Technical Support Document for Total Maximum Daily Load for Indicator Bacteria in Tres Palacios Creek Tidal

Segment 1501

Assessment Unit 1501_01

Tres Palacios Creek at FM 456

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Segment 1501

Assessment Unit 1501_01

Prepared for
Total Maximum Daily Load Program
Texas Commission on Environmental Quality
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PR1502

October 2017

Acknowledgements

Financial support for this study was provided by the U.S. Environmental Protection Agency and the Texas Commission on Environmental Quality. The lead agency for this study was the Texas Commission on Environmental Quality with the primary contract with the Texas AgriLife Texas Water Resources Institute. The Texas Institute for Applied Environmental Research developed this report as a subaward through the Texas Water Resources Institute.

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Abbreviations and Acronyms

AU	Assessment Unit
CCN	Certificate of Convenience and Necessity
cfs	Cubic Feet per Second
DAR	Drainage Area Ratio
ECHO	Enforcement & Compliance History Online
E. coli	*Escherichia coli*
FDC	Flow Duration Curve
FG	Future Growth
I&I	Inflow and infiltration
I-Plan	Implementation Plan
LA	Load Allocation
LDC	Load Duration Curve
MGD	Million Gallons per Day
mL	Milliliter
MOS	Margin of Safety
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
NEIWPCC	New England Interstate Water Pollution Control Commission
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OSSF	Onsite Sewage Facility
SSO	Sanitary Sewer Overflow
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TIAER	Texas Institute for Applied Environmental Research
TMDL	Total Maximum Daily Load
TNRIS	Texas Natural Resources Information System
TPDES	Texas Pollutant Discharge Elimination System
TWDB	Texas Water Development Board
USCB	United States Census Bureau
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SECTION 1
INTRODUCTION

1.1 Background

Section 303(d) of the federal Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. States must develop a Total Maximum Daily Load (TMDL) for each pollutant that contributes to the impairment of a listed water body. The Texas Commission on Environmental Quality (TCEQ) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

A TMDL is like a budget—it determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time, but may be expressed in other ways. In addition to the TMDL an implementation plan (I-Plan) is developed, which is a description of the regulatory and voluntary management measures necessary to improve water quality and restore full use of the water body.

The TCEQ's TMDL Program is a major component of Texas' overall process for managing the quality of its surface waters. The program addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in, or bordering on, the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses—such as drinking water supply, recreation, support of aquatic life, or fishing—of impaired or threatened water bodies.

The TCEQ first identified the bacteria impairment within Tres Palacios Creek Tidal (Segment 1501) in 2006 and then in each subsequent edition through the 2012 *Texas Water Quality Integrated Report for Clean Water Sections 305(b) and 303 (d)* (formerly called the *Texas Water Quality Inventory and 303(d) List*). Segment 1501 is also listed for bacteria impairment in the 2014 Integrated Report, which was in a draft status at the time of this report. For Tres Palacios Creek Above Tidal (Segment 1502), the bacteria impairment was first identified in 2006, and lastly in 2008. Because Segment 1502 has not been indicated in recent years to be experiencing bacteria impairments, the past impairments are not directly addressed in this report.

This document will, therefore, consider bacteria impairments in 1 water body (segment), consisting of 1 assessment unit (AU): Tres Palacios Creek Tidal (AU 1501_01).

1.2 Water Quality Standards

To protect public health, aquatic life, and development of industries and economies throughout Texas, water quality standards were established by the TCEQ. The water quality standards describe the limits for indicators which are monitored in an effort to assess the quality of available water for specific users. The TCEQ is charged with monitoring and assessing water bodies based on these water quality standards, and publishes the *Texas Water Quality Integrated Report* list biennially.

The *Texas Surface Water Quality Standards* (TCEQ, 2010) are rules that:

- designate the uses, or purposes, for which the state's water bodies should be suitable;
- establish numerical and narrative goals for water quality throughout the state; and
- provide a basis on which TCEQ regulatory programs can establish reasonable methods to implement and attain the state's goals for water quality.

Standards are established to protect designated uses assigned to water bodies of which the primary uses assigned in the Texas Surface Water Quality Standards to water bodies are:

- aquatic life use
- contact recreation
- domestic water supply
- general use

Fecal indicator bacteria are used to assess the risk of illness during contact recreation (e.g., swimming) from ingestion of water. Both *E. coli* (*Escherichia coli*) and Enterococcus spp. are present in the intestinal tracts of humans and other warm blooded animal. The presence of these bacteria in water indicates that associated pathogens from the wastes that may be reaching water bodies as a result of such sources as inadequately treated sewage, improperly managed animal waste from livestock, pets, aquatic birds, wildlife, and failing septic systems (TCEQ, 2006). *E. coli* is widely used as an indicator in freshwater, while Enterococci are more often used as an indicator in high saline inland waters. Enterococci are the relevant indictor for Tres Palacios Creek Tidal (1501).

On June 30, 2010 the TCEQ adopted revisions to the Texas Surface Water Quality Standards (TCEQ, 2010) and on June 29, 2011 the U.S. Environmental Protection Agency (EPA) approved the categorical levels of recreational use and their associated criteria. For saltwater, recreational use consists of three categories:

- Primary contact recreation is that with a significant risk of ingestion of water (such as swimming), and has a geometric mean criterion for Enterococci of 35 most probable number (MPN) per 100 mL and a single sample criterion of 104 MPN per 100 mL;
- Secondary contact recreation 1 covers activities with limited body contact and a less significant risk of ingestion of water (such as fishing), and has a geometric mean criterion for Enterococci of 175 per 100 mL;
- Noncontact recreation is that with no significant risk of ingestion of water, where contact recreation should not occur due to unsafe conditions. It has a geometric mean criterion for Enterococci of 350 per 100 mL.

The impaired assessment unit Tres Palacios Creek Tidal (1501_01) is approved for primary contact recreation, and since it is considered a saltwater water body, the associated Enterococci geometric mean criterion of a 35 MPN per 100 mL and single sample of 104 MPN per 100 mL is applied.

1.3 Report Purpose and Organization

The TMDL project for the watershed of Tres Palacios Creek Tidal was initiated through a contract between the TCEQ and the Texas Water Resources Institute (TWRI) with the Texas Institute for Applied Environmental Research (TIAER) as a subaward recipient to TWRI. The activities of this project to be performed by TIAER were to (1) acquire existing (historical) data and information necessary to support assessment activities; (2) perform the appropriate activities necessary to allocate Enterococci loadings; and (3) assist the TCEQ and TWRI in preparing the TMDL.

Using historical bacteria and flow data, this portion of the project was to: (1) review the characteristics of the watershed and explore the potential sources of Enterococci bacteria for the impaired segment; (2) develop an appropriate tool for development of a bacteria TMDL for the impaired segment; and (3) submit the draft and final technical support document for the impaired segment. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDL for the Tres Palacios Creek Tidal watershed. This report contains:

- information on historical data,
- watershed properties and characteristics,
- summary of historical bacteria data that confirm the State of Texas 303(d) listings of impairment due to presence of indicator bacteria (Enterococci),
- development of load duration curves, and
- application of the load duration curve approach for the pollutant load allocation process.

SECTION 2
WATERSHED OVERVIEW AND DATA REVIEW

2.1 Description of Study Area

Tres Palacios Creek, located along the Texas Gulf Coast midway between the cities of Victoria and Houston, is comprised of two segments – the upstream segment is designated as "Above Tidal (Segment 1502)" and the downstream segment is designated as simply "Tidal (Segment 1501)" (Figure 1). The above tidal portion of the creek is a perennial freshwater stream, while the below tidal portion is influenced by seawater from Tres Palacios Bay. For the purposes of this study, the entire watershed of Tres Palacios Creek is considered in this overview section. However, the focus will be on the water body with bacteria impairments – the most downstream segment and its AU, Tres Palacios Creek Tidal (1501_01).

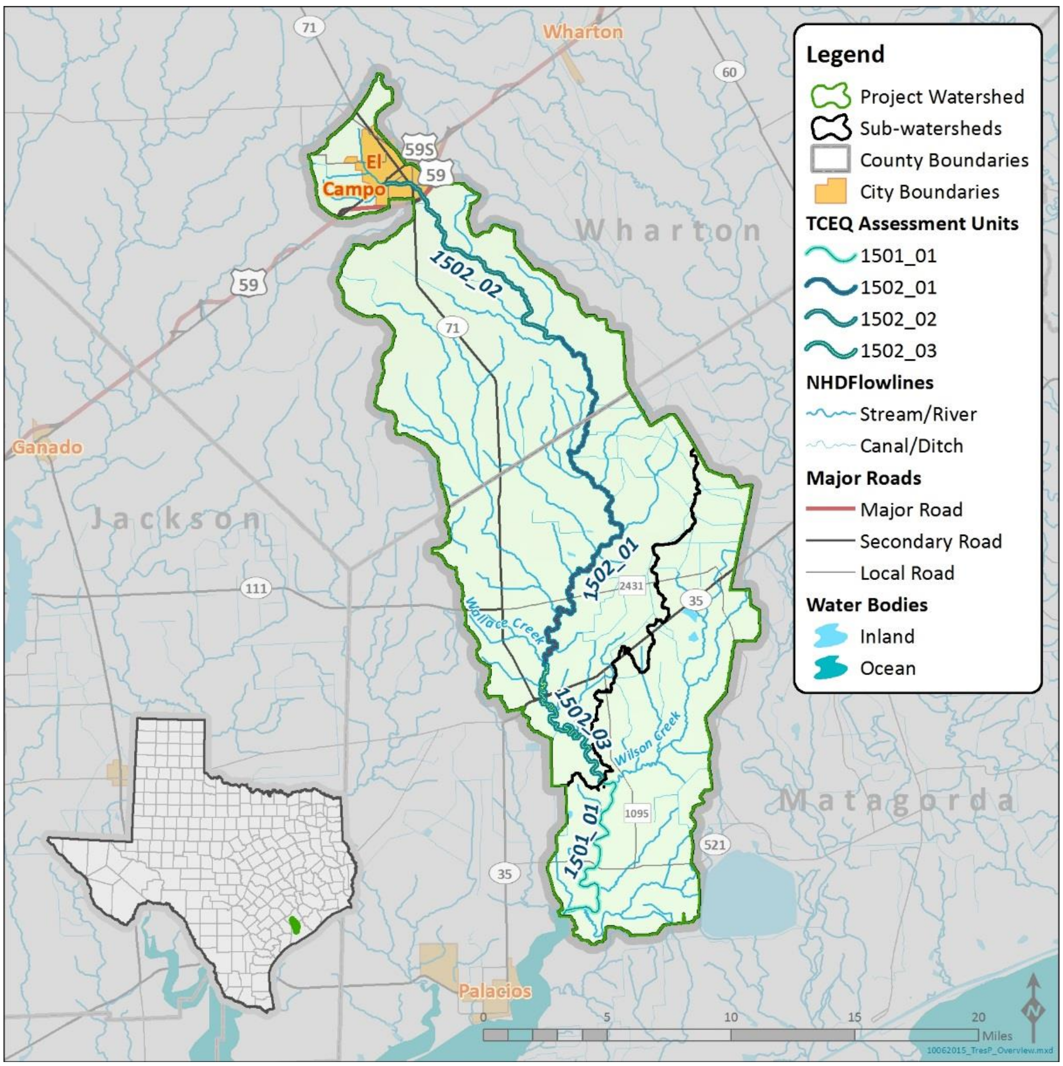

Figure 1. Overview map showing the Tres Palacios Creek AUs and watershed.

Sources: Assessment Units (TCEQ, 2011)

Tres Palacios Creek Above Tidal (Segment 1502) flows from the crossing of US 59 in Wharton County to a point 1.0 km (0.6 miles) upstream of the confluence of Wilson Creek in Matagorda County, where Tres Palacios Creek Tidal (Segment 1501) begins and flows to the outlet into Tres Palacios Bay (TCEQ, 2012a). At its mouth, Tres Palacios Creek drains 268.5 square miles (171,816 acres) in Wharton (64% of the watershed) and Matagorda (36% of the watershed) counties.

The 2012 Texas Integrated Report (TCEQ, 2012a) provides the following Segment and AU descriptions for the water bodies considered in this document:

- SegID: 1501 Tres Palacios Creek Tidal

  From the confluence with Tres Palacios Bay in Matagorda County to a point 1.0 km (0.6 miles) upstream of the confluence of Wilson creek in Matagorda County

  Segment Type: Tidal Stream

  - *AU_ID: 1501_01 - From the confluence with Willow Dam Creek at Tres Palacios Bay/Turtle Bay upstream to a point 1.0 km (0.6 miles) upstream of the confluence of Wilson creek in Matagorda County*
- SegID: 1502 Tres Palacios Creek Above Tidal

  From a point 1.0 km (0.6 miles) upstream of the confluence of Wilson Creek in Matagorda County to State Route 525 (Old US59) in Wharton County

  Segment Type: Freshwater Stream

  - *AU_ID: 1502_01 - Middle portion of segment from the confluence with Wallace Creek upstream to confluence with unnamed tributary with NHD RC 12100401013089 about 1.0 km SW of intersection of FM 418 and FM 422 NE of City of Danevang in Wharton County*
  - *AU_ID: 1502_02 - Upper portion of segment from the confluence with unnamed tributary about 1.0 km SW of intersection of 418 and 422 NE of City of Danevang in Wharton County upstream to US 59*
  - *AU_ID: 1502_03 - Lower portion of segment from a point 1.0 km (0.6 miles) upstream of the confluence of Wilson Creek upstream to confluence with Wallace Creek Matagorda County*

2.2 Watershed Climate and Hydrology

The Tres Palacios Creek watershed is located in the eastern portion of the state of Texas, where the climate is classified as "Subtropical Humid" (Larkin & Bomar, 1983). The region's subtropical climate is caused by the "predominant onshore flow of tropical maritime air from the Gulf of Mexico," while the increasing moisture content (from west to east) reflects variations in "intermittent seasonal intrusions of continental air" (Larkin & Bomar, 1983). For the period from 1981 to 2010, average annual precipitation over the Tres Palacios Creek watershed was 46 inches (PRISM Climate Group at Oregon State University, 2012) (Figure 2).

At the Danevang 1W weather station, located near the center of the watershed, the average high temperatures generally reach their peak of 93.5°F in August, and highs above 100°F can occur in June, July and August. Fair skies generally accompany the highest temperatures of summer when nightly average lows drop to about 72°F (NOAA, 2015b). During winter, the average low temperature bottoms out at 41.5°F in January (NOAA, 2015b). The frost-free period in the region generally lasts for about 292 days, with the average last frost occurring February

23rd and the average first frost occurring on December 12th (SRCC, 1994). In Danevang, the wettest month is normally September (5.1 inches), and the driest month is normally February (2.8 inches), although rainfall typically occurs year-round (NOAA, 2015b) (Figure 3).

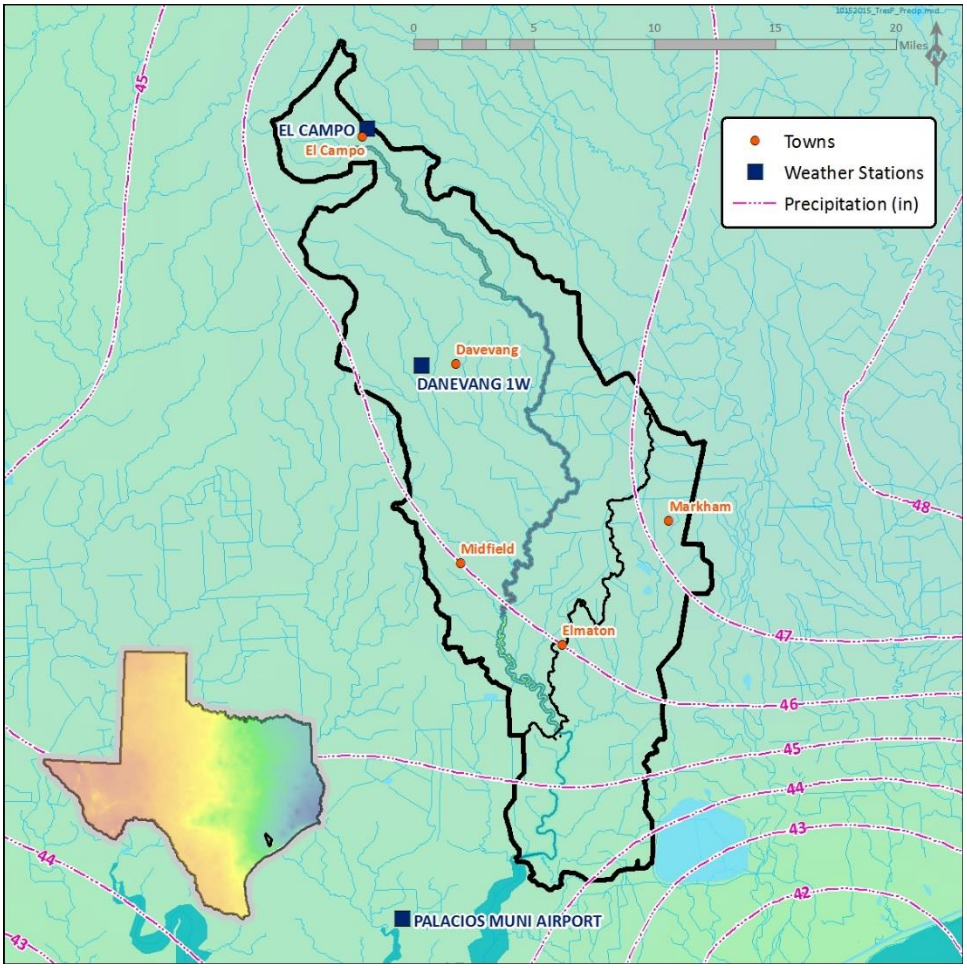

Figure 2. Annual average precipitation isohyets (in inches) in the Tres Palacios Creek watershed (1981-2010). Towns within the watershed, as well as the area NCDC weather stations, are shown.

