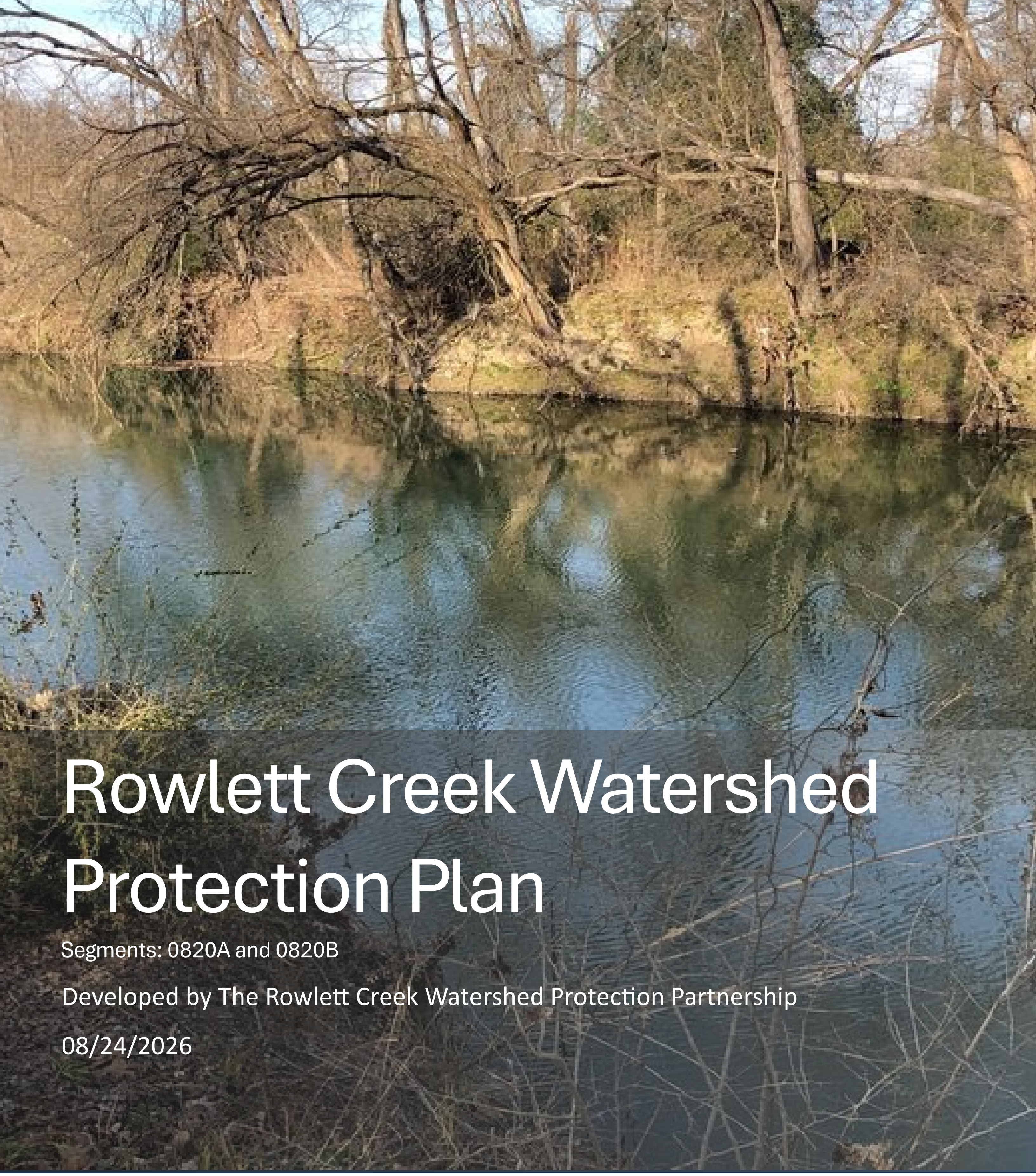

Rowlett Creek Watershed Protection Plan

Segments: 0820A and 0820B

Developed by The Rowlett Creek Watershed Protection Partnership

08/24/2026

Texas A&M AgriLife Extension

EPA United States Environmental Protection Agency

Texas Commission on Environmental Quality

Plano

Rowlett Creek Watershed Protection Plan

A document developed by the Rowlett Creek Watershed Partnership
to restore and protect water quality in Rowlett Creek (0820B)

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Front Cover: Rowlett Creek by Fouad Jaber, AgriLife Extension

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- City of Plano
- City of Murphy
- City of Frisco
- City of Dallas
- City of Garland
- City of Allen
- Collin County
- Dallas County
- North Texas Municipal Water District
- Collin College
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- Collin County AgriLife Extension
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Abbreviations	Meaning
ACCESS	Active Community and Citizen Education for Science and Stewardship
ACS	American Community Survey
AgriLife	Texas A&M AgriLife Research and Extension Service
AU	Assessment Unit
AnU	Animal Unit
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
CCN	Certificate of Convenience and Necessity
CFU	Colony Forming Units
CP	Conservation Plan
CRP	Clean Rivers Project
CSP	Conservation Stewardship Program
DFW	Dallas-Fort Worth Metroplex
DO	Dissolved Oxygen
DORBA	Dallas Off-Road Bicycle Association
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESC	Education Service Center
FDC	Flow Duration Curve
FIF	Flood Infrastructure Fund
g	Gram(s)
GI	Green Infrastructure
GIS	Geographic Information Software
HLHW	Healthy Lawns and Healthy Water
HOA	Homeowners Association
HUC	Hydrologic Unit Code
ISD	Independent School District
LCLU	Land Cover Land Use
LDC	Load Duration Curve
LID	Low Impact Development

Abbreviations	Meaning
m	Meter(s)
MGD	Million Gallons per Day
mi	Mile(s)
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
MRLC	Multi-Resolution Land Characteristics
MS4	Municipal Storm Sewer Systems
NASS	National Agriculture Survey Statistics
NCEI	National Centers for Environmental Information
NCTCOG	North Texas Council of Governments
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
NRI	Texas A&M Natural Resources Institute
NSE	Nash-Sutcliffe Efficiency
NTMWD	North Texas Municipal Water District
OSSF	On-Site Sewage Facility
PRISM	Parameter-elevation Regressions on Independent Slopes Model
PUCT	Public Utility Commission of Texas
RSR	Root Mean Square-Observations Standard Deviation
s	Second(s)
SEP	Supplemental Environmental Projects
SMU	Southern Methodist University
SNN	Spay Neuter Network
SSO	Sanitary Sewer Overflow
SWAT	Soil and Water Analysis Tool
SWCD	Soil and Water Conservation District
SWIFT	State Water Implementation Fund for Texas

Abbreviations	Meaning
SWQMIS	Surface Water Quality Monitoring Information System
TCAP	Texas Coalition for Animal Protection
TCEQ	Texas Commission on Environmental Quality
TEKS	Texas Essential Knowledge and Skills
TFS	Texas A&M Forest Service
TKN	Total Kjeldahl Nitrogen
TNR	Trap Neuter Return
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TRA	Trinity River Authority
TSSWCB	Texas State Soil and Water Conservation Board

Abbreviations	Meaning
TSWQS	Texas Surface Water Quality Standards
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
TxBN	Texan By Nature
TxDOT	Texas Department of Transportation
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility

Chapter 1 Introduction

Watersheds

A watershed is a geographical area defined by natural boundaries, such as ridges or mountains that collect and channel water including rainfall and runoff into a common outlet such as a river, lake, or ocean. All land surfaces on Earth are included in a watershed. Watersheds encapsulate the entire ecosystem of interconnected land and water bodies within their confines.

Types of Pollution

Point source pollution refers to the discharge of pollutants or contaminants from specific, identifiable sources. These sources typically include industrial facilities, wastewater treatment plants, and specific pipes or outlets. Point source pollution can be more easily regulated and monitored because it comes from an easily defined source, making it possible to measure and control the release of pollutants.

Nonpoint source pollution refers to the widespread and diffuse contamination of water bodies often caused by the collection of pollutants as rainfall turns into runoff contacting pollutants in the watershed. Unlike point source pollution, nonpoint source pollution does not have a single easily identifiable source. Instead, it results from a combination of factors such as agricultural runoff and urban areas. Managing and mitigating nonpoint source pollution is more challenging due to its diffuse nature and the need for broadscale, holistic environmental management strategies.

The Watershed Approach

The United States Environmental Protection Agency (EPA) describes the watershed approach as “a flexible framework for managing water resource quality and quantity within a specified drainage area of watershed” (EPA, 2008; EPA & Browner, 1996). In this approach, engagement with watershed stakeholders assists in making management decisions for the protection and enhancement of water quality. Stakeholders are anyone that lives, works, or has an interest in the watershed’s surface water quality. This could be individuals or groups, organizations, or agencies. Stakeholders are involved throughout the entire watershed protection plan development process which is critical for effectively selecting, designing, and implementing management strategies that improve or protect the watershed’s water quality.

Watershed Protection Plans

Watershed protection plans (WPPs) vary in methodology, content, and remediation options due to each watershed’s different characteristics, impairments, and community needs and desires. All watershed protection plans contain the common fundamental elements as defined by the EPA and listed below:

A. Identification of causes and sources of impairments
B. Expected load reductions from management strategies
C. Proposed management measures
D. Identified technical and financial assistance to implement management measures
E. Information, education, and public participation needed to support implementation
F. Schedule for implementation
G. Milestones to track progress
H. Criteria to determine success
I. Water quality monitoring

Detailed information on the EPA’s Elements of Successful Watershed Protection Plans is located in Appendix D (EPA, 2008).

Adaptive Management

Adaptive management is defined as "an intentional approach to making decisions and adjustments in response to new information and changes in context". When using adaptive management in watershed protection plans an iterative plan is developed to reduce pollutants and contaminants in the watershed to acceptable levels. After the plan has been implemented verification is necessary to make sure the plan is working as designed. Verification can take the form of testing, monitoring, evaluating strategies, and revising management approaches as new information and societal needs are determined. If the plan is not working as expected adjustments are made, the new plan is put in place, and the new plan is verified at a future date. This continues until the pollutants and contaminants have dropped to acceptable levels.

Education and Outreach

Without education, outreach, and engagement, the WPP is unlikely to be as successful as it could be. Long-term commitments from stakeholders are essential to accomplishing a comprehensive WPP in the Rowlett Creek watershed. Education and outreach components of the WPP include keeping stakeholders informed of project activities through periodic emails and meetings, and updated websites, providing information about appropriate best management practices to be implemented in the watershed, and identifying and forming partnerships to lead the implementation effort.

Problem Statement

A section of the Rowlett Creek exceeds water quality standards for primary contact recreation since 2014 according to the Texas Commission on Environmental Quality's (TCEQ) Texas Water Quality Inventory and 303(d) List due to elevated bacteria (TCEQ, 2014). The impairment identified in the *2014 Texas Integrated Report* (TCEQ, 2014), also called the 303 (d) List, is *Escherichia coli* (*E. coli*). Additionally, the nitrate nitrogen screening levels are of concern in the downstream portions.

Response

Texas A&M AgriLife Extension performed a watershed characterization assessment for Rowlett Creek in collaboration with the City of Plano and Southern Methodist University (SMU) (Jaber et al., 2023). The process was stakeholder driven and a stakeholder partnership was developed. A steering committee from the stakeholder partnership was also created which reviewed all modeling done in the characterization phase. Load duration curves (LDCs) for *E. coli*, nitrate/nitrite, total phosphorus, total suspended solids, ammonia nitrogen and Total Kjeldahl Nitrogen (TKN) were developed for five subwatersheds. This document presents the full WPP for the Rowlett Creek Watershed developed with stakeholder participation.

Chapter 2 Rowlett Creek Watershed Characterization

Introduction

This chapter provides an overview of the Rowlett Creek watershed. Rowlett Creek was first placed on the Texas 303(d) list in 2014 for bacterial impairment (TCEQ, 2014). Rowlett Creek is also listed as having a concern for nitrate. The water quality problems to be addressed are bacteria impairment and concern for nitrate. The information in this chapter primarily comes from city, state, and federal data resources, as well as local stakeholder knowledge. The information in this chapter is critical to an accurate assessment of potential sources of water quality impairment in the Rowlett Creek watershed, and to accurately recommend best management practices for the watershed.

