Watershed Protection Plan for Garcitas and Arenosa Creek

Arenosa Creek at Bischoff Road

Developed by the stakeholders of the Garcitas Creek watershed to restore and protect water quality in Garcitas Creek (Segment 2453A, Assessment Unit 2453A_01) and Arenosa Creek (Segment 2453C, Assessment Unit 2453C_01).

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Texas Water Resources Institute Technical Report
2019

Funding support for this project provided by the Texas Commission on Environmental Quality

Acknowledgements

This document presents the strategy developed by the stakeholders of the Garcitas and Arenosa Creek watersheds to restore and protect water quality. Local stakeholders dedicated considerable time and effort in discussing the watershed, influences on water quality, and developing management measures to address water quality concerns. The ultimate success of the watershed protection plan depends on the current and continued engagement of local stakeholders with technical and financial support from regional, state, and federal agencies.

Special appreciation is extended to the many watershed landowners and residents who attended the numerous meetings and events to provide direct input to the plan. The direct involvement of landowners and residents was critical to ensuring the plan included feasible management measures that address sources of water quality impairments in the watershed. The time and effort of landowners and residents are greatly appreciated and are reflected in the contents of this plan.

Support and input from agencies and local organizations was integral to the WPP development process. The following agencies and organizations provided technical guidance and specialized knowledge on many topics:

- Jackson Soil and Water Conservation District
- Victoria Soil and Water Conservation District
- Victoria County Environmental Health
- Lavaca-Navidad River Authority
- The Nature Conservancy
- Texas A&M AgriLife Extension Service
- Texas Commission on Environmental Quality
- Texas Parks and Wildlife Department
- Texas Sea Grant
- Texas State Soil and Water Conservation Board
- USDA Natural Resources Conservation Service

The Texas Commission on Environmental Quality provided financial support and project management for development of the watershed protection plan.

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Table of Abbreviations

ACEP	Agricultural Conservation Easement Program
AU	Assessment Unit
AVMA	American Veterinary Medical Association
cfu	colony forming unit
CIG	Conservation Innovation Grants
CMP	Coastal Management Program
CSP	Conservation Stewardship Program
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency (US)
EQIP	Environmental Quality Incentives Program
gal	Gallon
GBRA	Guadalupe-Blanco River Authority
LDC	Load Duration Curve
LNRA	Lavaca-Navidad River Authority
mg/L	Milligrams per Liter
mL	Milliliter
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
MSL	Mean Sea Level
NFWF	National Fish and Wildlife Foundation
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint sopurce
NRCS	Natural Resources Conservation Service
OSSF	On-site Sewage Facilities
RCPP	Regional Conservation Partnership Program
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SEP	Supplemental Environmental Projects
SWCD	Soil and Water Conservation District
SWQM	Surface Water Quality Monitoring
TCEQ	Texas Commission on Environmental Quality
TGLO	Texas General Land Office
TIG	Texas Trustee Implementation Group
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
USGS	U.S. Geological Survey
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF	Waste Water Treatment Facility

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Executive Summary

A watershed is an area of land that drains to a common body of water. Within a watershed, water follows natural hydrologic boundaries and is influenced by the landscape it flows across and through. Both natural and human influenced processes that occur within a watershed alter the quantity and quality of water within the system.

This document presents a plan to restore and protect water quality in the Garcitas Creek watershed. By approaching water quality issues at the watershed level rather than political boundaries, this plan holistically identifies potential pollutant sources and solutions. This approach also incorporates the values, visions, and knowledge of people with a direct stake in water quality conditions.

Problem Statement

Water quality monitoring indicates that Arenosa Creek, the major tributary to Garcitas Creek, does not meet water quality standards for recreation due to elevated levels of bacteria. Furthermore, the tidal segment of Garcitas Creek does not meet water quality standards for aquatic life use due to depressed levels of dissolved oxygen (DO).

Response

With the water quality impairments, comes a need to plan and implement actions that restore water quality and ensure safe and healthy water for stakeholders. To meet this need, an assessment and planning project was undertaken to develop a watershed protection plan (WPP).

The planning process began with a stakeholder group meeting in summer of 2018 to form and establish stakeholder group structure and rules. Over the next year, Texas Water Resources Institute (TWRI) met with the stakeholder group to provide data and information and receive feedback on approaches used to assess and characterize water quality in the watershed. Stakeholders provided direct input to assumptions used in the pollutant load analysis and decided upon the management measures most likely to succeed and be implemented by the watershed community.

Watershed Protection Plan Overview

This document is a culmination of a stakeholder process to identify sources of pollution and the methods to reduce pollutant loads in the Garcitas Creek watershed. 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 manners 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. The primary goal of this watershed protection plan is to restore water quality in Garcitas and Arenosa Creeks to meet the water quality standards established by the state. This means achieving a 7-year geometric mean of 126 most probable number (MPN) per 100 milliliters (mL) *Escherichia coli* (*E. coli*) in Arenosa Creek. This also requires reducing the percent exceedances of the 24-hr DO criteria (3 milligrams (mg) per liter (L) minimum DO and 4 mg per L average DO) to less than 10 percent.

Analysis of water quality and streamflow data indicate an annual bacteria load reduction of approximately 93 percent is needed to meet water quality standards in Arenosa Creek. No single pollutant source is the primary cause of water quality impairments in the watershed. A variety of sources, including livestock, wildlife, and septic systems are likely to contribute bacteria and nutrient loads to the watershed. Therefore, stakeholders identified a variety of diverse and feasible management measures that will reduce bacteria and nutrient loads. Stakeholders suggest the following management measures:

1) Reduce the number of failing on-site sewage facilities and straight-pipe discharges;
2) Promote effective feral hog management;
3) Promote and implement grazing and agricultural conservation practices;
4) Minimize future stormwater impacts from encroaching suburban development;
5) Improve water quality monitoring and available data.

Full implementation of the stakeholder recommended management measures over ten years has the potential to reduce *E. coli* bacteria loads by approximately 3.02×10^5 billion colonies per year, nitrogen loads by approximately 9,336 pounds per year, and phosphorus loads by 4,846 pounds per year.

To achieve the goal set forth in the plan, we established a 10-year implementation schedule with interim milestones and water quality targets to track progress. This plan will also help meet conditions for the state's Coastal Nonpoint Source Pollution Control Program as set forth in Section 6217 of the Coastal Zone Management Act. Since portions of the watershed fall within the Coastal Zone Boundary, the plan will also work to reduce runoff pollutant concentrations and volumes from entering tidal portions of the river and coastal zone.

Ultimately, this plan sets forth an approach to improve stewardship of the watershed resources that allows stakeholders to continue relying on the watershed as part of their livelihood while also restoring the quality of its water resources.

Chapter 1 Introduction to Watershed Planning

1.1 Watersheds

A watershed is the land area surrounding a water body that drains to a common waterway such as a stream, river or lake. All the land surfaces that contribute runoff to a water body are considered part of the watershed. Watersheds can vary greatly in size. Some watersheds can be very small and drain only a few square miles. Conversely, larger watersheds can encompass many smaller watersheds and drain large portions of states or regions of the country.

The Garcitas Creek watershed includes over 234,000 acres of land that drains to Lavaca Bay. The Lavaca Bay watershed itself is part of the larger Matagorda Bay watershed system. Neighboring watersheds in the Matagorda Bay systems include the Lavaca-Navidad River watersheds to the northeast.

The natural processes and human activities that occur within a watershed have the potential to improve or degrade water quality. For example, rainfall in the watershed can run across agricultural fields, roads, lawns, or industrial sites. Along the way, the water has opportunities to either slow down and infiltrate into the soil or speed up as it flows towards the water body while picking up sediment, nutrients, or pollutants along the way. The most effective way to address water quality issues in a water body are to examine the natural and human activities occurring in a watershed.

1.2 Types of Pollution

The discharge of pollutant from a single point, such as a pipe, outfall, or channel is referred to as a *point source*. Point source discharges require permits through the National Pollutant Discharge Elimination System (NPDES) and Texas Pollutant Discharge Elimination System (TPDES) permitting systems. Examples of permitted point source discharges include wastewater treatment facilities (WWTFs) and industrial dischargers.

Nonpoint source (NPS) pollution, unlike pollution from an industrial facility or WWTF, typically comes from many diffuse sources. NPS pollution is carried by rainfall runoff moving over and through the ground, carrying natural and artificial pollutants and finally depositing into surface waters. Surface water runoff represents a major source of NPS pollution in both urban and rural areas. Runoff from towns and cities can deliver pollutant from roadways and grassed areas. Rural stormwater runoff can transport pollutant loads from cropland, pastures, and livestock operations. Additional nonpoint sources can include on-site sewage facilities (OSSFs) that are poorly installed, faulty, improperly located, or in close proximity to a stream.

1.3 The Watershed Approach

The watershed approach is widely accepted by state and federal water resource management agencies to facilitate water quality management. The United States Environmental Protection Agency (EPA) describes the watershed approach as “a flexible framework for managing water resource quality and quantity within a specified drainage area or watershed” (EPA, 2008). The watershed approach requires engaging stakeholders to make management decisions that are backed by sound science. The critical aspect of the watershed approach is the focus on hydrologic boundaries rather than political boundaries to address potential impacts to anyone affected by management decisions.

Stakeholders are anyone who lives, works, or has interest within the watershed. Stakeholders may include people, groups, organizations, or agencies. The continuous involvement of stakeholders throughout the watershed approach is critical for effectively selecting, designing, and implementing management measures that improve or protect water quality throughout the watershed.

1.4 Watershed Protection Plans

Watershed protection plans are locally driven mechanisms for voluntarily addressing complex water quality problems across boundaries. A watershed protection plan serves as a framework to better leverage and coordinate resources of non-governmental organizations, private individuals, and governmental agencies.

The Plan follows the EPA's nine key elements, designed to provide guidance for the development of an effective watershed protection plan. Watershed protection plans vary in methodology, content, and strategy due to local priorities and needs. However, common fundamental elements are included in successful plan and are identified below:

1) Identification of causes and sources of impairments
2) Expected load reductions from management strategies
3) Proposed management measures
4) Identified technical and financial assistance to implement management measures
5) Information, education and public participation needed to support implementation
6) Schedule for implementation
7) Milestones to track progress
8) Criteria to determine success
9) Water quality monitoring

Appendix A gives detailed information on EPA's Elements of Successful Watershed Protection Plan. Appendix G links each of the sections and pages that fulfill each element.

1.5 Public Participation

Stakeholder group members have actively participated in the planning process. Stakeholders decided upon an informal stakeholder group structure that allowed for open discussion and consensus development during meetings. TWRI facilitated the development of the plan and stakeholder meetings in partnership with Texas Commission on Environmental Quality (TCEQ). In addition to local residents and property owners that participated in stakeholder meetings, representatives of the following agencies participated in the planning process or were met with separately to develop the plan:

- Jackson Soil and Water Conservation District
- Jackson County Extension
- Lavaca-Navidad River Authority
- Texas Parks and Wildlife Department
- Texas Sea Grant
- Texas State Soil and Water Conservation Board
- The Nature Conservancy
- Victoria Soil and Water Conservation District
- Victoria County Environmental Health
- US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS)

1.6 Adaptive Management

The process of watershed planning is iterative. Initial management measures might not result in success during the first or second cycles. Therefore, adjustments are expected to be made as new information becomes available. Adaptive management consists of developing a natural resource management strategy to facilitate decision-making based on an on-going science-based process (EPA, 2008). Such an approach includes results of continual testing, monitoring, evaluating applied strategies, and revising management approaches to incorporate new information, science, and societal needs.

As the management measures identified in the watershed protection plan are put into action, water quality and other measures of success will be monitored to adjust as needed. The utilization of an adaptive management approach will help focus effort, implement strategies, and maximize impact on pollutant loadings over time.

Chapter 2 Watershed Characterization

2.1 Introduction

The Garcitas Creek watershed is a small watershed within the Coastal Plains of Texas. The watershed encompasses many tributaries, however the major one is Arenosa Creek. Portions of Victoria, Jackson, De Witt, and Lavaca counties drain into the Garcitas Creek watershed.

This watershed has a rich history of livestock and agriculture, which is still evident today. The Coastal Plains yield grasslands and moderate temperatures that are ideal for livestock grazing. Such conditions allowed this region to become a leader within the cattle trade. Because of this success, the region established one of the first meat packing plants in Texas.

2.2 Physical Characteristics

2.2.1 Watershed Boundaries

The Arenosa and Garcitas Creek are located along the Texas Gulf Coast, between the cities of Victoria and Edna. It is comprised of two segments: the first being Arenosa Creek (Segment 2453C) (Figure 1) which flows into Garcitas Creek (Segment 2453A) (Figure 2, Figure 3). Segment 2453 flows from the crossing of US Highway 59 in Victoria County to a point 12.8 km (8.0 miles) downstream at the confluence of Garcitas and Arenosa Creek in Jackson County, where Segment 2453 begins and flows to the outlet into Lavaca Bay (TCEQ, 2012a). At its mouth, Garcitas Creek drains approximately 366 square miles in Victoria (73% of the watershed) and Jackson (24% of the watershed) counties (Table 1).

Table 1. Summary of county area within the watershed

County	Area in Arenosa Creek Watershed (square miles)	% of Arenosa Creek watershed	Area in Garcitas Creek (square miles, including the Arenosa Creek Watershed)	% of Garcitas Creek watershed
Victoria	89.96	52.26%	266.70	72.82%
Jackson	76.94	44.70%	88.40	24.14%
De Witt	0	0%	5.92	1.62%
Lavaca	5.23	3.04%	5.23	1.42%
Total	172.13	100%	366.25	100%

Figure 1. Arenosa Creek at Bischoff Road.

Figure 2. Garcitas Creek at FM616

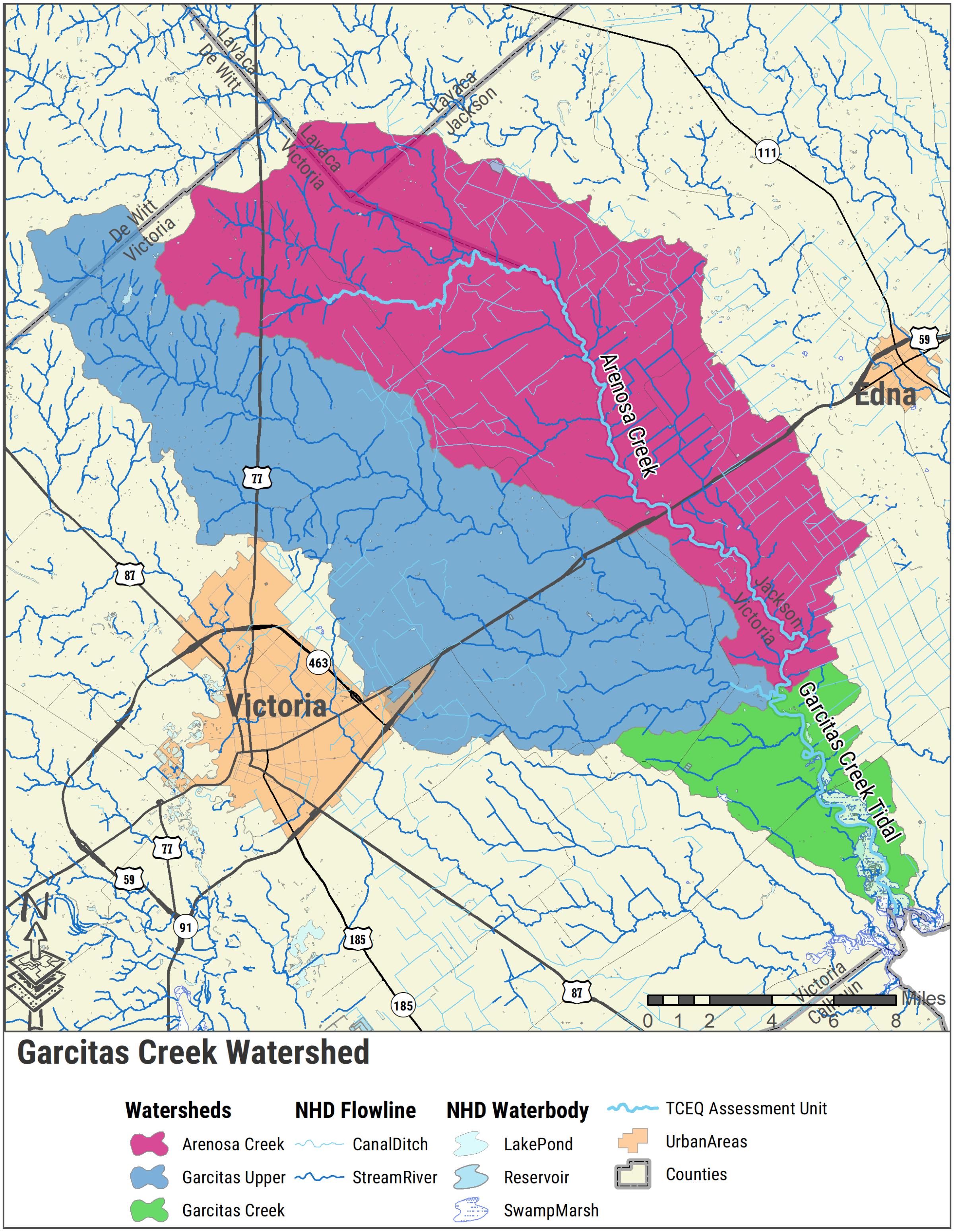

Figure 3. Overview of the Garcitas and Arenosa Creek watersheds.

2.2.2 Topography

The watershed is characterized by low relief. Elevation ranges from approximately 73 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 28 ft. above MSL. Slope ranges from zero to approximately 5.5 percent with a mean average slope of less than 0.1 percent. Figure 2.2 depicts the elevation of the Garcitas Creek watershed as derived from U.S. Geological Survey (USGS) National Elevation Dataset images (2013).

2.2.3 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 Garcitas 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.

2.2.4 Soils

Soils within the Garcitas Creek watershed, categorized by their Hydrologic Soil Group, are shown in Figure 4. Within the Garcitas Creek watershed, approximately 93 percent of the soils are high in clay and classified in Hydrologic Soil Group C and D. The largest portion is soil group D and has the following characteristics: a high runoff potential when thoroughly wet, restricted water movement though the soil, and a high shrink-swell potential (NRCS, 2007). Portions of the Garcitas & Arenosa Creek watersheds are dominated by soils classified within Hydrologic Soil Group C; these soils have a moderately high runoff potential when thoroughly wet.

2.2.5 Land Use and Land Cover

Figure 5 shows land use/land cover data for the Garcitas Creek watershed as obtained from the USGS 2011 National Land Cover Database (NLCD). The NLCD indicates that Pasture/Hay (50.34 percent) is the predominant land use in the Garcitas Creek segment of the watershed. The watershed is predominantly rural in land-use; approximately 4.33 percent of the area is classified as Developed (open space, low intensity, medium intensity, and high intensity). Table 2 summarizes the type of land uses within the watershed, as well as their corresponding percentage of land that each land use cover.

Table 2. NLCD summary

	Arenosa Creek		Garcitas Creek (including Arenosa Creek)	
Land Use/Land Cover	**Acres**	**Percent of Total**	**Acres**	**Percent of Total**
Open Water	81.84	0.1%	562.44	0.2%
Developed, Open Space	3,733.34	3.4%	8,930.04	3.8%
Developed, Low Intensity	185.25	0.2%	749.69	0.3%
Developed, Medium Intensity	91.85	0.1%	367.62	0.2%
Developed, High Intensity	1.11	< 0.1%	89.85	< 0.1%
Barren Land	31.8	< 0.1%	157.46	0.1%
Deciduous Forest	3,297.67	3.0%	9,685.52	4.1%
Evergreen Forest	3,803.62	3.5%	10,732.78	4.6%
Mixed Forest	1,156.01	1.0%	2,435.00	1.0%
Shrub/Scrub	10,556.86	9.6%	27,442.19	11.7%
Grassland/Herbaceous	4,373.84	4.0%	11,143.98	4.8%
Pasture/Hay	62,422.23	56.7%	11,7942.00	50.3%
Cultivated Crops	16,880.88	15.3%	34,674.70	14.8%
Woody Wetlands	3,249.86	2.9%	6,594.23	2.8%
Emergent Herbaceous Wetlands	299.34	0.3%	2,894.69	1.2%
Total	110,165.5	100%	234,402.2	100.0%

2.2.6 Climate

Located within the coastal plains of Texas, the Garcitas Creek watershed experiences warm summer temperatures and mild winter temperatures. Data collected from the Victoria Regional Airport weather station shows the warmest average daily maximum temperature to be 94.5°F in August (Figure 2.4). The same airport monitor reported the coldest average daily maximum temperature to be 45°F in January. Measurements from the same Victoria Airport station shows that monthly precipitation peaks in May with 4.59 inches, but drops down to 2.24 inches during the month of February [National Oceanic and Atmospheric Administration (NOAA 2015)].

2.2.7 Surface Water Resources

According to the USGS National Hydrography Dataset (NHD), there are approximately 633 stream miles within the Garcitas Creek watershed (USGS 2012). Of which, 83 miles are named perennial or intermittent streams (Figure 3). Garcitas Creek begins within Thomaston and meanders south approximately 48 miles to Garcitas Cove. The tidal segment of Garcitas Creek begins approximately 0.6 miles upstream of the confluence with Arenosa Creek. Open water habitat accounts for approximately 563 acres of land surface area in 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 acres in size (USGS 2012).

There is currently one USGS streamflow gage in the watershed, located on US Highway 59 nearly halfway between Victoria and Edna. Figure 8 shows (A) the full record of daily mean streamflows and trends in (B) minimum seven-day mean flows, (C) median of daily mean flows, and (D) maximum one-day mean flows. The solid lines indicate the smoothed trend for each annualized statistic. For the minimum seven-day, median, and maximum one-day flows we see a decreasing trend since 1993. Changes in streamflow are largely attributed to changes in farming practices (the reduction in rice farming, for example, reduced irrigation discharges to local waterways) and possibly encroachment of woody species on native prairies and pastures (localized studies on the impacts of woody and invasive species encroachment have not been conducted but would be a worthwhile project).

2.2.8 Groundwater Resources

Part of the Gulf Coast Aquifer is located in the Garcitas Creek watershed. 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 of the Houston metropolitan area are approximately 1,600 gallons/minute (Ashworth, 1995). About 90 percent of all water pumped from the aquifer is used for municipal and agricultural uses (Ashworth, 1995).

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 (Ashworth, 1995). Subsidence levels are generally less than 0.5 ft, but the Harris County area has seen subsidence up to 9 ft (Ashworth, 1995). 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 (Ashworth 1995). 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.

2.3 Demographics

Approximately 4947 people live in the Garcitas watershed and 1911 live in the Arenosa sub-basin. The watershed population is concentrated around the town of Inez and the outskirts of Victoria. Victoria County is expected to witness a 24% population increase between 2020 and 2070 based on projections provided by TWDB (Table 1). Jackson County anticipates a 7.5% population increase, while Dewitt County expects a 3% increase. Meanwhile, Lavaca County’s population will remain constant. Understanding the population projection of this region is crucial in preparing for the water needs of the future.

The majority of the population within this watershed has a high school education, while 13-16% have a college education (Table 2; USCB 2014). English is the primary language in this region. However, between 17% and 24% do not speak English as a primary language. These demographics are important for understanding the target audience in order to promote stakeholder engagement for the WPP development and implementation.