Source: PRISM Climate Group at Oregon State University (2012)

2.3 Watershed Population and Population Projections

According to the 2010 Census, there were an estimated 14,663 people in the Tres Palacios Creek watershed, indicating an average population density of approximately 55 people/ square mile (or 1 person/ 11.7 acres). Of those, an estimated 9,547 people (65%) are located within the city of El Campo, indicating that the watershed population is mostly urban, even though only 2% of the area of that watershed is within the city limits of El Campo (Figure 4 and Table 1).

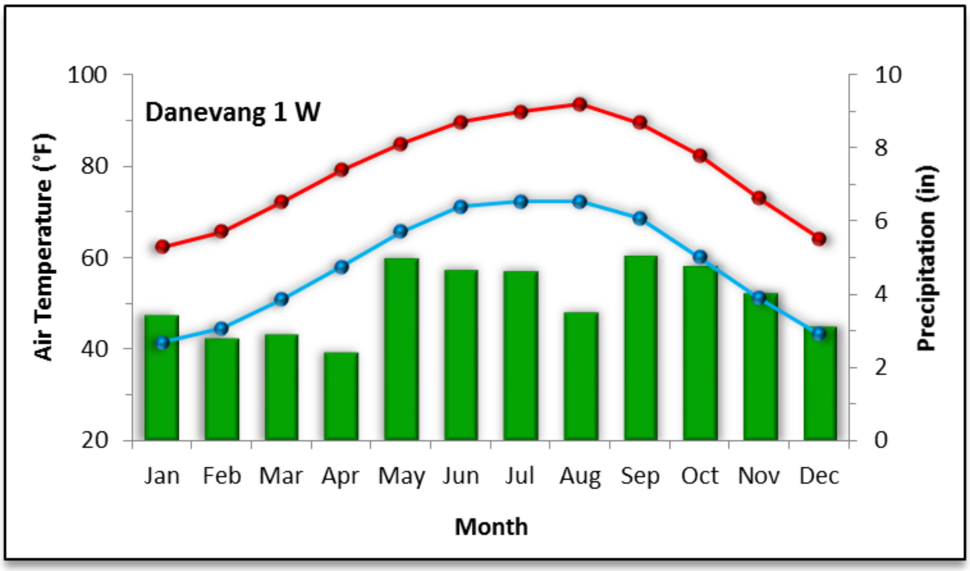

Figure 3. Average minimum and maximum air temperatures and total precipitation by month over 1981-2010 for the Danevang area.

Source: (NOAA, 2015b)

Calculations based on population projections developed by the Office of the State Demographer and the Texas Water Development Board (TWDB, 2014) indicate that, between 2010 and 2050, the populations of Matagorda and Wharton counties are expected to increase by 18.7% and 23.1%, respectively. Estimates for the Tres Palacios Creek watershed, refined by Water User Group (WUG), range from 17.3% to 22.5% (

Table **2**).

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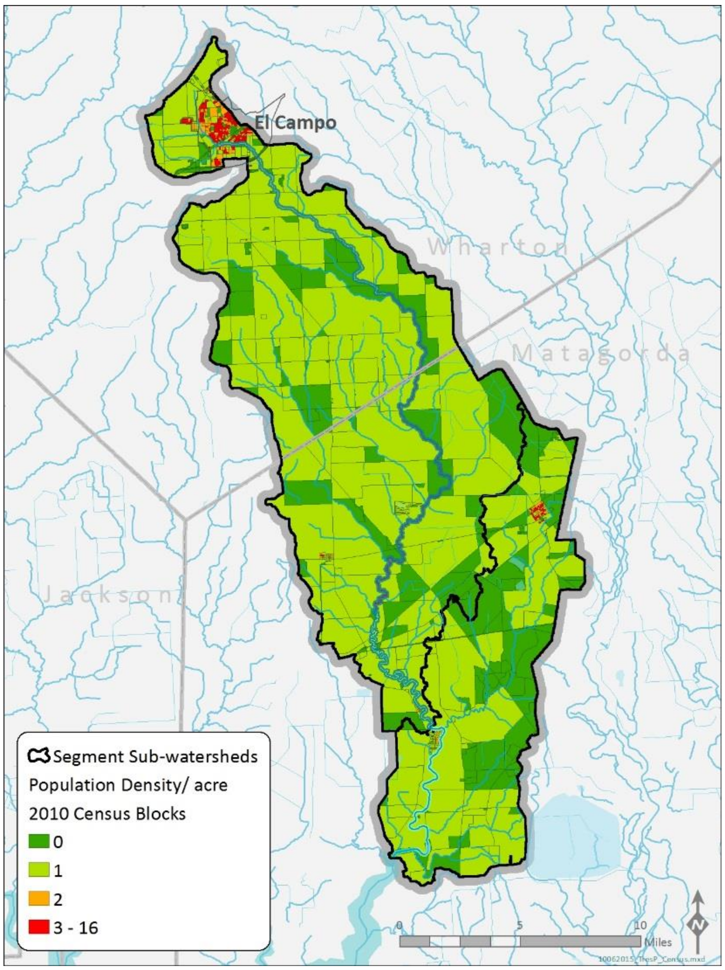

Figure 4. 2010 Total Population by Census Block.

Sources: StratMap city boundaries (TNRIS, 2012), Census Blocks (USCB, 2010)

Table 1. 2010 Population for the Tres Palacios Creek watershed.

Source: Calculated from Census Blocks (USCB, 2010)

Watershed	Segment	2010 Census Population
Tres Palacios Creek	Tidal (1501)	1,788
	Above Tidal (1502)	12,875

Watershed	Segment	2010 Census Population
	Total	**14,663**

Table 2. 2010 Population and 2020-2050 Population Projections for Water User Groups in the Tres Palacios Creek watershed.

Source: Calculated from 2016 Regional and 2017 State Water Plan Projections Data (TWDB, 2014)

Water User Group (WUG)	2010 U.S. Census	2020 Population Projection	2030 Population Projection	2040 Population Projection	2050 Population Projection	Percent Increase (2010 - 2050)
El Campo (in Wharton County)	9,544	10,470	10,959	11,350	11,688	22.46%
Wharton County - Other	2,189	2,250	2,418	2,552	2,669	21.93%
Matagorda County - Other	2,930	3,090	3,252	3,357	3,437	17.30%
Total	**14,663**	**15,810**	**16,629**	**17,259**	**17,794**	**21.33%**

2.4 Review of Tres Palacios Creek Watershed Routine Monitoring Data

2.4.1 Data Acquisition

Ambient *E. coli* and Enterococci data were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) on 30 September 2014. The data represented all the historical routine ambient bacteria and other water quality data collected in the project area, and included bacteria data collected in the Tres Palacios Creek watershed for the entire period of record. General assessment criteria methodologies established by TCEQ were used in data evaluations.

2.4.2 Analysis of Bacteria Data

Recent environmental bacteria monitoring in AU 1501_01 has occurred at two TCEQ monitoring stations within the watershed – 12515 and 20636 (Table 3 and Figure 5). Enterococci data collected at these stations over the seven-year period of 1 December 2003 through 30 November 2010 were used in assessing attainment of the primary contact recreation use as reported in the 2012 Texas Integrated Report (TCEQ, 2012a). The 2012 assessment data indicate non-support of the primary contact recreation use because geometric mean concentrations exceed the geometric mean criteria of 35 MPN/100 mL for Enterococci.

Table 3. 2012 Integrated Report Summary for the Impaired AU. (The geometric mean criterion for primary contact recreation use is 35 MPN/100 mL for Enterococci.)

Source: (TCEQ, 2012a)

Water Body	Segment Number	Assessment Unit (AU)	Parameter	Data Date Range	Stations	No. of Samples	Station Geometric Mean (MPN/100 mL)
Tres Palacios Creek Tidal	1501	1501_01	Enterococcus	12/2003 - 11/2010	12515	57	70
					20636	8	188
					Total	**65**	**79**

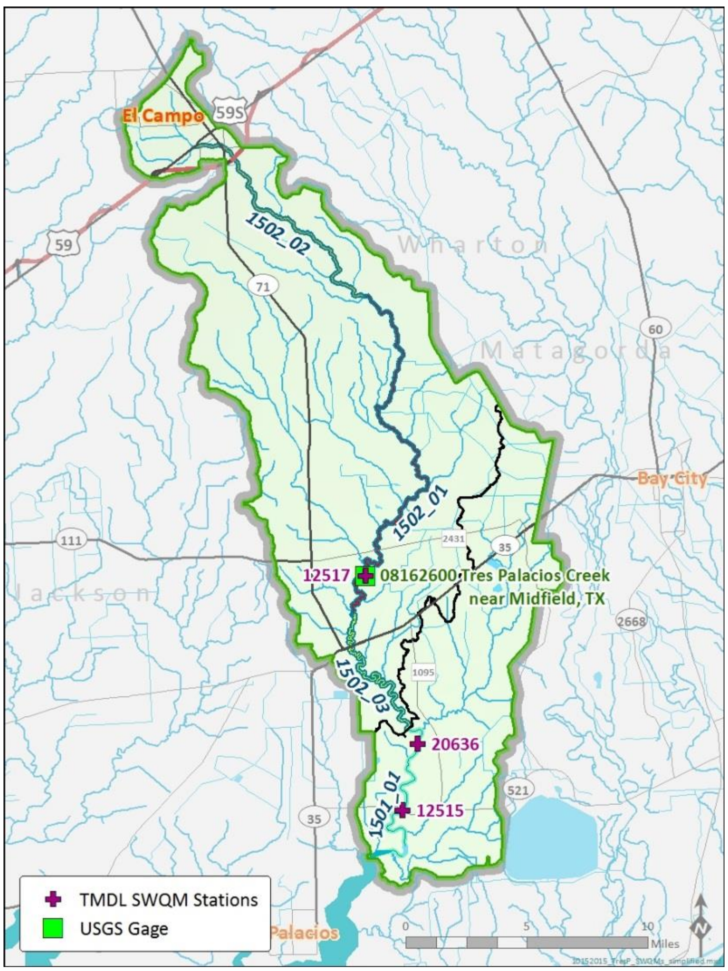

Figure 5. Tres Palacios Creek watershed showing selected TCEQ surface water quality monitoring (SWQM) stations and the USGS stream gage station for the Tres Palacios Creek.

Source: (TCEQ, 2014a)

2.5 Water Rights Review

Surface water rights in Texas are overseen by the TCEQ. A search of the TCEQ water rights database files (TCEQ, 2014d) revealed that, within the Tres Palacios Creek watershed, there are an estimated 16 surface water rights with counterparts in the Water Rights GIS coverage (TCEQ, 2014b), authorizing the diversion of 25,450 acre-feet annually. Fifteen of the water rights have an “Irrigation” use code, and one has the use codes of “Recreation”, “Domestic & Livestock Only” and “Other” with the remark “FILL RESERVOIR COMPLEX.” A review of water rights water use data files (TCEQ, 2014d) indicates that 10 of the 16 water users diverted an average of approximately 10,647 acre-feet annually (with the reminder reporting zero flows) from 1990-2013. Of this, 9,834 acre-feet were diverted downstream of the USGS gage, indicating that 813 acre-feet were diverted upstream of the USGS streamflow gage. The diversion locations relative to the USGS streamflow gage location has importance in the development of pollutant load allocation, which is discussed in detail in Sections 4 and 5.

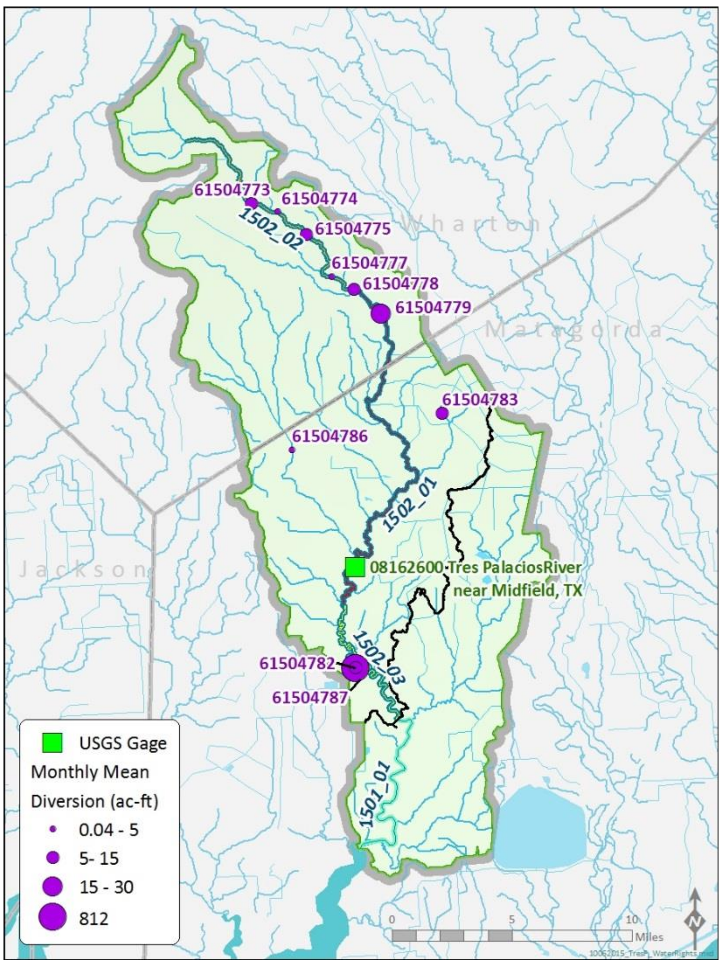

Figure 6. Monthly average diversion amounts over the period 1990- 2013 for surface water rights within the Tres Palacios Creek watershed, shown in relation to the USGS stream gage station. Water right diversion points are labeled by TCEQ water rights ID number.

Source: Surface Water Rights (TCEQ, 2014b)

2.6 Land Use

The land use/land cover data for the Tres Palacios Creek watershed was obtained from the U.S. Geological Survey 2011 National Land Cover Database (NLCD) and is displayed in Figure 7.

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

- *Open Water - areas of open water, generally with less than 25% cover of vegetation or soil.*
- *Developed, Open Space - areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% 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 - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.*
- *Developed, Medium Intensity - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.*
- *Developed High Intensity - 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% to 100% of the total cover.*
- *Barren Land (Rock/Sand/Clay) - 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% of total cover.*
- *Deciduous Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.*
- *Evergreen Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.*
- *Mixed Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.*
- *Shrub/Scrub - areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% 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 gramanoid or herbaceous vegetation, generally greater than 80% 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% of total vegetation.*

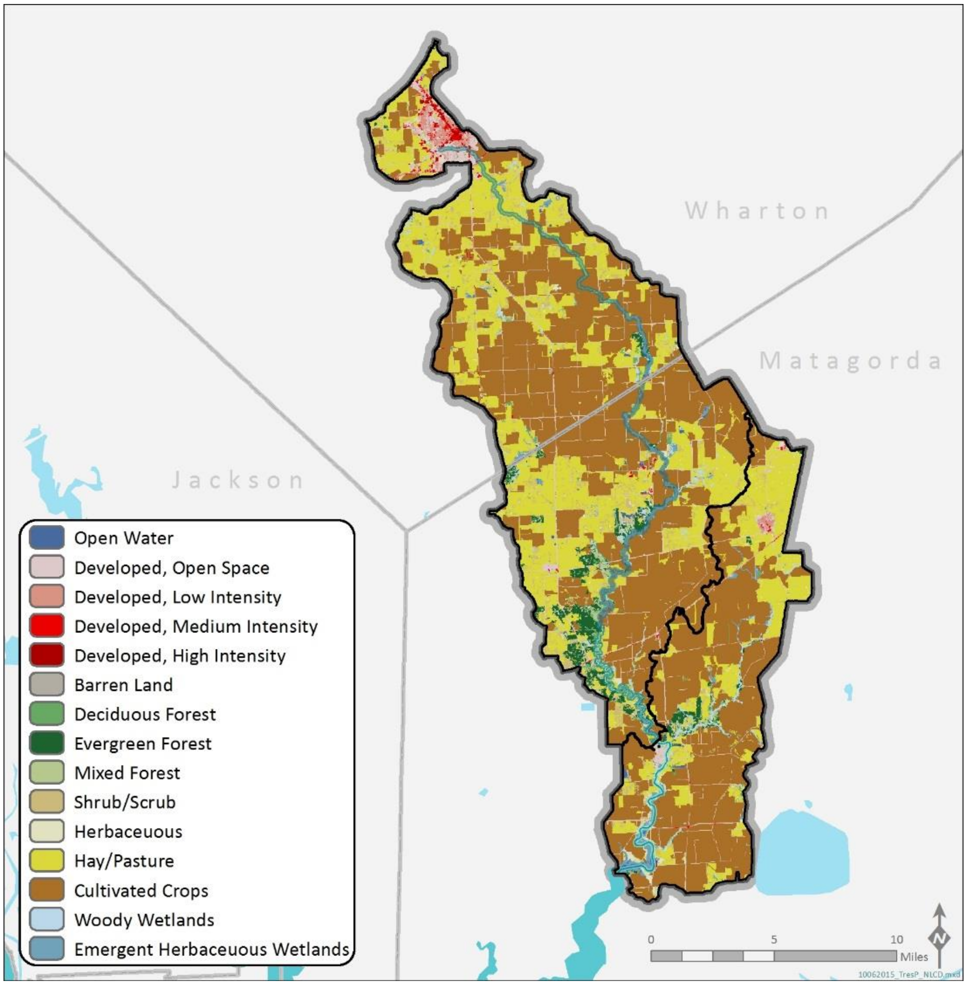

Figure 7. 2011 NLCD land use/ land cover within the Tres Palacios Creek watershed.

Source: (USGS, 2014)

- *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% of total vegetation. This class also includes all land being actively tilled.*
- *Woody Wetlands - areas where forest or shrubland vegetation accounts for greater than 20% 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% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.*

Table 4. Land use / land cover within the Tres Palacios Creek watershed.