Watershed Description

Rowlett Creek flows through the Dallas-Fort Worth (DFW) Metroplex cities of Plano, Garland, McKinney, Frisco, Allen, Murphy, and Rowlett, which constitute a highly urbanized watershed (Figure 2-9). The creek also flows to Lake Ray Hubbard, a major water supply reservoir owned by the City of Dallas. The majority of the creek is within the city limits of Plano. The City of Plano is the ninth most populous city in the state of Texas as of the latest United States Census Bureau (USCB) 2024 US Census data (Dearmore, 2025). Land uses in Plano consist of industrial (6%), commercial (23%), residential (66%), and agricultural (7%).

Rowlett Creek (Segment 0820B) and its tributaries make up a significant portion of the East Fork Trinity River drainage and Lake Ray Hubbard watershed. With continuous growth in the region, Rowlett Creek is exposed to water quality and habitat degradation caused by human activity, urban runoff, and erosion.

Spring Creek and its tributaries, Pittman Creek and Prairie Creek, make up a significant portion of the Rowlett Creek basin that drains into the East Fork Trinity River and Lake Ray Hubbard. The City of Plano contains the head waters of the Spring Creek basin, which eventually flows downstream through other Texas cities including Richardson and Garland. The land surfaces making up the Spring Creek watershed in Plano are mostly impervious, including roadways, alleys, buildings, parking lots, driveways, and sidewalks. Due to the lack of pervious surfaces and natural buffers in this drainage, over 90% of the precipitation that falls here flows to the stream, rather than being absorbed by the historical natural prairie habitat. Because of this, Spring Creek is exposed to water quality and habitat degradation caused by human activity, urban runoff, and erosion.

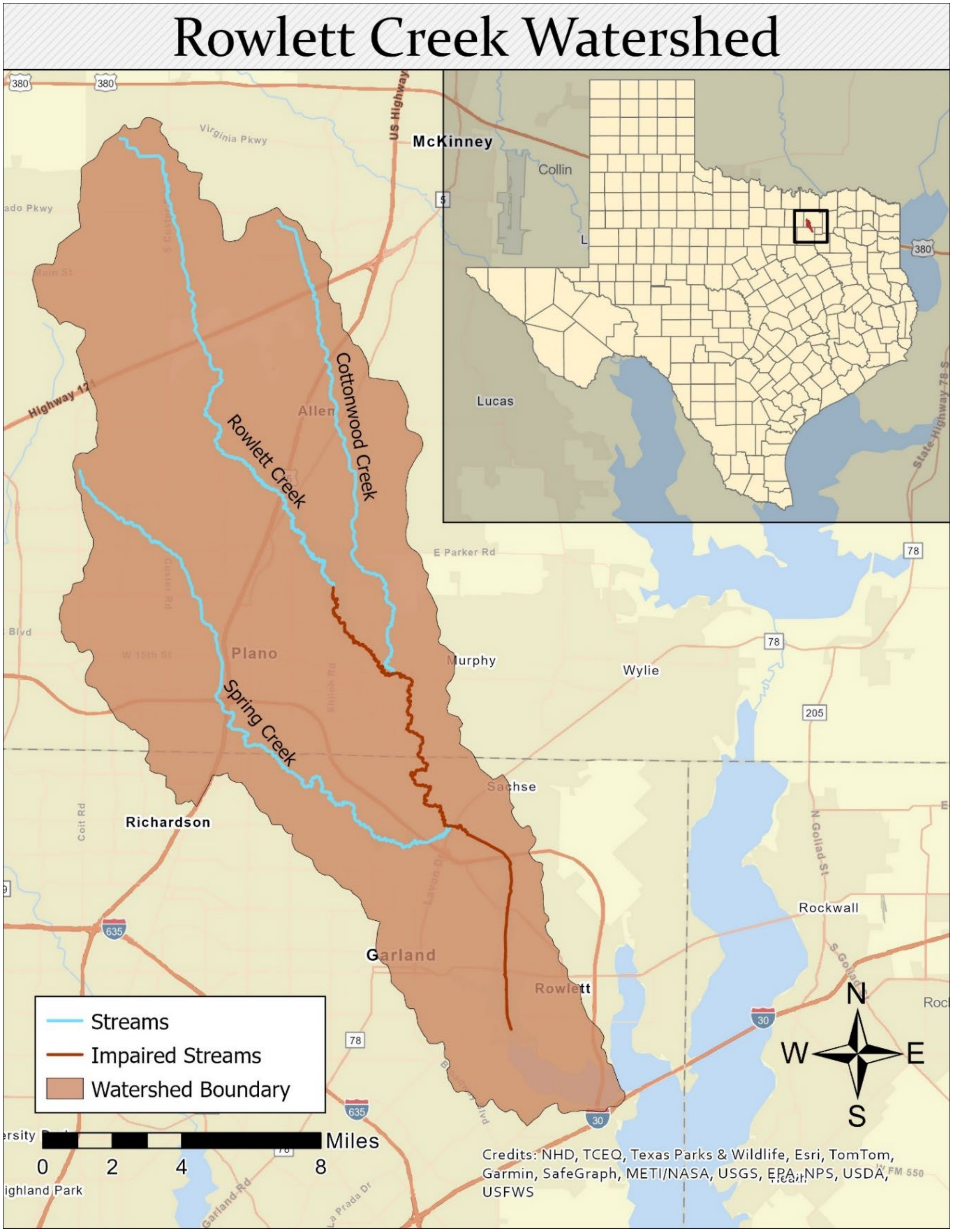

Figure 2-1. Rowlett Creek watershed.

Subwatersheds

The Rowlett Creek watershed, a Hydrologic Unit Code (HUC) 10 watershed, is subdivided into five HUC 12 subwatersheds (USGS, 2024). Data was collected at the outlet of each subwatershed (Figure 2-2; Table 2-1). The subwatersheds consist of the headwaters of Rowlett Creek (Site 1), Cottonwood Creek (Site 2), Brown Branch–Rowlett Creek (Site 3), Pittman Creek–Spring Creek (Site 4), and Rowlett Creek at Lake Hubbard (Site 5).

Table 2-1. HUC 12 watersheds (i.e., subwatersheds) within Rowlett Creek watershed (HUC 10) with IDs and area.

HUC 12	HUC 12 Name	Subwatershed ID (Figure 2)	Area (mi^2)
120301060404	Headwaters Rowlett Creek	1	38.6
120301060405	Town of Allen-Cottonwood Creek	2	19.3
120301060406	Brown Branch Rowlett Creek	3	25.5
120301060407	Pittman Creek-Spring Creek	4	36.7
120301060408	Rowlett Creek-Lake Ray Hubbard	5	27

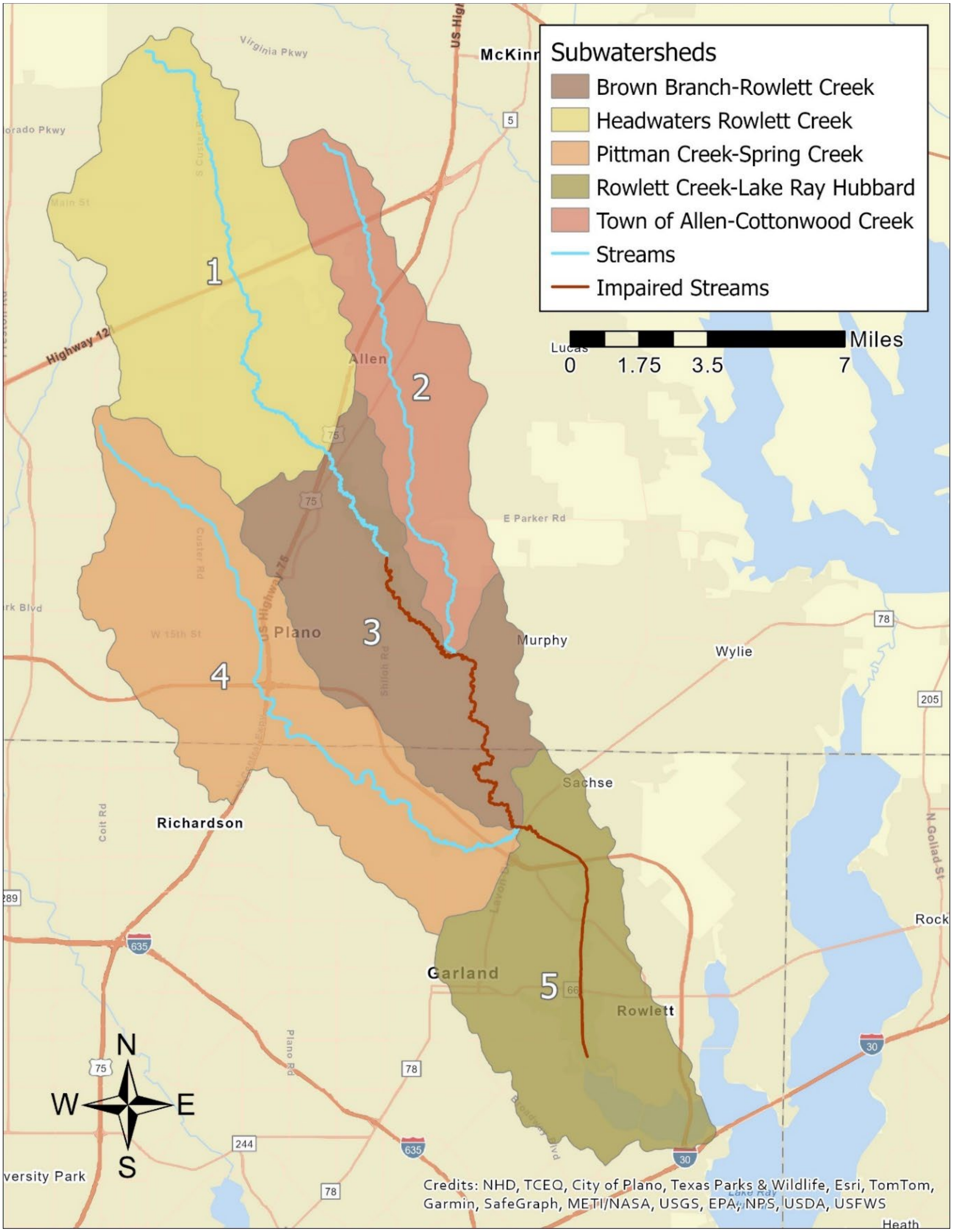

Figure 2-2. Rowlett Creek subwatersheds.

Ecoregions

Ecoregions are defined as land areas where ecosystems are generally similar in type, quality, and quantity of environmental and natural resources that include hydrology, geology, soils, climate, and vegetation (Omernik &

Griffith, 2014). This spatial framework was originally derived from Omernik (1987) in collaboration with the EPA, other Federal agencies, state resource management agencies, and neighboring North American countries. There are four levels of ecoregion classification which refine from the level prior, starting at Level I with 12 ecoregions to Level IV with 967 ecoregions. The land within the Rowlett Creek watershed is characterized only by one ecoregion, Ecoregion 32 Texas Blackland Prairies at Level III. The Texas Blackland Prairie is characterized by its fine-textured, clayey soils and the dominant prairie grass natural vegetation (Griffith et al., 2004). This region contains Vertisol, Alfisol, and Molisol soils. Looking at the further refined scale of Level IV Ecoregion, this watershed is in Ecoregion 32a Northern Blackland Prairie. This ecoregion is characterized by fine-textured, dark, clayey Vertisols and dominant natural vegetation of prairie grasses.