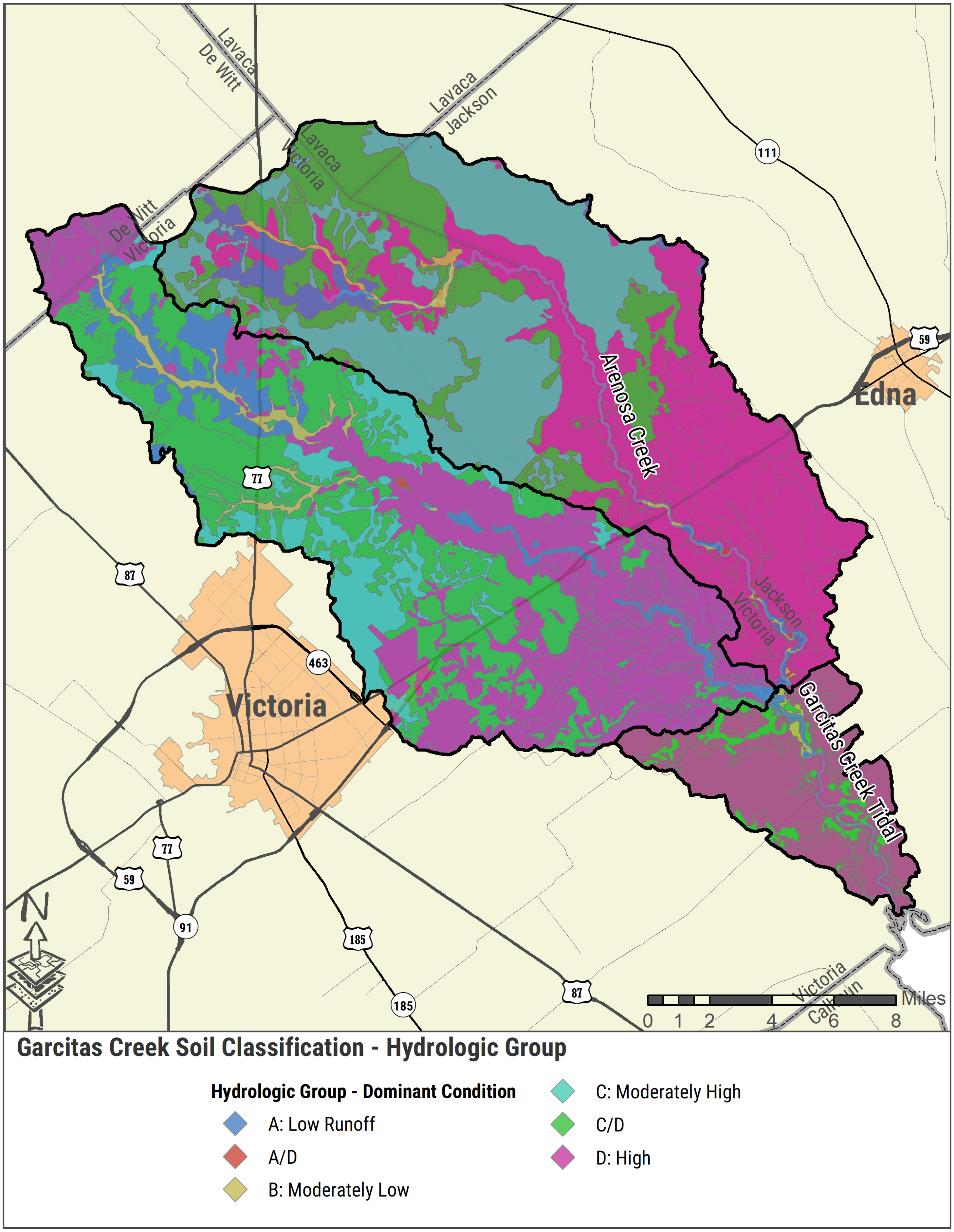

Figure 4. Watershed hydrologic soil group classifications

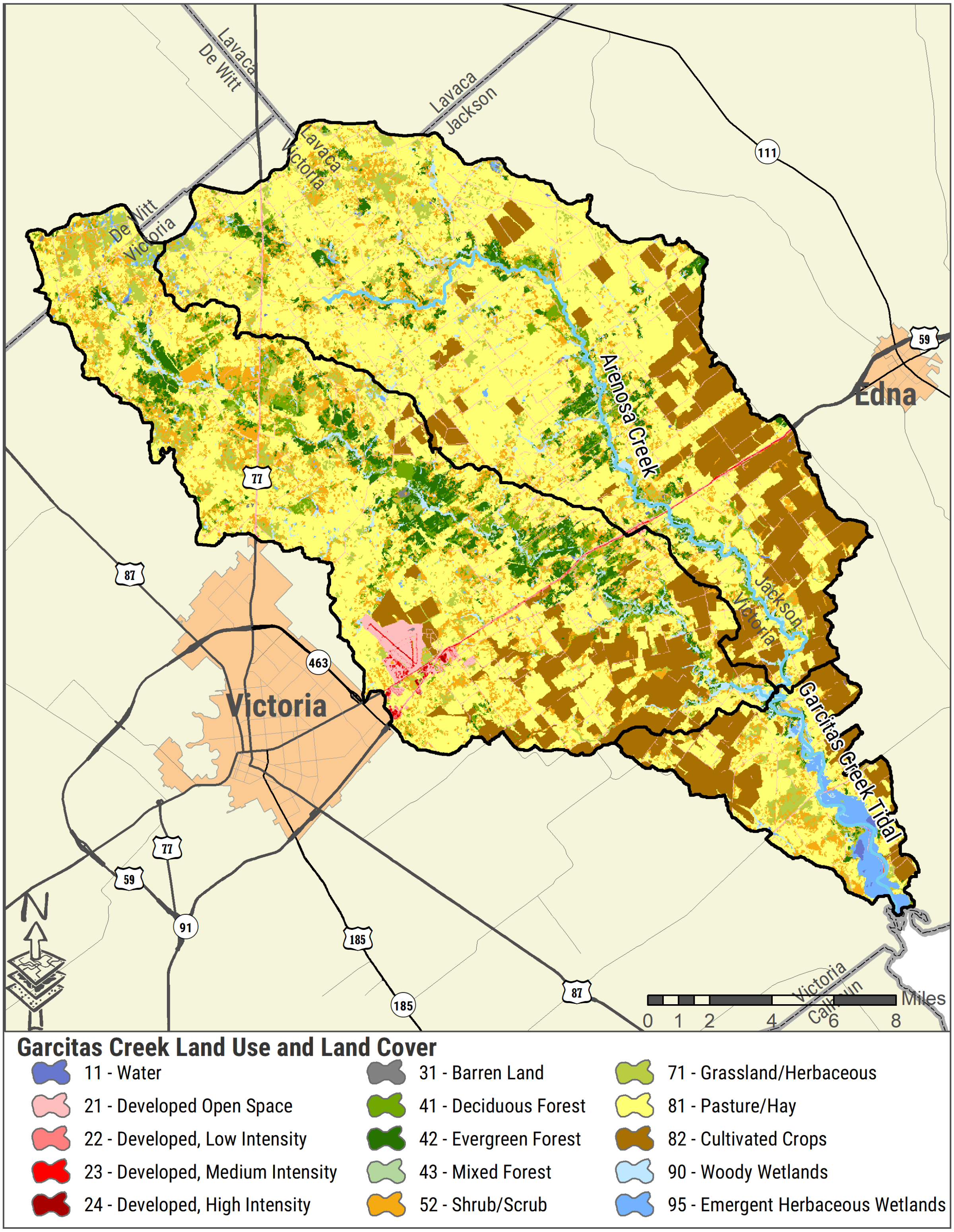

Figure 5. Watershed land use and land cover

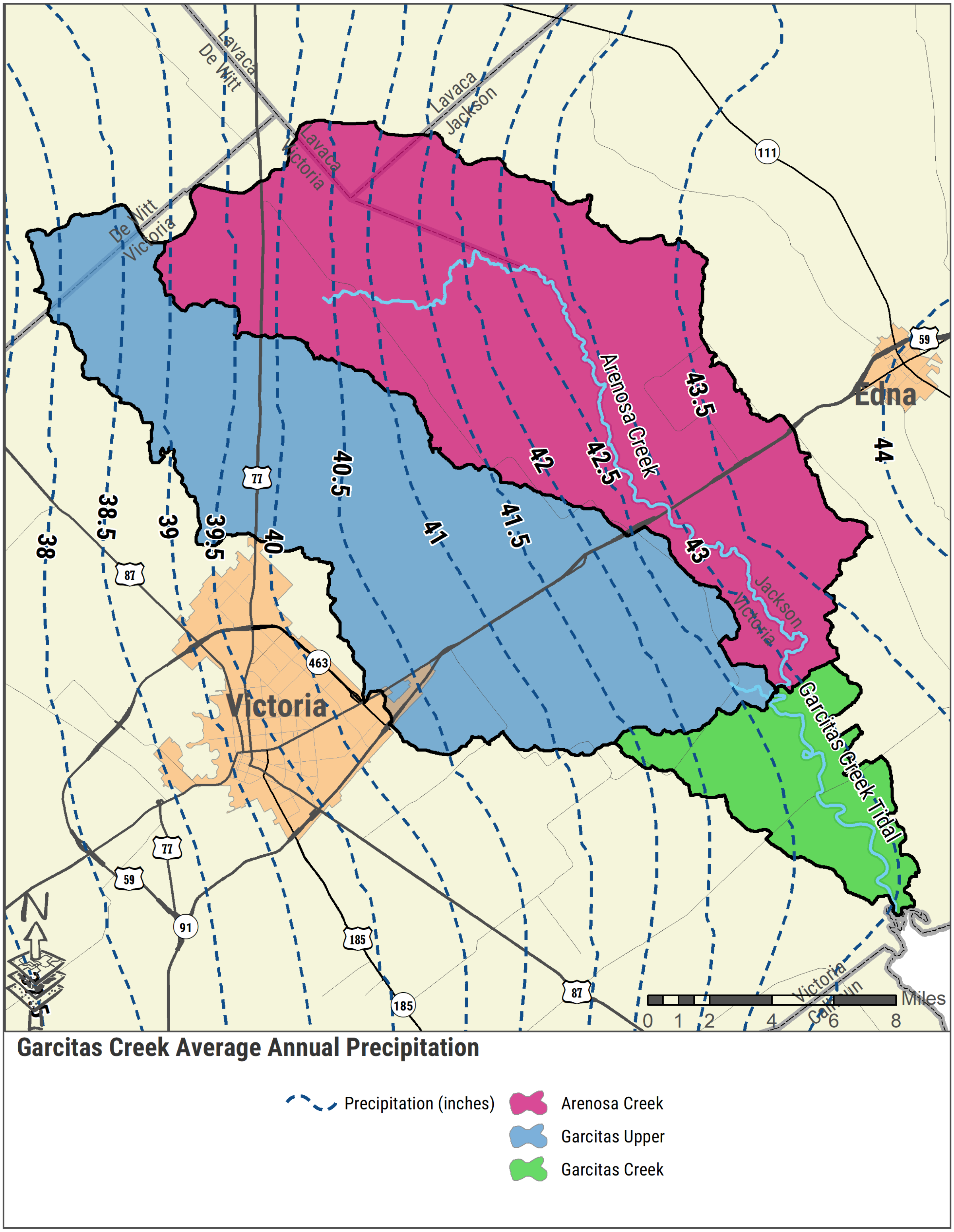

Figure 6. Average annual watershed precipitation

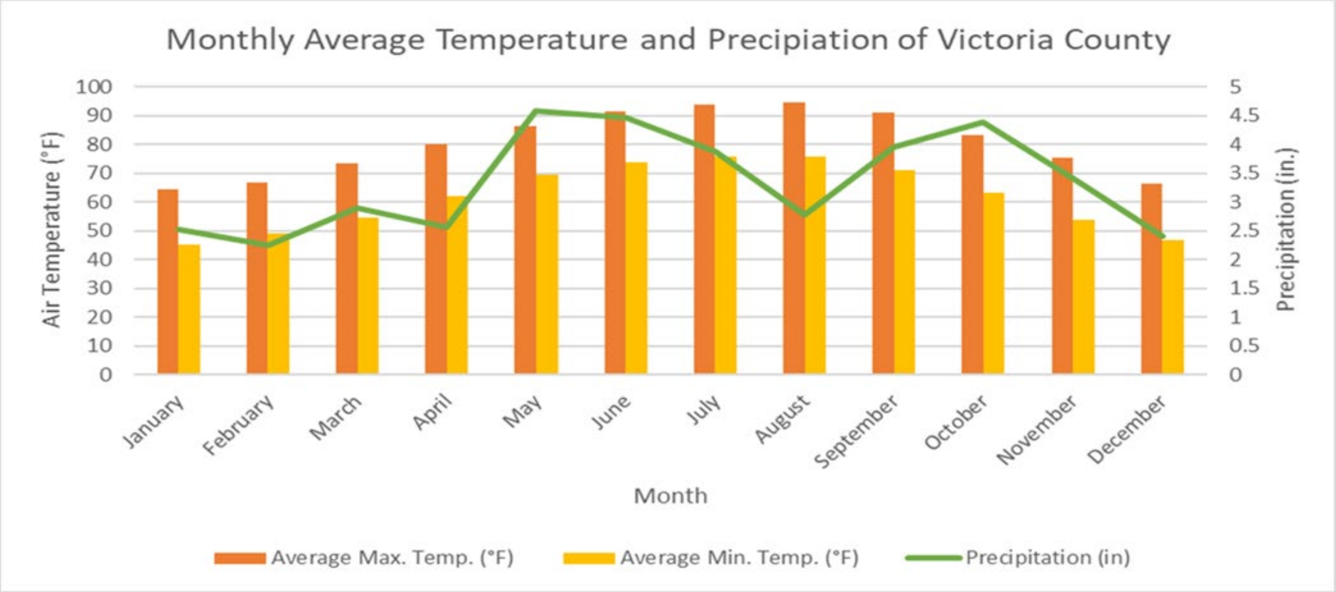

Figure 7. 10-year average precipitation and temperatures at the Victoria Regional Airport

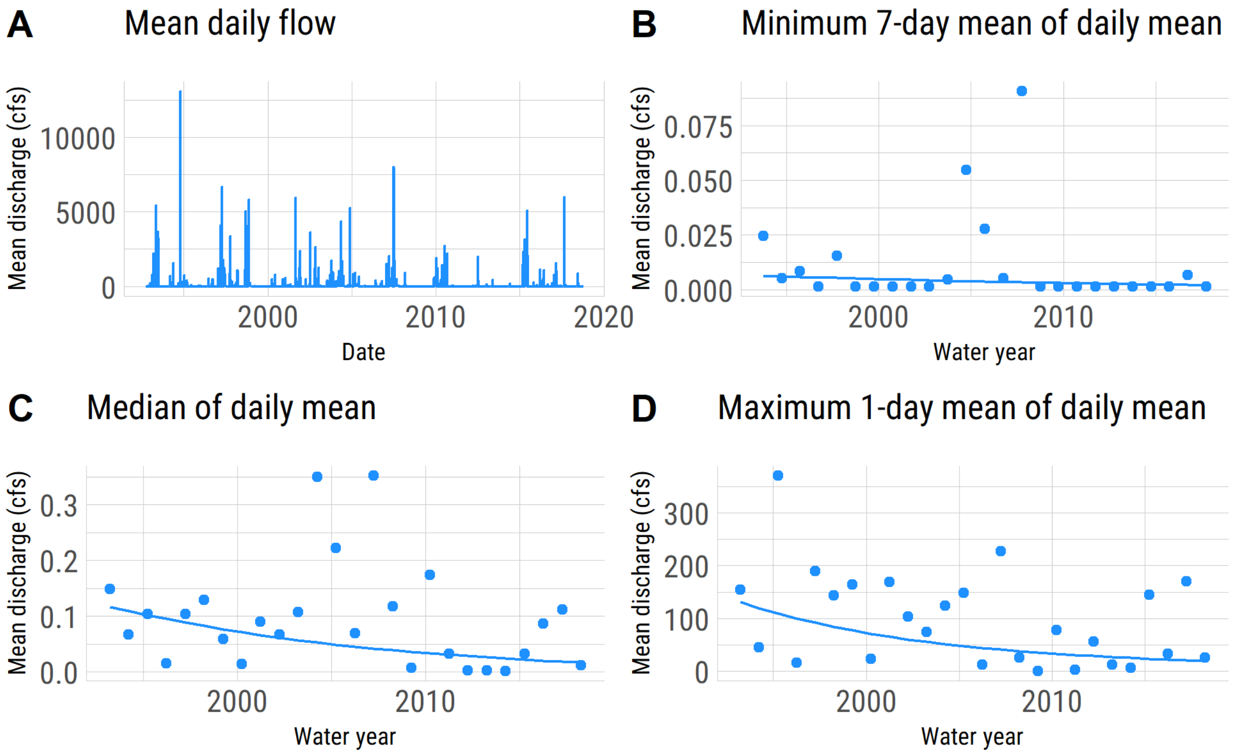

Figure 8. Streamflow statistics from the USGS Gage 08164600 on Garcitas Creek.

Table 3. County-wide population projections (TWDB 2018)

	Population by Year					
County	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
DeWitt	20,855	21,555	21,900	22,216	22,425	22,572
Jackson	14,606	15,119	15,336	15,515	15,627	15,699
Lavaca	19,263	19,263	19,263	19,263	19,263	19,263
Victoria	93,857	100,260	105,298	109,785	13,470	116,522

Table 4. Estimated county-wide educational attainment and primary languages (USCB 2014).

County	High School Diploma (%)	College Degree (%)	English Primary (%)	Non-English Primary (%)
DeWitt	76.2	13.3	82.5	17.5
Jackson	81.5	16.5	78.6	21.4
Lavaca	81.1	15.3	81.9	18.1
Victoria	81.1	16.8	75.5	24.5

Chapter 3 Water Quality

3.1 Introduction

Under the Federal Clean Water Act section 303(d) and 305(b), the State of Texas is required to identify water bodies that do not meet water quality standards for their designated uses. TCEQ assigns unique “segment” identifiers to each water body. Locations within a segment are broken up into hydrologically distinct assessment units (AUs). The AU are evaluated every two years to determine if they meet designated water quality standards, and those that do not meet requirements are listed on the Texas Integrated Report for the Texas 303(d) List: https://www.tceq.texas.gov/waterquality/assessment/14twqi/14txir. Within the watershed, there are two AUs and four surface water quality monitoring stations (Figure 9).

TCEQ defines the designated uses for all water bodies, which established the water quality criteria for which a water body must adhere Table 5. Support for recreation use is evaluated by measuring concentrations of fecal indicator bacteria in 100 mL of water. Aquatic life use is a measure of a water body’s ability to support a healthy aquatic ecosystem. Support of designated aquatic life use is determined by DO concentration, toxins substance concentration, ambient water and sediment toxicity, and indices of habitat, benthic macroinvertebrates and fish communities. General use water quality requirements also include measures of temperature, pH, chloride, sulfate, and total dissolved solids (TDS). Currently, water bodies are also screened for levels of pertinent nutrients and chlorophyll-a.

According to the 2014 Texas Integrated Report, Garcitas Creek (AU 2453A), is impaired due to depressed DO and Arenosa Creek (AU 2453C) is impaired due to elevated levels of bacteria (Figure 9). The remainder of this chapter discusses potential pollutant sources and provides a more detailed assessment of currently available water quality data.

Table 5. Designated uses and associated criteria for watershed waterbodies.

Designated Use	Criteria	Assessment Method
Primary Contact Recreation	126 MPN/100mL E.coli bacteria (freshwater) 35 MPN/100mL Enterococcus bacteria (tidal)	Geometric mean
High Aquatic Life Use	5.0 mg/L Avg DO (freshwater) 3.0 mg/L minimum DO (freshwater) 4.0 mg/L average DO (Saltwater) 3.0 mg/L minimum DO (Saltwater)	Number of exceedances > 10%

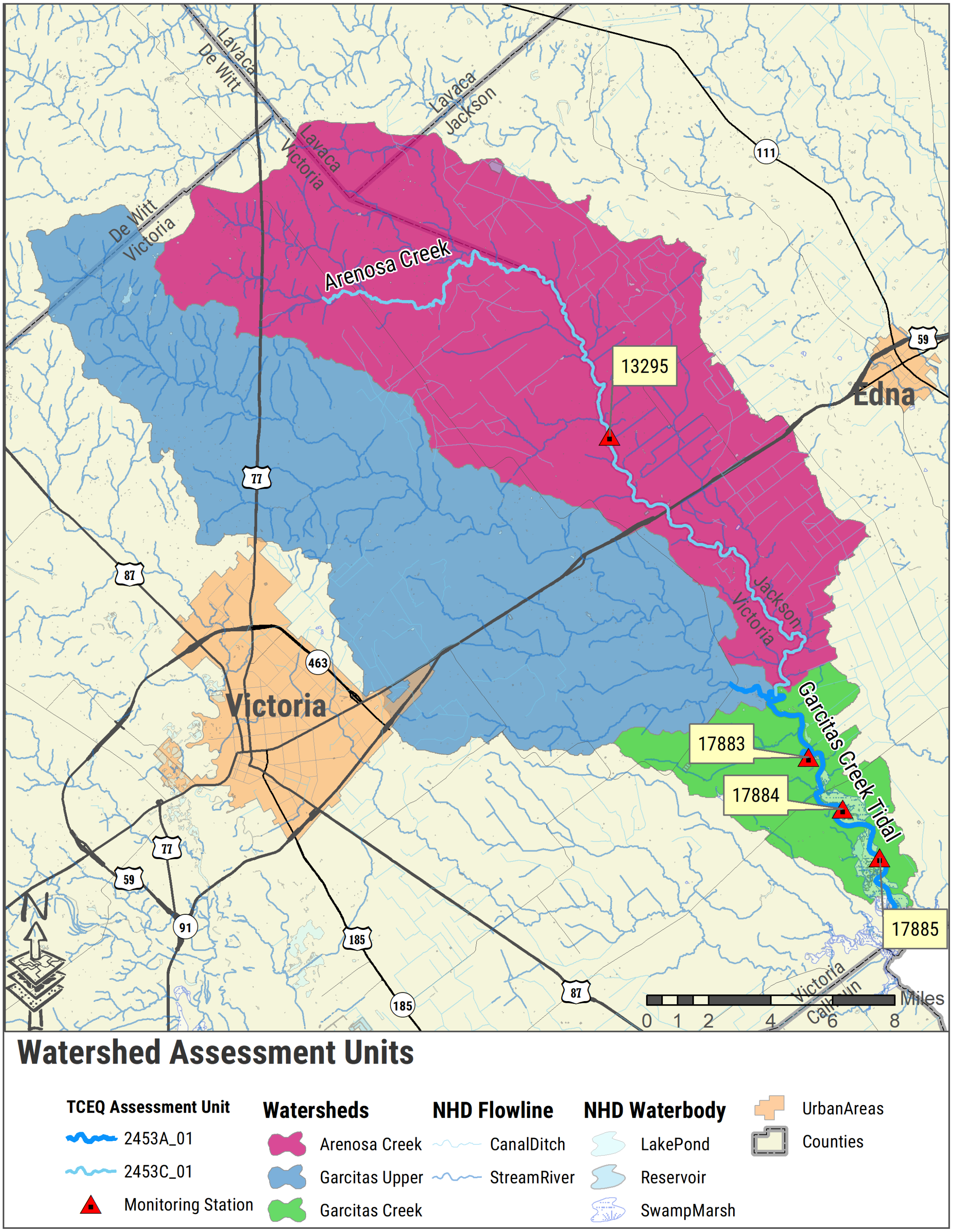

Figure 9. Assessment units and locations of surface water quality monitoring stations

3.2 Potential Point and Nonpoint Sources

When addressing polluted watersheds, it is important to identify the point and nonpoint sources. Point sources of indicator bacteria and nutrients pollution originate from permitted discharges, such as a municipal separate stormwater systems.

Meanwhile, nonpoint sources of bacteria and nutrients pollution emanate from unregulated sources. Such sources include wildlife, feral hogs, various agricultural practices, agricultural animals, land application fields, urban runoff not covered by a permit, failing OSSFs, and domestic pets. These sources are not easily differentiated without an in depth knowledge of the watershed and its residents' lifestyles.

3.2.1 Wildlife and Unmanaged Animals

Fecal indicator bacteria, such as *Enterococci* and *E. coli* are common inhabitants of the intestines of all warm-blooded animals, including mammals and birds. 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.

Within a rural watershed, wildlife populations are certainly extensive. However, reliable estimates for small mammals, birds, and non-game species are difficult to obtain or non-existent. Estimates for feral hogs and white-tailed deer were developed based on existing data and local stakeholder input.