Source: (USGS, 2014)

2011 NLCD	Tres Palacios Creek Tidal (1501)		Tres Palacios Creek Above Tidal (1502)		Tres Palacios Creek Watershed Total	
Classification	**mi²**	**% of Total**	**mi²**	**% of Total**	**mi²**	**% of Total**
Open Water	1.0	1.2%	0.5	0.3%	1.5	0.6%
Developed, Open Space	2.7	3.5%	9.0	4.8%	11.8	4.4%
Developed, Low Intensity	0.8	1.0%	2.2	1.2%	3.0	1.1%
Developed, Medium Intensity	0.1	0.1%	1.0	0.5%	1.1	0.4%
Developed, High Intensity	0.0	0.0%	0.4	0.2%	0.4	0.1%
Barren Land	0.1	0.1%	0.1	0.1%	0.2	0.1%
Deciduous Forest	0.6	0.8%	2.2	1.2%	2.8	1.0%
Evergreen Forest	1.1	1.4%	4.8	2.5%	5.8	2.2%
Mixed Forest	0.5	0.7%	1.8	0.9%	2.3	0.8%
Shrub/Scrub	1.8	2.3%	8.3	4.4%	10.1	3.8%
Herbaceous	1.4	1.7%	1.7	0.9%	3.0	1.1%
Hay/Pasture	18.8	23.9%	59.8	31.5%	78.6	29.3%
Cultivated Crops	47.0	59.8%	93.8	49.4%	140.9	52.5%
Woody Wetlands	1.2	1.5%	3.4	1.8%	4.6	1.7%
Emergent Herbaceous Wetlands	1.5	1.9%	0.9	0.5%	2.4	0.9%
Total	**78.6**	***100%***	**189.9**	***100%***	**268.5**	***100%***

As displayed in

Table **4**, the dominant land use in the watershed area encompassing both the Tidal and Above Tidal segments of Tres Palacios Creek is Cultivated Crops (52.5%) followed by Hay/Pasture (29.3%). The watershed is predominantly rural in land-use, as only approximately 6% of the area is classified as Developed (open space, low intensity, medium intensity and high intensity).

Analysis of the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Cropland Data Layer for 2014 indicates that the agricultural crops that covered the most area in the watershed include cotton (11.1% of the watershed), corn (9.6%), and sorghum (6.0%). The agricultural land cover data for the Tres Palacios Creek watershed is shown in Figure 8.

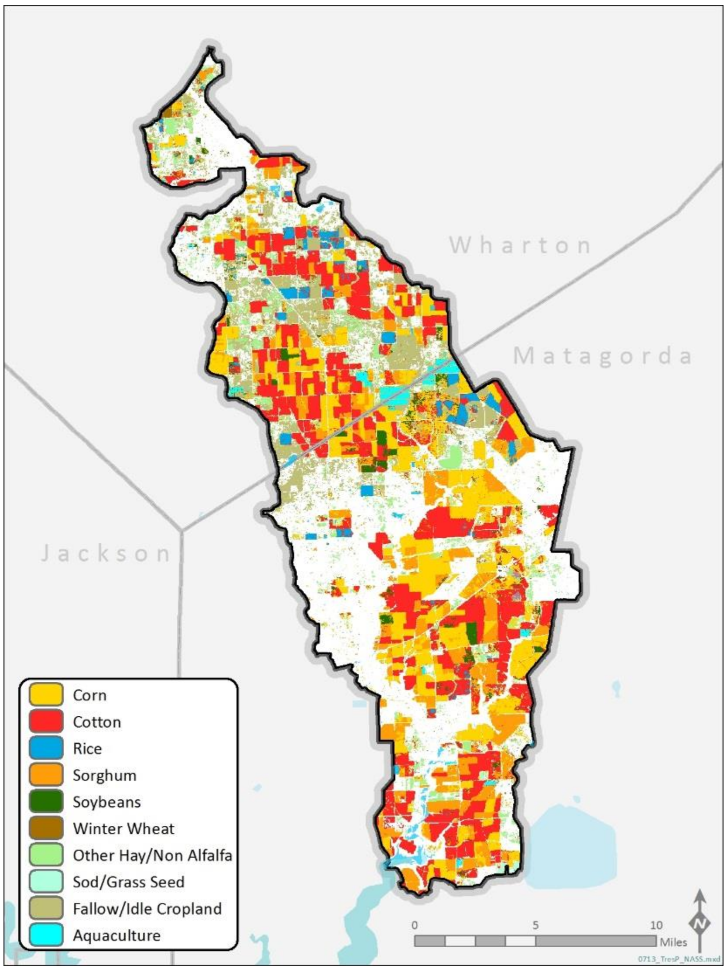

Figure 8. 2014 agricultural land cover within the Tres Palacios watershed.

Source: (USDA NASS, 2014a)

2.7 Soils

Soils within the Tres Palacios Creek watershed, categorized by their Hydrologic Soil Group, are shown in Figure 9. These data were obtained through the USDA Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database (NRCS, 2013). Within the Tres Palacios Creek watershed, approximately 98% of the soils are classified in Hydrologic Soil Group

D, and therefore have the following characteristics: a high runoff potential when thoroughly wet, restricted water movement though the soil, and a high shrink-swell potential (NRCS, 2007). Along portions of the Tres Palacios Creek Tidal segment (1501_01) occur soils classified within Hydrologic Soil Group C; these soils have a moderately high runoff potential when thoroughly wet (NRCS, 2007).

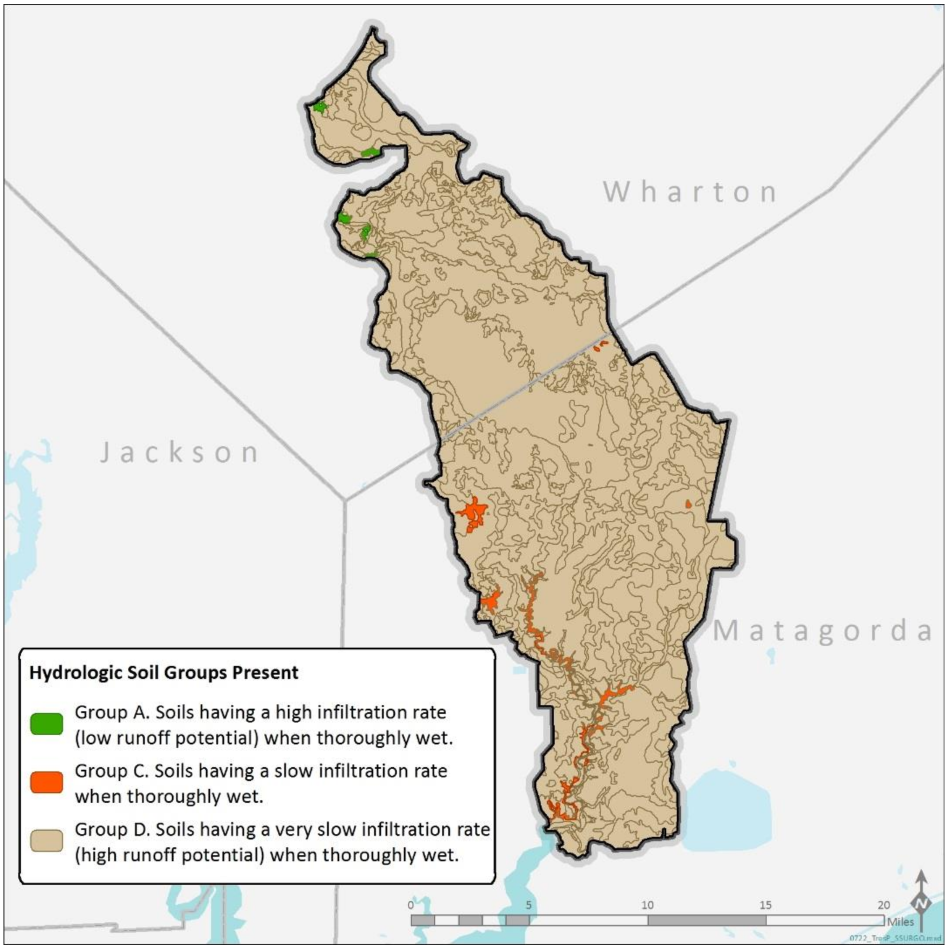

Figure 9. Tres Palacios Creek watershed soil map, soils categorized by Hydrologic Soil Group.

Source: (NRCS, 2013) (NRCS, 2013) (NRCS, 2014)

2.8 Potential Sources of Fecal Indicator Bacteria

Potential sources of indicator bacteria pollution can be divided into two primary categories: *regulated* and *unregulated*. Pollution sources that are regulated have permits under the Texas Pollutant Discharge Elimination System (TPDES) and National Pollutant Discharge Elimination System (NPDES) programs. Examples of regulated sources are wastewater treatment facility (WWTF) discharges and stormwater discharges from industries, construction, and municipal separate storm sewer systems (MS4s) of cities.

Unregulated sources are typically nonpoint source in nature, meaning the pollution originates from multiple locations and is usually carried to surface waters by rainfall runoff. Nonpoint sources are not regulated by permit.

With the exception of WWTFs, which receive individual waste load allocations or WLAs (see report Section 4.7.3, Waste Load Allocation), the regulated and unregulated sources in this section are presented to give a general account of the potential sources of bacteria in the watershed.

2.8.1 Permitted Sources

Permitted sources are regulated by permit under the TPDES and the NPDES programs. WWTF outfalls and stormwater discharges from industries represent the permitted sources in the Tres Palacios Creek watershed.

2.8.1.1 Domestic and Industrial Wastewater Treatment Facilities

As of October, 2015 there are four facilities with TPDES/ NPDES permits that operate within the watershed (Figure 10 and Table 5); three of the WWTFs are located in the Above Tidal portion of Tres Palacios Creek (Segment 1502) and one is located in the Tidal portion of Tres Palacios Creek (Segment 1501). Three facilities within the watershed treat exclusively domestic wastewater and one facility (Apex Matagorda Energy) treats wastes associated with a compressed air energy storage facility with no human waste component. Two of the facilities discharge directly into Tres Palacios Creek Above Tidal (1502), and two facilities discharge into tributaries of Tres Palacios Creek.

2.8.1.2 TPDES General Wastewater Permits

In addition to the individual wastewater discharge permits listed in Table 5, discharges of processed wastewater from certain types of facilities are required to be covered by one of several TPDES general permits:

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production facilities
- TXG340000 – petroleum bulk stations and terminals
- TXG670000 – hydrostatic test water discharges
- TXG830000 – water contaminated by petroleum fuel or petroleum substances
- TXG920000 – concentrated animal feeding operations
- WQG20000 – livestock manure compost operations (irrigation only)

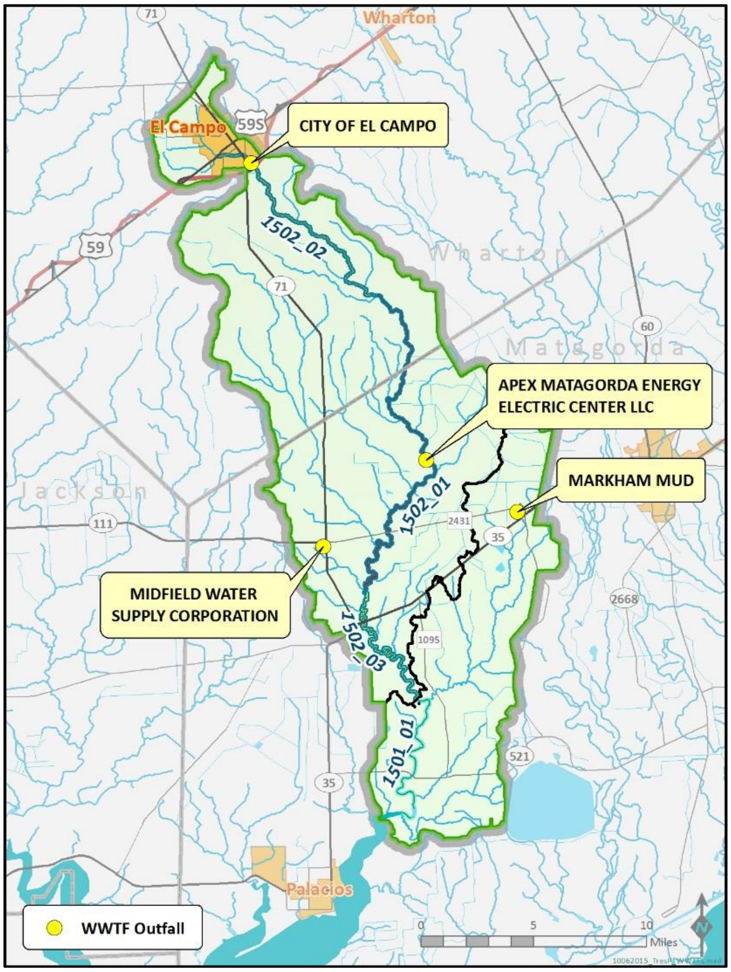

Figure 10. Tres Palacios Creek watershed showing WWTFs.

Source: Permitted outfalls (TCEQ, 2012b)

A review of active general permit coverage (TCEQ, 2015b) in the Tres Palacios Creek watershed as of 8 April 2015 found two aquaculture facilities covered by the general permit. These facilities are located in Segment 1502, above the impaired AU watershed. The two aquaculture facilities do not have bacteria reporting or limits in their permit. Both facilities were assumed to contain inconsequential amounts of indicator bacteria in their effluent; therefore, it was unnecessary to allocate bacteria load to these aquaculture facilities. No other active general wastewater permit facilities or operations were found. There were no facilities covered under the general permits for concrete production, petroleum bulk stations and terminals, hydrostatic test water discharges, water contaminated by petroleum fuel or petroleum substances, concentrated animal feeding operations or livestock manure compost operations.

Table 5. Permitted wastewater treatment facilities in the Tres Palacios Creek watershed.

Source: Individual TPDES Permits

TPDES Permit No.	Facility	Held By	AU	Receiving Waters	Discharge Type	Permitted Discharge[a] (MGD)	Recent Discharge (MGD)
WQ0005009000	Apex Matagorda Energy Center	Apex Matagorda Energy Center, LLC	1502_01	Tres Palacios Creek Above Tidal	wastes from a compressed air energy storage facility	0.223 (daily avg)	-[b]
WQ0010844001	City of El Campo Wastewater Treatment Facility	City of El Campo	1502_02	Tres Palacios Creek Above Tidal	treated domestic wastewater	2.628 (annual avg)	1.015[c]
WQ0013091001	Midfield Wastewater Treatment Facility	Midfield Water Supply Corporation	1502_03	an unnamed tributary; thence to Wallace Creek; thence to Tres Palacios Creek Above Tidal	treated domestic wastewater	0.03 (daily avg)	0.016[c]
WQ0015075001	Markham MUD Wastewater Treatment Facility	Markham Municipal Utility District	1501_01	an unnamed ditch; thence to Wilson Creek; thence to Tres Palacios Creek Tidal	treated domestic wastewater	0.3 (daily avg)	0.045[d]

[a] Significant figures reflect MGDs presented in TPDES permits

[b] No reported discharge; facility not built

[c] Average measured discharge from November 2009 through June 2014, as available

[d] Average measured discharge from November 2009 through October 2012

2.8.1.3 TPDES-Regulated Stormwater

When evaluating stormwater for a TMDL allocation, a distinction must be made between stormwater originating from an area under a TPDES or NPDES regulated discharge permit and stormwater originating from areas not under a TPDES or NPDES-regulated discharge permit. Stormwater discharges fall into two categories:

1) stormwater subject to regulation, which is any stormwater originating from TPDES-regulated Phase I and Phase II MS4, stormwater discharges associated with industrial activities, and stormwater discharges from regulated construction activities; and
2) stormwater runoff not subject to regulation.

Phase 1 MS4 permits are associated with large urban areas and as such, no permits of this nature occur for the Tres Palacios Creek watershed. Discharges of stormwater from a Phase II MS4 area, industrial facility, construction site, or other facility involved in certain activities are required to be covered under the following TPDES general permits:

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

Three of these permits (MS4, MSGP, and construction) pertain solely to stormwater discharges. The other two – concrete production facilities and petroleum bulk stations and terminals – also authorize the discharge of process wastewater as discussed above under TPDES General Wastewater Permits.

A review of active stormwater general permits coverage (TCEQ, 2015b) in the Tres Palacios Creek watershed, as of 15 April 2015, found seven active construction sites and five active industrial (MSGP) facilities. There are currently no Phase II MS4s or petroleum bulk stations and terminals facilities in the watershed. Based on the active stormwater general permits, regulated stormwater comprises 0.83% of the area of the entire Tres Palacios Creek watershed.

2.8.1.3 Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) are unauthorized discharges that must be addressed by the responsible party, either the TPDES permittee or the owner of the collection system that is connected to a permitted system. SSOs in dry weather most often result from blockages in the sewer collection pipes caused by tree roots, grease, and other debris. Inflow and infiltration (I&I) are typical causes of SSOs under conditions of high flow in the WWTF system. Blockages in the line may exacerbate the I&I problem. Other causes, such as a collapsed sewer line, may occur under any condition.

The TCEQ Region 12 Office maintains a database of SSO data reported by municipalities. These SSO data typically contain estimates of the total gallons spilled, responsible entity, and a general location of the spill. A search of the database, based on the three domestic facilities in

Segments 1501 and 1502, revealed that no SSOs have been reported since record-keeping began September 1, 2001 (TCEQ, 2015d). It is possible that SSOs are being under-reported in the Tres Palacios watershed as some data would have been anticipated over the period covered in the dataset.

2.8.1.4 Dry Weather Discharges/Illicit Discharges

Bacteria loads from regulated stormwater can enter the streams from permitted outfalls and illicit discharges under both dry and wet weather conditions. The term "illicit discharge" is defined in TPDES General Permit No. TXR040000 for Phase II Municipal Separate Storm Sewer Systems as "Any discharge to a municipal separate storm sewer that is not entirely composed of stormwater, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency firefighting activities." Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges identified in the Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities (NEIWPCC, 2003) includes:

Examples of direct illicit discharges:

- sanitary wastewater piping that is directly connected from a home to the storm sewer;
- materials (e.g., used motor oil) that have been dumped illegally into a storm drain catch basin;
- a shop floor drain that is connected to the storm sewer; and
- a cross-connection between the municipal sewer and storm sewer systems.

Examples of indirect illicit discharges:

- an old and damaged sanitary sewer line that is leaking fluids into a cracked storm sewer line; and
- a failing septic system that is leaking into a cracked storm sewer line or causing surface discharge into the storm sewer.

