Technical Support Document for a Total Maximum Daily Load for Indicator Bacteria for North Fork Fish Creek

Segment: 0841Q

Assessment Unit: 0841Q_01

North Fork Fish Creek at sampling station 17678

Technical Support Document for a Total Maximum Daily Load for Indicator Bacteria in North Fork Fish Creek

Segment: 0841Q

Assessment Unit: 0841Q_01

Prepared for
Total Maximum Daily Load Program
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Table of Contents

List of Figures

List of Tables

Abbreviations

AU	assessment unit
cfs	cubic feet per second
cfu	colony-forming units
DAR	drainage area ratio
DFW	Dallas/Fort Worth
DSLP	days since last precipitation
E. coli	*Escherichia coli*
FDA_{SWP}	fractional drainage area stormwater permit
FDC	flow duration curve
FIB	fecal indicator bacteria
FG	future growth
GIS	Geographic Information System
I&I	inflow and infiltration
I-Plan	implementation plan
LA	load allocation
LDC	load duration curve
MCM	minimum control measure
mL	milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
NCTCOG	North Central Texas Council of Governments
NPDES	National Pollutant Discharge Elimination System
OSSF	on-site sewage facility
RSA	regulated stormwater area
SSO	sanitary sewer overflow
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
TRA	Trinity River Authority
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	wasteload allocation
WLA_{SW}	wasteload allocation stormwater
WLA_{WWTF}	wasteload allocation wastewater treatment facilities
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 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 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 identified the bacteria impairment within North Fork Fish Creek in the *Draft 2016 Texas Integrated Report of Surface Water Quality*, which in this document will be referred to as the Draft 2016 Integrated Report.

This document will consider a bacteria impairment in one water body (segment) consisting of one assessment unit (AU): North Fork Fish Creek (AU 0841Q_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, North Fork Fish Creek may be referred to as AU 0841Q_01 or Segment 0841Q.

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 that are monitored in an effort to assess the quality of available water for specific users. The TCEQ is charged with monitoring and assessing water bodies based on these water quality standards, and publishes the Texas Water Quality Integrated Report list biennially.

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

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

Standards are established to protect 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. FIB are present in the intestinal tracts of humans and other warm-blooded animals. The presence of these bacteria in water indicates that associated pathogens from the wastes that may be reaching water bodies because of such sources as inadequately treated sewage, improperly managed animal waste from livestock, pets, aquatic birds, wildlife, and failing septic systems (TCEQ, 2006). *Escherichia coli* (*E. coli)* is a member of the fecal coliform bacteria group and is used in the State of Texas as the FIB in freshwater.

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

- Primary contact recreation is that with a significant risk of ingestion of water (such as swimming), and has a geometric mean criterion for *E. coli* of 126 colony-forming unit (cfu) per 100 milliliter (mL) and an additional single sample criterion of 399 cfu 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 *E. coli* of 630 cfu per 100 mL;
- Secondary contact recreation 2 is similar to secondary contact 1, but activities occur less frequently. It has a geometric mean criterion for *E. coli* of 1,030 cfu per 100 mL; and

- 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 *E. coli* of 2,060 cfu per 100 mL (TCEQ, 2010).

North Fork Fish Creek is presumed for primary contact recreation and has the associated *E. coli* geometric mean criterion of a 126 cfu per 100 mL and single sample criterion of 399 cfu per 100 mL.

1.3 Report Purpose and Organization

The North Fork Fish Creek TMDL project was initiated through a contract between the TCEQ and Texas Institute for Applied Environmental Research (TIAER). The tasks of this project were to (1) develop, have approved, and adhere to a quality assurance project plan; (2) develop a technical support document for the impaired watershed; and (3) assist the TCEQ with public participation. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDL for the impaired watershed of North Fork Fish Creek. 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 (*E. coli*),
- development of load duration curves (LDCs), and
- application of the LDC approach for the pollutant load allocation process.

Whenever it was feasible, the data development and computations for developing the LDC and pollutant load allocation were performed in a manner to remain consistent with the previously completed *Four TMDLs for Indicator Bacteria in the Cottonwood Creek, Fish Creek, Kirby Creek, and Crockett Branch Watersheds Upstream of Mountain Creek Lake* (TCEQ, 2016).

SECTION 2
HISTORICAL DATA REVIEW AND WATERSHED PROPERTIES

2.1 Description of Study Area

North Fork Fish Creek (Segment 0841Q) begins at the confluence with Fish Creek (Segment 0841K) in Dallas County and is approximately five miles in length with portions in both Tarrant and Dallas Counties (Figure 1). North Fork Fish Creek is an unclassified, freshwater stream with a perennial flow type designation. The North Fork Fish Creek watershed drains an area of approximately 3,663 acres. North Fork Fish Creek was considered a fully supporting contributing watershed to Fish Creek in a previous TMDL (TCEQ, 2016).

The draft 2016 Integrated Report (TCEQ, 2018a) provides the following AU description for North Fork Fish Creek:

- North Fork Fish Creek from confluence with Fish Creek in Dallas County upstream to SH 360 in Tarrant County.

This study incorporates a watershed approach where the drainage area of the stream is considered.

2.2 Watershed Climate

The TMDL study area is located near the center of the Dallas/Fort Worth (DFW) metroplex, which is classified having as humid subtropical climate (NOAA, 2009). Typically, the DFW area encounters mild winters with the first frost occurring in late November and the last frost in mid-March; however, brief periods of extreme cold do occur. Summers in the DFW area are hot and high temperatures frequently exceeding 100° F are typically accompanied by fair skies and westerly winds. Annual precipitation predominately occurs in the form of thunderstorms that are typically brief in nature and are recurrent in the spring.

For the Arlington Municipal Airport weather station located in the western portion of the Fish Creek (Segment 0841K) watershed, the average high temperatures typically peak in August (96.5 °F) with highs above 100 °F occurring June through August (Figure 2; NOAA, 2018). During winter, the average low temperature generally bottoms out at 35.7 °F in January (NOAA, 2018).

Weather data obtained from the National Climatic Data Center for the Arlington Municipal Airport station spanning a period from 2003 through 2017 indicate the wettest month is typically May (4.5 inches) while August (1.7 inches) is the normally the driest month, with rainfall occurring throughout the year (Figure 2; NOAA, 2018).

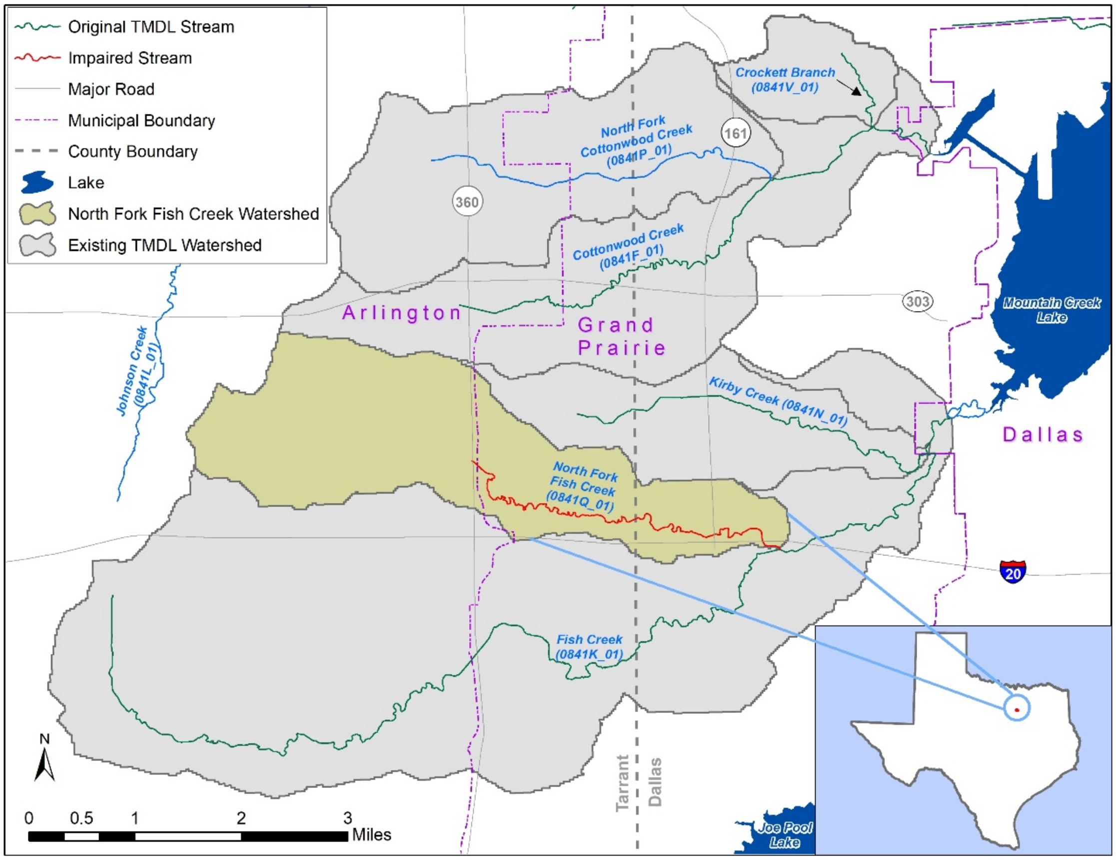

Figure 1. Map showing the approved TMDL watersheds and the current North Fork Fish Creek watershed.