Conservative estimates of statewide feral hog densities range from one hog per 39 acres to one hog per 71.9 acres (AgriLife Extension, 2012). A feral hog density of one hog per 33.3 acres was estimated for the nearby Mission and Aransas watersheds (Wagner & Moench 2009). During planning sessions, stakeholders developed a much higher density estimate of one hog per 8.325 habitable acres within the watershed. This density 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 results in an estimate of 26,852 feral hogs for the entire watershed (Table 6).

Texas Parks and Wildlife Department (TPWD) conduct white-tailed deer surveys to ensure healthy harvest and management. Based on Post Oak Savannah Resource Management Unit surveys, the watershed has an approximate density of one deer per 19 acres 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 12,338 deer (Table 6).

Table 6. Wildlife population estimates

Animal Type	Estimated Density	Arenosa Creek	Garcitas Creek (including Arenosa Creek)
Feral Hogs	1 animal per 8.325 acres	12,738	26,852
White-tailed deer	1 animal per 19 acres	5,853	12,338

3.2.2 Livestock

The number of cattle and calves in the watershed were estimated based on stakeholder estimated typical stocking densities. Local stakeholders estimate that cattle are stocked at a rate of one animal unit per 4 acres of pasture and one animal unit per 11 acres of unimproved rangeland on average.

Other livestock in the Arenosa Creek watershed were estimated from county-level data obtained from the 2012 Census of Agriculture (USDA National Agriculture Statistics Service 2014). The county-level data were refined to reflect acres of un-urbanized land within each watershed. The refinement was determined by the total area of each county and the impaired AU that was designated as un-urbanized by the 2010 U.S. Census. The ratio was the un-urbanized area of the AU that resides within a county divided by the total un-urbanized area of the county. Watershed-level livestock numbers are the ratio multiplied by county-level data.

3.2.3 Household Pets

When not properly disposed of, fecal matter from dogs and cats is transported to streams by runoff. This fecal matter is a potential source of bacteria loading. The American Veterinary Medical Association (AVMA) estimates there are 0.584 dogs per household and 0.638 cats per household (AVMA 2012). These estimates were multiplied by the number of households in the watersheds to find the total number of cats in dogs within the watersheds. According to US Census data, there are approximately 340 households in the Arenosa Creek watershed and a total of 2,020 households in the entire Garcitas Creek watershed. We estimated 1,180 dogs and 1,289 cats in the watershed (Table 7).

Table 7. Household pet estimates

Pet Type	Estimated Density	Arenosa Creek	Garcitas Creek (including Arenosa Creek)
Dogs	0.584 dogs per household	199	1,180
Cats	0.638 cats per household	217	1,289

3.2.4 On-Site Sewage Facilities

Nearly all the residences in the watershed are assumed to use an OSSF. 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 1,542 OSSFs occur in the watershed (Figure 10). Most of these systems are found in “very limited” soil types. Because of the surrounding soil types, the OSSFs have a 12-percent expected failure rate (Reed, Stowe & Yanke LLC, 2001).

Table 8. Estimated number of OSSFs across the watershed

	Arenosa Creek	Garcitas Creek (including Arenosa Creek)
Estimated Number of OSSFs	322	1,542

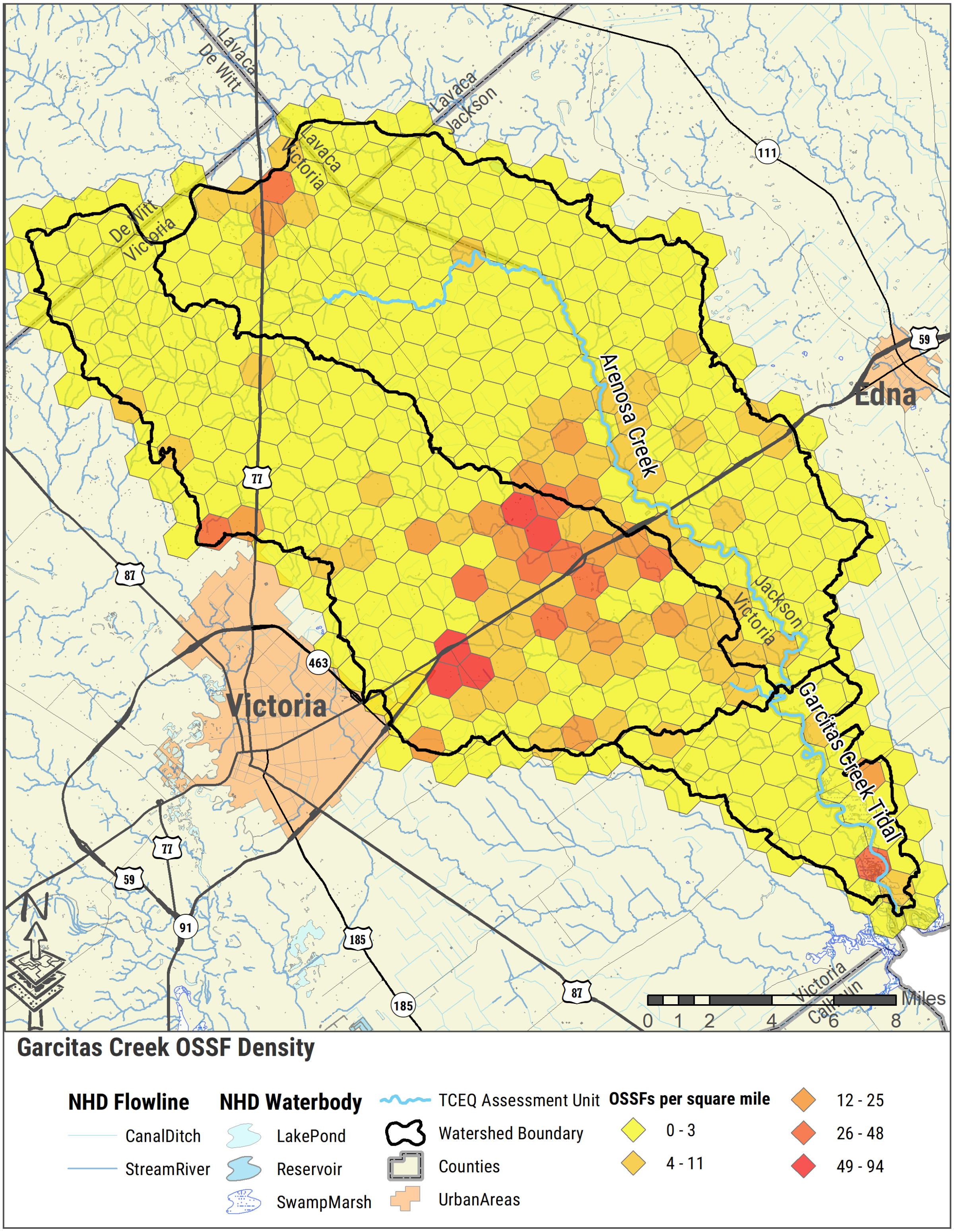

Figure 10. OSSF density

3.2.5 Permitted Dischargers

Permitted discharges are sources regulated by permit under the TPDES and the National Pollutant Discharge Elimination System (NPDES) programs.

Currently, there are two permitted wastewater discharges within the watershed, permitted for a total discharge of only 0.07 MGD (Table 9). Both facilities discharge into Garcitas Creek or tributary of Garcitas Creek. Both facilities are required to treat and test for *E. coli* bacteria, with an average limit of 126 MPN/100mL.

The Texas Department of Transportation operated facility is also required to monitor for and meet effluent limits for DO, pH, total suspended solids, residual chlorine, nitrogen-ammonia, and carbonaceous biological oxygen demand. Since 2015-10-01, the facility has reported non-compliance issues in 7 out of 13 quarters. Early non-compliances issues were due to exceedances in nitrogen-ammonia, which were resolved. The most recent non-compliances are due to excessive total suspended solids.

The Aqua Utilities operated facility serves the Brentwood Manor subdivision and required to monitor and report effluent levels of DO, 5-day Biological Oxygen Demand, pH, total suspended solids, nitrogen-ammonia, and residual chlorine. Since 2016-01-01, the facility has reported non-compliances in eight of 12 quarters. Two violations were for excessive *E. coli*. The remainder of quarterly noncompliance issues are due to high total suspended solids.

Table 9. Permitted wastewater dischargers in the watershed

EPA ID	Permittee Name	Site Name	Location	Permitted Flow (MGD)
TX0077291	Texas Department of Transportation	Victoria County Southbound Rest Area WWTP	US 59 Rest Area WWTF, Victoria County, TX 77995	0.02
TX0024601	Aqua Utilities Inc.	Brentwood Manor Subdivision	0.4MI S of US Hwy 59 And E of Mercado Creek, Victoria County, TX 77041	0.05

Discharges of stormwater from a Phase II municipal separate stormwater system (MS4) area, industrial facility, construction site, or other facility involved in certain activities are required to be covered under the following TPDES general permits:

- TXR040000 – stormwater Phase II MS4 general permit for urbanized areas
- TXR050000 – stormwater multi-sector general permit (MSGP) for industrial facilities
- TXR150000 – stormwater from construction activities disturbing more than one acre
- TXG110000 – concrete production facilities
- TXG340000 – petroleum bulk stations and terminals

Three of these permits (MS4, MSGP, and construction) pertain solely to stormwater discharges. The other two — concrete production facilities and petroleum bulk stations and terminals — also authorize the discharge of processed wastewater as discussed above under TPDES general wastewater permits. Currently, five permits MSGP permits have been issued in the watershed (Table 10). The Victoria County Drainage District also holds an MS4 permit that applies to the county and city of Victoria (Table 11). The MS4 permit refers to the permitting of municipal stormwater systems that are separate from sanitary sewer systems. They are broken down into "large" Phase I and "small" Phase II system permits based on population. Further details on MS4 permitting requirements are available from TCEQ: www.tceq.texas.gov/permitting/stormwater/ms4.

Based on the 2011 NLCD, only 4.33% of the watershed is urbanized. Thus, contributions to surface water impairments from regulated entities and urbanized development are assumed to be minor based on the relatively small amount of stormwater permits and devolved land. However, there are increasing development pressures, especially along Highway 59 between Victoria and Edna. In response to some of these development pressures, Victoria County adopted an updated Development Standards Manual in 2018 to better incorporate stormwater and sediment management for subdivisions in the county (http://vctx.org/pdf/HomePDF/Development%20Standards%20Manual.pdf).

Table 10. Stormwater Multi-Sector General Permits for Industrial Facilities

EPA ID	Permittee Name	Location
TXR05K406	Victoria Regional Airport	609 Foster Field Dr, Victoria, TX 77904-3624
TXR05CN34	Kinder Morgan Victoria Yard	407 Holt Rd, Victoria, TX 77905-5575
TXRNEAY17	Quality Carriers	9007 US Hwy 59 N, Victoria, TX 77905-5543
TXR05BD23	Victoria Bin	9402 US Hwy 59 N, Victoria, TX 77905-5569
TXR05R224	XPO Logistics Freight LVC	9301 US Hwy 59 N, Victoria, TX 77905-5517

Table 11. MS4 permits in the watershed

EPA ID	Permittee Name	Type	Location
TXR040632	Victoria County Drainage District 3 MS4	Small Phase II MS4	Area within the county of Victoria and located within Victoria, TX

3.2.6 Land Application Facilities

In the Arenosa Creek watershed, TCEQ has issued a permit for the land application of sewage sludge on 793 acres of land in Victoria County (Table 12). The permit limits the applicant to eight dry tons per year and does not permit for the discharge or runoff from the property. However, considerable stakeholder concern exists for the potential of stormwater flows from the property to negatively impact water quality.

Table 12. Permitted land application facilities

TPDES Permit No.	Permit Issue Date	Customer Name	Dates Monitored	Monthly Average Discharge	Final Permitted Discharge	Report Fecal Coliform Bacteria	Disinfection Requirement[2]
WQ0004666000	05/31/07	Beneficial Land Management LLC (Sludge)[1]	NA	NA	NA	NA	NA

NA = Not applicable; MGD = million gallons per day

Notes: [1] Permit does not contain a discharge provision

[2] An equivalent method of disinfection may be substituted with approval from TCEQ. Only chlorination (no dechlorination) is required for facilities operating under a capacity of 1 MGD

3.3 Water Quality Data

Data included in Texas' 2012 and 2014 Integrated Report on Surface Water Quality indicated the tidal portion of Garcitas Creek (Segment 2453A) is impaired due to low DO and the Arenosa Creek (Segment 2453C) is impaired for high bacteria. Three surface water quality monitoring station have been used to assess Garcitas Creek (Figure 9). Station 13295 is located 3 miles north at the intersection of US 59 and FM 444 in Victoria County. Stations 17883, 17884 and 17885 are located on either sides of FM 616. For this watershed plan, water quality data was obtained from the TCEQ Clean Rivers Program Data Tool (TCEQ 2018).

3.3.1 Bacteria

Concentrations of fecal indicator bacteria are evaluated to assess the risk of illness during contact recreation. In freshwater environments, such as Arenosa creek, concentrations of *E.coli* bacteria are measured. The presence of these fecal indicator bacteria may suggest that associated pathogens from the intestinal tracks of warm-blooded animals can reach water bodies and cause illness in people that recreate in them.

E. coli data from Arenosa Creek was collected from December 2000 through August 2003. Monitoring was halted for several years. TWRI worked with TCEQ to collect supplemental *E. coli* data from September 2014 through August 2015 to confirm the bacteria impairment. A total of 44 samples have been collected in Arenosa Creek with a geometric mean of 233.6 MPN/100mL (Figure 11, Table 13). No bacteria samples have been collected in Garcitas Creek.

Approximately half the samples were collected under extremely low flow conditions. Samples collected under these conditions exhibited extremely high variability, ranging from six MPN/100mL to 1,986 MPN/100mL. We plotted the linear regression relationship between streamflow and bacteria concentration for the remaining samples. There is a weak, but positive relationship between streamflow and bacteria concentrations with a multiple R^2 of 0.4162 and p-value < 0.001 (Figure 12).

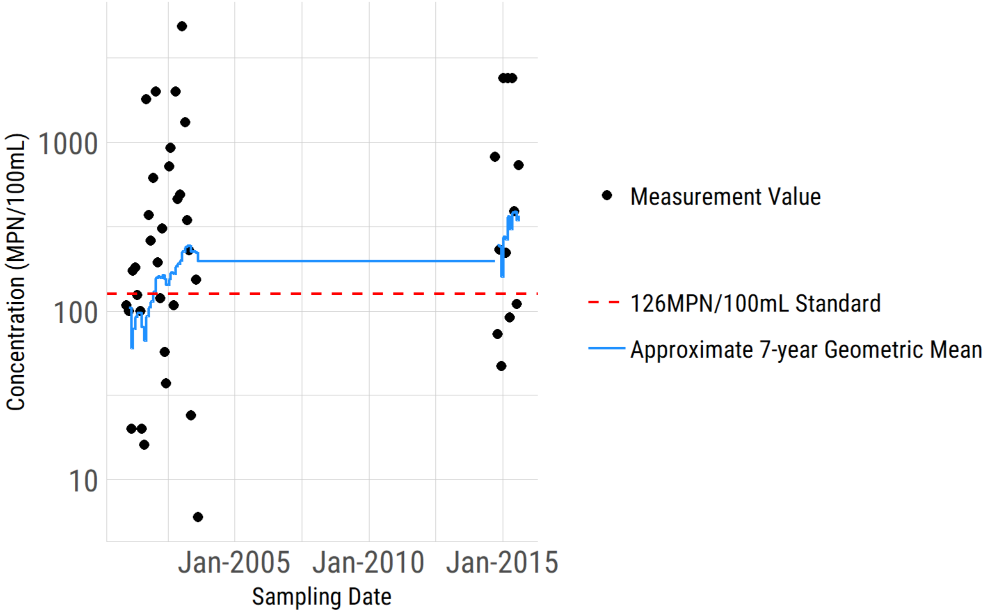

Figure 11. *E. coli* bacteria samples from Arenosa Creek and the approximate 7-year rolling geometric mean.

Table 13. Summary of *E. coli* bacteria data in collected from Arenosa Creek.

Parameter	**Segment**	**Date Range**	**Number of Samples**	**Geometric Mean**
E. coli	Arenosa Creek	2000-12-11 – 2015-08-06	44	233.6 MPN/100mL

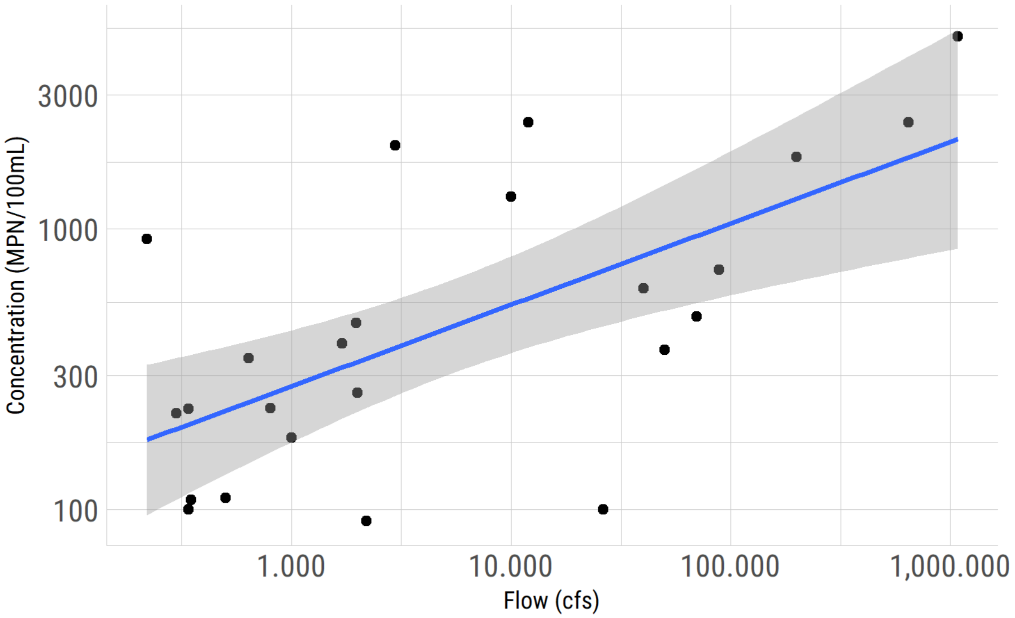

Figure 12. Linear relationship between log-transformed streamflow and *E. coli* concentration in Arenosa Creek.

3.3.2 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 by 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 Garcitas Creek is assigned a “High” Aquatic Life Use, with a corresponding DO criteria of 4.0 mg/L minimum average over 24-hours and 3.0 mg/L minimum.

In 2007, TPWD and TCEQ undertook a Use Attainability Analysis (UAA) in order to determine the appropriate DO criterion of Garcitas Creek tidal (Tolan et al., 2007). The study compared watershed characteristics, aquatic habitat, and the quantities and types of aquatic species in the Garcitas Creek tidal to a nearby reference creek. The study determined that DO was not a major driver of ecosystem health in the Garcitas Creek tidal. Importantly, data in the study suggests that current DO levels support healthy ecosystem function in Garcitas Creek, with mean DO levels from grab samples routinely above the 4.0 mg/L level. Based on the original standard, 29.2% of 24-hr DO samples were below 4.0 mg/L average criterion (Figure 13).

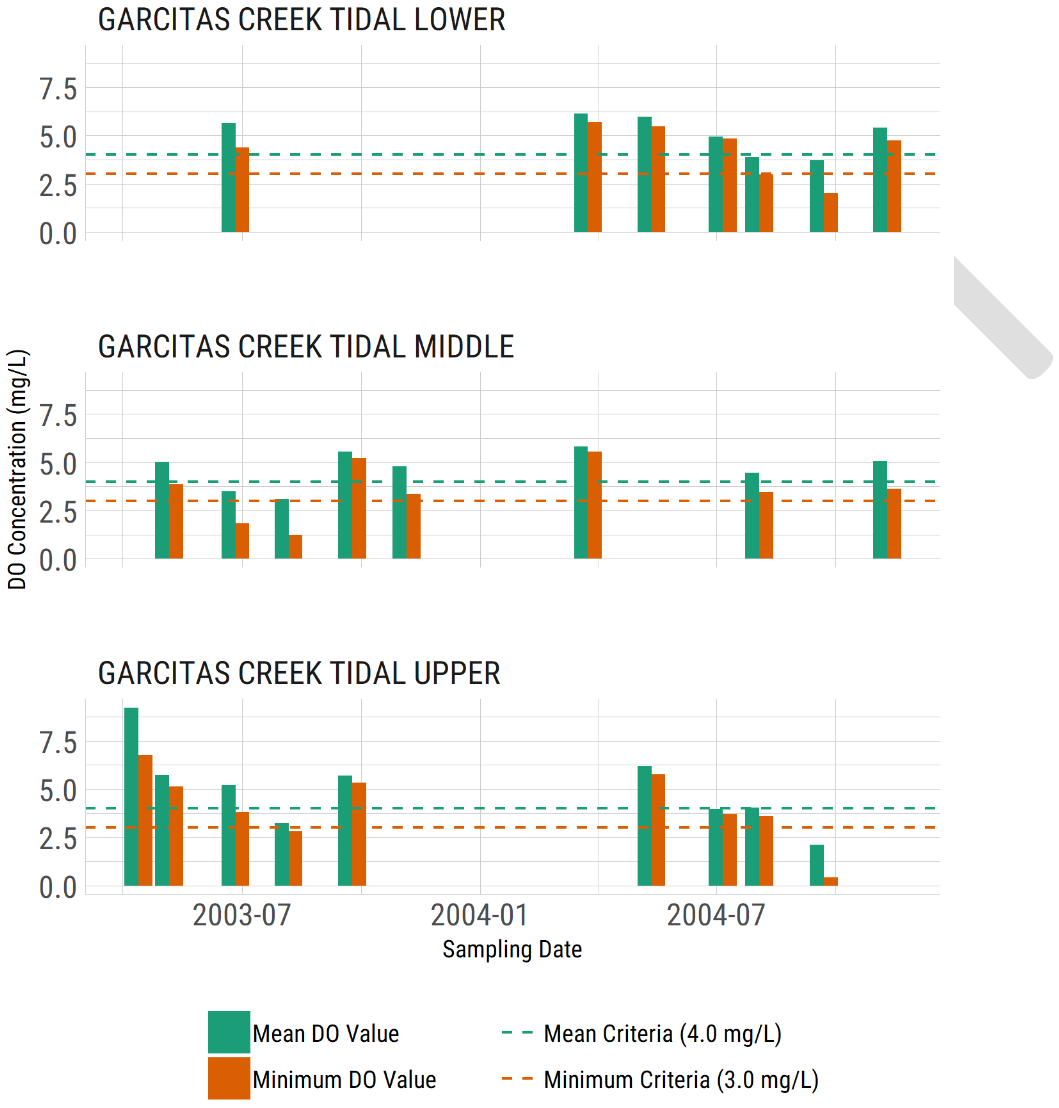

Figure 13. 24-hour dissolved oxygen values from Garcitas Creek Tidal (higher is better).

Attributing sources of depressed DO within the Garcitas 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 Garcitas 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 Garcitas 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. 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 limited understanding of natural background fluctuations in the Garcitas system.

In summary, it is not clear if the current criteria for Garcitas Creek is appropriate provided that aquatic life use is not hindered. Future work by TCEQ and its partners will likely provide further clarification in regards to the DO criteria for the segment. However, we generally assume that management measures applied to reduce bacteria loads will also reduce nutrient loads that could contribute to the DO impairment in Garcitas Creek.

Chapter 4 Pollutant Source Assessment

4.1 Introduction

Based on recent and historical water quality sampling, Arenosa Creek was identified as impaired due to elevated fecal indicator bacteria. The tidal portion of Garcitas Creek was identified as impaired due to depressed oxygen during. This chapter provides information about the pollutant load reductions required to meet water quality standards and results from spatial analysis of potential bacteria and nutrient sources. This information is critical to prioritize the types and locations of management measures intended to improve and protect water quality.