2.8.1.5 Review of Compliance Information on Permitted Sources

A review of the EPA Enforcement & Compliance History Online (ECHO) database (USEPA, 2014) conducted 9 April 2015, revealed non-compliance issues regarding bacteria for one WWTF in the Tres Palacios Creek watershed (See Table 6). The City of El Campo and Markham MUD both have a current *E. coli* compliance status of "No Violation"; the database does not contain a current *E. coli* compliance status for Midfield WWTF due to the recent addition of bacteria effluent limits. None of the bacteria effluent violations were reported as "Significant Non-compliance" effluent violations.

2.8.2 Unregulated Sources

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

Table 6. Bacteria monitoring requirements and compliance status for WWTFs in the Tres Palacios Creek watershed.

Data available through the EPA Enforcement & Compliance History Online (ECHO) database (USEPA, 2014), assessed through the Discharge Monitoring Report (DMR) Pollutant Loading Tool. "% Monthly Exceedances" were calculated based on reported monthly records for bacteria.

TPDES Permit No.	Facility	Held By	Bacteria Monitoring Requirement	Min. Self-Monitoring Requirement Frequency	Daily Average (Geometric Mean) Limitation	Single Grab (or Daily Max) Limitation	% Monthly Exceedances Daily Average	% Monthly Exceedances Single Grab
WQ0005009000	Apex Matagorda Energy Center	Apex Matagorda Energy Center, LLC	none	-	-	-	-	-
WQ0010844001	City of El Campo Wastewater Treatment Facility	City of El Campo	*E. coli*	one/week	126	394	0.00%[a]	2.63%[a]
WQ0013091001	Midfield Wastewater Treatment Facility	Midfield Water Supply Corporation	*E. coli*	one/quarter	126	399	No Data	No Data
WQ0015075001	Markham MUD Wastewater Treatment Facility	Markham Municipal Utility District	*E. coli*	one/month	126	399	0.00%[b]	0.00%[b]

[a] 38 monthly E. coli records (1/2012 - 2/2015)

[b] 14 monthly E. coli records (1/2014 - 3/2015)

2.8.2.1 Wildlife and Unmanaged Animal Contributions

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

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

For feral hogs, the Institute of Renewable Natural Resources (IRNR, 2013) estimated a range of feral hog densities within Texas (1.33 to 2.45 hogs/ square mile). The average hog density (1.89 hogs/ square mile) was multiplied by the hog-habitat area in the Tres Palacios Creek watershed (250.4 square miles). Habitat deemed suitable for hogs followed as closely as possible to the land use selections of the IRNR study and include from the 2011 NLCD: hay/pasture, cultivated crops, shrub/scrub, herbaceous, deciduous forest, evergreen forest, mixed forest, woody wetlands, and emergent herbaceous wetlands. Using this methodology, there are an estimated 473 feral hogs in the Tres Palacios Creek watershed.

For deer, the Texas Parks and Wildlife Department (TPWD) published data showing deer population-density estimates by Resource Management Unit (RMU) and Ecoregion in the state (TPWD , 2012). The Tres Palacios Creek watershed incorporates areas of RMU 12, for which the average deer density over the period 2005-2011 was calculated to be 35.9 deer/ square mile. Applying this value to the area of the entire watershed returns an estimated 9,643 deer within the Tres Palacios Creek watershed.

For birds, the Cornell Lab of Ornithology and the National Audubon Society maintain an online database (eBird, 2015) that provides bird abundance and distribution information at a variety of spatial scales. A query of Wharton and Matagorda counties reveals that there have been 352 species of birds observed within the last 5 years. Querying “Abundance” data by county for the last full year (2014) and summing the number of individuals by month indicates that there were 543,098 individuals observed in Matagorda County, and 133,688 individual birds observed in Wharton County in 2014.

2.8.2.2 Non-Permitted Agricultural Activities and Domesticated Animals

The number of livestock that are found within the Tres Palacios Creek watershed was estimated from county level data obtained from the 2012 Census of Agriculture (USDA NASS, 2014b). The county level data were refined to better reflect actual numbers within the impaired AU watershed. The refinement was performed by determining the total area of each county as well as the subject watershed that was designated as either “Herbaceous/ Grassland” or “Hay/ Pasture” in the 2011 National Land Cover Dataset (USGS, 2014). A ratio was then developed by dividing the selected land use area of the watershed area within a county by the total area of the county. This ratio was then applied to the county level data.

Activities, such as livestock grazing close to water bodies and farmers’ use of manure as fertilizer, can contribute fecal indicator bacteria to nearby water bodies. The livestock numbers in Table 7 are provided to demonstrate that livestock are a potential source of bacteria in the Tres Palacios Creek watershed. These numbers, however, are not used to develop an allocation of allowable bacteria loading to livestock.

Table 7. Estimated distributed domesticated animal populations within the Tres Palacios Creek watershed, based on proportional area.

Source: (USDA NASS, 2014b).

Watershed	Segment	Cattle and Calves	Goats	Hogs and Pigs	Horses and Ponies	Mules, Burros and Donkeys	Poultry	Sheep and Lambs
Tres Palacios Creek	Tidal (1501)	2,829	46	2	61	7	7	16
	Above Tidal (1502)	10,100	142	18	266	37	35	65
	Total	**12,929**	**188**	**20**	**327**	**44**	**42**	**81**

2.8.2.3 On-site Sewage Facilities

Private residential on-site sewage facilities (OSSFs), commonly referred to as septic systems, consist of various designs based on physical conditions of the local soils. Typical designs consist of 1) one or more septic tanks and a drainage or distribution field (anaerobic system) and 2) aerobic systems that have an aerated holding tank and often an above ground sprinkler system for distributing the liquid. In simplest terms, household waste flows into the septic tank or aerated tank, where solids settle out. The liquid portion of the water flows to the distribution system which may consist of buried perforated pipes or an above ground sprinkler system.

Several pathways of the liquid waste in OSSFs afford opportunities for bacteria to enter ground and surface waters, if the systems are not properly operating. Properly designed and operated, however, OSSFs would be expected to contribute virtually no fecal bacteria to surface waters. For example, it has been reported that less than 0.01% of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drainfield of a septic system (Weikel et al., (1996)). Reed, Stowe, and Yanke LLC (2001) provide information on estimated failure rates of OSSFs for different regions of Texas. Tres Palacios Creek is located within the east-central Texas area which has a reported failure rate of about 12 percent, providing insights into expected failure rates for the area.

Estimates of the number of OSSFs in the Tres Palacios Creek watershed were based on 2010 Census block data. For the area of the Tres Palacios Creek watershed, OSSFs were estimated to be households that were outside of either a Certificate of Convenience and Necessity (CCN) sewer area or a city boundary. The total estimate is shown in Table 8, and the OSSF density is shown in Figure 11. Additionally, an OSSF permits coverage was acquired from the Houston-Galveston Area Council, but was found to be incomplete and thus was not used (H-GAC, 2015).

Table 8. OSSF estimate for the Tres Palacios Creek watershed.

Source: Census Blocks (USCB, 2010)

Watershed	Segment	Estimated OSSFs
Tres Palacios Creek	Tidal (1501)	510
	Above Tidal (1502)	1,288
	Total	**1,798**

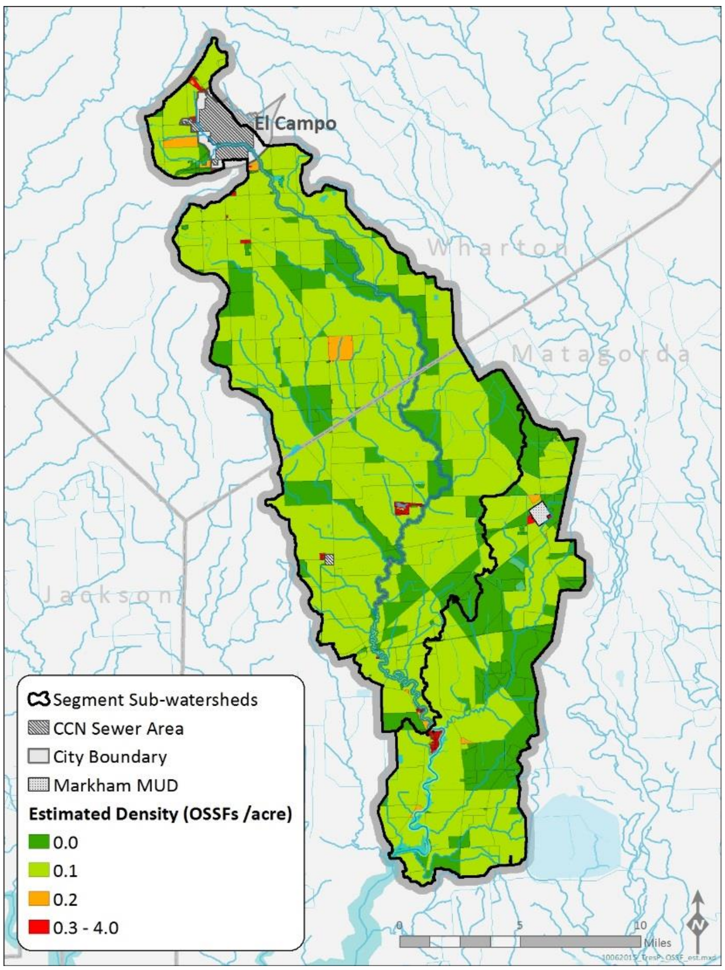

Figure 11. OSSF densities within the Tres Palacios Creek watershed.

Source: StratMap City boundary (TNRIS, 2012), CCN Sewer Areas (Public Utility Commission of Texas, 2014), Census Blocks (USCB, 2010), Water District Spatial Data (TCEQ, 2015c)

2.8.2.4 Domestic Pets

Fecal matter from dogs and cats is transported to streams by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 9 summarizes the estimated number of dogs and cats for the TMDL watershed. Pet population estimates were calculated as the estimated number of dogs (0.584) and cats (0.638) per household (AVMA (American Veterinary Medical Association), 2012). The actual contribution and significance of fecal coliform loads from pets reaching the water bodies of the watershed is unknown.

Table 9. Estimated Households and Pet Populations for the Tres Palacios Creek watershed.

Watershed	Segment	Estimated Number of Households	Estimated Dog Population	Estimated Cat Population
Tres Palacios Creek	Tidal (1501)	888	519	567
	Above Tidal (1502)	5,108	2,983	3,259
	Total	5,996	3,502	3,825

2.8.2.5 Bacteria Survival and Die-off

Bacteria are living organisms that survive and die. Certain enteric bacteria can survive and replicate in organic materials if appropriate conditions prevail (e.g., warm temperature). Fecal organisms can survive and replicate from improperly treated effluent during their transport in pipe networks and in organic rich materials such as compost and sludge. While the die-off of indicator bacteria has been demonstrated in natural water systems due to the presence of sunlight and predators, the potential for their replication is less well understood. Both processes (replication and die-off) are in-stream processes and are not considered in the bacteria source loading estimates for the TMDL watershed.

SECTION 3
DEVELOPMENT OF BACTERIA TOOLS

An essential component of a TMDL is to establish a linkage, or relationship, between pollutant sources and the water criteria. It is possible through this linkage to determine the capacity of the water body to assimilate bacteria loadings while still supporting its designated use. This section describes development of the tools used to provide this linkage and to provide the data for computing the pollutant load allocations of the project water bodies.

3.1 Model Selection

The TMDL allocation process for bacteria involves assigning bacteria, e.g., Enterococci, loads to their sources such that the total loads do not violate the pertinent numeric criterion protecting contact recreation use. To perform the allocation process, a tool must be developed to assist in allocating bacteria loads. Selection of the appropriate bacteria tool for the Tres Palacios Creek watershed considered availability of data and other information necessary for supportable application of the selected tool and guidance in the Texas bacteria task force report (TWRI, 2007). In general, two basic tools are commonly used for bacteria TMDLs—mechanistic computer models and an empirical approach referred to as the load duration curve (LDC).

Mechanistic computer models provide analytical abstractions of a real or prototype system. Mechanistic models, also referred to as process models, are based on theoretical principles that provide a representation of governing physical processes that determine the response of certain variables, such as stream flows and bacterial concentrations, to precipitation. Under circumstances where the governing physical processes are acceptably quantifiable, the mechanistic model provides an understanding of the important biological, chemical, and physical processes of the prototype system and reasonable predictive capabilities to evaluate alternative allocations of pollutant load sources.

The LDC method allows for estimation of existing and allowable loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). An adaptation of the LDC method to tidal waters has been successfully developed and applied by the State of Oregon (ODEQ, 2006). In addition to estimating stream loads, the load duration curve method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment. The LDC method has found relatively broad acceptance among the regulatory community, primarily due to the simplicity of the approach and ease of application. The regulatory community recognizes the frequent information limitations, often associated with bacteria TMDLs, which constrain the use of more powerful mechanistic models. Further, the bacteria task force appointed by the TCEQ and the Texas State Soil and Water Conservation Board (TSSWCB) supports application of the load duration curve method within their three-tiered approach to TMDL development (TWRI, 2007). The LDC method provides a means to estimate the difference in bacteria loads and relevant criterion, and can give indications of broad sources of the bacteria, i.e., point source and nonpoint source.

3.1.1 Situational Limitations of Mechanistic Modeling

The present surface water bacteria standards do not restrict what streamflow conditions the primary contact recreation criteria should meet; therefore, the allocation process must consider all streamflow conditions ranging from low flows to high flows. Additionally, the water body for TMDL development is tidally influenced, which adds yet another level of complexity to the processes that need to be considered. The TMDL allocation tool, therefore, must be capable of characterizing tidal influences, streamflow and bacteria loads at desired locations under the wide variety of environmental conditions experienced in the TMDL watershed. If a mechanistic modeling tool is applied, it must be capable of simulating response of bacterial loadings to streamflow and tidal conditions during base flow as well as during times of response to rainfall runoff and those intermediate conditions between well-defined base flow and strong rainfall-runoff response. The type of mechanistic tool with capabilities to simulate all these complexities is often referred to as a combined watershed loading and hydrologic/water quality model. These models simulate the hydrologic response of the watershed's land uses and land covers to rainfall, route runoff water through the conveyance channels of the watershed, add in point source contributions, and may include other hydrologic processes such as interaction of surface waters with shallow ground water.

While admittedly the streamflow and tidal processes requiring simulation are complex, these processes are generally better understood and more readily simulated than the bacterial processes. Nonetheless, mechanistic bacteria modeling has progressed significantly over the last several decades beginning in the late 1960s to early 1970s, as increasing computer resources made such endeavors possible. Regrettably for the application of mechanistic bacteria models, while the numerical equations to represent many pertinent processes exist and are incorporated in readily available models, these processes are appreciably more watershed specific than hydrologic processes. As one simple example, failing on-site treatment systems, such as septic systems, rarely makes measurable differences to streamflow, but can dramatically impact fecal bacteria concentrations present in the same streamflow. In the vast majority of circumstances, and the Tres Palacios Creek watershed is no exception, only very limited watershed-specific information is available to define many of the physical and biological processes that affect bacteria concentrations and loadings. Consequentially, the operator of the mechanistic model must specify, in many circumstances, numerous input parameters governing bacteria processes for which actual numeric values may not be known within a reasonable range of certainty.

3.1.2 Tres Palacios River Data Resources

Streamflow, water diversion, salinity, and Enterococci data availability were used to provide guidance in the allocation tool selection process. (Salinity data provided a measure of the degree of mixing of seawater and freshwater in the tidal segment.) As already mentioned, the information and data necessary to allow adequate definition of many of the physical and biological processes influencing in-stream bacteria concentrations for mechanistic model application are largely unavailable for the Tres Palacios Creek watershed, and these limitations became an important consideration in the allocation tool selection process. As a secondary source, availability of *E. coli* data for Tres Palacios Creek Above Tidal was also considered in the evaluation of data resources in order to provide additional information on conditions in the watershed.

Hydrologic data in the form of daily streamflow records were available for the mainstem portion of Tres Palacios Creek. Streamflow records are collected and made readily available by the U.S. Geological Survey (USGS), which operates one streamflow gage on Tres Palacios Creek (Table 10; Figure 5). USGS streamflow gage 08162600 is collocated with SWQM Station 12517, within the Above Tidal Segment 1502. This gage serves as the primary source for streamflow records used in this document.

Table 10. Basic information on the USGS streamflow gage in the project area.

Source: (USGS, 2015)

Gage No.	Site Description	Assessment Unit (AU)	Daily Streamflow Record (beginning & end date)
08162600	Tres Palacios Creek near Midfield, TX	1502_01	June 1970 – present

Self-reported data in the form of monthly discharge reports (DMRs) were available for at least the most recent 13 year timeframe (June 2001 - June 2014) for all but one of the WWTFs in the Tres Palacios Creek watershed. The exception was Markham MUD WWTF, where records were available for only the period of Dec. 2004 – Oct. 2012. For each WWTF, DMR data were downloaded as available from at least one of two EPA compliance databases – Enforcement and Compliance History Online (ECHO) or the Integrated Compliance Information System (ICIS).

Paired ambient Enterococci and salinity data were available through the TCEQ SWQMIS for one station in Segment 1501 and *E. coli* data were available for one station in Segment 1502 (Table 11).

Table 11. Summary of historical bacteria data sets.

Source: (TCEQ, 2014c)

Water Body	Assessment Unit (AU)	Station	Station Location	Indicator Bacteria	No. of Bacteria Samples	No. of Salinity Samples	Data Date Range
Tres Palacios Creek Tidal	1501_01	12515	Tres Palacios Creek at FM 521	Enterococci	160	75	1999 - 2013
Tres Palacios Creek Above Tidal	1502_01	12517	Tres Palacios Creek at FM 456	*E. coli*	112	N/A	1999 - 2013

In addition to streamflow data and water quality data, water diversion is an additional important data consideration for the Tres Palacios Creek watershed due to the size of the diversions and implications on streamflow. Water rights diversion data were available through the TCEQ Water Rights Permitting and Availability Section. Ten water rights within the Tres Palacios Creek watershed (shown in Figure 6 and Table 12) had diversion data for the period between 1990 and 2013 (TCEQ, 2014d).

Table 12. Summary of monthly diversion amounts data set over the period 1990- 2013 for surface water rights within the Tres Palacios Creek watershed.