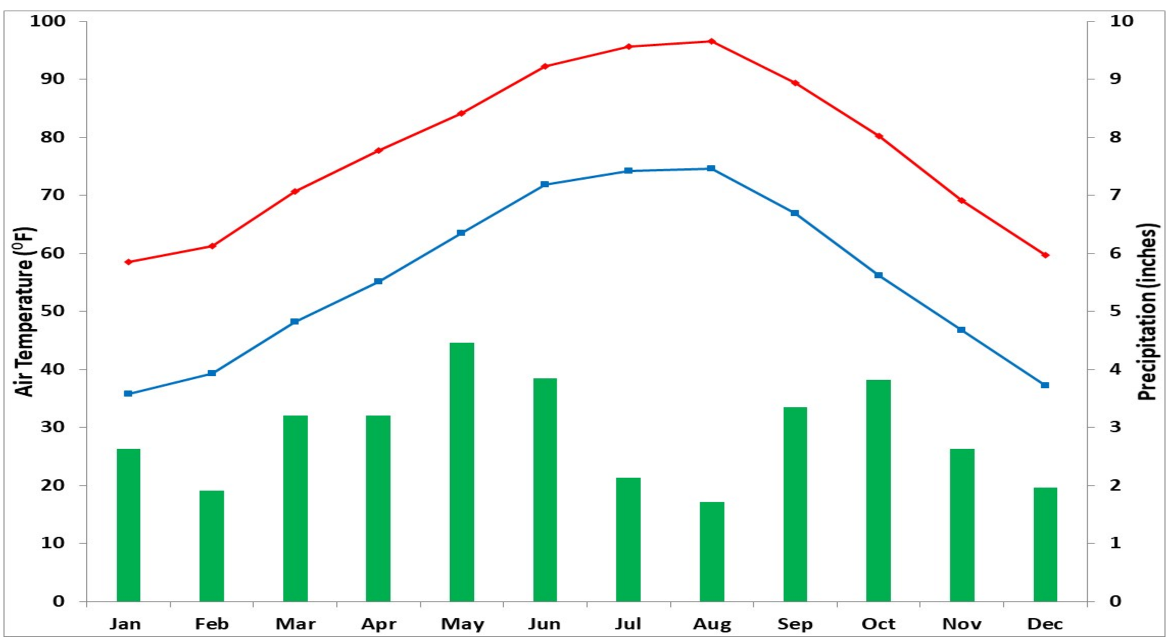

Figure 2. Average minimum and maximum air temperature and total precipitation by month from Jan 2003 – Dec 2017 for Arlington Municipal Airport.

2.3 Watershed Population and Population Projections

As depicted in Figure 1, the TMDL study area is geographically located within municipal incorporated boundaries of Arlington and Grand Prairie. Population estimates were developed using 2010 U.S. Census Block data allocated to the area within the North Fork Fish Creek watershed. Population projections for the year 2045 were developed by the North Central Texas Council of Governments (NCTCOG) by utilizing traffic survey zone allocations approximated to city boundaries. The projected populations were then allocated based on proportion of the area within the North Fork Fish Creek watershed. The projected population increase was then determined based on the increase from the 2010 population to the projected 2045 population and indicate that the population within the North Fork Fish Creek watershed will increase by 62.4% (Table 1; USCB, 2018 and NCTCOG, 2017a).

Table 1. 2010 Population and 2045 Population Projections for the North Fork Fish Creek watershed.

Water Body	Segment	2010 U.S. Census Population	2045 Projected Population	Projected Population Increase	Percent change (2010 - 2045)
North Fork Fish Creek	0841Q	30,749	49,926	19,177	62.4%

2.4 Review of Routine Monitoring Data

2.4.1 Data Acquisition

Ambient *E. coli* data were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) on November 20, 2018 (TCEQ, 2018b). The data represent all the historical routine ambient water quality data collected in the North Fork Fish Creek watershed, and include *E. coli* data collected from December 2001 through July 2017.

2.4.2 Analysis of Bacteria Data

Environmental monitoring within the North Fork Fish Creek watershed has occurred at three TCEQ monitoring stations (Figure 3). *E. coli* data collected at stations 20838, 10724, and 17678 over the seven-year period of December 1, 2007 through November, 30 2014 were used in assessing attainment of the primary contact recreation use as reported in the Draft 2016 Integrated Report (TCEQ, 2018a) and are summarized in Table 2. The 2016 assessment data for the North Fork Fish Creek watershed indicate non-support of the primary contact recreation use because geometric mean concentrations exceed the *E. coli* geometric mean criterion of 126 cfu/100 mL.

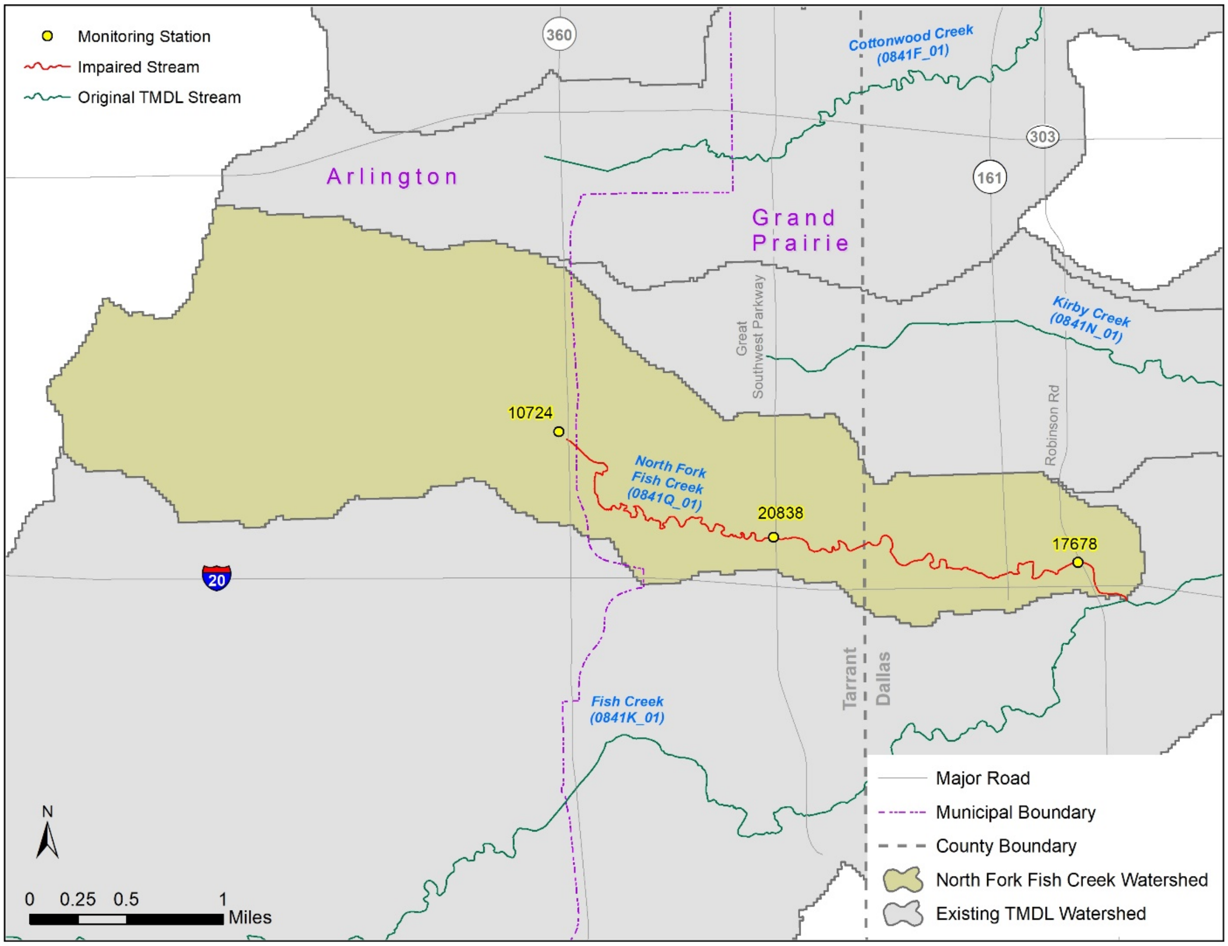

Figure 3. North Fork Fish Creek watershed (Segment 0841Q) showing TCEQ surface water quality monitoring (SWQM) stations.

Table 2. Draft 2016 Integrated Report Summary for the North Fork Fish Creek watershed.

Integrated Report Year	AU	Parameter	Stations	No. of Samples	Data Date Range	Geometric Mean (cfu/100 mL)
2016 (draft)	0841Q_01	*E. coli*	10724; 17678; 20838	84	2007-2014	183

2.5 Land Use

The land use/land cover data for the North Fork Fish Creek watershed were obtained from the North Central Texas Council of Governments (NCTCOG, 2017b) and represent land use/land cover estimates for 2015. The land use/land cover is represented by the following categories and definitions:

- Commercial/Industrial: land occupied by office, retail, industrial (manufacturing, warehouses, salvage yards, quarries, mines), utilities (sewage/water treatment plants, power infrastructure), stadiums, communication (radio, television, cable, and phone infrastructure), construction sites, and parking.

- Group Quarters: land occupied by nursing homes, dormitories, jails, military personnel quarters, and hotels/motels.
- Residential: land occupied by single family, multi-family, and mobile home residences.
- Institution: land occupied by churches, schools, museums, hospitals, medical clinics, libraries, government facilities, and military bases.
- Transit: land occupied by roads, rail lines, rail stations, bus lines and bus facilities.
- Dedicated: land occupied by public and private parks, golf courses, tennis courts, pools, campgrounds, amusement parks, and cemeteries.
- Vacant: land that is undeveloped with the potential to be developed or reserved for recreational use.
- Ranch/Farmland: land occupied by livestock or crops.
- Timberland: land covered by trees.
- Water: covered by lakes, rivers, and ponds.

The 2015 land use/land cover data from the NCTCOG is provided for the North Fork Fish Creek watershed in Figure 4. A summary of the land use/land cover data is provided in Table 3 and indicates that residential is the dominant land cover comprising approximately 41% of the total land cover.

