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Implementation Plan for One Total Maximum Daily Load for Indicator Bacteria in Carancahua Bay

Segment 2456

Assessment Unit 2456_02

Prepared by the Carancahua Bay Stakeholders and the Texas Water Resources Institute

With Support from the Water Quality Planning Division,
Office of Water, Texas Commission on Environmental Quality

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and the Texas Water Resources Institute

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This plan is based in part on technical reports prepared for TCEQ by:
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and in large part on the recommendations of the
stakeholders of the Carancahua Bay Watershed

Agencies that participated in the development of this document include:
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Texas State Soil and Water Conservation Board
Texas Water Resources Institute

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Abbreviations

An.U	animal unit
AU	assessment unit
BMP	best management practice
cfu	colony forming units
CIG	Conservation Innovation Grant
CMP	Coastal Management Program
CSP	Conservation Stewardship Program
CWA	Clean Water Act
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FC	fecal coliform
FG	future growth
I-Plan	implementation plan
LA	load allocation
mi^2	square miles
mL	milliliter
MGD	million gallons per day
MOS	margin of safety
MS4	municipal separate storm sewer system
NFWF	National Fish and Wildlife Foundation
NLCD	National Land Cover Database
NOAA	National Pollutant Discharge Elimination System
NPDES	National Oceanic and Atmospheric Administration
NPS	nonpoint source
NRCS	Natural Resources Conservation Service
OSSF	on-site sewage facility
RCPP	Regional Conservation Partnership Program
SEP	Supplemental Environmental Project
SSO	sanitary sewer overflows
SWCD	Soil and Water Conservation District
SWQM	Surface water quality monitoring
TCEQ	Texas Commission on Environmental Quality
TGLO	Texas General Land Office
TIAER	Texas Institute for Applied Environmental Research
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	wasteload allocation
WQMP	Water Quality Management Plan

WUGs	Water User Groups
WWTF	wastewater treatment facility

Implementation Plan for One TMDL for Indicator Bacteria in Carancahua Bay

Executive Summary

The Texas Commission on Environmental Quality (TCEQ) developed a total maximum daily load (TMDL) report, *One Total Maximum Daily Load for Indicator Bacteria in Carancahua Bay* (Segment 2456).

This implementation plan, or I-Plan:

- describes the steps that watershed stakeholders and TCEQ will take toward achieving pollutant reductions identified in the TMDL report, and
- outlines the schedule for implementation activities.

The goal of this I-Plan is to restore the primary contact recreation use in Segment 2456 by reducing concentrations of bacteria to levels established in the TMDL report. Enterococci are widely used as indicator bacteria to assess attainment of the contact recreation use in saltwater. The criteria for assessing attainment of the contact recreation use are expressed as the number of Enterococci, typically given as colony forming units (cfu). The primary contact recreation use is not supported when the geometric mean exceeds 35 cfu per 100 milliliters (mL) or when the single sample criterion of 130 cfu per 100 mL is exceeded 20 percent of the time as described in TCEQ's Guidance for Assessing and Reporting Surface Water Quality in Texas as amended. Carancahua Bay AU 2456_02 was first identified as impaired in the *2006 Texas Water Quality Inventory and 303(d) List* (TCEQ, 2007) and then in each subsequent edition of the *Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d)* (Texas Integrated Report). The 2018 Texas Integrated Report assessment data indicate non-support of the primary contact recreation use due to exceedance of the geometric mean criterion and the single sample criterion of 130 cfu/100 mL (TCEQ, 2019). As a result of revisions to bacteria criteria in the 2018 Texas Surface Water Quality Standards, recreation uses in coastal recreation waters, which includes bays designated as primary contact recreation, are assessed with geometric mean and single sample criteria (TCEQ, 2018a).

The TMDL report identified regulated and unregulated sources of bacteria in the watershed that could contribute to the water quality impairment. Regulated sources identified include a domestic wastewater treatment facility (WWTF) and regulated stormwater. Sanitary sewer overflows (SSOs), dry weather discharges, and illicit discharges are a subset of these regulated sources.

Unregulated sources that could contribute to the indicator bacteria load in the watershed include domestic animals (e.g., cattle, dogs, and horses), failing on-site sewage facilities (OSSFs), and wildlife and other unmanaged animals (e.g., deer and feral hogs).

This I-Plan includes six management measures that will be used to reduce bacteria in the Carancahua Bay watershed. Management measures are related to managing nonpoint sources (NPS) (unregulated), such as working to identify OSSFs in the watershed. Control actions are related to point sources (regulated discharges), such as industrial or domestic WWTFs or municipal separate storm sewer system (MS4) Phase II Stormwater Management Programs. No control actions related to regulated discharges are included in this plan.

Management Measures

1. *Promote and implement Water Quality Management Plans or conservation plans*
2. *Repair and replace failing OSSFs*
3. *Develop voluntary OSSF inspection program*
4. *Promote feral hog removal*
5. *Promote effective pet waste management*
6. *Restore oyster and coastal wetland habitat*

For each of the measures, this plan identifies the responsible parties, technical and financial needs, monitoring and outreach efforts, and a schedule of activities. Implementation of the management measures will largely be dependent upon the availability of funding.

The stakeholders and TCEQ will review progress under TCEQ's adaptive management process. The plan may be adjusted periodically as a result of progress reviews.

Introduction

To keep Texas' commitment to restore and maintain water quality in impaired rivers, lakes, and bays, TCEQ works with stakeholders to develop an I-Plan for each adopted TMDL. A TMDL is a technical analysis that:

- determines the amount of a particular pollutant that a water body can receive and still meet applicable water quality standards, and
- sets limits on categories of sources that will result in achieving standards.

This I-Plan is designed to guide activities that will achieve the water quality goals for the Carancahua Bay watershed as defined in the TMDL report. It is a flexible tool that governmental and nongovernmental organizations involved in implementation use to guide their activities to improve water quality. The

participating partners may accomplish the activities described in the plan through rule, order, guidance, or other appropriate formal or informal action.

This I-Plan contains the following components:

1) a description of management measures that will be implemented to achieve the water quality target;
2) a follow-up tracking and monitoring plan to determine the effectiveness of the management measures undertaken;
3) identification of measurable outcomes and other considerations TCEQ and stakeholders will use to determine whether the I-Plan has been properly executed, water quality standards are being achieved, or the plan needs to be modified;
4) identification of the communication strategies TCEQ will use to disseminate information to stakeholders; and
5) a review strategy that stakeholders will use to periodically review and revise the plan to ensure there is continued progress in improving water quality.

This plan also includes possible causes and sources of the impairment, management measure descriptions, estimated potential load reductions, technical and financial assistance needed, educational components for each measure, schedule of implementation, measurable milestones, indicators to measure progress, monitoring components, and responsible entities outlined in the Nonpoint Source Program Grants Guidelines for States and Territories (EPA, 2013). Consequently, projects developed to implement NPS (unregulated) elements of this plan that also meet the grant program conditions may be eligible for funding under the Environmental Protection Agency's (EPA) Section 319(h) incremental grant program.

Watershed Overview

Carancahua Bay (Segment 2456) is located along the Texas Gulf Coast midway between the cities of Palacios and Port Lavaca, with portions of the bay in Calhoun and Jackson counties (Figure 1). Carancahua Bay (Segment 2456) is comprised of two assessment units (AUs), with the upper portion of the bay designated as AU 2456_02 and the lower portion designated as 2456_01 (Figure 1). The impaired AU 2456_02 has a surface area of 4,503 acres (seven square miles [mi^2]). Two unclassified creeks, West Carancahua Creek (Segment 2456A) and East Carancahua Creek (no segment number assigned), merge immediately upstream of the confluence with Carancahua Bay AU 2456_02 and provide most of the streamflow into Carancahua Bay.

Carancahua Bay AU 2456_02 drains 204,242 acres (319 mi^2) with portions of the watershed in Calhoun (1.5 percent), Jackson (64.5 percent), Matagorda (16.7 percent), and Wharton (17.3 percent) counties.

The TMDL's I-Plan uses a watershed approach where the entire drainage area of AU 2456_02 is considered.

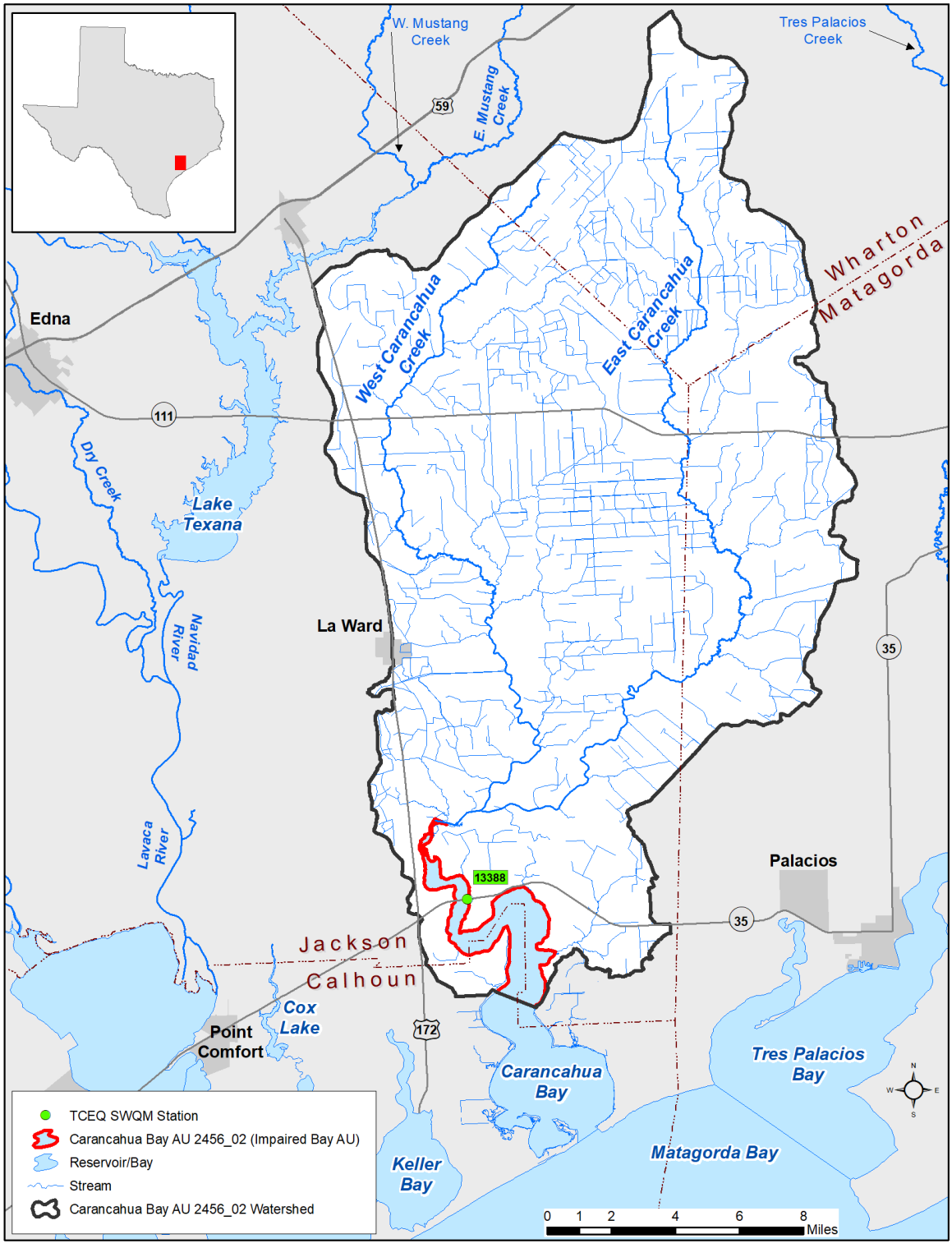

Figure 1. Overview map showing Carancahua Bay AU 2456_02 watershed and TCEQ surface water quality monitoring (SWQM) station.

Watershed Climate and Hydrology

The Carancahua Bay AU 2456_02 watershed is located in the southeast portion of the state of Texas along the Gulf of Mexico coastline (Figure 1) and falls within the subtropical humid climate region as classified by Larkin & Bomar (1983). This regional climate is characterized as a modified marine climate including warm summers with the occasional invasion of drier, cooler continental airflow offsetting the prevailing flow of tropical maritime air from the Gulf of Mexico (Larkin & Bomar, 1983).

As depicted in Figure 2, for the most recent 15-year period from 2002–2016 at the nearest National Oceanic and Atmospheric Administration (NOAA) weather station (Palacios Municipal Airport – USW00012935) located approximately eight miles east of AU 2456_02, average high temperatures generally peak in August (92.1˚F) (NOAA, 2017). During the winter, the average low temperature is 45.5˚F in January. Additionally, September (5.8 inches) is indicated to be the wettest month with February (1.6 inches) observed to be the driest month.

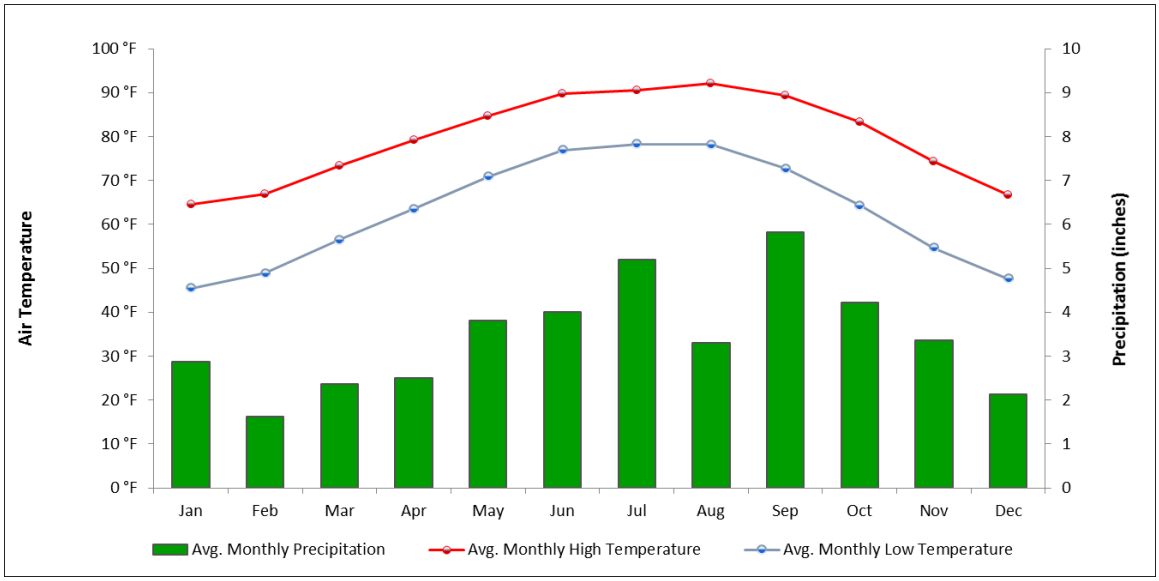

Figure 2. Average minimum and maximum air temperatures and average precipitation by month from 2002-2016 for the Palacios Municipal Airport.