Source: (TCEQ, 2014d)

AU	TCEQ ID	Mean (ac-ft)	Median (ac-ft)	Min (ac-ft)	Max (ac-ft)	Number of months reported
1502_02	61504773	9.4	0	0	60	288
1502_02	61504774	0.0	0	0	10	240
1502_01	61504775	6.6	0	0	110	288
1502_01	61504777	0.1	0	0	20	288
1502_01	61504778	13.5	0	0	100	288
1502_01	61504779	28.9	0	0	147	288
1502_03	61504782	7.5	0	0	120	288
1502_01	61504783	5.0	0	0	43.8	288
1502_01	61504786	4.2	0	0	80	288
1502_03	61504787	812.0	306.95	0	4,802	288

3.1.3 Allocation Tool Selection

The decision was made to use the load duration curve method with modifications to include tidal influences as opposed to a mechanistic watershed loading and hydrologic/water quality model based on the following factors: good availability of historical daily streamflow records, discharge information for large municipal WWTFs, ambient *E. coli* data for the Above Tidal segment (1502), Enterococci and salinity data for the Tidal segment (1501), and water rights diversion data, as well as deficiencies in data to describe bacterial landscape and in-stream processes. A modification of the LDC method (modified LDC method) developed by State of Oregon Department of Environmental Quality for bacteria TMDLs of tidal streams of the Umpqua River Basin (ODEQ, 2006) was adapted to the Tres Palacios Creek Tidal (Segment 1501). The LDC method without the modifications for a tidal system is being applied to Station 12517 of Tres Palacios Creek Above Tidal (Segment 1502) for informational purposes and to assist in determining broad categories of the bacteria impairment in downstream Segment 1501.

The modified LDC method is based on the assumption that combining of river water with seawater increases the loading capacity in the tidal river because seawater typically contains lower concentrations of indicator bacteria, such as Enterococci, than river water. The assumption of decreasing concentrations of Enterococci with distance from the tidal segment of Tres Palacios Creek into Tres Palacios Bay are borne out in the historical data. More details on the modified LDC method and the spatial trends of Enterococci are provided in Appendix A.

3.2 Methodology for Flow Duration & Load Duration Curve Development

LDCs display the maximum allowable load over the complete range of flow conditions by a curved line, using the calculation of flow multiplied by the water quality criterion. Through LDCs, a TMDL can be expressed as a continuous function of flow as expressed through the curved line or as a discrete value derived from a specific flow condition.

Accounting for the loading associated with water rights diversions provides an additional level of complexity for the Tres Palacios Creek watershed, especially since these diversions are significant. For the purpose of computing the TMDL, the water rights diversions are added back to the streamflow record, since these diversions represent water removed from the streamflow of Tres Palacios Creek that does have the capacity to contain additional allowable loading. This approach of adding the diversions back into the streamflow inherently assumes that return flows from the use of the diverted flows is insignificant. This assumption is considered valid based on the facts that the predominate use of the diverted water is for irrigation and the major diversion (TCEQ ID 61504787, Table 12) is located in the lower portion of the Tres Palacios Creek watershed (Figure 6) and predominately used for purposes of irrigation of lands to the west of this watershed.

To develop the FDCs and LDCs for Tres Palacios Creek, the previously discussed data resources were used in the following series of sequential steps. The LDC method without modifications for tidal influences, as being applied to Station 12517, follows the same general steps as that required for the modified LDC method except some steps can either be omitted or are simplified because of the absence of the complexity of tidal influences. The exceptions of the unmodified LDC are noted as needed in the steps below.

Step 1: Determine the hydrologic period of record to be used in developing the flow duration curves.

Step 2: Determine desired stream locations for which flow and load duration curves will be developed.

Step 3: Develop naturalized flows for desired stream locations.

Step 4: Develop regressions of salinity to streamflow at SWQM Station 12515. (This step is not required for SWQM Station 12517, which is located above tidal influences.)

Step 5: Develop daily streamflow records at desired stream locations using naturalized flows from Step 3, full permitted WWTF discharges, actual water rights diversions, and daily tidal volumes for the modified LDC method at Station 12515.

Step 6: Develop FDCs at two stream locations and segment into discrete flow regimes.

Step 7: Develop the allowable bacteria LDCs at the two stream locations based on the relevant criteria and the data from the FDCs.

Step 8: Superpose historical bacteria data on the allowable bacteria LDCs. Additional information explaining the LDC method may be found in (Cleland, 2003) and (NDEP, 2003). Information on the modified LDC method is found in (ODEQ, 2006).

3.2.1 Step 1: Determine Hydrologic Period

Optimally, the period of record to develop a FDC should include as much data as possible in order to capture extremes of high and low streamflows and hydrologic variability from high to low precipitation years, but the flow during the period of record selected should also be representative of recent conditions experienced within the watershed and when the Enterococci data were collected.

Daily hydrologic (streamflow) records were available for one USGS gage location within the Tres Palacios Creek watershed (Table 10; Figure 5). Gage number 08162600, which is located on the Tres Palacios Creek near Midfield, TX and collocated with the Above Tidal SWQM Station 12517, has a 44-year period-of-record, more than adequate to capture a reasonable variation in meteorological patterns of high and low rainfall periods.

A 15-year record of daily streamflow from 1 January 1999 through 31 December 2013 was selected to develop the streamflow duration curves at each station, and this period includes the collection dates of all available Enterococci data at the time this work effort was undertaken at Station 12515; the location for which the TMDL will be developed. A 15-year period is of sufficient duration to contain a reasonable variation from dry months and years to wet months and years and at the same time is short enough in duration to contain a hydrology that is responding to recent and current conditions in the watershed.

3.2.2 Step 2: Determine Desired Stream Locations

While bacteria data was available for several SWQM stations within the Tres Palacios Creek watershed, only two stations were selected for FDC/ LDC development – Station 12517 and Station 12515 (Figure 5). Station 12517 is collocated with USGS streamflow gage 08162600, within the Above Tidal Segment 1502. The Above Tidal segment is not listed as impaired for bacteria based on *E. coli*, but since it is an upstream location, an LDC for Station 12517 was developed for informational purposes. Station 12515 is located within the Tidal Segment 1501. The Tidal segment is listed as impaired for bacteria based on Enterococci, necessitating the development of an LDC.

Of note, other TCEQ stations within Segment 1502 and 1501 had bacteria data, but for all other stations, bacteria data was limited to samples collected only in 1999, except Station 20636. Station 20636 (within Segment 1501) had only 18 Enterococci samples collected between September 2009 and July 2012, which is short of the 24 samples that are recommended for LDC development (TWRI, 2007, p. 41).

3.2.3 Step 3: Develop Daily Streamflow Records

Once the hydrologic period of record and station locations were determined, the next step was to develop the 15-year daily record of "naturalized" flows for both monitoring stations. As used herein, naturalized flow is referring to the flow without the withdrawals from water rights and the additions of permitted discharges, i.e., the flows that would occur in response to precipitation, evapotranspiration, near-surface geology, soils, land covers of the watershed, and other factors. The naturalized daily streamflow records were developed from extant USGS records (see Table 10).

The method to develop the necessary streamflow record for each FDC/LDC location (Stations 12517 and 12515) involved a drainage-area ratio (DAR) approach. With this basic approach, each USGS gage daily streamflow value within the 15-year period was multiplied by a factor to estimate the flow at a desired SWQM station location. The factor was determined by dividing the drainage area above the desired monitoring station location by the drainage area above the USGS gage (Table 13).

Table 13. DARs for locations within the Tres Palacios Creek watershed.

Segment	Station No.	Location Description	Location Drainage Area (acres)	Drainage Area Ratio (DAR)
1502	TCEQ 12517 (USGS 08162600)	Tres Palacios Creek at FM 521	99,830	1.000
1501	TCEQ 12515	Tres Palacios Creek at FM 456	156,903	1.572

In order to properly apply the DAR, the "naturalized" flow at the USGS gage and Above Tidal location (Station 12517) was estimated first. The "naturalized" flow is the gaged flow without water rights diversions or permitted discharges. First, WWTF flows in the form of estimated daily DMR reported discharge (Table 5) for all WWTFs upstream of the USGS gage location were subtracted from the streamflow record of the gage, resulting in an adjusted streamflow record with point source discharge influences removed. For Station 12517, the upstream WWTFs included the City of El Campo and the Apex Matagorda Energy Center.

Next, water rights diversions in the form of estimated daily reported diversions (Table 12) for all water rights upstream of the USGS gage location were added back into the adjusted streamflow record, resulting in an adjusted streamflow record with upstream water right diversion influences removed (Table 12).

At this point, the "naturalized" flow at the USGS gage has been calculated. The next step was to multiply the DAR for Station 12515 (1.572) by the naturalized streamflow record at the USGS gage location giving the estimated daily flow record for the desired location in the downstream (Tidal) location. Because Station 12517 is collocated with the USGS gage, the DAR is 1.0 and the naturalized flow record at the gage required no additional adjustment to represent this monitoring station.

3.2.4 Step 4: Salinity to streamflow regression for Station 12515

Due to the complexities associated with the water rights diversions, two distinct streamflow records are required for Station 12515 in order to develop the modified LDC. The streamflow record representing an estimate of the actual daily flow experienced at Station 12515 for the selected hydrologic period of 1 January 1999 through 31 December 2013 is required in this step to develop the salinity to streamflow regression required for the modified LDC method. The second streamflow record is required to determine the pollutant load allocation and will be discussed in Step 5.

The estimated actual 15-year daily streamflow record for Station 12515 was created by taking the naturalized flows from Step 3 and adding in the sum of all the estimated discharges from permitted facilities above the station and subtracting all of the estimated water rights diversion above the station. For Station 12515, the upstream WWTFs included City of El Campo, Apex Matagorda Energy Center, Markham MUD and Midfield. Because of estimates of daily discharges and diversions used in this process, negative flows were occasionally computed. All negative flows were set to a value of zero.

As part of the development of the modified LDC method, it was necessary to develop a relationship between estimated actual daily streamflow and measured salinity for the Tidal location. The resulting regression was instrumental in determining the daily volume of saltwater present for each daily freshwater flow in the 15-year period of record. A salinity to streamflow regression was developed for Station 12515, located within the tidally-influenced portion of Tres Palacios Creek (Segment 1501). The resultant equation was used to calculate the volume of seawater that would flow through the station cross-section over the period of a day (Figure 12). It is noteworthy that above a streamflow of 100 cfs, tidal influences become minimal and measured salinities are at the background levels of the freshwater inflows.

For the Above Tidal location (Station 12517), no regression was necessary.

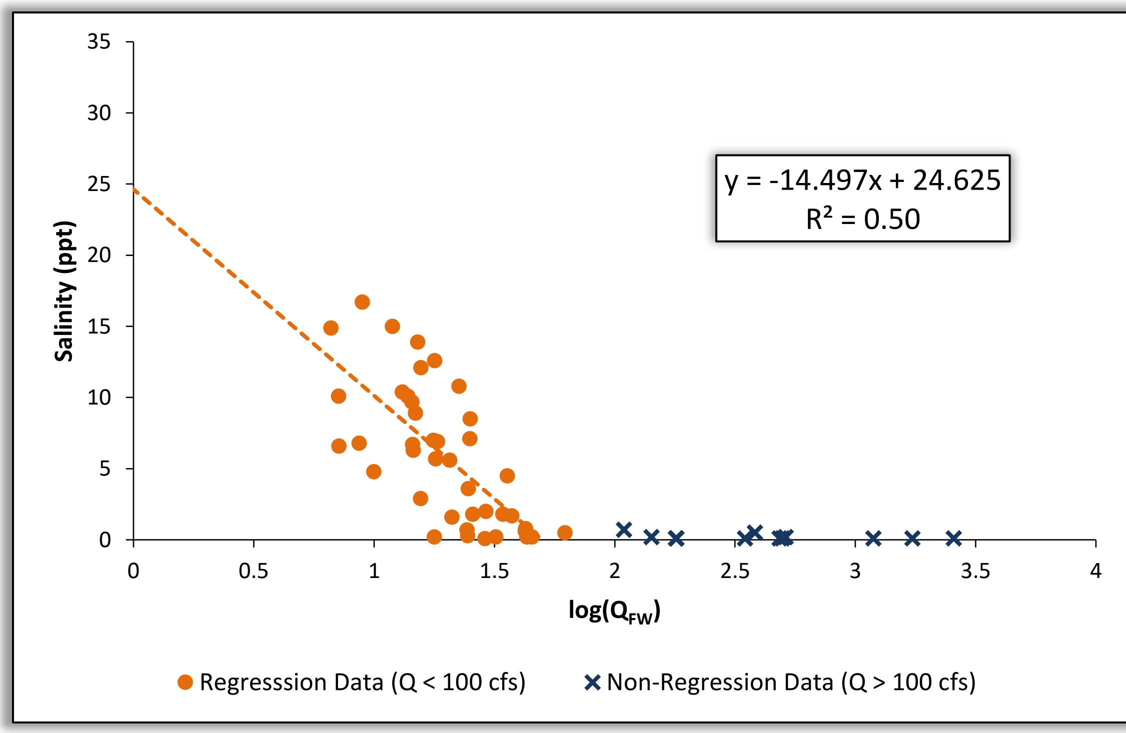

Figure 12. Salinity to Streamflow regression for Station 12515 (Segment 1501).

3.2.5 Step 5: Development of streamflow records at both stations

As previously mentioned, the daily streamflow record for tidally influenced Station 12515 contains an additional flow component which is not part of the streamflow record for freshwater Station 12517. Within this step, this daily tidal volume component is discussed first followed by discussion of the common components for both stations.

For the Tidal location (Station 12515), the regression equations from Step 4 were used in Step 5 to provide information to allow computation of a total daily flow volume including freshwater and seawater. The process requires manipulation of the following mass balance equation for salinity at a tidally influenced station:

$(V_r + V_s) * S_t = V_r * S_r + V_s * S_s$ (Eq. 1) Where

V_r = volume of daily freshwater (river) flow

V_s = volume of daily seawater flow

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

S_r = background salinity of upstream river water (ppt); assumed = 0 ppt

S_s = salinity of seawater (assumed to be 35 ppt)

Through algebraic manipulation this mass balance equation can be solved for the daily volume of seawater required to be mixed with freshwater (again, freshwater having an assumed salinity = 0) giving the equation found in the ODEQ (2006) technical information:

$V_s = V_r / (S_s/S_t - 1)$;

for S_t > than background salinity, otherwise $V_s = 0$ (Eq. 2)

Where S_t was computed for each day of the 15-year streamflow record using the station-specific regression equations of Step 4 and the estimated actual daily streamflow (V_r), also from Step 4, as input to the equation. The calculation of S_t allowed V_s to be computed from Eq. 2.

The modified daily flow volume (V_t) that includes the daily freshwater flow (V_r) and the daily volume of seawater flow (V_s) is computed as:

$V_t = V_r + V_s$ (Eq. 3)

For both the Above Tidal (Station 12517) and Tidal (Station 12515) locations, the adjusted streamflow records underwent the final modification of adding in adjusted upstream permitted discharges (full permitted discharge minus reported discharges) and upstream future growth discharge for each WWTF to which a waste load allocation will be assigned in the TMDL and the upstream actual water rights diversions. For the Above Tidal location (Station 12517), the additions included WWTF discharges and future growth terms (reported in Section 4.7.3) for the City of El Campo WWTF, along with the upstream water rights diversions indicated in Table 12. For the Tidal location (Station 12515), the additions included WWTF discharges and future growth terms for the cities of El Campo, Midfield, and Markham WWTFs, along with upstream water right numbers indicated in Table 12.

3.2.6 Step 6 Development of flow duration curves

In this step, the FDCs were developed for both stations. In order to generate a FDC (the following actions were undertaken:

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

Exceedance values along the x-axis represent the percent of days that flow was at or above the associated flow value on the y-axis. Exceedance values near 100% occur during low flow or drought conditions while values approaching 0% occur during periods of high flow or flood conditions. This graphical procedure provides information on basic hydrological characteristics in the stream based upon flows observed within specific reaches.

For Station 12515 on Tres Palacios Creek Tidal, the amount of estimated seawater is presented in the intermediate FDC using the flows from Step 4 (Figure 13). As expected from the modified daily flow volume equation, the amount of seawater present increases as both the freshwater flow decreases and the percent of days the flow is exceeded increases. Note that the x-axis direction of increase on the seawater plot is reversed from that on the FDC.

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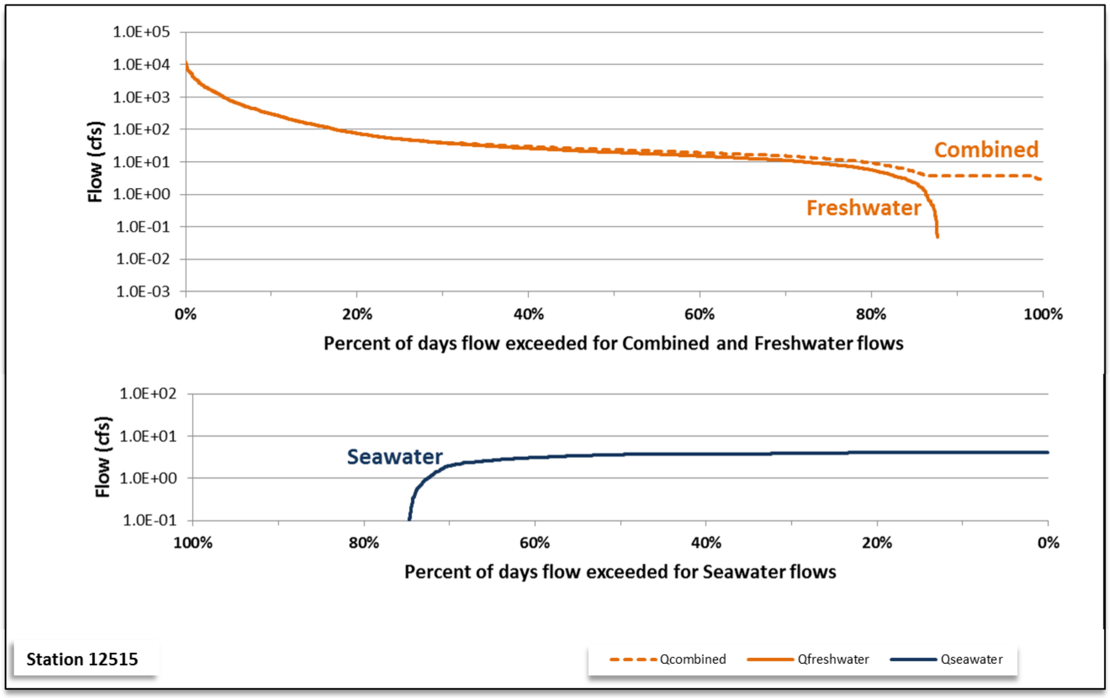

Figure 13. Flow duration curves for the Tidal location (Station 12515) showing the Freshwater and Seawater components, prior to final streamflow record modifications.