Land Use and Land Cover

Watershed land cover and land use (LCLU) data was obtained from the 2021 National Land Cover Database (NLCD) by the United States Geological Survey (USGS) in cooperation with the Multi-Resolution Land Characteristics Consortium (USGS, 2023b). Over 75% of Rowlett Creek watershed is developed land, with 19.0% being low density, 42.2% medium density, and 14.4% high density developed land. 8.3% is developed open land (Figure 2-3;

Table 2-2. Rowlett Creek watershed land cover and land use.
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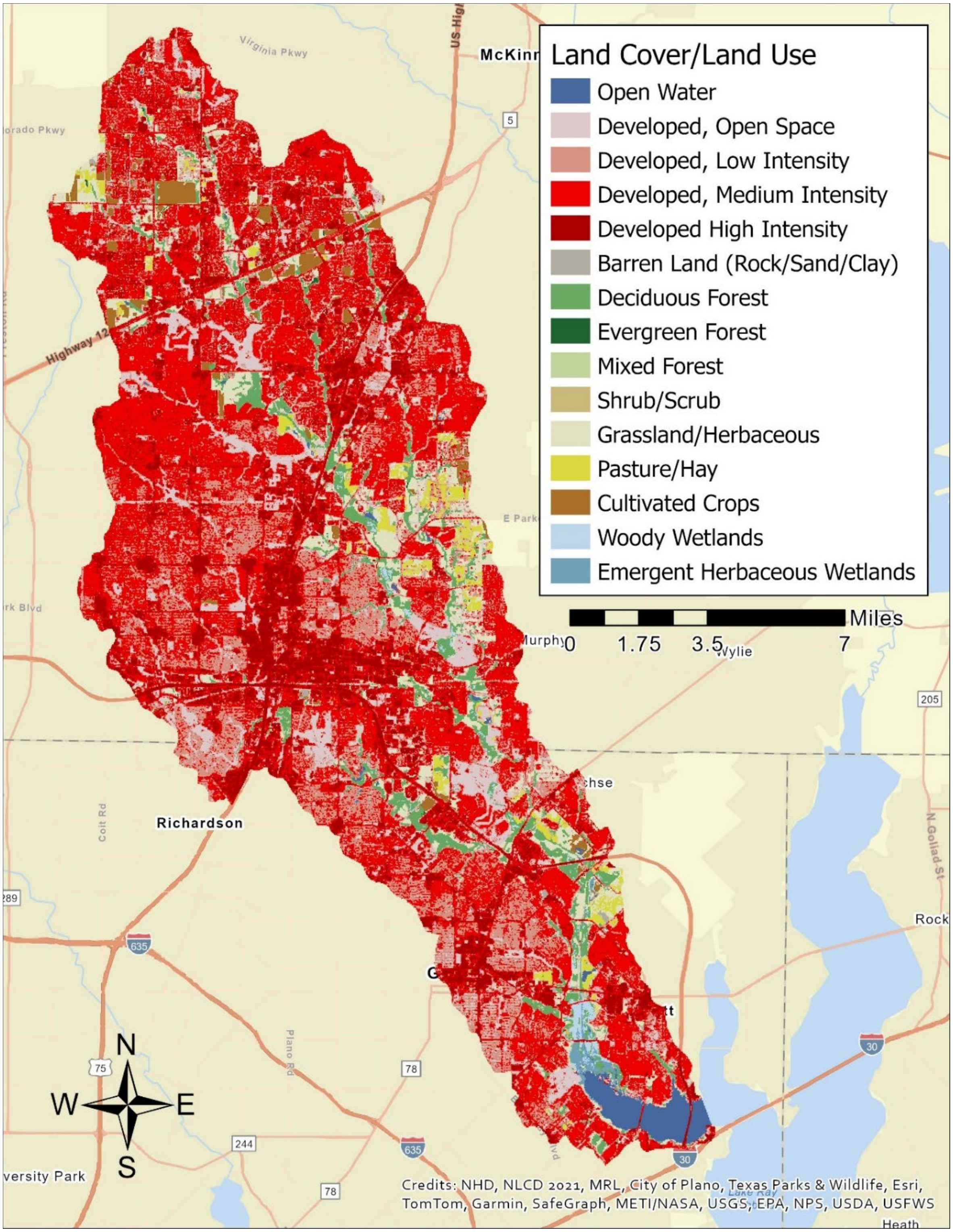

Figure 2-3. Land cover and land use in the Rowlett Creek watershed.

Table 2-2. Rowlett Creek watershed land cover and land use.

Name	Area (mi^2)	Percent Cover
Open Water	2.18	1.49
Developed, Open Space	12.15	8.27
Developed, Low Intensity	27.95	19.02
Developed, Medium Intensity	62.15	42.29
Developed, High Intensity	21.14	14.38
Barren Land (Rock/Sand/Clay)	0.28	0.19
Deciduous Forest	6.25	4.25
Evergreen Forest	0.05	0.04
Mixed Forest	0.10	0.07
Shrub/Scrub	0.30	0.20
Grassland/Herbaceous	8.13	5.54
Pasture/Hay	2.58	1.75
Cultivated Crops	2.58	1.75
Woody Wetlands	0.63	0.43
Emergent Herbaceous Wetlands	0.48	0.33
Overall	**146.95**	**100.0**

Soils and Topography

The hydrology of a watershed has many components, including soil properties and topography, specifically slope and elevation. Slope and elevation determine direction of water flow, while soil properties and elevation determine water speed and quantity that infiltrates, flows over, and moves through soil in the watershed.

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) provides information about soils collected by the National Cooperative Soil Survey, available through the Soil Survey Geographic (SSURGO) Database (Soil Survey Staff, 2022). The SSURGO database provides hydrologic ratings for soils, which are groups of soils with similar runoff properties. These ratings are useful for considering the potential for runoff from properties under consistent rainfall conditions. Within Rowlett Creek watershed, the majority of soils are hydrologic type “D” (Figure 2-4), which have a very slow infiltration rate and a very slow rate of water transmission (Table 2-3). Soil textures are dominated by clay (Figure 2-5).

According to USGS (2023a), the elevation of the watershed ranges from 132 to 245 feet above maximum sea level (MSL). The average slope of the watershed is 3.1% (Figure 2-6).

Table 2-3. Hydrologic soil groups as described by the USDA NRCS.

Hydrologic Soil Group	Description
A	Soils have a high infiltration rate when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmissions.
B	Soils have a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have a moderately fine texture to moderately coarse

	texture. These soils have a moderate rate of water transmission.
C	Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
D	Soils having a very slow infiltration rate when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a clay layer at or near the surface, and soils that are shallow over a nearly impervious material. These soils have a very slow rate of water transmission.

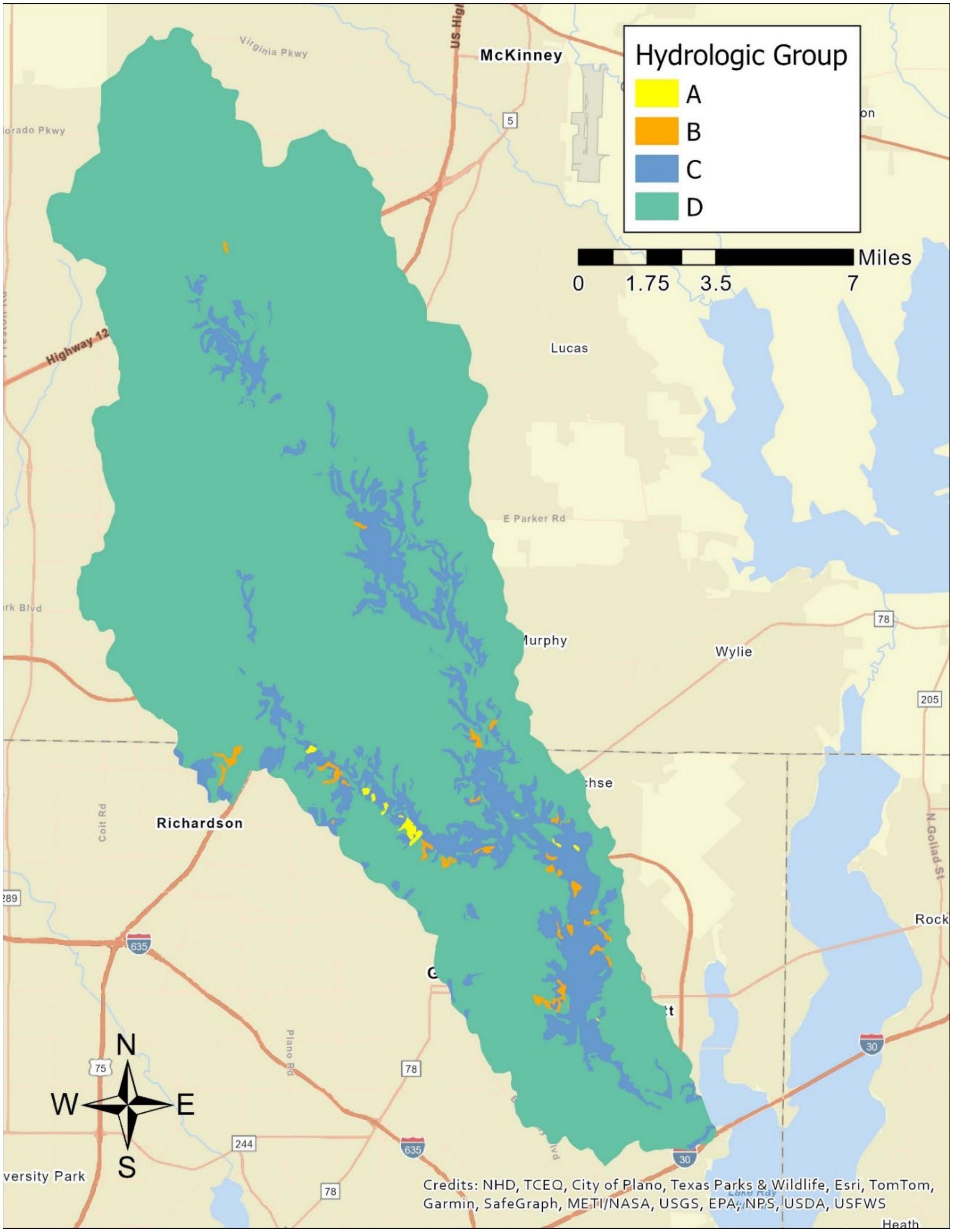

Figure 2-4. Map of the hydrologic soil groups in the Rowlett Creek watershed.

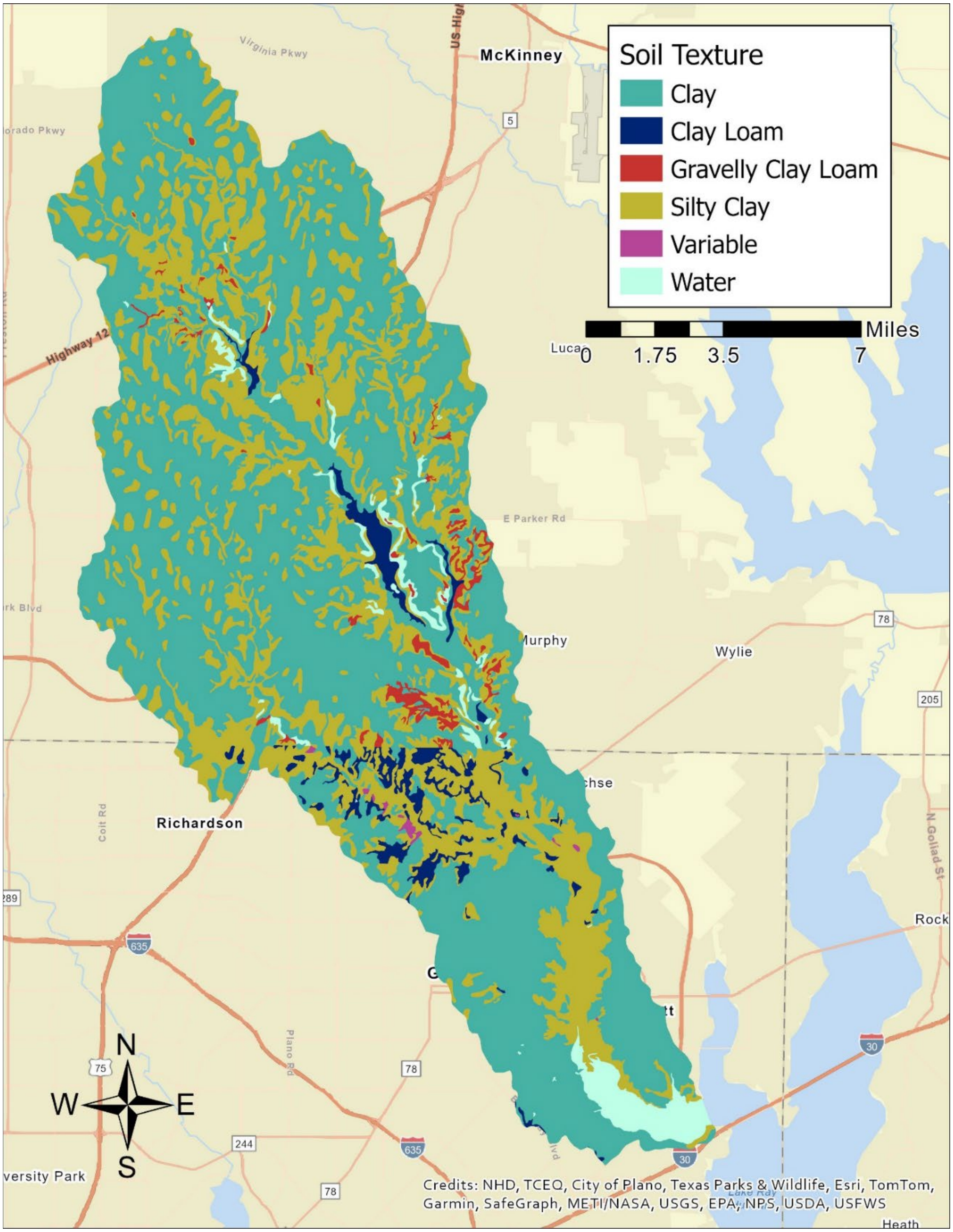
Soil Texture
Clay
Clay Loam
Gravelly Clay Loam
Silty Clay
Variable
Water
Miles
0
1.75
3.5
7
McKinney
Murphy
Wylie
Richardson
N
S
W
E
Credits: NHD, TCEQ, City of Plano, Texas Parks & Wildlife, Esri, TomTom, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA, USFWS

Figure 2-5. Map of the soil texture types in the Rowlett Creek watershed.