Watershed Population and Population Projections

As depicted in Figure 3, the Carancahua Bay AU 2456_02 watershed lies within portions of Calhoun, Jackson, Wharton, and Matagorda counties, and one municipal boundary (City of La Ward) lies partially within the watershed. According to the 2010 United States Census Bureau (USCB) data, there are an estimated 1,883 people within the watershed, revealing an average population density of approximately six people/mi^2 (USCB, 2017). Of those, an estimated 104 people (5.5 percent) are located within the City of La Ward, indicating that

the watershed population is mostly rural. Figure 3 provides a depiction of the population density per acre of the Carancahua Bay AU 2456_02 watershed.

Watershed population (USCB, 2017) and population projections from the Texas Water Development Board (TWDB) were obtained by Texas Institute for Applied Environmental Research (TIAER) to complete the population projection exercise. The steps of the population projection exercise are provided in Appendix B. The exercise indicates a population increase of 14.6 percent in the Carancahua Bay AU 2456_02 watershed by 2050 based on Water User Groups (WUGs; TWDB, 2015). The 2010-2050 WUG population projection increases range from 10.2 percent to 52.2 percent. The largest population percent increase over the 40-year span is anticipated to occur in that portion of the Carancahua Bay AU 2456_02 watershed that lies within Calhoun County, but that area only contributes 24 additional people by 2050. The City of La Ward population within the study area is projected to increase by 11 people by 2050. The Jackson County-Other population within the watershed maintains the largest projected per capita increase with 123 people by 2050. Table 1 provides a summary of the 2010–2050 population projections. Populations in Table 1 were estimated by TIAER by multiplying the estimated 2010 USCB populations by the percent increases projected by TWDB.

Table 1. 2010 population with population projections for the Carancahua Bay AU 2456_02 watershed.

Location or WUG	2010 U.S. Census Population	2020 Population Projection	2030 Population Projection	2040 Population Projection	2050 Population Projection	Projected Population Increase (2010 - 2050)	Percent Increase (2010 - 2050)
Calhoun County-Other	46	52	58	64	70	24	52.2
City of La Ward	104	108	112	114	115	11	10.6
Jackson County-Other	1,209	1,254	1,298	1,317	1,332	123	10.2
Matagorda County-Other	314	335	353	364	373	59	18.8
Wharton County-Other	210	225	242	255	267	57	27.1
Watershed Total	**1,883**	**1,974**	**2,063**	**2,114**	**2,157**	**274**	**14.6**

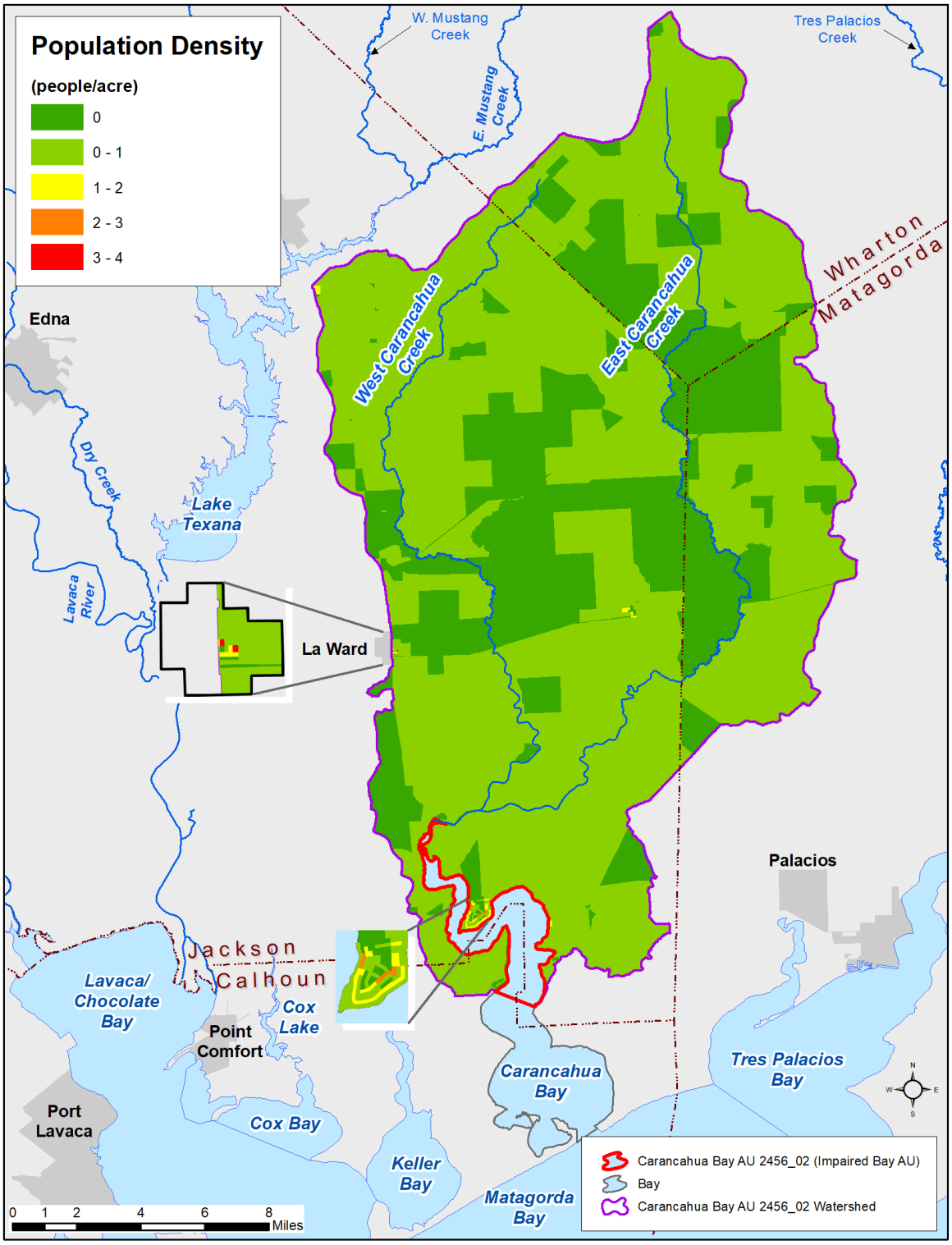

Figure 3. Population density for the Carancahua Bay AU 2456_02 watershed based on the 2010 U.S. Census Blocks.

Land Use

The land use/land cover data for the Carancahua Bay AU 2456_02 watershed was obtained from the United States Geological Survey (USGS) 2011 National Land Cover Database (NLCD) (USGS, 2014).

The land use/land cover is represented by the following categories and definitions (USGS, 2014):

- **Open Water** – All areas of open water, generally with less than 25 percent cover of vegetation or soil.
- **Developed, Open Space** – Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- **Developed, Low Intensity** – Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.
- **Developed, Medium Intensity** – Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.
- **Developed, High Intensity** – Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80-100 percent of the total cover.
- **Barren Land (Rock/Sand/Clay)** – Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15 percent of total cover.
- **Deciduous Forest** – Areas dominated by trees generally greater than five meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
- **Evergreen Forest** – Areas dominated by trees generally greater than five meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
- **Mixed Forest** – Areas dominated by trees generally greater than five meters tall, and greater than 20 percent of total vegetation cover.

Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.

- **Shrub/Scrub** – Areas dominated by shrubs; less than five meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
- **Grassland/Herbaceous** – Areas dominated by graminoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling but can be utilized for grazing.
- **Pasture/Hay** – Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.
- **Cultivated Crops** – Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
- **Woody Wetlands** – Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- **Emergent Herbaceous Wetlands** – Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

A summary of the land use/land cover data is provided in Table 2. As depicted in Table 2 and Figure 4, the dominant land uses are Cultivated Crops (approximately 46 percent) and Pasture/Hay (approximately 30 percent) comprising approximately 76 percent of the land use/land cover. To summarize, the land use coverage indicates a mostly rural, agricultural watershed with very little urbanization.

Table 2. Land use/land cover within the Carancahua Bay AU 2456_02 watershed.

2011 NLCD Classification	Area (acres)	Percent of Total
Open Water	4,972	2.43
Developed, Open Space	6,065	2.97
Developed, Low Intensity	520	0.25
Developed, Medium Intensity	33	0.02
Developed, High Intensity	2	0.00
Barren Land	687	0.34
Deciduous Forest	7,409	3.63
Evergreen Forest	7,437	3.64
Mixed Forest	2,335	1.14
Shrub/Scrub	11,907	5.83
Grassland/Herbaceous	3,461	1.69
Pasture/Hay	60,879	29.81
Cultivated Crops	93,450	45.75
Woody Wetlands	3,037	1.49
Emergent Herbaceous Wetlands	2,048	1.00
Total	**204,242**	**100**

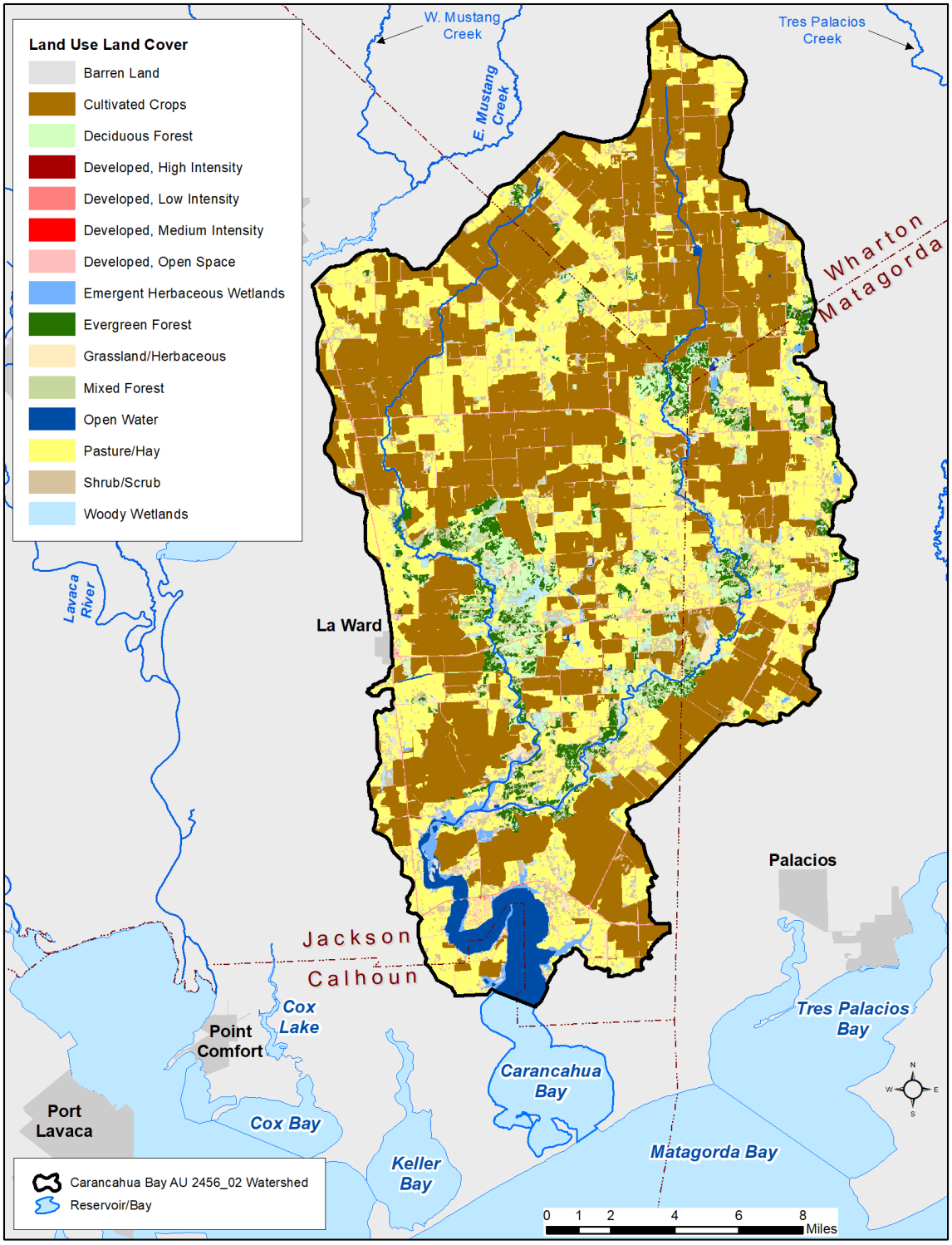

Figure 4. 2011 NLCD land use/land cover within the Carancahua Bay AU 2456_02 watershed.

Soils

Soils within the Carancahua Bay AU 2456_02 watershed are categorized by septic tank absorption field ratings, including dominant conditions. These data were obtained through the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic database (USDA NRCS, 2015).

Soil properties and features such as saturated hydraulic conductivity, flooding, depth to bedrock, depth to cemented pan, ponding, rocks, fractured bedrock, subsidence, and excessive slope, can affect septic tank effluent absorption, construction and maintenance, and public health (USDA NRCS, 2015). The dominant soil condition within a septic drainage field can be used to identify soils that may be problematic regarding septic system installation or performance, and potentially lead to system failures such as effluent surfacing or downslope seepage.

Soils are rated based on the limiting factors (or conditions) affecting proper effluent drainage and filtering capacity. Soil conditions for septic tank drainage fields are expressed by the following rating terms and definitions (USDA NRCS, 2015):

- **Not Limited** – Indicates that the soil has features that are very favorable for the specific use. Good performance and very low maintenance can be expected.
- **Somewhat Limited** – Indicates that the soil has one or more features that are moderately favorable for the specified use. The limitations can be overcome or minimized with special planning, design, installation procedures. Fair performance and moderate maintenance can be expected.
- **Very limited** – Indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.
- **Not Rated** – Indicates insufficient data exists for soil limitation interpretation.

As indicated in Figure 5, approximately 97 percent of the soils are rated “very limited” within the Carancahua Bay AU 2456_02 watershed based on the dominant soil condition for septic drainage field installation and operation.

