Technical Support Document for Total Maximum Daily Load for Indicator Bacteria in Oso Creek

Segment 2485A

Assessment Unit 2485A_01

Oso Creek at SH 286 (downstream view)

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Segment 2485A

Assessment Unit 2485A_01

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

Prepared by
Todd Adams
Larry Hauck
Texas Institute for Applied Environmental Research
Tarleton State University
Stephenville, Texas

TR 1610

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Abbreviations

AU	Assessment Unit
BMP	Best Management Practice
cfs	Cubic Feet per Second
CWSS	Center for Water Supply Studies
DAR	Drainage Area Ratio
DMR	Discharge Monitoring Report
DSLP	Days Since Last Precipitation
ECHO	Enforcement & Compliance History Online
E. coli	*Escherichia coli*
FDC	Flow Duration Curve
FG	Future Growth
FIB	Fecal Indicator Bacteria
GIS	Geographic Information System
I&I	Inflow and infiltration
I-Plan	Implementation Plan
LA	Load Allocation
LDC	Load Duration Curve
MGD	Million Gallons per Day
mi^2	Miles Squared or Square Miles
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
NRCS	Natural Resources Conservation Service
OSSF	Onsite Sewage Facility
SSO	Sanitary Sewer Overflow
SSURGO	Soil Survey Geographic
SWMP	Stormwater Management Program
SWQM	Surface Water Quality Monitoring
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
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department

TSS	Texas Secretary of State
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
WUG	Water User Group
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 the Oso Creek (Segment 2485A) watershed in the *2002 Texas Water Quality Inventory and 303(d) List* (TCEQ, 2002) and then in each subsequent edition through the latest edition, now known as the *2014 Texas Water Quality Integrated Report of Surface Water Quality for the Clean Water Sections 305(b) and 303(d)* (TCEQ, 2015). A bacteria TMDL for Oso Bay (Segment 2485) was adopted by TCEQ in 2007 and approved by the U. S. Environmental Protection Agency (USEPA) in 2008 (TCEQ, 2007). Additionally, there are three unclassified water bodies (Unnamed Tributary of Oso Creek (2485B), Unnamed Tributary of Oso Creek (2485C), and West Oso Creek (2485D)) within the Oso Creek watershed that are not listed for bacterial impairment.

This document will, therefore, consider bacteria impairment in one water body (segment), consisting of one assessment unit (AU): Oso Creek (AU 2485A_01). Because the impaired segment is composed of only one AU that encompasses the entire segment, the AU descriptor (_01) is often unnecessarily cumbersome. From this point forward, AU and segment may be used interchangeably. For example, Oso Creek may be referred to as AU 2485A_01 or Segment 2845A.

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 *2010 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 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 (FIB) are used to assess the risk of illness during contact recreation (e.g., swimming) from ingestion of water. FIBs, including *E. coli* (*Escherichia coli*) and Enterococcus spp. (Enterococci), 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 such 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 saltwater. Enterococci are the relevant indicator for Oso Creek (2485A), because it is a tidal stream.

On June 30, 2010, the TCEQ adopted revisions to the Texas Surface Water Quality Standards (TCEQ, 2010) and on June 29, 2011, the USEPA 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 milliliter (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 Oso Creek (AU 2485A_01) has a presumed primary contact recreation use. Since it is considered a saltwater water body, the associated Enterococci geometric mean criterion of 35 MPN per 100 mL and a single sample of 104 MPN per 100 mL is applied.

1.3 Report Purpose and Organization

The TMDL project for Oso Creek was initiated through a contract between the TCEQ and the Texas Institute for Applied Environmental Research (TIAER). 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 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 Oso Creek 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

Oso Creek (Segment 2485A) is an unclassified, tidal stream located south of Corpus Christi, Texas that feeds into classified Segment 2485 (Oso Bay) and thence into Segment 2481 (Corpus Christi Bay). As depicted in Figure 1, there are three unclassified water bodies of Oso Creek including two unnamed tributaries (Segments 2485B and 2485C) and West Oso Creek (Segment 2485D).

Oso Creek (Segment 2485A) begins at the confluence with Oso Bay and is approximately 25 miles in length. The entire Oso Creek (Segment 2485A) watershed, including the tributaries previously mentioned, drains an area of approximately 133,833 acres (209.1 mi^2) exclusively within Nueces County and making up 24.4 percent of the county land area.

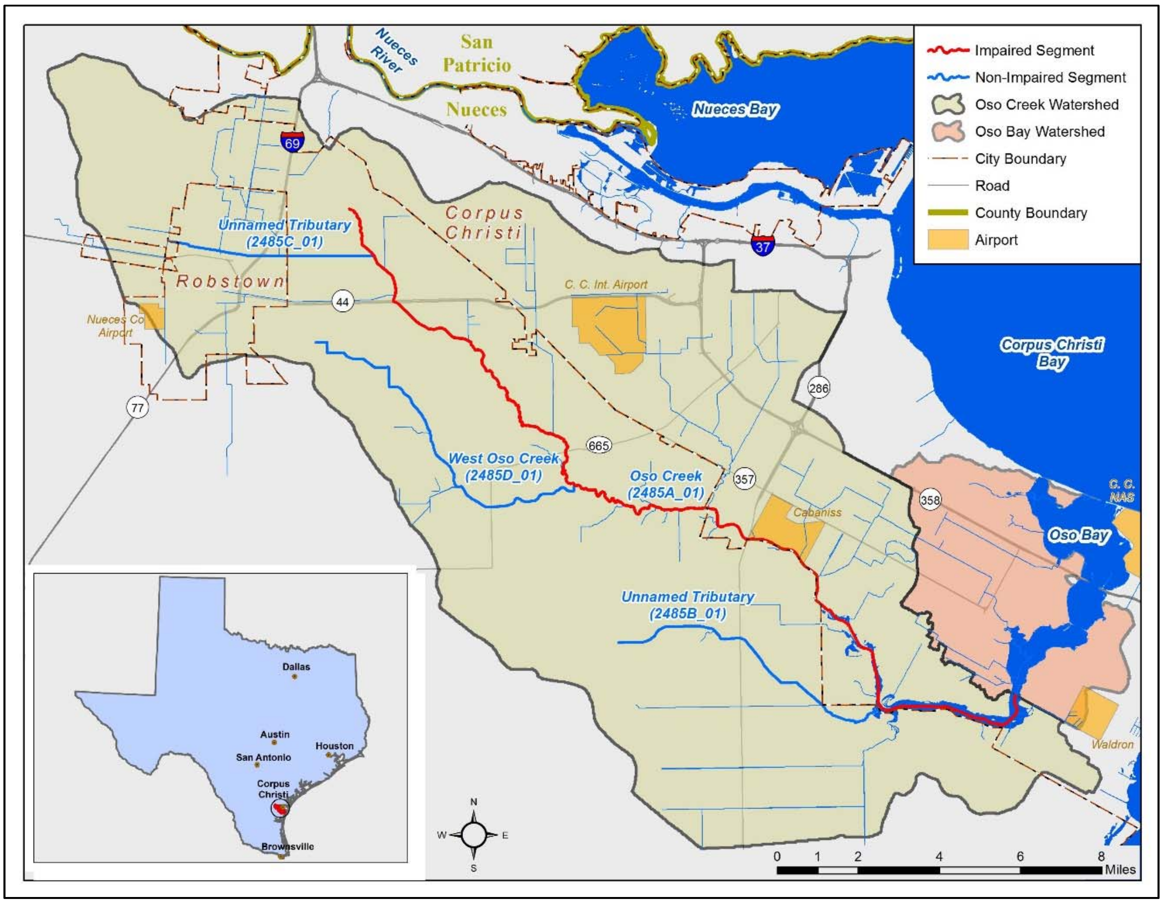

Figure 1. Overview map showing the Oso Creek Segments/AUs and watershed (including the Oso Bay watershed).

The 2014 Texas Integrated Report (TCEQ, 2015) provides the following Segment and AU description for the water body considered in this document:

- Segment 2485A (AU 2485A_01; entire segment) - From the Oso Bay confluence in southern Corpus Christi to a point 4.8 km (3 mi) upstream of SH 44, west of Corpus Christi in Nueces.

While Segments 2485B, 2485C, and 2485D are unclassified water bodies within the study area, none are listed for bacteria impairment. Only Oso Creek (Segment 2485A) is listed for bacteria impairment.

Furthermore and for the purposes of this report, the entire watershed of Oso Creek is considered in the overview section. However, TMDL development is for Segment 2485A only.

2.2 Watershed Climate and Hydrology

The Oso Creek watershed is located in the southern part of Texas near the Gulf Coast (Figure 1) in a climatological region designated humid subtropical. Typically, summers are characterized by warm, humid mornings with pleasant, clear afternoons achieving highs in the mid-90s (°F) that are moderated by afternoon coastal breezes with these conditions extending into the fall months (September – October). Temperatures seldom exceed 100 °F during the summer months near the bay and occur more frequently farther inland. Likewise, winters are considered mild as freezing temperatures rarely occur in the bay area with more frequent sub-32 °F temperatures materializing farther inland. First and last frosts generally happen in early November and mid-March, respectively. High relative humidity is present year-round. The hurricane season lasts from June to November with August and September observed as prime hurricane months. September is the peak precipitation month with precipitation totals largely influenced by hurricanes and tropical storms. However, periods of dry weather patterns lasting several months are frequent. Snowfall events are rare occurring only once every couple of years and generally last for a 24-hour or less duration (NOAA, 2016a). For the period from 1981 – 2010, average annual precipitation in the Oso Creek watershed was 31.0 inches (Figure 2; PRISM, 2012).

For the more recent 15 year period from 2001 – 2015 at Corpus Christi International Airport centrally located in the Oso Creek watershed (Figure 3), the average monthly high temperatures generally peak in August (95.8 °F) with average monthly lows ranging from 74.4 °F (June) to 75.7 °F (August) during the summer months (NOAA, 2016b). During winter, the average low temperature generally bottoms out at 47.2 °F in January (NOAA, 2016b). Additionally, September is indicated to be the wettest month averaging 6.1 inches of precipitation with December (1.1 inches) observed to be the driest month (Figure 3; NOAA, 2016b).

2.3 Watershed Population and Population Projections

As depicted in Figure 4, the Oso Creek watershed is geographically located entirely within Nueces County, with 36 percent of the watershed covered by municipal boundaries (Corpus Christi and Robstown) and 64 percent designated as “Other County” areas. According to the 2010 Census data (USCB, 2016), population data indicate the Oso Creek watershed has an estimated population of 119,130 people and an average population density of 570 people per mi^2.

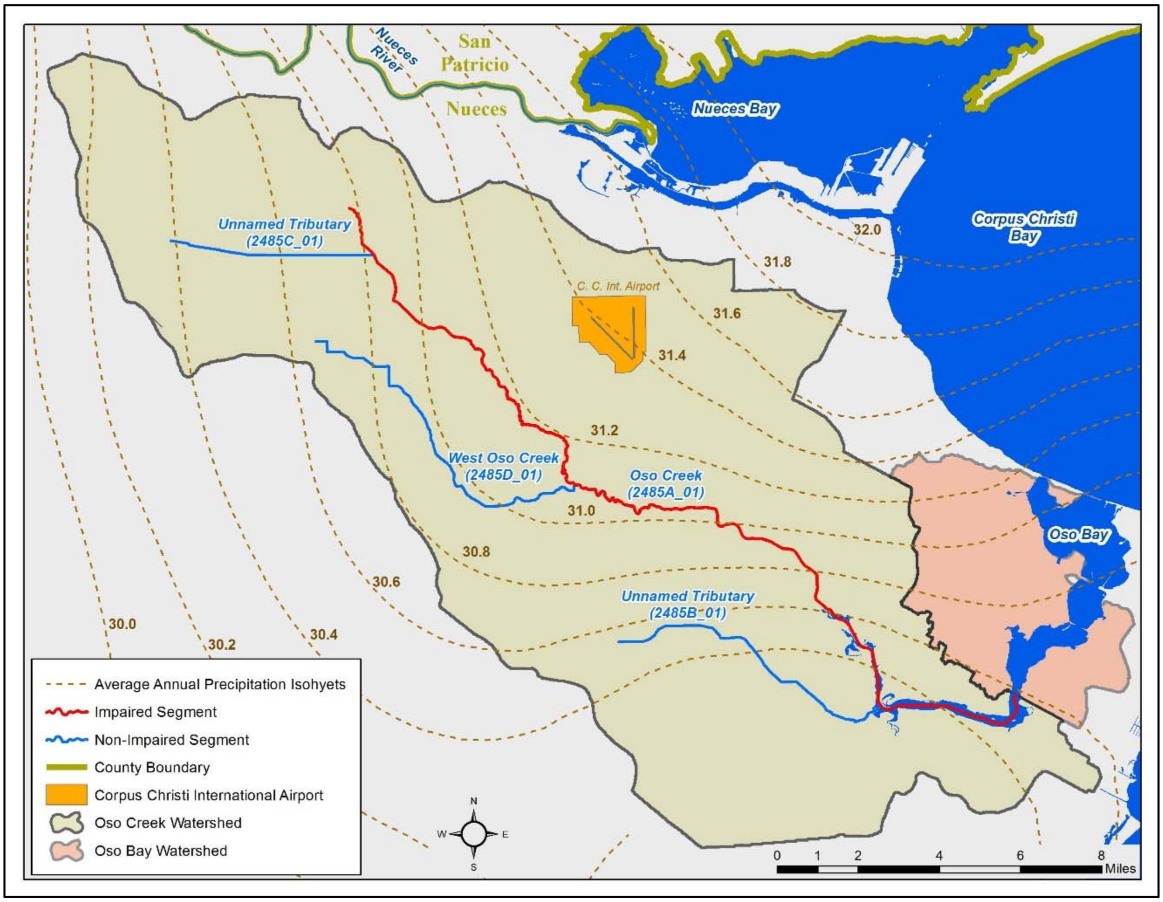

Figure 2. Annual average precipitation isohyets (in inches) in the Oso Creek watershed (1981-2010) including the Corpus Christi International Airport.

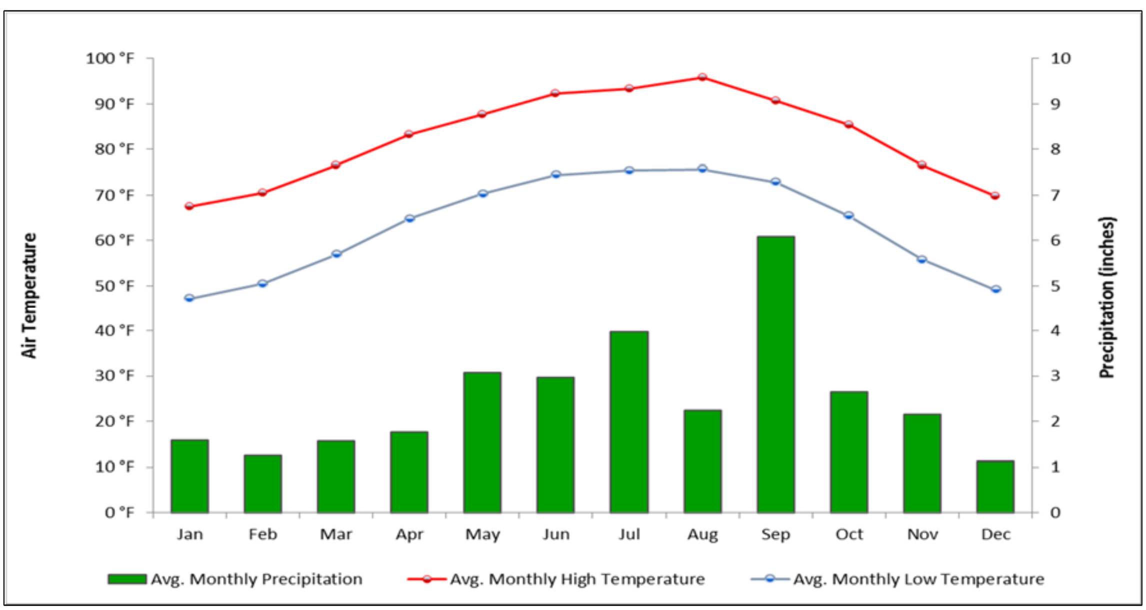

Figure 3. Average minimum and maximum air temperatures and average precipitation by month from 2001-2015 for the Corpus Christi International Airport.

However, 86.8 percent of the population estimate (103,411 people) is located within the Corpus Christi city limits followed by Robstown with 9.4 percent (11,237 people), indicating a largely urban watershed population. Figure 4 provides a depiction of the population density per acre of Oso Creek watershed.