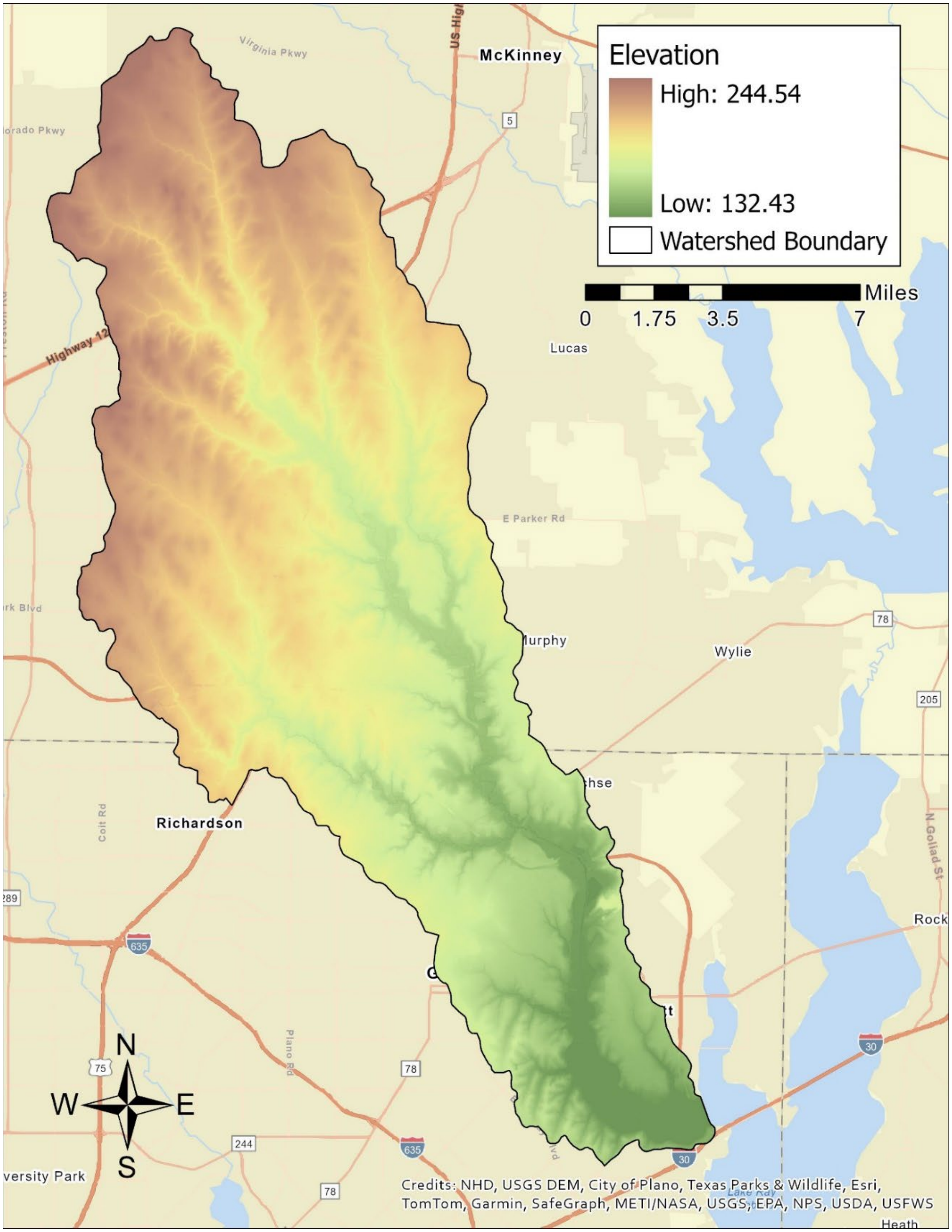

Figure 2-6. Elevation map of the Rowlett Creek watershed.

Climate

The Rowlett Creek watershed falls in the approximate boundaries of subtropical subhumid and subtropical humid climates as classified by Larkin & Bomar (1983), meaning it can share characteristics of both climate types. This classification system was based on the Köppen Climate Classification System and the long-term weather trends for Texas from 1951-1980. Subtropical subhumid climate is characterized by hot summers and dry winters, and subtropical humid by warm summers. According to the revised Köppen-Geiger Climate Subdivisions used internationally, including by the National Oceanic and Atmospheric Administration (NOAA), the regional climate is described as humid subtropical characterized by mild winters and hot summers with no dry season (Kottek et al., 2006). Therefore, we will consider this area as humid subtropical.

The 30-year climate normals of monthly precipitation and temperature data seen in Figure 2-7 were extracted from the Richardson, TX NOAA weather station, USC00417588, located within the watershed area from 1991 to 2020, generated using data from NOAA National Centers for Environmental Information (NOAA NCEI, 2021). The highest temperatures are during the summer months, August showing the normal hottest temperatures at 95.1 °F and the lowest at 73.8 °F. Winter months normal temperatures indicate a mild winter with minimum temperatures of 33.9 °F in January. The normal annual sum of precipitation is 41.61 inches with two rainy seasons in spring and fall months. May is the wettest month with a normal precipitation of 5.49 inches, while summer is the driest season with August normally receiving 2.18 inches. Additionally, looking at Figure 2-8 with data from the PRISM (Parameter-elevation Regressions on Independent Slopes Model) Climate Group at Oregon State University (PRISM Climate Group, 2022), the precipitation 30-year (1991 – 2020) normal for annual total precipitation indicates 40.1 to 40.9 inches across the Rowlett Creek watershed.

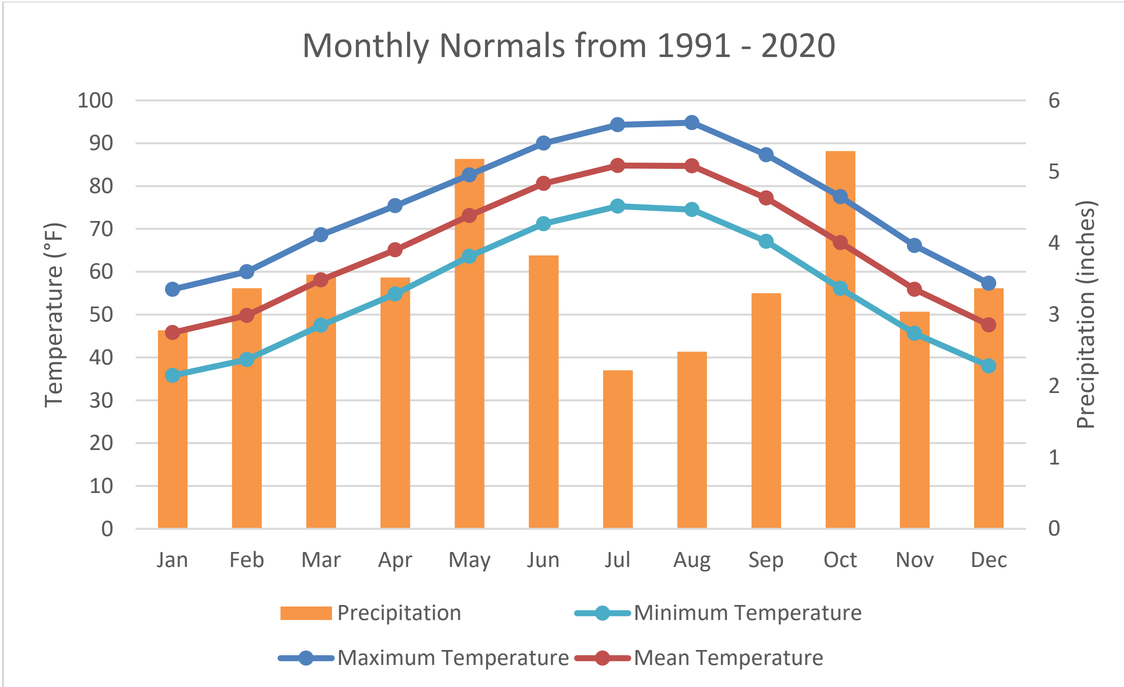

Figure 2-7. Chart of the monthly 30-year normal for the Richardson Weather Station located within Rowlett Creek watershed.

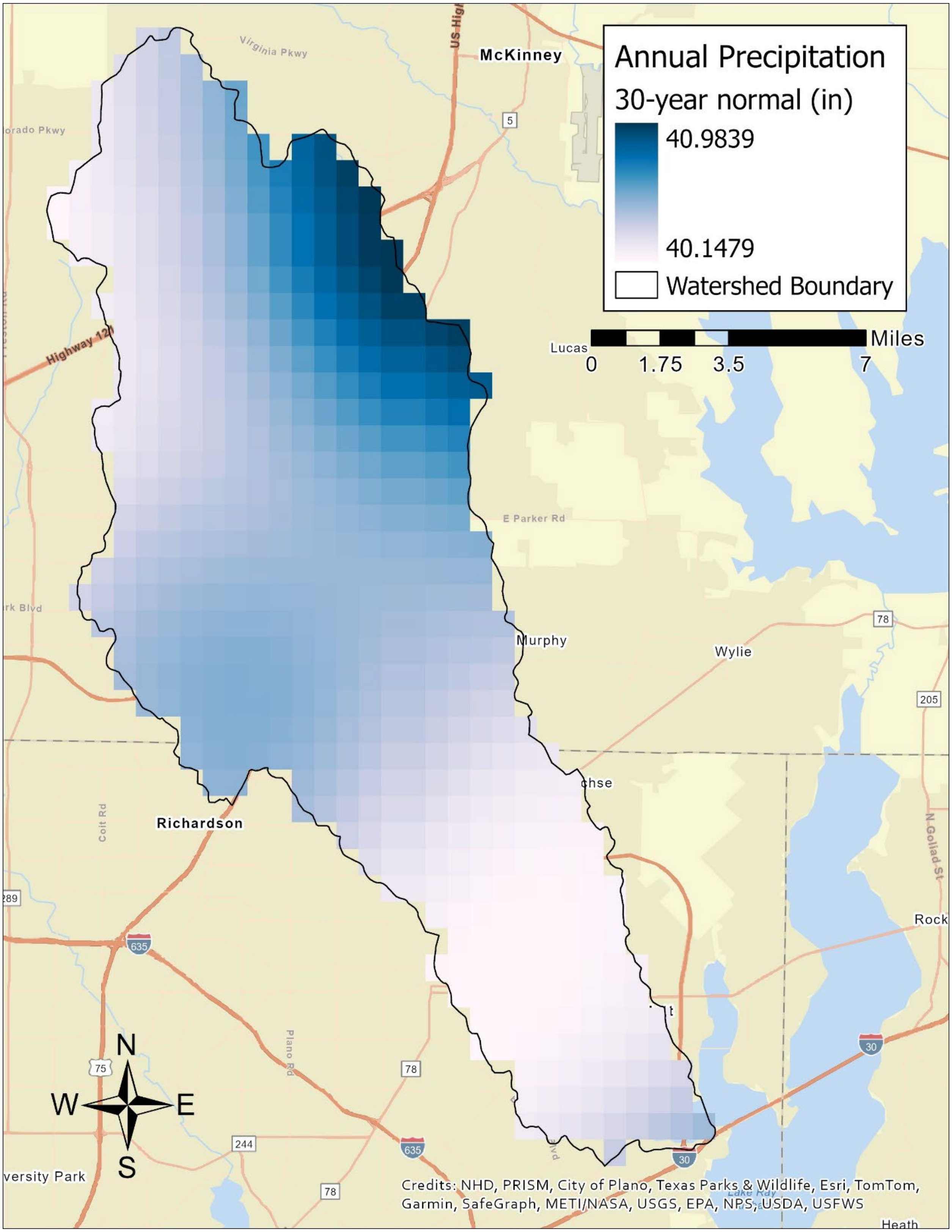

Figure 2-8. 30-year Normal Annual Precipitation from 1991-2020 in Rowlett Creek watershed.