The final FDCs were created as previously described, and are shown for Stations 12515 and 12517 in Figure 14. A comparison of the two FDCs reveals that the modified flow at the downstream Tidal location (Station 12515) is slightly higher than the modified flow at the upstream Above Tidal location (Station 12517), as would be expected due to the greater watershed size.

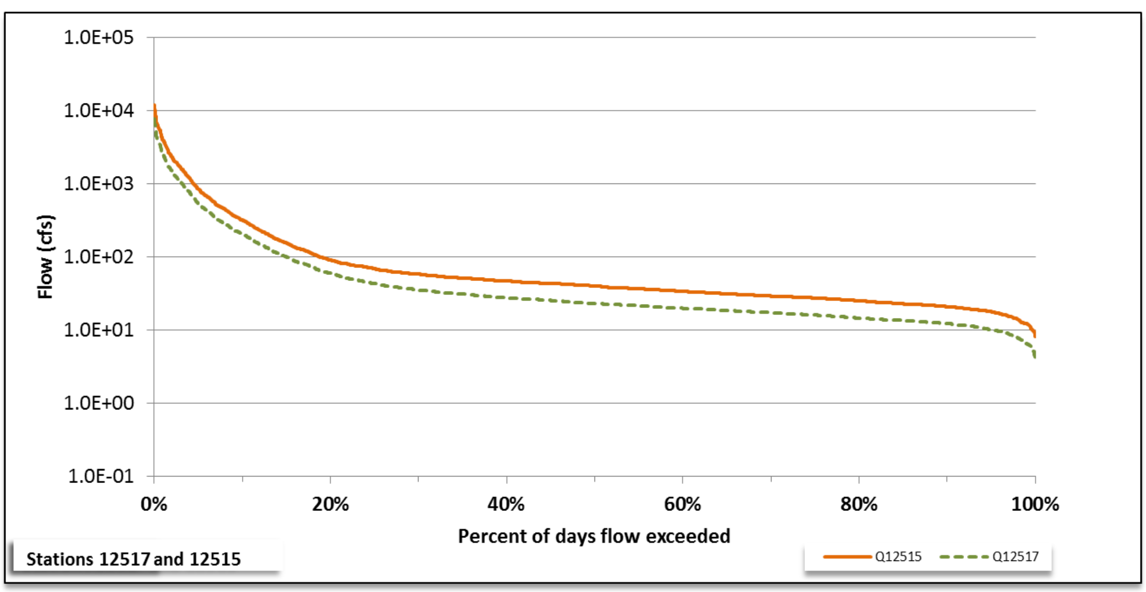

Figure 14. Flow duration curve for the Above Tidal (Station 12517) and Tidal (Station 12515) locations.

3.2.7 Step 7: Development of LDCs

In Step 7 the modified FDC for Station 12515 and unmodified FDC for Station 12517 were combined with the pertinent numeric water quality criterion established to protect the contact recreation use. The pertinent criterion for Station 12515 is the geometric mean concentration of Enterococci not to exceed 35 MPN per 100 mL and the pertinent criterion for Station 12517 is the geometric mean concentration of *E. coli* not to exceed 126 MPN per 100 mL. Each LDC was developed by multiplying the daily streamflow values (in cfs) from Step 6 by the appropriate bacteria criterion and by the conversion factor (2.44657×10^7) to express the loadings as MPN per day. Based on whether or not daily tidal volumes were included in the computed streamflow record, an unmodified LDC was created for Tres Palacios Creek Above Tidal (Station 12517) and a modified LDC was created for Tres Palacios Creek Tidal (Station 12515).

The shape of each LDC is identical to that of the FDC for the same station, because the data in the FDCs have all been multiplied by the same conversion factor. The label on the y-axis simply changes from Flow (cfs) to Enterococcus or *E. coli* (MPN/ day), and the label on the x-axis changes from "percent of days flow exceeded" to "percent of days load exceeded."

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

3.2.8 Step 8: Superpose historical bacteria data

In this step, historical bacteria measurements (Enterococci or *E. coli*) were aligned with the streamflow on the day of measurement. The historical bacteria measurements were then multiplied by the streamflow value and the conversion factor, as performed in Step 7, to calculate a loading associated with each measured bacteria concentration.

The points were then plotted on the LDC, and were symbolized according to whether the sampling event was considered to be a wet or non-wet weather event, based on antecedent rainfall. A sample was determined to be influenced by a wet weather event based on precipitation records from the Danevang 1W weather station (Figure 2); a wet weather event was one in which the sum of the past three days of total daily precipitation (NOAA, 2015a) exceeds 10 millimeters (0.39 inches). Points above a curve represent exceedances of the bacteria criteria and associated allowable loadings. Geometric mean loadings for the data points within each flow regime were calculated and displayed on each figure to aid in interpretation.

For both LDCs (Figure 15 and Figure 16), the wet weather data points occurred, as expected, predominately under the higher flow regimes and consistently exceeded the geometric mean criterion. Wet weather data points in the lowest flow regime typically represent bacteria data collected after a small rainfall runoff event when conditions up to the event were very dry.

The LDC developed for the Above Tidal location (Station 12517) within Tres Palacios Creek (Figure 15) indicates geometric mean *E. coli* loadings exceeded allowable loadings within two highest flow regimes, and the proportion of exceedences (based on the number of sampling events per flow regime) decreased with flow. *E. coli* loading exceedances were more common during wet weather events than during conditions not influenced by rainfall runoff. This LDC is provided only for informational purposes and the actual pollutant load allocation was based on the LDC for Station 12515.

The LDC developed for the Tidal location (Station 12515) within Tres Palacios Creek (Figure 16) indicates geometric mean Enterococci loadings exceeded allowable loadings within all flow regimes, and the proportion of exceedences (based on the number of sampling events per flow regime) decreased with flow. Enterococci loading exceedances were generally not restricted to wet weather events but also occurred during conditions not influenced by rainfall runoff. Actual interpretation of these curves in the context of the TMDL allocation process is reserved for the next report section.

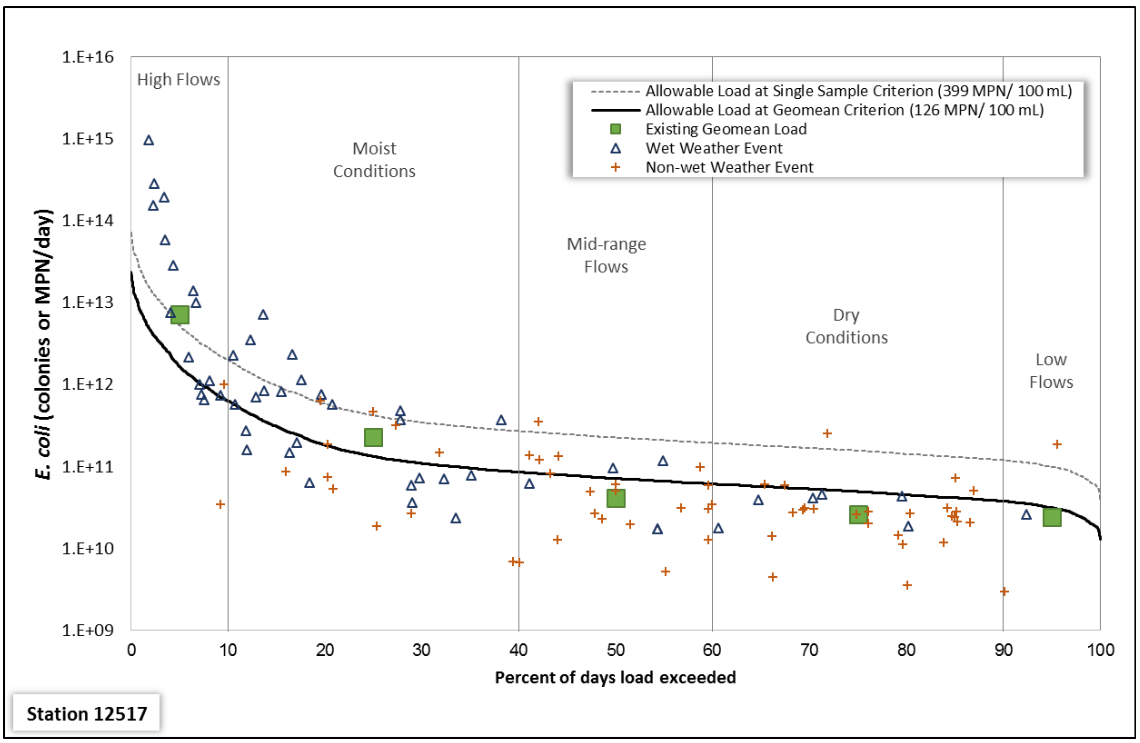

Figure 15. Load duration curve at Station 12517 on Tres Palacios Creek Above Tidal (Segment 1502) for the period of Jan 1, 1999 through December 31, 2013.

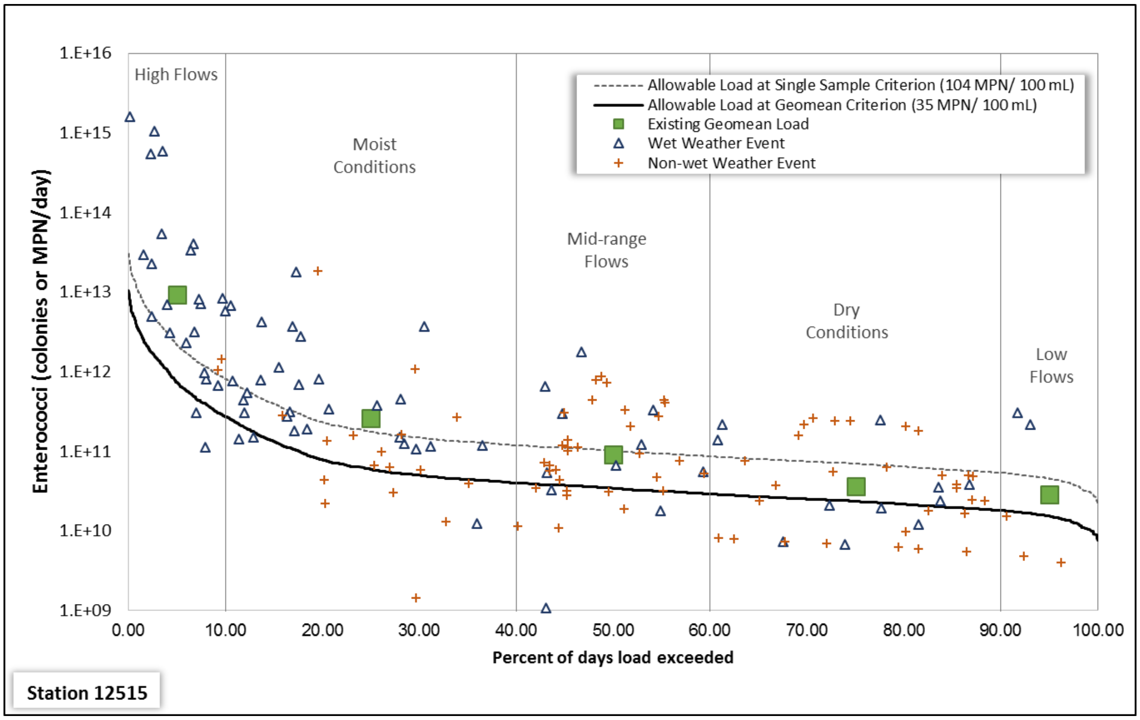

Figure 16. Load duration curve at Station 12515 on Tres Palacios Creek Tidal (Segment 1501) for the period of Jan 1, 1999 through December 31, 2013.

SECTION 4
TMDL ALLOCATION ANALYSIS

Presented in this report section is the development of the bacteria TMDL allocation for the TMDL watershed. The tool used for developing the TMDL allocation for Station 12515 was the modified LDC method, which accounts for tidal influences, as previously described in Section 3 — Bacteria Tool Development. Endpoint identification, margin of safety, load reduction analysis, TMDL allocations, and other TMDL components are described herein.

The modified LDC method provided a flow-based approach to determine necessary reductions in bacteria loadings and allowable loadings within the TMDL watershed. As developed previously in this report, the modified LDC method uses frequency distributions to assess a bacteria criterion over the historical range of flows, providing a means to determine maximum allowable loadings and the load reduction necessary to achieve support of the primary contact recreation use.

For the purposes of this TMDL study, the TMDL watershed is considered to be the entire Tres Palacios Creek watershed (AUs 1501_01, 1502_03, 1502_01, and 1502_02) as shown in the overview map (Figure 1). Although the LDCs were computed for the Above Tidal and Tidal locations, the TMDL was only calculated for the impaired Tidal water body (AU 1501_01). SWQM station 12515 was selected because its drainage area encompasses most of the Tres Palacios watershed and it is the only station in AU 1501_01 with an extensive time series of bacteria measurements.

4.1. Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions. Tres Palacios Creek Tidal has a use of primary contact recreation, which is measured against a numeric criterion for the indicator bacteria Enterococci due to the fact that it is tidally influenced. Indicator bacteria are not generally pathogenic and are indicative of potential viral, bacterial, and protozoan contamination originating from the feces of warm-blooded animals. The Enterococci criterion to protect contact recreation in saltwater systems consists of a geometric mean concentration not to exceed 35 MPN/100 mL (TCEQ, 2010).

The endpoint for this TMDL is to maintain concentrations of Enterococci below the geometric mean criterion of 35 MPN/100 mL. This endpoint is identical to the geometric mean criterion in the 2010 Surface Water Quality Standard (TCEQ, 2010) for primary contact recreation in saline water bodies.

4.2 Seasonality

Seasonal variations or seasonality occur(s) when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing Enterococci concentrations obtained from routine monitoring collected in the warmer months (May - September) against those collected during the cooler months (November - March). The months of April and October were considered transitional between the warm and cool seasons and were excluded from the seasonal analysis. Differences in Enterococci concentrations obtained in warmer versus cooler months were then evaluated by performing a Wilcoxon Rank Sum test on the original dataset. The nonparametric Wilcoxon Rank Sum test was selected because even with logarithmic transformation the bacteria data were non-normally distributed. This analysis of Enterococci data indicated that there was no significant difference (α=0.05, p=0.3018) in indicator bacteria between cool and warm weather seasons for Tres Palacios Creek Tidal (Station 12515, Segment 1501).

4.3 Linkage Analysis

Establishing the relationship between instream water quality and the source of loadings is an important component in developing a TMDL. It allows for the evaluation of management options that will achieve the desired endpoint. The relationship may be established through a variety of techniques.

Generally, if high bacteria concentrations are measured in a water body at low to median flow in the absence of runoff events, the main contributing sources are likely to be point sources and direct fecal material deposition into the water body. During ambient flows, these inputs to the system will increase pollutant concentrations depending on the magnitude and concentration of the sources. As flows increase in magnitude, the impact of point sources and direct deposition is typically diluted, and would therefore be a smaller part of the overall concentrations.

Bacteria load contributions from permitted and non-permitted stormwater sources are greatest during runoff events. Rainfall runoff, depending upon the severity of the storm, has the capacity to carry indicator bacteria from the land surface into the receiving stream. Generally, this loading follows a pattern of lower concentrations in the water body just before the rain event, followed by a rapid increase in bacteria concentrations in the water body as the first flush of storm runoff enters the receiving stream. Over time, the concentrations decline because the sources of indicator bacteria are attenuated as runoff washes them from the land surface and the volume of runoff decreases following the rain event.

Load duration curves were used to examine the relationship between instream water quality and the source of indicator bacteria loads. Inherent to the use of LDCs as the mechanism of linkage analysis is the assumption of a 1 to 1 relationship between instream loadings and loadings originating from point sources and the landscape as regulated and unregulated sources. Further this 1 to 1 relationship was also inherently assumed when using LDCs to define the TMDL pollutant load allocation (Section 4.7). That is the allocation of pollutant loads was based on apportioning the loadings based on flows assigned to WWTFs, a fractional proportioning of the remaining flow based on the area of the watershed under stormwater regulation, and assigning the remaining portion to unregulated stormwater.

4.4 Modified Load Duration Curve Analysis

A modified LDC method was used to examine the relationship between instream water quality and the broad sources of indicator bacteria loads, and are the basis of the TMDL allocations. The strength of this TMDL is the use of the modified LDC method to determine the TMDL allocations. Modified LDCs are a simple statistical method that provides a basic description of the water quality problem. This tool is easily developed and explained to stakeholders, and uses available water quality and flow data. The modified LDC method does not require any assumptions regarding loading rates, stream hydrology, land use conditions, and other conditions in the watershed. The EPA supports the use of the basic LDC approach to characterize pollutant sources including the modifications to include tidal influences. In addition, many other states are using this basic method to develop TMDLs, though the modified LDC method is more limited in its application. As discussed in more detail in Section 4.7 (Pollutant Load Allocation), the TMDL loads were based on the median flow within the high flow regime (or 5% flow), where exceedances of the primary contact recreation criteria are most pronounced. Under the high flow regime, there was no seawater volume computed as being present at Station 12515. With an absence of seawater at these high flows, the modified LDC results effectively simplified to those of the unmodified LDC method without adjustments to accommodate tidal influences (see Figure 13).

The modified LDC method allows for estimation of existing and TMDL loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003) with adjustments to include tidal influences (ODEQ, 2006). In addition to estimating stream loads, this method allows for the determination of the hydrologic conditions under which impairments are typically occurring, can give indications of the broad origins of the bacteria (*i.e*., point source and stormwater) and provides a means to allocate allowable loadings.