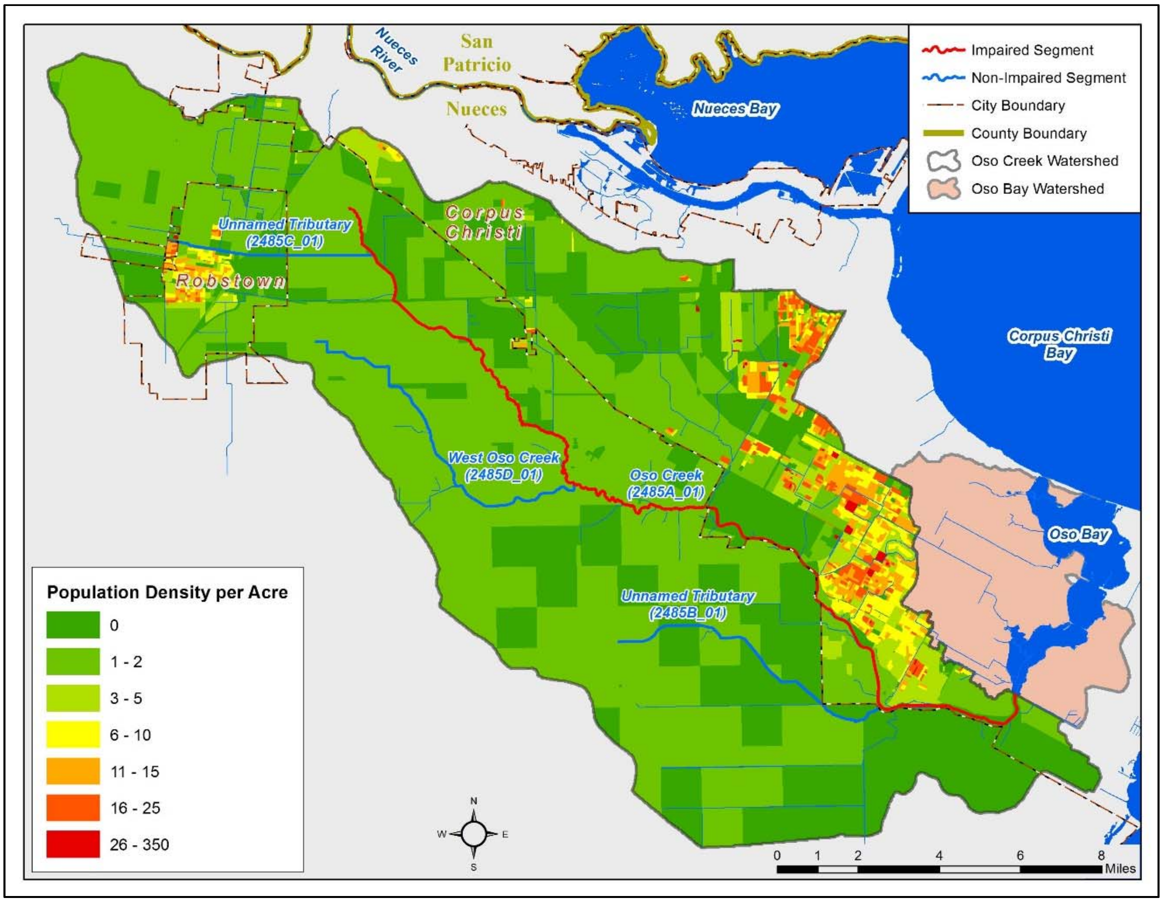

Figure 4. Population density for the Oso Creek watershed based on the 2010 U.S. Census blocks.

Population projections from 2010 - 2050 were developed by the Texas Water Development Board (TWDB) and indicate a population increase of 28.4 percent in the Oso Creek watershed by 2050 based on Water User Groups (WUGs; TWDB, 2015). Population projection increases range from 8.5 percent to 52.4 percent with the largest population percent increase (52.4 percent) over the 40-year span anticipated to occur in that portion of the Oso Creek watershed that falls outside of the Corpus Christi and Robstown municipal boundaries, but only contributes 2,348 additional people by 2050. The Corpus Christi population within the Oso Creek watershed is projected to increase by more than 30,000 people by 2050. Table 1 provides a summary of the 2010 – 2050 population projections.

Table 1. 2010 Population and 2020-2050 Population Projections for the Oso Creek watershed.

Location or WUG	2010 U. S. Census Population	2020 Population Projection	2030 Population Projection	2040 Population Projection	2050 Population Projection	Projected Population Increase (2010 - 2050)	Percent Change (2010 - 2050)
Corpus Christi	103,411	113,726	123,871	130,248	133,982	30,571	29.56%
Robstown	11,237	12,196	12,196	12,196	12,196	959	8.53%
County Other[a]	4,482	5,001	5,917	6,493	6,830	2,348	52.39%
Watershed Total	119,130	130,923	141,984	148,937	153,008	33,878	28.44%

[a] County Other is defined as that portion of the Oso Creek watershed that falls outside of the Corpus Christi and Robstown municipal boundaries.

2.4 Review of Oso Creek Watershed Routine Monitoring Data

2.4.1 Data Acquisition

Ambient indicator bacteria data were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) on August 9, 2016 (TCEQ, 2016a). 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 Oso Creek watershed for the entire period of record.

2.4.2 Analysis of Bacteria Data

Recent environmental bacteria monitoring in the Oso Creek watershed has occurred at seven TCEQ Surface Water Quality Monitoring (SWQM) stations within the watershed (Figure 5). Enterococci data collected at these stations over the seven-year period of December 1, 2005 through November 30, 2012 were used in assessing attainment of the primary contact recreation use as reported in the 2014 Texas Integrated Report (TCEQ, 2015) and are summarized in Table 2. The 2014 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. Additionally, primary contact recreation was not assessed for the two unnamed tributaries of Oso Creek (2485B and 2485C) and West Oso Creek (2485D). Note that a minimum of ten data points are required for assessment purposes, and the five available data points for West Oso Creek are insufficient to state definitively that impairment is occurring (Table 2).

2.5 Water Rights Review

Surface water rights in Texas are administered and overseen by the TCEQ. A search of the TCEQ water rights database file (TCEQ, 2016b) revealed that the Oso Creek watershed contains five permitted surface water rights owners as depicted in Figure 6. As noted in Table 3, diverted water uses include irrigation and recreation, with an authorized annual total diversion of 915.7 acre-feet and two water rights permits have two associated uses; Oso Creek Properties LC and City of Corpus Christi.

Table 2 2014 Integrated Report Summary for the Oso Creek Segment 2485A and 2485D. (The geometric mean criterion for primary contact recreation use is 35 MPN/100 mL for Enterococci.)

Water Body	Segment	Parameter	Stations	Data Date Range	No. of Samples	Geometric Mean (MPN/100 mL)
Oso Creek	2485A	Enterococci	13026, 13027, 13028, 13029, 16712, 18499, and 18500	Dec. 1, 2005 - Nov. 30, 2012	104	144
West Oso Creek	2485D	Enterococci	18501 and 20198	Dec. 1, 2005 - Nov. 30, 2012	5[a]	1,004

[a] Too few samples to assess for impairment

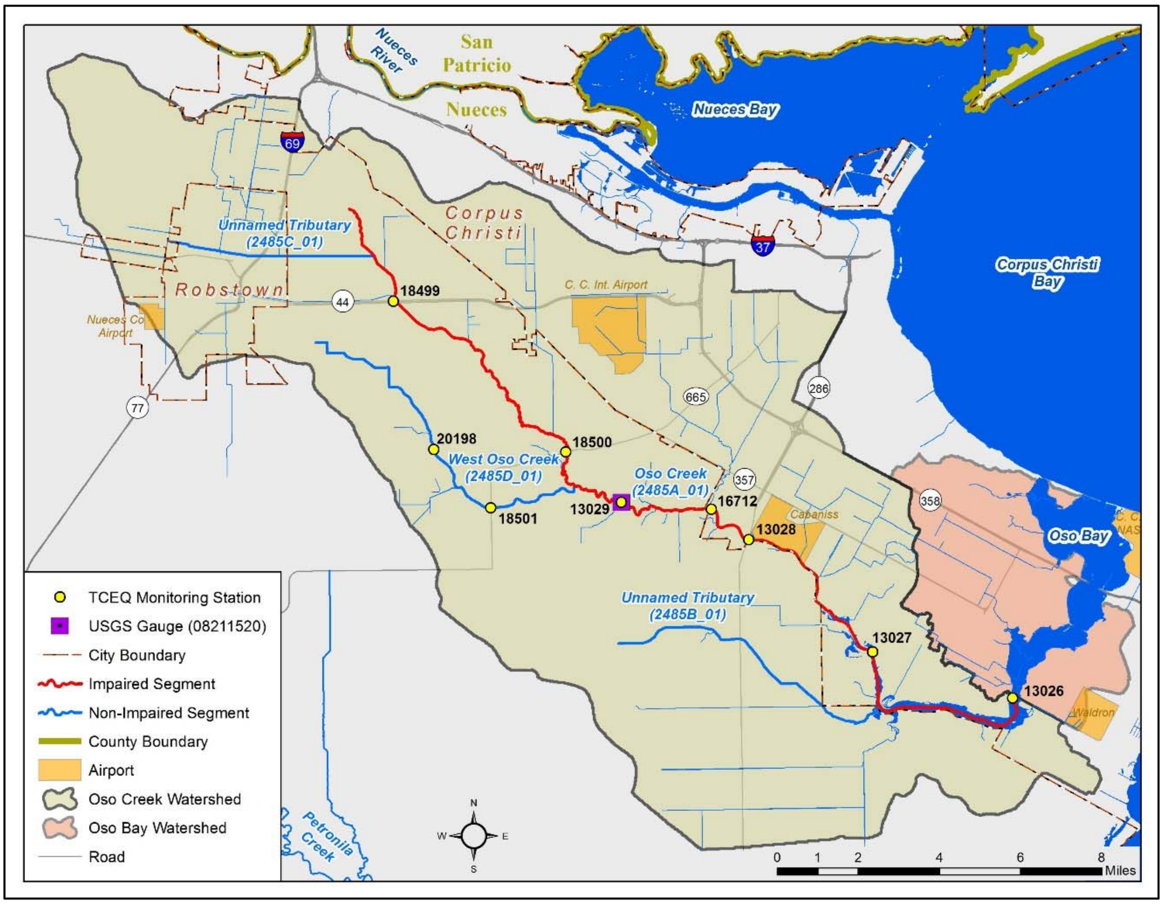

Figure 5. Oso Creek watershed showing selected TCEQ SWQM stations and United States Geological Survey (USGS) gauge.

A review of the water use data file containing historical reported water diversions indicates only one user, located above United States Geological Survey (USGS) gauge 08211520, reported a diversion of 15.84 acre-feet of water from the Oso Creek watershed from 1990 through 1999 (TCEQ, 2016c; Figure 6 and Table 3). No users reported diversion of water from 2000 through

2014 (TCEQ, 2016c). Because of the absence of any recently reported diversions of water from Oso Creek by surface water rights owners, it is assumed that water rights diversions will have no impact on stream hydrology and pollutant load allocations.

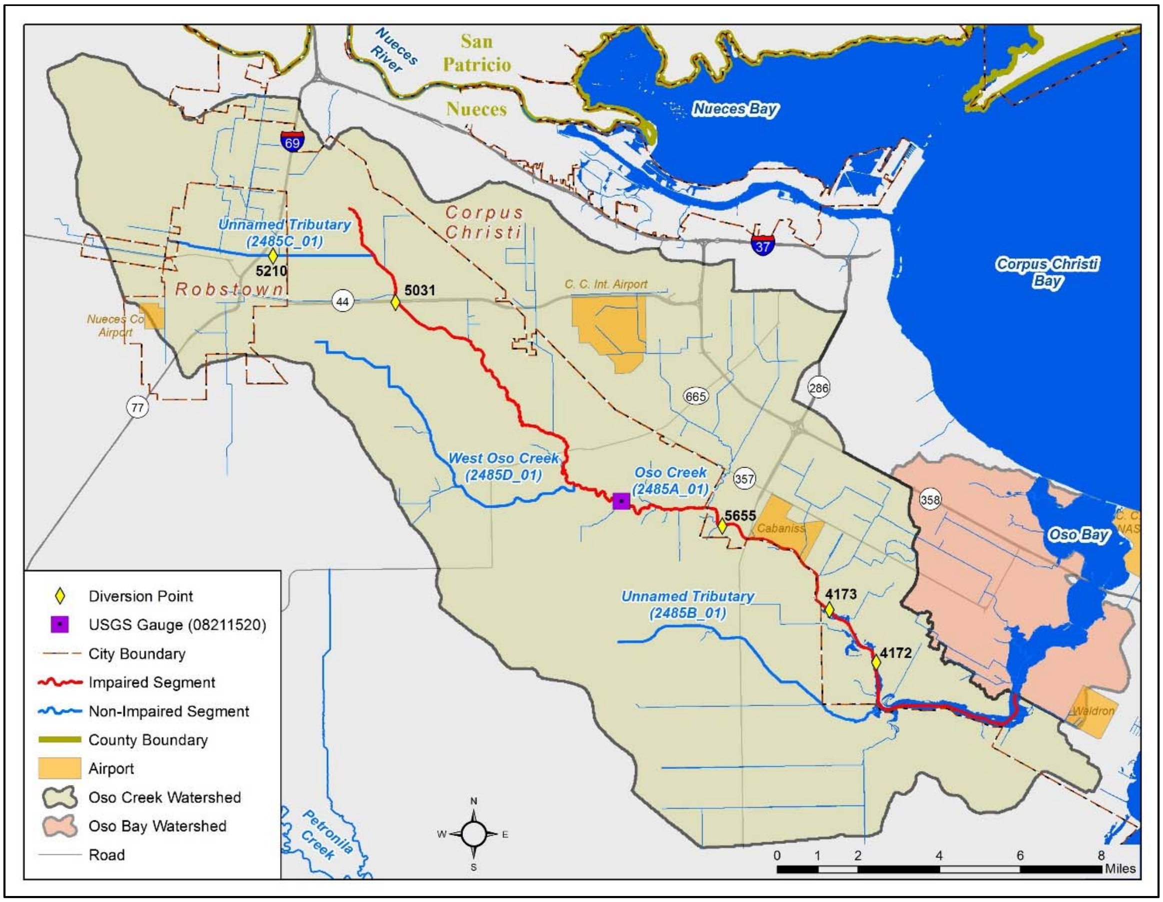

Figure 6. **Oso Creek watershed showing diversion points and permit numbers of surface water rights owners in relation to USGS gauge.**

Table 3. Permitted annual diversion amounts for water rights permittees in Oso Creek watershed.

Permit No.	Owner Name	Use	Diversion Located Above/Below USGS Gauge 08211520	Authorized Diversion Amount (acre-feet/year)
4172	OSO CREEK PROPERTIES LC	Irrigation	Below	645
4172	OSO CREEK PROPERTIES LC	Recreation	Below	-
4173	KINGS CROSSING GOLF & C C	Recreation	Below	127
5031	ST ANTHONY'S CATHOLIC CHURCH	Irrigation	Above	1
5210	2-B FARM & RANCH INC	Irrigation	Above	80
5655	City of Corpus Christi	Irrigation	Below	62.7
5655	City of Corpus Christi	Mining	Below	-
Watershed Total				915.7

2.6 Land Use

The land use/land cover data for the Oso Creek watershed was obtained from the U.S. Geological Survey 2011 National Land Cover Database (NLCD; Homer et al., 2015 and USGS, 2014).

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

- *Open Water - all areas of open water, generally with less than 25 percent cover or 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 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.*
- *Developed, Low Intensity - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.*
- *Developed, Medium Intensity - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.*
- *Developed, High Intensity - 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 percent of the total cover.*
- *Barren Land (Rock/Sand/Clay) - barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15 percent of total cover.*
- *Deciduous Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.*

- *Evergreen Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.*
- *Mixed Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.*
- *Shrub/Scrub - areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.*
- *Grassland/Herbaceous - areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.*
- *Pasture/Hay - areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.*
- *Cultivated Crops - areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.*
- *Woody Wetlands - areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.*
- *Emergent Herbaceous Wetlands - areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.*

The 2011 NLCD land use/land cover data is provided for the Oso Creek watershed in Figure 7. A summary of the land use/land cover data is provided in Table 4. The dominant land uses vary slightly with Cultivated Crops (62.7 percent) and Developed (open space, low intensity, medium intensity, and high intensity; 20.1 percent) comprising 82.8 percent of the land use/land cover. To summarize, the land use coverage indicates a mostly rural, agricultural watershed with areas of intense urbanization.