4.2 Load Duration Curve (LDC) Analysis

The relationship between flow and pollutant concentrations can be established using a Load Duration Curve (LDC). This approach allows existing pollutant loads to be calculated and compared to allowable pollutant loads. These comparisons serve as the basis for estimating the load reduction required to meet water quality standards. Concurrent with the development of this Watershed Protection Plan, TWRI in coordination with TCEQ, produced a report to provide technical documentation and supporting information for developing the bacteria LDC used in the Watershed Protection Plan and the Arenosa Creek Total Maximum Daily Load (TMDL).

Although LDCs cannot identify specific pollutant sources (urban vs agricultural, etc.), they can identify likely pollutant type (point source vs. NPS). Using the LDC, exceedances occurring under high flow or moist conditions are attributed to NPS. Conversely, exceedances during low flow conditions are attributed to point sources. Detailed information on Arenosa Creek LDC development and interpretation is in Jain et al. (2018) and Appendix C.

The Arenosa Creek LDC (Figure 14) shows that bacteria loadings primarily exceed the allowable pollutant load under high and mid-range flow conditions. Regulated stormwater comprises a minor portion of the Arenosa Creek watershed (less than one percent) and must be considered only a minor contributor. It is therefore likely that non-regulated stormwater comprises the majority of high-flow related loadings. There are no permitted WWTFs in the watershed; therefore, elevated loadings under the mid-range and lower flow conditions cannot be reasonably attributed exclusively to WWTF discharges. Other sources of bacteria loadings under lower flows and in the absence of overland flow contributions (i.e., without stormwater contribution) are most likely contributing bacteria directly to the water, as could occur through direct deposition of fecal material from such sources as wildlife (avian and non-avian), feral hogs, and livestock. The actual contribution of bacteria loadings attributable to these direct sources of fecal material deposition cannot be determined using LDCs.

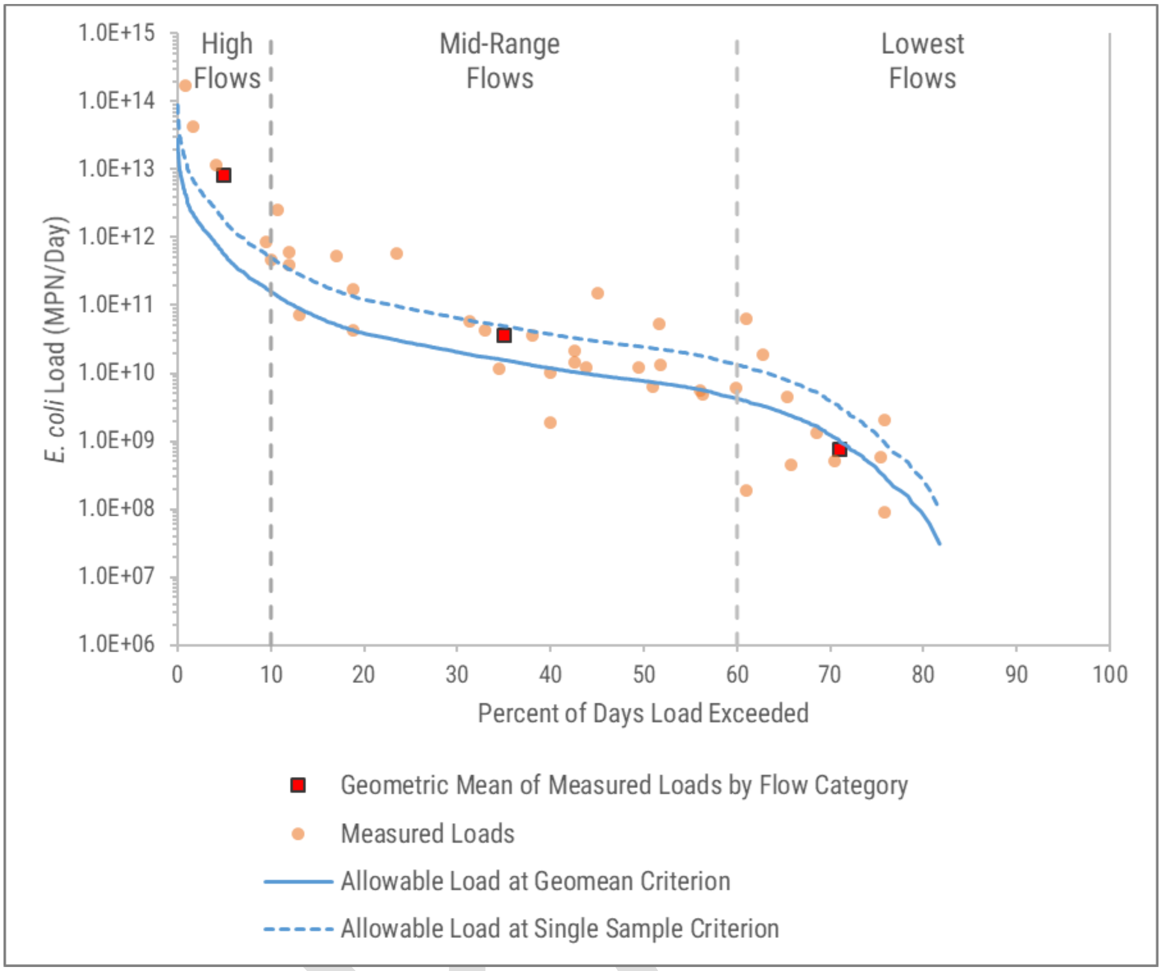

Figure 14. Load duration curve at station 13295 on Arenosa Creek for the period September 1, 2000 through August 31, 2015.

Table 14. Bacteria load reductions required to meet water quality goals in Arenosa Creek.

<table>
<tr><th rowspan="2"></th><th colspan="3">Flow Conditions</th></tr>
<tr><th>High</th><th>Mid-range</th><th>Low</th></tr>
<tr><td>Days per year</td><td>36.50</td><td>182.50</td><td>146.00</td></tr>
<tr><td>Median Flow (ft^3/sec)</td><td>181.29</td><td>5.09</td><td>0.34</td></tr>
<tr><td>Existing Geomean Concentration (MPN/100 mL)</td><td>1,891.92</td><td>284.45</td><td>89.16</td></tr>
<tr><td>Allowable Daily Load (Billion MPN)</td><td>558.86</td><td>15.69</td><td>1.05</td></tr>
<tr><td>Allowable Annual Load (Billion MPN)</td><td>20,398.35</td><td>2,863.61</td><td>153.01</td></tr>
<tr><td>Existing Daily Load (Billion MPN)</td><td>8,391.40</td><td>35.42</td><td>0.74</td></tr>
<tr><td>Existing Annual Load (Billion MPN)</td><td>306,286.17</td><td>6,464.70</td><td>108.33</td></tr>
<tr><td>Annual Load Reduction Needed (Billion MPN)</td><td>285,887.82</td><td>3,601.09</td><td>Not Applicable</td></tr>
<tr><td>Percent Reduction Needed</td><td>93.34</td><td>55.70</td><td>Not applicable</td></tr>
<tr><td rowspan="3">Possible Sources</td><td colspan="2">Overland Flow
Sanitary Sewer Overflows
Resuspension</td><td></td></tr>
<tr><td colspan="3">Failing or non-existent OSSFs</td></tr>
<tr><td></td><td colspan="2">Direct deposition from wildlife, feral hogs, livestock, pets
Illegal dumping</td></tr>
<tr><td>Total Annual Load (Billion MPN)</td><td colspan="3">312,859.20</td></tr>
<tr><td>Total Annual Load Reduction (Billion MPN)</td><td colspan="3">289,488.91</td></tr>
<tr><td>Total Percent Reduction</td><td colspan="3">92.53</td></tr>
</table>

4.3 Spatially Explicit Load Enrichment Calculation Tool (SELECT)

To aid in identifying potential areas of bacteria contributions within the watershed, we employed the approach used in Spatially Explicit Load Enrichment Calculation Tool (SELECT) (Borel et al., 2012). SELECT utilizes the best available information combined with stakeholder input to estimate potential pollutant loadings based on livestock population estimates, landcover, housing and population density, OSSF locations, and other available data. SELECT can be thought of as depicting the worst-case pollutant loading scenarios that can be used to identify areas to prioritize pollution prevention efforts and management.

The SELECT methodology was applied to potential for loadings from OSSFs, cattle, feral hogs, and deer in the Arenosa Creek watershed to identify priority areas for management measures that address bacteria loadings (Figure 15, Figure 16, Figure 17, Figure 18). Equations and sources for load estimation used in SELECT are included in Appendix E - SELECT Loading Calculations. Each map identify the potential loading per square mile of watershed to identify those areas with the highest potential for management measure to reduce instream bacteria loads. It is important to note that SELECT does not represent the bacteria transport and fate processes; therefore these maps do not represent actual bacteria loads.

4.3.1 OSSFs

Failing or unmaintained OSSFs can contribute bacteria loads to water bodies, in particular those where effluent is released near the water bodies. According to a study for the TCEQ, approximately 12% of OSSFs in this region of the state are expected to be in failing condition (Reed, Stowe & Yanke LLC, 2001). Most of the systems in the watershed are found on soils classified by the NRCS SSURGO soils database as “Very Limited” for septic system suitability. SELECT results indicate the highest intensity of potential OSSF *E. coli* loadings occur in subwatersheds 3 and 10 (Figure 15). Management measures targeting these subwatersheds and riparian areas throughout the watershed would have the highest potential for large bacteria load reductions.

4.3.2 Cattle

Cattle can contribute to *E. coli* bacteria loading in two ways. First, they can contribute through the direct deposition of fecal matter into streams while wading. Second, runoff from pasture and rangeland can contain elevated levels of *E. coli*, which in turn can increase bacteria loads in the stream. Improved grazing practices and land stewardship can dramatically reduce runoff and bacteria loadings. For example, recent research in Texas watersheds indicate that rotational grazing and grazing livestock in upland pastures during wet seasons results in significant reductions in *E. coli* levels (Wagner et al, 2012). Furthermore, alternative water sources and shade structures located outside of riparian areas significantly reduce the amount of time cattle spend in and near streams, thus resulting in improved water quality (Wagner et al, 2013; Clary et al, 2016). SELECT results indicate the highest intensity of potential *E. coli* loadings occur in subwatersheds 4, 6, and 7 (Figure 16).

4.3.3 Feral Hogs

Feral hogs (*Sus scrofa*) are an introduced, non-native, and invasive species. Early settlers released some of the first domestic hogs in the Texas landscape as early as the 1680s, with many of these hogs becoming feral over time as animals were left to fend for themselves (Mayer, 2009; Mapston, 2010). Documented introductions of Eurasian wild boar occurred in the early 1920s through the 1940s along the Texas Central Coast, including at the St. Charles Ranch in what is now the nearby Aransas National Wildlife Refuge (Mayer, 2009). Current population estimates of feral hogs in Texas alone range from 1 to 3 million individuals (Mayer, 2009; Mapston, 2010).

Feral hogs contribute to *E. coli* bacteria loadings through the direct deposition of fecal matter into streams while wading or wallowing in riparian areas. Riparian areas provide ideal habitats and migratory corridors for feral hogs as they search for food. While complete removal of feral hog populations is unlikely, habitat management and trapping programs can limit populations and associated damage. SELECT results show that targeting management measures in subwatersheds 6 and 12 would have the highest potential for reducing bacteria loads (Figure 17).

4.3.4 Deer

Although it is unlikely that specific management measures to reduce populations of deer will be pursued and implemented, SELECT was used to show areas with the highest potential for *E. coli* loadings from deer. In rural watersheds such as the Garcitas and Arenosa Creek watershed, wildlife can be substantial contributors to bacteria loadings. Although the potential loading intensity from deer differs from feral hogs, the spatial distribution is identical because the same land uses were used to distribute populations across the landscape (Figure 18).

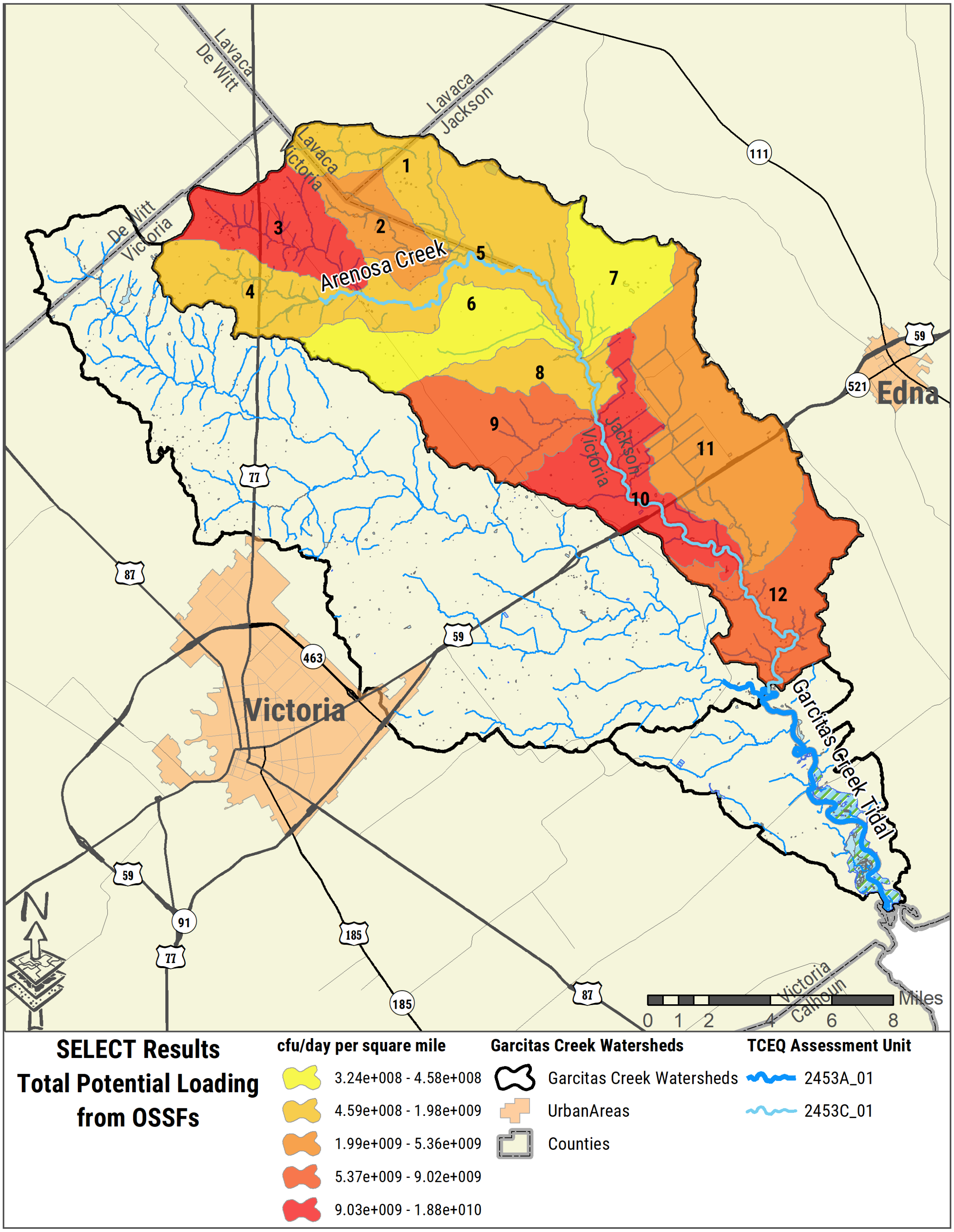

Figure 15. OSSF potential loading intensity. Numbers indicate subwatersheds 1-12.

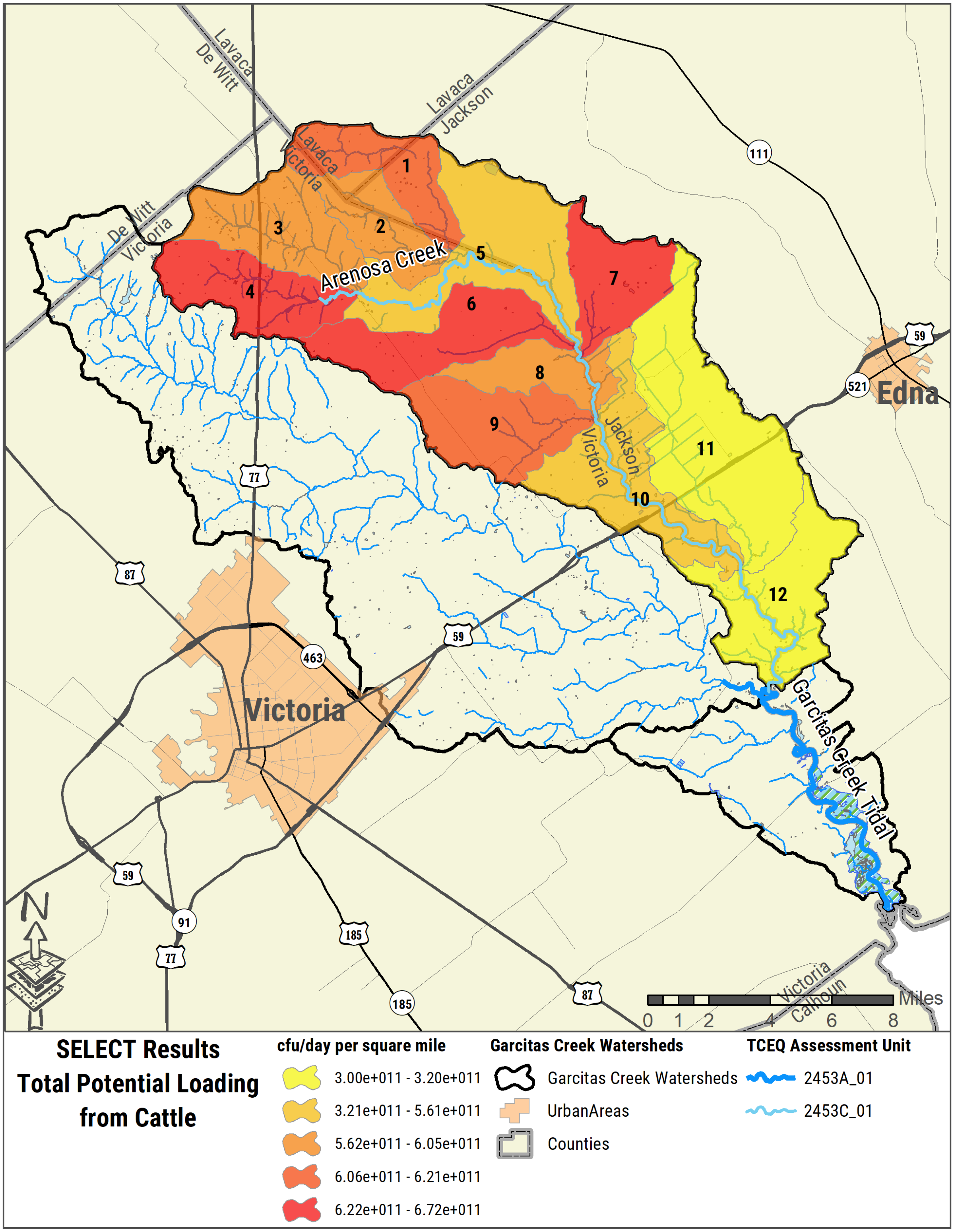

Figure 16. Cattle potential loading intensity. Numbers indicate subwatersheds 1-12.

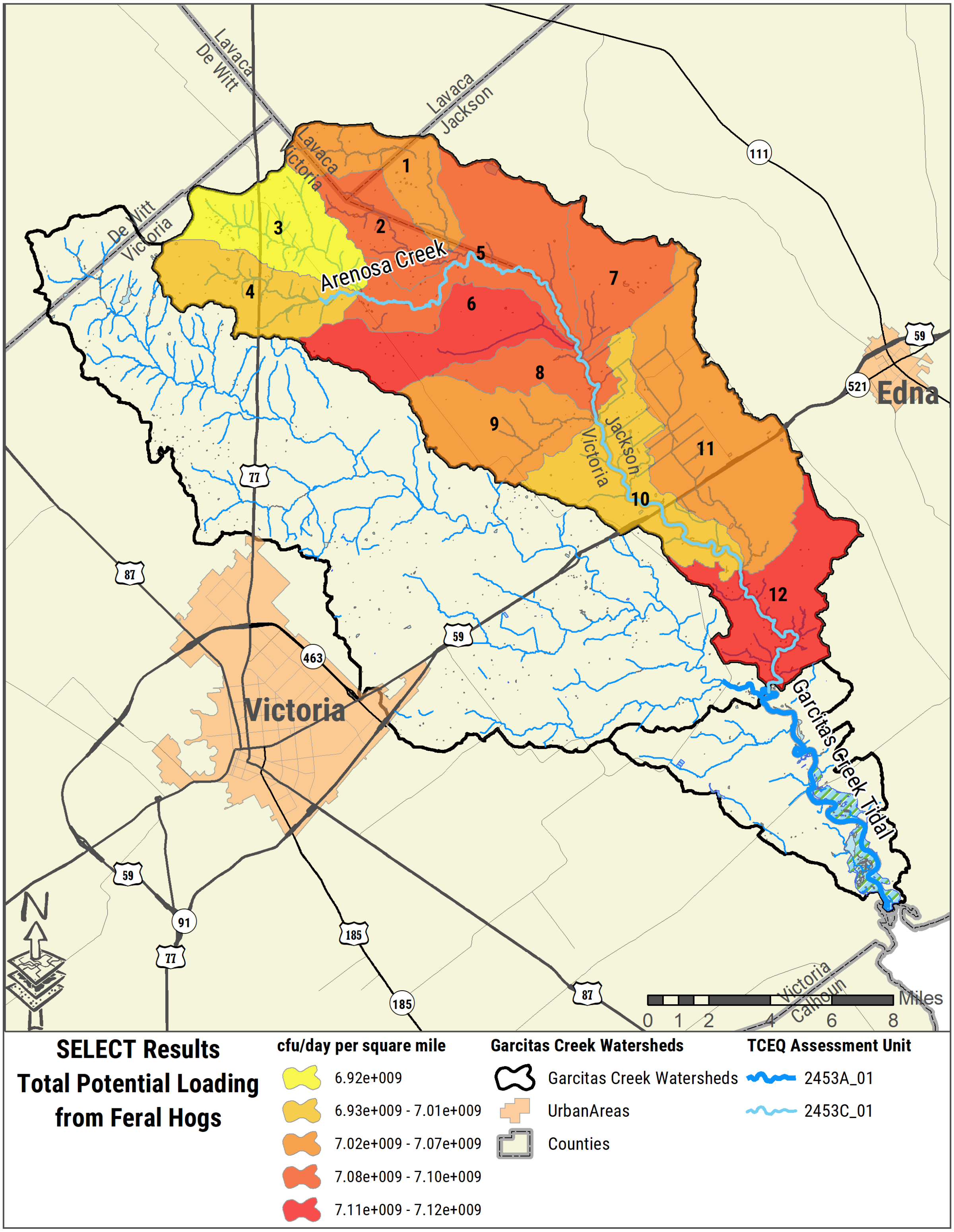

Figure 17. Feral hog potential loading intensity. Numbers indicate subwatersheds 1-12.

