2024</td><td>$25,000</td></tr>
<tr><td colspan="4">Estimated Load Reduction</td></tr>
<tr><td colspan="4">Pollution control requirements included in potential SWMPs are unknown prior to plan development. Therefore, quantifying load reductions resulting from plan development and implementation is not possible. However, working with municipalities on SWMP development ensures issues of concern included in the Tres Palacios Creek WPP are incorporated.</td></tr>
<tr><td>Effectiveness:</td><td colspan="3">Moderate – SWMP directly address loading from urban NPS runoff. However, the amount of urban-developed area in the watershed is very small relative to other land uses.</td></tr>
<tr><td>Certainty</td><td colspan="3">High – The City of El Campo will likely be required meet MS4 Phase II requirements as some point in the near future.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate – Requires the commitment of city officials and staff.</td></tr>
<tr><td>Needs</td><td colspan="3">Moderate – Funding and technical assistance for plan preparation and development will need to be identified.</td></tr>
<tr><td>* Potential Funding Sources</td><td colspan="3">Planning: TWDB, §319(h) grant programs, local funds (cannot be utilized once an MS4 is required)
Education: §319(h) grant programs, local funds (full list of sources in Chapter 5)</td></tr>
</table>

*Funding available from listed programs varies yearly so potential contributions are unknown

Management Measure 6 – Installation of Urban Best Management Practices

Management of potential urban sources of bacteria and nutrients can be addressed with a number of different BMPs. Urban stormwater BMPs reduce or delay runoff generated by impervious or highly compacted surfaces such as roofs, roads, and parking lots. A wide variety of urban stormwater BMPs are available, and performance in reducing flow volumes, bacteria and nutrients vary based on specific design and location. Examples of BMPs that can be used in urbanized areas include: grass swales, rain gardens, retention ponds, detention basins, wetland basins, and porous pavement. Well-placed and well-designed stormwater BMPs can substantially decrease and delay runoff as well as bacteria and nutrient loading.

Pollutant Source: Urban stormwater			
Problem: Bacteria and nutrient loading from urban stormwater runoff			
Objectives: • Plan and prioritize areas where urban BMP demonstration projects can be implemented • Implement urban BMP structures as funding allows • Educate residents about urban BMPs and riparian areas			
Critical Areas: City of El Campo (Figure 4.7)			
Goal: Identify potential locations for and to implement urban stormwater BMP demonstration projects to reduce runoff and loading into the Tres Palacios Creek			
Description: Potential locations for urban stormwater BMPs will be identified by working with local community representatives. Education and outreach will be used to teach residents about BMPs that can be used on their own properties and how they reduce pollution in the Tres Palacios Creek watershed.			
Implementation Strategies			
Participation	**Recommendations**	**Period**	**Capital Costs**
City of El Campo	Identify, plan, and prioritize areas for urban BMP stormwater demonstration projects	2017–2022	N/A
City of El Campo, contractors	Plan and construct urban BMP stormwater demonstration projects treating 50 urbanized ac as funding allows	2017–2022	$5 Million
City of El Campo, TCEQ, AgriLife Extension	Deliver education and outreach programs to area residents and property owners ($2,500 per workshop at 1 per CCN annually)	2017–2022	$37,500
Estimated Load Reduction			
As planned, 50 ac of urbanized acreage will be treated by stormwater BMPs in critical areas throughout the watershed. Treatment of the 50 ac as planned with highly efficient stormwater BMPs results in an expected annual loading reduction of 1.74×10^{10} cfu *Enterococcus*, 21.5 pounds of nitrogen and 5 pounds of phosphorus. See Appendix B and C for calculations.			
Effectiveness:	Moderate – The long-term effectiveness of urban BMPs at reducing bacteria loading is dependent on proper design, site selection, and maintenance.		
Certainty	Moderate – Requires a sustained commitment from city officials and staff and financial incentives or assistance to implement or construct BMPs.		
Commitment	Moderate – Requires the commitment of city officials and staff.		
Needs	High – Funding to identify, plan, and construct projects is limited.		
***Potential Funding Sources**	Identify and plan: TWDB, §319(h) grant programs, local funds Implementation: §319(h) grant programs, local funds Education: §319(h) grant programs, local funds (full list of sources in Chapter 5)		

*Funding available from listed programs varies yearly so potential contributions are unknown

Management Measure 7 – Development and Implementation of Pet Waste Programs

Bacteria loading from domestic pets was determined to be among the higher potential bacteria contributors in the watershed. Management strategies emphasize reducing the amount of pet waste that can be transferred to streams via overland transport. Providing waste bag dispensers and collection stations in areas of higher pet density (parks, neighborhoods) encourages pet owners to pick up pet waste before it can be transported to streams. Limiting the number of pets and the number of off-leash pets can also reduce the likelihood of pet waste reaching water bodies. Matagorda County and the City of El Campo already implement leash laws. El Campo also limits households to no more than five dogs and/or cats and requires registration of all pets. Finally, providing education and outreach materials to pet owners about bacteria and nutrient pollution and pet waste can increase the number of residents who pick up and dispose of pet waste. Recognizing that domestic pets in rural portions of the watershed likely have large areas to roam and that picking up pet waste is likely not feasible for all owners, management measures should target areas of the watershed with high housing and pet densities.

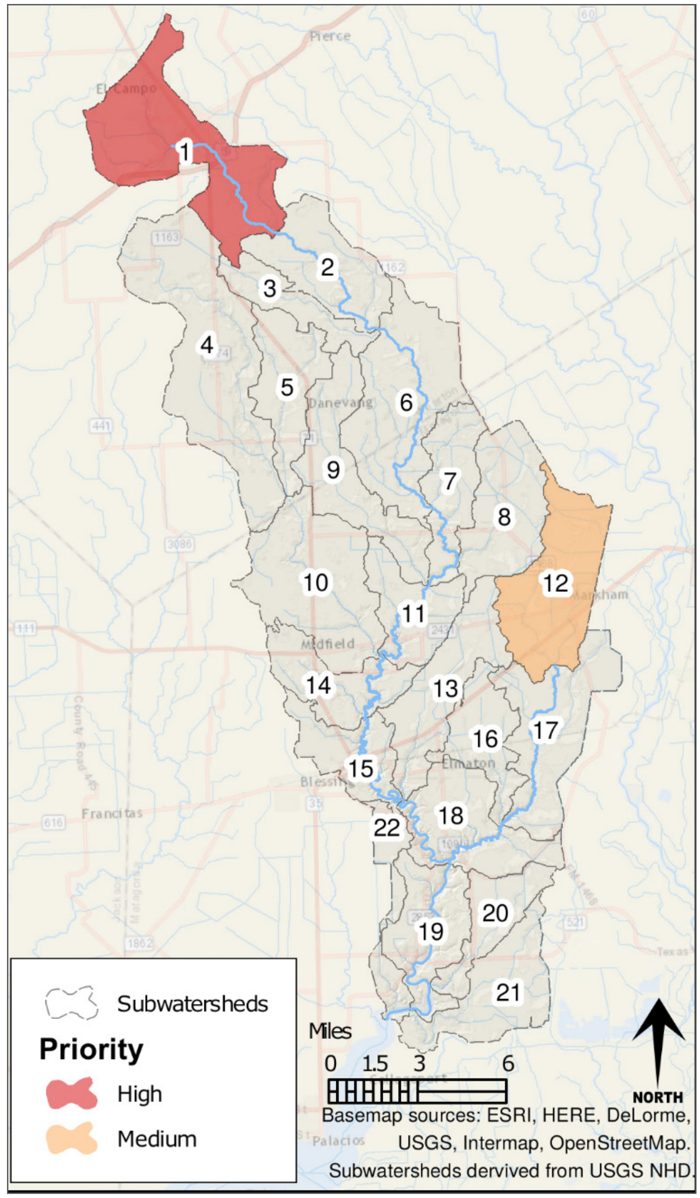

Figure 4.8. Priority areas for domestic pet management measures.

Pollutant Source: Household pets			
Problem: Pollutant loading from dogs and cats			
Objectives: • Install pet waste station in neighborhoods and parks where needed • Deliver education and outreach materials to pet owners			
Critical Areas: Subwatersheds 1 and 12, neighborhoods, parks, and areas of higher pet density (Figure 4.8)			
Goal: Implement or expand pet waste management			
Description: Voluntary implementation efforts to reduce the amount of pet waste throughout the watershed by providing pet waste stations and educating pet owners about bacteria pollution caused by pet waste.			
Implementation Strategies			
Participation	**Recommendations**	**Period**	**Capital Costs**
City of El Campo, landowners	Install and maintain 1 pet waste collection station per CCN ($3,500 ea)	2017–2022	$10,500
City of El Campo, TCEQ, AgriLife Extension	Provide and deliver education and outreach materials to pet owners ($2,500 per workshop at 1 per CCN annually)	2017–2022	$52,500
Estimated Load Reduction			
Estimating an expected load reduction from education and outreach materials is inherently difficult because the reach and effectiveness of programs can be uncertain. Targeted education and outreach efforts reaching at least 2,500 pet owners has an expected annual loading reduction of 9.58×10^{13} cfu *Enterococcus*, 3.14×10^{2} pounds of nitrogen and 72.4 pounds of phosphorus. See Appendix B and C for calculations.			
Effectiveness:	High – Reduction in pet waste will result in direct bacteria loading reductions in streams.		
Certainty	Low-Medium – It is not known how effective providing pet waste stations and educational materials to pet owners will be.		
Commitment	Moderate – Requires the commitment of city officials and staff, as well as land and pet owners.		
Needs	Moderate – Funding to install and maintain pet waste stations and to deliver education and outreach materials.		
***Potential Funding Sources**	Pet waste stations: §319(h) grant programs, local funds Education: §319(h) grant programs, local funds (full list of sources in Chapter 5)		

*Funding available from listed programs varies yearly so potential contributions are unknown

Wastewater Treatment Facility Strategies

WWTFs collect wastewater from developed residential and urban areas and treat the wastewater prior to discharging into the watershed. All WWTFs are subject to regulatory discharge requirements issued by TCEQ. Three WWTFs in the Tres Palacios Creek watershed contribute to bacteria and nutrient loading through direct discharges up to TCEQ-permitted concentrations. The City of El Campo WWTF is the largest, permitted to discharge up to 2.6 MGD of treated effluent. However, records and staff have indicated that discharges rarely exceed half that volume. All the WWTFs in the watershed have an excellent record of compliance and likely do not anticipate a need to upgrade or add additional facilities to accommodate increased populations.

Management Measure 8 – Planning and Implementation of Wastewater Reuse

The City of El Campo has expressed interest in pursuing wastewater reuse to reduce bacteria loadings in Tres Palacios Creek. Wastewater reuse decreases potential bacteria and nutrient loadings in the watershed by diverting WWTF effluent to non-potable uses such as irrigation or into constructed wetlands for enhanced wastewater treatment. The reuse of wastewater offers an attractive option for irrigation, especially in times of drought. However, viable options for wastewater reuse in El Campo have not been identified. Working with city staff and officials to identify and secure needed financial and technical resources is required to implement this measure.

<table>
<tr><td colspan="4">Pollutant Source: WWTFs</td></tr>
<tr><td colspan="4">Problem: Pollutant loading from WWTF discharges</td></tr>
<tr><td colspan="4">Objectives:
• Identify sites within El Campo with high potential for wastewater reuse
• Encourage and pursue wastewater reuse as funding allows</td></tr>
<tr><td colspan="4">Critical Areas: El Campo</td></tr>
<tr><td colspan="4">Goal: Encourage the adoption of wastewater reuse as an option to reduce bacteria loadings in the Tres Palacios Creek by reducing or eliminating WWTF discharges in the City of El Campo (Figure 4.7)</td></tr>
<tr><td colspan="4">Description: The City of El Campo has indicated interest in pursuing wastewater reuse to irrigate city properties. However, viable land options have not been identified. Identification of sites with high potential to use wastewater effluent as irrigation is needed. Securing funding for project planning and implementation will also be required.</td></tr>
<tr><td colspan="4">Implementation Strategies</td></tr>
<tr><td>Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>City of El Campo</td><td>Inventory, identify, and prioritize sites within El Campo that could use wastewater reuse</td><td>2017–2027</td><td>N/A</td></tr>
<tr><td>City of El Campo</td><td>Plan and implement wastewater reuse projects as funding allows</td><td>2017–2027</td><td>$3,600,000</td></tr>
<tr><td colspan="4">Estimated Load Reduction</td></tr>
<tr><td colspan="4">Wastewater reuse can reduce or eliminate loading to the watershed; the amount depends on how much effluent can be diverted for irrigative purposes. If 100 percent of the effluent can be diverted, a load reduction of 1.28×10^{12} cfu Enterococcus, 812 pounds of nitrogen and 7,791 pounds of phosphorus can be achieved.</td></tr>
<tr><td>Effectiveness:</td><td colspan="3">High – Reducing or eliminating effluent discharge into the Tres Palacios Creek will yield direct reductions in bacteria loadings in the watershed.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate – The level of funding available to plan and pursue wastewater reuse is uncertain. The availability of sites that can use treated effluent for irrigation is uncertain. The City of El Campo has pursued funding through the TWDB for initial planning.</td></tr>
<tr><td>Commitment</td><td colspan="3">High – City officials and staff have expressed high interest in pursuing this option.</td></tr>
<tr><td>Needs</td><td colspan="3">High – Funding to plan and implement wastewater reuse projects is limited, as is site availability.</td></tr>
<tr><td>*Potential Funding Sources</td><td colspan="3">Identify Sites: TWDB, local funds
Planning and project implementation: TWDB, local funds (full list of sources in Chapter 5)</td></tr>
</table>

*Funding available from listed programs varies yearly so potential contributions are unknown

Sanitary Sewer Overflow (SSO) Management Measures

Management Measure 9 – Infrastructure Maintenance and Replacement

SSOs are a minor contributor to bacteria loads in the Tres Palacios Creek watershed. The City of El Campo has reported a single SSO due to equipment malfunction over the previous 10 years. However, as the collection system infrastructure ages, the maintenance and replacement of equipment will be necessary to maintain proper operation and prevent any episodic releases of untreated wastewater.