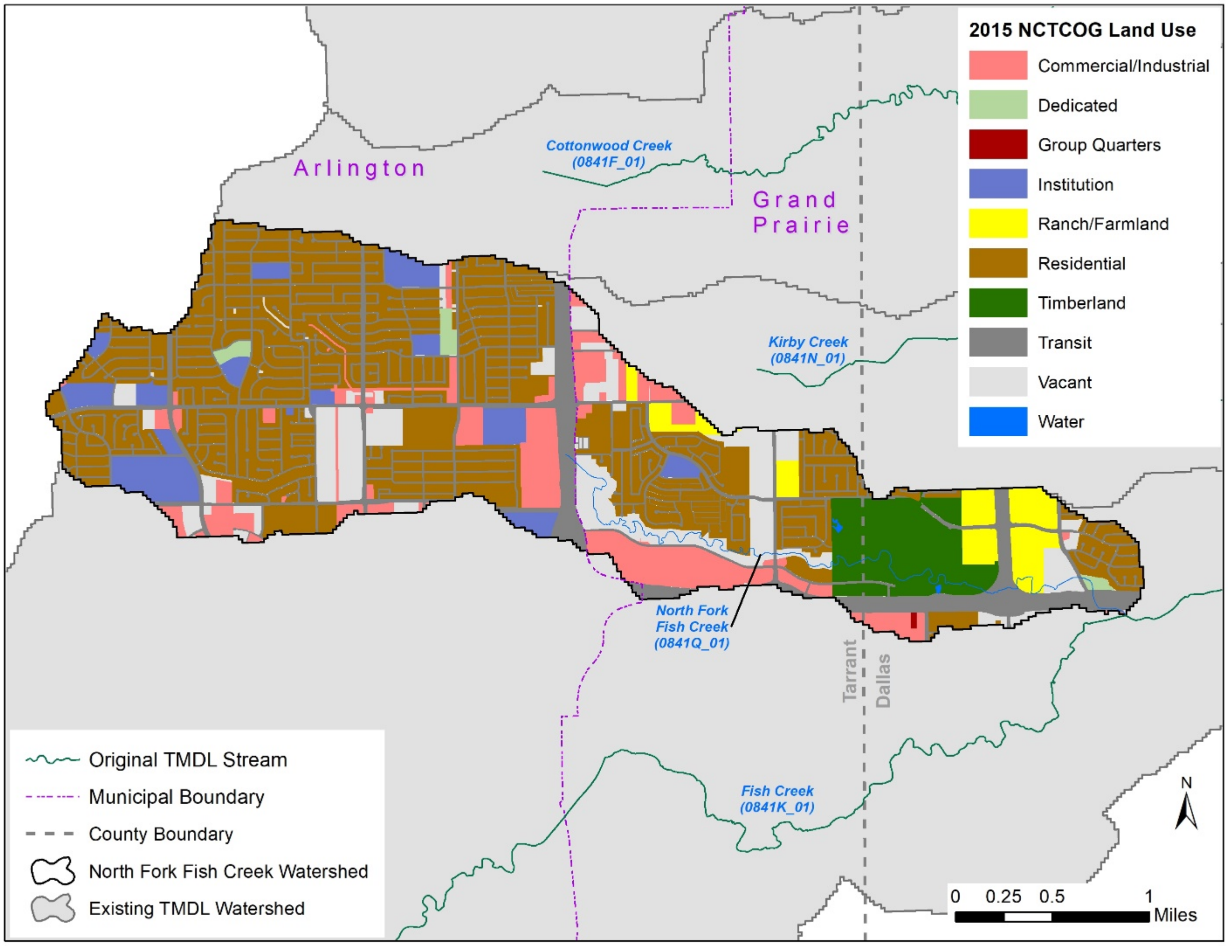

Figure 4. 2015 land use/land cover within the North Fork Fish Creek watershed.

Table 3. Land Use/Land Cover within the North Fork Fish Creek watershed.

Classification	Area (Acres)	% of Total
Commercial/Industrial	369.0	10.08%
Group Quarters	1.5	0.04%
Residential	1,509.8	41.22%
Institution	216.1	5.90%
Transit	780.8	21.32%
Dedicated	26.1	0.71%
Vacant	382.8	10.45%
Ranch/Farmland	149.0	4.07%
Timberland	225.5	6.16%
Water	1.9	0.05%
Total	3,662.5	100%

2.6 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 (MS4) 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 wasteload allocations or WLAs, the regulated and unregulated sources in this section are presented to give a general account of the potential sources of bacteria in the watershed.

2.6.1 Permitted Sources

Permitted sources are regulated by permit under the TPDES and the NPDES programs. WWTF outfalls and stormwater discharges from industries, construction, and MS4s represent the potential permitted sources in the TMDL watershed.

2.6.1.1 Domestic Wastewater Treatment Facility Discharges

No permitted WWTFs exist in the TMDL study area. Domestic wastewater is collected by and transported to the Trinity River Authority (TRA) Central Regional Wastewater System located outside the study area (Figure 5).

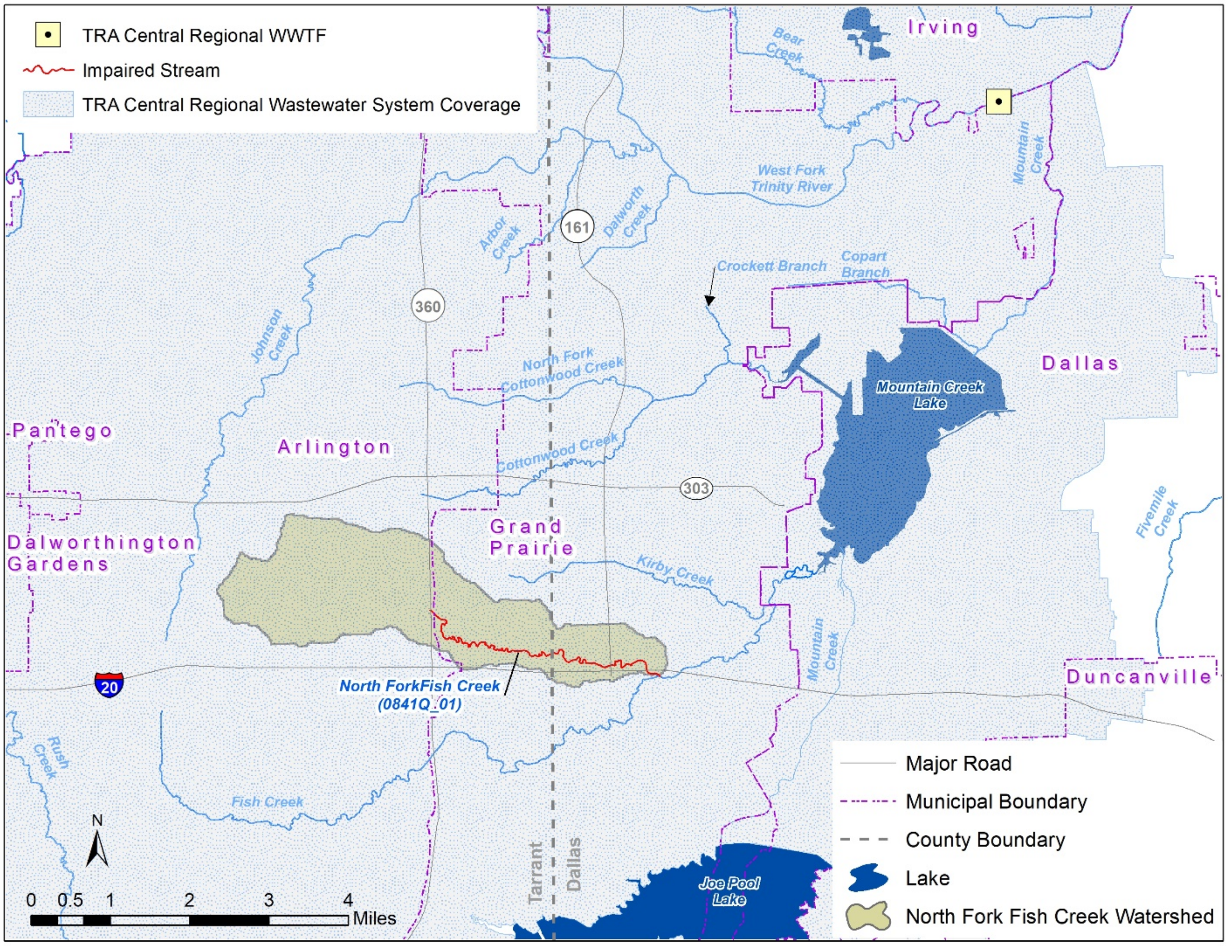

Figure 5. Coverage area of the TRA Central Regional Wastewater within the TMDL study area.

2.6.1.2 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.

Information regarding reported SSO incidents in the North Fork Fish Creek watershed were obtained from two datasets. The first dataset was acquired through the NCTCOG and represented incidents that occurred from 2007 to 2015. The second dataset was acquired from the TCEQ and represented more recent data from 2016 to 2018. Reported SSO incidents that occurred from 2007 to 2015 were refined by the NCTCOG by assigning latitude and longitude coordinates to each SSO event and plotted using Geographic Information System (GIS) software in an effort to characterize the frequency and magnitude of SSO events within the North Fork Fish Creek watershed (Figure 6). A summary of the NCTCOG refined data within the TMDL study area is shown in Table 4. Efforts were made to extract only the incidents that occurred within the TMDL study area from the SSO dataset containing more recent SSO events as well, however, incomplete geo-referenced SSO events made geospatial distinction of SSOs that occurred from 2016 through 2018 difficult. Thus, a summary of the reported SSO incidents from January 2016 through December 2018 for the cities of Arlington and Grand Prairie can be found in Table 5.

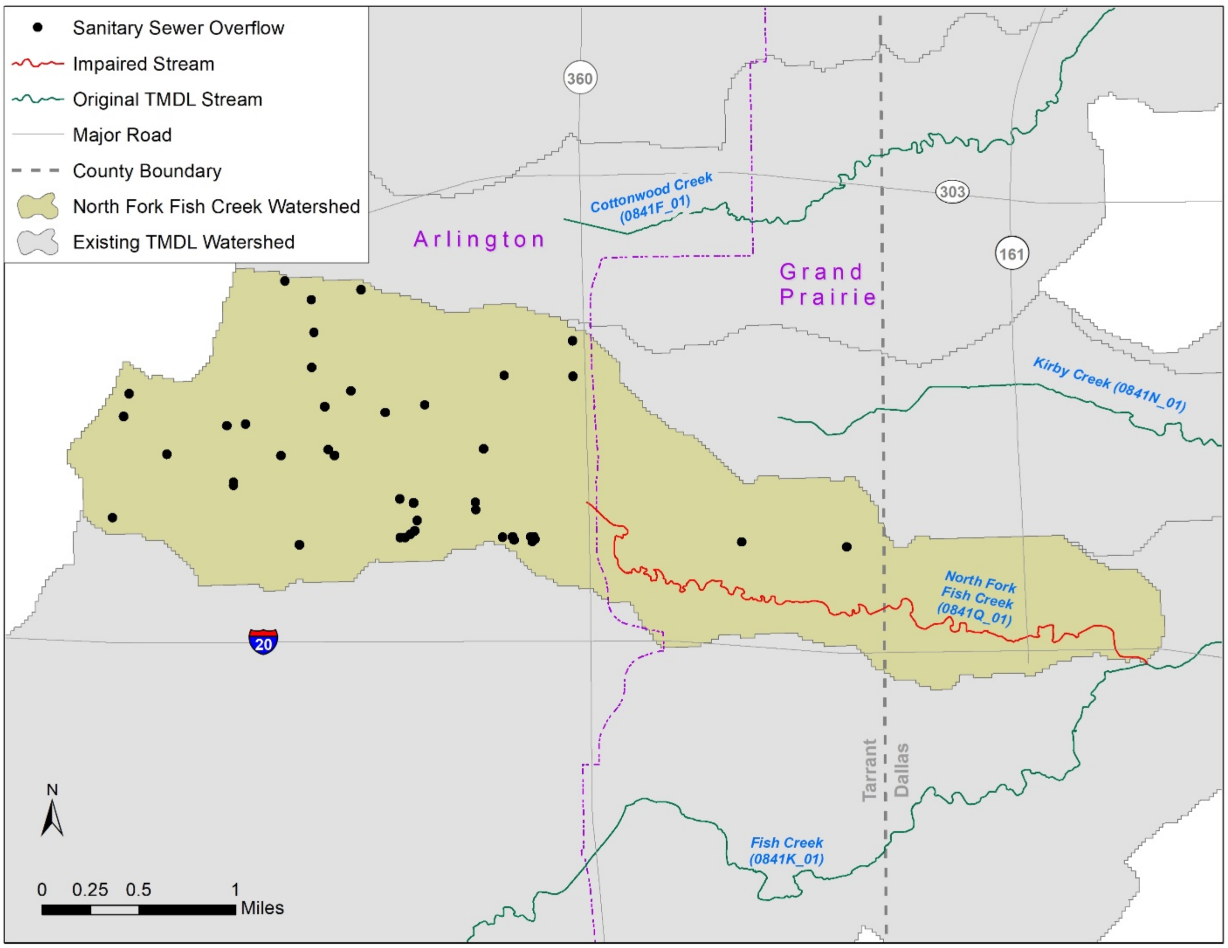

Figure 6. Sanitary Sewer Overflows that occurred from 2007 - 2015 within the North Fork Fish Creek Watershed.