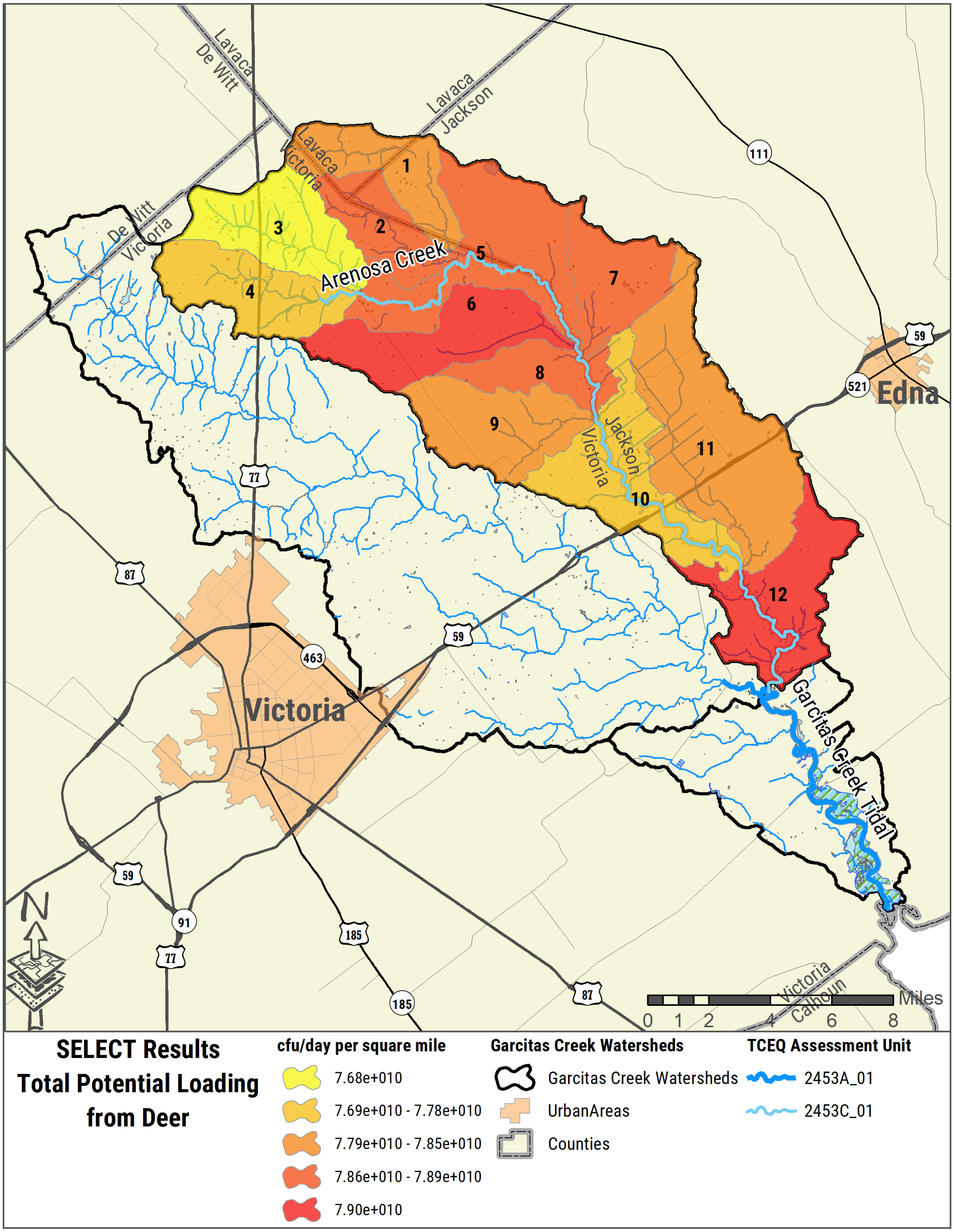

Figure 18. Deer potential loading intensity. Numbers indicate subwatersheds 1-12.

Chapter 5 Implementation Strategies

Stakeholders identified and recommended management measures to achieve *E. coli* bacteria and nutrient reductions. These management measures are based on the current understanding and knowledge of management effectiveness, feasibility, and local acceptance. We anticipate that managing sources of fecal bacteria will result in direct reductions of bacteria loads reaching local waterbodies. We also anticipate that managing nutrient sources will contribute to potential increases in DO. However, we note that the linkage between decreased nutrient loadings and increased DO is more tenuous. Many other factors influence DO concentration (for example, temperature, salinity, and flow). Much more data and resources are required to understand the DO dynamics specific to this tidal system. However, it is likely that the management measures outlined in this chapter include benefits to both bacteria and DO in most cases.

A variety of sources contribute bacteria and nutrients to the watershed. Therefore, an approach that addresses the diversity of sources is recommended to addresses pollutant loads. The approach outlined in the watershed protection plan focuses on the contributions that are most feasibly managed, have a chance to be locally accepted, and are most likely to reduce instream pollutant loads. Because stakeholders are ultimately responsible for the deployment of these voluntary management measures, stakeholder recommendations were critical and indicate a greater degree of feasibility and willingness to implement.

Priority areas for each management measure were identified using the SELECT results (Chapter 4). By focusing efforts in priority areas, the effectiveness, and efficiency of deployed resources will be maximized. Load reductions resulting from each management measure were calculated where possible to guide stakeholders in the understanding of the number of management measures and length of time it may take to see quantifiable improvements in water quality.

5.1 Management Measure 1 – Reduce the number of failing septic systems and straight pipe discharges

Analysis indicted that OSSFs are likely a contributor to potential bacterial loadings across the watershed. Nearly all the soils in the watershed are classified as “very limited” for OSSF suitability. This indicates that conventional septic tank systems are not suitable for proper treatment of household wastewater. In these areas, advanced treatment systems, most commonly aerobic treatment units, are suitable alternative options for wastewater treatment. While advanced treatment systems are highly effective, the operation and maintenance needs for these systems are rigorous compared to conventional septic systems. Limited awareness and lack of maintenance can lead to system failures.

Failing or non-existent OSSFs were a concern raised by stakeholders. The exact number of failing systems is unknown, but studies estimate that approximately 12 percent of systems are expected to be in failing condition (Reed, Stowe & Yanke 2001). Improper system design or selection, improper maintenance, and lack of education are likely reasons contributing to OSSF failure. In some cases, systems can be treated and repaired while in other cases, systems need to be redesigned and replaced; however, homeowners must have the awareness and resources to address OSSF problems when they arise.

Specifically, the goals of Management Measure 1 are to develop resources and programs to repair and replace 15 failing OSSFs in priority areas of the watershed over the next ten years. In addition, Management Measure 1 promotes the proper operation and maintenance of OSSFs by delivering OSSF operation and maintenance workshops to watershed residents. The estimated annual bacteria reduction from OSSF repair and replacement is 28,114.15 billion MPN/year *E. coli* (see OSSFs in Appendix F – Bacteria Load Reduction Calculations). The estimated nutrients reductions for OSSF repair and replacement are 66 pounds per year of phosphorus and 262 pounds per year of nitrogen (see OSSFs in Appendix G – Nutrient Load Reduction Calculations).

Table 15. Management Measure 1 – Reduce the number of failing septic systems and straight pipe discharges

Source: Failing OSSFs			
Problem: Pollutant loading from failing or nonexistent OSSFs			
Objectives: Secure funding to promote OSSF repairs/replacements Repair or replace 15 OSSFs as funding allows Deliver biennial OSSF operation and maintenance workshops			
Implementation Strategy			
Responsible Parties	Recommendations	Period	Capital Costs
County staff, designated representatives, AgriLife Extension, Watershed Coordinator	Develop and administer OSSF repair/replacement program to address deficient systems identified during inspections.	2022-2025	$115,000 in personnel + travel costs
Homeowners and contractors	Repair/replace OSSFs as funding allows.	2023-2025	$10,000 per system
AgriLife Extension, Watershed Coordinator	Provide an OSSF operation and maintenance workshop every other year	2021-2025	$1,000 per workshop
Priority Areas: Subwatersheds 3 and 10, any homes near riparian areas			
Estimated Load Reduction:			
28,114.15 billion MPN/year *E. coli* 262 pounds of nitrogen per year 66 pounds of phosphorus per year			
Effectiveness:	High: Replacement or repair of failing OSSFs will yield direct bacteria and nutrient load reductions to the waterways and near waterway areas of the watershed.		
Certainty:	Low: Funding available to identify, inspect and repair or replace OSSFs is limited; thus, the actual level of implementation attainable is uncertain.		
Commitment:	Moderate: Watershed stakeholders acknowledge failing OSSFs as a potential source of pollutant loading. However, lack of resources to address the issue prevents high levels of commitment.		
Resource Needs:	High: Funding to identify, inspect and repair/replace OSSFs limited. Costs to administer a program, identify, inspect and repair or replace OSSFs are considerable. Many homeowners with failing may not realize that their OSSF is failing, so delivering educational resources to them is critical. Some homeowners may know they need a new OSSF but may not have the funds available to acquire one.		
Potential Funding Sources:	CWA §319(h) grant program; Texas Supplemental Environmental Projects (SEP); local funds, property owners‡		

†Load reduction calculations described in Appendix F – Bacteria Load Reduction Calculations and Appendix G – Nutrient Load Reduction Calculations

‡Funding sources described in Chapter 7

5.2 Management Measure 2 – Promote feral hog management

While the complete eradication of feral hogs from the watershed is not feasible, a variety of methods are available to manage or reduce populations. Trapping animals is likely the most effective method available to landowners for removing large numbers of feral hogs. Shooting feral hogs removes comparatively fewer individuals before they begin to move to other parts of the watershed. Trapping requires some amount of effort and proper planning to maximize effectiveness, but it also gives landowners a means to recoup costs associated with trapping efforts through the sale of live hogs. Specifically, the State of Texas allows transport of live feral hogs to approved holding facilities for sale. The purchase price will vary by facility and comparative market prices. Furthermore, costs of purchasing or building live traps can also be split amongst landowners.

Additionally, given the opportunistic feeding nature of feral hogs, minimizing available food from deer feeders is important. Feeders can help support the survival of local feral hog populations while also lowering trapping success by reducing the likelihood of feral hogs entering traps. Feeders located in or near riparian zones may also help maintain populations in areas that maximize their potential impact on water quality. Therefore, constructing exclusion fences around feeders and locating feeders away from riparian areas are other important strategies for minimizing feral hog impacts on water quality.

The goals of Management Measure 2 are to (1) promote effective feral hog management by delivering feral hog management workshops, (2) seek the feasibility of funding a full or part-time trapper position and trapping equipment, (3) and seek the feasibility of a feral hog bounty program.

Load reductions resulting from feral hog management are highly uncertain. According to AgriLife Extension (2012), approximately 60 percent of the population must be culled just to maintain current population levels. Furthermore, populations are highly mobile and will travel in and out of the watershed making estimating changes in local populations nearly impossible. Therefore, load calculations resulting from feral hog management are not calculated in the plan. The plan estimates that a single feral hog has a loading potential of approximately 34.8 billion MPN *E. coli* per year (see Feral Hogs in Appendix F – Bacteria Load Reduction Calculations) and 2.3 pounds of phosphorus per year and 6.4 pounds of nitrogen per year. Therefore, any efforts to maintain or reduce local feral hog populations will either reduce future increases in bacteria loadings or decrease existing loads by the loading potential indicated above.

Table 16. Management Measure 2 – Promote feral hog management

Source: Feral Hogs			
Problem: Direct and indirect fecal loading, riparian habitat destruction, forest and pasture damage from feral hogs.			
Objectives: Promote effective feral hog management through workshops Fund full or part-time trapper position Fund feral hog bounty program			
Implementation Strategy			
Responsible Parties	Recommendations	Period	Capital Costs
AgriLife Extension, Watershed Coordinator	Provide feral hog workshops	2021-2030	$2,500 ea.
County government, Watershed Coordinator	Fund feral hog-trapper and equipment	2021-2030	$95,000/year
County government, Watershed Coordinator	Fund feral hog bounty program	2021-2030	NA
Priority Areas: Subwatersheds 6 and 12.			
Estimated Load Reduction:			
34.8 billion MPN *E. coli* per year per feral hog removed† 6.4 pounds of nitrogen per year per feral hog removed† 2.3 pounds of phosphorous per year per feral hog removed†			
Effectiveness:	Moderate: Reduction in feral hog population will result in a direct decrease in bacteria and nutrient loading in streams; however, removing enough hogs to decrease their population is difficult.		
Certainty:	Low: Feral hogs are transient, intelligent, and adapt to changes in environmental conditions. Population reductions require diligence on the part of landowners to reduce food availability and maintain trapping pressure.		
Commitment:	Moderate: Many landowners already engage in feral hog control to reduce damage to pastures and crops.		
Resource Needs:	Moderate: Landowners benefit from technical and educational resources to inform them about feral hog management options. Funds are needed to deliver these workshops.		
Potential Funding Sources:	CWA §319(h) grant program, local funds‡		

†Load reduction calculations described in Appendix F – Bacteria Load Reduction Calculations and Appendix G – Nutrient Load Reduction Calculations

‡Funding sources described in Chapter 7

5.3 Management Measure 3 – Promote and implement grazing and agricultural best management practices

Grazed pastures and rangeland can contribute to bacteria loadings across the watershed. While the fate and transport of fecal bacteria deposited on upland surfaces is not always certain, livestock may spend substantial time in and around waterbodies resulting in direct impacts on water quality. Importantly, livestock grazing behavior can be modified through food, shelter, fencing, and water availability. Modifying the time spent by livestock in riparian pastures through rotational grazing, alternative water supplies, shade structures, and supplemental feeding can directly reduce potential bacteria loads reaching nearby waterbodies. Additionally, these practices can improve cattle health and productivity.

NRCS and the Texas State Soil and Water Conservation Board (TSSWCB) provide technical and financial assistance to producers for planning and implementing best management practices (BMPs) that protect and improve water quality. NRCS offers a variety of programs to implement operation specific conservation plans that will meet producer goals and outline how BMPs will be implemented. TSSWCB, through local Soil and Water Conservation Districts (SWCDs), provides technical and financial assistance to develop and implement Water Quality Management Plans (WQMPs) through planning, implementation, and maintenance of each practice.

Promoting and implementing WQMPs and conservation plans is anticipated to provide direct benefits to water quality and can provide benefits to producers. A variety of BMPs are available to achieve goals of improving forage quality, distributing livestock across a property, and making water available to livestock. Table 17 provides a list of common practices available to producers. However, the list of practices available to producers is not limited to those in the table. The actual practices will vary by operation and should be determined through assistance from NRCS, TSSWCB, and local SWCDs as appropriate. In addition to reducing bacteria loads reaching waterways, these practices can reduce erosion, sediment loads, and nutrient loads that may contribute to DO exceedances.

The goals of Management Measure 3 are to (1) implement 30 Conservation Plans or Water Quality Management Plans; (2) fund and hire staff to assist with the development and processing of Conservation Plans and WQMPs; (3) promote adoption of best practices and participation in NRCS and TSSWCB programs through field days and workshops; and (4) promote nutrient management practices through education/outreach and soil testing campaigns. The plan estimates that this management measure will annually reduce *E. coli* loads by 277,098 Billion MPN, nitrogen by 9,073 pounds and phosphorus by 4,780 pounds (see Livestock in Appendix F – Bacteria Load Reduction Calculations and Livestock in Appendix G – Nutrient Load Reduction Calculations).

Table 17. NRCS Conservation Practices available for producers to improve water quality

Practice	NRCS Code	Focus Area or Benefit
Brush Management	314	Livestock, water quality, water quantity, wildlife
Fencing	382	Livestock, water quality
Filter strips	393	Livestock, water quality, wildlife
Grade stabilization structures	410	Water quality
Grazing land mechanical treatment	548	Livestock, water quality, wildlife
Heavy use area protection	562	Livestock, water quantity, water quality
Pond	378	Livestock, water quantity, water quality, wildlife
Prescribed burning	338	Livestock, water quality, wildlife
Prescribed grazing	528	Livestock, water quality, wildlife
Range/Pasture planting	550/512	Livestock, water quality, wildlife
Shade structure	NA	Livestock, water quality, wildlife
Stream crossing	578	Livestock, water quality
Supplemental feed location	NA	Livestock, water quality

Water well	642	Livestock, water quantity, wildlife
Watering facility	614	Livestock, water quantity

Table 18. Management Measure 3 - Promote and implement grazing and agricultural best management practices

<table>
<tr><th colspan="4">Source: Livestock and agricultural runoff</th></tr>
<tr><td colspan="4">Problem: Fecal bacteria and nutrient loading from livestock (direct and indirect loading) and agricultural runoff.</td></tr>
<tr><td colspan="4">Objectives:
Develop and implement property specific Conservation Plans or WQMPs
Provide technical and financial support to producers to develop and implement plans.
Develop and provide education and outreach materials and programs to landowners and producers.
Promote nutrient management and soil testing.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><td>Responsible Parties</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>Landowners, TSSWCB, NRCS, SWCD</td><td>Develop and implement 30 conservation plans or WQMPs.</td><td>2021-2030</td><td>$15,000 per plan</td></tr>
<tr><td>TSSWCB, NRCS, SWCD</td><td>Fund and hire field technician to develop conservation plans or WQMPs.</td><td>2021-2030</td><td>$75,000 per year</td></tr>
<tr><td>Watershed coordinator, AgriLife Extension, TSSWCB, NRCS, SWCD</td><td>Provide outreach and extension materials, workshops, and field days to promote conservation practices</td><td>2021-2030</td><td>NA</td></tr>
<tr><td>Landowners, producers, lessees, AgriLife Extension, NRCS, TSSWCB, SWCD, Watershed Coordinator</td><td>Develop and implement soil testing and nutrient management</td><td>2021-2030</td><td>$12 per sample + shipping (each sample covers 20 acres)</td></tr>
<tr><td colspan="4">Priority Areas: Subwatersheds 4, 6 and 7; and all riparian properties</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">277,098 Billion MPN/year <i>E.coli</i>[†]
9,073 pounds of nitrogen per year[†]
4,781 pounds of phosphorous per year[†]</td></tr>
<tr><td>Effectiveness:</td><td colspan="3">Medium/High – Conservation practices result in substantial reductions in edge-of-field bacteria and nutrient reductions. These edge-of-field reductions can, but do not always, translate to watershed-wide load reductions.</td></tr>
<tr><td>Certainty:</td><td colspan="3">Medium – Stakeholders acknowledge the importance of land stewardship practices. However, producers can be reluctant to implement new practices for many reasons (examples: costs, reluctance to enter into contracts with agencies, hesitancy about trying new practices).</td></tr>
<tr><td>Commitment:</td><td colspan="3">Medium – Landowners are willing to implement stewardship practices shown to improve productivity; however, because costs are often prohibitive, financial incentives are needed to increase implementation rates.</td></tr>
<tr><td>Resource Needs:</td><td colspan="3">High – Implementation will not occur without financial assistance programs. Educating landowners about conservation practices, available programs, and the benefits of conservation practices is required to increase adoption of needed practices.</td></tr>
<tr><td>Potential Funding Sources:</td><td colspan="3">EPA CWA §319 grant program; NRCS Environmental Quality Incentives Program (EQIP); Conservation Innovation Grants (CIG); Conservation Stewardship Program (CSP); Regional Conservation Partnership Program (RCPP)[‡]</td></tr>
</table>

[†] Load reduction calculations described in Appendix F – Bacteria Load Reduction Calculations and Appendix G – Nutrient Load Reduction Calculations

[‡] Funding sources described in Chapter 7

5.4 Management Measure 4 – Decrease stormwater impacts from encroaching development

The Arenosa and Garcitas watersheds are largely rural and characterized by pastures and rangeland. However, more subdivsions and development is occurring along the highway corridor between the cities of Victoria and Edna. As this area changes, the contributors to stormwater runoff, bacteria loads, and nutrient loads will changes as well. Runoff from impervious surfaces, nutrient loading from fertilized lawns, and bacteria loadings from household pets become an increasing concern. Educating residents about proper and effective management of residential lawns and gardens, irrigation, and pet waste management become increasing important.

For landowners that would like to protect existing rural and agricultural land uses, a number of conservation easement options are available. By working with a land trust organization or NRCS, landowners can create a property easement that restricts the type of uses that are allowed on a property. The benefits of conservation easements include conserving agricultural production, protecting water resources, and providing wildlife habitat (Lund, et al. 2019). Because every landowner has specific goals for their own property, there is not a one size fits all program for conservation easements. However, bringing in land trust organizations to discuss options at education and workshop events will provide local land owners the knowledge and option to participate if desired.

The goals of Management Measure 4 are to (1) deliver education and outreach programing the educate residents on urban/suburban management practices and (2) bring land trust organizations and other entities to discuss conservation easement options with local landowners.

Table 19. Management Measure 4 – Decrease stormwater impacts from encroaching development.

Source: Suburban runoff			
Problem: Prevent bacteria and nutrient loadings resulting from rural land conversion.			
Objectives: Provide biennial workshops on suburban lawn/turf/irrigation management Promote conservation easements through workshops and event speakers			
Implementation Strategy			
Responsible Parties	Recommendations	Period	Capital Costs
Watershed Coordinator, AgriLife Extension	Healthy Lawns and Healthy Waters Workshop	2022, 2024	NA
Watershed Coordinator	Provide conservation easement workshops or arrange speakers from land trusts to speak at events	2021-2030	NA
Priority Areas: Entire watershed			
Estimated Load Reduction			
No load reductions estimated for this management measure.			
Effectiveness:	Low/Medium – Developed areas are a relatively small portion of the watershed so overall impact is anticipated to be low. However, this can be an important to address future contributor to impairment.		
Certainty:	Low – Participation and action after education events is inherently uncertain.		
Commitment:	Medium/High – Stakeholders have clearly stated a high need for education and outreach related to water quality in the region.		
Resource Needs:	Low – The Healthy Lawns Healthy Waters workshop is currently funded through grants. It is relatively inexpensive to bring in speakers for workshops.		
Potential Funding Sources:	NRCS ACEP, CWA §319(h) grant program, local funds‡		

‡Funding sources described in Chapter 7

5.5 Management Measure 5 – Improved water quality monitoring

Arenosa Creek was dropped from routine water quality monitoring, resulting in a limited dataset for local stakeholders to make decisions from. Furthermore, local stakeholders have stated concerns regarding the potential impacts of the permitted land application facility in the Arenosa Creek watershed on the creek's water quality. In order to provide data for local stakeholder to make informed decisions from, additional water quality monitoring data is required. The goals for Management Measure 5 are to (1) engage TCEQ, the Guadalupe Blanco River Authority (GBRA), and the Lavaca-Navidad River Authority (LNRA) to reinstitute routine water quality monitoring on Arenosa Creek; (2) initiate a water quality monitoring project with LNRA and USGS related to potential land application facility impacts on Arenosa Creek water quality; and (3) provide volunteer water quality monitoring opportunities.

Table 20. Management Measure 5 – Improved water quality monitoring.

Source: General Water Quality			
Problem: Limited water quality data available for decision-making.			
Objectives: Reinstitute routine monitoring on Arenosa Creek Initiate special monitoring project to assess potential impacts on Arenosa Creek from permitted facilities Provide volunteer water quality monitoring opportunities			
Implementation Strategy			
Responsible Parties	Recommendations	Period	Capital Costs
Watershed Coordinator, TCEQ Clean Rivers Program, LNRA, GBRA	Routine monitoring on Arenosa Creek	2022-2030	$22,500 per station/year
LNRA, USGS	Monitoring project on Arenosa Creek	Underway	$5,258 per station/visit
Watershed Coordinator, LNRA, Meadows Center	Volunteer monitoring	2021-2030	NA
Priority Areas: Arenosa Creek			
Estimated Load Reduction			
No load reduction estimated for this management measure.			
Effectiveness:	None – Monitoring will be used to guide future decisions.		
Certainty:	None - Monitoring will be used to guide future decisions.		
Commitment:	Moderate – Local partners are working to secure resources for monitoring. It is uncertain if the Clean Rivers Program partner will continue monitoring on Arenosa Creek.		
Resource Needs:	Moderate – Monitoring is resource intense. However, capital and technical resources are available to pursue further monitoring.		
Potential Funding Sources:	CWA §319(h) grant program, local funds‡		

‡Funding sources described in Chapter 7

5.6 Estimated Load Reductions

Implementation of the management measures outlined above will provide direct and indirect reductions in bacteria and nutrient loads. Some management measures, such as implementing conservation plans and WQMPs on farms, will result in direct load reductions by reducing pollutant loads reaching waterbodies. Other management measures, such as providing suburban management practice workshops, will result in reductions that are not easily quantified because they depend on human behavior. We utilized the best available information to estimate likely reductions in bacteria and nutrient loads if the management measures are fully implemented. Appendix F – Bacteria Load Reduction Calculations and Appendix G – Nutrient Load Reduction Calculations provide the calculations used to estimate load reductions outlined in Table 21.