Demographics

According to the 2022 American Communities Survey (ACS), about 795,063 people live in the watershed in a total of 274,990 households (USCB, 2022). This watershed is in a highly urbanized area with population densities ranging from 843 to 13,119 persons per square mile (Figure 2-9). According to population projection statistics produced by the Office of the State Demographer and the Texas Water Development Board (TWDB), from 2020 to 2070, rapid development and population increases (**Error! Reference source not found.**) will continue for the county areas within the watershed (TWDB et al., 2020). Though much of that growth is expected to be outside of this watershed area in neighboring ones, the overall increase in demand will surpass existing supplies to put increasing pressures on the same water resources. For example, according to the TWDB 2022 State Water Plan, which synthesizes the 2021 Regional Water Plans, the City of Plano is projected to see its 2020 population of 286,600 to increase to 300,000 by 2070, or a 4.7% increase. Dallas County from 2020 to 2070 is estimated to increase by nearly 46% with an estimated population of over 3.7 million by 2070 (TWDB et al., 2020). Less than 10% of the population lives under the poverty level and a majority (>90%) have at least a high school degree. Renters constitute around 35% of the watersheds and around 37% do not consider English their primary language. The demographics are shown in Table 2-5 per subwatershed (USCB, 2022).

Table 2-4. Population projections from 2020 to 2070 by 10-year increments of the surrounding counties of the Rowlett Creek watershed (TWDB et al., 2020).

2021 Regional Water Plan
County Population Projections for 2020-2070

County	Population by Year						Percent Increase (2020-2070)
	2020	2030	2040	2050	2060	2070	
Collin County Total	1,050,506	1,239,303	1,497,921	1,807,279	2,093,720	2,373,092	125.9%
Dallas County Total	2,587,960	2,871,662	3,180,529	3,429,783	3,627,334	3,770,858	45.7%

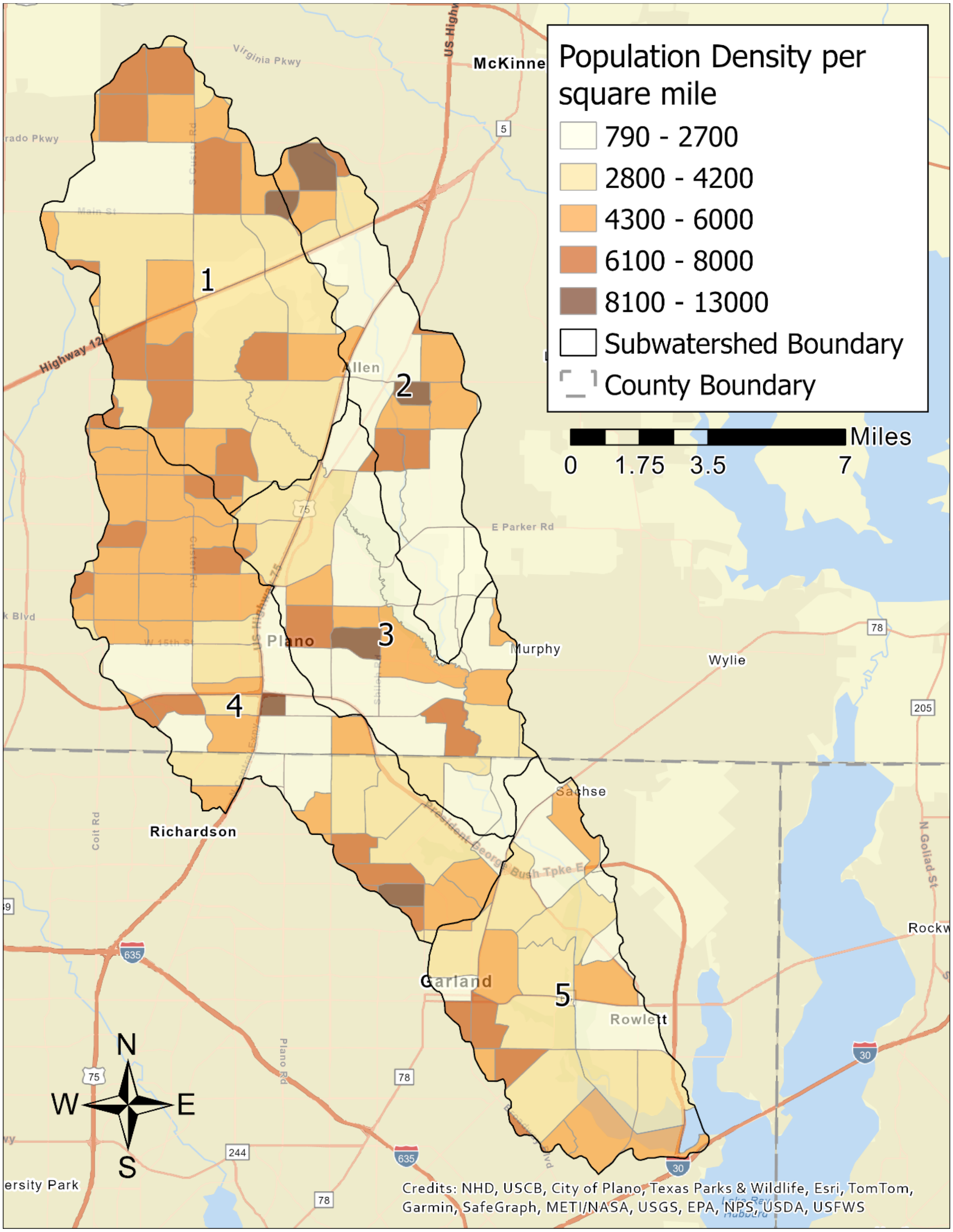

Figure 2-9. Population density from 2022 ACS data U.S. Census tracts within the Rowlett Creek watershed.

Table 2-5. Population demographics of the subwatersheds of the Rowlett Creek watershed (USCB, 2022).

ID	Subwatershed (HUC 12) Name	Number of Households	Poverty Level (%)	Renters (%)	Less Than High School (%)	Non-English Primary (%)
1	Headwaters Rowlett Creek	76,432	4.35	33.11	3.62	36.77
2	Town of Allen-Cottonwood Creek	33,998	5.99	25.10	4.10	24.91
3	Brown Branch-Rowlett Creek	32,590	9.12	40.24	10.90	42.91
4	Pittman Creek-Spring Creek	83,798	7.74	40.95	6.95	30.88
5	Rowlett Creek-Lake Ray Hubbard	48,172	10.06	33.26	18.12	48.45

Surface Water

The TWDB states that Region C, the region in which this watershed and DFW is found, relies almost entirely on surface water (TWDB, 2022; TWDB et al., 2020). The residents of this watershed and the surrounding metroplex receive municipal water services, which use only surface water supply (NTMWD, 2024; TWDB et al., 2020). North Texas Municipal Water District (NTMWD) is the single water supplier to residents within the watershed (NTMWD, 2024). NTMWD's primary water supply is from five reservoirs: Lavon Lake, Bois d'Arc Lake, Lake Texoma, Jim Chapman Lake, and Lake Tawakoni and an additional source is from the East Fork Wetlands Water Reuse Project. The reservoir Rowlett Creek feeds, Lake Ray Hubbard, is owned and operated by the City of Dallas and serves residents surrounding, but only outside the watershed. Water demand will continually increase over time for the region due to population growth, and the supply to meet the demand will come from expanding surface water reservoirs and water reuse.

Other Water Sources

Groundwater

There is only one major aquifer that is found in the boundaries of the watershed, the Trinity Aquifer (TWDB, 2007). The Trinity Aquifer covers the entirety of the watershed. The Trinity Aquifer is a large aquifer that extends across the central region of Texas into the northeast and into the southern portion of Oklahoma. The aquifer's freshwater saturated thickness averages about 600 feet in North Texas (George et al., 2011). The northern portion where the Rowlett Creek watershed is located is at the subsurface, the part of an aquifer that lies below other formations. According to the 2021 Regional Water Plan Summary for Region C, the water planning area that covers the county domains of the watershed, municipalities used about 75,000 acre-feet of water per year in 2020, of which 4,908 acre-feet were used in Collin County (TWDB et al., 2020). However, these water supply needs for groundwater use are not predicted to increase by 2070. Although groundwater is the most utilized water source in Texas, according to TWDB (2024) Groundwater Data Viewer, most wells in the Rowlett Creek watershed have been plugged back and surface water is the main water supply source.

Chapter 3 Water Quality

Introduction

Water quality in Texas is routinely assessed and monitored under programs administered by TCEQ in accordance with the federal Clean Water Act (CWA), 1972. Water quality standards are defined in the Texas Surface Water Quality Standards (TSWQS) and state that water quality conditions must be met to support and protect their designated uses and water quality criteria in accordance with EPA associated rules and the CWA, sections 305(b) and 303(d), Texas Surface Water Quality Standards §§307.2 - 307.10. (2022). Texas surface water quality is evaluated every two years, and the surface water segments are broken into smaller segments called assessment units (AUs).

Under Section 303(d) of the CWA, administered by EPA (40 CFR Section 130.7), states are required to identify the list of waters that do not meet water quality standards for their reported uses (often called the 303(d) List). Uses are broadly described as aquatic life use, recreation, domestic water supply, and oyster waters. Rowlett Creek (AU 0820B_01) was first listed for not meeting the contact recreation use on TCEQ's 2014 Texas Water Quality Inventory and 303(d) List due to elevated bacteria. All activities, both human and natural, that occur within a watershed's boundaries can influence water quality. As a result, an effective management strategy must examine all human activities and natural processes that can contribute pollutants within that watershed.

Data Acquisition

Long-term continuous water quality data was acquired through TCEQ's Surface Water Quality Monitoring Information System (SWQMIS) during the Rowlett Creek watershed characterization (TCEQ, 2024). An analysis of historical and collected water quality data at five locations (Figure 3-1) in Rowlett Creek was performed. The watershed was divided into five subwatersheds (also called subbasins) to better understand the sources and the causes of water quality impairments. Continuous long-term flow data was only available at the USGS station at Site 5. Accordingly, a Soil and Water Assessment Tool (SWAT) model was calibrated and validated at Site 5 and a flow time series for Sites 1 to 4 were generated (Gassman et al., 2007). Data for *E. coli*, nitrate/nitrite, ammonia, TKN, total phosphorus, and total suspended solids were obtained from historical data collected by the cities and some samples collected during this project. Details of these historical measures are included in the Rowlett Creek watershed characterization attached in the appendices of this watershed protection plan. These parameters were used to develop load duration curves for each of the five subwatersheds. Load duration curves are used to compare water quality data against TSWQS and Nutrient Screening Levels defined by TCEQ, which are outlined in the following subsections.