Table 4. Summary of SSO incidences reported in the North Fork Fish Creek Watershed from 2007 - 2015.

No. of Incidents	Total Volume (gallons)	Average Volume (gallons)	Minimum Volume (gallons)	Maximum Volume (gallons)
45	22,166	493	7	6,000

Table 5. Summary of SSO incidences reported for the cities of Arlington and Grand Prairie from Jan. 2016 – Dec. 2018.

Municipality	No. of Incidents	Total Volume (gallons)	Average Volume (gallons)	Min. Volume (gallons)	Max. Volume (gallons)
Arlington	205	147,354	719	5	40,375
Grand Prairie	69	35,590	516	10	20,000

2.6.1.3 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/NPDES regulated MS4 entities, industrial facilities, and construction activities; and
2) stormwater runoff not subject to regulation.

The TPDES/NPDES MS4 Phase I and II rules require municipalities and certain other entities in urban areas to obtain permit coverage for their stormwater systems. A regulated MS4 is a publicly owned system of conveyances and includes 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 of 100,000 or more based on the 1990 U.S. Census, whereas the Phase II general permit regulates smaller communities within a U.S. Census Bureau defined urbanized area. The purpose of an 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 SWMP describes the stormwater control practices that will be implemented consistent with permit requirements to minimize the discharge of pollutants from the MS4. The permits require that the SWMPs specify the best management practices to meet several minimum control measures (MCMs) that, when implemented in concert, are expected to result in significant reductions of pollutants discharged into receiving waterbodies. Phase II MS4 MCMs include:

- Public education, outreach, and involvement;
- Illicit discharge detection and elimination;
- Construction site stormwater runoff control;
- Post-construction stormwater management in new development and redevelopment;
- Pollution prevention and good housekeeping for municipal operations; and
- Industrial stormwater sources.

Phase I MS4 individual permits have similar MCMs organized a little differently and are further required to perform water quality monitoring.

The geographic region of the TMDL watershed covered by Phase I and II MS4 permits is that portion of the area within the jurisdictional boundaries of the regulated entities. For Phase I permits the jurisdictional area is defined by the city limits and for Phase II permits the jurisdictional area is defined as the intersection or overlapping areas of the city limits and the 2000 or 2010 Census urbanized area.

The area under the jurisdiction of Phase II general permits and Phase I individual permits was used to estimate the regulated stormwater areas for construction, industrial and MS4 permits (Figure 7). In this report the regulated area for the Phase II permits was based on the 2010 urbanized area from the U.S. Bureau of Census.

A review of active stormwater general permits coverage and a review of the central registry for Phase I MS4 permit coverage (TCEQ, 2018c) in the TMDL study area revealed that existing Phase I and Phase II permits (Table 6) provide 100% MS4 coverage for the TMDL study area (Figure 7).

Table 6. TPDES and NPDES MS4 permits associated with the TMDL study area.

Entity	TPDES Permit	NPDES Permit
City of Arlington	WQ004635-000	TXS000301
Texas Department of Transportation	WQ0005011-000	TXS002101
City of Grand Prairie	Phase II General Permit (TXR040000)	TXR040065

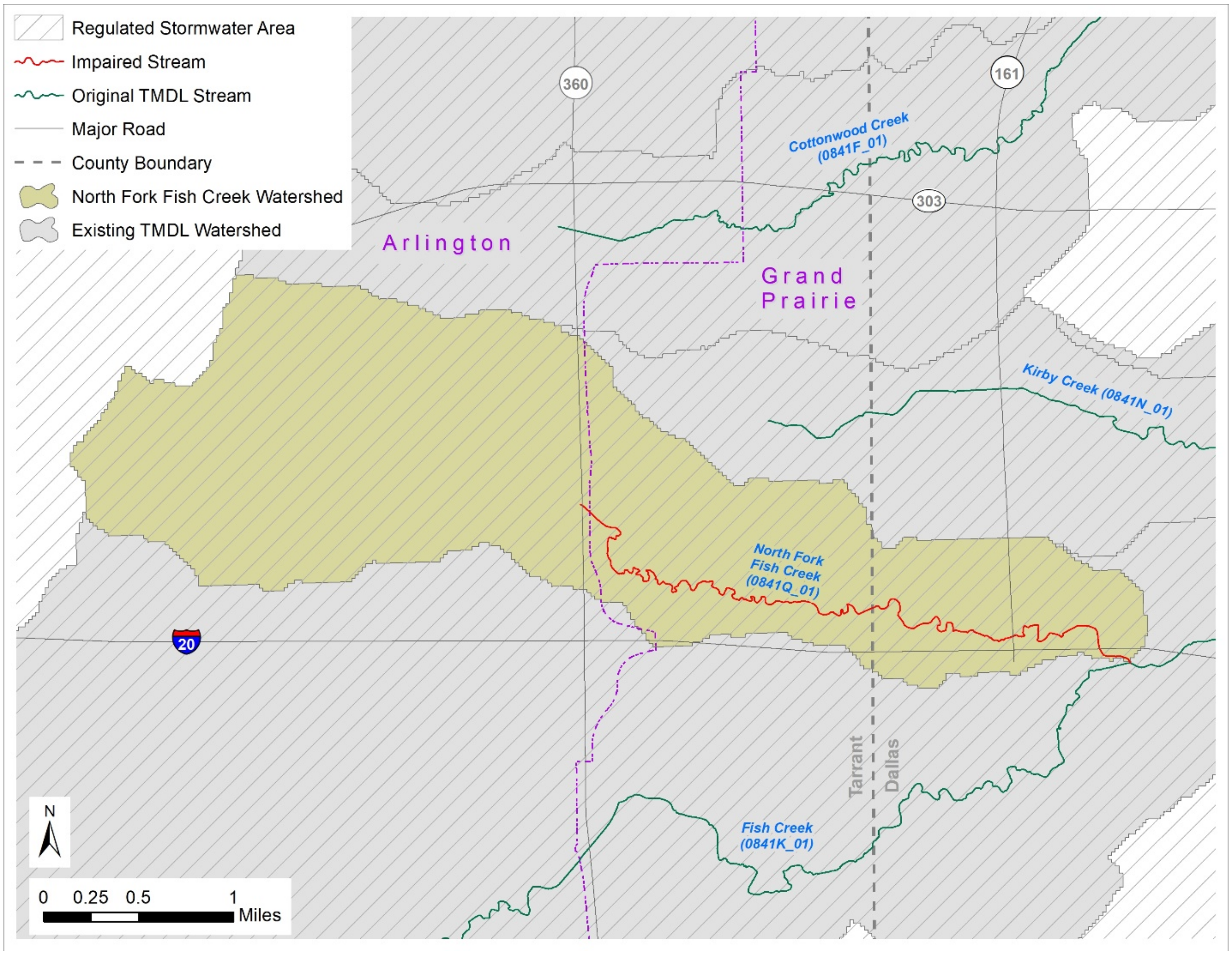

Figure 7. Regulated stormwater area based on Phase I and Phase II MS4 permits within the North Fork Fish Creek Watershed.

2.6.1.4 Dry Weather Discharges/Illicit Discharges

Bacteria loads from regulated stormwater can enter the streams from permitted outfalls and illicit discharges under both dry and wet weather conditions. The term "illicit discharge" is defined in TPDES General Permit No. TXR040000 for Phase II (Small) MS4 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.

2.6.1.5 TPDES General Wastewater Permits

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
- TXG500000 – quarries in John Graves Scenic Riverway
- TXG670000 – hydrostatic test water
- TXG830000 – petroleum fuel or petroleum substances
- TXG870000 – pesticides
- TXG920000 – concentrated animal feeding operations
- TXG100000 – wastewater evaporation
- WQG20000 – livestock manure compost operations (irrigation only)

A review of active general permit coverage (TCEQ, 2018c) in the North Fork Fish Creek watershed as of November 6, 2018, found no operations or facilities of the types described above.

2.6.2 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 on-site sewage facilities (OSSFs), and domestic pets.

2.6.2.1 Wildlife and Unmanaged Animal Contributions

E. coli bacteria are common inhabitants of the intestines of all warm-blooded animals, including feral hogs and wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify by watershed the potential for bacteria contributions from wildlife and feral hogs. Wildlife and feral hogs are naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, the direct deposition of wildlife and feral hog waste can be a concentrated source of bacteria loading to a water body. Fecal bacteria from wildlife and feral hogs are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. The *E. coli* contribution from feral hogs and wildlife in North Fork Fish Creek cannot be determined based on existing information.

2.6.2.2 On-Site Sewage Facilities

Failing OSSFs were not considered a major source of bacteria loading in the North Fork Fish Creek watershed, because the entire watershed area is served by a centralized wastewater collection and treatment system. Areas serviced by centralized treatment and collection systems typically contain very few OSSFs, and this is the situation for the TMDL watersheds, where NCTCOG information indicates that only 2 OSSFs exist in the TMDL study area.

2.6.2.3 Unregulated Agricultural Activities and Domesticated Animals

Activities, such as livestock grazing close to water bodies and farmers' use of manure as fertilizer, can contribute fecal indicator bacteria such as *E. coli* to nearby water bodies. Due to the highly urbanized nature of the TMDL study area, livestock were not considered a major source of bacteria loading.