Table 21. Estimated total annual load reductions from management measures implemented after ten years

Management Measure	***E. coli* (billion MPN/year)**	**Nitrogen (pounds/year)**	**Phosphorus (pounds/year)**
OSSF Repair and Replacement	28,114.15	262	66
Conservation Plans and WQMPs	277,098.26	9,073	4,781
Feral Hogs[a]	34.8[a]	2.3[a]	6.4[a]
Total Estimated Load Reduction	305,212.41	9,335	4,847
Required Reduction	289,488.91	Not required	Not required

[a] Feral hogs reductions included as "per hog removed." Feral hog removal was not included in the total load reduction calculation.

Chapter 6 – Plan Implementation

Effective implementation will take concerted efforts by many stakeholders. However, they will need additional support in many cases. Coordinating actual implementation efforts, working to secure funding, tracking progress, and water quality monitoring are all activities that are beyond the responsibility of a single stakeholder. This chapter outlines additional activities that are required to support implementation and outlines an implementation schedule.

6.1 Watershed Coordinator

Implementing the WPP will require significant time and effort. Therefore, we recommend a dedicated, funded watershed coordinator to support plan implementation. This position will be responsible for working with stakeholders to identify funding opportunities, develop and file funding applications, administer projects, keep stakeholders engaged, coordinate and organize educational programming, track implementation progress, and document changes in water quality condition. With the proximity of the Tres Palacios, Caranchua Bay, and Lavaca River watersheds and overlapping stakeholder groups common to these watersheds, it might be cost effective to share watershed coordinator resources with those watersheds. A full-time watershed coordinator is estimated at $95,000 per year with salary, benefits, travel, and supplies required for the position. Without municipalities, local NGO’s, and other potential organizations that could fund this position, grant funding will be critical.

6.2 Water Quality Monitoring

As mentioned in Management Measure 5, Arenosa Creek was dropped from routine water quality monitoring. Tracking progress toward water quality goals will require reinstating a routine water quality monitoring program on Arenosa Creek. The watershed coordinator will work with the TCEQ Clean Rivers Program partner, the GBRA, and LNRA to discuss how to reinstitute monitoring on the creek and suitable locations for monitoring in the future. Similarly, current routine monitoring data has not recently occurred on Garcitas Creek. The watershed coordinator will work will the TCEQ regional Field Office to discuss monitoring options once TCEQ provides further guidance regarding the DO standards in Garcitas Creek. Because of the limited existing data, routine monitoring of field and conventional parameters should occur to substantiate current listings before 24-hour sampling is conducted. Based on available data and known data gaps, quarterly monitoring for bacteria, field, and conventional parameters at both segment in the watershed will be used to track changes in water quality. Water quality monitoring will be conducted under Quality Assurance Project Plans approved by TCEQ and EPA to ensure the quality of data used in assessments and data reviews.

Stakeholders have expressed concerns that the current water quality monitoring station on Arenosa Creek is typically stagnant and water pools up behind the low water crossing, creating conditions that allow for accumulation of sediment and possibly bacteria. Therefore, the watershed coordinator will work with the local river authorities to assess if more suitable sites are available downstream that would better characterize the water quality in Arenosa Creek. Existing monitoring sites on Garcitas Creek require a boat or land owner permission. Establishing a station on Garcitas Creek at FM616 would make it easier to establish a long-term dataset to evaluate changes in water quality in Garcitas Creek.

6.3 Education and Outreach

Successful progress toward water quality goals requires stakeholders that are knowledgeable about water quality conditions, impacts, and how to improve it. Increased education and outreach efforts are required to positively change behavior and start water quality improvements. Targeted audiences include watershed residents and visitors, landowners, agricultural producers, county officials, SWCDs, OSSF authorized agents, and non-profit groups.

In addition to the education workshops outlined in the Chapter 5, other existing programs will be targeted to watershed stakeholders. These include but are not limited to:

- Texas Watershed Stewards
- Texas Riparian and Stream Ecosystem Education
- Texas Well Owner Network
- Lone Star Healthy Streams

In addition to traditional workshops, interested stakeholders can participate in volunteer water quality monitoring opportunities through the Texas Stream Team. Although the data is not used for regulatory purposes, long-term routine data from citizen scientists can be used to inform other stakeholders of ongoing water quality trends or acute water quality problems that occur in between routine sampling events. Furthermore, landowners can participate and provide context to water quality conditions that otherwise wouldn't be available because of limited river access. To initiate volunteer water quality monitoring, a Texas Stream Team training will be held, and resources secured to offer monitoring kits to interested groups.

Electronic and physical newsletters provide a periodic overview of the state of the watershed. Newsletters will be used to communicate water quality, available assistance programs, and promote best management practices.

Websites provide a centralized source of information and resources for watershed stakeholders. The Garcitas and Arenosa Creek Watershed website is updated and maintained by TWRI. The website contains information about the watershed, upcoming meetings, and previous meeting presentations. The website will continue to be maintained and improved to best serve project needs.

6.4 Implementation Schedule

Implementing the WPP will occur over a 10-year period. Additional time and management actions may be required and will be addressed through adaptive management. A complete schedule of management activities, activities, and estimated costs are included in Table 22.

6.5 Operation and Maintenance

Practices installed under WQMP or conservation plan agreements funded by TSSWCB or NRCS are required to be maintained by the operator. During the planning, installation, and reimbursement process, field staff will work with operators to ensure that practices are properly designed, installed, and maintained.

Homeowners with new OSSFs will require a permit from their respective county office, in addition to proof of annual service agreements. This ensures systems are adequately designed and maintained.

Table 22. Implementation schedule.

Management Measures and Activities	Responsible Party	Number implemented in year: 2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Unit Cost	Total Cost
WQMP, Conservation Plans	TSSWCB, SWCD, NRCS, Producers, Landowners	3	3	3	3	3	3	3	3	3	3	$15,000[a]	$450,000
WQMP Technician	TSSWCB, SWCD			1	1	1	1	1	1	1	1	$75,000	$600,000
Soil Tests	Landowners, Lessees, AgriLife Extension, TSSWCB, SWCD, Others	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	$15[c]	NA
Develop and deliver conservation practice education materials, outreach, workshops, and field days	AgriLife Extension, TSSWCB, SWCD, Others	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	NA	NA
OSSF Repair/Replacement Program	County staff, designated representatives, AgriLife Extension, Watershed Coordinator		1	1	1	1						-	$115,000[d]
OSSF Repair/Replacement	Homeowner			5	5	5						$10,000	$150,000
OSSF Education Workshop	AgriLife Extension			1				1			1	$3,000	$9,000
Feral Hog Workshop	AgriLife Extension	1		1		1		1		1		$2,500	$12,500
Feral Hog Trapper/Equipment	County government, Watershed Coordinator			1	1	1	1	1	1	1	1	$95,000	$760,000
Feral Hog Bounty Program	County Government, Watershed Coordinator			1	1	1	1	1	1	1	1	NA	NA
Healthy Lawns and Healthy Waters Workshop	AgriLife Extension		1		1							NA[e]	-

Management Measures and Activities	Responsible Party	Number implemented in year: 2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Unit Cost	Total Cost
Conservation Easement speakers and workshops	Watershed Coordination	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]		
Watershed Coordinator	AgriLife Extension, TWRI	1	1	1	1	1	1	1	1	1	1	$95,000	$950,000
Water Quality Monitoring	TCEQ, TWRI, Clean Rivers Program, LNRA, GBRA		1	1	1	1	1	1	1	1	1	$2,500[f]	$22,500 per station
Arenosa Monitoring Project	LNRA	1										NA	NA
Texas Watershed Stewards	AgriLife Extension		1				1					NA[e]	-
Texas Riparian and Stream Ecosystem Training	AgriLife Extension			1				1				NA[e]	-
Texas Well Owner Network	AgriLife Extension		1				1					NA[e]	-
Lone Star Healthy Streams	Extension			1				1				NA[e]	-
Volunteer monitoring, Texas Stream Team	Watershed Coordinator, LNRA, Meadows Center	1					1					NA[g]	-
Newsletter	Watershed Coordinator, TWRI	2	2	2	2	2	2	2	2	2	2	$500	$11,000
Website	Watershed Coordinator, TWRI	1	1	1	1	1	1	1	1	1	1	NA[h]	-

[a] Costs will vary by operation specific plan and cost share provided by agencies.

[b] As many as possible.

[c] Minimum cost is $12 for a basic soil test plus $2 shipping which covers about 20 acres.

[d] Based on salary costs from similar OSSF replacement projects.

[e] Costs covered by existing grant-funded projects.

[f] Cost per site monitored. Costs will vary based on the entity conducting the monitoring and the parameters sampled.

[g] Training costs are covered under existing grants, test kits and supplies start around $400 and the number purchased will depend on participation.

[h] Website is already provided through TWRI, costs may vary substantially if a different website is desired.

Chapter 7 - Implementation Resources

The watershed is largely rural with limited resources available for implementation of the management measures desired by stakeholders. This chapter identifies the potential sources of technical and financial assistance available to implement management measures. Grant funding will likely be a substantial source of implementation funding given the availability of resources identified so far.

7.1 Technical resources

Designing, planning, and implementing some of the management recommendations in the plan will require technical expertise. Numerous agencies and organizations are available to provide technical guidance in implementation

Table 23. Summary of technical assistance sources

Management Measure	Sources of Technical Assistance
Reduce the number of failing septic systems and straight pipe discharges	• AgriLife Extension, • Victoria County Public Health Department, • Jackson County Office of Permitting, • OSSF Service Providers
Promote feral hog management	• AgriLife Extension, • TPWD
Promote and implement grazing and agricultural best management practices	• AgriLife Extension, • Local SWCDs, • NRCS, • TSSWCB
Decrease stormwater impacts from encroaching development	• EPA, • TCEQ, • Victoria County Public Health Department, • Jackson County Office of Permitting, • Local engineering firms and consultants
Improved water quality monitoring	• GBRA, • LNRA, • USGS, • TCEQ, • TWRI, • Meadows Center

7.1.1 Management Measure 1 - Reduce the number of failing septic systems and straight pipe dischargers

The repair and replacement of OSSFs requires licensed personnel and permits through respective county offices. The Jackson County Office of Permitting and the Victoria County Public Health Department can assist with the permitting process within their respective jurisdictions. AgriLife Extension offers education, programs, and training associated with septic system maintenance, operations, and services. The design, construction, installation, and maintenance of new systems should be coordinated with local service providers.

7.1.2 Management Measure 2 – Promote feral hog management

Numerous resources are available to assist landowners and managers to control feral hog populations. AgriLife Extension offers technical materials and workshops on feral hog identification, impacts, and control methods. Similar resources are available through USDA Animal and Plant Health Inspection Services. TPWD offers general information about identification, trapping, hunting, and regulations regarding removal of feral hogs.

7.1.3 Management Measure 3 - Promote and implement grazing and agricultural best management practices

Developing and implementing practices to reduce runoff from agricultural lands will require substantial technical expertise. Technical assistance can be obtained by contacting local SWCDs, local NRCS offices, TSSWCB, and local AgriLife Extension offices. Producers requesting planning assistance will work with the local SWCD and local NRCS office to define operation-specific management goals and objectives and develop a management plan that prescribes effective practices that will achieve stated goals while also improving water quality.

Producers looking to incorporate soil testing should work with NRCS and SWCDs to discuss nutrient management and soil testing. Soil testing and nutrient management may fall within the scope of the conservation plan or WQMP developed with the producer. AgriLife Extension offers soil testing services through the Soil, Water and Forage Testing Laboratory at a minimal cost.

7.1.4 Management Measure 4 - Decrease stormwater impacts from encroaching development

EPA and TCEQ have materials and resources for MS4 and other municipalities that are required to manage and implement stormwater best practices. The Jackson County Office of Permitting and the Victoria County Public Health Department should be contacted by developers to ensure development codes are followed. Local engineers and consultants are also available for landowners and entities for design, construction, and other technical assistance associated with stormwater management.

7.1.5 Management Measure 5- Improved water quality monitoring

GBRA, LNRA, USGS, TCEQ, and TWRI oversee a number of water quality projects locally and statewide. These organizations have considerable in-house expertise to design and carry out monitoring programs. The Meadows Center is responsible for the Texas Stream Team volunteer water quality monitoring program and can provide training for volunteers as well as train the trainers programs to help start and maintain a local chapter of volunteer water quality monitors. LNRA has works with local volunteers and trainers to maintain volunteer monitoring programs in nearby watersheds.

7.2 Financial Assistance

Successful implementation of the WPP, as written, will require substantial fiscal resources. Diverse funding will be sought to meet these needs. Resources will be leveraged where possible to extend the impacts of acquired and contributed implementation funds. While this section outlines potential financial resource to assist with implementation, funding sources can change substantially year to year. Therefore, other sources of funding should be sought as appropriate.

Management Measure	Sources of Financial Assistance
Reduce the number of failing septic systems and straight pipe discharges	• Clean Water Act §319(h) Nonpoint Source Grant Program, • TCEQ Supplemental Environmental Projects (SEP), • Local funds
Promote feral hog management	• Clean Water Act §319(h) Nonpoint Source Grant Program (for education), • Local funds
Promote and implement grazing and agricultural best management practices	• Clean Water Act §319(h) Nonpoint Source Grant Program, • NRCS Conservation Innovation Grants (CIG), • NRCS Conservation Stewardship Program (CSP), • NRCS Environmental Quality Incentives Program (EQIP), • NRCS Regional Conservation Partnership Program (RCPP), • TSSWCB WQMP Program
Decrease stormwater impacts from encroaching development	• EPA Urban Waters Small Grants Program, • Clean Water Act §319(h) Nonpoint Source Grant Program, • NRCS Agricultural Conservation Easement Program (ACEP), • Local funds
Improved water quality monitoring	• Clean Water Act §319(h) Nonpoint Source Grant Program, • Local funds

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

The EPA gives grant funding to the State of Texas to implement projects that reduce NPS pollution through the §319(h) Nonpoint Source Grant Program. In Texas, these grants are administered by TCEQ and TSSWCB. Watershed protection plans that satisfy the nine key elements of successful watershed-based plans are eligible for funding through this program. To be eligible for funding, implementation measures must be included in the accepted watershed protection plan and meet other program rules.

7.2.2 EPA Urban Waters Small Grants Program

The objective of the Urban Waters Small Grants Program, 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.

7.2.3 NRCS Agricultural Conservation Easement Program (ACEP)

NRCS provides financial assistance to eligible partners for purchasing Agricultural Land Easements that protect the agricultural use and conservation values of eligible land. In the case of working farms, the program helps farmers and ranchers keep their land in agriculture. The program also protects grazing uses and related conservation values by conserving grassland, including rangeland, pastureland and shrubland.

Eligible partners include American Indian tribes, state and local governments and non-governmental organizations that have farmland, rangeland or grassland protection programs.

Under the Agricultural Land Easement component, NRCS may contribute up to 50 percent of the fair market value of the agricultural land easement. Where NRCS determines that grasslands of special environmental significance will be protected, NRCS may contribute up to 75 percent of the fair market value of the agricultural land easement. NRCS also provides technical and financial assistance directly to private landowners and Indian tribes to restore, protect, and enhance wetlands through the purchase of a wetland reserve easement.

7.2.4 NRCS Conservation Innovation Grants (CIG)

The USDA NRCS 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.

7.2.5 NRCS Conservation Stewardship Program (CSP)

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. The program is available for private agricultural lands including cropland, grassland, prairie land, improved pasture, and rangeland. CSP encourages landowners and stewards to improve conservation activities on their land by installing and adopting additional conservation practices. Practices may include, but are not limited to, prescribed grazing, nutrient management planning, precision nutrient application, manure application, and integrated pest management.

7.2.6 NRCS Environmental Quality Incentives Program (EQIP)

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 offer financial assistance to help plan and implement conservation practices that address natural resource concerns in addition to opportunities to improve soil, water, plant, animal, air, and related resources on agricultural land and non-industrial private forestland. People engaged in livestock or agricultural production on eligible land are permitted to participate in EQIP. Practices selected address natural resource concerns and are subject to the NRCS technical standards adapted for local conditions. They also must be approved by the local SWCD. Local Work Groups are formed to give recommendations to the USDA NRCS that advise the agency on allocations of EQIP county-based funds and identify local resource concerns. Watershed stakeholders are strongly encouraged to participate in their local Work Group to promote the objectives of this WPP with the resource concerns and conservation priorities of EQIP.

7.2.7 NRCS Regional Conservation Partnership Program (RCPP)

The RCPP is a 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 producers install and maintain conservation activities in selected project areas. Partners leverage RCPP funding in project areas and report on the benefits achieved.

Currently, Ducks Unlimited and NRCS have partnered on an RCPP project to help rice producers in Calhoun, Jackson, and Matagorda counties implement conservation practices that improve irrigation management, control sediment and nutrient runoff, and provide waterfowl habitat on rice production lands. Interested producers can find more information at: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/.

7.2.8 TCEQ Supplemental Environmental Projects (SEP)

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.

7.2.9 TSSWCB WQMP Program

WQMPs are management plans developed and implemented to improve land and water quality. Technical assistance to develop plans that meet producer and state goals is offered by the TSSWCB and local SWCDs. Once the plan is developed, the TSSWCB may financially assist implementing a portion of prescribed BMPs.

7.2.10 Other Sources of Financial Assistance

Private foundations, non-profit organizations, land trusts, other grant sources and individuals can potentially assist with implementation funding of some aspects of the WPP. Funding eligibility requirements for each program should be reviewed before applying to ensure applicability. Some groups that may be able to provide funding include but are not limited to:

- Coastal Management Program (CMP): The CMP, administered by NOAA and the Texas General Land Office (TGLO), 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 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 Coastal Zone Management Act, the National Coastal Zone Management 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. The Coastal Zone Management Program provides pass-through funding to TGLO, which, in turn, uses the funding to finance coastal restoration, conservation, and protection projects under TGLO's CMP.

- Cynthia and George Mitchell Foundation: Provides grants for water and land conservation programs to support sustainable protection and conservation of Texas' land and water resources

- Dixon Water Foundation: Provides grants to non-profit organizations to assist in improving/maintaining watershed health through sustainable land management

- Meadows Foundation: Provides grants to non-profit organizations, agencies, and universities engaged in protecting water quality and promoting land conservation practices to maintain water quality and water availability on private lands

- National Fish and Wildlife Foundation (NFWF) Gulf Environmental Benefit Fund: The Gulf Environmental Benefit Fund was established as a result of the BP and Transocean court cases for the Deepwater Horizon oil spill. The plea agreements directed $2.544 billion to NFWF to fund natural resource project on the Gulf Coast. Over five years, the Gulf Environmental Benefit Fund will direct $203 million for project on the Texas Gulf Coast.

- Texas Agricultural Land Trust: Funding provided by the trust assists in establishing conservation easements for enrolled lands
- Texas Trustee Implementation Group (TIG) Natural Resource Damage Assessment - The TIG administers funding for restoration projects designed to compensate for injuries to natural resources caused by the Deepwater Horizon oil spill. Over 15 years, the TIG will allocate $175 million in funding from projected selected to be part of the TIG developed restoration plan.

Chapter 8 – Measuring Success

Measuring the impacts of management measures on water quality is a critical, but complicated process. Ongoing water quality monitoring at locations with existing data will help provide the data needed to evaluate progress towards water quality goals. The watershed coordinator is also responsible for working with stakeholders to track implementation progress, so we can link implementation with water quality goals.

While progress towards water quality improvements is the ultimate measure of success. Progress can be slow due to delays in implementation or lag effects between implementation and water quality response. Therefore, establishing milestones that evaluate progress in implementation success is also important. By periodically evaluating progress towards milestones along with progress towards improvements in water quality we can assess what is working and adapt the plan as needed to maximize effectiveness. This approach is called adaptive management and is a crucial component of all watershed protection plans.

8.1 Water Quality Goals and Targets

The goal of the WPP is to achieve water quality standards established by the state of Texas for Garcitas Creek and Arenosa Creek. To achieve this goal, the geometric mean *E. coli* bacteria concentrations in Arenosa Creek must decrease to a concentration of 126 MPN/100mL and 10 percent of minimum and average DO measurements in Garcitas Creek must exceed 3 mg/L and 4 mg/L respectively. While the overall goal will take at least ten years to achieve, we expect incremental progress as implementation takes place. Therefore, incremental water quality targets are established to evaluate progress every few years.

8.1.1 Indicator Bacteria Goals and Targets

Sufficient data has not been collected to assess Arenosa Creek for bacteria in recent versions of the Texas Integrated Report. Since 2000, a total of 44 samples have been collected in Arenosa Creek with a geometric mean of 233.6 MPN/100mL (Figure 11, Table 13). In order to meet the goal of a seven-year geometric mean concentration of 126 MPN/100mL by 2030, an interim target of is established to achieve a seven-year geometric mean concentration of 179.8 MPN/100mL by 2026.

8.1.2 Dissolved Oxygen Goals and Targets

The 2014 Texas Integrated Report includes Garcitas Creek as impaired due to depressed DO. This listing was caused by at least 10 percent of the 24-hour average DO samples falling below the current standard of 4 mg. Although recent data has not been collected, past data indicated that 29 percent of the 24-hr average DO samples failed to meet standards (Figure 13). The DO goal is to reduce DO exceedances to fewer than 10 percent of samples by 2030. The interim target is to reduce DO exceedances to fewer than 15 percent of samples by 2025.

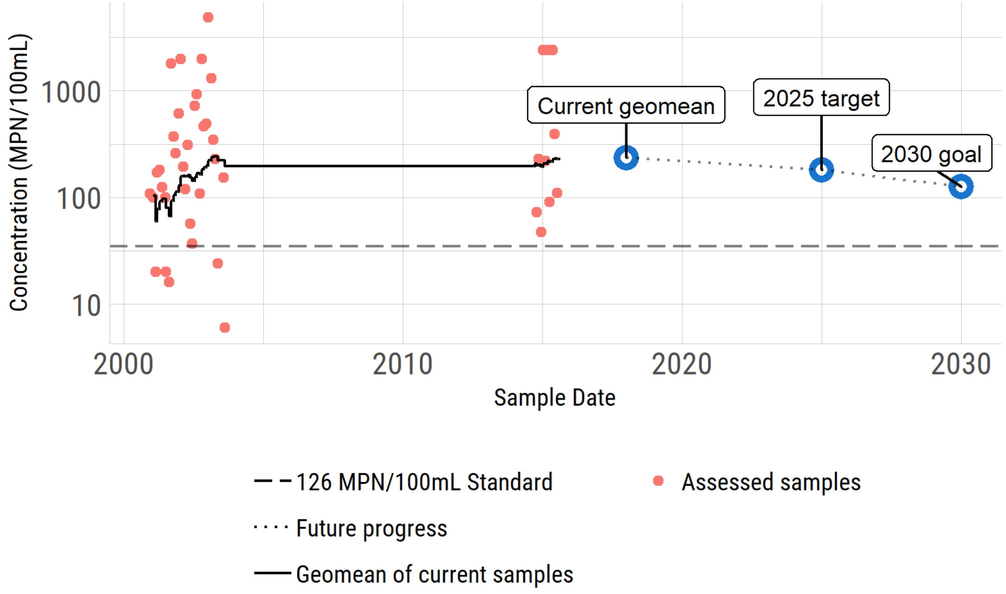

Figure 19. Indicator bacteria targets and goals

8.2 Data Review

Progress toward water quality targets and goals will be measured through three methods. First, TCEQ's Texas Integrated Report on Surface Water Quality is made available every two years and includes updates on current water quality impairments that are reported to EPA. The Integrated Report serves as the official regulatory document indicating the impairment status of a water body. However, the report is only made available every two years and includes a two-year data lag, so often the most recent data might be three or four years old by the time the report is made available.

The second method will be to independently calculate the seven-year geometric mean for *E. coli* and percent exceedances for DO based on water quality made available through the state's Surface Water Quality Monitoring Information System database. These assessments will serve to update stakeholders on an annual basis, but do not serve as official assessments for listing purposes.