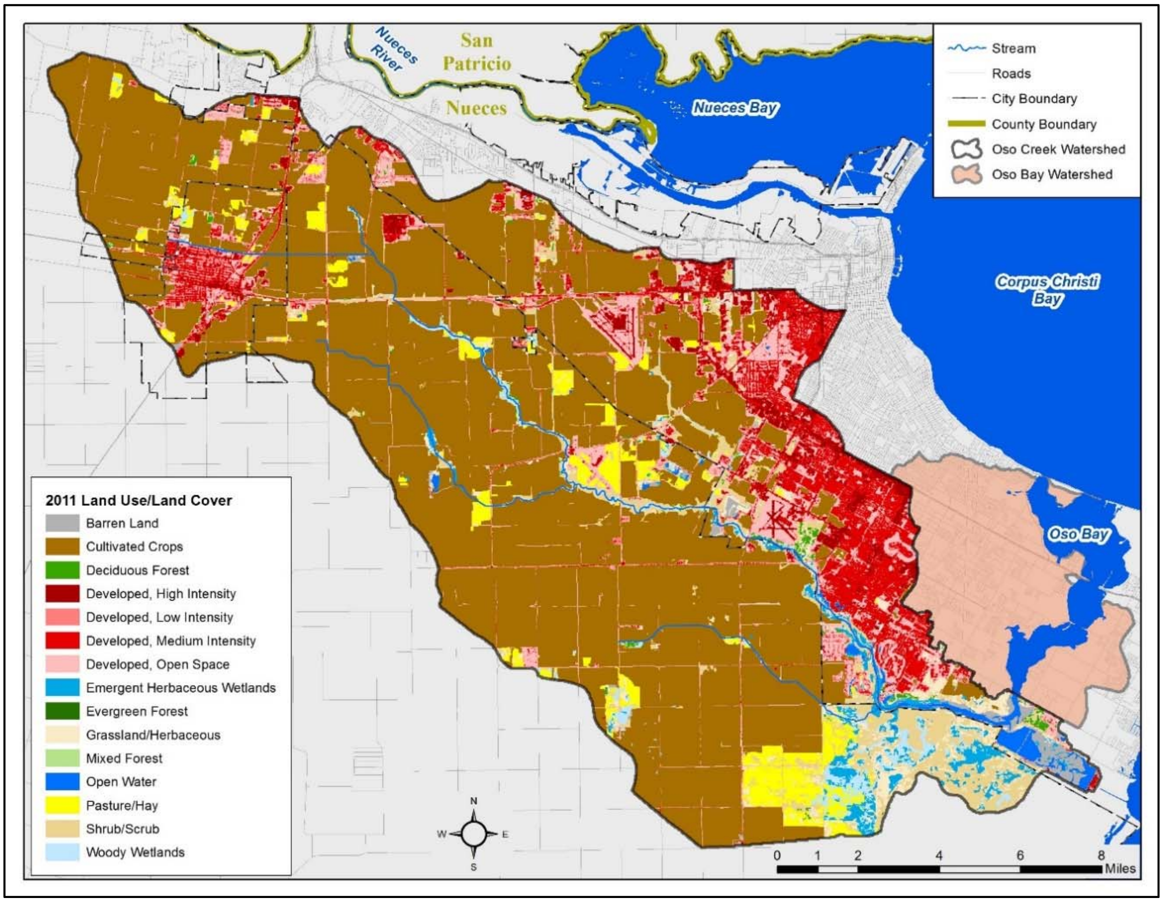

Figure 7. 2011 NLCD land use/ land cover within the Oso Creek watershed.

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

2011 NLCD Classification	Acres	Percent of Total
Open Water	1,144.3	0.86%
Developed, Open Space	8,293.7	6.20%
Developed, Low Intensity	5,755.4	4.30%
Developed, Medium Intensity	9,475.0	7.08%
Developed, High Intensity	3,323.6	2.48%
Barren Land	1,424.6	1.06%
Deciduous Forest	494.7	0.37%
Evergreen Forest	2.8	0.00%
Mixed Forest	3.8	0.00%
Shrub/Scrub	7,157.8	5.35%
Grassland/Herbaceous	3,195.8	2.39%
Pasture/Hay	5,380.1	4.02%
Cultivated Crops	83,882.7	62.68%
Woody Wetlands	2,248.7	1.68%
Emergent Herbaceous Wetlands	2,049.8	1.53%
Total	133,832.8	100.00%

2.7 Soils

Soils within the Oso Creek watershed were categorized by septic tank absorption field ratings – conditions are shown in Figure 8. These data were obtained through the USDA Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database (NRCS, 2015).

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

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

- *Not Limited – Indicates that the soil has features that are very favorable for the specific use. Good performance and very low maintenance can be expected.*
- *Somewhat Limited – Indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without*

major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

- *Very limited - Indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.*
- *Not Rated – Indicates insufficient data exists for soil limitation interpretation.*

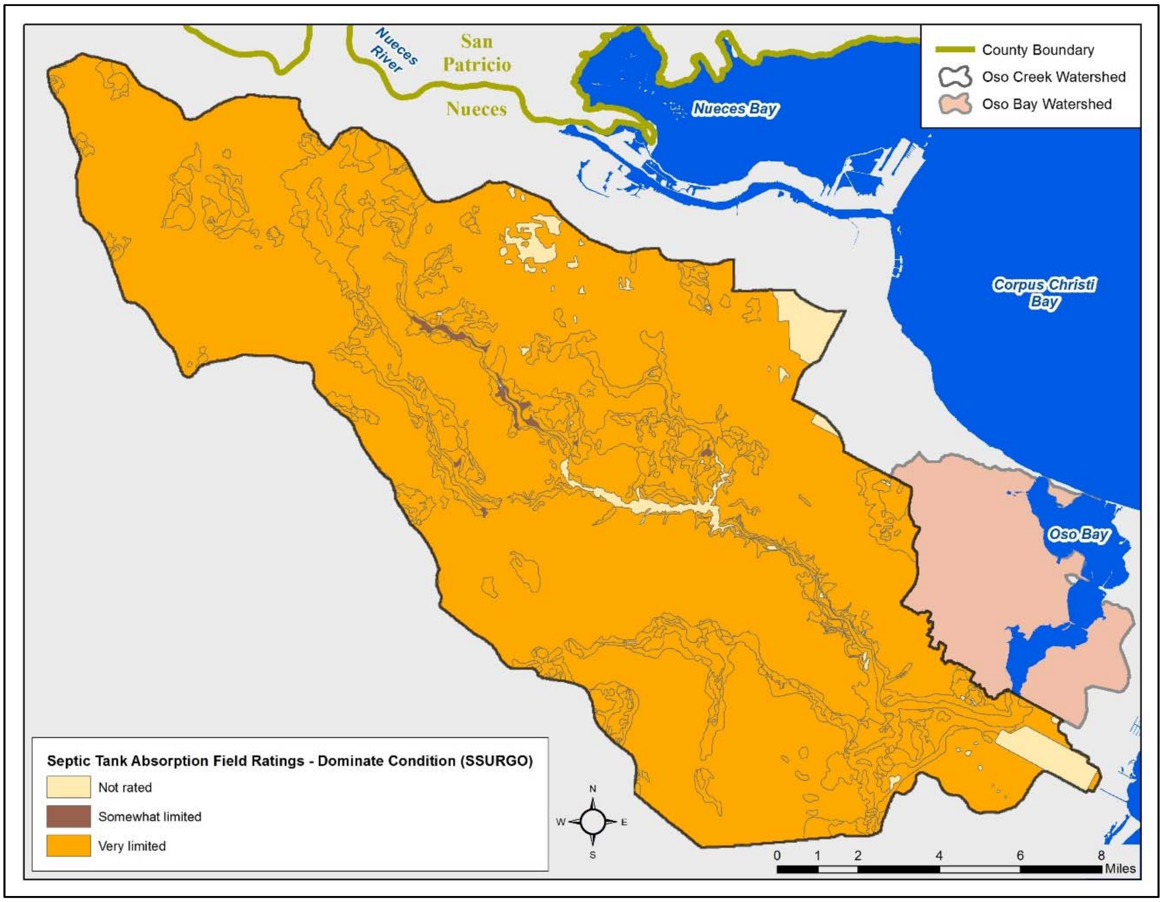

Figure 8. Septic tank absorption field limitation ratings for soils within the Oso Creek watershed.

Within the Oso Creek watershed, approximately 97 percent of the soils are rated as "Very Limited" based on the dominate soil condition for septic drainage field installation and operation.

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. Domestic and industrial WWTFs and municipal, construction, and industrial stormwater discharges represent the permitted sources in the Oso Creek watershed.

2.8.1.1 Domestic and Industrial Wastewater Treatment Facilities

As of July 2016, there are six facilities with TPDES/ NPDES permits that operate within the watershed (Figure 9 and Table 5). Four facilities within the watershed treat exclusively domestic wastewater, one industrial facility (Barney M. Davis LP) treats low-volume wastes associated with a natural gas power plant facility with no human waste component, and one industrial facility is permitted only for stormwater discharges. As noted in Table 5, three facilities discharge directly into Oso Creek. Discharge units are reported in million gallons per day (MGD).

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
- TXG870000 – pesticides
- TXG920000 – concentrated animal feeding operations
- WQG20000 – livestock manure compost operations (irrigation only)

A review performed August 11, 2016, of active general permit coverage (TCEQ, 2016d) in the Oso Creek watershed discovered four concrete production facilities and three pesticide permittees covered by the general permit. The concrete production facilities and pesticide management areas do not have bacteria reporting or limits in their permits. These facilities were assumed to contain inconsequential amounts of indicator bacteria in their effluent; therefore, it was unnecessary to allocate bacteria load to these facilities. No other active general wastewater permit facilities or operations were found. There were no facilities covered under the general permits for aquaculture, 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.

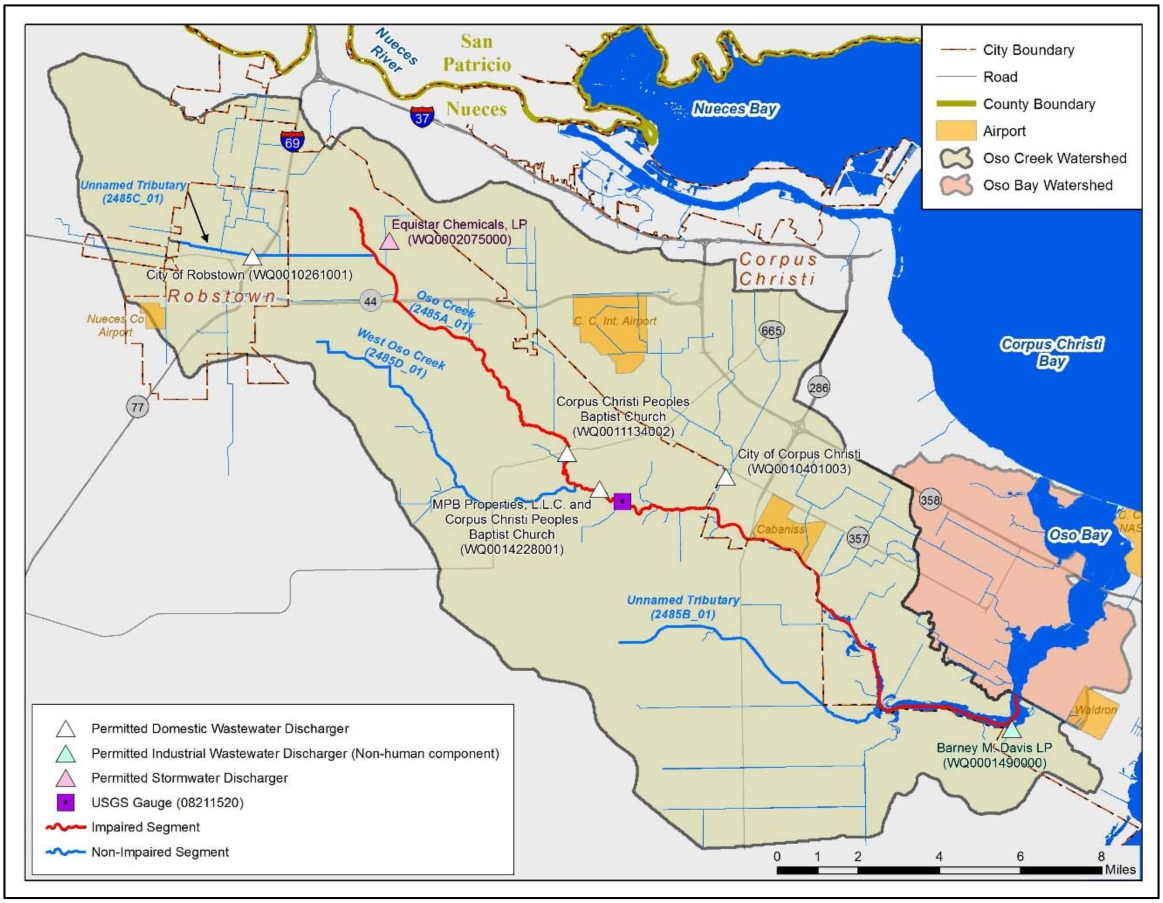

Figure 9. Oso Creek watershed showing permitted domestic and industrial regulated discharge facilities (WWTFs, Industrial wastewater and stormwater) and USGS gauging station.

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.

Table 5. Permitted domestic and industrial wastewater treatment facilities in the Oso Creek watershed.

AU	Facility	TPDES Permit No.	NPDES Permit No.	Receiving Waters	Discharge Type	Permitted Discharge (MGD)	Recent Discharge - 2012-2015 (MGD) [a]
2485C_01	City of Robstown	WQ0010261001	TX0020389	unnamed tributary; thence to Oso Creek	Domestic Wastewater	3.0 (annual avg)	1.2
2485A_01	Corpus Christi People's Baptist Church (Rollof WWTF)	WQ0011134002	TX0076767	Oso Creek	Domestic Wastewater	0.02 (daily avg)	0.008
2485A_01	City of Corpus Christi (Greenwood Plant)	WQ0010401003	TX0047074	unnamed tributary; thence to Oso Creek	Domestic Wastewater	16.0 (annual avg)	5.4
2485A_01	MPB Properties, L.L.C. and Corpus Christi People's Baptist Church (Cuddihy Airfield WWTF)	WQ0014228001	TX0123676	Oso Creek	Domestic Wastewater	0.06 (daily avg)	0.008
2485A_01	Barney M. Davis, LP	WQ0001490000	TX0008826	Oso Creek	Industrial - low volume wastewater, metal cleaning wastes, and stormwater	Intermittent and variable	–
					Industrial - once through cooling water and previously monitored effluents	540 (daily avg)	319
2485A_01	Equistar Chemicals, LP	WQ0002075000	TX0076996	unnamed ditch; thence to Oso Creek	Stormwater	Intermittent and variable	–

[a] Four- year average measured data from January 2012 through December 2015 from Discharge Monitoring Report data (USEPA, 2016)

The TPDES/NPDES MS4 Phase I and II rules require municipalities and certain other entities in urban areas to obtain permits for their stormwater systems. Both the Phase I and II permits include any conveyance such as ditches, curbs, gutters, and storm sewers that do not connect to a wastewater collection system or treatment facility. Phase I permits are individual permits for large and medium sized communities with populations exceeding 100,000, whereas Phase II permits are for smaller communities within an USEPA-defined urbanized area that are regulated by a general permit. The purpose of a MS4 permit is to reduce discharges of pollutants in stormwater to the "maximum extent practicable" by developing and implementing a Stormwater Management Program (SWMP). The SWMPs require specification of best management practices (BMPs) for six minimum control measures:

- Public education and outreach;
- Public participation/involvement;
- Illicit discharge detection and elimination;
- Construction site runoff control;
- Post-construction runoff control; and
- Pollution prevention/good housekeeping.

The geographic region of the Oso Creek watershed covered by Phase I and II MS4 permits is that portion of the area within the jurisdictional boundaries of the regulated entity. For Phase I permits, the jurisdictional area is defined by the city limits of Corpus Christi within the watershed, and for Phase II permits, the jurisdictional area is defined as the 2010 Census Urbanized Area(USCB, 2010) that was within the watershed but outside of the Corpus Christi city limits.

Areas included under Phase I and II MS4 permits were used to estimate the regulated stormwater areas for construction, industrial, and MS4 permits (Figure 10). The regulated area for the Phase II permits was based on the 2010 Urbanized Area from the U.S. Bureau of Census. The entities regulated under MS4 permits for the Oso Creek watershed are provided in Table 6.

A central registry search for active regulated stormwater entities for Phase I MS4 permit coverage (TCEQ, 2016e) in the TMDL study area revealed that a permit each for Phase I and Phase II permits (Table 6) exist for the City of Corpus Christi and Nueces County, respectively, providing 31.24 percent regulated stormwater coverage for the TMDL study area (Figure 10).

Table 6. TPDES and NPDES MS4 permits in the Oso Creek watershed.