Based on the LDC for Station 12515 to be used in the pollutant load allocation process with historical Enterococci data added to the graphs (SWQM Station 12515, Figure 16) and Section 2.8 (Potential Sources of Fecal Indicator Bacteria), the following broad linkage statements can be made. The historical Enterococci data indicate that elevated bacteria loadings occur under all flow conditions, but become most elevated under the highest flows and are often below the single sample criterion under the lowest flows. Regulated stormwater comprises only a relatively small portion of the Tres Palacios Creek watershed (0.83%) and must be considered only a minor contributor and most likely non-regulated stormwater comprises the majority of high flow related loadings. The elevated Enterococci loadings under the lower flow conditions cannot be reasonably attributed exclusively to WWTFs due to outfalls typically being located at distance from the SWQM stations and a relatively good compliance record for most WWTFs. Therefore, other sources of bacteria loadings under lower flows and in the absence of overland flow contributions (i.e., without stormwater contribution) are most likely contributing bacteria directly to the water as could occur through direct deposition of fecal material from such sources as wildlife, feral hogs and livestock. The actual contribution of bacteria loadings attributable to these direct sources of fecal material deposition cannot be determined using LDCs.

4.5 Margin of Safety

The margin of safety (MOS) is used to account for uncertainty in the analysis performed to develop the TMDL and thus provides a higher level of assurance that the goal of the TMDL will be met. According to EPA guidance (USEPA, 1991), the MOS can be incorporated into the TMDL using two methods:

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

The margin of safety is designed to account for any uncertainty that may arise in specifying water quality control strategies for the complex environmental processes that affect water quality. Quantification of this uncertainty, to the extent possible, is the basis for assigning a margin of safety.

The TMDL covered by this report incorporates an explicit MOS by setting a target for indicator bacteria loads that is 5 percent lower than the geometric mean criterion. For primary contact recreation, this equates to a geometric mean target for Enterococci of 33.3 MPN/100 mL. The net effect of the TMDL with MOS is that the assimilative capacity or allowable pollutant loading of each water body is slightly reduced.

4.6 Load Reduction Analysis

While the TMDL for the Tres Palacios Creek watershed was developed using an LDC and associated load allocations, additional insight may, in certain situations, be gained through a load reduction analysis. A single percent load reduction required to meet the allowable loading for each of the five flow regimes was determined using the historical bacteria data for Stations 12515 and 12517, which are the two stations for which LDCs were developed. For flow regime, the percent reduction required to achieve the geometric mean criterion was determined by calculating the difference in the existing (or measured) geometric mean Enterococci concentration and the 35 MPN/100 mL criterion and dividing that difference by the existing geometric mean concentration for Station 12515 and performing the same computations for Station 12517 using the *E. coli* geometric mean criterion of 126 MPN/100 mL (Table 14). The percent load reductions for Station 12517 are provided for informational purposes only, since Station 12517 is located in Segment 1501 which is not impaired.

Table 14. Percent reduction calculations for bacteria by flow regime for Stations 12515 and 12517.

Watershed Station (Bacteria Indicator)	**AU**	**High Flows (0-10%)**		**Moist Conditions (10-40%)**		**Mid-Range Flows (40-60%)**		**Dry Conditions (60-90%)**		**Low Flows (90-100%)**	
		Geometric Mean (MPN/100 mL)	**Required Percent Reduction**	**Geometric Mean (MPN/100 mL)**	**Required Percent Reduction**	**Geometric Mean (MPN/100 mL)**	**Required Percent Reduction**	**Geometric Mean (MPN/100 mL)**	**Required Percent Reduction**	**Geometric Mean (MPN/100 mL)**	**Required Percent Reduction**
Tres Palacios Creek Tidal 12515 (Enterococci)	1501_01	447	92%	155	77%	93	62%	55	36%	66	47%
Tres Palacios Creek Above Tidal 12517 (*E. coli*)	1502_01	551	77%	216	42%	73	0%	67	0%	98	0%

4.7 Pollutant Load Allocation

A TMDL represents the maximum amount of a pollutant that the water body can receive in a single day without exceeding water quality standards. The pollutant load allocations for the selected scenarios were calculated using the following equation:

TMDL = WLA + LA + FG + MOS (Eq. 4)

Where:

TMDL = total maximum daily load

WLA = waste load allocation, the amount of pollutant allowed by existing regulated or permitted dischargers

LA = load allocation, the amount of pollutant allowed by non-regulated or non-permitted sources

FG = loadings associated with future growth from potential permitted facilities

MOS = margin of safety

As stated in 40 CFR, §130.2(1), TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For Enterococci, TMDLs are expressed as MPN/day, and represent the maximum one-day load the water body can assimilate while still attaining the standards for surface water quality.

The TMDL component for the impaired AU covered in this report is derived using the median flow within the high flow regime (or 5% flow) of the LDC developed for the Tres Palacios Creek downstream SWQM station (12515). For the remainder of this report, each section will present an explanation of the TMDL component first, followed by the results of the calculation for that component.

4.7.1 AU-Level TMDL Computations

The bacteria TMDL for Tres Palacios Creek was developed as a pollutant load allocation based on information from the most downstream LDC (Figure 16). As discussed in more detail in Section 3, bacteria LDCs using modifications to include tidal influences were developed by multiplying each flow value along the flow duration curves by the Enterococci criterion (35 MPN/100 mL) and by the conversion factor used to represent maximum loading in MPN/day. Effectively, the "Allowable Load" displayed in the modified LDC at 5% exceedance (the median value of the high-flow regime) is the TMDL:

TMDL (MPN/day) = Criterion * Flow (cfs) * Conversion factor (Eq. 5)

Where:

Criterion = 35 MPN/100 mL (Enterococci)

Conversion factor (to MPN/day) = 283.168 100 mL/ft^3 * 86,400 sec/day

At 5% load duration exceedance, the TMDL values are provided in Table 15.

Table 15. Summary of allowable loading calculations for the impaired AU 1501_01 within Tres Palacios Creek.

5% Exceedance Flow (CFS)	5% Exceedance Load (MPN/day)	Indicator Bacteria	TMDL (Billion MPN/day)
847.722	7.25905E+11	Enterococci	725.905[a]

[a] Flow from LDC, Figure 16

4.7.2 Margin of Safety

The margin of safety is only applied to the allowable loading for a watershed. Therefore the margin of safety is expressed mathematically as the following:

MOS = 0.05 * TMDL (Eq. 6)

Where:

MOS = margin of safety load

TMDL = total maximum allowable load

Since the MOS is based solely on the TMDL term, the calculation is straightforward (Table 16).

Table 16. MOS calculations for downstream stations within the Tres Palacios Creek watershed.

Indicator Bacteria	TMDL [a] (Billion MPN/ day)	MOS [b] (Billion MPN/ day)
Enterococci	725.905	36.295

[a] TMDL from Table 15.

[b] MOS = 0.05 * TMDL (Eq. 6)

4.7.3 Waste Load Allocation

The Waste Load Allocation (WLA) consists of two parts – the waste load that is allocated to TPDES-regulated wastewater treatment facilities (WLA_{WWTF}) and the waste load that is allocated to regulated stormwater dischargers (WLA_{SW}).

$WLA = WLA_{WWTF} + WLA_{SW}$ (Eq. 7)

TPDES-permitted wastewater treatment facilities are allocated a daily waste load (WLA_{WWTF}) calculated as their full permitted discharge flow rate multiplied by the instream geometric criterion and also reduced to account for the required MOS. The saltwater Enterococci criterion (35 MPN/100mL) is used as the WWTF target. The WLA_{WWTF} term is also calculated for the freshwater *E. coli* primary contract recreation geometric mean criterion of 126 MPN/100 mL, since WWTF bacteria permit limits are often expressed in terms of *E. coli*. This is expressed in the following equation:

WLA_{WWTF} = Criterion * Flow * Conversion Factor * $(1 – F_{MOS})$ (Eq. 8)

Where:

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

Flow = full permitted flow (MGD)

Conversion Factor (to MPN/day) = 1.54723 cfs/MGD *283.168 100 mL/ft3 * 86,400 s/d

F_{MOS} = fraction of loading assigned to margin of safety (5% or 0.05)

Thus the daily allowable loading of Enterococci and *E. coli* assigned to WLA_{WWTF} was determined based on the full permitted flow of each WWTFs using Eq. 8 and summed for the watershed. Table 17 presents the waste load allocations for each individual WWTF located within the TMDL watershed. The WLA_{WWTF} for the Tidal AU (1501_01) includes the sum of the WWTF allocations for all upstream AUs. Since the pollutant load allocation is developed in terms of Enterococci as the indicator bacteria, it is the Enterococci loadings from Table 17 that will be used in subsequent computations. Note that Apex Matagorda Energy Center (TPDES permit number WQ0005009000) is not assigned a bacteria permit limit within this TMDL because there is no human waste component associated with its discharge and this facility is not included in Table 16.

Table 17. Waste load allocations for TPDES-permitted facilities in Tres Palacios Creek watershed.

AU	TPDES Permit No.	Facility	Full Permitted Flow (MGD) [a]	F_{MOS}	*E. coli* WLA_{WWTF} (Billion MPN/ day) [b]	Enterococci WLA_{WWTF} (Billion MPN/ day) [b]
1502_02	WQ0010844001	City of El Campo Wastewater Treatment Facility	2.628	0.05	11.908	3.307
1502_03	WQ0013091001	Midfield Wastewater Treatment Facility	0.03	0.05	0.136	0.038
1501_01	WQ0015075001	Markham MUD Wastewater Treatment Facility	0.3	0.05	1.359	0.378
Tres Palacios Creek Watershed Total					13.403	3.723

[a] Permitted Flow from Table 5

[b] WLA_{WWTF} = Criterion * Flow * Conversion Factor * (1- F_{MOS}) (Eq. 8)

Stormwater discharges from MS4, industrial, and construction areas are also considered permitted or regulated point sources. Therefore, the WLA calculations must also include an allocation for permitted stormwater discharges (WLA_{SW}). A simplified approach for estimating the WLA for these areas was used in the development of this TMDL due to the limited amount of data available, the complexities associated with simulating rainfall runoff, and the variability of stormwater loading. The percentage of the land area included in the Tres Palacios Creek watershed that is under the jurisdiction of stormwater permits is used to estimate the amount of the overall runoff load that should be allocated as the permitted stormwater contribution in the WLA_{SW} component of the TMDL. The LA component of the TMDL corresponds to direct nonpoint runoff and is the difference between the total load from stormwater runoff and the portion allocated to WLA_{SW}.

WLA_{SW} is the sum of loads from regulated stormwater sources and is calculated as follows:

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} \qquad \text{(Eq. 9)}$$

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 permitted facilities

MOS = margin of safety load

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

The fractional proportion of the drainage area under the jurisdiction of stormwater permits (FDA_{SWP}) must be determined in order to estimate the amount of overall runoff load that should be allocated to WLA_{SW}. The term FDA_{SWP} was calculated based on the area of the watershed under regulated stormwater permits. As described in Section 2.8.1.3, a search for all five categories of stormwater general permits was performed. The search results are displayed in Table 18.

No MS4 permits are held in the Tres Palacios Creek Watershed. For the Multi-Sector General Permits, only the acreages associated with active permits were tallied. These acreages were calculated by importing the location information associated with the authorizations into GIS, and measuring the estimated disturbed area based on the most recently available aerial imagery. For the Construction Activities general permits, the authorization contains an "Area Disturbed" field. The total acreage for the most recent full month (April 2015) was used. No Concrete Production Facilities or Petroleum Bulk Stations were located within the Tres Palacios Creek watershed.

Table 18. Regulated stormwater calculations for the Tres Palacios Creek watershed.

MS4 General Permit (acres)	Multi-sector General Permit (acres)	Construction Activities (acres)	Concrete Production Facilities (acres)	Petroleum Bulk Stations (acres)	Total Area of Permits (acres)	Watershed Area (acres)	FDA_{SWP}
0	839	586	0	0	1,425	171,815	0.829%

In order to calculate WLA_{SW} (Equation 9), the Future Growth (FG) term must be known. The calculation for the FG term is presented in the next section, but the results will be included here for continuity. Table 19 provides the information needed to compute WLA_{SW}.

Table 19. Regulated stormwater calculations for the Tres Palacios Creek watershed.

Load units expressed as billion MPN/day

Indicator	TMDL [a]	WLA_{WWTF} [b]	FG [c]	MOS [d]	FDA_{SWP} [e]	WLA_{SW} [f]
Enterococci	725.905	3.723	0.812	36.295	0.829%	5.679

[a] TMDL from Table 15
[b] WLA_{WWTF} from Table 17
[c] FG from Table 20
[d] MOS from Table 16
[e] FDA_{SWP} from Table 18
[f] $WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP}$ (Eq. 9)

4.7.4 Future Growth

The Future Growth (FG) component of the TMDL equation addresses the requirement of TMDLs to account for future loadings that may occur as a result of population growth, changes in community infrastructure, and development. The assimilative capacity of streams increases as the amount of flow increases. Increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard.

Currently, three facilities that treat domestic water are located within the impaired AU watershed and have been assigned a waste load allocation (Table 17). To account for the FG component of impaired AU 1501_01, the loading from all WWTFs are included in the FG computation, which is

based on the WLA_{WWTF} formula (Eq. 8). The FG equation (Eq. 10) contains an additional term to account for projected population growth between 2010 and 2050 in El Campo for the El Campo WWTF and Matagorda County for Midfield WWWTF and Markham MUD WWTF (provided previously in

Table **2**).

$$FG = Criterion * [\%POP_{2010\text{-}2050} * WWTF_{FP}] * Conversion\ Factor * (1-F_{MOS}) \quad \text{(Eq. 10)}$$

Where:

Criterion = 35 MPN/100 mL Enterococci or 126 MPN/100 mL for *E. coli*

$\%POP_{2010\text{-}2050}$ = estimated % increase in population between 2010 and 2050

$WWTF_{FP}$ = full permitted discharge (MGD)

Conversion Factor = 1.547 cfs/MGD *283.168 100 mL/ft^3 * 86,400 s/d

F_{MOS} = fraction of loading assigned to margin of safety (5% or 0.05)

The calculation results for the impaired AU watershed are shown in Table 20.

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Table 20. Future Growth Calculations for the Tres Palacios Creek watershed.

TPDES Permit No.	Facility	Full Permitted Flow (MGD)	Type/ Location of Outfall	% Increase (2000-2050)	2050 Permitted Flow (Future Growth) (MGD)[a]	Enterococci FG (Billion MPN/ day) [b]
WQ0010844001	City of El Campo Wastewater Treatment Facility	2.628	Municipal/ El Campo	22.46%	0.590	0.7425
WQ0013091001	Midfield Wastewater Treatment Facility	0.03	Municipal/ Matagorda County	17.30%	0.005	0.0063
WQ0015075001	Markham MUD Wastewater Treatment Facility	0.3	Municipal/ Matagorda County	17.30%	0.05	0.0629
Tres Palacios Creek Total					0.645	0.812

[a] Significant digits based on full permitted flow

[b] FG = Criterion * [%$POP_{2010-2050}$*$WWTF_{FP}$] * Conversion Factor *(1-F_{MOS}) (Eq. 10)

4.7.5 Load Allocation

The load allocation (LA) is the loads from unregulated sources, and is calculated as:

$$LA = TMDL – WLA_{WWTF} - WLA_{SW} - FG - MOS \quad \text{(Eq. 11)}$$

Where:

LA = allowable loads from unregulated sources within the AU

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 permitted facilities

MOS = margin of safety load

The calculation results are shown in Table 21.

Table 21. Load allocation calculations for the Tres Palacios Creek watershed.

Load units expressed as billion MPN/day

Indicator	TMDL [a]	WLA_{WWTF} [b]	WLA_{SW} [c]	FG [d]	MOS [e]	LA [f]
Enterococci	725.905	3.723	5.679	0.812	36.295	679.396

[a] TMDL from Table 15
[b] WLA_{WWTF} from Table 17
[c] WLA_{SW} from Table 19
[d] FG from Table 20
[e] MOS from Table 16
[f] LA = TMDL – WLA_{WWTF} - WLA_{SW} - FG – MOS (Eq. 6)

4.8 Summary of TMDL Calculations

Table 22 summarizes the TMDL calculations for Tres Palacios Creek Tidal (1501_01). The TMDL was calculated based on the median flow in the 0-10 percentile range (5% exceedance, high flow regime) for flow exceedance from the LDC developed for the downstream SWQM station in the watershed (12515). Allocations are based on the current geometric mean criterion for Enterococci of 35 MPN/100 mL for each component of the TMDL.

Table 22. TMDL allocation summary for the Tres Palacios Creek watershed.

Load units expressed as billion MPN/day

AU	Stream Name	Indicator	TMDL [a]	MOS [b]	WLA_{WWTF} [c]	WLA_{SW} [d]	LA [e]	Future Growth [f]
1501_01	Tres Palacios Creek Tidal	Enterococci	725.905	36.295	3.723	5.679	679.396	0.812

[a] TMDL from Table 15
[b] MOS from Table 16
[c] WLA_{WWTF} from Table 17
[d] WLA_{SW} from Table 19
[e] LA from Table 21
[f] Future Growth from Table 20

The final TMDL allocations (Table 23) needed to comply with the requirements of 40 CFR 130.7 include the future growth component within the WLA_{WWTF}.

In the event that the criterion changes due to future revisions in the state's surface water quality standards, Appendix B provides guidance for recalculating the allocations in Table 23. Figure B-1 was developed to demonstrate how assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of proposed water quality criteria for Enterococci. The equations provided, along with Figure B-1, allows calculation of a new TMDL and pollutant load allocation based on any potential new water quality criterion for Enterococci.

Table 23. Final TMDL allocations for the impaired Tres Palacios Creek AU 1501_01 watershed.

Load units expressed as billion MPN/day

AU	TMDL	WLA_{WWTF} [a]	WLA_{SW}	LA	MOS
1501_01	725.905	4.535	5.679	679.396	36.295

[a] WLA_{WWTF} includes the FG component

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Appendix A. Modified Load Duration Curve

Traditionally the LDC approach has been restricted in TMDL development to freshwater, non-tidally influenced streams and rivers. The reason for excluding application of LDCs in TMDL development for tidally influenced stream and river systems is the presence of seawater in these river systems, i.e., an additional flow that has a loading. An assumption behind the LDC approach is that the loadings of bacteria are derived exclusively from the sources of the streamflows. These sources and their associated loadings may be varied, but it is inherently assumed that they may be computationally determined based on the streamflow at the selected exceedance frequency on the LDC used for the load allocation. But in a tidal system there is other water (i.e., seawater) that is a source with an associated loading that must be considered.