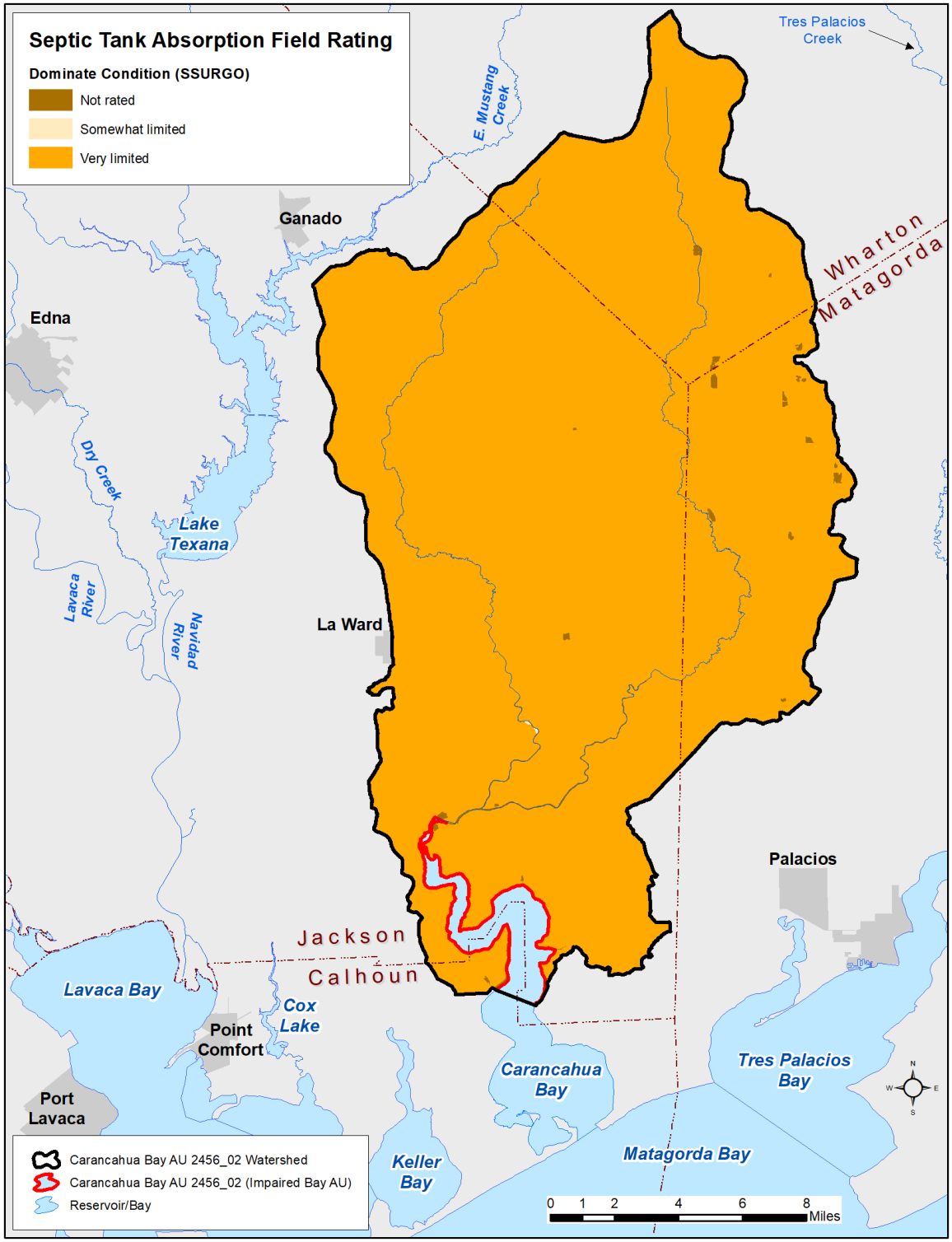

Figure 5. Septic tank absorption field limitation ratings for soils within the Carancahua Bay AU 2456_02 watershed.

Summary of TMDLs

This section summarizes the information developed for *One Total Maximum Daily Load for Indicator Bacteria in Carancahua Bay* (TCEQ, 2018b). Additional background information including the problem definition, endpoint identification, source analysis, linkages between sources and receiving waters and pollutant load allocations (LAs) can be found in the TMDL report. Table 3 provides a summary of *One Total Maximum Daily Load for Indicator Bacteria in Carancahua Bay.*

Table 3. Final TMDL allocations for the Carancahua Bay AU 2456_02 watershed.

AU	TMDL	WLA_{WWTF}[a]	WLA_{SW}	LA	MOS[b]
2456_02	947.387	0.064	1.440	898.514	47.369

Load units expressed as billion cfu/day

[a] WLA_{WWTF} includes the future growth component

[b] Margin of Safety

Pollutant Sources and Loads

Wasteload Allocation

The wasteload allocation (WLA) is the sum of wasteloads for regulated source contributions in the watershed including WWTFs (WLA_{WWTF}) and regulated stormwater discharges (WLA_{SW}).

$$WLA = WLA_{WWTF} + WLA_{SW}$$

Wastewater Treatment Facilities

WWTFs regulated under the Texas Pollutant Discharge Elimination System (TPDES) program are allocated a daily wasteload (WLA_{WWTF}), calculated as their full permitted discharge flow rate multiplied by the instream geometric criterion. The saltwater Enterococci criterion (35 cfu/100mL) is used as the WWTF target. The WLA_{WWTF} term is also calculated for the freshwater *E. coli* primary contact recreation geometric mean criterion of 126 cfu/100 mL, since WWTF bacteria permit limits are often expressed in terms of *E.* coli. This is expressed in the following equation:

$$WLA_{WWTF} = \text{criterion} * \text{flow} * \text{conversion factor}$$

Where:

Criterion = 35 cfu/100 mL for Enterococci; 126 cfu/100 mL for *E. coli*

Flow = full permitted flow [million gallons per day (MGD)]

Conversion factor (to cfu/day) = 1.54723 cubic feet per second /MGD *283.168 100 mL/cubic feet * 86,400 seconds per day

Table 4 provides a summary of the WLA attributed to the WWTF.

Table 4. Wasteload allocations for the TPDES-permitted facility in Carancahua Bay AU 2456_02.

AU	TPDES Permit Number	*NPDES Permit Number	Facility	Full Permitted Flow (MGD)	*E. coli* WLA_{WWTF} (Billion cfu/day)	Enterococci WLA_{WWTF} (Billion cfu/day)
2456_02	WQ0013479001	TX0105104	City of La Ward WWTF	0.024	0.114	0.032

*National Pollutant Discharge Elimination System

Regulated Stormwater

Stormwater discharges from MS4, industrial, and construction areas are considered regulated point sources. Regulated stormwater discharges (WLA_{SW}) must be included in the WLA. Further detail on how the WLA_{SW} was calculated can be found in the *One Total Maximum Daily Load for Indicator Bacteria in Carancahua Bay.* The calculation for allowable loads from regulated stormwater is expressed by the following equation:

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP}$$

Where:

WLA_{SW} = sum of all regulated stormwater loads

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

FDA_{SWP} = fractional proportion of drainage area under jurisdiction of stormwater permits

Table 5 provides a summary of the regulated stormwater area. To calculate WLA_{SW}, the future growth (FG) term must be known. The calculation for the FG term is presented in a later section, but the results will be included here for continuity. Table 6 provides the information needed to compute WLA_{SW}. Table 7 provides a summary of the WLA attributed to regulated stormwater.

Table 5. Regulated stormwater FDA_{SWP} basis for the Carancahua Bay AU 2456_02 watershed.

MS4 General Permit (acres)	Construction General Permit (acres)	Multi-Sector General Permit (acres)	Concrete Production Facilities (acres)	Petroleum Bulk Stations (acres)	Total Area of Permits (acres)	Watershed Area (acres)	FDA_{SWP}
0	320	0	0	0	320	204,242	0.16%

Table 6. Regulated stormwater calculations for the Carancahua Bay AU 2456_02 watershed.

Indicator Bacteria	TMDL	WLA_{WWTF}	FG	MOS	FDA_{SWP}	WLA_{SW}
Enterococci	947.387	0.032	0.032	47.369	0.16%	1.440

Load units expressed as billion cfu/day

Once the WLA_{SW} and WLA_{WWTF} terms are known, the WLA term can be calculated as the sum of the two parts, as shown in Table 7.

Table 7. Wasteload allocation calculations for the Carancahua Bay AU 2456_02 watershed.

WLA_{WWTF}	WLA_{SW}	WLA
0.032	1.440	1.472

Load units expressed as billion cfu/day

Load Allocation

The LA is the sum of loads from unregulated sources and is calculated as:

$$LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS$$

Where:

LA = allowable load from unregulated sources

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

WLA_{SW} = sum of all regulated stormwater loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

The calculation results are shown in Table 8.

Table 8. Load allocation calculations for the Carancahua Bay AU 2456_02 watershed.

Indicator Bacteria	TMDL	WLA_{WWTF}	WLA_{SW}	FG	MOS	LA
Enterococci	947.387	0.032	1.440	0.032	47.369	898.514

Load units expressed as billion cfu/day

Allowance for Future Growth

The FG component of the TMDL equation addresses the requirement to account for future loadings that may occur due to population growth, changes in community infrastructure, and development. Specifically, this TMDL component takes into account the probability that new flows from WWTF discharges may occur in the future. The assimilative capacity of streams increases as the amount of flow increases.

The above definition of FG is relevant for the Carancahua Bay AU 2456_02 watershed, since application of the projected population growth (10.6 percent; Table 1) over the period of 2010 to 2050 for the City of La Ward yields an additional flow of only 0.0025 MGD. The distinct possibility exists, however, for additional community development along the bay front of Carancahua Bay AU 2456_02 (see inset showing bay area on the population density map of Figure 3), which could necessitate a future WWTF that almost certainly would be greater than 0.0025 MGD in size. To accommodate for the possibility of such an occurrence along the bay front or anywhere else in the watershed, a FG flow of 0.024 MGD was assigned, which is equivalent to the City of La Ward WWTF. Table 9 provides information necessary for the FG computations for the Carancahua Bay AU 2456_02 watershed, which is the same equation used for computing the WLA_{WWTF} term.

Table 9. Future growth calculations for the Carancahua Bay AU 2456_02 watershed.

FG Flow (MGD)	FG (Enterococci Billion cfu/day)
0.024	0.032

Total Maximum Daily Load

Table 10 summarizes the TMDL calculations for the impaired Carancahua Bay AU 2456_02. The TMDL was based on the median flow in the 0-10 percentile range (five percent exceedance, high flow regime) for flow exceedance from the load duration curve developed for SWQM station 13388. Allocations are based on the current geometric mean criterion for Enterococci of 35 cfu/100 mL for each component of the TMDL.

Table 10. TMDL allocation summary for the Carancahua Bay AU 2456_02 watershed.

AU	Segment Name	TMDL	WLA_{WWTF}	WLA_{SW}	LA	FG	MOS
2456_02	Carancahua Bay	947.387	0.032	1.440	898.514	0.032	47.369

Load units expressed as billion cfu/day

Implementation Strategy

This plan documents six management measures to reduce bacteria loads. Management measures were selected based on feasibility, costs, support, and timing. Activities can be implemented in phases based on the needs of the stakeholders, availability of funding, and the progress made in improving water quality.

Adaptive Implementation

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

At annual meetings, the stakeholders will periodically assess progress using the schedule of implementation, interim measurable milestones, water quality data, and the communication plan included in this document. If periodic assessments find that insufficient progress has been made or that implementation activities have improved water quality, the implementation strategy can be adjusted.

Activities and Milestones

To facilitate the development of the Carancahua Bay TMDL I-Plan, the Texas Water Resources Institute (TWRI), under contract with TCEQ, held a series of public meetings in the watershed from August 2017 through July 2018. Collectively, the Carancahua Bay watershed stakeholder group held five meetings to develop this I-Plan. The stakeholder group developed detailed, consensus-based action plans that later became sections of this I-Plan. The planned implementation activities are described in the following section.

Management Measures

The Carancahua Bay I-Plan includes six management measures.

1. *Promote and implement Water Quality Management Plans or conservation plans*
2. *Repair and replace failing OSSFs*
3. *Develop voluntary OSSF inspection program*
4. *Promote feral hog removal*
5. *Promote effective pet waste management*
6. *Restore oyster and coastal wetland habitat*

Management Measure 1

Promote and implement Water Quality Management Plans or conservation plans

Bacteria loadings from grazed lands in the Carancahua Bay watershed are likely to be relatively high compared to other evaluated sources. While the fate and transport of fecal bacteria deposited on upland surfaces is not always certain, livestock may spend substantial time in and around water bodies 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 water bodies. Additionally, these practices can improve cattle health and productivity.

NRCS and 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 operator 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 11 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. Figure 6 provides priority areas for implementing this management measure.

This management measure will develop and implement 70 WQMPs or conservation plans that include practices that benefit water quality. In order to support this management measure, a field technician will be hired to assist operators with developing plans. Field technicians are hired through the local SWCDs and may serve multiple watersheds if necessary. Implementation efforts in the adjacent Lavaca and Tres Palacios watersheds include this measure and efforts to hire a technician will be coordinated as appropriate. Furthermore, the development and delivery of outreach materials to inform landowners and promote participation is required to increase participation rates. The priority areas for this management measure are subwatersheds 1 and 2 (Figure 6). The numbers on the priority area maps in this management measure and subsequent management measures indicate the subwatershed number while color indicates the relative potential loading. The highest priority areas are associated with the highest relative loadings.

Currently, 24 operations in the watershed, covering 5,277 acres, have WQMPs. However, the costs of implementing practices and committing to maintain practices are anticipated barriers that might prevent operators from participating in these programs. Fortunately, several programs are available to provide cost share and other assistance for participation. Increasing awareness of availability and benefit of these programs will be critical to increase adoption.