Entity	TPDES Permit	NPDES Permit
City of Corpus Christi, Del Mar College District, Port of Corpus Christi Authority, Texas A&M University – Corpus Christi	WQ0004200000	TXS000601
Texas Department of Transportation	WQ0005011000	TXS002101
Nueces County	Phase II General Permit (TXR040000)	TXR040054

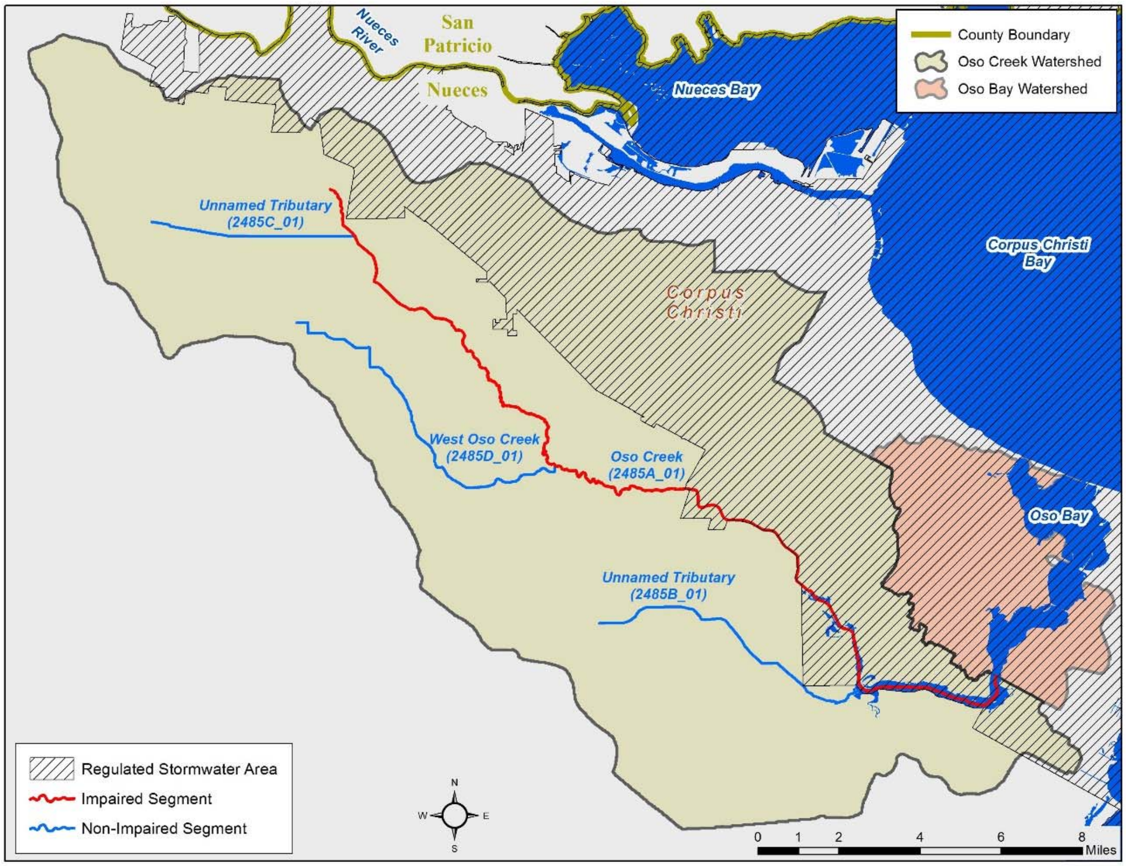

Figure 10. Regulated stormwater area based on Phase I and Phase II MS4 permits within Oso Creek watershed.

2.8.1.4 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.

City of Corpus Christi SSO data from 2008-2013 containing estimates of the total gallons spilled, responsible entity, and a general location of the spill were provided by the Center for Water Supply Studies (CWSS, 2016). SSO incidents for this dataset were refined by CWSS by assigning latitude and longitude coordinates to each SSO event and plotted using Geographic Information System (GIS) software to characterize the frequency and magnitude of SSO events within the Oso Creek watershed (Figure 11). A summary of the CWSS refined data within the Oso Creek watershed is shown in Table 7. Additionally, SSO data from 2008-2016 was provided by the TCEQ Region 14 office (TCEQ, 2016f). Efforts were made to extract only the incidents that occurred within the Oso Creek watershed area from this dataset as well; however, the lack of georeferenced SSO events made geospatial distinction of SSOs contained in this dataset difficult. Thus, a summary of the reported SSO incidents from the TCEQ Region 14 dataset for the cities of Corpus Christi and Robstown can be found in Table 8.

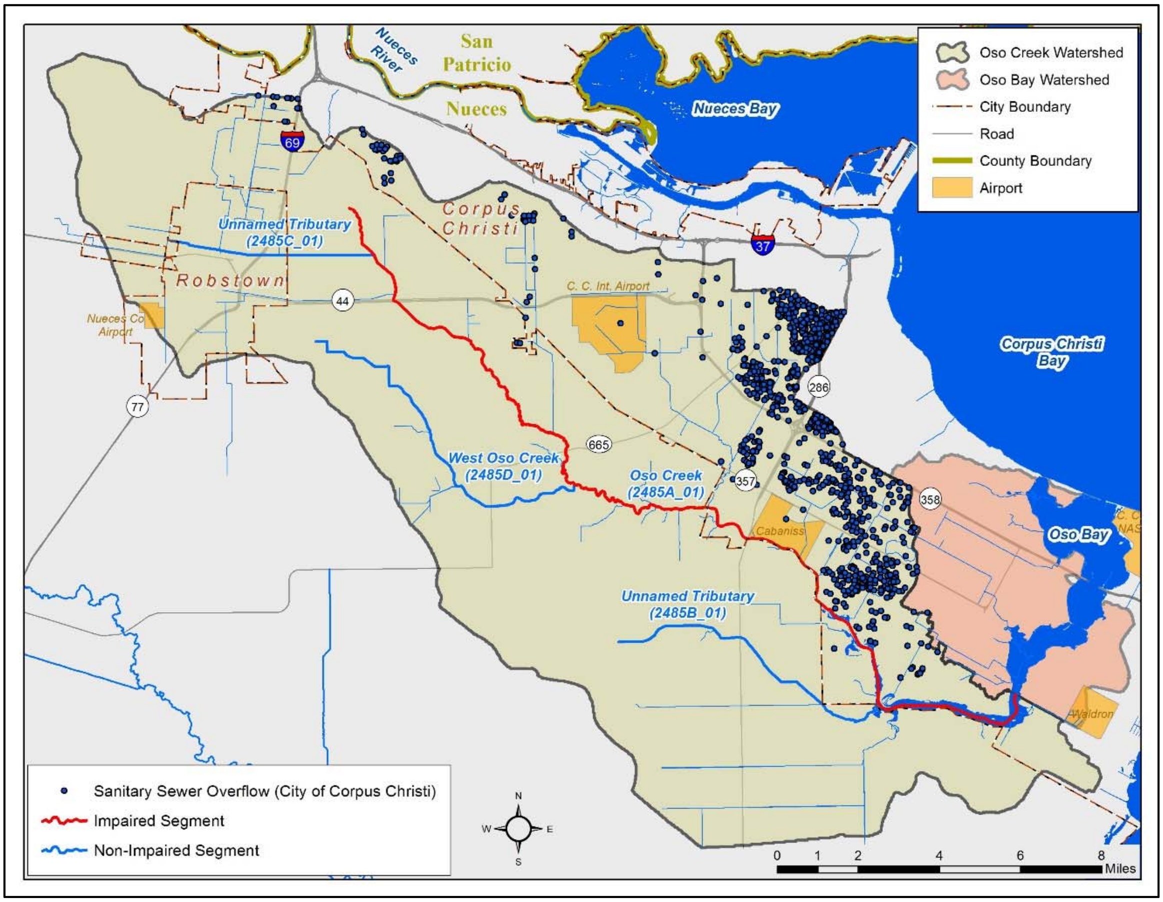

Figure 11. SSOs for the City of Corpus Christi from 2008-2013 within Oso Creek watershed.

Table 7. Summary of SSO incidences reported in the Oso Creek watershed from 2008–2013.

Watershed	No. of Incidents	Total Volume (gallons)	Average Volume (gallons)	Minimum Volume (gallons)	Maximum Volume (gallons)
Oso Creek	1,715	228,773	133	1	100,000

Table 8. Summary of SSO incidences reported for the cities of Corpus Christi and Robstown from 2008–2016.

Municipality	No. of Incidents	Total Volume (gallons)	Average Volume (gallons)	Minimum Volume (gallons)	Maximum Volume (gallons)
Corpus Christi	1,211	719,847	594	0.1	273,696
Robstown	11	5,590	508	15	1,600

2.8.1.5 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) include:

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.

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.

It should be noted that a previous two-year study (2008-2009) identified 67 potential inflows (e.g. WWTF outfalls, stormwater drains) along Oso Creek and its tributaries and concluded that dry weather inflows do contribute to the overall Enterococci loadings of Oso Creek (Mott and Hay, 2009).

2.8.1.6 Review of Compliance Information on Permitted Sources

A review of the USEPA Enforcement & Compliance History Online (ECHO) database (USEPA, 2016) conducted August 27, 2016, revealed non-compliance issues regarding bacteria for one WWTF in the Oso Creek watershed (Table 9). No other non-compliance effluent violations were noted for the balance of WWTFs. None of the bacteria effluent violations were reported as "Significant Non-compliance" effluent violations.

Table 9. Bacteria monitoring requirements and compliance status for WWTFs in the Oso Creek watershed.

Data available through the USEPA ECHO database (USEPA, 2016), 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	Bacteria Monitoring Requirement	Min. Self Monitoring Requirement Frequency	Daily Average (Geometric Mean) Limitation	Single Grab (or Daily Max) Limitation	No. of Violations	% Monthly Exceedances Daily Average	% Monthly Exceedances Single Grab (or Daily Max)
WQ0010261001	City of Robstown	*E. coli*	One/week	126	399	0	-	-
WQ0011134002	Corpus Christi People's Baptist Church (Rollof WWTF)	*E. coli*	One/quarter	126	399	0	-	-
WQ0010401003	City of Corpus Christi (Greenwood Plant)	Enterococci	Daily	35	104	6	0.0%	22.2%[a]
WQ0014228001	MPB Properties, L.L.C. and Corpus Christi People's Baptist Church (Cuddihy Airfield WWTF)	*E. coli*	One/quarter	126	399	0	-	-

[a] Based on 27 monthly Enterococci records (April 30, 2014 - June 30, 2016)

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.

Additionally, a previous multi-year bacteria source tracking study confirmed that livestock, wildlife (non-avian), and birds were contributing sources of bacteria to Oso Creek (Mott et al., 2012).

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.

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. This holds true especially when considering potential wildlife bacteria contributors such as birds. While it is noted that Oso Creek lies within the Central Flyway for migrating birds in North America (Shackelford et al., 2005) and migratory locations that provide rest areas and food sources (e.g. row crop fields) exist within the watershed (TPWD, 2016a), no data is available for avian population densities for the Oso Creek watershed.

However, population estimates for feral hogs and deer are readily available for the Oso Creek watershed. For feral hogs, the Texas Parks and Wildlife Department (TPWD) estimated the average feral hog densities within the Oso Creek watershed to be approximately 36.81 hogs/mi^2 of suitable habitat with heavier densities in the southeastern portion of the watershed (TPWD, 2016b). The TPWD hog density estimate was multiplied by the total suitable habitat identified within the Oso Creek watershed (11.19 mi^2). Habitat deemed suitable for hogs were identified from the 2011 NLCD (USGS, 2014) and include: shrub/scrub, grassland/herbaceous, deciduous forest, evergreen forest, and mixed forest. Using this methodology, there are an estimated 412 feral hogs in the Oso Creek watershed.

The same methodology used for feral hog population estimates was used to obtain the population of white-tailed deer within the Oso Creek watershed. The TPWD estimated the white-tailed deer average density to be 41.86 deer/mi^2 of suitable habitat (TPWD, 2016b). Applying this value to the area of suitable habitat (11.19 mi^2) as previously determined for feral hogs yielded an estimated white-tailed deer population of 468 deer for the Oso Creek watershed.

2.8.2.2 Non-Permitted Agricultural Activities and Domesticated Animals

The number of livestock that are found within the Oso Creek watershed was estimated from county level data obtained from the 2012 Census of Agriculture (USDA NASS, 2014). The county level data were refined to better reflect actual numbers within the impaired AU watershed. Using the 2011 NLCD, the refinement was performed by determining the total area of the suitable livestock land cover categories of "Herbaceous/ Grassland" and "Hay/ Pasture" within the Oso Creek watershed and Nueces County. A ratio was then computed by dividing the livestock total land use area of the watershed by the livestock total land use area of the county. The county level agricultural census data were then multiplied by the ratio to determine the estimated Oso Creek watershed domestic animal populations (Table 10).

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 10 are provided to demonstrate that livestock are a potential source of bacteria in the Oso Creek watershed. These numbers, however, are not used to develop an allocation of allowable bacteria loading to livestock.

Table 10. Estimated distributed domesticated animal populations within the Oso Creek watershed, based on proportional area.

Watershed	Cattle and Calves	Hogs and Pigs	Sheep and Lambs	Goats	Horses and Ponies	Mules, Burros, and Donkeys	Poultry
Oso Creek	2,470	60	84	158	170	12	11

2.8.2.3 On-site Sewage Facilities

Private residential 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. Oso Creek is located within the east-central Texas region 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 Oso Creek watershed were based on 2010 Census block data. OSSFs were estimated to be households that were outside of either a Certificate of Convenience and Necessity sewer area (PUCT, 2016) or a city boundary, although it is noted that some OSSFs may exist within these boundaries. The total estimate is shown in Table 11 and the OSSF density is depicted in Figure 12.

Additionally, OSSFs located within 100 meters of Oso Creek AU 2485A_01 and colonias existing within the Oso Creek watershed were identified by the CWSS and are included in Figure 12 (CWSS, 2016). Colonias are generally described by the Texas Secretary of State (TSS) as low-income residential areas located in rural and urban areas that can be bereft of common living conveniences such as potable water, electricity, and sewage systems (TSS, 2016).

Table 11. OSSF estimate for the Oso Creek watershed.

Watershed	Estimated OSSFs
Oso Creek	1,020

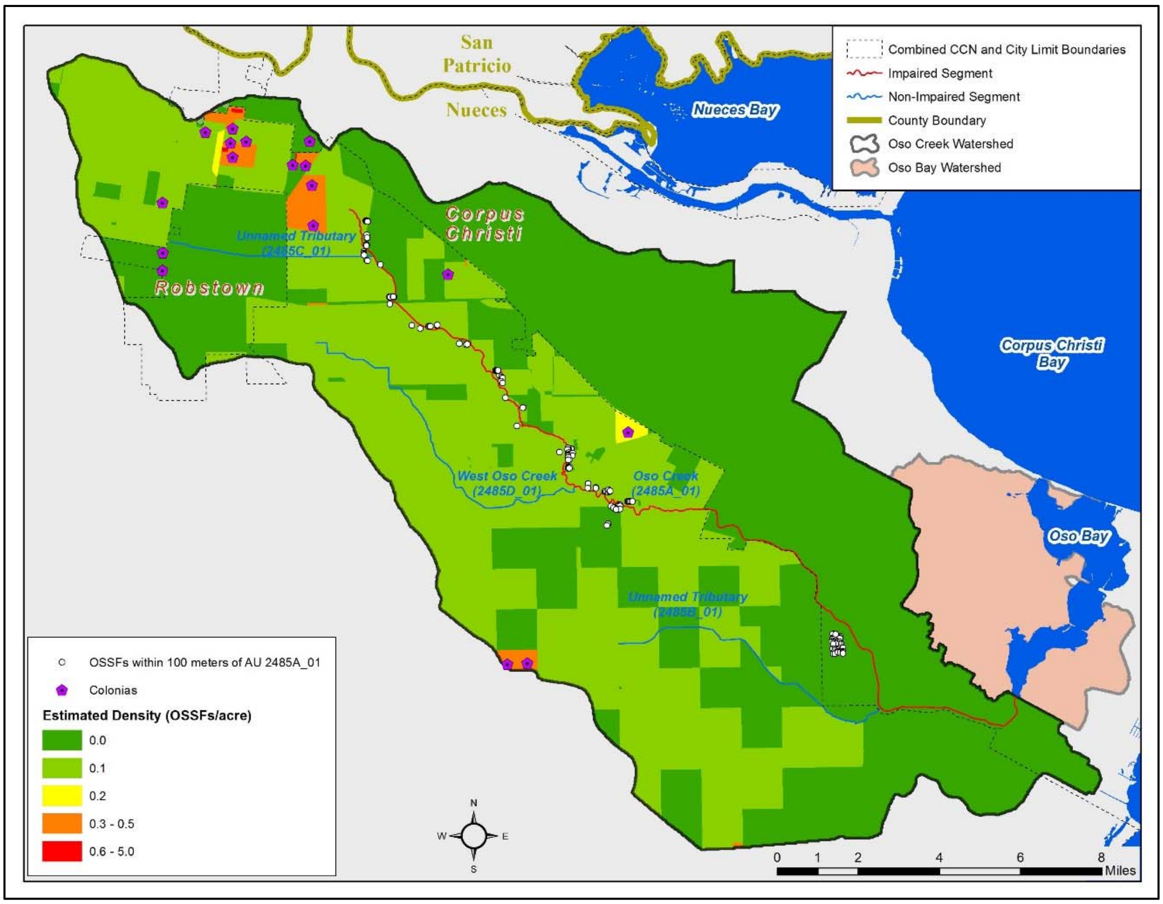

Figure 12. OSSF densities, OSSFs located adjacent to Oso creek, and colonias within the Oso Creek watershed.

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 12 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, 2012). The actual contribution and significance of fecal coliform loads from pets reaching the water bodies of the watershed is unknown.

Table 12. Estimated households and pet populations for the Oso Creek watershed.

Watershed	Households	Estimated Dog Population	Estimated Cat Population
Oso Creek	41,818	24,422	26,680

2.8.2.5 Other Considerations

Supporting this TMDL was the availability of studies performed in the Oso Creek watershed targeting potential sources of indicator bacteria to Oso Creek. Specifically, groundwater, subsurface seepage, and soil from agricultural fields were investigated as potential sources of Enterococci.