If the LDC approach is to be adapted to tidally influenced streams and rivers, some means of addressing the additional water and loadings from the seawater that mixes with freshwater in tidal rivers is needed. Oregon's Umpqua Basin Bacteria TMDL provides a modification of the LDC approach that accounts for the seawater component (ODEQ, 2006).

Their approach is based on determining the volume of seawater that must be mixed with the volume of freshwater going down the river to arrive at the "observed" salinity using a simple mass balance approach as provided in the following:

$$(V_r + V_s)*S_t = V_r*S_r + V_s*S_s \quad \text{(A-1)}$$

Where

V_r = volume daily river flow (m^3) = Q (cfs)*86,400 (sec/day); where Q = river flow (cfs)

V_s = volume of seawater

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

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

S_s = salinity of seawater (35 ppt)

As noted in the computation of V_r, the volumes are actually time-associated using a day as the temporal measure, thus providing the proper association for the daily pollutant load computation. Through algebraic manipulation this mass balance equation can be solved for the daily volume of seawater required to be mixed with freshwater (again, freshwater having an assumed salinity = 0) giving the equation found in the ODEQ (2006) technical information:

$$V_s = V_r / (S_s/S_t - 1);$$

$$\text{for } S_t > \text{ than background salinity; otherwise } V_s = 0 \quad \text{(A-2)}$$

For the Umpqua Basin tidal streams (e.g., Figure A-1), as well as the present application to the Tres Palacios Creek Tidal (Figure 12 in this report), regressions were developed of S_t to Q using measured salinity data (S_t) with freshwater flows (Q). These regressions all had some streamflow above which S_t = 0. The daily Q and regression developed S_t were then used to compute V_s. As St approaches 0.0, V_s likewise approaches a value of 0.0 in Equation A-2, meaning the only flow present is the river flow (Q or V_r).

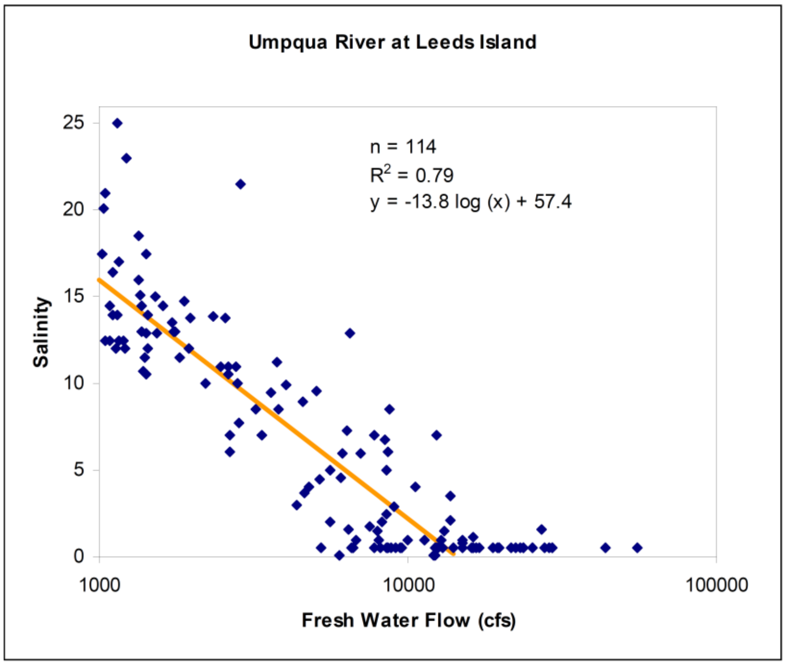

Figure A-1. Example salinity to flow regression from Umpqua Basin Tidal streams (ODEQ, 2006).

It is also relevant to discuss the response of measured salinities at assessment stations to streamflow and the streamflows above which salinities approach background levels (again, assumed to be 0.0) within the context of FDC for Tres Palacios Creek. These FDCs and the plotted flow exceedance values where salinities approach background should be viewed from the perspective of TCEQ's approach for bacteria TMDLs. Within the TCEQ TMDL approach with indicator bacteria, the highest flow regime is selected for developing the pollutant load allocation. This flow regime is defined as the range of 0-10% for the Tres Palacios Creek Tidal segment. All the flows in the highest flow regime are greater than the amount of streamflow indicated by the regression analysis as needed to result in an absence of seawater.

The significance of the above observation is related to what happens within the Modified LDC approach when salinities are at background. As salinity approaches background, V_s in Equation A-2 approaches a value of zero, and in fact would be defined as zero when salinities are at background levels, resulting in the Modified LDC flow volume ($V_s + V_r$) defaulting to the flow of the river, i.e., no modification occurring to that portion of the LDC. Therefore regarding the pollutant load allocation process for Tres Palacios Creel Tidal, the modified LDC method provides identical allowable loadings in the highest flow regime to those that would be computed using the standard LDC method that does not include tidal influences. The identical results of the modified and standard LDC method for the highest flow regime is the physical reality indicated in the observed salinity data that at these elevated streamflows seawater is effectively pushed completely out into Tres Palacios Bay. But the other implication, in hindsight, is that for these two tidal rivers, the same Pollutant Load Allocation results would be determined with the LDC method with or without tidal influences being considered due to development of the TMDL for the higher streamflows.

Continuing with the theoretical development of the Modified LDC for the Umpqua TMDLs, a total daily volume (V_t) is comprised of V_r computed from Q and the volume of seawater (V_s):

$$V_t = V_r + V_s \qquad \text{(A-3)}$$

Resulting in

$$\text{TMDL (MPN/day)} = \text{Criterion} * V_t * \text{Conversion factor} \qquad \text{(A-4)}$$

The modified LDC method as captured in Equation A-4 is based on the assumption that combining of river water with seawater increases the loading capacity in the tidal river because seawater typically contains lower concentrations of indicator bacteria, such as Enterococci, than river water.

To confirm the assumption that the tidal water or seawater has low concentrations of Enterococci historical data were obtained from TCEQ SWQMIS for stations in Tres Palacios Creek, Tres Palacios Bay, and Matagorda Bay from near the Gulf of Mexico to Tres Palacios Creek Above Tidal (Figure A-3). As shown in Figures A-4, the geometric means of historical Enterococci data at these stations do indicate a decreasing trend in Enterococci concentrations with distance toward the Gulf of Mexico.

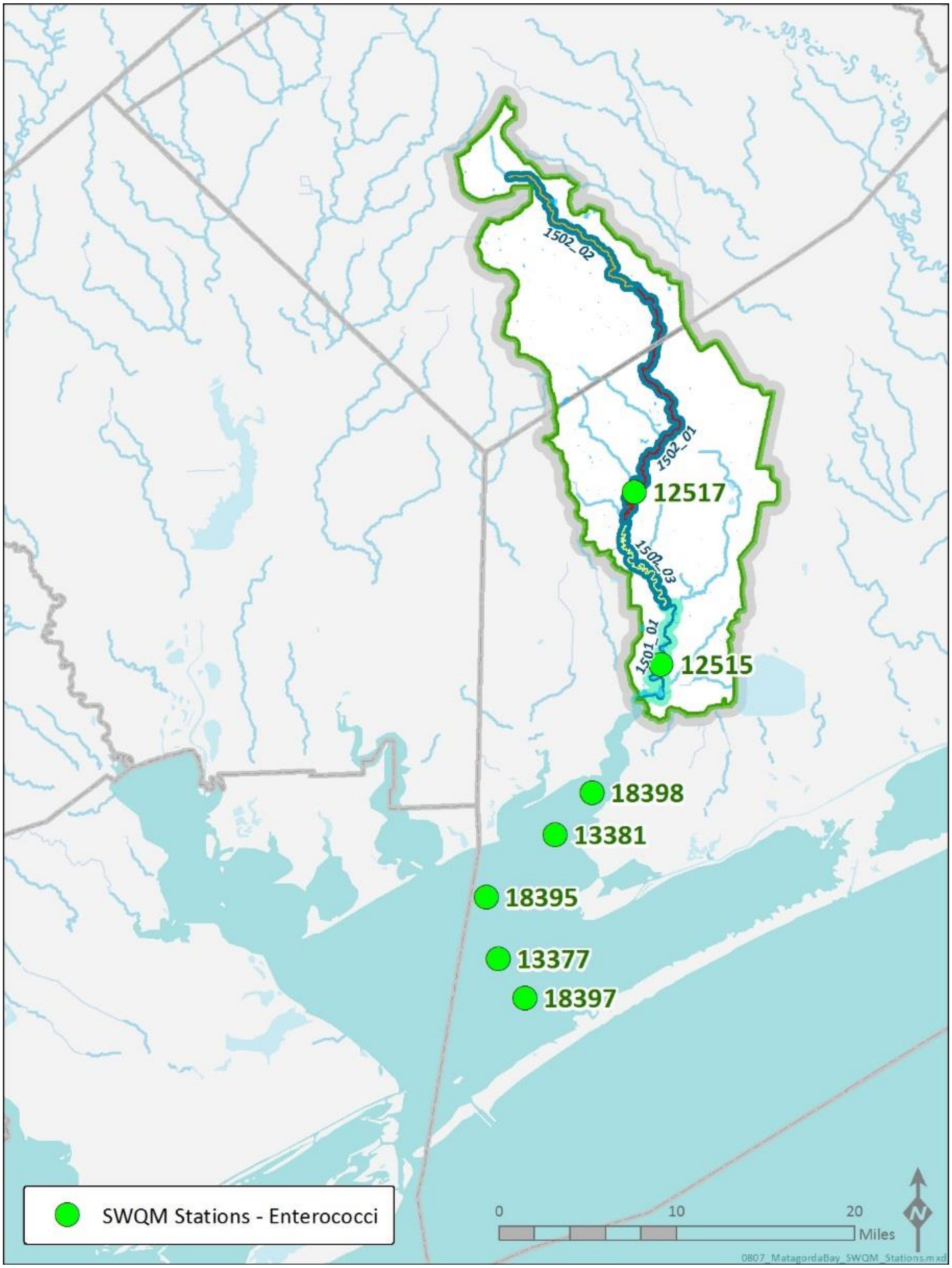

Figure A-2. SWQM stations with Enterococci data in Tres Palacios Creek, Tres Palacios Bay and Matagorda Bay.

Source: (TCEQ, 2015a)

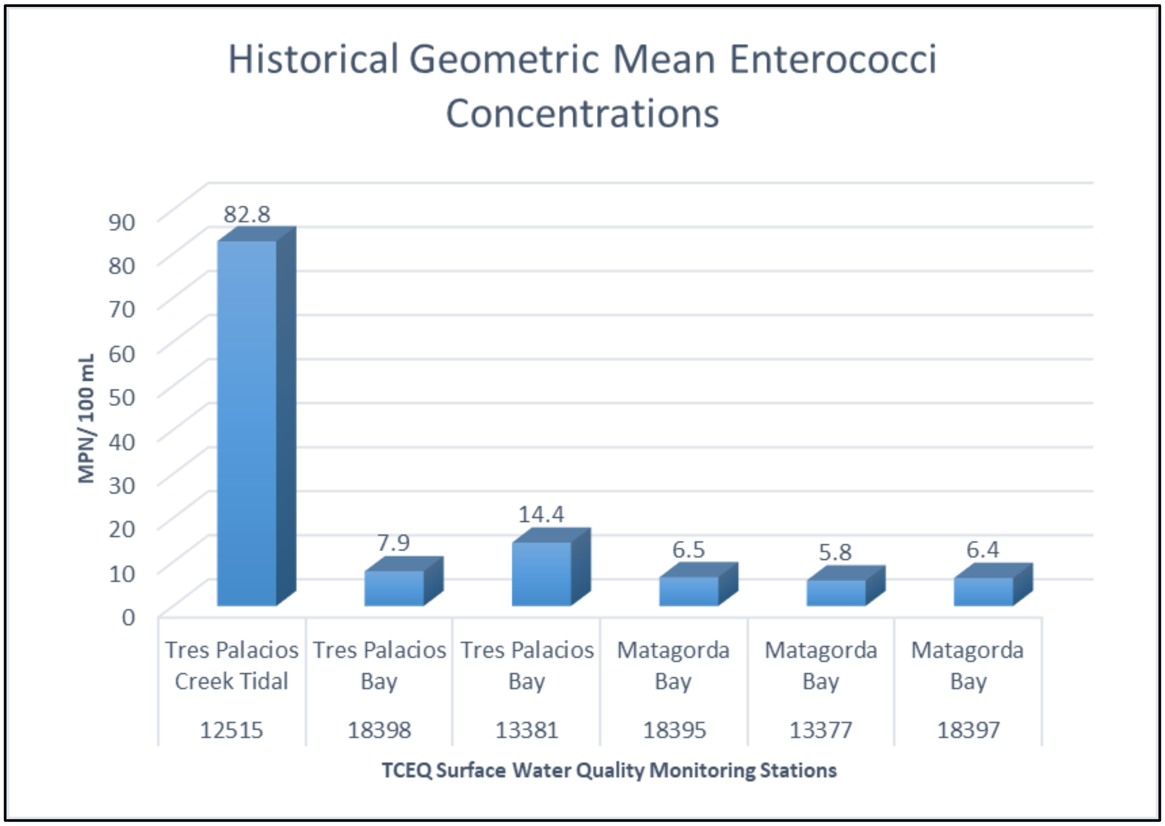

Figure A-3. Geometric Mean Enterococci concentrations at SWQM stations with historical data in Tres Palacios Creek, Tres Palacios Bay, and Matagorda Bay.

Source: (TCEQ, 2015a)

Appendix B. Equations for Calculating TMDL Allocations for Changed Contact Recreation Standard

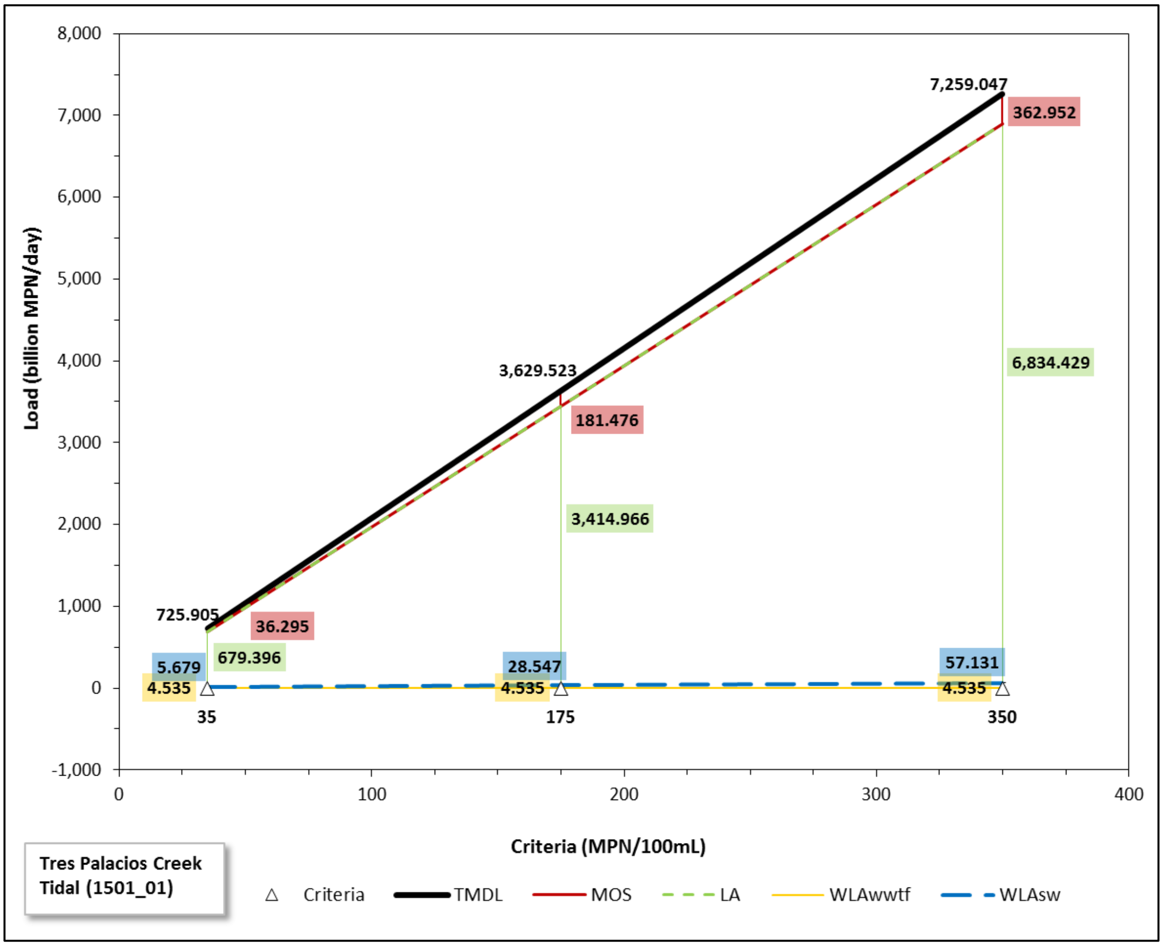

Figure B-1. Allocation loads for Tres Palacios Creek Tidal (1501_01) as a function of water quality criteria.

Equations for calculating new TMDL and allocations (billion MPN/day)

TMDL	=20.7401339 * Std
MOS	=1.0370067 * Std
LA	=19.5397883 * Std -4.4969080
WLA_{WWTF}	=4.5345000
WLA_{SW}	=0.1633389 * Std -0.0375914

Where:

Std =	Revised Contact Recreation Standard
MOS =	Margin of Safety
LA =	Total load allocation (non-permitted source contributions)
WLA_{WWTF} =	Waste load allocation (permitted WWTF load + future growth) [Note: WWTF load held at Primary Contact (35 MPN/ 100 mL) criterion]
WLA_{SW} =	Waste load allocation (permitted stormwater)