Table 11. Available best management practices 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

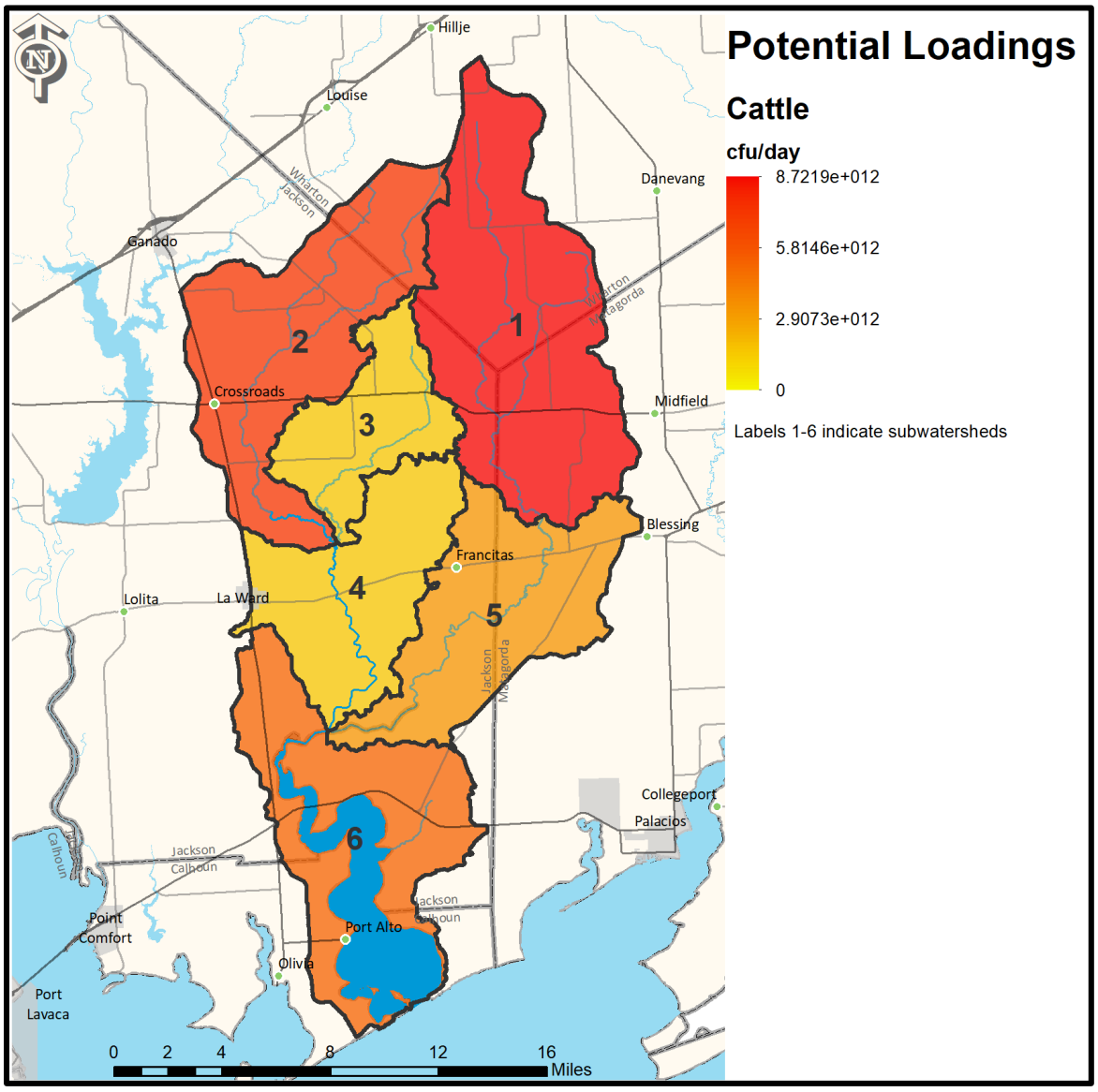

Figure 6. Livestock management measure priority areas based on potential loading.

Responsible Parties and Funding

Each organization listed below will be responsible only for expenses associated with its own efforts.

- **Watershed coordinator** – TWRI will serve as the watershed coordinator for the watershed. The watershed coordinator will work with other responsible parties to develop needed funding resources. The watershed coordinator will work with other entities to organize, develop, and/or deliver education and outreach components of management measure 1.
- **Local stakeholders** – Local stakeholders, specifically landowners and producers, may evaluate the option of adopting WQMPs and conservation plans. If found feasible, the individual stakeholder is responsible for approaching the appropriate agency and working with that agency to develop a WQMP or conservation plan to mitigate operation impacts on water quality. Stakeholders that adopt WQMPs or conservation plans should adhere to the requirements written into their specific plan. Stakeholders may receive assistance from other responsible parties to adopt and implement conservation plans.
- **Texas A&M AgriLife Extension Service** – Texas A&M AgriLife Extension Service (AgriLife Extension) will work with the watershed coordinator in the continued development and delivery of education and outreach programs related to this management measure.
- **Texas State Soil and Water Conservation Board** – The TSSWCB is the lead agency in Texas responsible for planning, implementing, and managing programs and practices for preventing and abating agricultural and silvicultural NPS pollution. The TSSWCB is responsible for administering the certified WQMP program that provides, through SWCDs, cost-share assistance for management practices on agricultural and silvicultural lands; however, not all WQMPs receive financial assistance. The TSSWCB, in collaboration with NRCS and SWCDs, will continue to provide technical assistance to landowners in developing and implementing WQMPs in the watershed.
- **Soil and Water Conservation Districts** – Local SWCDs (Calhoun SWCD #345 Jackson SWCD #336, Matagorda SWCD #316, and Wharton SWCD #342) in collaboration with TSSWCB and NRCS are responsible for providing technical assistance to local stakeholders for the preparation and completion of WQMPs and conservation plans.
- **U.S. Department of Agriculture Natural Resources Conservation Service** – NRCS is responsible for providing conservation planning and technical assistance to landowners, groups, and units of government to develop and implement conservation plans that protect, conserve, and enhance their natural resources. The NRCS, with assistance from local SWCDs, TSSWCB, and the watershed coordinator, will work with local stakeholders to develop and implement conservation plans. The NRCS also administers numerous

Farm Bill Programs authorized by the U.S. Congress that provide financial assistance for many conservation activities. All practices are subject to NRCS technical standards described in the Field Office Technical Guide and adapted for local conditions. The local SWCD approves the conservation plan. Local work groups provide recommendations to NRCS on allocating Environmental Quality Incentives Program (EQIP) county base funds and on resource concerns for other USDA Farm Bill programs. The Carancahua Bay watershed stakeholders are encouraged to participate in local work groups to promote the goals of this I-Plan, as compatible with the resource concerns and conservation priorities for EQIP.

The entities mentioned in this section provide technical and financial assistance for management measure 1, but funding sources for this management measure need not be limited to these entities. The intent of the previously mentioned programs is for the agencies listed under management measure 1 to work with landowners to voluntarily implement WQMPs or conservation plans. Technical assistance to agricultural producers for developing WQMPs and conservation plans is provided through the TSSWCB's WQMP Program, which is funded through state general revenue.

The TSSWCB, SWCDs, and NRCS will continue to provide appropriate levels of cost-share assistance to agricultural producers that will facilitate the implementation of WQMPs or conservation plans in the Carancahua Bay watershed, as described in management measure 1. However, it is anticipated that additional levels of funding will be needed to meet implementation needs. Potential outside sources of funding to assist implementation are outlined below.

- **Conservation Innovation Grants** (CIG) – The CIG is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, EQIP funds are used to award competitive grants to non-federal governmental or nongovernmental organizations, tribes, or individuals.
- **Conservation Stewardship Program** (CSP) – The CSP helps agricultural producers maintain and improve their existing conservation systems and adopt additional conservation activities to address priority resource concerns. Participants earn CSP payments for conservation performance – the higher the performance, the higher the payment.
- **Environmental Quality Incentives Program** – EQIP is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of ten years. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air, and related resources on agricultural

land and non-industrial private forestland. An additional purpose of EQIP is to help producers meet federal, state, tribal, and local environmental regulations.

- **Federal and State Clean Water Act (CWA) §319(h) Grants** (EPA/TCEQ/TSSWCB) – The EPA provides grant funding to Texas to implement the state's approved Nonpoint Source Management Program. The EPA-approved Texas program provides the framework for determining which activities are eligible for funding under CWA Section 319(h). In general, these activities include non-regulatory programs and are related to controlling NPS pollution. EPA-approved NPS programs cover costs associated with technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific NPS projects. This program requires a 40 percent match through local funding or in-kind services.
- **Regional Conservation Partnership Program** (RCPP) – The RCPP is a new, comprehensive, and flexible program that uses partnerships to stretch and multiply conservation investments and reach conservation goals on a regional or watershed scale. Through RCPP, the NRCS and 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.

Estimated Load Reductions

Prescribed management will reduce loadings associated with livestock by reducing runoff from pastures and rangeland as well as reducing direct deposition by livestock. Through this management measure, 70 WQMPs or conservation plans will be developed and implemented in the Carancahua Bay watershed. Implementation of 70 WQMPs and conservation plans is estimated to reduce annual loads from livestock by 3.59×10^{14} cfu Enterococci per year in the Carancahua Bay watershed (Table 12, Appendix A).

Measurable Milestones

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

Years 1-2:

- The TSSWCB, SWCDs, NRCS, and local stakeholders will develop and implement seven WQMPs or conservation plans across the Carancahua Bay watershed in each year.

Year 3:

- The watershed coordinator, TSSWCB, SWCDs, and NRCS will work to secure funding for a regional or watershed field technician to develop WQMPs.

- The TSSWCB, SWCDs, NRCS, and local stakeholders will develop and implement seven additional WQMPs or conservation plans across the Carancahua Bay watershed.
- AgriLife Extension will deliver a Lone Star Healthy Streams grazing management workshop.

Years 4-7:

- The watershed coordinator, TSSWCB, SWCDs, and NRCS will work to secure funding for a regional or watershed field technician to develop WQMPs.
- The TSSWCB, SWCDs, NRCS, and local stakeholders will develop and implement seven additional WQMPs or conservation plans across the Carancahua Bay watershed in each year.

Year 8:

- The watershed coordinator, TSSWCB, SWCDs, and NRCS will work to secure funding for a regional or watershed field technician to develop WQMPs.
- The TSSWCB, SWCDs, NRCS, and local stakeholders will develop and implement seven additional WQMPs or conservation plans across the Carancahua Bay watershed.
- AgriLife Extension will deliver a Lone Star Healthy Streams grazing management workshop.

Years 9-10:

- The watershed coordinator, TSSWCB, SWCDs, and NRCS will work to secure funding for a regional or watershed field technician to develop WQMPs.
- The TSSWCB, SWCDs, NRCS, and local stakeholders will develop and implement seven additional WQMPs or conservation plans across the Carancahua Bay watershed in each year.

Table 12. Management Measure 1: Promote and implement Water Quality Management Plans or conservation plans.

Causes and Sources: Fecal loading from cattle and other livestock in pastures, rangeland, and direct deposition in streams

Potential Load Reduction	Technical and Financial Assistance Needed	Education Component	Schedule of Implementation	Interim, Measurable Milestones	Indicators of Progress	Monitoring Component	Responsible Entities
3.59×10^{14} cfu/year	Technical: A WQMP technician will be needed to provide technical assistance with development of WQMPs. Financial: Significant financial needs are anticipated with an estimated $75,000 per year for a WQMP technician; and an estimated $15,000 to develop, implement, and provide cost share per conservation plan or WQMP.	Education and outreach will be required to demonstrate benefits to producers and their operations. The Lone Star Healthy Streams program will be delivered to livestock producers in the watershed.	Years 1-2: Develop seven plans across the watershed each year Year 3: Develop seven additional plans across the watershed; secure funding for field technician; deliver Lone Star Healthy Streams workshop Years 4-7: Develop seven additional plans across the watershed each year; secure funding for field technician Year 8: Develop seven additional plans across the watershed; secure funding for field technician; deliver Lone Star Healthy Streams workshop Years 9-10: Develop seven additional plans across the watershed each year; secure funding for field technician	Number of WQMP and conservation plans developed. Education and outreach programs delivered.	Funding leveraged for a WQMP technician. Number of plans developed. Amount of funding leveraged for WQMP and conservation plan development and implementation. Number of education and outreach programs delivered.	The watershed coordinator will request reports from TSSWCB, local SWCDs, and NRCS on the number of plans developed and implemented. The watershed coordinator will track grants and other funding applied for. The watershed coordinator will track education and outreach delivered in the watershed.	Watershed coordinator Local stakeholders AgriLife Extension TSSWCB SWCDs NRCS

Management Measure 2

Repair and replace failing OSSFs

Analysis indicate that OSSFs are likely a moderate contributor to potential bacterial loadings across the watershed. There are an estimated 992 OSSFs in the watershed. Nearly all the soils in the watershed are classified "very limited" for OSSF suitability. This indicates that conventional septic tank standard trench bed 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 literature rates estimate that approximately 12 percent of systems are expected to be failing. Improper system design or selection, maintenance, use, and lack of education are likely reasons contributing to OSSF failure (Reed, Stowe, and Yanke, 2001). Local stakeholders agreed with this estimate. 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.

In addition to voluntary inspections (management measure 3), this management measure recommends the replacement of 30 systems by acquiring programmatic resources and funding to replace high priority systems (subwatershed 6) as indicated in Figure 7. Local stakeholders determined the goal of replacing 30 systems based on the feasibility of securing funding among other things.

This management measure will also be used to support Texas' Coastal Nonpoint Source Pollution Control Program by prioritizing systems in the coastal zone boundary that are failing and/or if their system is by nitrogen-limited (N-Limited) waters. A detailed OSSF Geographic Information System-based inventory database was completed by TCEQ in 2017, in support of the Texas Coastal Nonpoint Source Pollution Control Program.

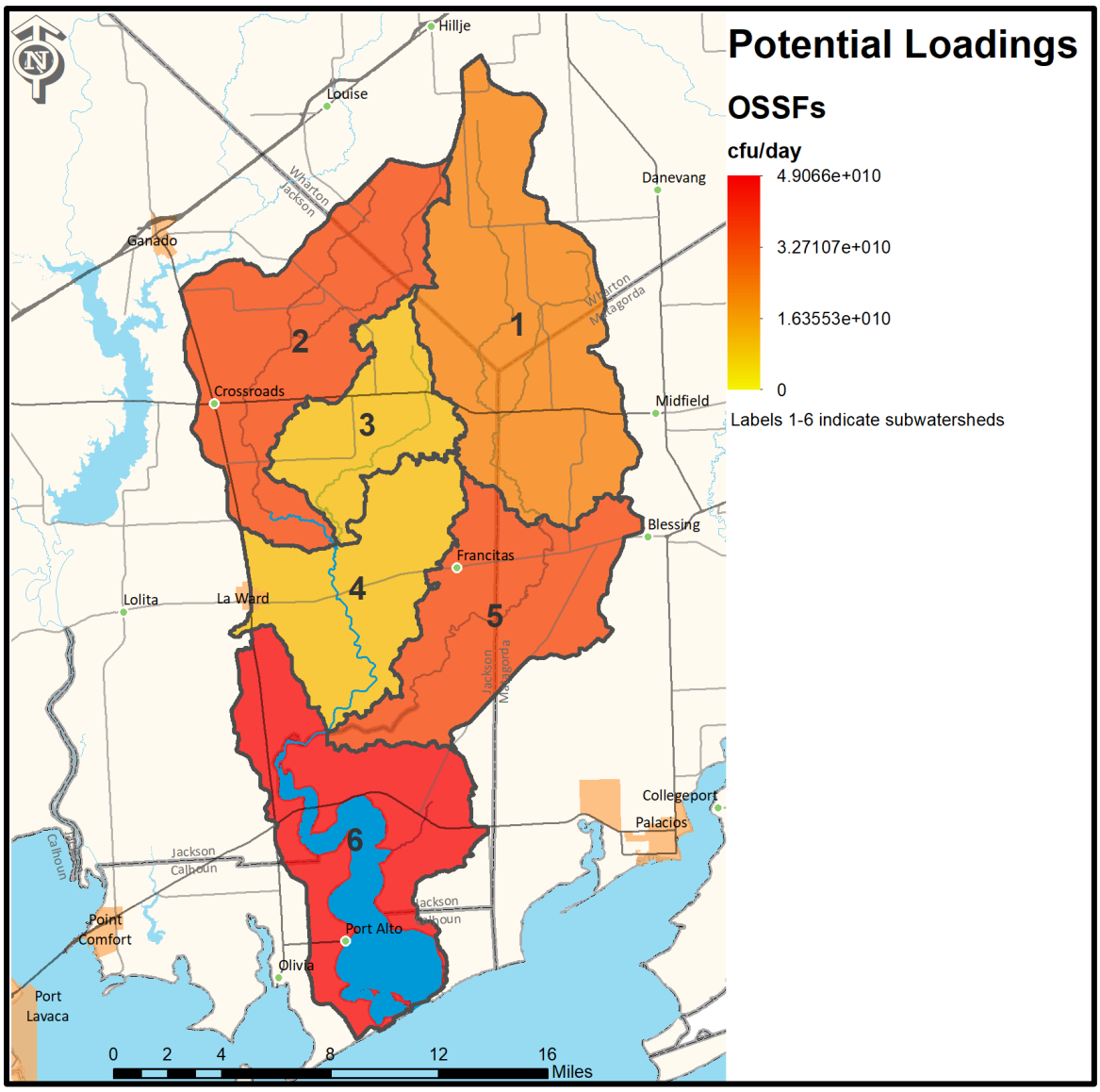

Figure 7. OSSF management measure priority areas based on potential loading.