Inflow and infiltration (I/I) was voiced as a possible concern by city representatives. Inflow is surface runoff that enters collection systems through manhole covers, sewer cleanouts, illicit connections, or damaged infrastructure. Infiltration is groundwater that enters the collection system through compromised infrastructure. I/I have the potential to overload a system during storm events, causing the discharge of untreated waste. Furthermore, I/I have a diluting effect that may decrease treatment efficiency and can increase pumping and treatment costs.

Management measures for SSO and I/I include identifying and repairing the oldest or most problematic sections of the collection system infrastructure to prevent episodic releases to Tres Palacios Creek.

Pollutant Source: SSO and I/I			
Problem: Pollutant loading from episodic releases due to SSOs and I/I			
Objectives: • Identify areas in the collection system where I/I or aging infrastructure is a problem • Repair and replace identified infrastructure components • Provide education to operators and staff on aging infrastructure and maintenance			
Critical Areas: El Campo (Figure 4.7)			
Goal: Reduce the potential for episodic releases of untreated wastewater into Tres Palacios Creek			
Description: Identify problematic areas of the collection systems and set up a schedule for repair/replacement. Repairs should be done during the driest times of the year when groundwater and stormwater are not a factor. Repairs can also coincide with routine scheduled maintenance or WWTF upgrades in order to eliminate dilution, exceedance of design capacity and overflows.			
Implementation Strategies			
Participation	**Recommendations**	**Period**	**Capital Costs**
City and WWTF staff and operators	Coordinate workshops or trainings for operators or staff on identifying aging and failing infrastructure	2017 – 2022	$30,000
City and WWTF staff and operators	Identify the oldest parts of the collection system and areas with significant I/I. Plan projects to repair or replace components. Coordinate repairs with WWTF upgrades when possible.	2017 – 2022	$400,000
Estimated Load Reduction			
Minimal load reductions are expected because the compliance and SSO history in the area has indicated minimal problems attributable directly to SSOs. Load reduction potential was not calculated because there have not been a sufficient number of SSO events in the watershed to base loadings on.			
Effectiveness:	Moderate – SSO and I/I have a good track record in the watershed. Continuation of good performance requires prioritization and continual maintenance as infrastructure ages.		
Certainty	High – The City of El Campo has demonstrated commitment to maintaining and providing collection system services to city residents.		
Commitment	Moderate – Requires the continued commitment of city officials, staff, and plant operators to identify and maintain equipment.		
Needs	Moderate to High – Funding to identify and repair/replace aging infrastructure and deliver educational programs to staff is needed.		
***Potential Funding Sources**	Identify, Plan, Repair: TWDB Education: local funds (full list of sources in Chapter 5)		

*Funding available from listed programs varies yearly so potential contributions are unknown

Education and Outreach

An essential element in implementation of this WPP is an effective education and outreach campaign. Long-term commitments from citizens and landowners will be needed to accomplish comprehensive improvements in the Tres Palacios Creek watershed. The education and outreach component of implementation must focus on keeping the public, landowners, and agency personnel informed of project activities, provide information about appropriate management practices, and assist in identifying and forming partnerships to lead the effort.

The Watershed Coordinator

The role of the Watershed Coordinator is an important one that is the heart of WPP development and implementation. In addition to serving as a single point of contact for WPP-related issues, the Watershed Coordinator facilitates stakeholder meetings, coordinates with state and federal agencies to ensure compliance with agreements, and keeps the implementation of the WPP on schedule. This role also includes identifying and securing necessary funds for implementing the WPP and maintaining stakeholder support. Texas Water Resources Institute (TWRI) has taken the lead on this role and continues to guide the effort.

Public Meetings

Throughout the course of developing the WPP, stakeholder engagement has been critical. Beginning in July 2015, stakeholders have been engaged in the planning process. Table 4.1 includes the various stakeholder groups actively engaged in this WPP's development. Using stakeholder feedback and data collected led to the application of planning tools with the WPP as an end goal. This WPP integrates science and stakeholder input to develop a comprehensive watershed-specific plan for restoring and protecting water quality in the Tres Palacios Creek. Public meetings engaging watershed stakeholders and local officials have been integral to this effort. Through these meetings, educational information on practices that landowners could begin implementing to improve watershed health and water quality while enhancing the operation of their ranch was conveyed as well.

Future Stakeholder Engagement

Watershed stakeholders will continue to be engaged throughout and following the transition of efforts from development to implementation of the WPP. The Watershed Coordinator will play a critical role in this transition by continuing to organize and host periodic public meetings and needed educational events, and by meeting with focused groups of stakeholders to seek out and secure implementation funds. The coordinator will also provide content to maintain and update the project website, track WPP implementation progress, and participate in local events to promote watershed awareness and stewardship. News articles, newsletters, and the project website will be primary tools used to communicate with watershed stakeholders on a regular basis and will be developed to update readers periodically on implementation progress, provide information on new implementation opportunities, available technical or financial assistance, and other items of interest related to the WPP effort.

In addition to continued correspondence and additional educational events with stakeholders, a volunteer monitoring group is being organized by Texas Stream Team. A Texas Stream Team representative is working with the interested stakeholders to set up monitoring along the Tres Palacios Creek. This initiative will help keep stakeholders engaged but will also provide additional supplemental water quality information as the plan is being implemented.

Table 4.1. Stakeholder groups engaged during the watershed planning process.

Stakeholder Groups
Local residents and landowners
City of El Campo – City manager, water and sewer utility, and public works
Wharton and Matagorda counties – County commissioners and judges
State agencies – TCEQ, TSSWCB, and TPWD
Federal agencies – USDA NRCS
Local and regional entities – Lower Colorado River Authority and SWCD board members, Palacios Chamber of Commerce
NGOs – Colorado River Land Trust

Education Programs

Educational programming will be a critical part of the WPP implementation process. Multiple programs geared to provide information on various sources of potential pollutants and feasible management strategies will be delivered in and near the Tres Palacios Creek watershed and advertised to watershed stakeholders. An approximate schedule for planned programming has been provided in Chapter 6. This schedule will be used as a starting point for planned programming, and efforts will be made to abide by this schedule to the extent possible. As implementation and data collection continues, the adaptive management process will be used to modify this schedule and respective educational needs as appropriate.

Feral Hog Management Workshop

The Watershed Coordinator will coordinate with AgriLife Extension personnel to deliver periodic workshops focusing on feral hog management. This workshop will educate landowners on the negative impacts of feral hogs, effective control methods, and resources to help them control these pests. Workshop frequency will be approximately every five years unless there are significant changes in available means and methods to control feral hogs. Feral hog management is incorporated into the *Lone Star Healthy Streams* education program and, as such, is the appropriate delivery mechanism for this programming. Information on this program can be found online at: lshs.tamu.edu.

Lone Star Healthy Streams Workshop (grazing cattle component)

The Watershed Coordinator will coordinate with AgriLife Extension personnel to deliver the Lone Star Healthy Streams curriculum. This program is geared to expand knowledge of how to improve grazing lands by beef cattle producers to reduce NPS pollution. This statewide program promotes the adoption of BMPs that have proven to effectively reduce bacterial contamination of streams. This program provides educational support for the development of conservation plans by illustrating to program participants the benefits of many practices available for inclusion in a conservation plan. This program will likely be delivered in the watershed once every five years or as needed. Information on this program can be found online at: lshs.tamu.edu.

OSSF Operation and Maintenance Workshop

OSSFs in the tidal portion of the watershed have been inventoried through the Coastal Zone Reauthorization Amendments Coastal NPS management efforts. OSSFs in the above tidal watershed have yet to be identified and inventoried. OSSF education and training for homeowners will be offered. There will be education and outreach to promote the proper management of existing OSSFs. AgriLife Extension provides the needed expertise to deliver this training. Based on needs identified early during WPP planning, trainings will be scheduled for every third year. Training workshops will be advertised through community newsletters, news releases, the project website, and other appropriate venues. Additionally, an online training module that provides an overview of septic systems, how they operate and what maintenance is required to sustain proper functionality and extend system life will be made available to anyone interested through the partnership website. This training module was developed by the Guadalupe-Blanco River Authority in cooperation with AgriLife Extension and is currently available online at: www.gbra.org/septic.swf.

Texas Well Owners Network Training

Private water wells provide a source of water to many Texas residents. The Texas Well Owners Network (TWON) program provides needed education and outreach regarding private drinking water wells and the impacts on human health and the environment that can be mitigated by using proper management practices. Water quality screenings are conducted through this program and provide useful information to well owners that will benefit them in better managing their water supplies. The "Well Educated" training focuses on informing landowners about groundwater resources, septic system maintenance, well maintenance, water conservation, water quality, and water treatment. As well, TWON has online information and fact sheets about maintaining septic systems to protect well water. The Watershed Coordinator is currently coordinating with AgriLife Extension personnel to deliver this program in the Tres Palacios Creek watershed. Information on this program can be found at: twon.tamu.edu.

Riparian and Stream Ecosystem Education Program

Healthy watersheds and good water quality go hand in hand with properly managed riparian and stream ecosystems. Delivery of the Riparian and Stream Ecosystem Education program will increase stakeholder awareness, understanding and knowledge about the nature and function of riparian zones and BMPs that can be used to protect them while minimizing NPS pollution. Through this program, riparian landowners will be connected with local technical and financial resources to improve management and promote healthy watersheds and riparian areas on their land. The Watershed Coordinator will work to plan an associated field day to coincide with this event.

Wildlife Management Workshops

Wildlife have a significant impact on the Tres Palacios Creek watershed in numerous ways, and, as a result, periodic wildlife management workshops are warranted to provide information on management strategies and available resources. The Watershed Coordinator will work with AgriLife Extension Wildlife Specialists and TPWD to plan and secure funding to deliver workshops in and near the Tres Palacios Creek watershed. With the variety of wildlife species prevalent in the Tres Palacios Creek watershed, it is anticipated that workshops focused on at least one game species will be delivered every other year. Wildlife management workshops will be advertised through newsletters, news releases, the project website, and other avenues as appropriate.

Public Meetings

Continuing to periodically conduct public stakeholder meetings is necessary to serve several major roles of WPP implementation. Public meetings provide a platform for the Watershed Coordinator and project personnel to provide pertinent WPP implementation information including implementation progress, near-term implementation goals and projects, information on how to sign-up or participate in active implementation programs, and other information as appropriate. These meetings will also effectively keep stakeholders engaged in the WPP process and provide a platform to discuss adaptive management to keep the WPP relevant to watershed and water quality needs. This will largely be accomplished by reviewing implementation goals and milestones during at least one public meeting annually and actively discussing how watershed needs can be better served. Feedback will be incorporated into WPP addendums as appropriate. It is anticipated that public meetings will be held on a semiannual basis but will largely be scheduled based on need.

Newsletters and News Releases

Tres Palacios Creek watershed newsletters will be developed and sent to actively engaged stakeholders. Newsletters will be sent annually and will be staged such that they come out between project meetings. News releases will also be developed and distributed as needed through the mass media outlets in the area and will be used to highlight significant happenings related to WPP implementation and to continue to raise public awareness and support for watershed protection. These means will be used to inform stakeholders of practice implementation programs, eligibility requirements, when and where to sign-up and what the specific program will entail. Public meetings and other WPP-related activities will be advertised through these outlets.

Sources

Timmons, J.B., Higginbotham, B., Lopez, R., Cathey, J.C., Mellish, J., Griffin, J., Sumrall, A., and Skow, K. 2012. Feral Hog Population Growth, Density and Harvest in Texas. College Station, TX: Texas A&M AgriLife Extension. Report SP-472. Retrieved from: <http://feralhogs.tamu.edu/files/2010/04/FeralHogPopulationGrwoth-DensityandHervestinTexasedited.pdf>

Chapter 5
Sources for Watershed Protection Plan Implementation

Tres Palacios Creek at FM 2431.

Introduction

The Tres Palacios Creek watershed is a largely rural watershed with limited resources available for the implementation of the management measures outlined in Chapter 4. Identification of potential sources of technical and financial assistance is needed to maximize the implementation of various management recommendations. Grant funding will likely be a substantial source of implementation funding given the availability of resources identified thus far in the area. In addition to technical and financial assistance, the Watershed Coordinator position serves a critical role for ensuring WPP success. It is recommended that local funds be identified and used to hire a local Watershed Coordinator to guide WPP implementation and facilitate long-term success.