Generally, groundwater is considered more of a “pathway” for pollutant loadings, but can be considered a potential source of bacteria loadings if pollutant transport to surface waters is determined. In a previous study, the CWSS monitored groundwater in the Oso Creek watershed for Enterococci, determined the hydraulic properties of the aquifer, and subsequently modeled bacteria fluxes into Oso Creek in an effort to determine if groundwater was a contributing source of indicator bacteria contamination (Hay, 2011). Results of the CWSS study indicated that Enterococci concentrations were lower (by orders of magnitude) in groundwater than historical surface water concentrations and, while present in the aquifer, the potential for significant Enterococci transport into Oso Creek from adjacent groundwater was very low due to insufficient hydraulic properties (i.e., low hydraulic conductivity and gradient).

In a separate study but similar to the CWSS study previously mentioned, Mott et al. (2012) further investigated groundwater pollutant transport including sub-surface seepage into Oso Creek. Results of this study indicated that groundwater and subsurface seepage were unlikely sources of Enterococci contamination to Oso Creek supporting the CWSS study conclusions.

Additionally, Mott et al. (2012) investigated soil from agricultural fields with different cover crops (e.g. cotton, sorghum, sesame, and pasture) as a potential source of Enterococci contamination based on occurrences of high Enterococci and sediment concentrations from agricultural field runoff observed in a previous study by Ockerman and Fernandez (2010). It was concluded that soil containing either indigenous bacteria or bacteria from animal/plant origins may be a potential contributor of indicator bacteria during wet weather, high sediment runoff events (Mott et al., 2012).

2.8.2.6 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

BACTERIA TOOL DEVELOPMENT

This section describes the rationale of the bacteria tool selection for TMDL development and details the procedures and results of load duration curve development.

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 impaired AUs in the TMDL watersheds 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 LDC method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment. The LDC method has found relatively broad acceptance among the regulatory community, primarily due to the simplicity of the approach and ease of application. The regulatory community recognizes the frequent information limitations, 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 supports application of the LDC 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. The TMDL allocation tool, therefore, must be capable of characterizing streamflow and bacteria loads at desired locations under the wide variety of environmental conditions experienced in the TMDL watersheds. If a mechanistic modeling tool is applied, it must be capable of simulating response of bacterial loadings to streamflow 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.

The bacteria component of the model is in many ways even more complex than the hydrologic component and typically must include many different processes. Point sources and nonpoint sources of bacteria need to be defined and simulated by the model. Movement or washoff of bacteria from the various landscapes (e.g., urban yards, roads, pastures, wooded areas, areas of animal concentration), potential illegal connections of sewage lines to stormwater lines, broken sewer lines, and sewer overflows in response to rainfall are only some of the sources possibly needing to be represented in the model. Streamflow transport of the bacteria in tributaries and in the mainstem river and the response of the bacteria while in transport to settling, die-off, resuspension, regrowth in the water column, regrowth in the sediment, etc. need to be defined with adequate certainty to allow proper model representation for each of these physical and biological processes.

While admittedly the hydrologic 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 have 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 into readily available models, these processes are appreciably more watershed specific than hydrologic processes. As one simple example, failing OSSFs, 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 Oso 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. Studies performed in this watershed to evaluate bacteria sources as summarized in Section 2.8.2.5 (Other Considerations) do address several, though not all, of these watershed-specific data requirements for bacteria modeling.

3.1.2 Data Resources of Oso Creek

Streamflow, specific conductance, Enterococci, and WWTF discharge data availability were used to provide guidance in the allocation tool selection process. 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 Oso Creek watershed, and these limitations became an important consideration in the allocation tool selection process.

Streamflow data for Oso Creek are collected and made readily available by the U.S. Geological Survey (USGS, 2016), which operates the Oso Creek streamflow gauge. USGS streamflow gauge 080211520 is located along the mainstem of Oso Creek and is collocated with SWQM Station 13029 (Table 13; Figure 5).

Table 13. Basic information on Oso Creek USGS streamflow gauge

Gauge No.	Site Description	Drainage Area (acres)	Daily Streamflow Record (beginning & end date)
08211520	Oso Creek at Corpus Christi, TX.	56,845	Sept. 1972 - present

Self-reported data in the form of monthly discharge reports (DMRs) were obtained for the 16 year timeframe of January 2000 - December 2015 for the WWTFs in the Oso Creek watershed. For each WWTF, DMR data were downloaded as available from these USEPA compliance databases: ECHO and the combined Permit Compliance System and Integrated Compliance Information System.

Ambient indicator bacteria data, including Enterococci, *E. coli,* and fecal coliform, were available through the TCEQ SWQMIS (TCEQ, 2016a) for seven stations along Oso Creek (Table 14; Figure 5). The most pertinent bacteria data for this study is for Enterococci, since that is the relevant indicator bacteria in tidal streams. Seven stations were sampled at various times for Enterococci, but all these data were collected between 1999 and 2016 as of the August 2016 data request from SWQMIS (TCEQ, 2016a). Presently only station 13028, Oso Creek at SH 286, is being monitored and this station also has the most continuous and complete Enterococci data series with 117 sampling dates during the period of late 1999 through early 2016.

All seven of these stations also have field parameters collected at them, which includes specific conductance that can be used to estimate salinity concentrations. Salinity is an important parameter which would be used in both mechanistic model development and application of the adaption of the LDC method to tidal streams. In general, the specific conductance data are available for a longer period of time and for more sampling events than the Enterococci data, since field parameters are routinely collected at a station as a matter of protocol any time sampling occurs at a station.

Table 14. Summary of historical indicator bacteria data for Oso Creek stations obtained from SWQMIS

Station	Station Description	Indicator Bacteria	Count	Date Range	Geometric Mean (MPN/100 mL)
13026	Oso Creek at Yorktown Bridge	Enterococci	69	1999 – 2006; 2013	29.7
13026	Oso Creek at Yorktown Bridge	E. coli	15	1999 - 2000	16.0
13026	Oso Creek at Yorktown Bridge	fecal coliform	87	1973 – 2014	14.7
13027	Oso Creek at FM 2444	Enterococci	52	1999 – 2006	253.6
13027	Oso Creek at FM 2444	E. coli	15	1999 – 2000	187.5
13027	Oso Creek at FM 2444	fecal coliform	30	1984 – 2000	230.8
13028	Oso Creek at SH 286	Enterococci	117	1999 – 2016	201.3
13028	Oso Creek at SH 286	E. coli	21	1999 – 2000	365.3
13028	Oso Creek at SH 286	fecal coliform	85	1973 – 2003	275.7
13029	Oso Creek at FM 763	Enterococci	56	1999 – 2006	850.7
13029	Oso Creek at FM 763	E. coli	15	1999 – 2000	419.8
13029	Oso Creek at FM 763	fecal coliform	33	1989 – 2000	320.9
16712	Oso Creek at Elliot Landfill	Enterococci	51	1999 – 2006	443.0
16712	Oso Creek at Elliot Landfill	E. coli	15	1999 – 2000	556.5
16712	Oso Creek at Elliot Landfill	fecal coliform	18	1999 – 2000	465.9
18499	Oso Creek at SH 44	Enterococci	45	2005 – 2011	1,232
18499	Oso Creek at SH 44	E. coli	0	–	–
18499	Oso Creek at SH 44	fecal coliform	0	–	–
18500	Oso Creek at FM 665	Enterococci	45	2005 – 2011	1,088
18500	Oso Creek at FM 665	E. coli	0	–	–
18500	Oso Creek at FM 665	fecal coliform	0	–	–

3.1.3 Allocation Tool Selection

Assessment of readily available information indicated a historical daily streamflow record at one location, specific conductance data at several stations, DMR data for WWTF discharges, and ambient Enterococci data at several stations. As with most watersheds, deficiencies exist in site specific data to describe bacterial landscape and in-stream processes, though as discussed in Section 2.8.2.5 (Other Considerations) several watershed-specific studies have been performed that enhance the understanding of indicator bacteria sources and transport. Another consideration in allocation tool selection is the acceptance and common use of the LDC method for developing bacteria TMDLs in Texas.

While the LDC method seemed appropriate for use as the allocation tool, two complexities with applying the method to Oso Creek had to be considered prior to the definitive decision to use that method in lieu of a mechanistic model. First, Oso Creek is a tidal stream, and the lower portions of the creek definitely are subject to tidal influence. Second, the Barney M. Davis Power Station permitted outfall at the extreme downstream end of Oso Creek (Figure 9) allows the discharge of water taken from the north extremity of the Laguna Madre to be used as cooling water and discharged into Oso Creek. Historically, this permit stipulated a daily average discharge not to exceed 540 MGD (over 800 cubic feet per second (cfs)) and the influx of discharge has a significant influence on water quality in lower Oso Creek and Oso Bay (Hay and Mott, 2005). The facility was out of operation for a few years. Under new ownership, the facility is now operating with somewhat less discharge, and over a recent four-year period (2012 – 2015) has discharged an average of 300 MGD (500 cfs).

Effectively, the facility’s large discharge of cooling water compromises the applicability of the adaptation of the LDC method to Oso Creek. The adaptation relies on being able to represent the temporal variability of salinity at a location through a statistical relationship between streamflow and salinity. The large amount of salt water pumped as cooling water from the Laguna Madre into Oso Bay by the power station confounds the ability to develop such a relationship. The large discharge, however, does not preclude application of the standard LDC method, if the point of application of the tool is not significantly influenced by tides.

Based on the following information, it was concluded that the pertinent station for determination of pollutant load allocation, station 13028, on Oso Creek is either not tidally influenced or is only feebly influenced by tides:

- While somewhat upstream, at the collocation of USGS 08211520 and TCEQ station 13029, the successful operation of a standard streamflow gauging station using water levels to determine flows indicates no tidal influence at this location under probably all but the most extreme conditions of tidal surge.
- The Nueces River Authority staff indicated that station 13028 does not seem to be tidally influenced when sample collection occurs, though they were careful to clarify that they could not state definitively that the location was not tidally influenced at times or to a small degree (NRA, 2016).

- Specific conductance data were collected typically on the same day for a one-year period of May 2005 through April 2006 at four SWQM stations in the middle portion of Oso Creek; from downstream to upstream stations 13027, 13028, 16712, and 13029 (Figure 13). The specific conductance data at these four stations do not show the expected decreasing trend from downstream to upstream that occurs in a tidally influenced stream. Interestingly, the most upstream station (13029), which is not tidally influenced as supported by the active USGS streamflow gauge at this location, often has the highest specific conductance reading on any day of common measurement. The relatively high specific conductance readings at all four stations do indicate saline influences, but the dominate source is not indicated by these data to be tidal influence propagating high salinity water upstream from Oso Bay since the highest readings typically occur at the most upstream station.
- Much of the tidally influenced portion of Oso Creek has a sustained baseflow due to WWTFs discharges, which would hydrodynamically operate to diminish tidal exchange within the weakly tidally influenced portions of the creek. In particular the City of Corpus Christi Greenwood WWTF discharges into a tributary (locally known as La Volla Creek) of Oso Creek upstream of station 13028. Within the five-year period of 2011-2015, the daily average discharge of the Greenwood WWTF was 5.4 MGD (8.3 cfs), which is the same as the daily average flow only exceeded 15 percent of the time at the upstream USGS gauge location. Therefore, a relatively high baseflow is present to maintain a downstream-directed flow direction and to greatly reduce or eliminate true tidal exchange with reversal of flow direction.
- Water-level fluctuation as tidal range was determined to average 0.54 feet at the Conrad Blucher Institute operated gauge on Oso Creek at FM 43. This gauge is located approximately 1-½ miles downstream of station 13028. This average tidal range was computed based on 30-minute water-level data obtained for the gauge for the period of June 22, 2016 through February 27, 2017 (Blucher, 2017). This period spans the time from the resumption of gauge operation after completion of road construction on the Oso Creek FM 43 bridge to the last full day of information at the time of the data retrieval. The analysis included only data for those days for which the flow at the upstream USGS streamflow gauge was less than 5 cfs to avoid consideration of days when streamflow was sufficiently high to cause possible damping of the tidal fluctuation. The tidal range was estimated as the difference between the maximum and minimum water levels of each 25-hour period, which is the period used in the computation to approximate the 24.8 hour duration of a lunar day or complete tidal cycle. The average tidal range of 0.54 feet represents one contrary piece of evidence that station 13028 is either minimally or not tidally influenced. It should be noted that this relatively small average tidal range does not necessarily indicate that there is an actual reversal from a downstream flow direction to an upstream direction, but could only signify that the downstream freshwater flow is diminished in magnitude as water is, in essence, backed up in the creek during the flood (rising) tide. Indeed the other

points provided above would support such an interpretation of limited or no tidal flow reversal.

Based on the weight of evidence from the factors listed above, it is concluded that Oso Creek in the vicinity of station 13028 is either not tidally influenced or is only weakly tidally influenced and that any tidal influence is offset by the relatively high baseflow of the creek such that seawater does not occur at the location under most conditions. Therefore, application of the standard flow duration curve (FDC) method is applicable to much of Oso Creek, at least as far downstream as station 13028 and probably as far downstream as station 13027. Note that the standard FDC method was used for the most downstream station, station 13026, even though conditions will be strongly tidally influenced at that location on Oso Creek. The FDC and LDC for station 13026 are provided for informational purposes only to show under which freshwater flow conditions bacteria impairments were more likely at that location and are not intended for development of pollutant load allocations for this TMDL.

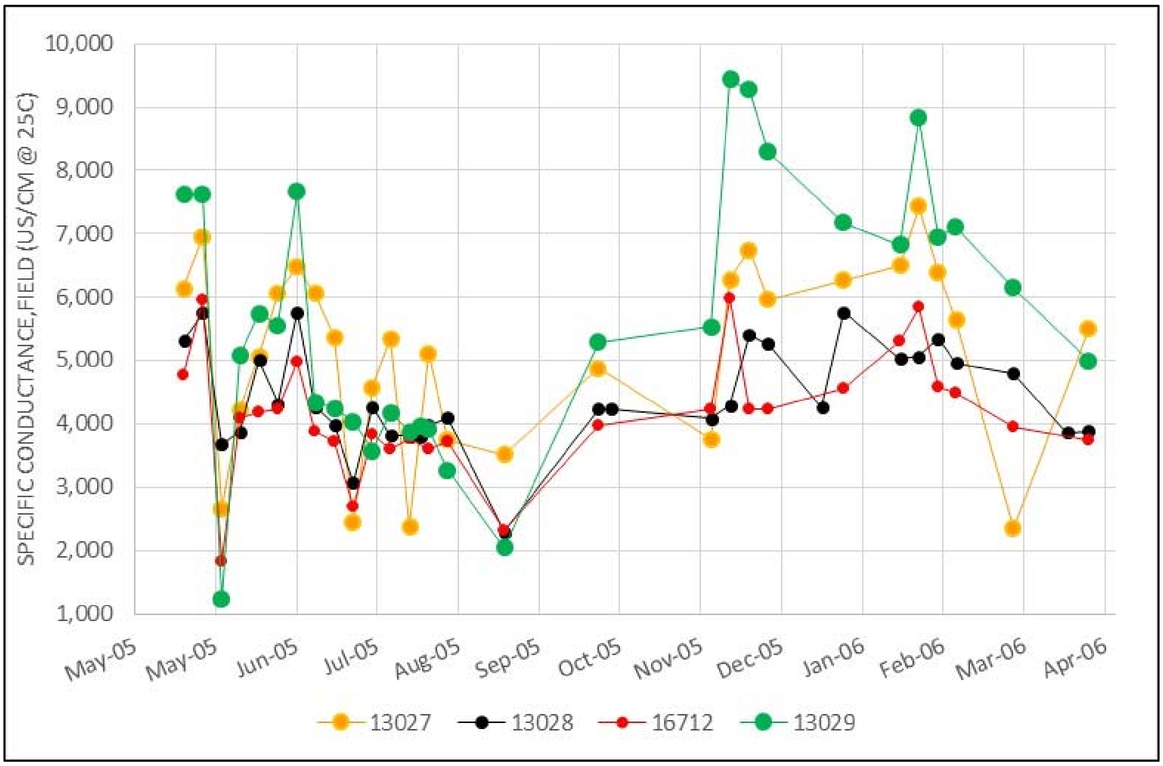

Figure 13. Time series of specific conductance at station 13027, 13028, 16712, and 13029 along Oso Creek for the period of May 2005 through April 2006

3.2 Methodology for Flow Duration & Load Duration Curve Development

To develop the FDCs and LDCs for Oso Creek, the previously discussed data resources were used in the following series of sequential steps.

3.2.1 Step 1: Determine Hydrologic Period

A hydrologic (streamflow) record from 1972 through early 2016 was available for USGS gauge 08211520 located on Oso Creek (Table 13, Figure 5). The period of record is more than adequate to capture a reasonable variation in meteorological patterns of high and low rainfall periods.

Optimally, the period of record to develop FDCs 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. Therefore, a 16-year record of daily streamflow from January 1, 2000 through December 31, 2015 was selected to develop the FDCs at each station, and this period includes the collection dates of all available Enterococci data at the time this work effort was undertaken except those data collected October – November 2015 and January – March 2016. A 16-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

The seven SWQM stations along Oso Creek with Enterococci data (Table 14) were selected for FDCs and LDCs development. The primary station and the one for which the Oso Creek pollutant load will be developed is station 13028, which was selected because it is the station with continuous monitoring of Enterococci from October 1999 through the present (including scheduling for sampling under the Fiscal Year 2017 Clean Rivers Program). The other six stations are to provide additional information regarding bacteria impairment.