Responsible Parties and Funding

Each organization listed below will be responsible only for expenses associated with its own efforts.

- **Watershed coordinator** – TWRI will serve as the watershed coordinator for the watershed. The watershed coordinator will work with other responsible parties to develop needed funding resources. The watershed coordinator will work with other entities to organize, develop, and/or deliver education and outreach components of management measure 2.
- **Texas A&M AgriLife Extension Service** – AgriLife Extension will work with the watershed coordinator in the continued development and delivery of education and outreach programs related to this management measure.

- **Local stakeholders** – Local stakeholders, specifically homeowners, are responsible for repairing or replacing faulty OSSFs on their own property. The watershed coordinator will work with local stakeholders and organizations to leverage funding resources where needed to provide cost share if the need is identified.
- **Calhoun County Designated Representative** – OSSF construction or replacement in Calhoun County requires a permit on file with Calhoun County. Permits must be applied for through a TCEQ licensed professional Installer. The County Designated Representative is responsible for approving or denying permits. Site evaluations in Calhoun County must be done by a TCEQ licensed Site & Soil Evaluator, licensed maintenance provider, or licensed professional Installer. The County Designated Representative will work with the watershed coordinator as needed in the identification and development of programmatic needs, such as OSSF repair and replacement programs.
- **Jackson County Office of Septic and Development Permitting** – As an authorized agent of TCEQ, Jackson County is responsible for implementing and enforcing rules pertaining to OSSFs under the Texas Health and Safety Code and Texas Administrative Code. These codes establish minimum standards for the planning, permitting, construction, and maintenance of OSSFs. The office will work with the watershed coordinator as needed in the identification and development of programmatic needs, such as OSSF repair and replacement programs.
- **Matagorda County Designated Representative** – OSSF construction or replacement in Matagorda County requires a permit on file with Matagorda County. Permits must be applied for through a TCEQ licensed professional Installer. The County Designated Representative is responsible for approving or denying permits. Site evaluations in Matagorda County must be done by a TCEQ licensed Site & Soil Evaluator, licensed maintenance provider, or licensed professional Installer. The County Designated Representative will work with the watershed coordinator as needed in the identification and development of programmatic needs, such as OSSF repair and replacement programs.
- **Wharton County Designated Representative** – OSSF construction or replacement in Wharton County requires a permit on file with Wharton County. Permits must be applied for through a TCEQ licensed professional Installer. The County Designated Representative is responsible for approving or denying permits. Site evaluations in Wharton County must be done by a TCEQ licensed Site & Soil Evaluator, licensed maintenance provider, or licensed professional Installer. The County Designated Representative will work with the watershed coordinator as needed in the identification and development of programmatic needs, such as OSSF repair and replacement programs.

The entities mentioned in this section provide technical and/or financial assistance for management measure 2, but funding sources for this management measure need not be limited to these entities. Potential outside sources of funding to assist implementation are outlined below.

- **Federal and State CWA §319(h) Grants (EPA/TCEQ/TSSWCB)** – The EPA provides grant funding to Texas to implement the state's approved Nonpoint Source Management Program. The EPA-approved Texas program provides the framework for determining which activities are eligible for funding under CWA Section 319(h). In general, these activities include non-regulatory programs and are related to controlling NPS pollution. EPA-approved NPS programs cover costs associated with technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific NPS projects. This program requires a 40 percent match through local funding or in-kind services.
- **Texas Coastal Management Program** (CMP) – The CMP, administered by 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. Some of the key elements of the National Coastal Zone Management Program include:
  - Protecting natural resources
  - Managing development in high hazard areas
  - Giving development priority to coastal-dependent uses
  - Providing public access for recreation
  - Coordinating state and federal actions

  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 Texas' CMP. However, CMP funds cannot be used on private property, so funding through this program would only be appropriate for efforts related to OSSF outreach and education in this management measure.
- **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 to entities (such as Resource Conservation and Development Councils) with pre-approved "umbrella" projects.

- **Houston-Galveston Area Council OSSF SEP** – Available in Wharton and Matagorda Counties to repair or replace failing OSSFs. There are income requirements for eligibility.

Estimated Load Reductions

As planned, repair or replacement of 30 failing systems in the Carancahua Bay watershed results in a potential load reduction of 6.91×10^{12} cfu Enterococci per year (Table 13, Appendix A).

Measurable Milestones

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

Years 1-2:

- The watershed coordinator, Jackson County Office of Septic and Development Permitting, Calhoun, Matagorda and Wharton County Designated Representatives, and local stakeholders will coordinate to secure funding and resources to develop an OSSF repair/replacement program.

Year 3:

- The watershed coordinator, Jackson County Office of Septic and Development Permitting, Calhoun, Matagorda and Wharton County Designated Representatives, and local stakeholders will coordinate to secure funding and resources to develop an OSSF repair/replacement program.
- The watershed coordinator and AgriLife Extension will deliver one OSSF Education Workshop.

Years 4-6:

- The watershed coordinator, Jackson County Office of Septic and Development Permitting, Calhoun, Matagorda and Wharton County Designated Representatives, and local stakeholders will coordinate to secure funding and resources to develop an OSSF repair/replacement program.
- Local homeowners, in coordination with appropriate local agencies, will repair or replace five failing OSSFs annually. The watershed coordinator will

coordinate with local stakeholders, AgriLife Extension, and local agencies to leverage funding to provide cost-share assistance where needed.

Year 7:

- The watershed coordinator, Jackson County Office of Septic and Development Permitting, Calhoun, Matagorda and Wharton County Designated Representatives, and local stakeholders will coordinate to secure funding and resources to develop an OSSF repair/replacement program.
- Local homeowners, in coordination with appropriate local agencies, will repair or replace five failing OSSFs. The watershed coordinator will coordinate with local stakeholders, AgriLife Extension, and local agencies to leverage funding to provide cost-share assistance where needed.
- The watershed coordinator and AgriLife Extension will deliver one OSSF Education Workshop.

Years 8-9:

- The watershed coordinator, Jackson County Office of Septic and Development Permitting, Calhoun, Matagorda and Wharton County Designated Representatives, and local stakeholders will coordinate to secure funding and resources to develop an OSSF repair/replacement program.
- Local homeowners, in coordination with appropriate local agencies, will repair or replace four failing OSSFs annually. The watershed coordinator will coordinate with local stakeholders, AgriLife Extension, and local agencies to leverage funding to provide cost-share assistance where needed.

Year 10:

- The watershed coordinator, Jackson County Office of Septic and Development Permitting, Calhoun, Matagorda and Wharton County Designated Representatives, and local stakeholders will coordinate to secure funding and resources to develop an OSSF repair/replacement program.
- Local homeowners, in coordination with appropriate local agencies, will repair or replace two failing OSSFs. The watershed coordinator will coordinate with local stakeholders, AgriLife Extension, and local agencies to leverage funding to provide cost-share assistance where needed.
- The watershed coordinator and AgriLife Extension will deliver one OSSF Education Workshop.

Table 13. Management Measure 2: Repair and replace failing OSSFs.

Causes and Sources: Fecal loading reaching streams from untreated or insufficiently treated household sewage discharged from faulty OSSFs

Potential Load Reduction	Technical and Financial Assistance Needed	Education Component	Schedule of Implementation	Interim, Measurable Milestones	Indicators of Progress	Monitoring Component	Responsible Entity
6.91×10^{12} cfu/year	Technical: Resources/staff to identify and prioritize repair and replacement of failing OSSFs. Financial: Costs incurred for OSSF repair or replacement, estimated at $5,000 to $10,000 per system.	Expanded efforts to develop and deliver OSSF operations and maintenance workshops will be delivered to local stakeholders.	Years 1-2: Secure funding and resources to develop repair and replacement program. Year 3: Secure funding and resources to develop repair and replacement program; deliver OSSF workshop Years 4-6: Secure funding and resources to develop repair and replacement program; repair/replace five failing OSSFs annually Year 7: Secure funding and resources to develop repair and replacement program; deliver OSSF workshop; repair/replace five OSSFs Years 8-9: Secure funding and resources to develop repair and replacement program; repair/replace four OSSFs annually Year 10: Secure funding and resources to develop repair and replacement program; deliver OSSF workshop; repair/replace two failing OSSFs	Number of homeowners attending workshops Number of workshops held Number of OSSFs replaced	Funding leveraged for OSSF repair and replacement program Number of attendees at education and outreach programs Number of education and outreach programs Number of failing OSSFs repaired or replaced	The watershed coordinator will track funding applied for and any OSSFs repaired or replaced. The watershed coordinator will also track education and outreach programming delivered in the watershed.	Watershed coordinator Local Homeowners AgriLife Extension Jackson County Office of Septic and Development Permitting Calhoun, Matagorda, and Wharton County Designated Representatives

Management Measure 3

Develop voluntary OSSF inspection program

There are an estimated 992 OSSFs in the watershed, with an estimated 12 percent failure rate (Reed, Stowe, and Yanke, 2001). Proactive inspection and maintenance of systems is needed to ensure they do not discharge fecal waste to surface water bodies. While newer systems are required to have a permit and maintenance contract on file with the responsible county, an unknown number of older systems operate without routine inspection. In order to encourage inspection and maintenance of systems, a voluntary OSSF inspection program will be implemented. The cost for these inspections should be free or reduced cost for homeowners and include recommendations to homeowners on what needs to be done next. It is anticipated that not all homeowners need to (newer construction for example) or are willing to participate in such a program. Therefore, half the OSSFs (496) in the watershed will be targeted.

Responsible Parties and Funding

Each organization listed below will be responsible only for expenses associated with its own efforts.

- **Watershed coordinator** – TWRI will serve as the watershed coordinator for the watershed. The watershed coordinator will work with other responsible parties to develop needed funding resources. The watershed coordinator will work with other entities to organize, develop, and/or deliver education and outreach components of management measure 3.
- **Texas A&M AgriLife Extension Service** – AgriLife Extension will work with the watershed coordinator in the continued development and delivery of education and outreach programs related to this management measure.
- **Calhoun County Designated Representative** – OSSF construction or replacement in Calhoun County requires a permit on file with Calhoun County. Permits must be applied for through a TCEQ licensed professional Installer. The County Designated Representative is responsible for approving or denying permits. Site evaluations in Calhoun County must be done by a TCEQ licensed Site & Soil Evaluator, licensed maintenance provider, or licensed professional Installer. The County Designated Representative will work with the watershed coordinator as needed in the identification and development of programmatic needs, such as OSSF repair and replacement programs.
- **Jackson County Office of Septic and Development Permitting** – As an authorized agent of TCEQ, Jackson County is responsible for implementing and enforcing rules pertaining to OSSFs under the Texas Health and Safety Code and Texas Administrative Code. These codes establish minimum standards for the planning, permitting, construction, and maintenance of OSSFs. The office will work with the watershed coordinator as needed in the

identification and development of programmatic needs, such as OSSF repair and replacement programs.

- **Matagorda County Designated Representative** – OSSF construction or replacement in Matagorda County requires a permit on file with Matagorda County. Permits must be applied for through a TCEQ licensed professional Installer. The County Designated Representative is responsible for approving or denying permits. Site evaluations in Matagorda County must be done by a TCEQ licensed Site & Soil Evaluator, licensed maintenance provider, or licensed professional Installer. The County Designated Representative will work with the watershed coordinator as needed in the identification and development of programmatic needs, such as OSSF repair and replacement programs.
- **Wharton County Designated Representative** – OSSF construction or replacement in Wharton County requires a permit on file with Wharton County. Permits must be applied for through a TCEQ licensed professional Installer. The County Designated Representative is responsible for approving or denying permits. Site evaluations in Wharton County must be done by a TCEQ licensed Site & Soil Evaluator, licensed maintenance provider, or licensed professional Installer. The County Designated Representative will work with the watershed coordinator as needed in the identification and development of programmatic needs, such as OSSF repair and replacement programs.

The entities mentioned in this section provide technical and/or financial assistance for management measure 3, but funding sources for this management measure need not be limited to these entities. Potential outside sources of funding to assist implementation are outlined below.

- **Federal and State CWA §319(h) Grants (EPA/TCEQ/TSSWCB)** – The EPA provides grant funding to Texas to implement the state's approved Nonpoint Source Management Program. The EPA-approved Texas program provides the framework for determining which activities are eligible for funding under CWA Section 319(h). In general, these activities include non-regulatory programs and are related to controlling NPS pollution. EPA-approved NPS programs cover costs associated with technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific NPS projects. This program requires a 40 percent match through local funding or in-kind services.
- **Supplemental Environmental Projects** – The SEP program, administered by TCEQ, directs fines, fees, and penalties for environmental violations toward environmentally beneficial uses. Through this program, a respondent in an enforcement matter can choose to invest penalty dollars in improving the environment, rather than paying into the Texas General Revenue Fund. Program dollars may be directed to OSSF repair, trash dump clean up, and wildlife habitat restoration or improvement, among other things. Program

dollars may be directed to entities for single, one-time projects that require special approval from TCEQ or directed to entities (such as Resource Conservation and Development Councils) with pre-approved "umbrella" projects.

Estimated Load Reductions

Load reductions were not calculated for this management measure (Table 14). Load reductions resulting from this management measure are highly dependent on actual failure rates determined by inspections and the actions taken by property owners after inspections.

Measurable Milestones

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

Year 5-10:

- County representatives, AgriLife Extension, the watershed coordinator, and county staff will work to develop a Voluntary OSSF Inspection Program.

Table 14. Management Measure 3: Develop voluntary OSSF inspection program.