Third, statistical trend analysis of water quality constituent concentrations and loads will be used. By reporting statistical trends in concentrations, stakeholders will be made aware of significant progress (or degradation) of instream water quality conditions. Trend analysis of constituent loads can also indicate progress towards instream conditions. Importantly, constituent load analysis can control for changes in flow, so stakeholders can be made aware of impacts of land management on the amount of NPS pollutant reaching waterbodies.

8.3 Project Milestones

The successful implementation of management measures over the next ten years will drive progress towards the accomplishing water quality goals outlined above. Interim milestones have been established for each management measure to evaluate progress. These milestones are established to evaluate if progress is being made slower or faster than anticipated. By breaking up management measures into smaller achievable milestones, we can focus on implementing achievable actions and visualize real progress from year to year. Project milestones are indicated below.

- Management Measure 1
  - Develop and administer an OSSF repair and replacement program by the end of 2022
  - Repair and replace 15 OSSFs by the end of 2025
- Management Measure 2
  - Provide three feral hog workshops by the end of 2025
  - Fund a feral hog trapper and equipment program by the end of 2025
  - Implement a feral hog bounty program by the end of 2025
- Management Measure 3
  - Develop and implement 15 total conservation plans or WQMPs by the end of 2025
  - Develop and implement 30 total conservation plans of WQMPs by the end of 2025
  - Hire a technician to assist local SWCDs and NRCS with planning efforts by the end of 2023
- Management Measure 4
  - Provide two Healthy Waters Healthy Lawns workshops by the end of 2025
- Management Measure 5
  - Resume quarterly routine water quality monitoring by the end of 2023
- General
  - Fund a watershed coordinator by the end of 2023
  - Provide four general water quality education workshops; initiate coordinated volunteer water quality monitoring by the end of 2025

8.4 Adaptive Management

The WPP is a living document, intended to be reviewed and revised as required. The ultimate measure of success will be the achievement of water quality goals. However, as new data and methods to improve water quality become available, there will be a need to revise the number or types of management measures required to improve water quality in the watershed.

Adaptive management is a structured, iterative process of decision making in the face of uncertainty. As we learn what works and does not work at improving water quality in the watershed, stakeholders will give guidance to improve the contents of the plan with a goal of achieving improved water quality outcomes.

Stakeholders will formally review progress at least every five years, as facilitated by the watershed coordinator. Progress will be reviewed using the following assessments:

1. Water Quality – Stakeholders will review water quality assessments of Arenosa Creek and Garcitas. Additional water quality analysis, as available will also be used. This might include trend analysis of pollutant concentrations and loads. An increase in pollutant concentrations or percent exceedances will be considered a negative outcome.
2. Implementation Progress – Stakeholders will review the overall progress of the WPP in meeting anticipated interim milestones. Substantial delays or lower than expected achievements in milestones will be considered a negative outcome.
3. External factors – Stakeholders will evaluate, as appropriate, available data concerning trends in population growth, land use, economic factors, and other available data to evaluate changes to the amount or numbers of potential pollutant sources outlined in the WPP. Significant increases in potential pollutant sources or hydrologic changes will be considered a negative outcome.

If negative outcomes are identified by two or more of the above assessments during the formal review, stakeholders will make changes based on adaptive management.

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Appendix A – EPA Nine Elements

The Clean Water Act section 319(h) grant funding program requires watershed protection plan development to follow the 'Elements of Successful Watershed Plans' in EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (2008) and contain sufficient information on these elements in order to be eligible for implementation funding.

A. Identification of Causes and Sources of Impairment

Identify the causes and sources that need to be controlled to achieve load reductions estimated in the watershed protection 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.

B. Expected Load Reductions

Estimate the load reduction expected for the management measures proposed as part of the watershed protection plan.

C. Proposed Management Measures

Describe the management measures that will need to be implemented to achieve the estimated load reductions (element b) and identify the critical areas where measures are needed to implement the plan.

D. Technical and Financial Assistance Needs

Estimate the technical and financial assistance needed, associated costs and/or the sources and authorities that will be relied upon to implement this plan.

E. Information, Education and Public Participation Component

Describe the information/education component to enhance public understanding and encourage early and continued participation in selecting, designing and implementing the appropriate NPS management measures.

F. Schedule

Provide a schedule for implementing the NPS management measures in the watershed protection plan that is reasonable expeditious.

G. Milestones

Provides a description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented.

H. Load Reduction Evaluation Criteria

Provide a criteria to determine if loading reductions are being achieved over time and progress is being made towards attaining water quality standards and, if not, criteria for determining whether the watershed protection plan needs to be revised.

I. Monitoring Component

A monitoring component to evaluate the implementation effectiveness over time. The monitoring component should include required project-specific needs, the evaluation criteria and local monitoring efforts.

Appendix B – EPA Nine Elements Review Checklist

Name of Water Body	Garcitas Creek Tidal and Arenosa Creek
Assessment Units	2453A_01 (Garcitas Creek Tidal); 2453C_01 (Arenosa Creek)
Impairments Addressed	Indicator Bacteria (2453C_01), Dissolved Oxygen (2453A_01)
Concerns Addressed	NA

Element	**Report Section(s) and Page Number(s)**
Element A: Identification of Causes and Sources	
1. Sources Identified, described, and mapped	3.2 Potential Point and Nonpoint Sources, page 17 4.2 Load Duration Curve (LDC) Analysis, page 27
2. Subwatershed sources	4.3 Spatially Explicit Load Enrichment Calculation Tool (SELECT), page 30
3. Data sources are accurate and verifiable	References, page 60
4. Data gaps identified	5.5 Management Measure 5 – Improved water quality monitoring, page 44 6.2 Water Quality Monitoring, page 46
Element B: Expected Load Reductions	
1. Load reductions achieve environmental goal	5.6 Estimated Load Reductions, page 45
2. Load reductions linked to sources	4.2 Load Duration Curve (LDC) Analysis, page 27
3. Model complexity is appropriate	4.2 Load Duration Curve (LDC) Analysis, page 27 Appendix C - Load Duration Curve, page 69
4. Basis of effectiveness estimates explained	Appendix E - SELECT Loading Calculations, page 78 Appendix F – Bacteria Load Reduction Calculations, page 80 Appendix G – Nutrient Load Reduction Calculations, page 82
5. Methods and data cited and verifiable	References, page 60 Appendix F – Bacteria Load Reduction Calculations, page 80 Appendix G – Nutrient Load Reduction Calculations, page 82
Element C: Management Measures Identified	
1. Specific management measures are identified	5.1 ,5.2 , 5.3 , 5.4 , 5.5 , pages 36-44
2. Priority areas	4.3 Spatially Explicit Load Enrichment Calculation Tool (SELECT), page 30
3. Measure selection rationale documented	Chapter 5, page 36
4. Technically sound	Chapter 5, page 36 Appendix E - SELECT Loading Calculations, page 78 Appendix F – Bacteria Load Reduction Calculations, page 80

Element	Report Section(s) and Page Number(s)
	Appendix G – Nutrient Load Reduction Calculations, page 82
Element D: Technical and Financial Assistance	
1. Estimate of technical assistance	7.1 Technical resources, page 50
2. Estimate of financial assistance	7.2 Financial Assistance, page 51
Element E: Education/Outreach	
1. Public education/information	6.3 Education and Outreach, page 46
2. All relevant stakeholders are identified in outreach process	6.3 Education and Outreach, page 46
3. Stakeholder outreach	6.3 Education and Outreach, page 46
4. Public participation in plan development	1.5 Public Participation, page 2
5. Emphasis on achieving water quality standards	8.1 Water Quality Goals and Targets, page 56
6. Operation and maintenance of BMPs	6.5 Operation and Maintenance, page 47
Element F: Implementation Schedule	
1. Includes completion dates	6.4 Implementation Schedule, page 47
2. Schedule is appropriate	6.4 Implementation Schedule, page 47
Element G: Milestones	
1. Milestones are measurable and attainable	8.3 Project Milestones, page 57
2. Milestones include completion dates	8.3 Project Milestones, page 57
3. Progress evaluation and course correction	8.4 Adaptive Management, page 58
4. Milestones linked to schedule	6.4 Implementation Schedule, page 47 8.3 Project Milestones, page 57
Element H: Load Reduction Criteria	
1. Criteria are measurable and quantifiable	8.1 Water Quality Goals and Targets, page 56
2. Criteria measure progress toward load reduction goal	8.1 Water Quality Goals and Targets, page 56
3. Data and models identified	8.2 Data Review, page 57
4. Target achievement dates for reduction	8.1 Water Quality Goals and Targets, page 56
5. Review of progress toward goals	8.2 Data Review, page 57
6. Criteria for revision	8.2 Data Review, page 57 8.4 Adaptive Management, page 58
7. Adaptive management	8.4 Adaptive Management, page 58
Element I: Monitoring	
1. Description of how monitoring used to evaluate implementation	6.2 Water Quality Monitoring, page 46 8.2 Data Review, page 57
2. Monitoring measures evaluation criteria	8.1 Water Quality Goals and Targets, page 56
3. Routine reporting of progress and methods	8.2 Data Review, page 57
4. Parameters are appropriate	6.2 Water Quality Monitoring, page 46
5. Number of sites is adequate	6.2 Water Quality Monitoring, page 46
6. Frequency of sampling is adequate	6.2 Water Quality Monitoring, page 46
7. Monitoring tied to QAPP	6.2 Water Quality Monitoring, page 46
8. Can link implementation to improved water quality	Chapter 8, page 56

Appendix C - Load Duration Curve

Jain et al. (2018) utilize the LDC method to estimate allowable and existing E. coli loads in Arenosa Creek to support development of the Arenosa Creek TMDL and this Watershed Protection Plan. This appendix summarizes Section 3 of the report.

Model Selection

The TMDL allocation process for bacteria involves assigning bacteria, e.g., *E. coli*, loads to their sources such that the total loads do not violate the pertinent numeric criterion protecting contact recreation use. To perform the allocation process, a tool must be developed to assist in allocating bacteria loads. Selection of the appropriate bacteria tool for the impaired AU in the TMDL watershed considered the availability of data and other information necessary for the supportable application of the selected tool and guidance in the Texas bacteria task force report (Texas Water Resources Institute, 2007).

The LDC method allows for estimation of existing and allowable loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, the LDC method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment. The LDC method has found relatively broad acceptance among the regulatory community, primarily due to the simplicity of the approach and ease of application. The regulatory community recognizes the frequent information limitations with the bacteria TMDLs that constrain the use of the more powerful mechanistic models. Further, the bacteria task force appointed by the TCEQ and TSSWCB supports the application of the LDC method within their three-tiered approach to TMDL development (Texas Water Resources Institute, 2007). The LDC method lacks the predictive capabilities to evaluate alternative allocation approaches to reach TMDL goals, nor can it be used to quantify specific source contributions and instream fate and transport processes. However, the method does provide a means to estimate the difference in bacteria loads and relevant criterion and can give indications of broad sources of the bacteria, i.e., point source and nonpoint source.

Data Resources

Streamflow and *E. coli* data availability were used to provide guidance in the allocation tool selection process. As already mentioned, the necessary information and data are largely unavailable for the study area to allow the adequate definition of many of the physical and biological processes influencing instream bacteria concentrations for mechanistic model application, and these limitations became an important consideration in the allocation tool selection process.

Hydrologic data in the form of daily streamflow records were unavailable in the TMDL watershed. However, streamflow records are available in an adjacent watershed (Garcitas Creek) with similar characteristics. Garcitas Creek daily streamflow records are collected and made available by the USGS, which operates one streamflow gage in the watershed (Table 24, Figure 20). USGS streamflow gage 08164600 was used to develop mean daily streamflow for AU 2453C_01.

Historical ambient *E. coli* data used for the development of LDCs was obtained through a data request to the TCEQ Data Management and Analysis Team (Texas Commission on Environmental Quality, 2017) (Table 25).

Table 24. Basic information on the USGS streamflow gage used for streamflow development in Arenosa Creek

Gage No.	Site Description	AU Location	Drainage Area (square miles)	Daily Streamflow Record
08164600	Garcitas Creek near Inez, Texas	2453C_01	91.7	01-01-2000 – 10-09-2017

Table 25. Summary of historical bacteria dataset for station 13295

Water Body	AU	Station	Station Location	No. of Samples	Data Date Range	Geomean (MPN/100mL)	% exceeding single sample criterion
Arenosa Creek	2453C_01	13295	Arenosa Creek north of Inez	44	12-11-2000 – 08-06-2015	233.6	61.4%

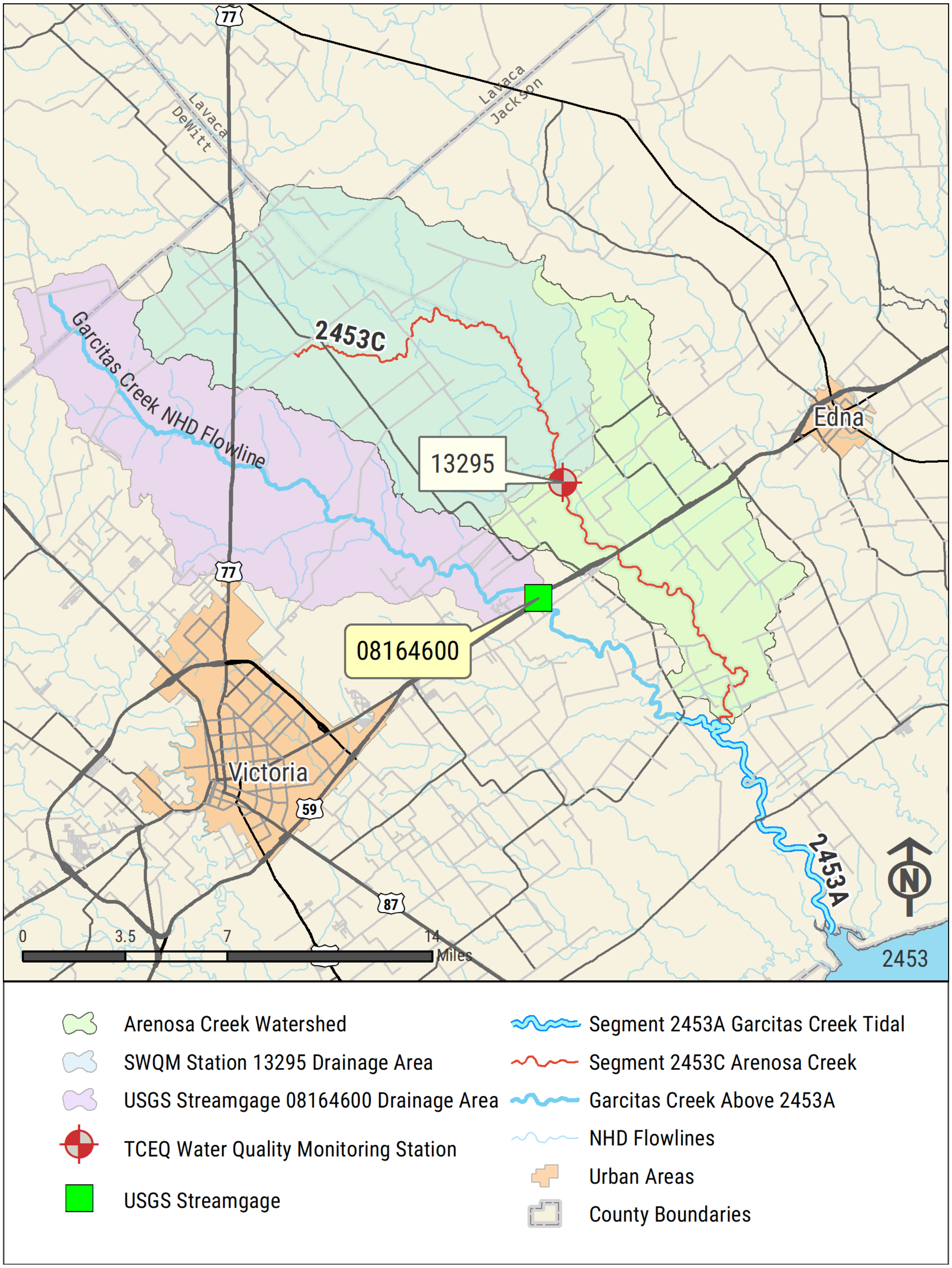

Figure 20. USGS streamflow gage and watershed used in streamflow development for Arenosa Creek.

Methodology for Flow Duration & Load Duration Curve Development

To develop the flow duration curves (FDCs) and LDCs, the previously discussed data resources were used in the following series of sequential steps.

- Step 1: Determine the hydrologic period of record to be used in developing the FDCs.
- Step 2: Determine the desired stream location for which FDC and LDC development is desired.
- Step 3: Develop daily streamflow records at desired stream location using daily gaged streamflow records and drainage area ratios.
- Step 4: Develop FDC at the desired stream location, segmented into discrete flow regimes.
- Step 5: Develop allowable bacteria LDC at the same stream location based on the relevant criteria and the data from the FDC.
- Step 6: Superimpose historical bacteria data on the allowable bacteria LDC.

Additional information explaining the LDC method may be found in Cleland (2003) and EPA (2007).

Step 1: Determine Hydrologic Period

Daily hydrologic (streamflow) records were developed from the USGS gage 08164600 in the adjacent Garcitas Creek watershed. Optimally, the period of record to develop FDCs should include as much data as possible to capture extremes of high and low streamflows and hydrologic variability from high to low precipitation years, but the flow during the period of record selected should also be representative of conditions experienced when the *E. coli* data were collected. A 15-year period from September 2000 to September 2015 was selected. This 15-year period of record was selected to capture a reasonable range of extreme high and low streamflow and represents a period in which all the *E. coli* data were collected.

Step 2: Determine Stream Location

There is a single Surface Water Quality Monitoring (SWQM) station (13295) within the impaired AU with adequate data for LDC development. Forty-four *E. coli* samples are available at the station, meeting the 24 minimum sample suggestion for development of LDCs (Texas Water Resources Institute, 2007). It was determined to develop an FDC and LDC at station 13295.

Step 3: Develop Daily Streamflow Records

Once the hydrologic period of record and the stream location were determined, the next step was to develop the 15-year daily streamflow record for the station. The daily streamflow record was developed from extant USGS records.

The method to develop the necessary streamflow record for the FDC/LDC location involved a drainage-area ratio (DAR) approach. With this basic approach, each USGS gage's daily streamflow value within the 15-year period was multiplied by a factor to estimate flow at the desired SWQM station location. The equation for this approach is:

$$Y = X\left(\frac{A_y}{A_x}\right)^{\phi}$$

Where:

Y = streamflow for the ungaged location,

X = streamflow for the gaged location,

A_y = drainage area for the ungaged location,

A_x = drainage area for the gaged location,

ϕ = bias correction factor based on streamflow percentile (Asquith et al. 2006)

Often, $\phi = 1$ is used in the DAR approach. However, empirical analysis of streamflows in Texas indicates that $\phi = 1$ results in substantial bias in streamflow estimates at very low and very high streamflow percentiles (Asquith et al. 2006). Based on these observations, values of ϕ are used based on suggestions by Asquith et al (2006). The value of ϕ varies with streamflow percentiles and lies between 0.7 and 0.935.

Table 26 provides the DAR used to develop streamflows at SWQM station 13295. Garcitas Creek was chosen because of its proximity and the similar land use characteristics above USGS gage 08164600 to Arenosa Creek. Because there are no regulated dischargers in either watershed, further adjustments were not required to develop streamflow estimates.

Table 26. Drainage-area ratio calculations

Watershed	**Drainage Area (square miles)**	**DAR**
Garcitas Creek above USGS Gage 08164600	91.7	NA
SWQM Station 13295[1]	109.1	1.2
Outlet of 2453C_01[2]	172.1	1.9

[1] location of FDC and LDC development

[2] included for informational purposes, not used for flow development

Steps 4 through 6: Flow Duration Curve and Load Duration Curve

FDCs and LDCs are graphs that visualize the percentage of time during which a value of flow or load is equaled or exceeded. To develop an FDC for a location the following steps were undertaken:

1. Order the daily streamflow data for the location from highest to lowest and assign a rank to each data point (1 for the highest flow, 2 for the second highest flow, and so on);
2. Compute the percent of days each flow was exceeded by dividing each rank by the total number of data points plus 1; and
3. Plot the corresponding flow data against exceedance percentages.

Further, when developing an LDC:

- Multiply the streamflow in cubic feet per second (cfs) by the appropriate water quality criterion for *E. coli* (geometric mean of 126 MPN/100 mL or 1.26 MPN/mL) and by a conversion factor (2.44658×109), which gives you a loading unit of MPN/day; and
- Plot the exceedance percentages, which are identical to the value for streamflow data points, against the geometric mean criterion for E. coli.

The resulting curve represents the maximum daily allowable loadings for the geometric mean criterion. The next step was to plot the measured *E. coli* data on the developed LDC using the following steps:

- Compute the daily loads for each sample by multiplying the measured E. coli concentrations on a particular day by the corresponding streamflow on that day and the conversion factor (2.44658×10^9); and
- Plot on the LDC for each station the load for each measurement at the exceedance percentage for its corresponding streamflow.

The plots of the LDC with the measured loads (*E. coli* concentrations times daily streamflow) display the frequency and magnitude that measured loads exceed the maximum allowable loadings for the geometric mean criterion. Measured loads that are above a maximum allowable loading curve indicated an exceedance of the water quality criterion, while those below a curve show compliance.

Flow Duration Curve

An FDC was developed for Arenosa Creek (AU 2453C_01) at SWQM station 13295 (Figure 21). For this report, the FDC was developed by applying the DAR method and using the USGS gage and period record (2000-2015) described in the previous section. As with Garcitas Creek, FDC indicates no instream flow approximately 19 percent of the time, which is anticipated to be reflective of actual conditions in the creek.

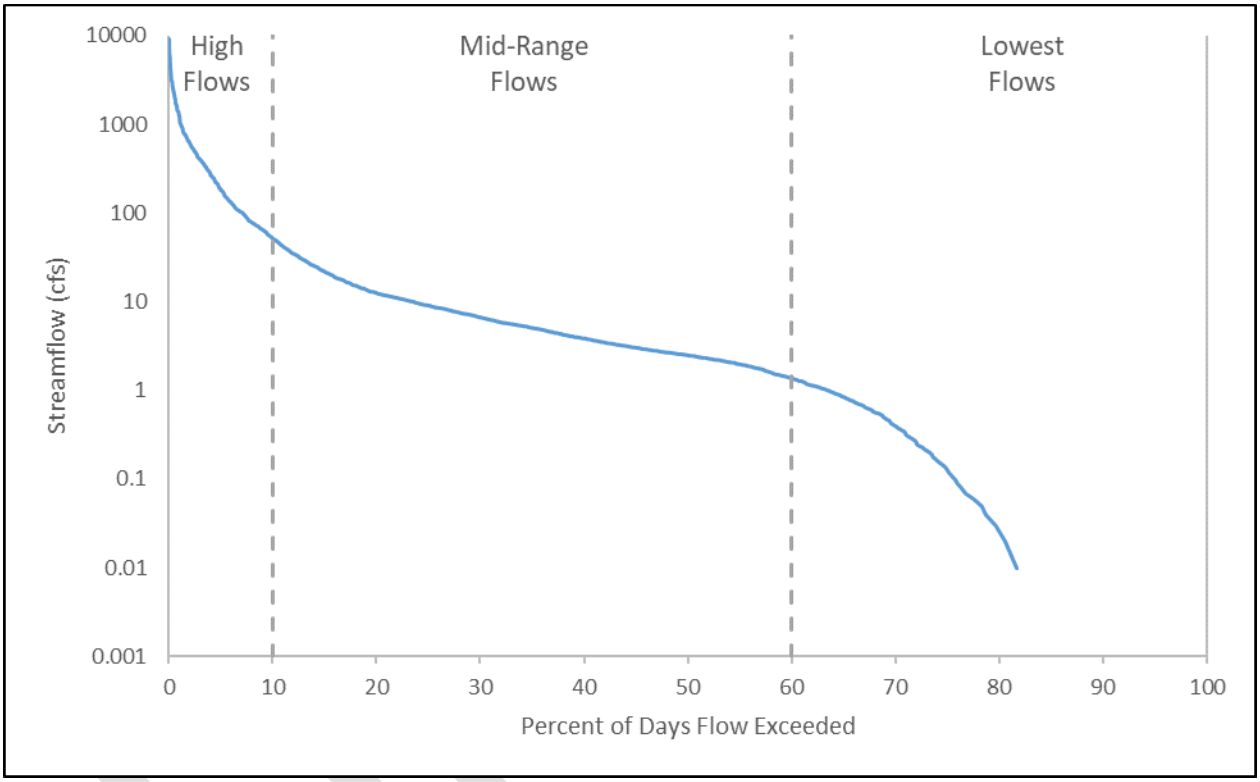

Figure 21. Flow duration curve for Arenosa Creek at station 13295

Load Duration Curve

An LDC was developed for Arenosa Creek (AU 2453C_01) at SWQM station 13295. A useful refinement of the LDC approach is to divide the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curves. This approach can assist in determining streamflow conditions under which exceedances are occurring. A commonly used set of regimes that is provided in Cleland (2003) is based on the following five intervals along the x-axis of the FDCs and LDCs: (1) 0-10 percent (high flows); (2) 10-40 percent (moist conditions); (3) 40-60 percent (mid-range flows); (4) 60-90 percent (dry conditions); and (5) 90-100 percent (low flows).