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 7 summarizes the estimated number of dogs and cats within the North Fork Fish Creek watershed. Pet population estimates were calculated as the estimated number of dogs (0.584) and cats (0.638) per household according to data from the American Veterinary Medical

Association 2012 U.S Pet Statistics (AVMA, 2015). The number of households in the watershed was estimated using 2010 United States Census Bureau (USCB) data (USCB, 2018). The actual contribution and significance of fecal coliform loads from pets reaching the water bodies of the North Fork Fish Creek watershed is unknown.

Table 7. Estimated distribution of dog and cat populations within the North Fork Fish Creek watershed.

Households	Dogs	Cats
9,962	5,818	6,356

2.6.2.4 Bacteria Survival and Die-off

Bacteria are living organisms that survive and die in the environment. Certain enteric bacteria can survive and replicate in organic materials if appropriate conditions prevail (*e.g.*, warm temperature). Fecal organisms from improperly treated effluent can survive and replicate during their transport in pipe networks, and they can survive and replicate 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 re-growth 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 North Fork Fish Creek.

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 LDC development.

3.1 Tool Selection

For consistency between this TMDL and the previously completed TMDLs located upstream of Mountain Creek Lake, the pollutant load allocation activities for North Fork Fish Creek used the LDC method. The LDC method has been previously used on TCEQ-adopted and USEPA-approved TMDLs for the *Four Total Maximum Daily Loads for Indicator Bacteria in the Cottonwood Creek, Fish Creek, Kirby Creek, and Crockett Branch Watersheds* (TCEQ, 2016).

The LDC method allows for estimation of existing and allowable loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, the LDC method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment. The LDC method has found relatively broad acceptance among the regulatory community, primarily due to the simplicity of the approach and ease of application. The regulatory community recognizes the frequent information limitations, often associated with bacteria TMDLs, that 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 (Jones *et al.*, 2009). 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.

3.2 North Fork Fish Creek Data Resources

Successful application of the LDC method requires two basic types of data: continuous daily streamflow data and historical bacteria data for the relevant indicator bacteria, which in this case is *E. coli*.

Hydrologic data in the form of daily streamflow records were unavailable for the North Fork Fish Creek watershed; however, streamflow records were available for the nearby Walnut Creek watershed. Streamflow records for Walnut Creek watershed are collected and made readily available by the U.S. Geological Survey (USGS; USGS, 2018), which operates the Walnut Creek streamflow gage (Table 8; Figure 8). USGS streamflow gage 080497000 is located along the mainstem of the Walnut Creek within Segment 0838C and serves as the primary source for streamflow records used in this document. The Walnut Creek streamflow gage served as the source of streamflow records used in the existing four TMDLs to which the North Fork Fish Creek TMDL will be appended.

Table 8. Basic information on Walnut Creek USGS streamflow gage

Gage No.	Site Description	Segment	Drainage Area (acres)	Daily Streamflow Record (beginning & end date)
08049700	Walnut Creek near Mansfield, TX.	0838C	40,179	Oct. 1960 - present

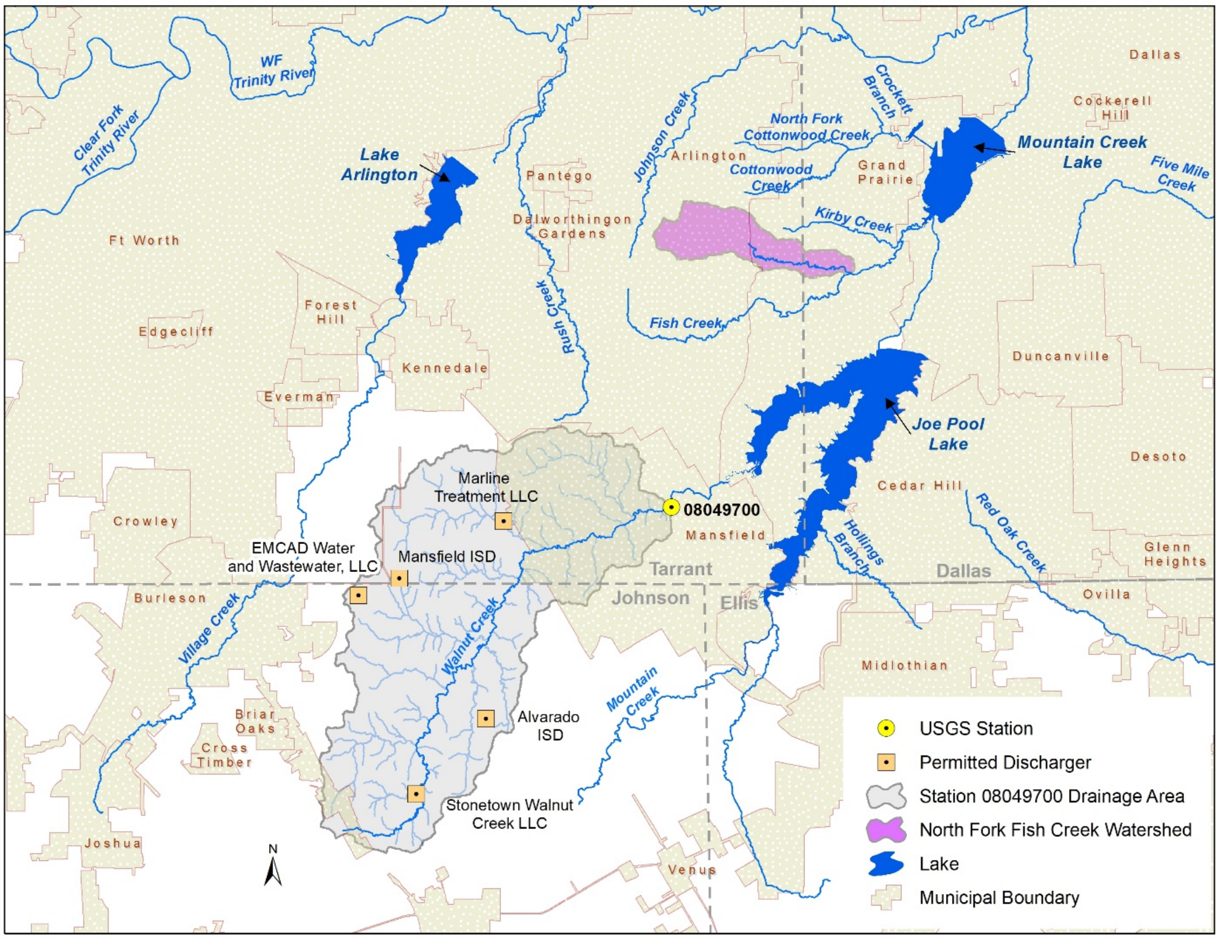

Figure 8. TMDL study area, Walnut Creek watershed, and USGS Station 08049700 location near Mansfield, Texas.

Ambient *E. coli* data were available through the TCEQ SWQMIS for three stations located along North Fork Fish Creek (Table 9).

Table 9. Summary of historical data set of *E. coli* concentrations collected at sampling stations along North Fork Fish Creek.

Station (s)	Station Location	No. of *E. coli* Samples	Data Date Range
10724	South Watson Road, Arlington, TX	37	2002-2014
20838	South Great Southwest Parkway, Grand Prairie, TX	70	2009-2017
17678	Robinson Road, Grand Prairie, TX	76	2001-2008

3.3 Methodology for Flow Duration & Load Duration Curve Development

To develop the flow duration curve (FDC) and LDC, the previously discussed data resources were used in the following series of sequential steps.

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

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

3.3.1 Step 1: Determine Hydrologic Period

A 58-year daily hydrologic (streamflow) record was available for USGS gauge 08049700 located on nearby Walnut Creek (Table 8, Figure 8). Optimally, the period of record to develop FDCs should include as much data as possible in order to capture extremes of high and low streamflow 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 *E. coli* data were collected. Therefore, a 25-year record of daily streamflow from January 1993 through December

2017 was selected to develop the FDCs at the sampling station location, and this period includes the collection dates of all available *E. coli* data at the time this work effort was undertaken. A 25-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. A 25-year hydrologic period was also used in the previously completed *Four TMDLs for Indicator Bacteria in the Cottonwood Creek, Fish Creek, Kirby Creek, and Crockett Branch Watersheds Upstream of Mountain Creek Lake* (TCEQ, 2016), which maintains consistency of the North Fork Fish Creek TMDL with the previous TMDLs.

3.3.2 Step 2: Determine Desired Stream Locations

The three sampling locations located on North Fork Fish Creek and for which adequate *E. coli* data were available determined the stream locations for which FDCs and LDCs were developed. The most downstream monitoring station (17678) was selected as the location for developing the pollutant load allocation in order to maximize the amount of watershed included above the sampling location. The other two upstream sampling stations are used to provide additional information.

3.3.3 Step 3: Develop Daily Streamflow Records

Once the hydrologic period of record and station locations were determined, the next step was to develop the 25-year daily streamflow record for the monitoring stations. The daily streamflow records were developed from extant USGS records.

The method to develop the necessary streamflow record for the FDC/LDC location (SWQM station location) involved a DAR approach. The DAR approach involves multiplying a USGS gaging station daily streamflow value by a factor to estimate the flow at a desired monitoring station location. The factor is determined by dividing the drainage area above the desired monitoring station by the drainage area above the USGS gauge (Table 10).

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 from the flow record of the Walnut Creek gage prior to application of the ratio. There are five active WWTF discharges above the USGS gage on Walnut Creek (Figure 8); however, each of these discharges is small (largest permitted discharge of 0.04 million gallons per day) and all are greater than 10 stream miles from the gage location. The combination of the small size of the discharges, their distance from the gage and the fact that the USGS gage location for the 25-year period of record experienced zero streamflow 8 percent of the time and flow less than 0.05 cubic feet per second (cfs) 15 percent of the time lead to the assumption that the existing discharges are not significantly impacting the gaged streamflow record. Therefore, no adjustments for WWTF discharges were made to the Walnut Creek USGS gage record prior to application of the DARs.

In addition to WWTF discharges, surface water diversions associated with water rights permits have the potential of impacting stream hydrology in regards to the application of the DAR approach. A spatial query of water rights features (diversions, withdrawals, return flows) revealed that the North Fork Fish Creek did not contain any active water rights permits; however there was one active water right permit located in the Walnut Creek watershed with two active diversion locations (TCEQ, 2019a). A review of the water use data file containing historical reported water diversions (TCEQ, 2019b) indicates only one user, located above the USGS gauge 08049700, reported diversions for only one year in 2014. The impact of the monthly diversions was investigated by applying the diversion amounts to the streamflow record and found to have no significant impact on streamflow calculations and ultimately no impact on TMDL calculations. Therefore, diversions associated with water rights permits were not considered in the development of the streamflow record.