Causes and Sources: Fecal loading reaching streams from untreated or insufficiently treated household sewage discharged from faulty OSSFs

Potential Load Reduction	Technical and Financial Assistance Needed	Education Component	Schedule of Implementation	Interim, Measurable Milestones	Indicators of Progress	Monitoring Component	Responsible Entity
Not calculated	Technical: Resources/staff to inspect OSSFs Financial: Costs incurred for OSSF inspection, estimated at $400 per system or $198,400 for half the OSSFs in the watershed (496).	Education efforts will be coordinated with management measure 2	Years 5-10: Develop voluntary inspection program.	Program funded and developed	Funding leveraged for OSSF inspection program. Number systems inspected.	The watershed coordinator will track funding applied for and number of OSSFs inspected	Watershed coordinator AgriLife Extension Jackson County Office of Septic and Development Permitting Calhoun, Matagorda, and Wharton County Designated Representatives

Management Measure 4

Promote feral hog removal

Spatial analysis indicated that potential bacteria loadings from feral hogs were moderate compared to other sources. While other sources of potential bacteria loadings were higher, feral hogs demonstrate a preference for the dense habitat, water, and shade provide by riparian areas. Feral hog behavior and habitat preferences suggest a high likelihood for negative impacts on riparian habitat and water quality.

While the complete eradication of feral hogs from the watershed is not feasible, a variety of methods are available to manage or reduce populations. The goal of this management measure is to reduce and maintain feral hog populations 15 percent below current populations through promotion and implementation of feral hog removal and management practices. Stakeholders determined the 15 percent number to be ambitious but attainable if landowners participate in feral hog management. It is estimated that approximately 66 percent of feral hogs need to be harvested on an annual basis to maintain the population (Texas A&M AgriLife Extension, 2012). Based on growth rate estimates, it would be very difficult to remove enough feral hogs to decrease populations much more than 15 percent according to stakeholders.

Trapping animals is likely the most effective method available to landowners for removing large numbers of feral hogs. Hunting 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 provides 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 among 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. Priority areas are subwatersheds 1, 2, and 4 as shown in Figure 8.

Education programs and workshops will be used to improve feral hog removal effectiveness. Currently, AgriLife Extension provides a variety of educational

resources for landowners: http://feralhogs.tamu.edu. Delivering up-to-date information and resources to landowners through workshops and demonstrations is critical to maximizing landowner success in removing feral hogs.

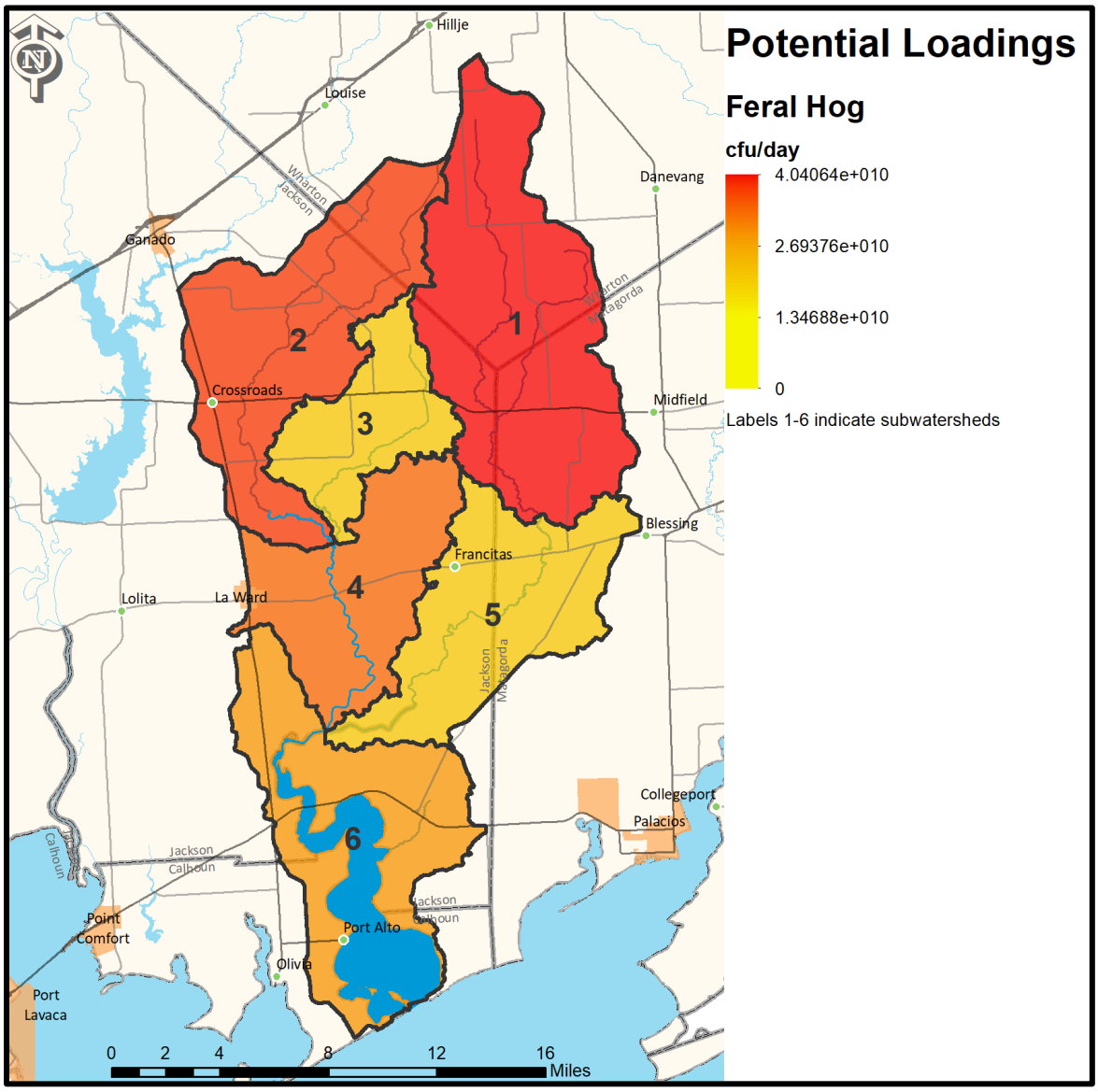

Figure 8. Feral hog management measure priority areas based on potential loading.

Responsible Parties and Funding

Each organization listed below will be responsible only for expenses associated with its own efforts.

- **Watershed coordinator** – TWRI will serve as the watershed coordinator for the watershed. The watershed coordinator will work with other responsible parties to develop needed funding resources. The watershed coordinator will

work with other entities to organize, develop, and/or deliver education and outreach components of management measure 4.

- **Local stakeholders** – Local stakeholders, specifically landowners, will evaluate the option of constructing exclusionary fencing around deer feeders. Landowners will also be responsible for voluntarily trapping, hunting, and removing feral hogs to reduce numbers as feasible. Finally, individual landowners will evaluate the option of developing wildlife habitat management plans or wildlife practices within conservation plans and WQMPs. If found feasible, the individual stakeholder is responsible for approaching the appropriate agency and working with that agency to develop the plan. Stakeholders may receive assistance from other responsible parties to adopt and implement these plans.
- **Texas A&M AgriLife Extension Service** – AgriLife Extension will work with the watershed coordinator in the continued development and delivery of education and outreach programs related to this management measure.

The entities mentioned in this section provide technical and/or financial assistance for management measure 4 but funding sources for this management measure need not be limited to these entities. The intent of the previously mentioned programs is for the agencies listed under management measure 4 to work with landowners to voluntarily implement the measure.

- **Federal and State CWA §319(h) Grants (EPA/TCEQ/TSSWCB)** – The EPA provides grant funding to Texas to implement the state's approved Nonpoint Source Management Program. The EPA-approved Texas program provides the framework for determining which activities are eligible for funding under CWA Section 319(h). In general, these activities include non-regulatory programs and are related to controlling NPS pollution. EPA-approved NPS programs cover costs associated with technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific NPS projects. This program requires a 40 percent match through local funding or in-kind services.

Estimated Load Reductions

Removing and maintaining feral hog populations directly reduces fecal loading potential to water bodies in the watershed. Reducing the population by 15 percent in the Carancahua Bay watershed is estimated to reduce potential annual loads by 8.39×10^{12} cfu Enterococci annually (Table 15, Appendix A).

Measurable Milestones

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

Years 1-2:

- Local stakeholders will trap/hunt/remove feral hogs, with a goal of removing 15 percent or approximately 868 feral hogs annually.
- Local stakeholders will work to install as many feral hog exclosures around deer feeders as is feasible.

Year 3:

- Local stakeholders will trap/hunt/remove feral hogs, with a goal of removing 15 percent or approximately 868 feral hogs annually.
- The watershed coordinator and AgriLife Extension will deliver a feral hog management workshop.
- Local stakeholders will work to install as many feral hog exclosures around deer feeders as is feasible.

Years 4-5:

- Local stakeholders will trap/hunt/remove feral hogs, with a goal of removing 15 percent or approximately 868 feral hogs annually.
- Local stakeholders will work to install as many feral hog exclosures around deer feeders as is feasible.

Year 6:

- Local stakeholders will trap/hunt/remove feral hogs, with a goal of removing 15 percent or approximately 868 feral hogs annually.
- The watershed coordinator and AgriLife Extension will deliver a feral hog management workshop.
- Local stakeholders will work to install as many feral hog exclosures around deer feeders as is feasible.

Years 7-10:

- Local stakeholders will trap/hunt/remove feral hogs, with a goal of removing 15 percent or approximately 868 feral hogs annually.
- Local stakeholders will work to install as many feral hog exclosures around deer feeders as is feasible.

Table 15. Management Measure 4: Promote feral hog removal.

Causes and Sources: Fecal loading from feral hogs directly in streams and in riparian habitats

Potential Load Reduction	Technical and Financial Assistance Needed	Education Component	Schedule of Implementation	Interim, Measurable Milestones	Indicators of Progress	Monitoring Component	Responsible Entity
8.39×10^{12} cfu/year	Technical: Education and outreach workshops will provide landowners and managers with knowledge of available management options. Financial: Estimated at $200 per feral hog exclosure; and $2,500 per feral hog workshop.	Landowners will receive knowledge on available management practices and options for feral hog control through feral hog management workshops conducted by AgriLife Extension in collaboration with other agencies as appropriate.	Years 1-2: Landowners will install feral hog exclosures as feasible; Landowners will trap/hunt/remove feral hogs on site with a goal of a 15 percent population reduction annually. Year 3: Landowners will install feral hog exclosures as feasible; Landowners will trap/hunt/remove feral hogs on site with a goal of a 15 percent population reduction; Watershed coordinator and AgriLife Extension will deliver a feral hog workshop. Years 4-5: Landowners will install feral hog exclosures as feasible; Landowners will trap/hunt/remove feral hogs on site with a goal of a 15 percent population reduction annually.	Number of landowners attending workshops Number of workshops held Estimated number of feral hogs removed	Funding leveraged for education and workshop delivery Number of education and outreach programs delivered Number of individuals reporting feral hogs removed Number of feral hogs removed	Landowners will be requested to report feral hogs trapped and removed to the feral hog tracker and the watershed coordinator. The watershed coordinator will track number of attendees and workshops delivered.	Watershed coordinator Local stakeholders AgriLife Extension

Potential Load Reduction	Technical and Financial Assistance Needed	Education Component	Schedule of Implementation	Interim, Measurable Milestones	Indicators of Progress	Monitoring Component	Responsible Entity
			Year 6: Landowners will install feral hog exclosures as feasible; Landowners will trap/hunt/remove feral hogs on site with a goal of a 15 percent population reduction; Watershed coordinator and AgriLife Extension will deliver a feral hog workshop. Years 7-10: Landowners will install feral hog exclosures as feasible; Landowners will trap/hunt/remove feral hogs on site with a goal of a 15 percent population reduction annually.				

Management Measure 5

Promote effective pet waste management

Pet waste, compared to other sources of fecal bacteria, contains extremely high concentrations of fecal bacteria. Although population densities are low in the watershed, pets can contribute an outsized amount of fecal loadings due to the high density of fecal loads in their waste. Typical methods used to reduce the amount of dog and cat fecal material include education programs and pet waste stations. Due to the low residential density and lack of public parks and other recreation areas in the watershed, deploying pet waste stations is neither feasible nor anticipated to be effective. Therefore, increasing resident and visitor knowledge about the impacts of pet waste on water quality and human health is recommended as the primary method to reduce pet waste loadings.

To increase knowledge and desired behavior, education and outreach materials will be delivered to watershed residents in sub-watershed 6 (Figure 9), as resources are made available. This will include flyers, factsheets, signage, and other outreach materials that are determined to be most effective at reaching area residents.

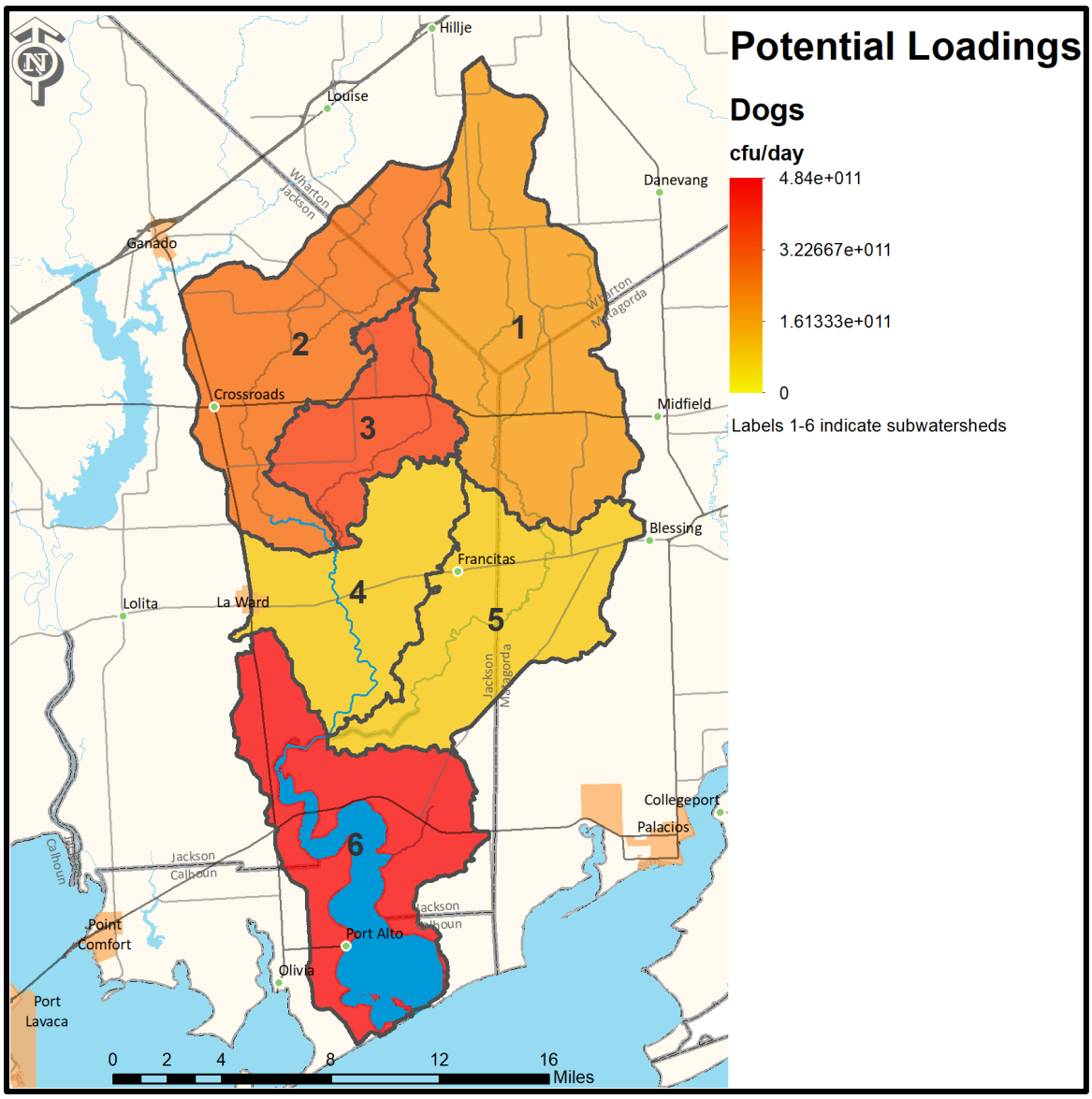

Figure 9. Household pet management measure priority areas based on potential loading.