For Arenosa Creek the curve was divided into three flow regimes to assist in determining streamflow conditions under which exceedances occurred.

- High flow (0-10 percent flow exceedance) – related to flood conditions and nonpoint sources loadings

- Mid-range flow (10-60 percent flow exceedance) – intermediate conditions of receding hydrographs after storm runoff and baseline conditions
- Lowest flows (60-100 percent flow exceedance) – related to dry conditions

The selection of the flow regime intervals was based on general observation of the developed LDC. Figure 22 depicts the LDC for Arenosa Creek (AU 2453C_01). The geometric mean loading in each flow regime is also shown to aid interpretation.

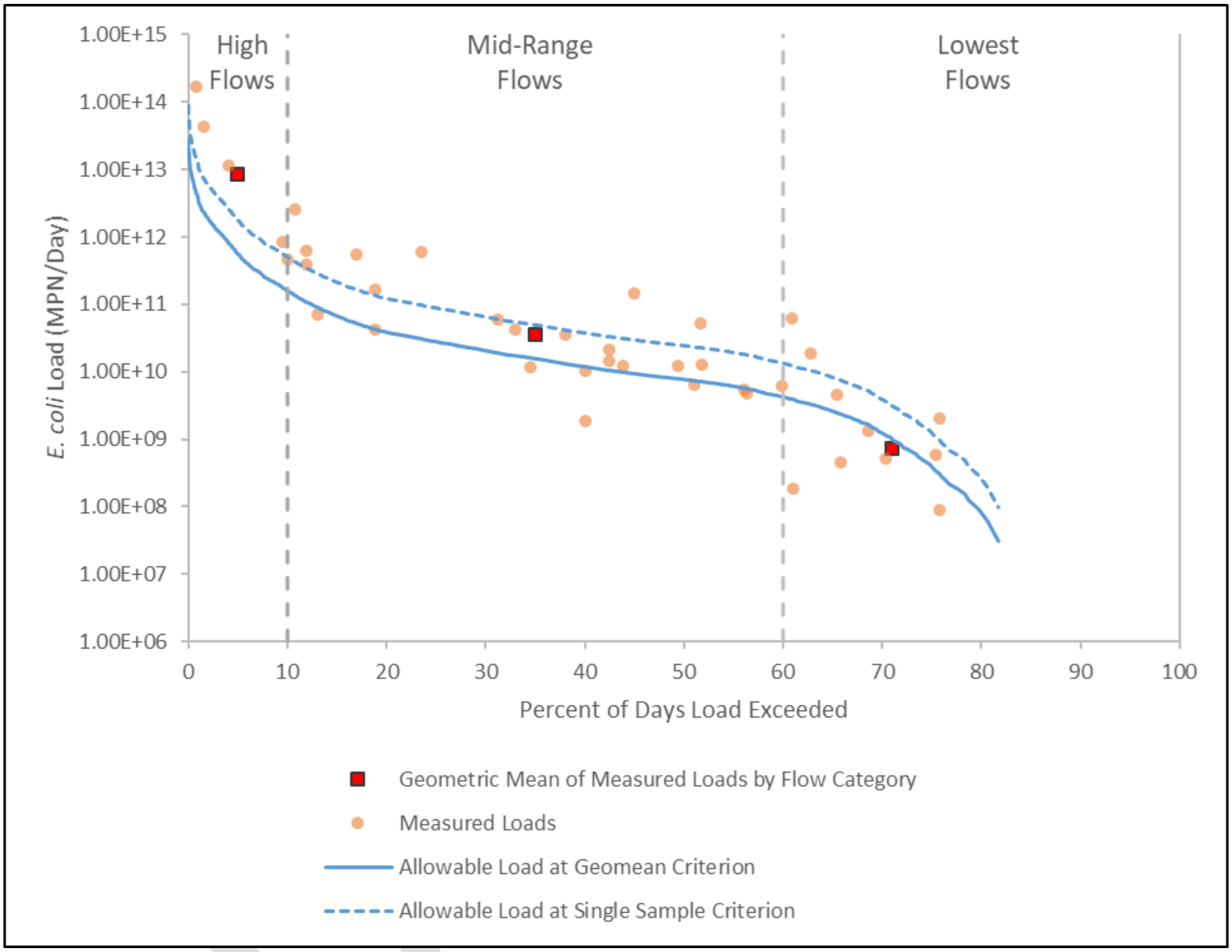

Figure 22. Load duration curve for Arenosa Creek at station 13295

Appendix D - Annual Bacteria Load Reduction Requirements

LDCs and measured loads are summarized by range of flows (high, mid-range, and low). The generalized loading capacity for each of the three flow categories was computed by using the median daily loading capacity within that flow regime (five percent , 35 percent, and 80 percent load exceedances). The required daily load reduction was calculated as the difference between the median loading capacity and the geometric mean of observed *E. coli* loading within each flow category. To estimate the needed annual bacteria load reductions, the required daily load was multiplied by the number of days per year in each flow condition. Table 27 includes the calculations used to determine annual reductions in each flow condition. The sum of load reductions within each flow condition is the estimated annual load reductions required in the watershed. Table 28 includes the calculated bacteria load reduction values for Arenosa Creek. Different fecal bacteria sources contribute to loadings at different flow regimes. Table 29 provides a generalized flow-based source assessment that indicates the relative importance of potential fecal bacteria sources under different flow conditions.

Table 27. Bacteria load reduction calculations by flow condition

	Flow Conditions		
	High	**Mid-Range**	**Lowest**
Days per year	10% × 365	50% × 365	40% × 365
Median non-zero flow (cubic feet per second)	Median observed or median estimated flow in each flow category		
Existing geomean concentration	Geometric mean of observed *E. coli* samples in each flow category		
Allowable daily load	Median Flow × 126 MPN/100 mL × 283.168 100mL/cubic foot × 86400 seconds/day		
Allowable Annual Load	Allowable Daily Load × Days per year		
Existing daily load	Median Flow × Existing Geomean Concentration × 283.2 100mL/cubic foot × 86400 seconds/day		
Existing annual load	Existing Daily Load × Days per year		
Annual load reduction needed	Existing Annual Load – Allowable Annual Load		
Percent reduction needed	(Existing Annual Load – Allowable Annual Load)/Allowable Annual Load × 100		
Total annual load	Sum of Existing Annual Loads		
Total annual load reduction	Sum of Annual Load Reductions Needed		
Total percent reduction	Total Annual Load Reduction/Total Annual Load × 100		

Table 28. Load reduction calculations for Arenosa Creek.

	Flow Conditions		
	High	Mid-range	Low
Days per year	36.50	182.50	146.00
Median Flow (ft^3/sec)	181.29	5.09	0.34
Existing Geomean Concentration (MPN/100 mL)	1,891.92	284.45	89.16
Allowable Daily Load (Billion MPN)	558.86	15.69	1.05
Allowable Annual Load (Billion MPN)	20,398.35	2,863.61	153.01
Existing Daily Load (Billion MPN)	8,391.40	35.42	0.74
Existing Annual Load (Billion MPN)	306,286.17	6,464.70	108.33
Annual Load Reduction Needed (Billion MPN)	285,887.82	3,601.09	Not Applicable
Percent Reduction Needed	93.34	55.70	Not applicable
Total Annual Load (Billion MPN)	312,859.20		
Total Annual Load Reduction (Billion MPN)	289,488.91		
Total Percent Reduction	92.53		

Table 29. Generalized flow-based assessment

	Range of Flow Conditions		
Possible Sources	**High**	**Mid-Range**	**Lowest**
Overland flow	High Contributions	Moderate Contributions	Low Contributions
Resuspension of bacteria and sediment	High Contributions	Moderate Contributions	Low Contributions
Failing/non existent OSSFs	High Contributions	High Contributions	High Contributions
Direct deposition (wildlife, livestock, pets)	Low Contributions	Moderate Contributions	High Contributions
Point-Sources	Low Contributions	Moderate Contributions	High Contributions

Appendix E - SELECT Loading Calculations

Estimates for potential loads are based on the best available data (local, state, and federal databases; scientific research) and local knowledge developed from stakeholder input (e.g. local livestock stocking practices, wildlife densities, etc.). The developed potential loading rates assume a worst-case scenario and are primarily used to calculate where management measures should be implemented first in order to maximize effectiveness and estimate potential load reductions.

OSSFs

Methods to estimate OSSF locations and numbers are described in On-Site Sewage Facilities within Chapter 3. Using the OSSF estimates, potential *E. coli* loading for individual subwatersheds was estimated. The daily load from OSSFs was calculated as:

$$PAL_{ossf} = N_{oosf} \times N_{hh} \times Production \times FC_s \times Conversion$$

Where:

PAL_{ossf} = Potential annual *E. coli* loading attributed to OSSFs

N_{ossf} = Number of OSSFs

N_{hh} = Average number of people per household (2.05)

$Production$ = Assumed sewage discharge rate; 70 gallons (gal) per person per day (Borel et al., 2015)

FC_s = Fecal coliform concentration in sewage; 1.0×10^6 colony forming unit (cfu) per 100mL (EPA, 2001)

$Conversion$ = Conversion rate from fecal coliform to *E. coli* (Wagner & Moench, 2009) and mL to gal (3578.4 mL per gal)

Livestock

The first step to calculate potential bacteria loads from cattle is to develop cattle population estimates. Stakeholder input was critical to develop livestock population estimates across the watershed. Based on input from the stakeholder group, we estimated stocking rates of one animal unit per four acres of pasture and one animal unit per 11 acres of rangeland. This stocking rate likely fluctuates annually based on local conditions, but provides a baseline to estimate potential loadings that can be adjusted and fine-tuned if new data becomes available. Other difficulties in developing cattle population estimates include the reliance on the NLCD to identify pasture and rangeland. From this dataset, it is impossible to parse out land that is used for hay production versus grazed pasture. Furthermore, identifying the actual stocking rate used by a particular landowner is not possible with this dataset. Therefore, reliance on local stakeholders was critical to properly estimating cattle populations. Finally, estimates were compared to NASS cattle population estimates for watershed counties to evaluate if the generated estimates compared to USDA census figures.

Using cattle population estimates generated with GIS analysis, potential *E. coli* loading across the watershed and for individual subwatersheds was estimated. The daily load from cattle was calculated as:

$$PAL_{cattle} = Animal\ Units \times FC_{cattle} \times Conversion$$

Where:

PAL_{cattle} = Potential annual *E. coli* loading attributed to cattle

$Animal\ Units$ = Animal Units of cattle (~1,000 lbs of cattle)

FC_{cattle} = Fecal coliform loading rate of cattle, 8.55×10^{9} cfu fecal coliform per Animal Unit per day (Wagner & Moench, 2009)

$Conversion$ = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner & Moench, 2009)

Feral Hogs

Methods to estimate feral hog numbers are described in Wildlife and Unmanaged Animals within Chapter 3. Using feral hog estimates, potential *E. coli* loading for individual subwatersheds was estimated. The daily potential load from feral hogs was calculated as:

$$PAL_{fh} = N_{fh} \times Animal\ Unit\ Conversion \times FC_{fh} \times Conversion$$

Where:

PAL_{fh} = Potential annual *E. coli* loading attributed to feral hogs

N_{fh} = Number of feral hogs

$Animal\ Unit\ Conversion$ = 0.125 animal units/feral hog (Wagner & Moench, 2009)

FC_{fh} = Fecal coliform loading rate of feral hogs, 1.21×10^{9} cfu fecal coliform per animal unit per day (Wagner & Moench, 2009)

$Conversion$ = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner & Moench, 2009)

Deer

Methods to estimate deer numbers are described in Wildlife and Unmanaged Animals within Chapter 3. Using deer estimates, potential *E. coli* loading for individual subwatersheds was estimated. The daily potential load from deer was calculated as:

$$PAL_{deer} = N_{deer} \times Animal\ Unit\ Conversion \times FC_{deer} \times Conversion$$

Where:

PAL_{deer} = Potential annual *E. coli* loading attributed to deer

N_{deer} = Number of deer

$Animal\ Unit\ Conversion$ = 0.112 animal units/deer (Wagner & Moench, 2009)

FC_{deer} = Fecal coliform loading rate of deer, 1.50×10^{10} cfu fecal coliform per animal unit per day (Wagner & Moench, 2009)

$Conversion$ = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner & Moench, 2009)

Appendix F – Bacteria Load Reduction Calculations

OSSFs

The following equation was used to estimate annual bacteria load reductions from the repair and replacement of failing OSSFs:

$$Load_{ossf} = N_{ossf} \times N_{hh} \times Production \times FC_s \times Conversion \times 365\ days/year$$

Where:

$Load_{ossf}$ = Potential annual load reduction of *E. coli* attributed to OSSF repair/replacement

N_{ossf} = Number of OSSFs repaired/replaced

N_{hh} = Average number of people per household (2.05)

Production = Assumed sewage discharge rate; 70 gal per person per day (Borel et al., 2015)

FC_s = Fecal coliform concentration in sewage; 1.0×10^6 cfu/100mL (EPA, 2001)

Conversion = Conversion rate from fecal coliform to *E. coli* (Wagner & Moench, 2009) and mL to gal (3578.4 mL per gal)

Livestock

The following equation was used to estimate annual bacteria load reductions from implementation of conservation plans and WQMPs on ranches:

$$Load_{cattle} = Head/Operation \times N_{plans} \times FC_{cattle} \times Median\ Efficacy \times Conversion \times Prox \times 365\ days/year$$

Where:

$Load_{cattle}$ = Potential annual load reduction of *E. coli* attributed to cattle

Head/Operation = Average number of head of cattle per operation in Jackson and Victoria counties (approximately 54 according to the 2012 Agriculture Census)

N_{plans} = Number of conservation plans or WQMPs developed and implemented

FC_{cattle} = Fecal coliform produced by one animal unit cattle per day (8.5×10^9 cfu/day) (Wagner & Moench, 2009)

Median Efficacy = Median efficacy of selected conservation practices at reducing bacteria loads (0.58 used, see below)

Conversion = Conversion rate from fecal coliform to *E. coli* (Wagner & Moench, 2009)

Prox = Approximate proximate factor to account for distance of management practices from riparian areas (0.15 used, see below)

The effectiveness of WQMPs and conservation plans at reducing bacteria loads is highly dependent on the specific conservation practices installed by the rancher or farmer. To estimate expected *E. coli* reductions, efficacy values of likely BMPs were calculated from median literature reported values (Table 30). Because the actual BMPs implemented per WQMP or conservation plan are unknown, an overall median efficacy value of 0.58 (58%) was used to calculate load reductions. Finally, the proximity of implemented BMPs to water bodies will influence the effectiveness at reducing loads. Typically, a proximity factor of 0.05 (5%) is used for BMPs in upland areas and 0.25 used in riparian areas. Since there is uncertainty in both the specific BMPs and the locations where plans are implemented, an average proximity factor of 0.15 was used.

Table 30. Summary of literature reported values for conservation practice effectiveness in reducing indicator bacteria loads.

	E. coli **Removal Efficacy**		
Management Practice	**Low**	**High**	**Median**
Exclusionary Fencing[1]	30%	94%	62%
Prescribed Grazing[2]	42%	66%	54%
Stream Crossing[3]	44%	52%	48%
Watering Facility[4]	51%	94%	73%

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

[2] Tate et al. 2004; EPA 2010.

[3] Inamdar et al. 2002; Meals 2001

[4] Byers et al. 2005; Hagedorn et al. 1999; Sheffield et al. 1997

Feral Hogs

An overall load reduction for feral hogs was not calculated because the number of hogs removed and population reductions resulting from feral hog management are highly uncertain. However, a potential annual load reduction for each feral hog removed is provided below:

$$Load_{fh} = N_{fh} \times Animal\ Unit\ Conversion \times FC_{fh} \times Conversion \times 365\ days/year$$

Where:

$Load_{fh}$ = Potential annual *E. coli* loading reduction from removed feral hogs

N_{fh} = Number of feral hogs removed

$Animal\ Unit\ Conversion$ = 0.125 animal units/feral hog (Wagner & Moench, 2009)

FC_{fh} = Fecal coliform loading rate of feral hogs, 1.21×10^9 cfu fecal coliform per animal unit per day (Wagner & Moench, 2009)

$Conversion$ = Estimated fecal coliform to *E. coli* conversion rate; 126/200 (Wagner & Moench, 2009)

Appendix G – Nutrient Load Reduction Calculations

OSSFs

The following equation was used to estimate annual phosphorus load reductions from the repair and replacement of failing OSSFs:

$$Phosphorus_{ossf} = N_{ossf} \times N_{hh} \times Production \times P_s \times Conversion \times 365\ days/year$$

Where:

$Phosphorus_{ossf}$ = Potential annual load reduction of phosphorus attributed to OSSF repair/replacement

N_{ossf} = Number of OSSFs repaired/replaced

N_{hh} = Average number of people per household (2.05)

Production = Assumed sewage discharge rate; 70 gal per person per day (Borel et al., 2015)

P_s = Phosphorus concentration in sewage; 10 mg per liter (Davis & Cornwell, 1991)

Conversion = Conversion rate from pounds per milligram (2.2×10^{-6} pounds per mg) and liters per gal (3.79 liters per gal)

The following equation was used to estimate annual nitrogen load reductions from the repair and replacement of failing OSSFs:

$$Nitrogen_{ossf} = N_{ossf} \times N_{hh} \times Production \times P_s \times Conversion \times 365\ days/year$$

Where:

$Nitrogen_{ossf}$ = Potential annual load reduction of nitrogen attributed to OSSF repair/replacement

N_{ossf} = Number of OSSFs repaired/replaced

N_{hh} = Average number of people per household (2.05)

Production = Assumed sewage discharge rate; 70 gal per person per day (Borel et al., 2015)

P_s = Phosphorus concentration in sewage; 40 mg per liter (Davis & Cornwell, 1991)

Conversion = Conversion rate from pounds per mg (2.2×10^{-6} pounds per mg) and liters per gal (3.79 liters per gal)

Livestock

The following equation was used to estimate annual phosphorus load reductions from implementation of conservation plans and WQMPs on ranches:

$$Phosphorus_{cattle} = Head/Operation \times N_{plans} \times Production_p \times Median\ Efficacy \times Prox \times 365\ days/year$$

Where:

$Phosphorus_{cattle}$ = Potential annual load reduction of phosphorus attributed to cattle

$Head/Operation$ = Average number of head of cattle per operation in Jackson and Victoria counties (approximately 54 according to the 2012 Agriculture Census)

N_{plans} = Number of conservation plans or WQMPs developed and implemented

$Production_p$ = Pounds of phosphorus produced per animal per day, 0.11 pounds per day (NRCS, 2009)

$Median\ Efficacy$ = Median efficacy of selected conservation practices at reducing phosphorus loads, 0.49 (see below)

$Prox$ = Approximate proximate factor to account for distance of management practices from riparian areas, 0.15 (see below)

The following equation was used to estimate annual nitrogen load reductions from implementation of conservation plans and WQMPs on ranches:

$$Nitrogen_{cattle} = Head/Operation \times N_{plans} \times Production_n \times Median\ Efficacy \times Prox \times 365\ days/year$$

Where:

$Nitrogen_{cattle}$ = Potential annual load reduction of nitrogen attributed to cattle

$Head/Operation$ = Average number of head of cattle per operation in Jackson and Victoria counties (approximately 54 according to the 2012 Agriculture Census)

N_{plans} = Number of conservation plans or WQMPs developed and implemented

$Production_n$ = Pounds of nitrogen produced per animal per day, 0.31 pounds per day (NRCS, 2009)

$Median\ Efficacy$ = Median efficacy of selected conservation practices at reducing nitrogen loads, 0.33 (see below)

$Prox$ = Approximate proximate factor to account for distance of management practices from riparian areas, 0.15 (see below)

The effectiveness of WQMPs and conservation plans at reducing nutrient loads is highly dependent on the specific conservation practices installed by the rancher or farmer. To estimate expected nutrient reductions, efficacy values of likely BMPs were calculated from median literature reported values (Table 27). Because the actual BMPs implemented per WQMP or conservation plan are unknown, an overall median efficacy value of 0.49 (49%) was used to calculate phosphorus load reductions and 0.33 (33%) was used to calculate nitrogen load reductions (Table 31). Finally, the proximity of implemented BMPs to water bodies will influence the effectiveness at reducing loads. Typically, a proximity factor of 0.05 (5%) is used for BMPs in upland areas and 0.25 used in riparian areas. Since there is uncertainty in both the specific BMPs and the locations where plans are implemented, an average proximity factor of 0.15 was used.

Table 31. Summary of literature reported values for conservation practice effectiveness in reducing indicator nutrient loads.

Conservation Practice	**Median Nitrogen Reduction Effectiveness**	**Median Phosphorus Reduction Effectiveness**
Exclusionary Fence	33% (Line et al., 2000)	49% (Flores-Lopez et al., 2010; Kay et al., 2009; Line et al., 2000, 2016; Sharpley et al., 2009
Prescribed Grazing	55% (Chesapeake Bay Program, 2017; Olness et al., 1980; Tuppad et al., 2010)	41% (Chesapeake Bay Program, 2017; Olness et al., 1980; Sharpley et al., 2009; Tuppad et al., 2010)
Watering Facility	5% (Byers et al., 2005; Chesapeake Bay Program, 2017)	57% (Byers et al., 2005; Kay et al., 2009; Sheffield et al., 1997)

Feral Hogs

An overall nutrient load reduction for feral hogs was not calculated because the number of hogs removed and population reductions resulting from feral hog management are highly uncertain. However, a potential annual load reduction for phosphorus and nitrogen attributed to each feral hog removed are provided below:

$$Phosphorus_{fh} = N_{fh} \times Animal\ Unit\ Conversion \times Production_{p} \times 365\ days/year$$

Where:

$Phosphorus_{fh}$ = Potential annual phosphorus loading reduction from removed feral hogs

N_{fh} = Number of feral hogs removed

$Animal\ Unit\ Conversion$ = 0.125 animal units/feral hog (Wagner & Moench, 2009)

$Production_{p}$ = Pounds of phosphorus per animal unit per day, 0.05 (National Resource Conservation Service, 2009)

$$Nitrogen_{fh} = N_{fh} \times Animal\ Unit\ Conversion \times Production_{n} \times 365\ days/year$$

Where:

$Nitrogen_{fh}$ = Potential annual phosphorus loading reduction from removed feral hogs

N_{fh} = Number of feral hogs removed

$Animal\ Unit\ Conversion$ = 0.125 animal units/feral hog (Wagner & Moench, 2009)

$Production_{n}$ = Pounds of nitrogen per animal unit per day, 0.05 (National Resource Conservation Service, 2009)