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 16-year daily streamflow record for each monitoring station. The daily streamflow records were based on the USGS gauge 08211520 record (Table 13).

The method to develop the necessary streamflow record for each FDC/LDC location (SWQM station location) involved a drainage-area ratio (DAR) approach. With this basic approach, the USGS gauge 08211520 daily streamflow value within the 16-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 gauge.

Because an assumption of the DAR approach is similarity of hydrologic response based on commonality of landscape features such as geology, soils, and land use/land cover, point source derived flows should first be considered for removal (subtraction) from the flow record of the gauge prior to application of the ratio. There are three active WWTF discharges above the USGS gauge on Oso Creek and the Greenwood WWTF discharge enters Oso Creek immediately below the gauge location (Figure 9). The three facilities are the City of Robstown, Rollof, and Cuddihy Airfield WWTFs. Both the Rollof and Cuddihy Airfield WWTFs discharge directly into Oso Creek within a few miles above the USGS gauge location, whereas the City of Robstown WWTF is located over 15 miles upstream. Because of proximity, the entire Rollof and Cuddihy Airfield WWTF discharge was subtracted from the gauged flow. Due to distance upstream, only 75 percent of the City of Robstown WWTF discharge was subtracted, thus assuming that 25 percent of the discharge was lost before reaching the gauge. Using this approach for correcting the gauged streamflow record, zero streamflow was estimated to occur at the gauge location 28 percent of the time. The 28 percent occurrences of zero flow was considered reasonable based on zero flow occurring 37 percent of the time at Medio Creek near Beeville, Texas and 36 percent of the time at Copano Creek near Refugio, Texas, which were the only two gauges in the region with a multi-year flow record; comparable drainage areas; and no significant discharges, diversions, or other hydrologic complexities upstream of the gauge location.

The flows from each of the three WWTF outfalls for the period 2000 – 2015 were determined from the monthly average discharges reported in DMRs and accessed through the USEPA compliance databases previously discussed. Missing data were estimated using available data from adjacent months. The determined monthly average discharge was used as the value for each day of that month.

The DARs for locations within the TMDL study area are presented in Table 15. The computation of the daily streamflow record at each station was performed by first multiplying each daily streamflow in the 16-year Oso Creek gauged record by the appropriate DAR for that station. Next, to account for WWTFs at their daily permitted discharge limit, as required in the TMDL, the summation of the full permitted daily average discharges from all upstream WWTFs was added to the DAR calculated streamflow record at the desired location. To account for future growth of discharges from WWTFs treating domestic wastewater, additional constant flow was added based on the full permitted discharge allowed in existing permits and the future growth projections through 2050 (Table 16).

Table 15.   DARs for locations along Oso Creek based on the drainage area of USGS gauge 08211520.

Gauge/Station	Drainage Area (acres)	Drainage Area Ratio (DAR)
08211520	56,845	–
13026	133,833	2.354
13027	100,547	1.769
13028	86,775	1.527
16712	85,341	1.501
13029	56,845	1.000
18500	40,715	0.716
18499	24,438	0.430

Table 16. Full permitted flows and 2050 future growth flows for WWTFs located in the Oso Creek watershed.

Segment	TPDES Permit No.	NPDES Permit No.	Facility	Full Permitted Flow (MGD)	% Increase (2010 - 2050)	Future Growth Flow (MGD)
2485A	WQ0010261001	TX0020389	City of Robstown	3.0	8.5%	0.256
2485A	WQ0011134002	TX0076767	Rollof	0.02	52.4%	0.010
2485A	WQ0010401003	TX0047074	Greenwood Plant	16.0	29.6%	4.730
2485A	WQ0014228001	TX0123676	Cuddihy	0.06	52.4%	0.031
Total				19.08		5.027

3.2.4 Steps 4-6: Flow Duration Curve and Load Duration Curve Methods

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

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

Further, when developing a LDC:

- multiply the streamflow in cubic feet per second (cfs) by the appropriate water quality criterion for Enterococci (geometric mean of 35 MPN/100 mL, single sample of 104 MPN/100 mL) and by a conversion factor (2.44658×10^7), which gives a loading in units of MPN/day; and
- plot the exceedance percentages, which are identical to the value for the streamflow data points, against geometric mean and singe sample criteria of Enterococci.

The resulting curves represent the maximum allowable daily loadings for the geometric mean criterion and for the single sample criterion. The geometric mean criterion is used in computation of the pollutant load allocation, while the single sample criterion is plotted to provide additional context for the measured Enterococci that are added to each plot as follows:

- using the unique data for each monitoring station, compute the daily loads for each sample by multiplying the measured Enterococci concentrations on a particular day by the corresponding streamflow on that day and the conversion factor (2.44658×10^7); and
- plot on the LDC for each station the load for each measurement at the exceedance percentage for its corresponding streamflow.

The plots of the LDC with the measured loads (Enterococci concentration multiplied by the daily streamflow) display the frequency and magnitude that measured loads exceed the maximum allowable loadings for the geometric mean criterion. Measured loads that are above a maximum allowable loading curve indicate an exceedance of the water quality criterion, while those below a curve show compliance.

3.3 Flow Duration Curves for Sampling Stations within TMDL Watersheds

FDCs were developed for all monitoring stations in Oso Creek with historical Enterococci data (Table 14) and are presented in Figure 14. For this report, FDCs were developed by applying the DAR method and using the streamflow record of the Oso Creek USGS gauge 08211520 for the period of 2000 – 2015 as described in the previous sections. Flow exceedances less than 10% typically represent streamflows influenced by storm runoff while higher flow exceedances represent receding hydrographs after a runoff event, base flow and low flow conditions. The shape of the low flow portion of each FDC strongly reflects the influence of the two major WWTF discharges. The FDCs for the three most upstream stations (18499, 18500, and 13029) reflect the permitted discharge from the Robstown WWTF and the FDCs for the four most downstream stations (16712, 13028, 13027, and 13026) reflect the permitted discharges from both the Robstown WWTF and City of Corpus Christi Greenwood WWTF.

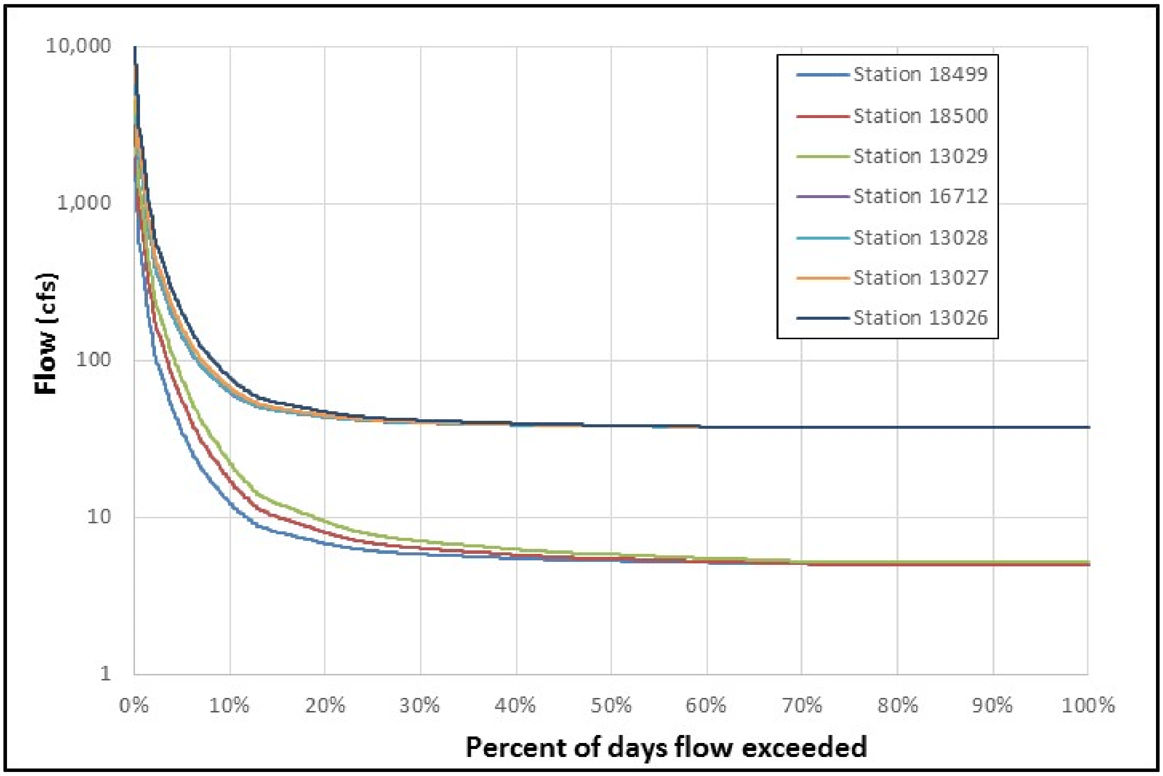

Figure 14. FDCs for SWQM stations along Oso Creek.

3.4 Load Duration Curves for Sampling Stations within TMDL Watersheds

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

For the Oso Creek watershed, a three-interval division was selected:

- High flow regime: 0-10 percent range, related to flood conditions and nonpoint source loading
- Mid-range flow regime: 10-60 percent range, intermediate conditions of receding hydrographs after storm runoff and base line conditions
- Low flow regime: 60-100 percent range, related to dry conditions

The selection of the flow regime intervals was based on general observations of all the monitoring station LDCs. Both the 10 and 60 percentile divisions are convenient, as data collected during wet weather occurs more frequently below the 10th percentile, and non-wet weather data occurs more frequently above the 60th percentile. (Wet and non-wet weather events are defined in the next section.) Additionally, for the high flow regime, the 0-10% range generally represents the steepest portion of the LDC.

The load duration curves with these three flow regimes for all seven SWQM stations with Enterococci data are provided in Figures 15 - 21. Geometric mean loadings for the data points within each flow regime have also been distinguished on each figure to aid interpretation. The LDCs for the water quality monitoring stations provide a means of identifying the streamflow conditions under which exceedances in Enterococci concentrations have occurred. The LDCs depict the allowable loadings at the stations under the geometric mean criterion (35 MPN/100 mL) and show that existing loadings often exceed the criterion. In addition, the LDCs also present the allowable loading at the stations under the single sample criterion (104 MPN/100 mL).

On each graph the measured Enterococci data are presented as associated with a “wet weather event” or a “non-wet weather event.” A sample was determined to be influenced by a wet weather event based on the reported “days since last precipitation” (DSLP) as noted on field data sheets associated with each sampling event. DSLP (TCEQ water quality parameter code 72053) is a field parameter that may be noted during a sampling event to inform of the general climatic and hydrologic conditions. A “wet weather event” influenced bacteria sample was defined as occurring on any collection date with DSLP ≤ 4 days. Note that a wet weather event can be indicated even under low flow conditions as a result of only a small runoff event during a period of very low base flow in the stream.

The LDC for station 13026, Oso Creek at the Yorktown Bridge, is provided in Figure 15. Geographically, this is the most downstream location in the watershed and is positioned right at the downstream terminus of AU 2485A_01. As mentioned previously, it is not technically correct to develop a standard FDC and LDC for this location because tidal influences would be significant at station 13026. However the LDC and the plotted monitoring data do give an indication of the flow conditions under which bacteria impairment is most likely to occur. The LDC indicates that elevated bacteria loadings and concentrations predominately occur under only the highest flow regime indicating that impairments at this location are largely stormwater runoff driven.

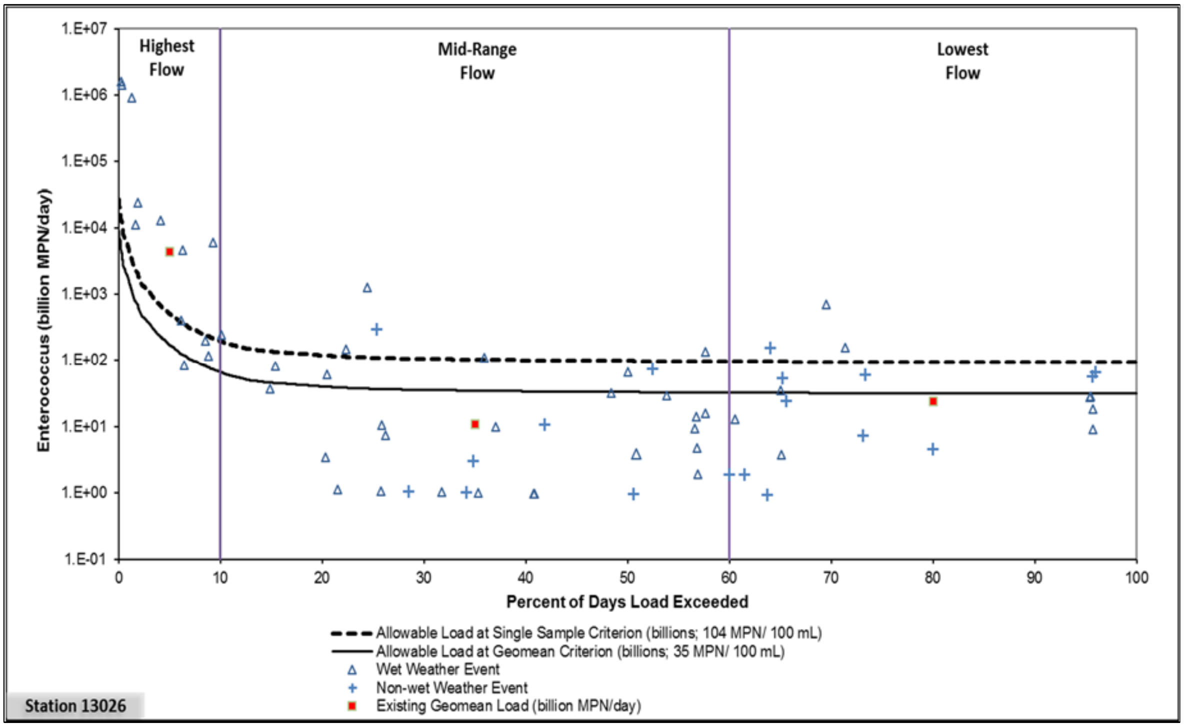

Figure 15. **Load duration curve for Station 13026, Oso Creek at Yorktown Bridge.**

The LDC for station 13027, Oso Creek at FM 2444, is provided in Figure 16. This location is the second most downstream in the watershed. Tidal influences appeared to be appreciably moderated at this location, so it was concluded that the standard FDC and LDC was applicable for this location. Measured Enterococci data are relatively sparse at this location. Elevated bacteria levels are definitely occurring at this location during stormwater runoff events under the highest flow regime. Much of the measured data for this location were collected under wet weather conditions, as defined herein as any collection date with DSLP ≤ 4 days. Elevated bacteria levels occurred under all three flow regimes, but under the mid-range and lowest flow regimes there were also occurrences of low bacteria levels below the geometric mean criterion. A note of caution with this LDC is that station 13027 was only sampled during special studies, and the most recently collected Enterococci data at this station were in 2006.

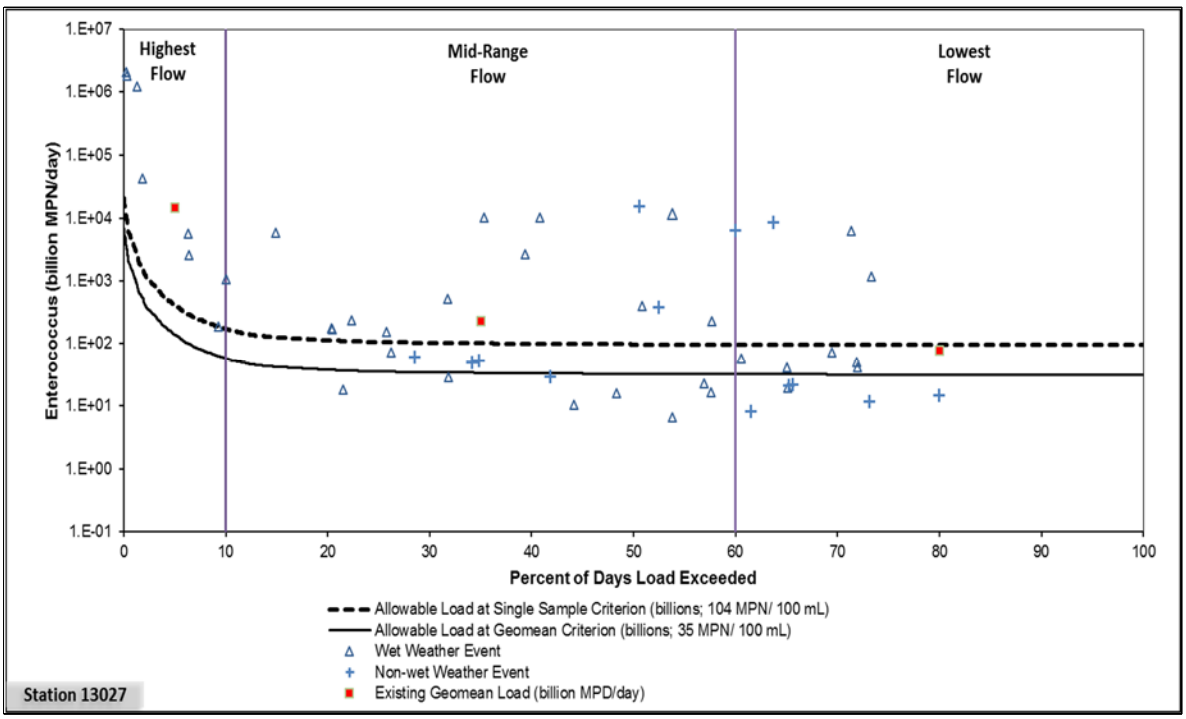

Figure 16. Load duration curve for Station 13027, Oso Creek at FM 2444.