The DARs for locations within the TMDL study area are presented in Table 10. The computation of the daily streamflow record at each station was performed by multiplying each daily streamflow in the 25-year Walnut Creek gaged record by the appropriate DAR for that station.

Table 10. DARs for locations within the North Fork Fish Creek watershed based on the drainage area of the Walnut Creek USGS gage.

Gage/Station	Drainage Area (acres)	DAR
USGS Gage 8049700	40,179	1.0
SWQM Station 10724	1,939	0.0483
SWQM Station 20838	2,756	0.0686
SWQM Station 17678	3,553	0.0884

3.3.4 Steps 4-6: Flow Duration Curve and Load Duration Curve Method

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 cfs by the appropriate water quality criterion for *E. coli* (geometric mean of 126 cfu/100 mL) and by a conversion factor ($2.44658x10^7$), which gives a loading in units of cfu/day; and
- plot the exceedance percentages, which are identical to the value for the streamflow data points, against geometric mean criterion of *E. coli*.

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

- using the unique data for the monitoring station, compute the daily loads for each sample by multiplying the measured *E. coli* concentrations on a particular day by the corresponding streamflow on that day and the conversion factor ($2.44658x10^7$), which gives a loading in units of cfu/day; and
- plot on the LDC the load for each measurement at the exceedance percentage for its corresponding streamflow.

The plots of the LDC with the measured loads (*E. coli* 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.

3.4: Flow Duration Curves for Sampling Stations within the North Fork Fish Creek Watershed

FDCs were developed for three monitoring stations located within the North Fork Fish Creek watershed (Figure 9). For this report, FDCs were developed by applying the DAR method and using the Walnut Creek USGS gage and period of record (1993-2017) described in the previous sections. Flow exceedances less than 10 percent typically represent streamflows influenced by storm runoff while higher flow exceedances represent receding hydrographs after a runoff event, base flow and no flow conditions. The stair-step pattern in each LDC between the 80 and 90 percentiles of flow exceedance is an artifact that the low flows in the gaged streamflow record are reported to two significant digits to the right of the decimal point (e.g., 0.01 cfs and 0.02 cfs). Also, as contained in the streamflow record for Walnut Creek, almost 10 percent of the time each FDC shows the condition of no flow, which is anticipated to be reflective of actual conditions in North Fork Fish Creek.

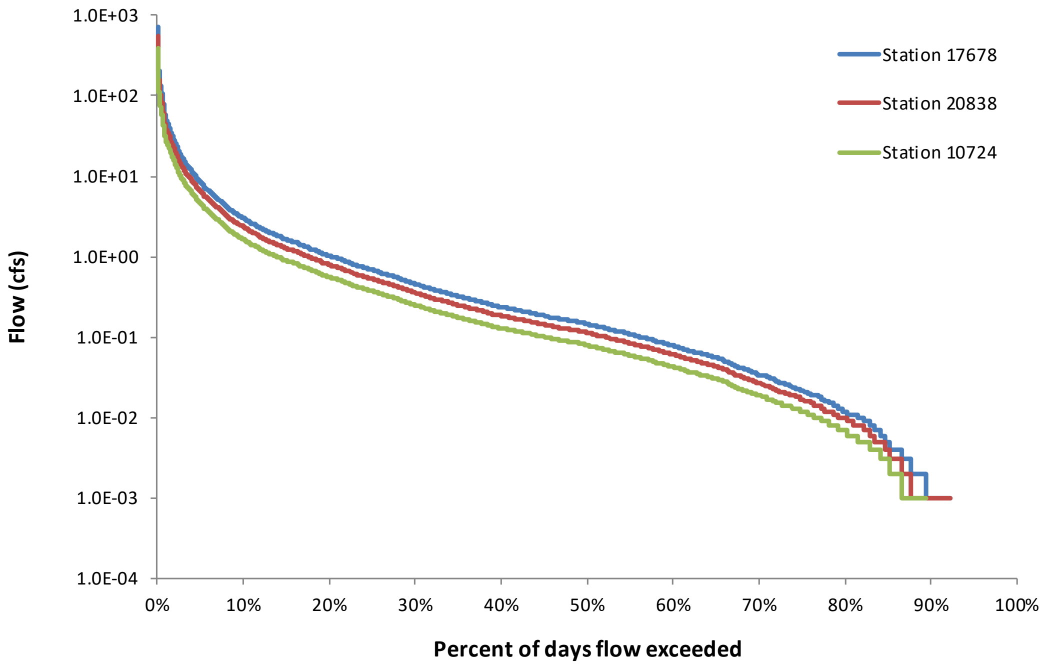

Figure 9. Flow duration curve for North Fork Fish Creek.

3.5: Load Duration Curves for Sampling Stations within the North Fork Fish Creek Watershed

LDCs were developed for each of the three monitoring stations within the North Fork Fish Creek watershed. 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 North Fork Fish Creek watershed, a three-interval division was selected:

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

The selection of the flow regime intervals was based on general observations of the monitoring station LDCs. The selected flow regime intervals also provides consistency with the previously completed TMDLs in the Mountain Creek Lake watershed. 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 LDCs with these three flow regimes for water quality monitoring stations are provided in Figures 10 through 12. The LDC for station 17678 (Figure 10) was constructed for developing the TMDL allocation for the North Fork Fish Creek watershed. 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 *E. coli* concentrations have occurred. The LDCs depict the allowable loadings at the stations under the geometric mean criterion (126 cfu/100 mL) and show that existing loadings often exceed the criterion. In addition, the LDCs present the allowable loading at the stations under the single sample criterion (399 cfu/100 mL).

On each graph the measured *E. coli* 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 sample with DSLP ≤ 2 days was defined as wet-weather influenced.

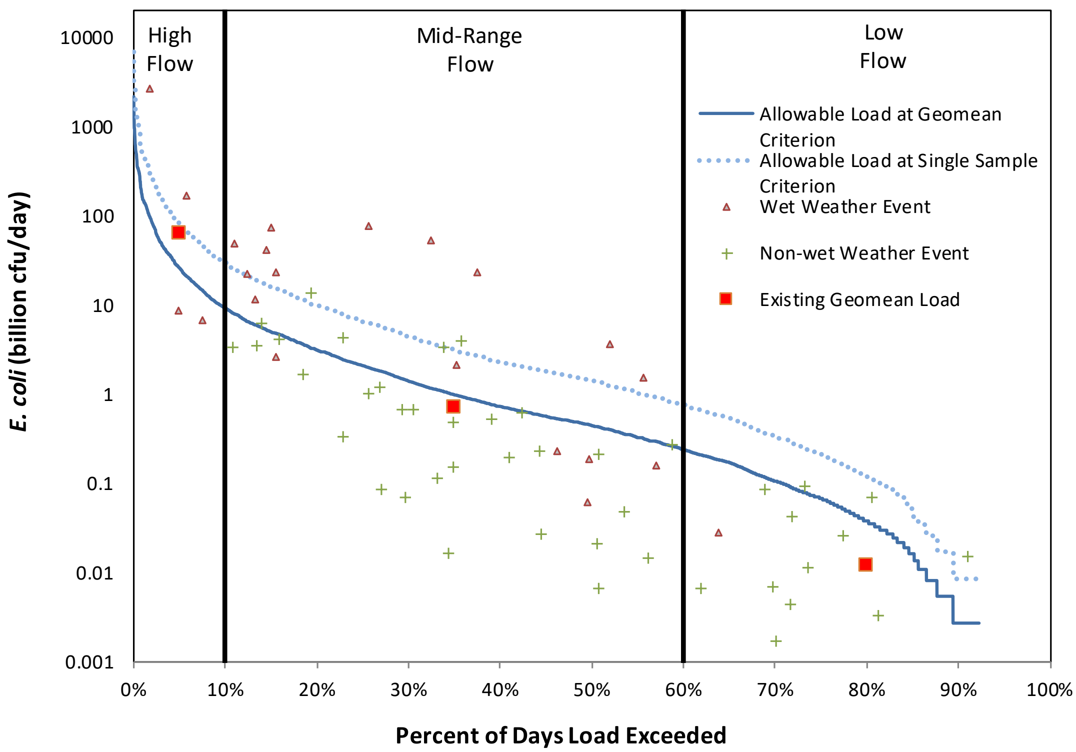

Figure 10. LDC for station 17678.

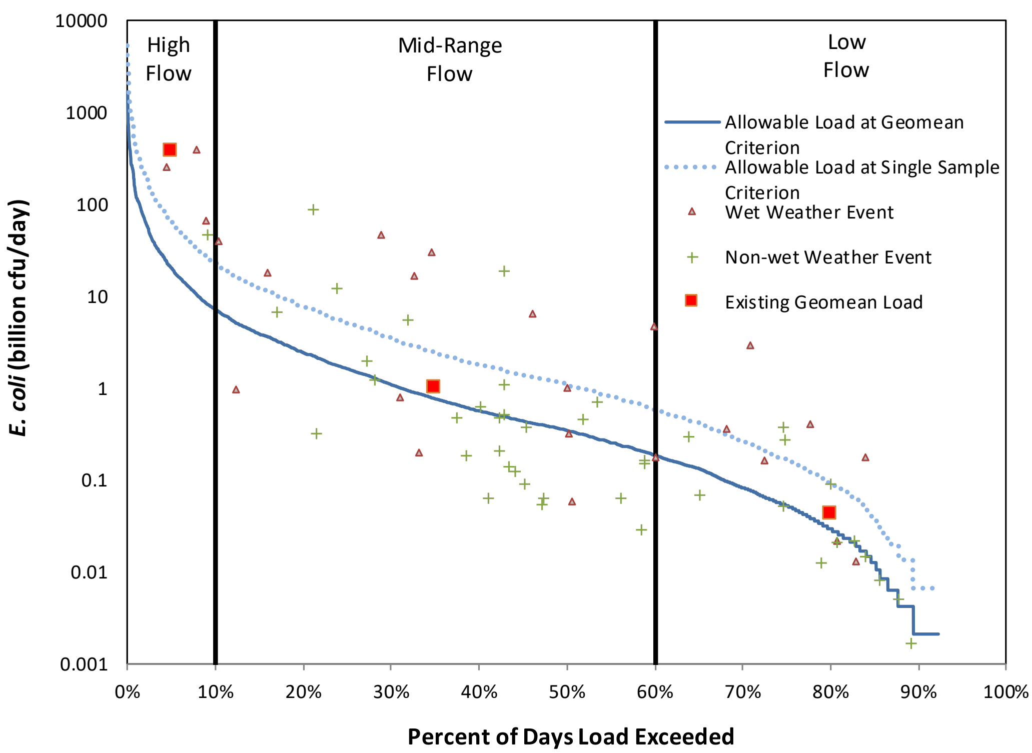

Figure 11. LDC for station 20838.