Sources of Technical Assistance

Technical assistance needs in the watershed vary substantially depending on the sources of pollution being addressed and the specific management recommendation being used. Many watershed stakeholders have this expertise, but in some instances additional technical knowledge is needed. Table 5.1 lists sources of technical assistance that contributed to guidance on planning and implementing management practices associated with the Tres Palacios Creek WPP.

Table 5.1. Sources of technical assistance for WPP implementation.

Management Measure	Technical Assistance
MM 1: Developing and Implementing Conservation Plans in Priority Areas of the Watershed	• TSSWCB • AgriLife Extension and Extension county agents • NRCS • SWCD • TPWD
MM 2: Feral Hog Removal and Management	• Texas A&M AgriLife Extension • Texas Wildlife Services
MM 3: Identify OSSFs, Prioritize Problem Areas, and Systematically Work to Bring Systems into Compliance	• TCEQ Region 12 • TCEQ Small Business and Local Government Assistance Program • AgriLife Extension
MM 4: Reduction of Illicit Dumping and Proper Disposal of Animal Carcasses	• TCEQ Region 12 • TCEQ Small Business and Local Government Assistance Program
MM 5: Urban Stormwater Planning and Management	• TCEQ Region 12
MM 6: Installation of Urban Best Management Practices	• TCEQ Region 12
MM 7: Development and Implementation of Pet Waste Programs	• TCEQ Region 12
MM 8: Planning and Implementation of Wastewater Reuse	• TCEQ, Texas A&M Engineering Extension Service (TEEX)
MM 9: Infrastructure Maintenance and Replacement	• TEEX – WWTF operation and maintenance • Texas Rural Water Association (TRWA) • TCEQ SSO Initiative • Private Engineering firms – general civil engineering services

Private Firms

Private firms offer onsite training to their customers as part of their water and wastewater treatment services. This is accomplished through hands-on instruction and seminars on basic water treatment practices and procedures control testing, and the safe handling of chemicals.

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. It is through this conservation partnership that local SWCDs are able to 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 Tres Palacios Creek watershed lies inside the Wharton SWCD #342 and Matagorda SWCD #316.

Texas A&M AgriLife Extension Service County Agents

AgriLife Extension county agents will assist in educational activities related to mitigation of illicit dumping and proper disposal of animal carcasses.

Texas A&M AgriLife Extension Service

The V.G. Young Institute of County Government is a part of AgriLife Extension and The Texas A&M University System. Located in College Station, the institute works to meet the educational needs of county officials and the public by anticipating, identifying, and addressing the challenges and opportunities faced by Texas county governments. The institute fulfills this charge by offering various educational programs, published reference materials and counsel to county officials, community organizations, and citizens across the state.

Texas A&M Engineering Extension Service

TEEX offers a Water and Wastewater Technical Assistance Program for small wastewater systems within the state. The program provides technical assistance and training to small wastewater systems to help correct operational problems common to small WWTFs. One-on-one technical assistance is available for these small wastewater systems to determine the causes of common performance problems and to ensure the small wastewater systems are operating within permit requirements and in compliance with effluent limits.

Texas Commission on Environmental Quality SSO Initiative

The TCEQ SSO Initiative is a voluntary program open to publicly owned permitted facilities that are not currently under formal enforcement actions for SSOs. Participation in TCEQ's SSO Initiative requires meeting with TCEQ officials and development of an SSO plan for improving, updating, and repairing the wastewater collection system. Participation in the SSO Initiative precludes formal enforcement actions by TCEQ for most continuing SSO violations but not from formal enforcement action by EPA. It also allows municipalities to direct resources towards corrective actions as opposed to penalties associated with enforcement orders.

Texas Commission on Environmental Quality Region 12

TCEQ Region 12 will receive and record unauthorized discharge information from respective CCN holders and assist cities with TCEQ rules and regulations. As resources are available, Region 12 will also provide local governments with support for, and/or assistance with, efforts to mitigate illicit dumping in the TMDL watersheds.

TCEQ Small Business and Local Government Assistance Program

TCEQ's Small Business and Local Government Assistance Program will provide, as resources are available, technical assistance to local governments for developing the best approaches to reducing illicit dumping in the TMDL watersheds, and to identify the best approach for addressing OSSF issues.

TCEQ will partner with TEEX and other relevant organizations to provide technical assistance to the WWTF owners and operators in the TMDL watersheds. TCEQ's Small Business and Government Assistance Program can also provide, as resources are available, technical assistance to local governments for evaluating the capabilities and operating procedures of existing wastewater systems. TEEX provides education and training to wastewater operators and focuses training on optimizing treatment quality.

TCEQ is responsible for monitoring permit compliance and enforcement and can also provide technical assistance to the WWTF owners and operators through TCEQ's Small Business and Government Assistance Program.

Texas Comptroller of Public Accounts

Technical assistance may be needed from the Texas Comptroller of Public Accounts office to ensure all requirements of the tax code have been met. Also, other technical assistance may be needed and will be pursued as necessary.

Texas Parks and Wildlife Department

TPWD's Private Lands Services is a program for private landowners to provide practical information on ways to manage wildlife resources consistent with other land use goals, to ensure plant and animal diversity, to provide aesthetic and economic benefits, and to conserve soil, water, and related natural resources. To participate, landowners may request assistance by contacting TPWD district serving their county. TPWD biologists serving specific geographical areas can be found at the following TPWD website: www.tpwd.state.tx.us/landwater/land/technical_guidance/biologists/.

Texas Rural Water Association

TRWA has two wastewater training and technical assistance providers who assist wastewater system operators across the state. They provide training workshops that include topics such as wastewater operations and maintenance, testing procedures, rule updates, facility management, security, and other topics, as needed or requested, that relate to WWTF operations. TRWA staff also provide on-site technical assistance to non-profit wastewater systems, districts, and small cities with populations of less than 10,000. This technical assistance deals with operations, maintenance, collection systems, treatment facilities, rates, system management, rule changes, state laws, and other topics or issues that affect small wastewater systems.

Texas State Soil and Water Conservation Board

Technical assistance to agricultural producers for developing management and conservation plans is provided through the TSSWCB WQMP Program, funded through state general revenue. It is anticipated that other sources of funding will be required to implement the activities associated with Management Measure 1; it should also be noted that the TSSWCB WQMP Program is dependent on continued appropriations from the Texas Legislature.

TSSWCB, NRCS, and TPWD will continue to provide appropriate levels of cost-share assistance to agricultural producers to facilitate the implementation of BMPs and conservation programs in the Mission and Aransas River watersheds, as described in Management Measure 1. Historically, according to TSSWCB data, conservation plan development and implementation in this watershed has been moderately low; as such, it is anticipated additional levels of funding will be needed to meet implementation needs.

Texas Wildlife Services

Texas Wildlife Services anticipates additional cooperative funding will be necessary to continue the focused feral hog control activities in the state.

United States Department of Agriculture Natural Resources Conservation Service

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. NRCS provides conservation planning and technical assistance to landowners, groups, and units of government to develop and implement conservation plans. 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. NRCS also integrates ecological and economic considerations in order to address private and public concerns.

Sources of Financial Assistance

Successful implementation of the Tres Palacios Creek WPP, as written, will require substantial fiscal resources. Due to the extremely rural nature of the watershed, substantial local sources of funding do not exist in the watershed. As a result, grant and other external sources of funding will be needed to support implementation efforts. Many landowners are already engaged in implementing the WPP through the development and implementation of WQMPs and installation of other conservation practices through Farm Bill-funded programs such as USDA NRCS EQIP. The continued funding support from federal and state governments will provide a large portion of funds needed to implement the WPP. Aside from these programs, other sources of federal funding do not currently exist to implement the WPP.

There are few local sources of funding. Monetary support from local watershed residents is limited to landowners willing to invest money to support management needs on their respective properties.

Grant funds will be relied upon for implementation of WPP items, as they are the only source of money identified, thus far, that can contribute to this effort. Some specific sources of funding that are applicable and available for use in implementing this WPP are exhibited in Table 5.2 and described below.

Table 5.2. Sources of financial assistance for WPP implementation

Management Measure	Financial Assistance Program
MM 1: Developing and Implementing Conservation Plans in Priority Areas of the Watershed	• Coastal Zone Management Administration (CZMA) Awards • Conservation Innovation Grants • Conservation Stewardship Program (CSP) • Environmental Education Grants • EQIP • Farm Business Management and Benchmarking (FBMB) Program • Federal and State CWA §319(h) Grants (EPA/TCEQ/TSSWCB) • Integrated Programs • National Integrated Water Quality Program (NIWQP) • Regional Conservation Partnership Program (RCPP) • Sustainable Agriculture Research & Education (SARE) • TSSWCB WQMP Program
MM 2: Feral Hog Removal and Management	• State CWA §319(h) Grants (TSSWCB, cannot be used for control or removal efforts) or other available opportunities • Texas Department of Agriculture (TDA) • County Hog Abatement Matching Program (CHAMP) • Texas Wildlife Services
MM 3: Identify OSSFs, Prioritize Problem Areas, and Systematically Work to Bring Systems into Compliance	• Coastal Impact Assistance Program • Coastal Management Program • National Coastal Zone Management Program (CZM) • State CWA §319(h) grants (TCEQ) • Texas SEP Fund
MM 4: Reduction of Illicit Dumping and Proper Disposal of Animal Carcasses	• State CWA §319(h) Grants (TCEQ/TSSWCB) • USDA Rural Utilities Service (RUS) Water and Waste Disposal Loans and Grants
MM 5: Urban Stormwater Planning and Management	• State CWA §319(h) Grants (TCEQ) • Clean Water State Revolving Fund (CWSRF)
MM 6: Installation of Urban Best Management Practices	• CWSRF • Environmental Education Grants • State CWA §319(h) Grants (TCEQ) • Urban Water Small Grants
MM 7: Development and Implementation of Pet Waste Programs	• State CWA §319(h) Grants (TCEQ)
MM 8: Planning and Implementation of Wastewater Reuse	• CWSRF • Water and Waste Disposal Loans and Grants
MM 9: Infrastructure Maintenance and Replacement	• CWSRF • Economically Distressed Areas Program (EDAP) • Water and Waste Disposal Loans and Grants

Coastal Zone Management Program and Coastal Management Program

The CZM Program, administered by NOAA and the Texas General Land Office (GLO) is a voluntary partnership between the federal government and U.S. Coastal and Great Lake states and territories and is authorized by the Coastal Zone Management Act (CZMA) of 1972 to address national coastal issues. The act provides funding for protecting, restoring, and responsibly developing our nation's diverse coastal communities and resources. To meet the goals of the CZMA, the National CZM Program takes a comprehensive approach to coastal resource management—balancing the often competing, and occasionally conflicting, demands of coastal resource use, economic development, and resource conservation. Some of the key elements of the National CZM Program include:

- protecting natural resources;
- managing development in high hazard areas;
- giving development priority to coastal-dependent uses;
- providing public access for recreation; and
- coordinating state and federal actions.

The CZM Program provides pass-through funding to GLO, which, in turn, uses the funding to finance coastal restoration, conservation and protection projects under GLO's Coastal Management Program.

Conservation Innovation Grants (CIG)

The USDA administers the CIG Program, which is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, EQIP funds are used to award competitive grants to non-federal governmental or nongovernmental organizations, tribes, or individuals.

Conservation Stewardship Program

The CSP is a voluntary conservation program administered by USDA NRCS that encourages producers to address resource concerns in a comprehensive manner by undertaking additional conservation activities, as well as improving, maintaining, and managing existing conservation activities. Participants earn CSP payments for conservation performance—the higher the performance, the higher the payment.

Environmental Education Grants

Under the Environmental Education Grant Program, EPA seeks grant proposals from eligible applicants to support environmental education projects that promote environmental stewardship and help develop knowledgeable and responsible students, teachers, and citizens. This grant program provides financial support for projects that design, demonstrate, and/or disseminate environmental education practices, methods, or techniques as described in the Environmental Education Grant Program solicitation notices. EPA expects to award two rounds of environmental education grants from the ten EPA Regional offices.

Environmental Quality Incentives Program

Operated by USDA NRCS, EQIP is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of 10 years. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air, and related resources on agricultural land and non-industrial private forestland. An additional purpose of EQIP is to help producers meet federal, state, tribal, and local environmental regulations.

Farm Business Management and Benchmarking Competitive Grants Program

The USDA National Institute of Food and Agriculture (NIFA) FBMB Competitive Grants Program provides funds to (1) improve the farm management knowledge and skills of agricultural producers; and (2) establish and maintain a national, publicly available, farm financial management database to support improved farm management.

Federal Clean Water Act §319(h) Nonpoint Source Grant Program

The CWA requires the EPA to award §319(h) grants to the state agencies designated by the governor to implement the state's approved Nonpoint Source Management Program to achieve and maintain beneficial uses of surface water, such as swimming or fishing. EPA-approved state Nonpoint Source Management Programs provide the framework for determining which activities are eligible for funding under CWA §319(h). In general, these activities include non-regulatory programs and are related to controlling NPS pollution; EPA-approved NPS programs cover costs associated with technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific NPS projects.