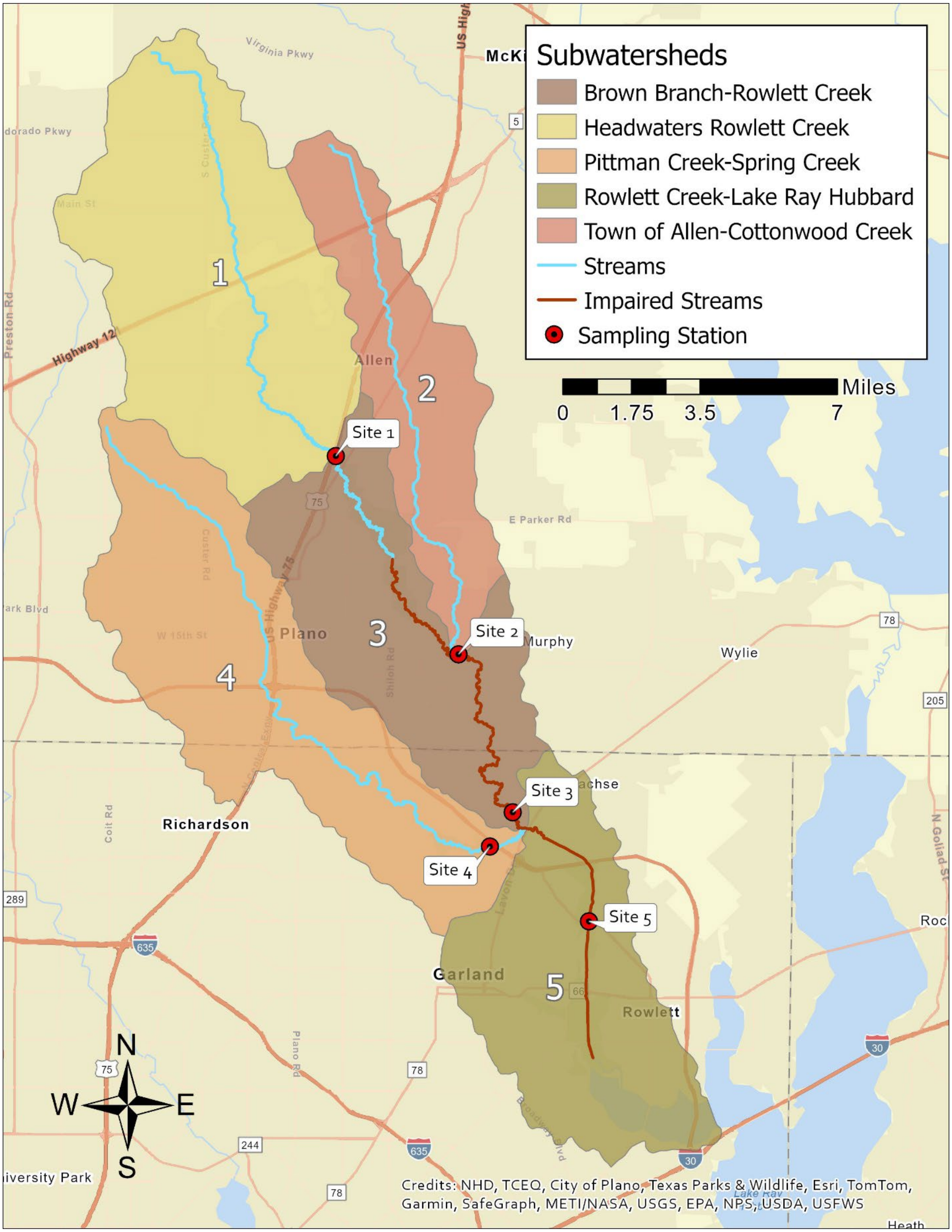

Figure 3-1. Surface water sampling stations in Rowlett Creek watershed.

Bacteria

E. coli bacteria are commonly found in the lower intestine of warm-blooded organisms. *E. coli* is considered an indicator organism, used to identify fecal contamination in freshwater and indicate the possible presence of disease-causing bacteria and viruses (pathogens) that lead to human illness. The higher the concentration of *E.*

coli, the greater the possibility that there will be other bacteria or viruses that can be ingested while swimming, wading, or boating in waterbodies. Additionally, the presence of pathogens in a waterway may cause decreased levels of dissolved oxygen (DO) and degrade aquatic habitats. Since *E. coli* is found in warm-blooded animals, contributions can be attributed to related sources in the watershed. Any waste that is excreted onto the ground, can be picked up by stormwater runoff and be either channeled into surface water or ground water.

Contributing sources may include wildlife, livestock, pets, urban and agriculture runoff, malfunctioning on-site sewage facilities (OSSFs), discharge from wastewater treatment facilities (WWTFs) and sewer pipe leaks and overflows. Additionally, some natural fertilizers can contain these fecal pathogens and be carried by stormwater runoff from both urban and agricultural lands. The Rowlett Creek watershed is an intensely developed urban landscape. Therefore, a large portion of the significant contributing sources of bacteria can be linked to human activity for this watershed and not from wildlife sources. TCEQ has designated the presumed use for Rowlett Creek to be primary contact recreation. This standard for primary contact recreation is a geometric mean of *E. coli* 126 CFU/100 ml (colony forming units per 100 milliliters), which is equivalent to 126 MPN/100 ml (most probable number) and was used in this project.

Nutrients

Nitrogen and phosphorus are essential nutrients for aquatic plants and algae but can also cause detrimental effects in aquatic ecosystems if found in overabundance. The excess nutrients can result in algae blooms, indicated from measurements of chlorophyll *a* (the green pigment in plants and algae) concentrations as an index of phytoplankton biomass. Significant increases in algae harm habitat and food resources necessary for other aquatic life and deplete the water of DO, creating what are called hypoxic zones. This effect can kill fish and destroy their habitat, impairing the recovery of the freshwater ecosystem without intervention. Stormwater runoff carries residential and agricultural fertilizers that contain nutrients. Runoff can also carry animal waste and pollutants from sanitary sewer overflows and sewage outfalls that also contribute to nutrient overloading in waterways.

The water quality parameter of total nitrogen is composed of nitrate, nitrite and TKN. Nitrate is very abundant as an inorganic, oxidized form of nitrogen and nitrite is a less common, inorganic, oxidized form of nitrogen. TKN contains organic nitrogen and ammonia, the inorganic form of nitrogen. TP is a parameter used to analyze a water sample for all forms of phosphorus. Forms of phosphorus include organic and inorganic forms as well as dissolved and particulate forms. Though individual water quality standards for many of these nutrient parameters are not currently established by the TCEQ, the impacts of these nutrients are recognized. TCEQ has established screening levels for most nutrient parameters and also has specified nutrient criteria for certain reservoirs such as the concentration of chlorophyll *a* (Appendix F of the TSWQS) (TCEQ, 2022). Chlorophyll *a* is monitored such that excessive aquatic vegetation growth does not impede designated uses of the water body or impart an unpleasant taste to drinking water.

Dissolved Oxygen

Dissolved Oxygen is a physiological requirement of aquatic communities. DO refers to the amount of oxygen gas mixed in water. Oxygen enters water directly by absorption from the atmosphere, called diffusion, and is released from aquatic plants through photosynthesis. Aquatic environments depend on available DO in the water to support the life of plants, algae, fish, and aquatic invertebrates. DO levels do naturally fluctuate in an ecosystem and are influenced by both temperature and nutrient concentrations. Moreover, seasonal changes can impact the levels of DO because the change in water temperature also influences the amount of DO in the water; warm water holds less DO than cold water. Especially in climates such as Texas where the summers are hot, it is expected to see lower DO in the water during the summer. Increasing air temperatures in the summer months that can extend beyond historical summer trends are expected to further limit the DO available seasonally.

The amount of DO in the water column is also impacted by decomposition processes and primary productivity. Though aquatic plants contribute oxygen to the water body, overabundant plant growth stimulated by excess nutrient runoff will reduce DO. When plant growth is excessive it utilizes much of the oxygen for respiration and its later decomposition. Decomposition of organic waste (e.g., dead plants and algae, lawn clippings, animal waste, and sewage) contribute to low DO levels because the process of decomposition consumes DO. Additionally, embedded sediments can prevent DO from freely passing through the sediment layers of the water body floor where some aquatic organisms survive. As DO levels decline, aquatic species requiring greater DO concentrations die first, including larger game fish such as bluegill, bass, and trout, and eventually the habitat itself and the health of all the organisms within degrades. Given the importance of DO, it is the main water quality parameter to determine a waterbody's habitat suitability. DO concentrations below the criterion of 4.0 mg/L (milligrams per liter) are deemed inadequate to support a functioning habitat.

Other Parameters

Other water quality parameters can be measured to give a more detailed picture of a waterbody's ability to support aquatic life and general waterbody uses. These parameters may include but not limited to: water temperature, specific conductance, pH, and total suspended solids.

The temperature of water is directly associated with aquatic organisms' physiological processes. As described in an earlier section, DO decreases in the water column as the temperature increases. This results in an increased oxygen demand by the aquatic community and subsequent stress on higher-level organisms. Furthermore, rapid variations in water temperature are detrimental to aquatic species since their ability to flee is limited.

Specific conductance is best described as the effectiveness of a liquid conducting electricity and a standard temperature of 25°C. Conductivity increases in a waterbody when ionic dissolved solids levels increase. Nutrients and salts make up ionic dissolved solids. Reduced water quality occurs when ionic dissolved solids, specifically nutrients, increase and DO subsequently decreases.

Water pH is the potential hydrogen of the water and is also referred to as acidity and basicity. A healthy aquatic waterbody falls within a pH range of 6.5 to 9.0 and is considered neutral if the pH is 7.0. Values less than 7.0 would classify the body as acidic whereas values greater than 7.0 would classify the waterbody as alkaline.

Total suspended solids are suspended particles in a water column that, when sampled, are not capable of passing through a specific pore sized filter. Solids are made up of organic matter, such as algae and micro-organisms, as well as inorganic matter, including soil sediments from erosion. TSS can transport pollutants and nutrients during stormwater runoff events and those particles can be resuspended in the stream as well.

Flow

Streamflow is the amount and rate of water, in cubic meters per second (m^3/s), carried by streams and rivers. Streamflow, much like other water quality parameters, is best compared to individual historical records. Changes in flow can affect water supplies, water quality, aquatic habitat, health of aquatic life, and riparian plants. Flows do fluctuate naturally with precipitation events that come from seasonal changes. However, they can also be impacted by human activity, such as changes in land cover. Conversion of natural landscapes to urban concrete infrastructure can increase runoff that in turn increases streamflow. These impacts can be exacerbated from the recent increase in precipitation trends. Streams are interconnected and do have impacts on water quality and quantity downstream. From a water quality perspective, streamflow influences pollutant concentrations and how they travel downstream or accumulate at certain locations.

The Rowlett Creek watershed was divided into five subwatersheds to better understand the sources and the causes of water quality impairments. Continuous long-term flow data was only available at the USGS station at Site 5. The SWAT model was calibrated and validated, and a flow time series was generated for the Sites 1 to 4.

The final results of the calibration of the Rowlett Creek watershed at the USGS station location are shown in Figure 3-2. The results show good match with the observed data. The goodness-of-fit measures results are shown in Table 3-1. These results allow us to use the SWAT model to extract flow time series for the outlets of the five subwatersheds studied.