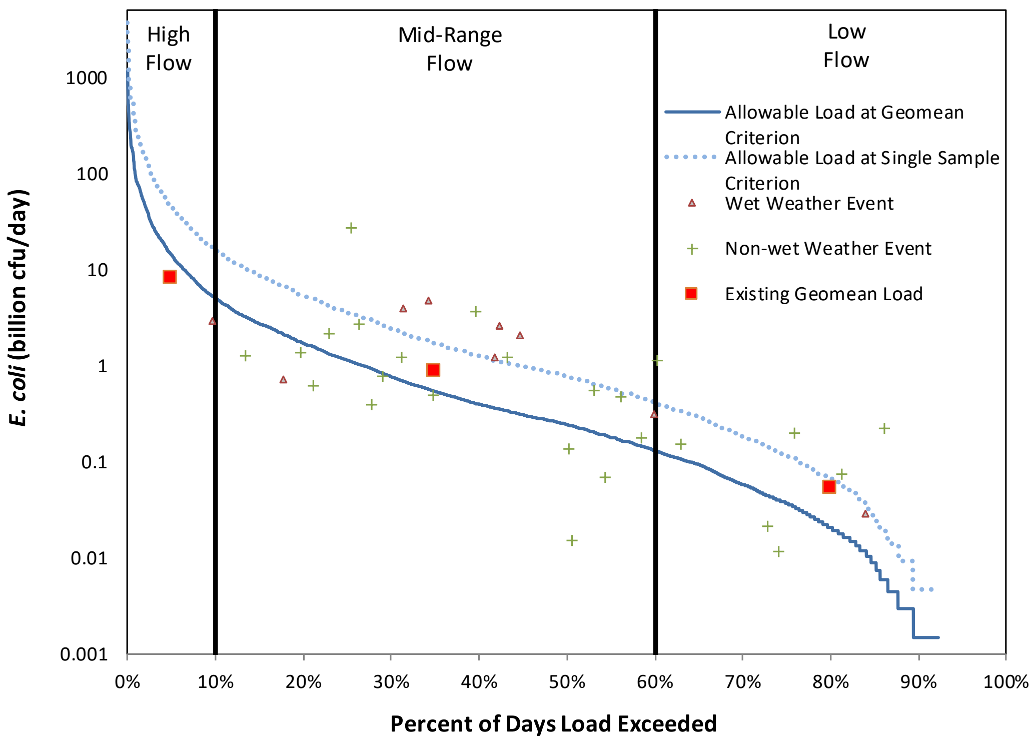

Figure 12. LDC for station 10724.

SECTION 4
TMDL ALLOCATION ANALYSIS

Presented in this report section is the development of the bacteria TMDL allocation for the North Fork Fish Creek watershed. The tool used for developing the TMDL allocation was the LDC method previously described in Section 3– Bacteria Tool Development. Endpoint identification, margin of safety (MOS), load reduction analysis, TMDL allocations, and other TMDL components are described herein.

The LDC method provided a flow-based approach to determine necessary reductions in bacteria loadings and allowable loadings within the North Fork Fish Creek 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 North Fork Fish Creek watershed (AU 0841Q_01) as shown in the overview map (Figure 1). Although LDCs were computed for all three of the sampling stations, the TMDL is only calculated for the most downstream sampling station (station 17678). The most downstream station was selected to encompass more of the drainage area of the watershed and should be representative of conditions in more of the watershed than stations located further upstream. Also, the selection of the most downstream station maintains consistency with the previously approved TMDLs in the Mountain Creek Lake watershed.

Additionally, a DAR approach using historical streamflow records from a USGS gage on Walnut Creek was employed to estimate the daily flow for each station.

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. The North Fork Fish Creek watershed has a use of primary contact recreation, which is measured against a numeric criterion for the indicator bacteria *E. coli*. 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 *E. coli* criterion to protect contact recreation in freshwater streams consists of a geometric mean concentration not to exceed 126 cfu/100 mL (TCEQ, 2010).

The endpoint for this TMDL is to maintain concentrations of *E. coli* below the geometric mean criterion of 126 cfu/100 mL. This endpoint is identical to the geometric mean criterion in the 2010 Surface Water Quality Standards (TCEQ, 2010).

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 *E. coli* concentrations obtained from seventeen years (2001 – 2017) of routine monitoring collected in the warmer months (April - September) against those collected during the cooler months (October – March). Differences in *E. coli* concentrations obtained in warmer versus cooler months were then evaluated by performing a t-test on the natural log transformed dataset. This analysis of *E. coli* data indicated that there was a significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for North Fork Fish Creek (α=0.008), 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 regulated and unregulated 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.

LDCs 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 one-to-one relationship between instream loadings and loadings originating from point sources and the landscape as regulated and non-regulated sources. Further, this one-to-one 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 LDC method was used to examine the relationship between instream water quality, the broad sources of indicator bacteria load, 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. 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 Wet Conditions flow regime (or 5 percent flow), where exceedances to the primary contact recreation criteria are most pronounced.

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 used in the pollutant load allocation process with historical *E. coli* data added to the graph (Figure 10) and Section 2.6 (Potential Sources of Fecal Indicator Bacteria), the following broad linkage statements can be made. For the North Fork Fish Creek watershed, the historical *E. coli* data indicate that elevated bacteria loadings occur especially under the highest flow regime. There is some moderation of the elevated loadings under mid-range and low flow regimes. On Figure 10, the geometric means of the measured data for each flow regime generally support these observations of decreasing concentration with decreasing flow.

4.5 Margin of Safety

The 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 MOS 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 in this report incorporates an explicit MOS of five percent.

4.6 Load Reduction Analysis

While the TMDL for the North Fork Fish Creek AU 0841Q_01 was developed using LDC method 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 *E. coli* data obtained from the most downstream station within AU 0841Q_01.

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 concentration and the 126 cfu/100 mL criterion and dividing that difference by the existing geometric mean concentration (Table 11).

Table 11. Percent reduction calculations for North Fork Fish Creek station 17678 (AU 0841Q_01).

Flow Regime	Number of Samples	Geometric Mean by Flow Regime (cfu/100 mL)	Percent Reduction by Flow Regime
High Flow (0-10%)	4	303	58.4%
Mid-Range Flow (10-60%)	48	91	None
Low Flow (60-100%)	24	40	None

4.7. Pollutant Load Allocation

The bacteria TMDL for North Fork Fish Creek (AU 0841Q_01) was developed as a pollutant load allocation based on information from the LDC for North Fork Fish Creek monitoring station 17678 (Figure 3). As discussed in more detail in Section 3, the bacteria LDC was developed by multiplying each flow value along the flow duration curve by the *E. coli* criterion (126 cfu/100 mL) and by the conversion factor used to represent maximum loading in cfu/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 (billion cfu/day) = Criterion * Flow (cfs) * Conversion Factor (Eq. 1)

Where:

Criterion = 126 cfu/100 mL (*E. coli*)

Conversion Factor (to billion cfu/day) = (283.1685 100 mL/ft^3 * 86,400 sec/day)/1.0E+9

4.7.1 Definitions of TMDL Components

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 basic equation:

$$TMDL = WLA + LA + FG + MOS \qquad \text{(Eq. 2)}$$

Where:

TMDL = total maximum daily load

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

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

FG = future growth, loadings associated with future growth from potential permitted facilities

MOS = margin of safety load

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

The TMDL components for the North Fork Fish Creek watershed covered in this report are derived using the median flow within the high flow regime (or 5 percent flow) of the LDC developed for SWQM station 17678.

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:

$$MOS = 0.05 * TMDL \qquad \text{(Eq. 3)}$$

Where:

MOS = margin of safety load

TMDL = total maximum daily load

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

$$WLA = WLA_{WWTF} + WLA_{SW} \qquad \text{(Eq. 4)}$$

TPDES-permitted wastewater treatment facilities would be allocated a daily wasteload (WLA_{WWTF}) calculated as their full permitted discharge flow rate multiplied by one-half the instream geometric criterion. One-half of the water quality criterion (63 cfu/100mL) is used as the WWTF target to provide instream and downstream load capacity, and to be consistent with previously developed TMDLs. Thus WLA_{WWTF} is expressed in the following equation:

$$WLA_{WWTF} = Target * Flow * Conversion\ Factor \quad \text{(Eq. 5)}$$

Where:

Target= 63 cfu/100 mL

Flow = full permitted flow (MGD)

Conversion Factor (to billion cfu/day) = (1.54723 cfs/MGD *283.1685 100 mL/ft3 * 86,400 s/d) / 1.0E+9

Due to the absence of any permitted dischargers in the North Fork Fish Creek watershed and to remain consistent with the previous TMDLs, the WLA_{WWTF} component is zero.

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 these TMDLs 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 North Fork Fish Creek watershed that is under the jurisdiction of stormwater permits is used to estimate the amount of the overall runoff load that should be allocated as the permitted stormwater contribution in the WLA_{SW} component of the TMDL.

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

$$WLA_{SW} = (TMDL – WLA_{WWTF} – FG – MOS) * FDA_{SWP} \quad \text{(Eq. 6)}$$

Where:

WLA_{SW} = sum of all regulated stormwater loads

TMDL = total maximum daily load

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

As noted previously in section 2.6.1.1, the North Fork Fish Creek watershed is entirely within the collection system area of the TRA Central Regional WWTF. Additionally there are no WWTFs within the North Fork Fish Creek watershed and there are no plans to build a new WWTF within the watershed (TRA, 2019). Due to 100 percent coverage of wastewater collection by the TRA Central Regional WWTF Collection System and the absence of WWTFs in the North Fork Fish Creek watershed, the FG component for impaired segment 0841Q is zero. This approach for FG also remains consistent with the previous TMDLs.

4.7.2 AU-Level TMDL Calculations

The allowable loading of *E. coli* that the impaired AU 0841Q_01 can receive on a daily basis was determined using Equation 1 based on the median value within the high flow regime of the FDC (or 5 percent flow exceedance value) for the SWQM station 17678 (Table 12).

Table 12. Summary of allowable loading calculations for North Fork Fish Creek (AU 0841Q_01).