The LDC for station 13028, Oso Creek at SH 286, is provided in Figure 17. The LDC for this location was used to develop the pollutant load allocation for Oso Creek as described in Section 4. Station 13028 was selected as the location to develop the pollutant load allocation because it has a good history of Enterococci data and this station is the most downstream station along Oso Creek that is currently being monitored and is scheduled for continued monitoring under the Clean Rivers Program 2017 sampling schedule. Elevated bacteria levels were measured under all flow regimes at station 13028 with a greater likelihood of elevated values under wet weather conditions as compared to non-wet weather conditions.

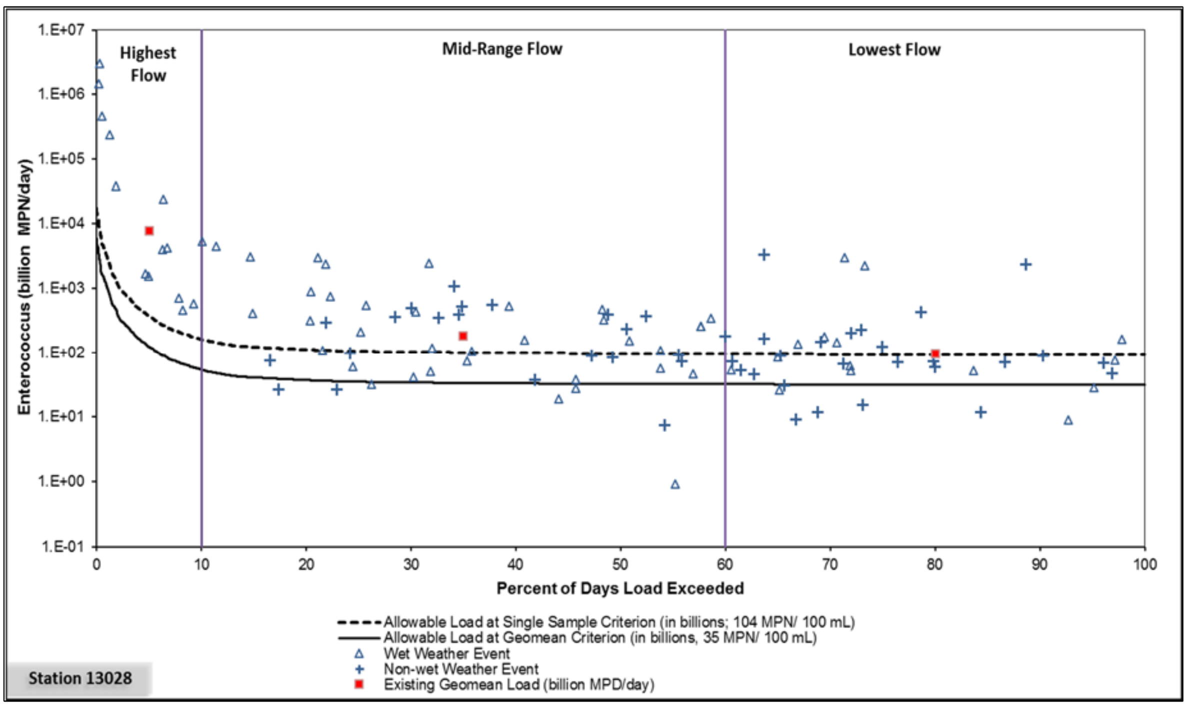

Figure 17. Load duration curve for Station 13028, Oso Creek at SH 286.

The LDC for station 16712, Oso Creek at the Elliot Landfill, is provided in Figure 18. This location is the next upstream station above station 13028. Elevated bacteria levels were measured under all flow regimes at station 16712 with a greater likelihood of elevated values under wet weather conditions under the highest flow regime. Much of the measured data was collected under wet weather conditions as defined for this study. Under the mid-range and lowest flow regimes, both the wet weather and non-wet weather data were elevated and always greater than the geometric mean criterion and often above the single sample criterion. A note of caution with this LDC is that station 16712 was only sampled during special studies, and the most recently collected Enterococci data at this station were in 2006.

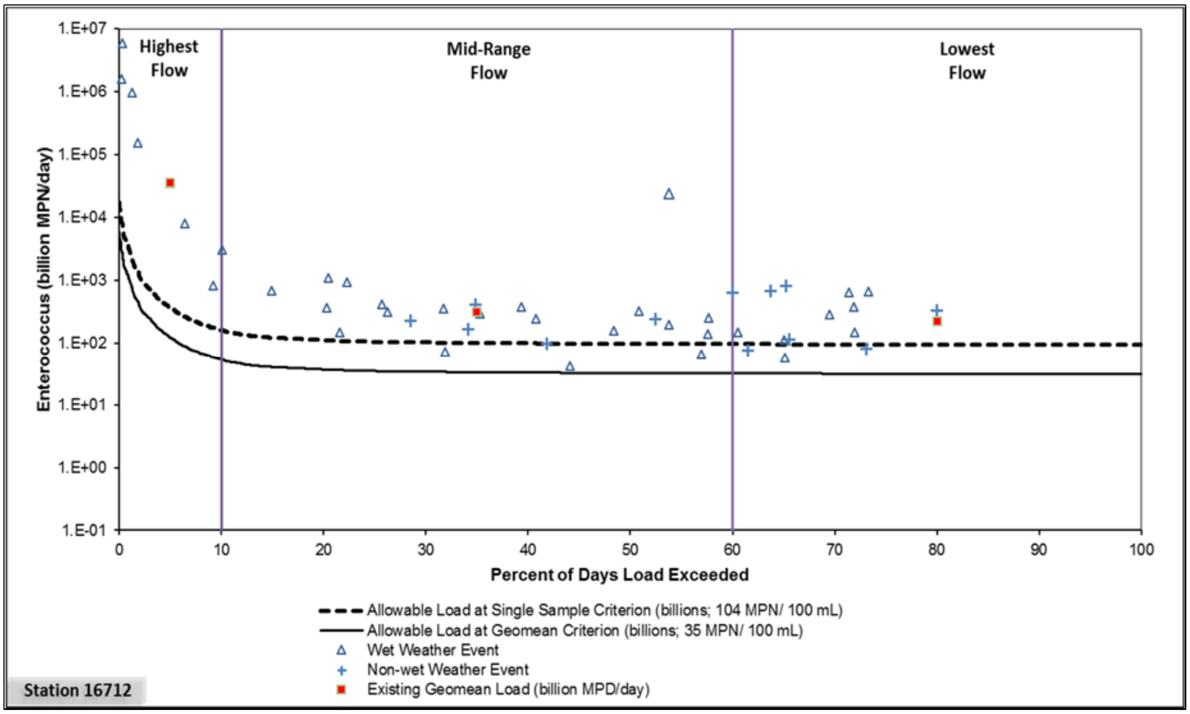

Figure 18. **Load duration curve for Station 16712, Oso Creek at Elliot Landfill.**

The LDC for station 13029, Oso Creek at FM763, is provided in Figure 19. The location of this station continues the upward progression of the LDC presentation from the most downstream station (13026). Elevated bacteria levels were measured under all flow regimes at station 13029. As observed at station 16712 (Figure 18), a greater likelihood of elevated values occurred during wet weather conditions under the highest flow regime than the other two regimes and much of the measured data was collected during wet weather conditions as defined for this study. Additionally for station 13029 and similar to station 16712, under the mid-range and lowest flow regimes, both the wet weather and non-wet weather data were elevated and always greater than the geometric mean criterion and predominately above the single sample criterion. Measured data were noticeably more elevated at station 13029 than at downstream station 16712 (compare measured data on Figures 18 and 19). A note of caution with this LDC is that station 13029 was only sampled during special studies, and the most recently collected Enterococci data at this station were in 2006.

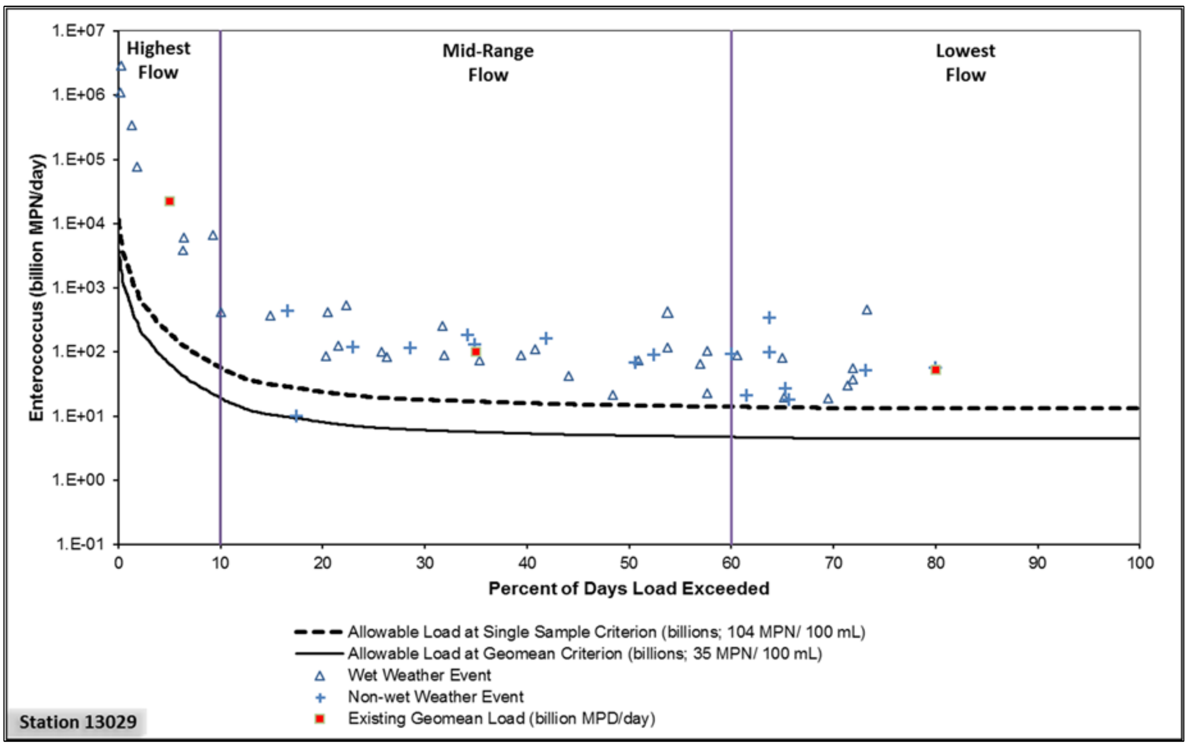

Figure 19. Load duration curve for Station 13029, Oso Creek at FM 763.

The LDC for station 18500, Oso Creek at FM 665, is provided in Figure 20. The location of this station also continues the upward progression of the LDC presentation and is the second most upstream location with monitoring data along Oso Creek. As observed at station 13029 (Figure 19) and 16712 (Figure 18), elevated bacteria levels were measured under all flow regimes. All measured data, whether associated with wet weather or non-wet weather conditions, are above even the single sample criterion. The measured data were still predominately collected under wet weather conditions, but there are a greater proportion of non-wet weather data than observed at stations 13029 and 16712. A note of caution with this LDC is that station 18500 was only sampled during special studies, and the most recently collected Enterococci data at this station were in 2011, which is somewhat more recent than at the previous two stations.

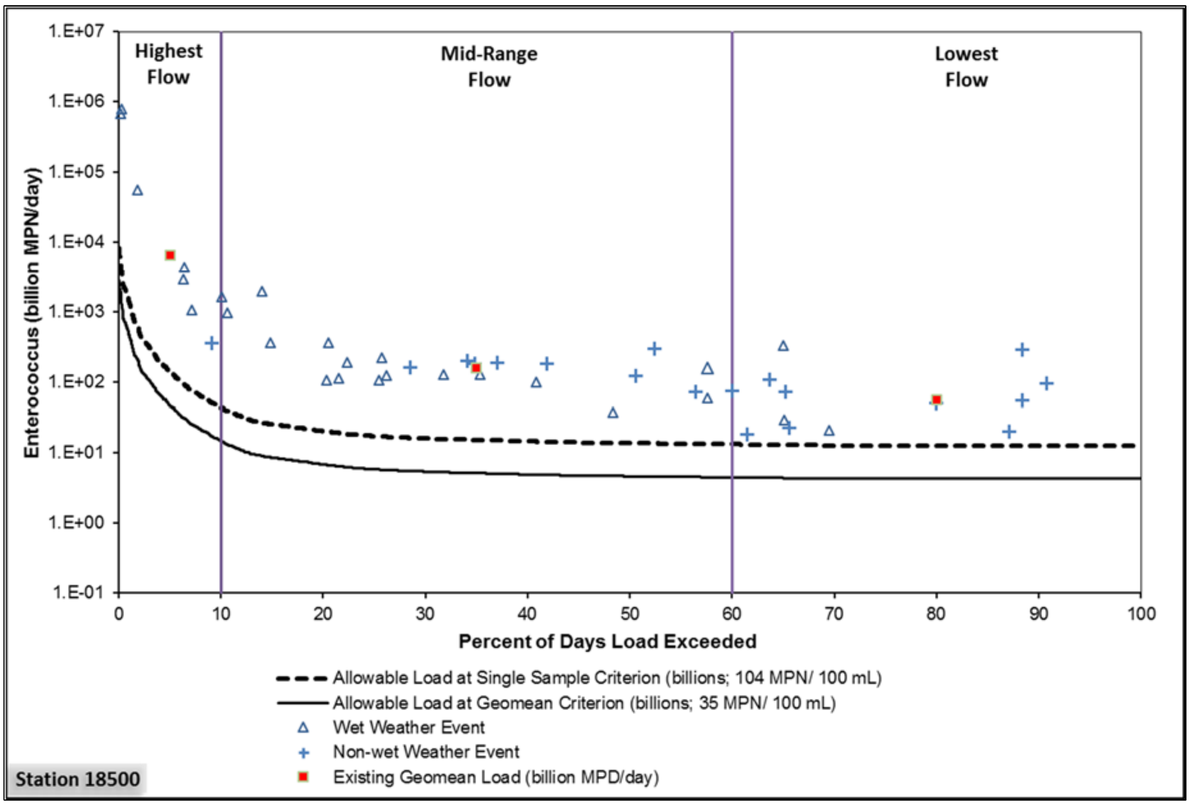

Figure 20. Load duration curve for Station 18500, Oso Creek at FM 665.

The LDC for station 18499, Oso Creek at SH 44, is provided in Figure 21. The location of this station is the most upstream along Oso Creek. The observed data at this location are very similar to those at station 18500 (Figure 20). In summary, elevated bacteria levels were measured under all flow regimes and all measured data, whether associated with wet weather or non-wet weather conditions, are above even the single sample criterion. A note of caution with this LDC is that station 18499 was only sampled during special studies, and the most recently collected Enterococci data at this station were in 2011.