Integrated Programs

The USDA NIFA Integrated Programs provide support for integrated research, education, and extension activities. Integrated, multi-functional projects are particularly effective in addressing important agricultural issues through the conduct of problem-focused research that is combined with education and extension of knowledge to those in need of solutions. These activities address critical national, regional, and multi-state agricultural issues, priorities, or problems. Integrated Programs hold the greatest potential to produce and disseminate knowledge and technology directly to end users while providing for educational opportunities to assure agricultural expertise in future generations.

National Integrated Water Quality Program

The NIWQP, administered by USDA, provides funding for research, education, and extension projects aimed at improving water quality in agricultural and rural watersheds, and has identified eight "themes" that are being promoted in research, education, and extension: (1) animal manure and waste management, (2) drinking water and human health, (3) environmental restoration, (4) nutrient and pesticide management (5) pollution assessment and prevention, (6) watershed management, (7) water conservation and agricultural water management, and (8) water policy and economics. Awards are made in four program areas – National Projects, Regional Coordination Projects, Extension Education Projects, and Integrated Research, Education, and Extension Projects. It is important to note that funding from this program is only available to universities.

Regional Conservation Partnership Program

The USDA NRCS's RCPP is a new, comprehensive, and flexible program that uses partnerships to stretch and multiply conservation investments and reach conservation goals on a regional or watershed scale. Through the RCPP and NRCS, state, local, and regional partners coordinate resources to help agricultural producers install and maintain conservation activities in selected project areas. Partners leverage RCPP funding in project areas and report on the benefits achieved. The program is increasing investment in conservation from a diversity of partners, leading to cleaner and more abundant water, improved soil and air quality, enhanced wildlife habitat, and stronger rural economies.

Sustainable Agriculture Research and Education

SARE is administered by USDA and implements programs that enhance the capabilities of Texas agricultural professionals in the area of sustainable agriculture. Grants and education are available to advance innovations in sustainable agriculture. The grants are aimed at advancing sustainable innovations and have contributed to an impressive portfolio of sustainable agriculture efforts across the nation.

Urban Water Small Grants Program

The objective of the Urban Waters Small Grants, administered by the EPA, is to fund projects that will foster a comprehensive understanding of local urban water issues, identify and address these issues at the local level, and educate and empower the community. In particular, the Urban Waters Small Grants Program seeks to help restore and protect urban water quality and revitalize adjacent neighborhoods by engaging communities in activities that increase their connection to, understanding of, and stewardship of, local urban waterways.

State Sources

Clean Water State Revolving Fund

Through the TWDB, the CWSRF program provides low-interest loans to local governments and wastewater service providers for infrastructure projects that include stormwater BMPs. The loans can spread project costs over a repayment period of up to 20 years. Repayments are cycled back into the fund and used to pay for additional projects.

County Hog Abatement Matching Program

The TDA administers CHAMP, which is designed to encourage counties across Texas to create partnerships with other counties, local governments, businesses, landowners, and associations to reduce feral hog populations and the damage caused by these animals in Texas.

Economically Distressed Areas Program

The EDAP is administered by TWDB and provides financial assistance to fund water and wastewater services in economically distressed areas where such services do not exist or where services do not meet minimum state standards.

Federal Clean Water Act §319(h) Nonpoint Source Grant Program

Local stakeholders should pursue funding for urban stormwater education and outreach and for urban BMP installation through TCEQ's CWA §319(h) Grant Program. Funding for Agricultural BMPs can be pursued through TSSWCB's 319 Grant Program.

Supplemental Environmental Projects

The SEP program, administered by TCEQ, directs fines, fees, and penalties for environmental violations toward environmentally beneficial uses. Through this program, a respondent in an enforcement matter can choose to invest penalty dollars in improving the environment, rather than paying into the Texas General Revenue Fund. Program dollars may be directed to OSSF repair, trash dump clean-up, and wildlife habitat restoration or improvement, among other things. Program dollars may be directed to entities for single, one-time projects that require special approval from TCEQ or directed entities (such as Resource Conservation and Development Councils) with pre-approved "umbrella" projects.

TCEQ

The state's general revenue funds and federal 106 grant money may be used to fund water quality monitoring in addition to the ongoing Clean Rivers Program (CRP) efforts.

TSSWCB Water Quality Management Plan Program

WQMPs are property-specific plans that prescribe management practices that, when implemented, will improve the quality of land and water on the property. Through TSSWCB and the local SWCD, technical assistance is provided to develop plans to meet both producer and state goals. Once developed, TSSWCB may be able to provide financial assistance for implementing a portion of the practices.

Texas Wildlife Services Program

The Texas Wildlife Services Program is available to provide assistance in addressing feral hog issues to all citizens of the state. While direct control will be limited to availability of personnel in cooperative association areas (i.e., areas designated by groups of landowners to improve wildlife habitats and other associated wildlife programs), technical assistance can be provided to individuals on how to best resolve feral hog problems. Since 2008, TDA has awarded grants to Texas Wildlife Services for a feral hog abatement program. The grants are used to carry out a number of specifically identified direct control projects 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.

Tres Palacios Creek at County Road 456.

Chapter 6 Measures of Success

Dock on Tres Palacios water body at FM 521.

Introduction

Measuring the impacts of implementing a WPP on instream water quality is a critical, yet inherently complicated, process due to ever changing conditions in the watershed. Planned water quality monitoring at critical locations will provide data needed to document progress toward achieving water quality goals for the watershed. While improvements in water quality are the preferred measure of success, documenting implementation accomplishments can also be used to measure implementation success. Data on water quality collected over time and implementation accomplishments will facilitate adaptive management by illustrating which recommended measures are working and which measures need modification.

Water Quality Targets

The primary goal of the WPP is to restore measured instream *Enterococcus* and 24-hour DO levels to a point where they are meeting the state's designated water quality standards (Table 6.1). Consistent with this goal, Table 6.2 outlines incremental *Enterococcus* targets that should be realized if WPP implementation proceeds according to schedule. The ultimate water quality goal for *Enterococcus* also includes a 5 percent margin of safety to account for variability in water quality measurements; however, water quality meeting the state's *Enterococcus* standard will be considered as successful restoration.

Table 6.1 Water quality goals for Tres Palacios Creek.

Water Quality Metric	Goal	Evaluation
Enterococcus	33.3 cfu/100mL	7-year geometric mean
24-hour dissolved oxygen	5 mg/L Average 4 mg/L Minimum	Exceeded by 90 percent of samples

As discussed in Chapter 3, station 12515 is considered the index site for the watershed due to its historic data set and plans are to continue monitoring this station. Through the CRP program, this station is scheduled to be sampled four

Table 6.2. *Enterococcus* target concentration for station 20636 and 12515 during the 5-year implementation schedule. For implementation purposes, the implementation year calculator begins upon EPA approval of the WPP.

	***Enterococcus* Concentration (cfu/100mL)**		
Year	**Station 20636**	**Station 12515**	**Both Stations**
2012 303(d) List	149	49	67
Year 1	120.4	45.1	58.7
Year 2	95.4	41.7	51.4
Year 3	70.5	38.3	44.1
Year 4	45.6	34.9	36.9
Year 5	33.3	33.3	33.3

times per year and samples analyzed for conventional parameters and bacteria. While more data would be ideal, this data set will serve as a good basis for assessing long-term changes in water quality. Additionally, this data is what TCEQ will use to determine if the water body is meeting its designated water quality standard.

Additional Data Collection Needs

Additional water quality data collection in the watershed is needed to properly evaluate WPP implementation improvements. The first approach that would provide useful data is increasing the frequency of CRP data collection at index sites from quarterly to at least monthly. This would improve data availability and better illustrate variations in water quality within the year. This data would also enhance trend analyses done on the collected data and make their results more representative of what is actually occurring in the water body. Additional resources will be needed to expand the monitoring program beyond its current levels.

Additional 24-hour DO monitoring will be required to measure progress toward meeting the water quality standards for the established Aquatic Life Use designation. The WPP recommends resuming 24-hr DO monitoring in years 3 and 5 of implementation to gauge progress and provide assessment data for TCEQ.

Data Review

Watershed stakeholders will use two methods to evaluate WPP implementation impacts on instream water quality. The first is to use TCEQ's statewide biennial water quality assessment approach, which uses a moving seven-year geometric mean of *Enterococcus* data and binomial method for 24-hr DO data collected through the state's CRP program. This assessment is published in the *Texas Integrated Report and 303(d) List*, which is made readily available online at https://www.tceq.texas.gov/. It should be noted that this list incorporates a two-year lag in data reporting. For example, the 2014 303(d) List considers water quality data collected between November 1, 2005 and October 31, 2012. As a result, the 2020 303(d) List will likely be the first list to include water quality data collected during implementation.

In addition to DO and bacteria, trends in nutrients will also be examined. The second approach will be to participate in the annual CRP meeting. During this meeting, water quality data collected in the Tres Palacios Creek will be presented and discussed. This data will be compared to water quality targets and will be useful in gauging implementation success and the need for adaptive management within the WPP. Information gained at these meetings should be shared with the stakeholders by the Watershed Coordinator.

Should water quality not meet the target values presented in Table 6.1 or considerable progress not be made in meeting those values, watershed stakeholders will discuss the deficiency and the potential need to adjust the WPP and its management recommendations. This discussion should include changes in water quality as compared to implementation completed at a minimum.

Interim Measurable Milestones

Milestones are useful for incrementally evaluating the implementation progress of specific management measures recommended in the WPP. Milestones outline a clear tracking method that illustrates progress toward implementing management measures as scheduled. They are simply goals of when a specific practice or measure is targeted for implementation and may be completed faster or slower than planned. As needed, adaptive management will be employed to reevaluate the goal and modify plans. At a minimum, implementation progress should be evaluated annually following the start of implementation to document progress and make adjustments to the plan as needed. This will allow ample time for funding to be secured and data to be collected that will support needed adaptations to the recommended management implementation strategy.

Milestones are separated into short-, mid-, and long-term increments. Short-term milestones should be accomplished quickly using existing or available resources during the first three years of WPP implementation. Mid-term milestones take more time to complete and will likely need additional funds secured before they can be undertaken and completed. This is likely to occur within four to five years of beginning to implement the WPP. Long-term milestones are management measures that will take longer to plan, acquire funds, and implement. Due to the significant time and effort needed to implement this group of management measures, it will likely be at least five years before they can be implemented. The single long-term measure identified by the WPP is the implementation of wastewater reuse in the City of El Campo. Interim measurable milestones are identified in the implementation schedule presented in Tables 6.3 and 6.4.

Tres Palacios Creek at Carl Park.

Table 6.3. Summary table of implementation activities, schedules, and costs.

Management Activity	Responsible Party	Implementation Milestone (Years)					Unit Cost	Total Cost
		1	2	3	4	5		
Agricultural Nonpoint Source Management Measures								
Develop 45 total Conservation Plans	SWCDs, NRCS	Implement 9 Conservation Plans	Implement 9 Conservation Plans	Implement 9 Conserva-tion Plans	Implement 9 Conservation Plans	Implement 9 Conservation Plans	$15,000	$675,000
Wildlife and Non-Domestic Animal Management Measure								
Feeder Exclusions	Landowners	Unknown number of exclusions needed					$200	N/A
On-Site Sewage Facility Management Measures								
Identify Failing OSSFs	Counties	1 person paid for identifying OSSFs					$40,000/yr	$200,000
Maintain Database	Counties	Maintenance of 1 database					$50,000	$50,000
Administer Replace-ment Program	Counties	Annual Administration of Program					$15,000/yr	$75,000
Repair/Replace 30 Systems	Contractor	Address 6 Systems	Address 6 Systems	Address 6 Systems	Address 6 Systems	Address 6 Systems	$7,500	$225,000
Illegal Dumping Management Measures								
Implement Signage, etc. and maintenance	Counties	Implement measures at 5 crossings	Implement measures at 5 crossings	Implement measures at 5 crossings	Implement measures at 5 crossings	Implement measures at 5 crossings	$960	$24,000
Urban Management Measures								
Stormwater Permit Planning	City of El Campo	Estimated to begin planning process around year 2020					$25,000	$25,000
Implement BMPs	City of El Campo	Capture 50 ac of urban area					$5 million	$5 million
Pet Waste Stations	1 per CCN	Install 3 Pet Waste Stations	N/A	N/A	N/A	N/A	$3,500	$10,500
Wastewater Treatment Facility Strategies								
Planning for Reuse	City of El Campo	Begin planning process based on resource availability					N/A	N/A
Implement Reuse	City of El Campo	Initiate planning and acquire resources to implement wastewater reuse options in El Campo (5-10 year implementation milestone).					Develop Storage capacity @ $1 million; Distribution System @ $2 million; Develop reuse filtration @ $600k	$3.6 million

Table 6.3. continued

Sanitary Sewer Overflow Management Measures								
Replace Aging Infra-structure	All CCNs	Identify and replace aging infrastructure	Identify and replace aging infrastructure	Identify and replace aging infra-structure	Identify and replace aging infrastructure	Identify and replace aging infrastructure	$80,000	$400,000