Responsible Parties and Funding

Each organization listed below will be responsible only for expenses associated with its own efforts.

- **Watershed coordinator** – TWRI will serve as the watershed coordinator for the watershed. The watershed coordinator will work with other responsible parties to develop needed funding resources. The watershed coordinator will work with other entities to organize, develop, and/or deliver education and outreach components of management measure 5.

- **Texas A&M AgriLife Extension Service** – AgriLife Extension will work with the watershed coordinator in the continued development and delivery of education and outreach programs related to this management measure.

The entities mentioned in this section provide technical and/or financial assistance for management measure 5, but funding sources for this management measure need not be limited to these entities. Potential outside sources of funding to assist implementation are outlined below.

- **Federal and State CWA §319(h) Grants** (EPA/TCEQ/TSSWCB) – The EPA provides grant funding to Texas to implement the state's approved Nonpoint Source Management Program. The EPA-approved Texas program provides the framework for determining which activities are eligible for funding under CWA Section 319(h). In general, these activities include non-regulatory programs and are related to controlling NPS pollution. EPA-approved NPS programs cover costs associated with technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific NPS projects. This program requires a 40 percent match through local funding or in-kind services.
- **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. 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.
- **Texas Coastal Management Program** – The CMP, administered 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. Some of the key elements of the National Coastal Zone Management Program include:
  - Protecting natural resources
  - Managing development in high hazard areas
  - Giving development priority to coastal-dependent uses
  - Providing public access for recreation
  - Coordinating state and federal actions

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 Texas' CMP. However, CMP funds cannot be used on private property.

Estimated Load Reductions

Load reductions resulting from this management measure are reliant on changes in people's behavior, and therefore uncertain. Based on previous survey results we assumed that approximately 12 percent of dog owners will adjust behavior based on outreach efforts (Center for Watershed Protection, 1999). Assuming 12 percent of dogs have their waste properly disposed of, an annual load reduction of 1.32×10^{13} cfu Enterococci per year is expected in the Carancahua Bay watershed (Table 16, Appendix A). Although this management measure will be targeted towards cat and dog owners, load reductions were only estimated for reductions in dog waste because of the relative difficulty in managing waste for outdoor cats.

Measurable Milestones

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

Years 4-10:

- The watershed coordinator will coordinate with AgriLife Extension and other stakeholders as appropriate to develop and deliver educational and outreach materials to residents across the watershed.

Table 16. Management Measure 5: Promote effective pet waste management.

Causes and Sources: Direct and indirect fecal loading from improperly disposed pet waste

Potential Load Reduction	Technical and Financial Assistance Needed	Education Component	Schedule of Implementation	Interim, Measurable Milestones	Indicators of Progress	Monitoring Component	Responsible Entity
1.32×10^{13} cfu/year	Technical: Minimal technical assistance needed to develop materials. Sample source materials available from EPA and other watershed projects in the region. Financial: Moderate financial requirements to develop and deliver materials. Estimated at $1,700 per year.	The watershed coordinator will develop and deliver educational materials targeted to local communities in coordination AgriLife Extension and other stakeholders as appropriate.	Years 4-10: Develop and deliver educational and outreach materials to households	Number of educational materials developed and delivered.	Number of educational materials developed and delivered.	The watershed coordinator will track funding resources applied for and obtained. The watershed coordinator will also track the number of educational materials developed and delivered.	Watershed coordinator AgriLife Extension Other stakeholders as appropriate

Management Measure 6

Restore oyster and coastal wetland habitat

As oysters grow, they form rock-like reefs that provide valuable ecosystem services. These structures provide valuable habitat for small fish and invertebrates. Oyster reefs are areas of high biodiversity and support a number of recreational and commercially important fish species. These reefs also help stabilize shoreline, marsh, and bottom habitats in the bay against erosive impacts from wave action, tides, and storm surges. Finally, oysters provide water quality benefits through their natural filtering behavior. A single oyster filters up to 50 gallons per day, removing suspended sediment, particle bound nutrients, and chlorophyll-*a* (Beseres Pollack, Yoskowitz, Kim, & Montagna, 2013; Dame, Zingmark, & Haskin, 1984; Nelson, Leonard, Posey, Alphin, & Mallin, 2004).

Numerous factors have combined to decrease oyster populations, size, and habitat in Carancahua Bay. Notably, recent periods of extreme low and high freshwater inflow created periods of prolonged high and low salinity in the bay, reducing oyster resistance to disease and predators and reducing recruitment of spat (free floating larval oysters) in the bay. Oyster spat require hard-bottomed habitat to attach and grow. Some structures include oyster shells, calcareous rocks, piers, and pilings. In order to increase available habitat and populations of oysters in the bay, bayfront property owners can work with Texas Sea Grant to build community oyster gardens and support living shoreline and reef restoration projects in Carancahua Bay.

Coastal wetlands provide similar services, estimated to value billions of dollars nationally (Pendleton, 2010). Coastal wetlands provide flood protection, erosion control, wildlife habitat, and support commercial fisheries (Costanza et al., 2008; Engle, 2011; Gedan, Kirwan, Wolanski, Barbier, & Silliman, 2011). Coastal wetlands also provide an important role in improving water quality by reducing nitrogen and phosphorus loads (Ardón, Morse, Doyle, & Bernhardt, 2010; Verhoeven, Arheimer, Yin, & Hefting, 2006). Currently, a project is underway to initiate restoration and protection of two miles of Carancahua Bay shorelines and 1,000 acres of habitat in Carancahua Bay. The watershed coordinator will work with stakeholders to support this project and other restoration projects as opportunities are identified.

Stakeholders identified this management measure for inclusion based on the potential for oyster restoration and wetland restoration projects to improve general water quality as noted above. The filtering ability of oysters is anticipated to reduce suspended sediment, increase water clarity, reduce algae, and potentially indirectly reduce bacteria residence times. While the impacts on bacteria are not supported or rejected by the scientific literature, improvements

to general water quality are well supported by the scientific community and noted for inclusion by local stakeholders.

Responsible Parties and Funding

Each organization listed below will be responsible only for expenses associated with its own efforts.

- **Watershed coordinator** – The watershed coordinator will work with other responsible parties to develop needed funding resources. The watershed coordinator will work with other entities to organize, develop, and/or deliver education and outreach components of management measure 6.
- **Texas Sea Grant** – Texas Sea Grant will work with the watershed coordinator in the continued development and delivery of education and outreach programs related to this management measure and work with property owners to secure resources and develop community oyster gardens.
- **Property owners** – Property owners may participate in the program and in the installation and maintenance of community oyster gardens.

The entities mentioned in this section provide technical and/or financial assistance for management measure 6, but funding sources for this management measure need not be limited to these entities. Potential outside sources of funding to assist implementation are outlined below.

- **Federal and State CWA §319(h) Grants** (EPA/TCEQ/TSSWCB) – The EPA provides grant funding to Texas to implement the state's approved Nonpoint Source Management Program. The EPA-approved Texas program provides the framework for determining which activities are eligible for funding under CWA Section 319(h). In general, these activities include non-regulatory programs and are related to controlling NPS pollution. EPA-approved NPS programs cover costs associated with technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific NPS projects. This program requires a 40 percent match through local funding or in-kind services.
- **National Fish and Wildlife Foundation (NFWF) Gulf Environmental Benefit Fund** – The Gulf Environmental Benefit Fund was established as a result of the British Petroleum and Transocean court cases for the Deepwater Horizon oil spill. The plea agreements directed $2.544 billion to NFWF to fund natural resource projects on the Gulf Coast. Over five years, the Gulf Environmental Benefit Fund will direct $203 million for projects on the Texas Gulf Coast.
- **Texas Coastal Management Program** – The CMP, administered by 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. Some of the key elements of the National Coastal Zone Management Program include:

- Protecting natural resources
- Managing development in high hazard areas
- Giving development priority to coastal-dependent uses
- Providing public access for recreation
- Coordinating state and federal actions

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 Texas' CMP. However, CMP funds cannot be used on private property.

Estimated Load Reductions

Improved oyster habitat, increased oyster populations, and increased coastal wetland habitat are likely to have associated water quality benefits (Beseres Pollack, Yoskowitz, Kim, & Montagna, 2013; Dame, Zingmark, & Haskin, 1984; Nelson, Leonard, Posey, Alphin, & Mallin, 2004). However, load reductions are not calculated for this management measure because of substantial uncertainty in population and habitat impact associated with this measure (Table 17).

Measurable Milestones

Years 1-10:

- The watershed coordinator will coordinate with Texas Sea Grant, local property owners, and other entities as appropriate to install community oyster gardens as resources permit.
- The watershed coordinator will coordinate with Texas Sea Grant, local property owners, and other entities as appropriate to support living shoreline, coastal wetland marsh restoration, and oyster reef restoration efforts as resources permit.

Table 17. Management Measure 6: Restore oyster and coastal wetland habitat.

Causes and Sources: Decreased ecosystem resilience resulting from reduced oyster populations

Potential Load Reduction	Technical and Financial Assistance Needed	Education Component	Schedule of Implementation	Interim, Measurable Milestones	Indicators of Progress	Monitoring Component	Responsible Entity
Not calculated	Technical: Technical assistance is available from and will be provided by Texas Sea Grant. Financial: Each community garden is estimated to cost approximately $250 in materials. Costs for individual restoration projects vary substantially and are not estimated.	The watershed coordinator will coordinate with Texas Sea Grant to educate participants on how to install and maintain community oyster gardens.	Years 1-10: Work with stakeholders to create community oyster gardens, support oyster reef restoration, living shorelines, and coastal wetland and marsh restoration	Number of community oyster gardens installed and other restoration efforts.	Funding secured to obtain materials needed for oyster gardens.	The watershed coordinator will track funding resources applied for and obtained. The watershed coordinator will also track the number of oyster gardens installed and other restoration efforts.	Watershed coordinator Texas Sea Grant Property owners

Sustainability

TCEQ, the responsible parties, and other stakeholders in TMDL implementation projects periodically assess the results of the planned activities, along with other information, to evaluate the effectiveness of the I-Plan. Responsible parties and other stakeholders evaluate several factors, such as the pace of implementation, the effectiveness of BMPs, load reductions, and progress toward meeting water quality standards.

The responsible parties and other stakeholders will track progress using both implementation milestones and water quality indicators. These terms are defined as:

- **Water Quality Indicator** – A measure of water quality conditions for comparison to pre-existing conditions, constituent loadings, and water quality standards.
- **Implementation Milestones** – A measure of administrative actions undertaken to affect an improvement in water quality.

Water Quality Indicators

TCEQ and its Clean Rivers Program partner will continue to monitor the status of water quality during implementation as funding and resources allow. Additional funding will be sought by the watershed coordinator to conduct supplemental monitoring in the watershed. The bacteria indicator that will be used to measure improvement in water quality are Enterococci.

Implementation Milestones

Implementation tracking provides information that can be used to determine if progress is being made toward meeting goals of the TMDL. Tracking also allows stakeholders to evaluate actions taken, identify those which may not be working, and make any changes that may be necessary to get the plan back on target.

Schedules of implementation activities and milestones for this I-Plan are included in each management measure section.

Communication Strategy

TCEQ will work with responsible parties and other stakeholders to hold meetings or obtain annual I-Plan updates for up to five years, so stakeholders may evaluate their progress. Responsible parties and stakeholders will continue to provide annual updates and/or take part in any meetings over the five-year period to evaluate implementation efforts. At the completion of the scheduled I-Plan activities, stakeholders will assemble and evaluate the actions, overall impacts, and results of their implementation efforts.

References

Ardón, M., Morse, J. L., Doyle, M. W., & Bernhardt, E. S. 2010. The Water Quality Consequences of Restoring Wetland Hydrology to a Large Agricultural Watershed in the Southeastern Coastal Plain. Ecosystems, 13(7), 1060–1078. <https://doi.org/10.1007/s10021-010-9374-x>

Beseres Pollack, J., Yoskowitz, D., Kim, H. C., & Montagna, P. A. 2013. Role and Value of Nitrogen Regulation Provided by Oysters (*Crassostrea virginica*) in the Mission-Aransas Estuary, Texas, USA. PLoS ONE, 8(6), 6–13. <https://doi.org/10.1371/journal.pone.0065314>

Center for Watershed Protection. 1999. A Survey of Residential Nutrient Behavior in the Chesapeake Bay. Ellicott City, MD. Available online at <https://cfpub.epa.gov/npstbx/files/UNEP_all.pdf>

Costanza, R., Pérez-Maqueo, O., Martinez, M. L., Sutton, P., Anderson, S. J., & Mulder, K. 2008. The Value of Coastal Wetlands for Hurricane Protection. AMBIO: A Journal of the Human Environment, 37(4), 241–248. <https://doi.org/10.1579/0044-7447(2008)37[241:TVOCWF]2.0.CO;2>

Dame, R. F., Zingmark, R. G., & Haskin, E. 1984. Oyster Reefs as Processors of Estuarine Materials. Journal of Experimental Marine Biology and Ecology, 83(3), 239–247. <https://doi.org/10.1016/S0022-0981(84)80003-9>

Engle, V. D. 2011. Estimating the Provision of Ecosystem Eervices by Gulf of Mexico Coastal Wetlands. Wetlands, *31*(1), 179–193. <https://doi.org/10.1007/s13157-010-0132-9>

EPA. 2013. Nonpoint Source Program and Grants Guidelines for States and Territories. <https://www.epa.gov/fedrgstr/EPA-WATER/2003/October/Day-23/w26755.htm>

Gedan, K. B., Kirwan, M. L., Wolanski, E., Barbier, E. B., & Silliman, B. R. 2011. The Present and Future Role of Coastal Wetland Vegetation in Protecting Shorelines: Answering Recent Challenges to the Paradigm. Climatic Change, 106(1), 7–29. <https://doi.org/10.1007/s10584-010-0003-7>

Larkin, T. J., & Bomar, G. W. 1983. Climatic Atlas of Texas. Retrieved May 4, 2017, from Texas Water Development Board: <https://www.twdb.texas.gov/publications/reports/limited_printing/doc/LP192.pdf>

Nelson, K. A., Leonard, L. A., Posey, M. H., Alphin, T. D., & Mallin, M. A. 2004. Using Transplanted Oyster (*Crassostrea virginica*) Beds to Improve Water Quality in Small Tidal Creeks: A Pilot Study. Journal of Experimental Marine Biology and Ecology, 298(2), 347–368. <https://doi.org/10.1016/S0022-0981(03)00367-8>

NOAA, National Centers for Environmental Information. 2017. Monthly Summaries for Palacios Airport. Retrieved May 4, 2017, from <https://www.ncdc.noaa.gov/cdo-web/>

Pendleton, L. 2010. The Economic and Market Value of Coasts and Estuaries: What's at Stake? (L. Pendleton, Ed.). Arlington: Restore America's Estuaries. Retrieved from <https://www.cabdirect.org/abstracts/20103283407.html>

Reed, Stowe, and Yanke, LLC. 2001. Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-site Sewage Facility Systems in Texas. Retrieved May 3, 2017. <https://www.tceq.texas.gov/assets/public/compliance/compliance_support/regulatory/ossf/StudyToDetermine.pdf>

TCEQ. 2007. 2006 Texas Water Quality Inventory and 303(d) List. Retrieved April 24, 2017. <https://www.tceq.texas.gov/waterquality/assessment/06twqi/twqi06.html>

TCEQ. 2018a. 2018 Texas Surface Water Quality Standards. Final 2018 TAC Chapter 307 Rule. Retrieved June 11, 2019. <https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=307&rl=Y>

TCEQ. 2018b. One Total Maximum Daily Load for Indicator Bacteria in Carancahua Bay.