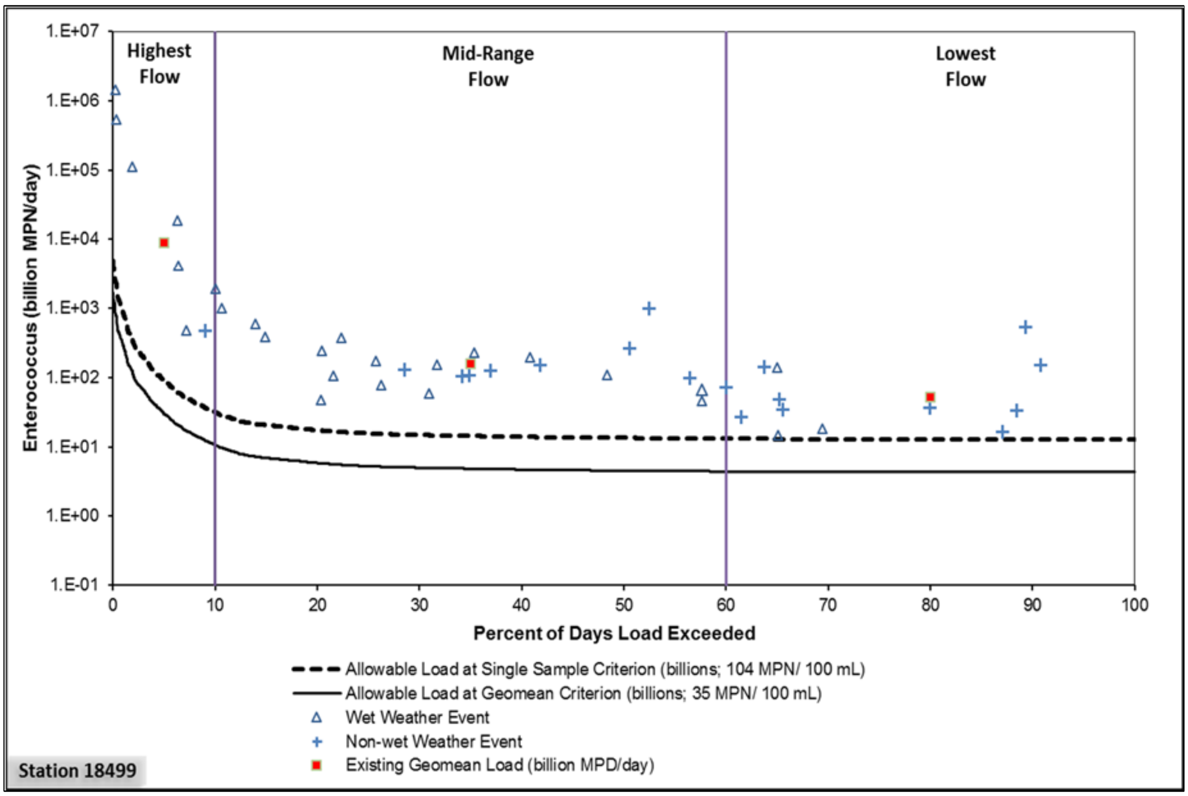

Figure 21. Load duration curve for Station 18499, Oso Creek at SH 44.

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 13028 was the standard LDC method 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 standard 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 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 Oso Creek watershed (AUs 2485A_01, 2485B_01, 2485C_01, and 2485D_01) as shown in the overview map (Figure 1). Although the LDCs were computed for the each of the seven SWQM stations located along AU 2485A_01, the TMDL was only calculated for the station 13028. As indicated in Chapter 3 of this report, SWQM station 13028 was selected because of its minimal or non-existent tidal influence. It is the only station in AU 2485A_01 with an extensive time series of bacteria measurements and is a station currently being monitored on Oso Creek.

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. Oso Creek has a use of primary contact recreation, which is measured against a numeric criterion for the indicator bacteria Enterococci due to the fact that the creek is designated as being 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 t-test on the natural log transformed dataset.

This analysis of Enterococci data indicated that there was a significant difference ($\alpha=0.05$, $p=0.0320$) in indicator bacteria between cool and warm weather seasons for Oso Creek with the warm season having the higher concentrations.

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).

4.4 Load Duration Curve Analysis

A standard 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 LDC method to determine the TMDL allocations.

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 LDC method does not require any assumptions regarding loading rates, stream hydrology, land use conditions, and other conditions in the watershed. The USEPA 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. 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 percent flow), where exceedances of the primary contact recreation criteria are most pronounced. Furthermore, as discussed in Chapter 3, Oso Creek is considered a tidal stream and while a modification to the LDC method exists to account for tidal influences, analysis of several factors (see Section 3.1.3 Allocation Tool Selection) at the point of pollutant load allocation development (station 13028) led to the conclusion that the standard LDC could be applied at this location due to the minimal occurrence of tidal influence at that location.

The 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). 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 13028 to be used in the pollutant load allocation process with historical Enterococci data added to the graphs (SWQM station 13028, Figure 17) 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, followed by mid-range flows with some moderation in elevated loadings occurring at the lowest flow regime. Additionally, regulated stormwater comprises a significant portion of the Oso Creek watershed and must be considered a contributor of bacteria loadings during high flow events with unregulated sources contributing as well, and possibly to an even greater degree than the regulated sources given the regulated stormwater area comprises 31 percent of the entire watershed. Elevated concentrations of Enterococci at the lower flow regimes follow the rationale of contributing sources derived from point (i.e. WWTFs) and direct deposition sources such as wildlife (avian and non-avian), feral hogs, and livestock. These conclusions are further supported by previous studies indicating direct bacteria deposition occurring from known inflows such as permitted dischargers and stormwater drains (Mott and Hay, 2009) and wildlife (avian and non-avian) contributions (Mott et al., 2012). 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 USEPA 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 Oso Creek watershed was developed using a 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 three flow regimes was determined using the historical bacteria data for station 13028. For each 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 (Table 17).

Table 17. Percent reduction calculations for bacteria by flow regime for Station 13028.

Watershed	Station	Segment	High Flows (0-10%)		Mid-Range Flow (10-60%)		Low Flows (60-100%)	
			Geometric Mean (MPN/100 mL)	Required Percent Reduction	Geometric Mean (MPN/100 mL)	Required Percent Reduction	Geometric Mean (MPN/100 mL)	Required Percent Reduction
Oso Creek	13028	2485A	2,173	98.4%	188	81.4%	100	65.1%

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. 1)

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 Oso Creek SWQM station 13028. 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 Oso Creek was developed as a pollutant load allocation based on information from the most downstream LDC with abundant historical bacteria data and indications of continued monitoring through the Clean Rivers Program monitoring schedule. As discussed in more detail in Section 3, bacteria LDCs 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 LDC at 5 percent exceedance (the median value of the high-flow regime) is the TMDL:

TMDL (MPN/day) = Criterion * Flow (cfs) * Conversion factor (Eq. 1)

Where:

Criterion = 35 MPN/100 mL (Enterococci)

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

At the 5 percent load duration exceedance, the TMDL value is provided in Table 18.

Table 18. Summary of allowable loading calculations for AU 2485A_01 of Oso Creek.

Indicator Bacteria	5% Exceedance Flow (cfs)	5% Exceedance Load (MPN/day)	TMDL (Billion MPN/day)
Enterococci	142.552	1.22068E+11	122.068

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:

$$MOS = 0.05 * TMDL \quad \text{(Eq. 2)}$$

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 19).

Table 19. MOS calculations for AU 2485A_01 of Oso Creek.

Indicator Bacteria	TMDL (Billion MPN/day)	MOS (Billion MPN/day)
Enterococci	122.068	6.103

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}).

$$WLA = WLA_{WWTF} + WLA_{SW} \quad \text{(Eq. 3)}$$

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/100 mL) 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:

$$WLA_{WWTF} = \text{Criterion} * \text{Flow} * \text{Conversion Factor} * (1 – F_{MOS}) \quad \text{(Eq. 4)}$$

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 assigned to WLA_{WWTF} was determined based on the full permitted flow of each WWTFs using Eq. 4 and summed for the watershed. Table 20 presents the waste load allocation for each individual WWTF located within the TMDL watershed. The WLA_{WWTF} for Oso Creek AU 2485A_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 20 that will be used in subsequent computations. Note that Barney M Davis LP (TPDES permit number WQ0001490000) 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 20.

Table 20. Waste load allocations for TPDES-permitted facilities in Oso Creek watershed with domestic wastewater component.

Segment	TPDES Permit No.	NPDES Permit No.	Facility	Full Permitted Flow (MGD)[a]	*E. coli* WLA_{WWTF} (Billion MPN/day)	Enterococci WLA_{WWTF} (Billion MPN/day)
2485A	WQ0010261001	TX0020389	City of Robstown	3.0	13.593	3.776
2485A	WQ0011134002	TX0076767	Rollof	0.02	0.091	0.025
2485A	WQ0010401003	TX0047074	Greenwood Plant	16.0	72.498	20.138
2485A	WQ0014228001	TX0123676	Cuddihy	0.06	0.272	0.076
Oso Creek Watershed Total					86.454	24.015

[a] Full Permitted Flow from Table 5.

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 Oso Creek watershed that is under the jurisdiction of Phase I and II MS4 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:

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} \qquad \text{(Eq. 5)}$$

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 (Table 21).

As indicated in Figure 10 and Table 6 of Section 2.8.1.3, both Phase I and Phase II MS4 permits exist within the Oso Creek Watershed and these areas were used to estimate the areas under stormwater regulation for construction, industrial, and MS4 permits.

Table 21. Regulated stormwater FDA_{SWP} basis for the Oso Creek watershed.

Waterbody	Estimated Area Under Stormwater Regulation (acres)	Total Watershed Area (acres)	FDA_{SWP} (%)
Oso Creek	41,815	133,833	31.24

In order to calculate WLA_{SW} (Equation 5), 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 22 provides the information needed to compute WLA_{SW}.

Table 22. Regulated stormwater calculations for the Oso Creek watershed (AU 2485A_01).

All loads expressed as billion MPN/day Enterococci

Indicator Bacteria	TMDL[a]	WLA_{WWTF}[b]	FG[c]	MOS[d]	FDA_{SWP}[e]	WLA_{SW}[f]
Enterococci	122.068	24.015	6.328	6.103	31.24%	26.748

[a] TMDL from Table 18

[b] WLA_{WWTF} from Table 20

[c] FG from Table 23

[d] MOS from Table 19

[e] FDA_{SWP} from Table 21

[f] WLA_{SW} = (TMDL – WLA_{WWTF} – FG – MOS) * FDA_{SWP} (Eq. 5)

4.7.4 Future Growth

The Future Growth 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. Specifically, this TMDL component takes into account the probability that new flows from WWTF discharges may occur in the future. The assimilative capacity of streams increases as the amount of flow increases. Increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard.

The allowance for future growth will result in protection of existing beneficial uses and conform to Texas's antidegradation policy.

The future growth component of impaired Segment 2485A was based on the percent population increase information of WUGs between 2010 and 2050 (provided previously in Table 1) and the existing full permitted discharge for each WWTF within a WUG. While the future growth allowance is computed using information from existing WWTF permits, it is not intended to restrict any future assignments of this allocation solely to expansions at these facilities. Rather the future growth allocation is purposed for any new facilities that may occur and expansions of existing facilities.

$$FG = Criterion * [\%POP_{2010\text{-}2050} * WWTF_{FP}] * Conversion\ Factor * (1 - F_{MOS}) \quad \text{(Eq. 6)}$$

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 23.

Table 23. Future Growth Calculations for the Oso Creek watershed (AU 2485A_01).

WUG	Full Permitted Flow within WUG	% Increase (2010-2050)	Future Growth (MGD)	FG (Enterococci Billion MPN/Day)[a]
Corpus Christi	16.0	29.56%	4.730	5.953
Robstown	3.0	8.53%	0.2560	0.322
County Other	0.08	52.39%	0.0420	0.053
Watershed Total	—	—	5.028	6.328

[a] $FG = Criterion * [\%POP_{2010\text{-}2050} * WWTF_{FP}] * Conversion\ Factor * (1 - F_{MOS})$ (Eq. 6)

4.7.5 Load Allocation

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

$$LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS \quad \text{(Eq. 7)}$$

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 24.

Table 24. Load allocation calculations for the Oso Creek watershed (AU 2485A_01).

All load units expressed as billion MPN/day Enterococci

Indicator Bacteria	TMDL[a]	WLA_{WWTF}[b]	WLA_{SW}[c]	FG[d]	MOS[e]	LA[f]
Enterococci	122.068	24.015	26.748	6.328	6.103	58.874

[a] TMDL from Table 18

[b] WLA_{WWTF} from Table 20

[c] WLA_{SW} from Table 22

[d] FG from Table 23

[e] MOS from Table 19

[f] LA = TMDL – WLA_{WWTF} - WLA_{SW} - FG – MOS (Eq. 7)

4.8 Summary of TMDL Calculations

Table 25 summarizes the TMDL calculations for Oso Creek (2485A_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 SWQM station 13028, which is the Oso Creek station with the most historical data and the station currently being monitored. Allocations are based on the current geometric mean criterion for Enterococci of 35 MPN/100 mL for each component of the TMDL.

The final TMDL allocations (Table 26) 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 A provides guidance for recalculating the allocations in Table 26. Figure A-1 was developed to demonstrate how assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of water quality criteria for Enterococci. The equations provided, along with Figure A-1, allow calculation of a new TMDL and pollutant load allocation based on any potential new water quality criterion for Enterococci.

Table 25. TMDL allocation summary for the Oso Creek watershed (AU 2485A_01).

All load units expressed as billion MPN/day Enterococci

AU	Stream Name	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	LA[e]	FG[f]
2485A_01	Oso Creek	122.068	6.103	24.015	26.748	58.874	6.328

[a] TMDL = 35 MPN/100 mL * Median flow (highest flow regime) * Conversion Factor; where the Conversion Factor = 283.168 100 mL/ft3 * 86,400 s/d; Median (5 percent exceedance) Flow from Table 18

[b] MOS = 0.05 * TMDL (Table 19)

[c] WLA_{WWTF} = 35 MPN/day * Flows (MGD) * Conversion Factor * (1 – F_{MOS}); where Flow is the full permitted flow from regulated discharging facilities; Conversion Factor = 1.547 cfs/MGD * 283.168 100 mL/ft3; FMOS = 5 percent or 0.05 (Table 20)

[d] WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} (Table 22)

[e] LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS (Table 24)

[f] Future Growth = 35 MPN/100 mL * [%POP2010-2050 * $WWTF_{FP}$] * Conversion Factor * (1 – F_{MOS}); Conversion Factor = 1.547 cfs/MGD * 283.168 100 mL/ft3; $WWTF_{FP}$ is full permitted flows and %POP2010-2050 is from Table 23

Table 26. Final TMDL allocations for the impaired Oso Creek watershed (AU 2485A_01).

All load units expressed as billion MPN/day Enterococci

AU	TMDL	MOS	WLA_{WWTF}[a]	WLA_{SW}	LA
2485A_01	122.068	6.103	30.343	26.748	58.874

[a] WLA_{WWTF} includes the FG component

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APPENDIX A

EQUATIONS FOR CALCULATING TMDL ALLOCATIONS FOR CHANGED CONTACT RECREATION STANDARD

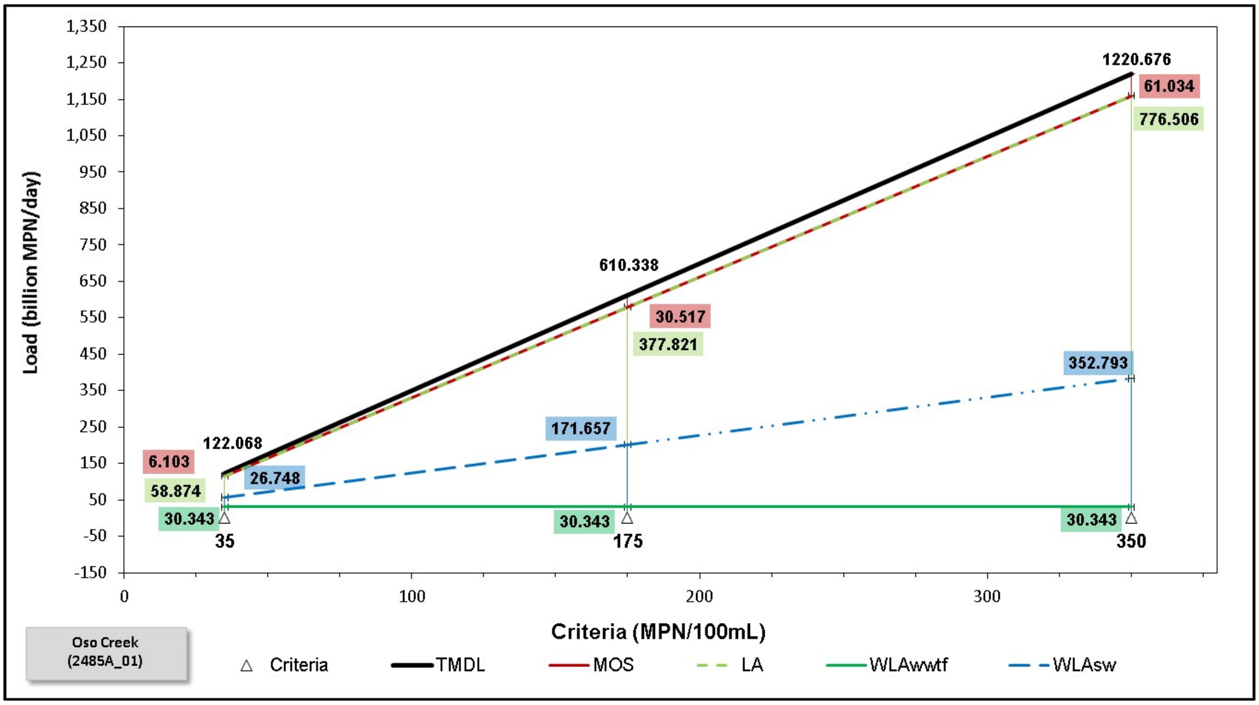

Figure A-1 Allocation loads for the Oso Creek watershed (AU 2485A_01) as a function of water quality criteria.

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

TMDL = 3.487644 * Std

MOS = 0.174384 Std

LA = 2.278196 * Std – 20.863098

WLA_{WWTF} = 30.343

WLA_{sw} = 1.035063 * Std – 9.4791803

Where:

Std = Revised Contact Recreation Standard

MOS = Margin of Safety

LA = Total load allocation (unregulated sources)

WLA_{WWTF} = Waste load allocation (permitted WWTF load + future growth)

WLA_{SW} = Waste load allocation (permitted stormwater)