Table 6.4. Summary table of scheduled education and outreach activities

Program	Responsible Party	Planned Program Delivery (Years)					Unit Cost	Total Cost
		1	2	3	4	5		
Agricultural Nonpoint Source Management Measures								
Lone Star Healthy Streams	WS Coord./ AgriLife Extension	Provide 1 Workshop		Provide 1 Workshop		Provide 1 Workshop	N/A*	N/A*
Management Practice Field Days	WS Coord./ AgriLife Exten-sion/ SWCDs	Provide 1 Workshop		Provide 1 Workshop		Provide 1 Workshop	$1,000	$3,000
Riparian and Stream Ecosystem Manage-ment	WS Coord./ TWRI		Provide 1 Workshop		Provide 1 Workshop		N/A*	N/A*
Wildlife and Non-Domestic Animal Management Measure								
Feral Hog Manage-ment	WS Coord./ AgriLife Extension	Provide 1 Workshop		Provide 1 Workshop		Provide 1 Workshop	$7,500	$22,500
Wildlife Management	WS Coord./ AgriLife Exten-sion/ TPWD	Provide 1 Workshop		Provide 1 Workshop		Provide 1 Workshop	$7,500	$22,500
On-Site Sewage Facility Management Measures								
OSSF Operation & Maintenance Workshops	WS Coord./ AgriLife Extension	Provide 1 Workshop		Provide 1 Workshop		Provide 1 Workshop	$7,500	$22,500
OSSF Installer and Maintenance Provider Workshop	WS Coord./ AgriLife Extension	Provide 1 Workshop		Provide 1 Workshop		Provide 1 Workshop	$7,500	$22,500
Texas Well Owner Network	WS Coord./ AgriLife Extension		Provide 1 Workshop		Provide 1 Workshop		N/A*	N/A*
Illegal Dumping Management Measures								
Illegal Dumping Education	WS Coord./ AgriLife Extension	Development of an illegal dumping and animal carcass disposal education program					$115,000	$115,000

Table 6.4. continued

Program	Responsible Party	Planned Program Delivery (Years)					Unit Cost	Total Cost
		1	2	3	4	5		
Urban Management Measures								
Stormwater Education Programs	City of El Campo	Provide 1 Workshop	Provide 1 Workshop	Provide 1 Workshop	Provide 1 Workshop	Provide 1 Workshop	$2,500	$37,500
Pet Education Program	1 per CCN Annually	Deliver 3 Education Programs	Deliver 3 Education Programs	Deliver 3 Education Programs	Deliver 3 Education Programs	Deliver 3 Education Programs	$2,500	$52,500
Sanitary Sewer Overflow Management Measures								
Education	TEEX	Deliver 1 staff workshop	Deliver 1 staff workshop	Deliver 1 staff workshop	Deliver 1 staff workshop	Deliver 1 staff workshop	$6,000	$30,000

*Funding currently provided through existing programs

Adaptive Implementation (AI)

Due to the dynamic nature of watersheds and the countless variables governing landscape processes across scales of time and space, some uncertainty is to be expected when a WPP is developed and implemented. As the recommended restoration measures of the Tres Palacios Creek WPP are put into action, it will be necessary to track the water quality response over time and make any needed adjustments to the implementation strategy. To provide flexibility and enable such adjustments, AI will be utilized throughout the process.

AI is often referred to as "learning by doing" (Franklin et al. 2007). It is the ongoing process of accumulating knowledge of the cause of impairment as implementation efforts progress, which results in reduced uncertainty associated with modeled loads. As implementation activities are instituted, water quality is tracked to assess impacts and guide adjustments, if necessary, to future implementation activities. This on-going, cyclic implementation and evaluation process serves to focus project efforts and optimize impacts. Watersheds in which the impairment is dominated by NPS pollutants, such as Tres Palacios Creek, are good candidates for AI.

AI relies on constant input of watershed information and the establishment of intermediate and final water quality targets. Pollutant concentration targets for Tres Palacios Creek were developed based on complete implementation of the WPP and assume full accomplishment of pollutant load reductions by the end of the five-year project period (Table 6.1). While some of the less complex management measures recommended here will be relatively simple to implement early in the process, implementation of other measures will require more time, energy, and funding. For this reason, reductions in pollutant loads and associated concentrations initially may be gradual. However, it can be assumed that reductions in the loadings will be tied to the implementation of management measures throughout the watershed. Thus, these projected pollutant targets will serve as benchmarks of progress, indicating the need to maintain or adjust planned activities. While water quality conditions likely will change and may not precisely follow the projections indicated here, these estimates serve as a tool to facilitate stakeholder evaluation and decision making based on AI.

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Tres Palacios Creek at FM 2431.

Appendix A: LDC Curve Analysis

Modified LDC Analysis

A widely accepted approach for analyzing water quality is the use of a LDC. A LDC allows for a visual determination of how streamflow may or may not impact water quality, in regard to a specific parameter. The modified FDC/LDC approach used in this document, is an accepted methodology for developing FDCs/LDCs in tidally influenced streams by accounting for the additional daily flow volume derived from tidal influences. The methodology used for FDC/LDC development for the tidal segment of the Tres Palacios Creek is outlined below:

1. Determine the period of record used in developing FDCs.
2. Develop naturalized flows.
3. Develop regressions of salinity to streamflow.
4. Develop daily streamflow records using naturalized flows in step 2, permitted discharges, water rights diversions, and daily tidal volumes.
5. Develop the FDC.
6. Develop the LDC.

The primary difference between the standard FDC/LDC approach outlined in Chapter 3 and the modified method discussed here, are steps 3 and 4, which were used to develop FDCs that account for both diversions and the additional daily flow volume from tidal influences.

The decision was made to develop the FDC with 15-year period of records of daily streamflow data from January 1, 1999 through December 31, 2013 at Station 12515 (step 1). Naturalized flow records (referring to flows without withdrawals from water rights and the additions of permitted discharges) were developed using the drainage-area ration approach at station 12515 and the upstream USGS flow gauge (step 2). An estimated actual 15-year daily streamflow record was developed at Station 12515 by taking the naturalized flows and adding in the sum of all estimated discharges and subtracting all the estimated water rights diversions above the station. Because continuous records of salinity were not recorded at the point of interest, regressions are developed of S_t to V_r using measured salinity data with freshwater inflows (step 3). The resulting equation was used to calculate the volume of seawater that would flow through the station of the period of a day (Figure A-1). Note that at streamflows above 100 cfs, tidal influence became minimal and measured salinities are at background levels.

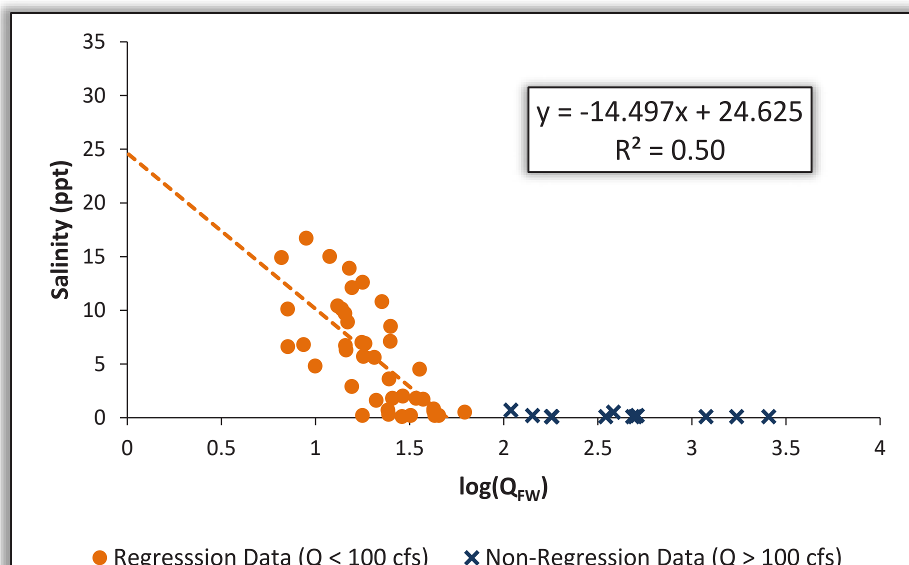

Figure A-1.

The basis of step 4 is a mass balance equation that can be used to determine the volume of seawater that must be mixed with the volume of freshwater in the river to arrive at the measured salinities:

$$(V_r + V_s) \times S_t = V_r \times S_r + V_s \times S_s$$

where

V_r = volume daily river flow

V_s = volume of seawater

S_t = salinity in river (parts per thousand or ppt)

S_r = background salinity of river water (ppt); assumed to be close to 0 ppt

S_s = salinity of seawater (35 ppt)

This mass balance equation can be solved for the daily volume of seawater required to be mixed with freshwater:

$$V_s = {}^{V_r}/_{(S_s/S_t - 1)}$$

for S_t> background salinity; otherwise V_s= 0 and where $S_t$was computed for each day of the 15-year streamflow record using the regression equation developed in step 3 and the estimated daily streamflow (V_r). The modified total daily volume (V_t) is then derived from:

$$V_t = V_r + V_s$$

In step 5, the FDCs were developed by ordering daily streamflow data from highest to lowest and assigning a rank to each point; computing the percent of days each flow was exceeded; plotting each flow data point against percent exceedance. Figure A-2 presents the FDC as developed for station 12515 and includes the intermediate FDC to show the relationship between saltwater flows and freshwater inflows (as the amount of seawater present increases, as freshwater flow decreases, and the percent of days' flow exceeded increases).

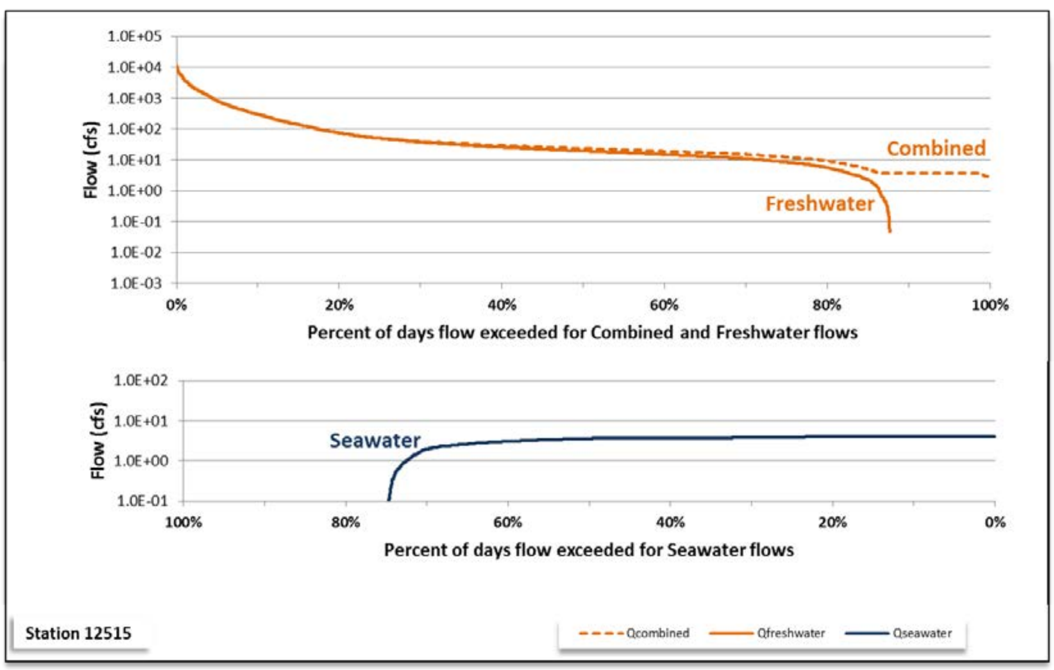

Figure A-2. Flow duration curve for Station 12515

For the last step, the LDC is developed by multiplying the daily streamflow values by the 35 cfu/100mL *Enterococci* water quality criterion and a conversion factor of 2.44657×10^7 to express loadings as CFU or MPN (most probably number) per day. Historical bacteria data is then superimposed on the LDC by multiplying bacteria measurements with the streamflow value and conversion factor to calculate a loading associated with the measured bacteria concentration (Figure A-3). Further details on LDC development for the Tres Palacios Creek can be found in Painter, McFarland, and Hauck 2015.