Water Body	AU	5% Exceedance Flow (cfs)	5% Exceedance Load (cfu/day)	TMDL (billion cfu/day)
North Fork Fish Creek	0841Q_01	8.460	2.608E+10	26.08

Using the values of TMDL for AU 0841Q_01 provided in Table 12, the MOS may be readily computed by proper substitution into Equation 3 (Table 13).

Table 13. MOS calculations for the North Fork Fish Creek watershed.
Load units expressed as billion cfu/day *E. coli*

Water Body	AU	TMDL[a]	MOS
North Fork Fish Creek	0841Q_01	26.08	1.30

[a] TMDL from Table 12.

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 combined area under regulated stormwater permits. As described in Section 2.6.1.3, the North Fork Fish Creek watershed is covered 100 percent by MS4 Phase II permit (City of Grand Prairie) and Phase I permit (City of Arlington). However, even in highly urbanized areas such as the North Fork Fish Creek watershed, there remain small areas of streams within each watershed that are not strictly regulated and which may receive bacteria loadings from unregulated sources such as wildlife. To account for these small unregulated areas, the stream length based on the TCEQ definition of AU 0841Q and a stream width estimated from measurements recorded as part of a recreational use attainability analysis on North Fork Fish Creek (TIAER, 2010) was used to compute an area of unregulated stormwater contribution (Table 14).

Table 14. Basis of unregulated stormwater area and computation of FDA_{SWP}

Water Body	AU	Total Area (acres)	Stream Length (feet)	Estimated Average Stream Width (feet)	Estimated Stream Area (acres)	Fraction Unregulated Area	FDA_{SWP}
North Fork Fish Creek	0841Q_01	3,663	25,328	6.9	4.2	0.001	0.999

The daily allowable loading of *E. coli* assigned to WLA_{SW} was determined based on the combined area under regulated stormwater permits. In order to calculate the WLA_{SW} (Eq. 6), the FG term must be known. Since it is unforeseen that any regulated facilities with a human waste component will occur in the North Fork Fish Creek watershed, the FG term is zero. With the information provided in Tables 12 – 14 and the zero values for the WLA_{WWTF} and FG, the information to calculate the WLA_{SW} term is presented in Table 15.

Table 15. Regulated Stormwater calculations for the North Fork Fish Creek watershed
Load units expressed as billion cfu/day *E. coli*

Water Body	AU	TMDL[a]	WLA_{WWTF}[b]	FG[c]	MOS[d]	FDA_{SWP}[e]	WLA_{SW}[f]
North Fork Fish Creek	0841Q_01	26.08	0	0	1.30	0.999	24.75

[a] TMDL from Table 12

[b] WLA_{WWTF} = 0 cfu/100 mL due to an absence of any WWTFs within the North Fork Fish Creek watershed

[c] FG = 0 cfu/100 mL since the establishment of WWTFs within the North Fork Fish Creek watershed is highly unlikely

[d] MOS from Table 13

[e] FDA_{SWP} from Table 14

[f] $WLA_{SW} = (TMDL – WLA_{WWTF} – FG – MOS) * FDA_{SWP}$ (Eq. 6)

Once the WLA_{SW} and WLA_{WWTF} terms are known, the WLA term can be calculated based on Equation 4, as shown in Table 16.

Table 16. Wasteload allocation calculations for the North Fork Fish Creek watershed

Load units expressed as billion cfu/day *E. coli*

Water Body	AU	WLA_{WWTF}[a]	WLA_{SW}[b]	WLA[c]
North Fork Fish Creek	0841Q_01	0	24.75	24.75

[a] WLA_{WWTF} = 0 cfu/100 mL due to an absence of any WWTFs within the North Fork Fish Creek watershed

[b] WLA_{SW} from Table 15

[c] WLA = (WLA_{WWTF} + WLA_{SW}) (Eq. 4)

The last term in the TMDL requiring computation is LA, which is the allowable bacteria loading assigned to unregulated sources within the North Fork Fish Creek watershed. Within the North Fork Fish Creek watershed, a small area not regulated by stormwater permits was assigned as detailed in Table 14. The LA for the North Fork Fish Creek watershed was calculated based on Equation 7, as shown in Table 17.

Table 17. Unregulated stormwater calculations for the North Fork Fish Creek watershed.

Load units expressed as billion cfu/ day *E. coli*

Water Body	AU	TMDL[a]	WLA_{WWTF}[b]	WLA_{SW}[c]	FG[d]	MOS[e]	LA[f]
North Fork Fish Creek	0841Q_01	26.08	0	24.75	0	1.30	0.03

[a] TMDL from Table 12

[b] WLA_{WWTF} = 0 cfu/100 mL due to an absence of any WWTFs within the North Fork Fish Creek watershed

[c] WLA_{SW} from Table 15

[d] Future Growth = 0 cfu/100 mL since the establishment of WWTFs within the North Fork Fish Creek watershed is highly unlikely

[e] MOS from Table 13

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

4.8 Summary of TMDL Calculations

Table 18 summarizes the TMDL calculations for North Fork Fish Creek AU 0841Q_01. The TMDL was calculated based on the median flow in the 0-10 percentile range (5 percent exceedance, high flow regime) for flow exceedance from the LDC developed for the downstream SWQM station 17678. Allocations are based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDL.

Table 18. TMDL allocation summary for North Fork Fish Creek AU 0841Q_01.

Load units expressed as billion cfu/ day *E. coli*

Water Body	AU	TMDL[a]	WLA_{WWTF}[b]	WLA_{SW}[c]	LA[d]	FG[e]	MOS[f]
North Fork Fish Creek	0841Q_01	26.08	0	24.75	0.03	0	1.30

[a] TMDL = from Table 12

[b] WLA_{WWTF} 0 cfu/100 mL due to an absence of any WWTFs within the North Fork Fish Creek watershed

[c] WLA_{SW} = from Table 15

[d] LA = from Table 17

[e] FG = 0 cfu/100 mL since the establishment of WWTFs within the North Fork Fish Creek watershed is highly unlikely

[f] MOS = from Table 13

The final TMDL allocations (Table 19) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the WLA_{WWTF}, which was zero due to the absence of any permitted discharges and the anticipation of no future permitted discharges with a human waste component.

Table 19. Final TMDL allocations for the North Fork Fish Creek Watershed (AU 0841Q_01)

Load units expressed as billion cfu/ day *E. coli*

Water Body	AU	TMDL	WLA_{WWTF}	WLA_{SW}	LA	MOS
North Fork Fish Creek	0841Q_01	26.08	0	24.75	0.03	1.30

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 19. Figure A-1 and Table A-1 of Appendix A were developed to demonstrate how assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of proposed water quality criteria for *E. coli*. The equations provided, along with Figure A-1 and Table A-1 allow calculation of a new TMDL and pollutant load allocation based on any potential new water quality criterion for *E. coli*.

Section 5
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APPENDIX A
EQUATIONS FOR CALCULATING TMDL ALLOCATIONS FOR CHANGED CONTACT RECREATION STANDARD

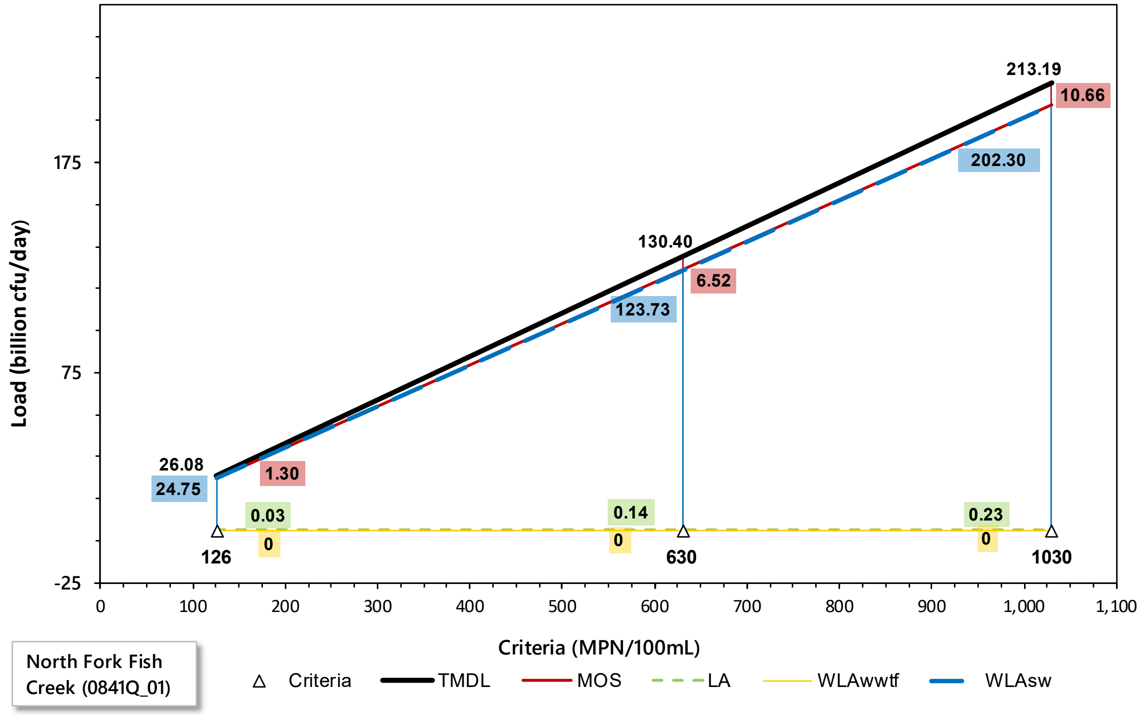

Figure A-1. Allocation loads for the North Fork Fish Creek watershed (0841Q_01) as a function of water quality criteria

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

$TMDL = 0.2069775 * Std$

$MOS = 0.0103488 * Std$

$LA = 0.0002242 * Std$

$WLA_{WWTF} = 0$

$WLA_{SW} = 0.1964046 * Std$

Where:

Std = revised contact recreation standard

MOS = margin of safety

LA = total load allocation (unregulated sources)

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

WLA_{SW} = wasteload allocation (permitted stormwater)

Table A-1 TMDL allocations for the North Fork Fish Creek watershed for potential changed contact recreation standards.

Units expressed as billion cfu/day *E. coli* except contact recreation criterion

Contact Recreation Criterion (cfu/100 mL)	TMDL	WLA_{WWTF}	WLA_{SW}	LA	MOS
126	26.08	0	24.75	0.03	1.30
630	130.40	0	123.73	0.14	6.52
1,030	213.19	0	202.30	0.23	10.66