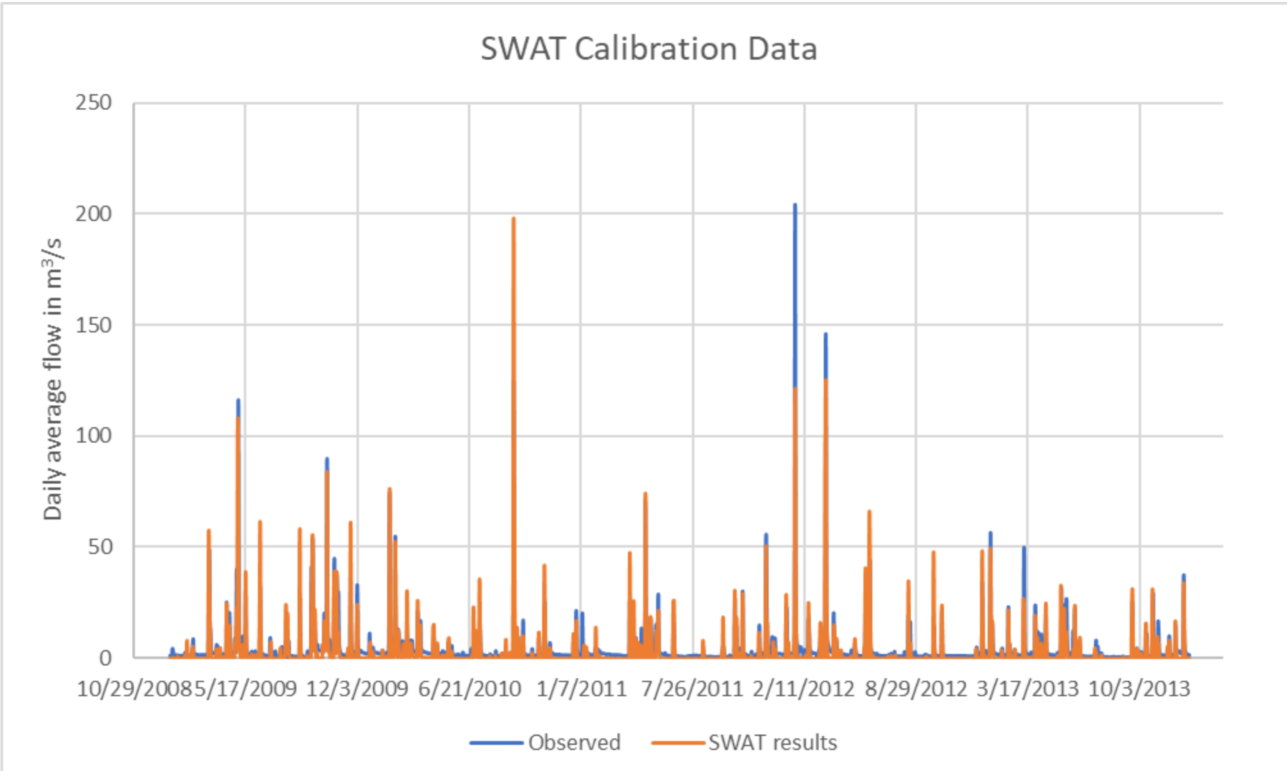

Figure 3-2. SWAT Model results compared with observed data at the Rowlett Creek USGS Station.

Table 3-1. Goodness-of-fit results measured based on Moriasi et al. (2007) for final calibration of the SWAT model determined and further detailed in the Rowlett Creek Modeling Report found at https://agrilife.org/lid/rowlett-creek-watershed-protection-plan/

Statistic	Value	Performance Rating
Root Mean Square-Observations Standard Deviation (RSR)[1]	0.60	good
Nash-Sutcliffe Efficiency (NSE)[2]	0.65	good
Percent Bias (PBIAS)[3] %	15.97	satisfactory

[1]RSR - Standardizes the root mean square error using the observation standard deviation. The optimal value of RSR is 0.0 which represents perfect model simulation. Lower RSR values present better model performance.

[2]NSE- Nash-Sutcliffe Efficiency statistic evaluates the relative difference between the magnitude of residual data variance ("noise") and the measured data variance (“information”). NSE of 1 indicates one-to-one match between the observed and simulated values.

[3]PBIAS – Percent bias determines if the simulated values are on average larger or smaller than the corresponding observed values. Varies from 0% to infinity, with 0 being the optimal. Positive PBIAS means the model under-estimates observed data.

Potential Nonpoint Sources of Pollutants

Nonpoint source (NPS) pollution results when rainwater drains from land as runoff and carries with it the existing pollutants on the land and in the soil into drainage systems, streams, rivers, wetlands, and lakes. NPS pollution comes from many diffuse sources from the landscape and is the most common source of surface water pollution in urban watersheds. Potential sources contributing bacteria in the Rowlett Creek watershed were identified through a variety of avenues including stakeholder input, local experience in the watershed from project partners and conducting watershed reconnaissance surveys. The potential sources described in this subsection are not a comprehensive list, but rather the ones relevant to the watershed and identified by the stakeholders.

Domestic Pets

Dogs and cats can contribute significant quantities of *E. coli* to a watershed if their waste is not properly disposed of and allowed to remain on the ground, this is especially true for urban watersheds due to the high density of these pets. Picking up after dogs effectively removes this source from a watershed. However, a considerable amount of pet waste, especially from dogs, is left in parks, yards, or near homesteads in rural areas and can enter waterways during runoff events. Because dogs and cats are most often associated with people, the highest potential *E. coli* loading areas are near population centers in the watersheds. A national survey conducted by the American Veterinary Medical Association (AVMA) 2024 report suggests there are approximately 0.68 dogs per household in the U.S. (AVMA, 2024). The population of domestic dogs is estimated for the watershed based on the number of households reported in the Census and average number of pets per household estimated by AVMA.

Disposing of household cat litter box waste in municipal solid waste effectively removes this source from a watershed. Feral, or stray, cat populations have gained considerable interest with concerns for bird predation and disease transfer; however, they also pose to be considerable contributors of bacterial pollution in a watershed. Feral cats reside permanently outdoors and excreting their waste outdoors without the opportunity for proper disposal (Hyer & Moyer, 2004; Ram et al., 2007). Though many cats bury their waste, some will not bury their waste most likely due to territorial behavior which is much more common among feral cats (Shojai & Smart, 2024). Despite a feral cats' attempts to bury their waste, soil conditions (clayey or loamy soils) may not permit for a successful burying of their waste plus with any moderate or significant rainfall event the soil would wash away and expose the waste to contribute *E. coli* in the runoff. This reasoning is validated by studies that have found cats/feral cats to be a quantifiable source of bacterial pollution in urban watersheds and stormwater (Dabritz et al., 2006; Kitts et al., 2002; Ram et al., 2007). U.S. feral cat population estimates are not well documented with some estimates at 30-80 million by Loss et al. (2013), and another at 32 million with approximately 76% living in urban areas according to the National Feline Research Council (Rowan et al., 2019). Feral cats could be a notable source in urban watersheds and have been considered in some watershed plans (MPCA et al., 2014). In the DFW metroplex there was an estimated 350,000 feral cats reported in a 2016 Dallas Morning News article which also states the growing concern among animal shelters that are already exceeding capacity (Rajwani & Tsiaperas, 2016). The Texas Coalition for Animal Protection (TCAP) provides feral cat low-cost sterilization at eight locations across DFW and reported sterilizing 16,329 feral cats in 2024 (TCAP, 2025). TCAP is one of many active Trap Neuter Return (TNR) programs across the metroplex.

Though estimates of feral cat populations throughout the U.S. are not well known, some studies have attempted to evaluate this. One 2004 study in Chicago estimated that there were 0.5 feral cats per household (Levy & Crawford, 2004). Another study from Loss et al. (2013) estimated there to be 30-80 million cats in the US., given that there are approximately 131.4 million households according to the 2023 Census that would mean an estimated number of 0.23 to 0.61 feral cats per household. After reviewing local TNR numbers and attaining stakeholder feedback, it was decided to use the conservative population estimate of 0.23 cats per household. This follows how the estimation of dogs was counted in the watershed, see Table 3-2. It is noted that the 63,248 feral cats are likely an overestimate for the watershed based on stakeholder input however, no documentation on local population estimates has ever been knowingly conducted and consequently this is the most scientifically based approach applicable for this analysis.

Wildlife and Feral Hogs

Wildlife contributes *E. coli* loading through direct deposition of fecal matter into streams while wading or wallowing in riparian areas and through fecal deposition across the landscape. Indirect contributions can also occur from fecal matter being transported through runoff. Wildlife most commonly found here are those that thrive in urban environments. This includes waterfowl, birds, rats, raccoons, squirrels, opossums, skunks, rabbits, armadillos. Some less populous wildlife that do inhabit the area are coyote, bats, bobcats, beavers, nutria, and river otters. Much of the wildlife experience high urban pressure, pushing them toward the few remaining green spaces which are largely the riparian corridors leading to increased *E. coli* and nutrient loadings associated with wildlife.

Feral hogs create extensive land disturbance in riparian and upland areas that can contribute to increased soil erosion and pollutant runoff. Due to the highly urbanized nature of this region, see Figure 2-3, there is little land that is suitable for feral hog habitat (Timmons et al., 2012). There have been recent documented sightings of feral hogs in DFW of areas of urban-rural interface, though none of these sightings have been within the Rowlett Creek watershed (iNaturalist community, 2025; Panicker, 2023). The areas closest to the watershed being impacted by feral hogs are in the cities of Frisco and McKinney, being approximately 3.7 and 6.4 miles from the watershed boundary. It has also been noted that the Spring Creek Forest Preserve as of 2023 feral hogs and deer have not been found in the preserve (Preservation Society for Spring Creek Forest, 2025). According to a 2012 study performed by AgriLife, feral hog population densities in Texas are estimated to range from 8.9 to 16.4 hogs per square mile (mi^2) (Timmons et al., 2012). Based on stakeholders and local observations, an estimated density rate of 8.9 hogs per mi^2 of suitable habitat was used in the analysis. Following Timmons et al. (2012), suitable habitat for feral hogs and wildlife were sums of area of the following categories using 2021 LCLU data: all forest types, shrub/scrub, grasslands/herbaceous, pasture/hay, cultivated crops, woody wetlands, and emergent herbaceous wetlands. The area of suitable habitat was calculated to be 21.1 mi^2, giving an estimated population of 187 feral hogs in the watershed.

Texas holds important wintering and migratory habitats in the central flyway, flyways are important to maintain healthy avian populations and specifically several species of waterfowl. The watershed is within the flyway and serves as a stopover point along the migratory path. Conserving avian populations is a national and global priority, and this is in part accomplished by managing birds and their habitats in conservation partnerships comprising federal and state agencies. Habitat loss and human behaviors can create ecological “traps” for migratory bird species; this happens in urban areas where temperatures are generally warmer compared to rural areas and food sources are plentiful creating an environment that migratory birds are attracted to and stay in for longer than they need to which delays their seasonal migration. This leads to overpopulation of migratory waterfowl in urban detention ponds and water bodies that degrade water quality. Human feeding of waterfowl not only leads to excess waste; uneaten food decomposes and encourages bacterial growth that also degrades water quality.

One way to evaluate the estimated population of waterfowl is through the Texas Parks and Wildlife Department (TPWD) annual wintering bird surveys, which are conducted in the month of January each year divided into ecoregion areas and broken down by species and groups (TPWD, 2018). In this analysis ducks were investigated since ducks (particularly Mallards) are the most commonly sighted year-round waterfowl species observed according to eBird surveys at the Oak Point Park and Nature Preserve in the Rowlett Creek Watershed (eBird, 2021). The latest available TWPD survey at the Oak Woods/Blackland Prairie region from 2018 showed there were an estimated 971,251 ducks, which included 18 species of ducks. The survey area size was approximately 57,943.35 mi^2, which gives an estimated population density of 16.76 ducks/mi^2. It can be noted that this estimate could be inflated since not all duck species are found year-round in the region and this survey targeted their migratory season. This density estimate was then used to estimate the population of ducks per square mile of wildlife suitable habitat, the same used in the feral hog analysis, giving an estimated population of 353 ducks in the watershed.

Domestic Livestock

Cattle, goats, horses, pigs, and sheep are all potential *E. coli* loading contributors in the watersheds. Livestock estimates derived from USDA Census of Agriculture (USDA & NASS, 2022) county population data and stakeholder input were used to estimate potential *E. coli* loads. Spatial distribution of relative *E. coli* loading potential for each type of livestock was calculated and combined to produce the total potential livestock *E. coli* load across the watersheds. The estimated numbers can be found in Table 3-2.

Table 3-2. Estimated number of animals for each subwatershed and the watershed totals.