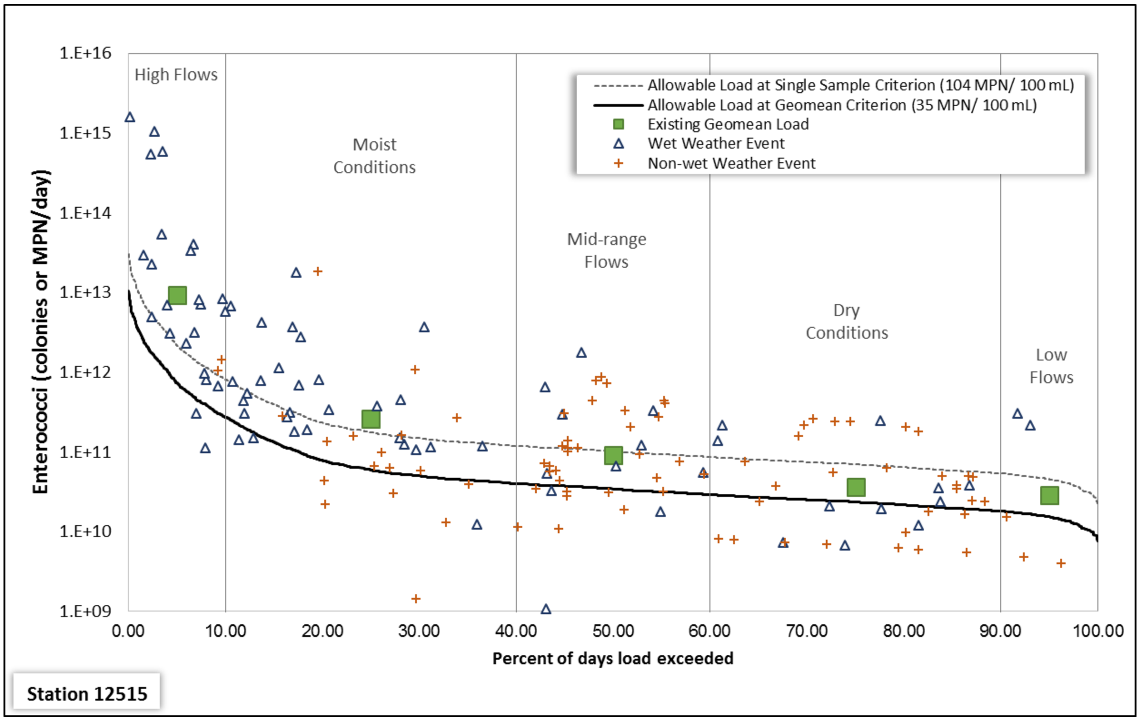

Figure A-3. Load duration curve and historical bacteria concentration measurements for station 12515

Sources

Painter, S., McFarland, A., and Hauck, L. 2015. Technical support document for total maximum daily load for indicator bacteria in Tres Palacios Creek Tidal. Tarleton State University. Stephenville, TX: Texas Institute for Applied Environmental Research.

Appendix B: Potential Bacteria Load and Bacteria Load Reduction Calculations

Estimates for bacteria load reductions in this WPP were based on the best available information regarding the effectiveness of recommended management, loading estimates informed by technical data sources, and local knowledge derived from stakeholder input. Real world conditions based on where implementation is completed will ultimately determine the actual load reduction achieved once complete. Stakeholder input was critical for deriving agricultural estimates, estimating existing management measures, and determining feasible management measures.

Agricultural Nonpoint Source Management Measures

Cattle Loadings

Stakeholder input was critical to develop livestock population estimates across the watershed. Based on suggestions from the Agriculture work group meeting, a 5 ac/ 1 cattle stocking rate was agreed to as an average stocking rate across all pasture and rangeland in the watershed. The local NRCS recommended stocking rate is 3 ac/Animal Unit (An.U) for pasture and 7 ac/An U for rangeland. Applying this estimate across appropriate land cover in the watershed generated an estimate of 13,131 cattle.

Using the SELECT methodology in the GIS analysis, potential *Enterococcus* loading from cattle was estimated across the watershed and for each subwatershed. The fecal coliform production rate was assumed to be 8.55×10^9 cfu/An.U×day^{-1} with the assumption that 1 An.U equals 1 cattle (Wagner and Moench 2009). The conversion rate from fecal coliform to *E. coli* was assumed to be $\frac{126}{200}$ (Wagner and Moench 2009). The conversion rate from *E. coli* to *Enterococcus* was assumed to be $\frac{35}{126}$ (Wagner and Moench 2009). Therefore, the daily potential *Enterococcus* load from cattle was calculated as:

$$Potential\ Load = Head\ of\ Cattle\ \times \frac{8.55 \times 10^9 cfu\ fecal\ coliform}{Head \times day^{-1}} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli}$$

Multiplied by 365 days/yr, GIS analysis estimated a potential annual load of 7.23×10^{15} cfu/yr across the entire watershed from cattle.

Horse Loadings

Estimates for horse populations were derived by multiplying the total number of horses in Matagorda and Wharton counties, identified in NASS census data (USDA NASS, 2014), by the percentage county area the watershed occupies within the county. The estimate of 327 horses was deemed reasonably accurate by stakeholders. To generate potential loadings with GIS analysis, the total number of horses was distributed over developed open space, grassland/herbaceous, and pasture/hay land uses. The fecal coliform production rate was assumed to be 2.91×10^8 cfu/An.U×day^{-1} (Wagner and Moench, 2009). The number of horses were multiplied by an animal unit conversion factor of 1.25. The conversion rate from fecal coliform to *E. coli* was assumed to be $\frac{126}{200}$. The conversion rate from *E. coli* to *Enterococcus* was assumed to be $\frac{35}{126}$.

Therefore, the daily potential *Enterococcus* load from horses was calculated as:

$$Potential\ Load = number\ of\ horses \times \frac{1.25\ An.U}{horse} \times \frac{2.91 \times 10^{8} cfu\ fecal\ coliform}{An.U \times day^{-1}} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli}$$

Multiplied by 365 days/yr, GIS analysis estimated a potential annual load of 7.66×10^{12} cfu/yr across the entire watershed from horses.

Bacteria Load Reductions from Livestock Management

The potential load reduction that can be achieved by implementing conservation practices will depend on the specific BMPs implemented by each landowner, the number of cattle in each operation, existing practices, and existing land condition. The bacteria reduction efficiencies of these BMPs have been estimated in various research efforts and an estimated 69 percent median effectiveness for BMPs likely to be employed in the watershed was assumed (Table B-1).

Table B-1. Livestock management effectiveness

Management Practice	Effectiveness Low	High	Median
Exclusionary Fencing[1]	30%	94%	62%
Filter Strips[2]	30%	100%	65%
Prescribed Grazing[3]	42%	66%	54%
Stream Crossing[4]	44%	52%	48%
Watering Facility[5]	51%	94%	72.5%

[1] Brenner et al. 1996, Cook 1998, Hagedorn et al. 1999, Line 2002, Line 2003, Lombardo et al. 2000, Meals 2001, Meals 2004, Petersen et al. 2011

[2] Cook 1998, Coyne et al. 1995, Fajardo et al. 2001, Goel et al. 2004, Larsen et al. 1994, Lewis et al. 2010, Mankin and Okoren 2003, Roodsari et al. 2005, Stuntebeck and Bannerman 1998, Sullivan et al. 2007, Tate et al. 2006, Young et al. 1980.

[3] Tate et al. 2004, EPA 2010

[4] Inamdar et al. 2002, Meals 2001

[5] Byers et al. 2005, Hagedorn et al. 1999, Sheffield et al. 1997

The total potential load reduction will be strongly influenced by the number of ranchers participating and the number of cattle impacted. Specific load reduction estimates are simply estimates that will strongly depend on the specific management practices implemented. Based on NASS data for Matagorda and Wharton counties we estimated there are 213 farms within the watershed (USDA NASS 2014). Using the estimated 13,131 cattle in the watershed, there are an estimated 61 head/ farm. Daily potential load reduction expected from cattle management practices were then estimated with:

$$Potential\ Load\ Reduction = Number\ of\ management\ plans \times \frac{cattle}{mgmt\ plan} \times \frac{8.55 \times 10^{9} cfu\ fecal\ coliform}{An.U \times day^{-1}} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli} \times BMP\ reduction\ rate \times Proximity\ factor$$

The proximity factor is a percentage-based impact factor based on the assumed proximity of the management measures to the water body. Potential load reductions were calculated assuming that nine farms would adopt conservation measures per year for five years. The total annual potential load reduction after 45 farms adopted conservation measures was 2.61×10^{14} cfu/yr of *Enterococcus*.

Wildlife and Non-Domestic Animal Management Measures

Feral Hog Loadings

The stakeholders determined 4,856 feral hogs as an appropriate population estimate based on values in nearby watersheds, and an estimated population density of 1 feral hog per 33.3 ac across all land covers in the watershed except for developed and open water. GIS analysis was used to estimate potential loadings from feral hogs across the watershed and within subwatersheds. To estimate loadings, the number of feral hogs were converted to animal units with a conversion factor of 0.125. The assumed fecal coliform production rate for feral hogs was 1.21×10^9 cfu/An.U×day^{-1} (Wagner and Moench 2009). The conversion rate from fecal coliform to *E. coli* was assumed to be $\frac{126}{200}$. The conversion rate from *E. coli* to *Enterococcus* was assumed to be $\frac{35}{126}$. Therefore, the daily potential *Enterococcus* load from feral hogs was calculated as:

$$Potential\ Load = number\ of\ feral\ hogs \times \frac{0.125\ An.U}{feral\ hog} \times \frac{1.21 \times 10^9 cfu\ fecal\ coliform}{An.U \times day^{-1}} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli}$$

Multiplied by 365 days/yr, GIS analysis estimated a potential annual load of 4.73×10^{13} cfu/yr across the entire watershed from feral hogs.

Deer Loadings

Stakeholders determined 8,435 deer as an appropriate estimate for the watershed. This estimate was based on TWPD biologist density estimates of 1 deer per 19 ac. This density was applied to all land cover types in the watershed except for developed and open water to calculate populations across the watershed and within subwatersheds to calculate potential loadings in GIS. To estimate loadings, the number of deer were converted to An.Us with a conversion factor of 0.112. The assumed fecal coliform production rate for deer was 1.5×10^{10} cfu/An.U×day^{-1} (Wagner and Moench 2009). The conversion rate from fecal coliform to *E. coli* was assumed to be $\frac{126}{200}$. The conversion rate from *E. coli* to *Enterococcus* was assumed to be $\frac{35}{126}$. Daily potential loading from deer was calculated as:

$$Potential\ Load = number\ of\ deer \times \frac{0.112\ An.U}{deer} \times \frac{1.50 \times 10^{10} cfu\ fecal\ coliform}{An.U \times day^{-1}} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli}$$

Multiplied by 365 days/yr, GIS analysis estimated a potential annual load of 9.12×10^{14} cfu/yr across the entire watershed from deer.

Bacteria Load Reductions from Feral Hog Management

The potential load reductions for feral hog management depend on how much the population can be directly reduced. Load reduction was calculated based on the number of hogs removed annually.

Therefore, the same equation to calculate daily loading was used:

$$Potential\ Load\ Reduction = feral\ hogs\ removed \times \frac{1.21 \times 10^9 cfu\ fecal\ coliform}{An.U \times day^{-1}} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli}$$

Reducing the feral hog population by approximately 20 percent would be the equivalent of removing the potential load from 1000 feral hogs from the watershed per year. This equates to an annual load reduction of 9.66×10^{12} cfu/yr of *Enterococcus.*

OSSF Management Measures

OSSF Loadings

Stakeholders estimated 1,490 OSSFs exist within the watershed based on residential 911 addresses within the watershed and outside WWTF service areas. Of these, 1,422 or 95 percent were on soils classified as 'very limited' with an expected failure rate of 15 percent. Potential loadings were modeled in GIS for each subwatershed and across the entire watershed. For each address, the average number of persons per household was obtained using 2010 Census block data (2.4 people per household). The assumed fecal coliform concentration of a failing OSSF was 10×10^6 cfu/100 mL (EPA 2001). A sewage discharge rate of 70 gal/person day^{-1} was used (Borel et al. 2015). The OSSF failure rate was assumed to be 15 percent. The conversion rate from fecal coliform to *E. coli* was assumed to be $\frac{126}{200}$. The conversion rate from *E. coli* to *Enterococcus* was assumed to be $\frac{35}{126}$. Daily potential load per household was calculated as:

$$Potential\ OSSF\ Load = Number\ of\ OSSFs \times \frac{number\ of\ people}{household} \times \frac{70\ gal}{person \times day^{-1}} \times 0.15\ Failure\ rate \times \frac{1 \times 10^6\ cfu\ fecal\ coliform}{100\ ml} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli} \times 3578.4\ {}^{mL}/_{gal}$$

Potential daily *Enterococcus* loading from OSSF failure was estimated as 2.35×10^{11} cfu/day. Potential annual *Enterococcus* loading from OSSF failure was estimated as 8.58×10^{13} cfu/yr.

Bacteria Load Reductions from Replacement of Faulty OSSFs

Total load reductions from the replacement of failing OSSF systems depend on the amount of effluent discharged by the system and proximity of the system to a water body. Because these actual values are not known before identification and replacement of a failing OSSF, approximate values are used to identify potential load reductions. For load reduction calculations, 2.4 people per household, a discharge rate of 70 gal/person day^{-1}, and a fecal coliform concentration of 1×10^6 cfu/100 mL were assumed.

Potential annual load reductions can be calculated as:

$$Potential\ Load\ Reduction = Number\ of\ OSSFs\ replaced\ per\ year \times \frac{2.4\ persons}{household} \times \frac{70\ gal}{person \times day^{-1}} \times \frac{1 \times 10^{6}\ cfu\ fecal\ coliform}{100\ ml} \times 3578.4\ {}^{mL}/_{gal} \times {}^{365\ days}/_{year}$$

Assuming that six failing OSSFs are replaced annually for five years, the potential annual load reduction is 1.22×10^{13} cfu/yr.