TCEQ. 2019. 2018 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d). Retrieved Sept 10, 2019. <https://www.tceq.texas.gov/waterquality/assessment/18twqi/18txir>

TWDB. 2015. 2016 Approved Regional Water Plans (Regions K, L, and P). November - December 2015. Retrieved on April 20, 2017. <https://www.twdb.texas.gov/waterplanning/rwp/plans/2016/index.asp#region->

Texas A&M AgriLife Extension. 2012. Feral Hog Population Growth, Density and Harvest in Texas. College Station, TX. SP-472. Available online at <https://wildpigs.nri.tamu.edu/media/1155/sp-472-feral-hog-population-growth-density-and-harvest-in-texas-edited.pdf>

USCB. 2017. 2010 Census Block Shapefiles for Calhoun, Jackson, Matagorda, and Wharton counties. Retrieved March 31, 2017. <https://www.census.gov/cgi-bin/geo/shapefiles/index.php>; Tabular data from: 2010 Census Block Households and Families. <factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>

USDA NRCS. 2015. Soil Survey Geographic Database (SSURGO). Retrieved April 11, 2017. <https://catalog.data.gov/dataset/soil-survey-geographic-ssurgo-database-for-various-soil-survey-areas-in-the-united-states->

USGS. 2014. National Land Cover Database 2011 Land Cover (2011 Edition, amended 2014). Retrieved February 28, 2017. <https://www.usgs.gov/core-science-systems/ngp/tnm-delivery/>

Verhoeven, J. T. A., Arheimer, B., Yin, C., & Hefting, M. M. 2006. Regional and Global Concerns Over Wetlands and Water Quality. Trends in Ecology and Evolution, *21*(2), 96–103. <http://doi.org/10.1016/j.tree.2005.11.015>

Appendix A.
Load Reduction Estimates

Load Reduction Estimates

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

Management Measure 1: Promote and implement Water Quality Management Plans or conservation plans

The potential load reduction that can be achieved by implementing conservation practices will depend on the specific BMPs implemented by each landowner, the number of cattle in each operation, existing practices, and existing land condition. The bacteria reduction efficiencies of these BMPs have been estimated in various research efforts and an estimated 62.8 percent average median effectiveness for BMPs likely to be employed in the watershed was assumed (Table A-1).

Table A-1. Livestock management effectiveness.

	Low	High	Median
Exclusionary Fencing[1]	30%	94%	62%
Prescribed Grazing[2]	42%	66%	54%
Watering Facility[3]	51%	94%	72.5%
Average	**41.0%**	**84.7%**	**62.8%**

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

[2] Tate et al. 2004, EPA 2010

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

The total potential load reduction will be strongly influenced by the number of ranchers that participate and the number of cattle that will be impacted. Specific load reduction estimates are simply estimates that will strongly depend on the specific management practices implemented. Based on National Agricultural Statistics Service data, there is an estimated 235 farms within the watershed (USDA National Agricultural Statistics Service, 2014). Using the estimated 14,060 cattle in the watershed, there are an estimated 60 head per farm. One head of cattle is assumed to equal one animal unit (An.U). Daily potential load reduction expected from cattle management practices were then estimated with:

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

The proximity factor is a percentage-based impact factor based on the assumed proximity of the management measures to the water body and estimated at 25 percent. Potential load reductions were calculated assuming that seven farms would adopt conservation measures per year for ten years. The total annual potential load reduction after 70 farms adopted conservation measures was 3.59×10^{14} cfu/year.

Management Measure 2: Repair or replace failing OSSFs

Total load reductions from the replacement of failing OSSF systems depend on the amount of effluent discharged by the system and proximity of the system to a water body. For load reduction calculations, 1.36 people per household, a discharge rate of 70 gal/person day^{-1} (Borel, et. al., 2015), and a fecal coliform (FC) concentration of $1x10^{6}$ cfu/100 mL (EPA, 2001) were assumed. The number of OSSFs needing to be replaced was calculated by taking the total number of OSSFs, 992, and multiplying that number by a 12 percent failure rate (Reed, Stowe, and Yanke, 2001) to get 119 OSSFs. Of those 119 OSSFs, 25 percent will be replaced or 30 total OSSFs. Potential annual load reductions can be calculated as:

$$Potential\ Load\ Reduction = Number\ of\ OSSFs\ replaced \times \frac{1.36\ persons}{household} \times \frac{70\ gal}{person \times day^{-1}} \times \frac{1 \times 10^{6}\ cfu\ fecal\ coliform}{100\ mL} \times 3758.4\ {}^{mL}/_{gal} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli} \times {}^{365\ days}/_{year}$$

Assuming that 30 OSSFs are replaced over ten years, the potential annual load reduction is 6.91×10^{12} cfu/year.

Management Measure 4: Promote feral hog removal

The stakeholders determined 5,785 feral hogs as an appropriate population estimate based on values in nearby watersheds, and an estimated population density of one feral hog per 33.3 acres across all land covers in the watershed except for developed and open water. To estimate load reductions, the number of feral hogs removed (15 percent of the population) was converted to An.U with a conversion factor of 0.125. The assumed FC production rate for feral hogs was 1.21×10^{9} cfu/An.U×day^{-1} (Wagner and Moench, 2009). The conversion rate from FC to *E. coli* was assumed to be $\frac{126}{200}$. The conversion rate from *E. coli* to Enterococci was assumed to be $\frac{35}{126}$. Therefore, the daily potential Enterococci load from feral hogs was calculated as:

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

Reducing the feral hog population by approximately 15 percent would be the equivalent of removing the potential load from 868 feral hogs from the watershed per year. This equates to an annual load reduction of 8.39×10^{12} cfu/year.

Management Measure 5: Promote effective pet waste management

Stakeholders estimated a population of 958 household pets (cats and dogs) in the watershed. This estimate was based on residential 911 addresses and the American Veterinary Medical Association estimated number of dogs (0.584) and cats (0.638) per household (AVMA, 2012). Potential load reductions for pet waste depends on the number of pets that contribute loading and the amount of pet waste that is picked up and disposed of properly. Although this management measure will be targeted towards cat and dog owners, load reductions were only estimated for reductions in dog waste because of the relative difficulty in managing waste for outdoor cats. Assessing the number of dog owners who do not pick up waste or who would change behavior based on education or availability of pet waste stations is inherently difficult. It is estimated that 12 percent of dogs in the watershed will have their waste picked up and disposed of (Center for Watershed Protection, 1999). The assumed FC production rate per animal was 5.0×10^{9} cfu/day (EPA, 2001). The conversion rate from FC to *E. coli* was assumed to be $\frac{126}{200}$. The conversion rate from *E. coli* to Enterococci was assumed to be $\frac{35}{126}$. Daily potential loading from household dogs was calculated as:

$$Potential\ Load\ Reduction = Dogs\ in\ watershed \times 0.12 \times \frac{5.00 \times 10^{9} cfu\ fecal\ coliform}{An.U \times day^{-1}} \times \frac{126\ cfu\ E.coli}{200\ fecal\ coliform} \times \frac{35\ cfu\ Enterococcus}{126\ cfu\ E.coli}$$

The potential annual Enterococci load reduction is 1.32×10^{13} cfu/year.

Appendix A References

AVMA (American Veterinary Medical Association). 2012. In: U.S. Pet Ownership and Demographics Sourcebook (2012 Edition). Retrieved May 1, 2015, from <https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx>

Borel, K., Gregory, L., Karthikeyan, R. 2012. Modeling Support for the Attoyac Bayou Bacteria Assessment Using SELECT. College Station, TX: Texas Water Resources Institute. TR-454. Available online at <https://tinyurl.com/y3y6sr6z>

Brenner, F.J., Mondok, J.J, McDonald, Jr, R.J. 1996. Watershed Restoration Through Changing Agricultural Practices. Proceedings of the AWRA Annual Symposium Watershed Restoration Management: Physical, Chemical and Biological Considerations. Herndon, VA: American Water Resources Association, TPS-96-1, pp. 397-404.

Byers, H.L., Cabrera, M.L., Matthews, M.K., Franklin, D.H., Andrae, J.G., Radcliffe, D.E., McCann, M.A., Kuykendall, H.A., Hoveland, C.S., Calvert II, V.H. 2005. Phosphorus, Sediment, and *Escherichia coli* Loads in Unfenced Streams of the Georgia Piedmont, USA. Journal of Environmental Quality. 34, 2293-2300.

Center for Watershed Protection. 1999. A Survey of Residential Nutrient Behavior in the Chesapeake Bay. Ellicott City, MD. Available online at <https://cfpub.epa.gov/npstbx/files/UNEP_all.pdf>

Cook, M.N. 1998. Impact of Animal Waste Best Management Practices on the Bacteriological Quality of Surface Water. Master's Thesis. Virginia Polytechnic Institute and State University.

EPA. 2001. Protocol for Developing Pathogen TMDLs: Source Assessment. First Edition. EPA Office of Water. 841-R-00-002. Available online at <https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20004QSZ.txt>

EPA. 2010. Implementing Best Management Practices Improves Water Quality. Washington D.C.: EPA Office of Water. 841-F-10-001F.

Hagedorn, C., Robinson, S.L., Filts, J.R., Grubbs, S.M., Angier, T.A., Reneau Jr., R.B. 1999. Determining Sources of Fecal Pollution in a Rural Virginia Watershed with Antibiotic Resistance Patterns in Fecal Streptococci. Applied and Environmental Microbiology. 65, 5522-5531.

Line, D.E. 2002. Changes in Land Use/Management and Water Quality in the Long Creek Watershed. Journal of the American Society of Agronomy. 38, 1691-1701.

Line, D.E. 2003. Changes in a Stream's Physical and Biological Conditions Following Livestock Exclusion. Transactions of the ASAE. 46, 287-293.

Lombardo, L.A., Grabow, G.L., Spooner, J., Line, D.E., Osmond, D.L., Jennings, G.D. 2000. Section 319 Nonpoint Source National Monitoring Program: Successes and Recommendations. NCSU Water Quality Group, Biological and Agricultural Engineering Department, NC State University, Raleigh, North Carolina.

Meals, D.W. 2001. Water Quality Response to Riparian Restoration in an Agricultural Watershed in Vermont, USA. Water Science Technology 43:175-182.

Meals, D.W. 2004. Water Quality Improvements Following Riparian Restoration in Two Vermont Agricultural Watersheds. In Manley, T.O., Manley, P.L., and Mihuc, T.B. (Eds.), Lake Champlain: Partnerships and Research in the New Millennium. New York: Kluwer Academic/Plenum Publishers.

Peterson, J.L., Redmon, L.A., McFarland, M.L. 2011. Reducing Bacteria with Best Management Practices for Livestock: Heavy Use Area Protection. Texas A&M AgriLife Extension Service. ESP-406.

Reed, Stowe, and Yanke, LLC. 2001. Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-site Sewage Facility Systems in Texas. Retrieved May 3, 2017. <https://www.tceq.texas.gov/assets/public/compliance/compliance_support/regulatory/ossf/StudyToDetermine.pdf>

Sheffield, R.E., Mostaghimi, S., Vaughan, D.H., Collins Jr., E.R., Allen, V.G. 1997. Off-stream Water Sources for Grazing Cattle as a Stream Bank Stabilization and Water Quality BMP. Transactions of the ASAE. 40, 595-604.

Tate, K.W., Pereira, M.D.G., Atwill, E.R. 2004. Efficacy of Vegetated Buffer Strips for Retaining *Cryptosporidium parvum*. Journal of Environmental Quality. 33, 2243-2251.

USDA National Agricultural Statistics Service. 2014. Quick Stats (2012 Census). Retrieved January 1, 2018, from <https://quickstats.nass.usda.gov/?source_desc=CENSUS>

Wagner, K. L. and Moench, E. 2009. Education Program for Improved Water Quality in Copano Bay. Task Two Report. College Station, TX: Texas Water Resources Institute. TR-347. Available online at <https://tinyurl.com/y665oe5t>

Appendix B.
Population Projections

TIAER took the following series of steps to complete the population projection exercise:

1. Obtained U.S. Census data at the block level
2. Developed 2010 watershed populations using the block level data for these locations: the portion of the community of La Ward and the four counties of Calhoun, Jackson, Matagorda, and Wharton within the watershed
3. For blocks not entirely within the watershed, a simple fraction of area within the watershed was proportioned
4. Obtained TWDB 2016 Regional Water Plan information to be used for population projections
5. No large cities are in the watershed, only the small community of La Ward and rural areas, which indicates there are no direct TWDB projections for La Ward and other rural areas
6. The TWDB Regional Water Plan does, however, provide projections for a category called "County – Other", which were used to determine growth rates for La Ward and other rural areas
7. "County – Other" projections for Calhoun, Jackson, Matagorda, and Wharton counties were used
8. From the Regional Water Plans, the decadal population projections are available for "County – Other", and decadal percent increases in population were calculated using those projections
9. The decadal percent population increases for each county were applied to the 2010 population for the watershed locations of La Ward and the portions of the four counties in the watershed, and these projections were summed by decade to give the decadal population projections out to 2050