Urban Management Measures

Domestic and Household Pet Loadings

Stakeholders estimated a population of 6,370 household pets (cats and dogs) in the watershed. This estimate was based on residential 911 addresses and AVMA estimated number of dogs (0.584) and cats (0.638) per household (AVMA 2012). GIS analysis was used to estimate potential loadings across the watershed and in each subwatershed based on the number of households estimated within respective boundaries. The assumed fecal coliform production rate per animal was 5.0×10^{9} cfu/day (EPA 2001). The conversion rate from fecal coliform to *E. coli* was assumed to be $\frac{126}{200}$. The conversion rate from *E. coli* to *Enterococcus* was assumed to be $\frac{35}{126}$. Daily potential loading from household pets was calculated as:

$$Potential\ Load = household\ pets \times \frac{5.00 \times 10^{9} cfu\ fecal\ coliform}{animal \times day^{-1}} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli}$$

Multiplied by 365 days/yr, GIS analysis estimated a potential annual load of 2.05×10^{15} cfu/yr across the entire watershed from household pets.

Bacteria Load Reductions from Household Pet Waste Management

Potential load reductions for household animal waste depends on the number of pets that contribute loading and the amount of pet waste that is picked up and disposed of properly. Assessing the number of pet owners who do not pick up pet waste or who would change behavior based on education or availability of pet waste stations is inherently difficult. However, some estimates currently exist that can be used as baseline assumptions. Survey data from the Chesapeake Bay basin indicate 50 percent of dog owners walk their dogs, 40 percent of those walkers do not currently pick up their dog's waste, and of those who do not pick up their dog's waste, about 60 percent would be willing to change behavior (Swann 1999). Therefore, daily potential load reduction was calculated as:

$$Potential\ Load\ Reduction = pet\ owners\ targeted \times 0.50 \times 0.40 \times 0.60 \times \frac{5.00 \times 10^9 cfu\ fecal\ coliform}{An.U \times day^{-1}} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli}$$

Recognizing that landowners in rural areas of the watershed with high acreage properties are unlikely to pick up pet waste because pets have large areas to roam, subwatersheds with higher densities of households and pets were targeted (subwatershed 1 and 12). Therefore, only 2,500 pet owners in the watershed were included in the load reduction calculation. The potential annual *Enterococcus* load reduction is 9.58×10^{13} cfu/yr.

Urban Stormwater Loadings

GIS analysis was used to calculate potential loadings from stormwater runoff across the watershed and within subwatersheds. According to NLCD land cover data, 2,893 ac in the watershed consist of high, medium, or low intensity developed cover. Assuming that a typical fecal coliform loading rate for urban runoff is 5.60×10^9 cfu/hectare yr^{-1} (Herrera 2011), a fecal coliform to *E. coli* conversion rate of $\frac{126}{200}$, and *E. coli* to *Enterococcus* conversion rate of $\frac{35}{126}$, potential urban runoff loading can be estimated by:

$$Potential\ Load = urban\ acerage \times \frac{5.60 \times 10^9 cfu\ fecal\ coliform}{ha \times yr^{-1}} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli} \times 0.404686\ {}^{ha}/_{ac}$$

An estimated potential annual *Enterococcus* load of 1.14×10^{12} cfu/yr from urban runoff occurs across the watershed.

Bacteria Load Reductions from Urban Stormwater BMPs

A wide variety of BMPs are available to control and treat urban stormwater runoff. The actual load reduction achieved depends on the appropriateness of the BMP chosen, BMP design, site characteristics, and long-term maintenance. To estimate a load reduction potential, we assumed 50 additional ac of urban land cover would be treated by stormwater BMPs with an 88 percent fecal coliform reduction potential (as cited for dry basins in CWP 2007).

$$\begin{aligned} Potential\ Load\ Reduction = {} & urban\ acerage \\ & \times \frac{5.60 \times 10^{9} cfu\ fecal\ coliform}{ha \times yr^{-1}} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \\ & \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli} \times 0.404686\ {}^{ha}/_{ac} \times 0.88 \end{aligned}$$

The potential annual *Enterococcus* load reduction is estimated at 1.74×10^{10} cfu/yr.

WWTF Management Measures

WWTF Loadings

There are three WWTFs in the Tres Palacios Creek watershed with discharge permits for bacteria. Potential loadings for each WWTF were modeled at respective maximum discharge and an *E. coli* concentration of 126 cfu/100mL, although monitoring data indicate discharge concentrations are routinely quite low. The conversion rate from *E. coli* to *Enterococcus* was assumed to be $\frac{35}{126}$. Daily potential loading from WWTF across the watershed was calculated as the sum of individual plant loadings, where individual plant loadings are calculated as:

$$\begin{aligned} Potential\ Load_{WWTP} = {} & maximum\ permitted\ discharge\ ({}^{Gal}/_{day}) \\ & \times \frac{126\ cfu\ E.coli}{100\ ml} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli} \\ & \times 3785.2\ {}^{ml}/_{Gal} \end{aligned}$$

Potential daily *Enterococcus* loading is estimated at 3.88×10^{9} cfu/day and potential annual loading is estimated at 1.42×10^{12} cfu/yr.

Bacteria Load Reductions from WWTF Management Measures

Potential load reductions can be achieved through the reduction of the total effluent discharged into the Tres Palacios Creek and tributaries. The adoption of wastewater reuse by the City of El Campo WWTF could divert 100 percent of the wastewater effluent to irrigation or other non-potable uses. Potential load reduction is equivalent to the potential load at the El Campo WWTF, or 1.28×10^{12} cfu/yr of *Enterococcus*.

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Appendix C: Potential Nutrient Load Reductions

Agricultural Nonpoint Source Management Measures

Potential Load Estimates from Livestock

Using the estimates developed in Appendix B for livestock populations (13,131 An.U cattle), potential nitrogen and potential phosphorus loads were calculated based on estimated content of nitrogen and phosphorus in cattle manure. The nitrogen production rate of cattle was assumed to be 0.31 pounds per day per An.U (USDA NRCS 2009). The phosphorus production rate was assumed to be 0.11 pounds per day per An.U (USDA NRCS 2009). The potential daily nitrogen load attributed to cattle was calculated as:

$$Potential\ Load = Head\ of\ Cattle \times \frac{0.31\ pounds\ Nitrogen}{day}$$

The potential daily phosphorus load attributed to cattle was calculated as:

$$Potential\ Load = Head\ of\ Cattle \times \frac{0.11\ pounds\ Phosphorus}{day}$$

Multiplied by 365 days per year, the estimated nitrogen load from cattle across the watershed is 1.49×10^6 pounds of nitrogen per year. The estimated phosphorus load from cattle is 5.27×10^5 pounds of phosphorus per year.

Nutrient Load Reductions from Livestock Management

The potential load reduction that can be achieved by implementing conservation practices will depend on the specific BMPs implemented by each landowner, the number of cattle in each operation, existing practices, and existing land condition. The bacteria reduction efficiencies of these BMPs have been estimated in various research efforts and an estimated 42 percent median effectiveness for nitrogen reduction and 44 percent median effectiveness for phosphorus reduction was determined based on the practices likely to be employed in the watershed (Table C-1).

Table C-1. Livestock management effectiveness.

Management Practice	**Median Nitrogen Reduction Effectiveness**	**Median Phosphorus Reduction Effectiveness**
Exclusionary Fencing[1]	33%	76%
Filter Strips[2]	51%	55%
Prescribed Grazing[3]	55%	33%
Watering Facility[4]	5%	32%

[1] Line et al. 2000
[2] CAST 2016; Zhang et al. 2010
[3] CAST 2016; Olnes et al. 1980; Tuppad et al. 2010
[4] CAST 2016; Byers et al. 2004

The total potential nutrient load reduction will be strongly influenced by the number of ranchers participating and the number of cattle impacted. Specific load reduction estimates are simply estimates that will strongly depend on the specific management practices implemented. Based on NASS data for Matagorda and Wharton counties we estimated there are 213 farms within the watershed (USDA NASS 2014). Using the estimated 13,131 cattle in the watershed, there are an estimated 61 head per farm. A median nitrogen reduction efficiency of 42 percent and median phosphorus reduction efficiency of 44 percent were utilized. A proximity factor of 0.25 was assumed based on the proximity of practices to waterbodies. Daily potential nitrogen load reductions expected from cattle management practices were estimated with:

$$Potential\ Load\ Reduction = Number\ of\ management\ plans \times \frac{cattle}{mgmt\ plan} \times \frac{0.31\ pounds\ Nitrogen}{day} \times BMP\ reduction\ rate \times Proximity\ Factor$$

Daily potential phosphorus load reductions from cattle management practices were estimated with:

$$Potential\ Load\ Reduction = Number\ of\ management\ plans \times \frac{cattle}{mgmt\ plan} \times \frac{0.11\ pounds\ Phosphorus}{day} \times BMP\ reduction\ rate \times Proximity\ Factor$$

Based on the above assumptions and equations, the total potential nitrogen load reduction from implementation of 45 conservation plans is estimated to be 3.30×10^4 pounds of nitrogen per year. The total potential phosphorus load reduction from implementation of 45 conservation plans is estimated to be 1.24×10^4 pounds of phosphorus per year.

Wildlife and Non-Domestic Animal Management Measures

Feral Hog Loadings

The stakeholders determined 4,856 feral hogs as an appropriate population estimate based on values in nearby watersheds, and an estimated population density of 1 feral hog per 33.3 ac across all land covers in the watershed except for developed and open water. To the best of our knowledge, nutrient loadings attributed to feral hogs have not been researched. Therefore, we use assumed values from domestic swine of 0.14 pounds of nitrogen per An.U per day and 0.05 pounds of phosphorus per An.U per day (USDA NRCS 2009). Importantly, nutrition plays an important role in nitrogen and phosphorus loads in pig waste, and is unknown in feral hogs. Therefore, we assume the most conservative values for nutrients loads within pig waste. Additionally, increased loads associated with sediments released by riparian wallowing and riparian habitat damage are likely. The loads estimated below are likely conservative based on these assumptions. The daily potential nitrogen load from feral hogs was estimated as:

$$Potential\ Load = number\ of\ feral\ hogs \times \frac{0.14\ pounds\ Nitrogen}{An.U\ \times day^{-1}} \times \frac{0.125\ animal\ units}{feral\ hog}$$

The daily potential phosphorus load from feral hogs was estimated as:

$$Potential\ Load = number\ of\ feral\ hogs \times \frac{0.05\ pounds\ Phosphorus}{An.U\ \times day^{-1}} \times \frac{0.125\ animal\ units}{feral\ hog}$$

Multiplied by 365 days per year, the potential nutrient loads from feral hogs across the watershed are 3.10×10^4 pounds of nitrogen per year and 1.11×10^4 pounds of phosphorus per year.

Nutrient Load Reductions from Feral Hog Management

The potential load reductions for feral hog management depend on how much the population can be directly reduced. Load reduction was calculated based on the number of hogs removed annually. Therefore, the same equations to calculate daily loading were used:

$$Potential\ Load\ Reduction = feral\ hogs\ removed \times \frac{0.14\ pounds\ Nitrogen}{An.U\ \times day^{-1}} \times \frac{0.125\ animal\ units}{feral\ hog}$$

$$Potential\ Load\ Reduction = feral\ hogs\ removed \times \frac{0.05\ pounds\ Phosphorus}{An.U\ \times day^{-1}} \times \frac{0.125\ animal\ units}{feral\ hog}$$

Reducing the feral hog population by approximately 20 percent would be the equivalent of removing 1,000 feral hogs from the watershed per year. This equates to an annual load reduction of $6.39{\times}10^3$ pounds of nitrogen per year and $2.28{\times}10^3$ pounds of phosphorus per year.

OSSF Management Measures

OSSF Loadings

Stakeholders estimated 1,490 OSSFs exist within the watershed based on residential 911 addresses within the watershed and outside WWTF service areas. Of these, 1,422 or 95 percent were on soils classified as 'very limited', with an expected failure rate of 15 percent. Potential loadings were modeled in GIS for each subwatershed and across the entire watershed. For each address, the average number of persons per household was obtained using 2010 Census block data (2.4 people per household). The assumed nutrient concentration of a failing OSSF was 40 mg nitrogen/L and 10 mg phosphorus/L (Davis and Cornwell 1991). A sewage discharge rate of 70 gal/person day^{-1} was used (Borel et al. 2015). The OSSF failure rate was assumed to be 15 percent. Potential daily nitrogen loads from OSSFs were calculated as:

$$Potential\ Load = Number\ of\ OSSFs \times \frac{number\ of\ people}{household} \times \frac{70\ gal}{person\ \times day^{-1}} \times 0.15\ Failure\ rate \times \frac{40\ mg\ Nitrogen}{L} \times \frac{1\ pound}{453{,}592\ mg} \times \frac{1\ L}{0.264172\ gal}$$

Potential daily phosphorus loads from OSSFs were calculated as:

$$Potential\ Load = Number\ of\ OSSFs \times \frac{number\ of\ people}{household} \times \frac{70\ gal}{person\ \times day^{-1}} \times 0.15\ Failure\ rate \times \frac{10\ mg\ Phosporus}{L} \times \frac{1\ pound}{453{,}592\ mg} \times \frac{1\ L}{0.264172\ gal}$$

Potential annual nutrient loading from OSSF failure was estimated as $4.48{\times}10^3$ pounds of nitrogen per year and $1.12{\times}10^3$ pounds of phosphorus per year.

Nutrient Load Reductions from Replacement of Faulty OSSFs

Total load reductions from the replacement of failing OSSF systems depend on the amount of effluent discharged by the system and proximity of the system to a water body. Because these actual values are not known before identification and replacement of a failing OSSF, approximate values are used to identify potential load reductions. For load reduction calculations, 2.4 people per household, a discharge rate of 70 gal/person day^{-1}, and nutrient concentrations of 40 mg nitrogen/L and 10 mg phosphorus/L were assumed. Potential nitrogen load reductions can be calculated as:

$$Potential\ Load\ Reduction = Number\ of\ OSSFs\ replaced \times \frac{number\ of\ people}{household} \times \frac{70\ gal}{person\ \times day^{-1}} \times \frac{40\ mg\ Nitrogen}{L} \times \frac{1\ pound}{453{,}592\ mg} \times \frac{1\ L}{0.264172\ gal}$$

Potential phosphorus load reductions can be calculated as:

$$Potential\ Load\ Reduction = Number\ of\ OSSFs\ replaced \times \frac{number\ of\ people}{household} \times \frac{70\ gal}{person\ \times day^{-1}} \times \frac{10\ mg\ Phosphorus}{L} \times \frac{1\ pound}{453{,}592\ mg} \times \frac{1\ L}{0.264172\ gal}$$

Assuming that six failing OSSFs are replaced annually for five years, the potential annual nutrient load reductions is 6.14×10^{2} pounds of nitrogen per year and 1.45×10^{2} pounds of phosphorus per year.

Urban Nonpoint Source Management Measures

Domestic and Household Pet Loadings

Stakeholders estimated a population of 6,370 household pets (cats and dogs) in the watershed. This estimate was based on residential 911 addresses and AVMA estimated number of dogs (0.584) and cats (0.638) per household (AVMA 2012). There is limited research regarding the nitrogen and phosphorus content in pet waste. A rough estimate is that each typical animal deposits 1.3 grams of nitrogen per day and 0.3 grams of phosphorus per day (Schuster and Grismer 2004). Using this value (recognizing there is likely large variability in nitrogen content based on pet size and quality of food pets are provided), potential nitrogen loadings from pets were estimated as:

$$Potential\ Load = household\ pets \times \frac{1.3\ grams\ Nitrogen}{day} \times \frac{1\ pound}{453.592\ grams}$$

Total potential phosphorus loadings were estimated as:

$$Potential\ Load = household\ pets \times \frac{0.3\ grams\ Phosphorus}{day} \times \frac{1\ pound}{453.592\ grams}$$

Multiplied by 365 days per year, the estimated nitrogen load from household pets across the watershed is 6.66×10^{3} pounds of nitrogen per year. The estimated phosphorus load from cattle is 1.54×10^{3} pounds of phosphorus per year.

Nutrient Load Reductions from Household Pet Waste Management

Potential load reductions for household animal waste depends on the number of pets that contribute loading and the amount of pet waste that is picked up and disposed of properly. Assessing the number of pet owners who do not pick up pet waste or who would change behavior based on education or availability of pet waste stations is inherently difficult. However, some estimates currently exist that can be used as baseline assumptions. Survey data from the Chesapeake Bay basin indicate 50 percent of dog owners walk their dogs, 40 percent of those walkers do not currently pick up their dog's waste, and of those who do not pick up their dog's waste, about 60 percent would be willing to change behavior (Swann 1999). Therefore, daily potential nitrogen load reductions were calculated as:

$$Potential\ Load\ Reduction = pet\ owners\ targeted\ \times 0.50\ \times 0.40 \times 0.60 \times \frac{1.3\ grams\ Nitrogen}{day} \times \frac{1\ pound}{453.592\ grams}$$

Daily potential phosphorus load reductions were calculated as:

$$Potential\ Load\ Reduction = pet\ owners\ targeted\ \times 0.50\ \times 0.40 \times 0.60 \times \frac{0.3\ grams\ Phosphorus}{day} \times \frac{1\ pound}{453.592\ grams}$$

Based on targeting approximately 2,500 pet owners across the watershed annual nitrogen load reductions are estimated at 3.14×10^3 pounds of nitrogen per year. Phosphorus load reductions are estimated at 72.4 pounds per year.

Urban Stormwater Loadings

According to NLCD land cover data, 2,893 ac in the watershed consist of high, medium, or low intensity developed cover. Assuming an urban nutrient accumulation rate of 0.07 pounds of nitrogen per hectare per day and 0.0051 pounds of phosphorus per hectare per day (Haith and Shoenaker 1987). It is important to note, that these urban stormwater loadings are generalized and do not differentiate from sources such as pets, birds, or other sources of nutrient loading that might be present in urban stormwater runoff. Therefore, some amount of double-counting may occur in pet waste loads and urban stormwater loads. Daily potential nitrogen loads were calculated as:

$$Potential\ Load = urban\ acerage \times \frac{0.07\ pounds\ Nitrogen}{ha\ \times day^{-1}} \times \frac{0.404686\ ha}{ac}$$

Daily potential phosphorus loads were calculated as:

$$Potential\ Load = urban\ acerage \times \frac{0.0051\ pounds\ Phosphorus}{ha\ \times day^{-1}} \times \frac{0.404686\ ha}{ac}$$

Multiplied by 365 days per year, the total potential nutrient load from urban runoff was estimated as 2.99×10^4 pounds per year of nitrogen and 2.18×10^3 pounds per year of phosphorus.

Nutrient Load Reductions from Urban Stormwater BMPs

A wide variety of BMPs are available to control and treat urban stormwater runoff. The actual load reduction achieved depends on the appropriateness of the BMP chosen, BMP design, site characteristics, and long-term maintenance. To estimate a load reduction potential, we assumed 50 additional ac of urban land cover would be treated by stormwater BMPs with a median 4.15 percent nitrogen reduction potential and median 13.5 percent phosphorus reduction potential (based on the chosen dry detention pond reduction efficiencies cited in CAST [2015] and Clary et al. [2017]). Because the chosen BMP has relatively low nutrient removal efficiencies compared some other available options, the calculated load reductions are assumed conservative. Potential nitrogen reductions were calculated as:

$$Potential\ Load\ Reduction = urban\ acerage\ treated \times \frac{0.07\ pounds\ Nitrogen}{ha\ \times day^{-1}} \times \frac{0.404686\ ha}{ac} \times 0.0415$$

Potential phosphorus reductions were calculated as:

$$Potential\ Load\ Reduction = urban\ acerage\ treated \times \frac{0.0051\ pounds\ Phosphorus}{ha\ \times day^{-1}} \times \frac{0.404686\ ha}{ac} \times 0.135$$

Potential annual nutrient reductions from urban stormwater BMPs are 21.5 pounds of nitrogen per year and 5 pounds of phosphorus per year.

WWTF Management Measures

WWTF Loadings

Two WWTF's (City of El Campo and Markham) report nitrogen discharges as part of their discharge permits. We estimated annual nutrient loads for each plant as the average pounds of nitrogen reported in each plant's Discharge Monitoring Reports available from 2000 through 2016 (Table C-2). Nitrogen loadings were not available for the Midfield WWTF. For the Midfield WWTF, estimates were derived using literature reported effluent concentrations for WWTFs that utilize primary and secondary concentrations (Table C-3). We then summed the average from each plant to determine total nitrogen load in the Tres Palacios attributable to WWTFs. Based on this data, total potential nitrogen load (as ammonia) from WWTFs is 1,139 pounds per year.

It is important to note that, effluent quality is highly variable and dependent on the quality of influent raw wastewater and the specific treatment processes employed by the WWTF. Therefore, we utilized conservative literature derived concentrations that may be higher than actually occurring in the watershed. However, both El Campo and Markham routinely report effluent ammonia as nitrogen concentrations well below the typical values reported in the literature for WWTFs with secondary and even some types of tertiary treatment.

Table C-2. Annual pounds of nitrogen discharged by WWTFs.

	Ammonia as Nitrogen							
WWTF	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Markham	-	-	-	-	31.47	191	93.43	105.3
El Campo	424	349	361	734	1,443	945	1,427	811.8571

Table C-3. Estimated pounds of nitrogen discharged by Midfield WWTF.

	Ammonia as Nitrogen[1, 2]							
WWTF	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Midfield	206.71	96.23	626.06	280.36	129.49	100.98	116.42	222.32

[1] Annual values estimated as reported mean daily flow (MGD) × 3.9 mg NH4/mL × 3785411.78 Liters/Mgal × 1 pound/453,592 mg × 365 days/year

[2] Average ammonia as nitrogen concentration derived as the average of reported mean concentration in WWTF effluent from plants with secondary treatment (5.0 mg/L [Metcalf & Eddy 2014] and 2.8 mg/L [Pocernich & Litke 1997]).

WWTFs in the watershed are not required to report total phosphorus concentrations in their effluent. We developed potential total phosphorus loading estimates using the average daily reported discharges from 2010 through 2016 and literature reported average values for WWTF effluent total phosphorus concentrations. We summed the average annual potential total phosphorus loads to estimate potential phosphorus loads discharged into the Tres Palacios per year attributed to WWTFs. Based on the literature derived estimates, the total potential phosphorus load is 15,217 pounds per year.

Table C-4. Estimated pounds of phosphorus discharged by watershed WWTFs.

	Total Phosphorus[1,2]							
WWTF	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
Markham	-	-	-	-	887.19	1,123.95	1,231.69	1,080.94
El Campo	-	-	7,783.79	7,499.58	7,272.58	8,289.40	8,114.02	7,791.87
Midfield	231.44	107.74	700.97	313.91	144.98	113.06	130.35	248.92
							Total:	15,217.42

[1] Annual values estimated as reported mean daily flow (MGD) × 4.367 mg phosphorus/mL × 3785411.78 Liters/Mgal × 1 pound/453,592 mg × 365 days/year

[2] Average phosphorus concentration derived as the average of reported mean concentration in WWTF effluent from plants with secondary treatment (1.25 mg/L [Metcalf & Eddy 2014] and 3.1 mg/L [Pocernich & Litke 1997], 3.0 mg/L [National Research Council, 1993]).

Nutrient Load Reductions from WWTF Management Measures

Potential load reductions can be achieved through the reduction of the total effluent discharged into the Tres Palacios Creek and tributaries. The adoption of wastewater reuse by the City of El Campo WWTF could divert 100 percent of the wastewater effluent to irrigation or other non-potable uses. Potential load reduction is equivalent to the potential load at the El Campo WWTF, or 811 pounds of nitrogen and 7,792 pounds of phosphorus per year.

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Appendix D: Elements of Successful WPPs

The EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* describes the nine elements critical for achieving improvements in water quality that must by sufficiently included in the WPP for it to be eligible for implementation funding through the CWA Section 319 funds. These elements do not preclude additional information from being included in the WPP.

A: Identification of Causes and Sources of Impairment

An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed based plan (and to achieve any other watershed goals identified in the watershed based plan). Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed. Information can be based on a watershed inventory, extrapolated from a sub-watershed inventory, aerial photos, GIS data, and other sources.

See Chapters 2, 3, and Appendix B.

B: Estimated Load Reductions

An estimate of the load reductions expected for the management measures proposed as part of the watershed plan.

See Chapter 4 and Appendix B.

C: Proposed Management Measures

A description of the management measures that will need to be implemented to achieve the estimated load reductions and identification (using a map or description) of the critical areas in which those measures will be needed to implement the plan. These are defined as including BMPs and measures needed to institutionalize changes. A critical area should be determined for each combination of source BMP.

See Chapter 4.

D: Technical and Financial Assistance Needs

An estimate of the amounts of technical and financial assistance needed, associated costs and/or the sources and authorities that will be relied upon to implement this plan. Authorities include the specific state or local legislation that allows, prohibits, or requires an activity.

See Chapters 4 (under each management measure) and 5 (Sources of Technical Assistance, Sources of Financial Assistance).

E: Information, Education, and Public Participation Component

An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the appropriate NPS management measures.

See Chapter 4 (Education and Outreach).

F: Schedule

A schedule for implementing the NPS management measures identified in the plan that is reasonably expeditious.

See Chapter 6 (Interim Measurable Milestones).

G: Milestones

A description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented. Milestones should be tied to the progress of the plan to determine if it is moving in the right direction.

See Chapter 6 (Interim Measurable Milestones).

H: Load Reduction Evaluation Criteria

A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether the watershed based plan needs to be revised. The criteria for the plan needing revision should be based on the milestones and water quality changes.

See Chapter 6 (Water Quality Targets, Data Review, Adaptive Implementation).

I: Monitoring Component

A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the evaluation criteria. The monitoring component should include required project-specific needs, the evaluation criteria, and local monitoring efforts. It should also be tied to the state water quality monitoring efforts.

See Chapter 6 (Water Quality Targets, Additional Data Collection Needs, Data Review).

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