Subwatershed ID	Estimated Animal Count								
	Chickens	Cows	Horses	Pigs/ Hogs	Sheep	Dogs[1]	Feral Cats[2]	Feral Hogs[3]	Ducks[4]
1	84	245	28	5	21	51,974	17,579	53	100
2	57	166	19	4	14	23,119	7,820	36	68
3	33	70	7	1	6	22,161	7,496	38	72
4	11	20	2	1	2	56,983	19,273	15	28
5	75	111	9	1	9	32,757	11,080	45	85
Total	260	612	65	12	52	186,994	63,248	187	353

[1]Estimated as 0.68 dogs per household (AVMA, 2024)
[2]Estimated as 0.23 feral cats per household
[3]Estimated as 8.9 feral hogs per square mile
[4]Estimated as 16.76 wintering ducks per square mile

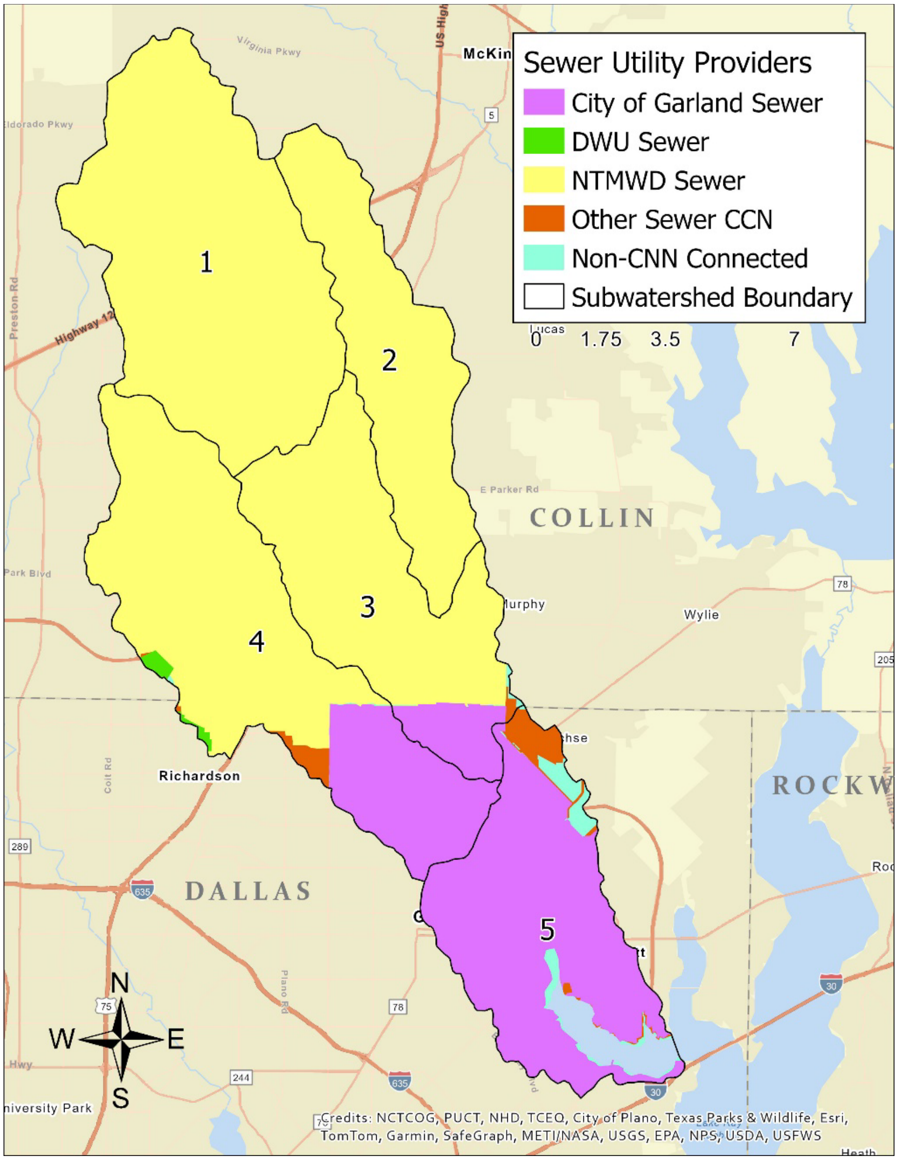

Figure 3-3. Sewer (wastewater) service areas in Rowlett Creek watershed

On-Site Sewage Facilities

The current use and installation of OSSFs in this watershed is highly limited due to the connection of homes to centralized sewage treatment facilities throughout almost all of the watershed. Many factors affect the efficiency of OSSFs, including the soil properties of the soil absorption field. Other factors impact OSSF function, including lack of maintenance and damage. If routine maintenance is neglected, the system may malfunction and discharge improperly treated wastewater into the ground or on the surface. The majority of older OSSFs in the watershed use a conventional septic tank and subsurface soil absorption to treat discharged wastewater. In these systems, wastewater is first passed through a septic tank, which separates solids and liquid before dispersing effluent into a soil absorption field where wastewater is further treated by percolating through the soil, further details on different types of septic systems found at https://www.epa.gov/septic/types-septic-systems.

The use of OSSFs is highly limited due to the transformation of rural to urbanized land over the past several decades, with a current coverage of 75% developed (Table 2-2). Urban areas are provided wastewater services through municipality infrastructure; in this case, the majority of the area is provided by the City of Garland and North Texas Municipal Water District (Figure 3-3). Sewer (wastewater) service areas in the watershed are provided under a Certificate of Convenience and Necessity (CCN) issued by the Public Utility Commission of

Texas. Data was provided by the North Texas Council of Governments (NCTCOG, 2024) and the Public Utility Commission of Texas (PUCT, 2024).
It can be estimated that at least 95% of the area is covered by a municipal sewer network. Thus, contributions of OSSFs in the Rowlett Creek watershed can be deemed minimal enough to not measure as a quantifiable source at this scale.

Potential Point Sources of Water Quality Issues

Point source pollution is the discharge of pollutants from a single and identifiable origin point. These types of discharges to Texas surface water are permitted and monitored by the Texas Pollutant Discharge Elimination System (TPDES) regulatory program, which is authorized through the National Pollutant Discharge Elimination System (NPDES) program. WWTF operations are common permit holders of discharges to surface water. Other permitted discharges include stormwater discharges by industrial and construction sites, and from municipal separate storm systems.

Permitted Wastewater Discharges

Municipal wastewater is treated by WWTFs before ultimately being released as effluent into a nearby water body. These permitted discharges of the treated effluent are tested and reported to TCEQ. These reports indicate whether a WWTF is meeting their permitted discharge levels. If the discharge exceeds their permit, the facility may need improvements to infrastructure or expansion to meet increasing wastewater intake.

There is one WWTF within subwatershed 3 permitted to discharge into AU 0820B_01, the Rowlett Creek WWTF shown in **Error! Reference source not found.**. Measured levels of *E. coli* in effluent at the Rowlett Creek WWTF are far below the state standard. It is therefore unlikely that the WWTF discharge is a source of excessive *E. coli* in the watershed. Additionally, the Rowlett Creek WWTF recently underwent upgrades to their facilities to increase capacity at peak flow. NTMWD, owner and operators, completed the majority of these upgrades in November 2021.

Unauthorized Discharges

Unauthorized discharges of wastewater can come from municipal, industrial, and recreational sources and can occur directly into a water body or the land, where it ultimately enters the water through runoff. These discharges contribute to bacterial pollution and excess nutrients, hence instances must be reported to TCEQ and addressed by the party responsible for the discharge. Sanitary sewer overflows (SSOs) are a type of unauthorized discharge of untreated or partially treated wastewater from any point in a sewer system. Most common causes of SSOs include blockages, sewer defects that overload the system, power failures, line breaks, poor design, and vandalism. These discharges can be either single instance events, such as in the case of storm design failure during extreme rainfall events, or can be continuous discharges, such as sewer line breaks.

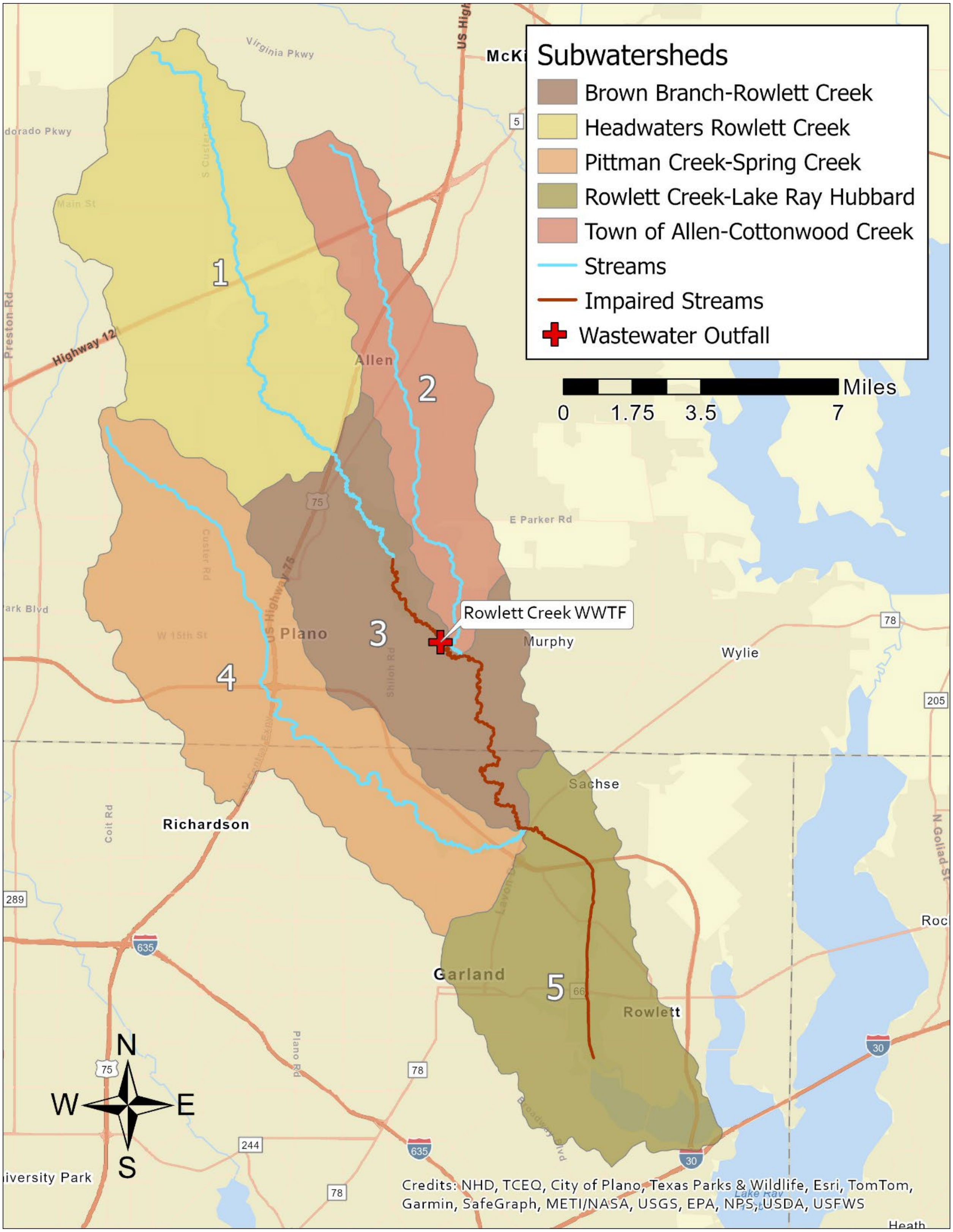

Figure 3-4. Location of the Rowlett Creek WWTF

Permitted Stormwater Discharges

Some urban activities (construction, industrial, and municipal separate storm sewer systems (MS4) are permitted to discharge stormwater as a point source discharge through the TPDES program. These permits are designed to manage stormwater runoff and reduce the amount of pollution discharged. MS4s are regulated stormwater operations that discharge stormwater into water bodies. MS4 permits are designed to:

- Control stormwater runoff in a way that protects waterways from pollution
- Maintain and upgrade stormwater systems as needed
- Monitor water quality of stormwater runoff
- Apply treatment or pollution removal techniques when necessary

MS4 permits are categorized as either medium to large Phase I or small Phase II permits based on population. There are three Phase I MS4 permit holders in the Rowlett Creek watershed: City of Dallas, City of Garland, and City of Plano. There are two Phase II MS4 permit holders: City of Frisco, and City of Allen. Given the highly urbanized area in this watershed, there are several industrial and construction permits that are active and will occur in the future which can contribute to increased TSS in waterways.

Table 3-3. Summary of potential pollutant sources for bacteria.

Pollutant Source	Source Type	Potential Impact	Potential Causes
Urban Stormwater Runoff	Non-point	Untreated stormwater discharged carrying bacteria, nutrients, etc. directly into waterways	Increased runoff from impervious surfaces
			Lack of education on urban runoff impacts
			Excessive application of pesticides and fertilizers
			Disposing chemicals in storm drains
Domestic Pets	Non-point	Bacteria and nutrients directly deposited or through runoff into streams, and transfer of disease	Lack of proper waste disposal at home and in public areas
			Increased runoff from impervious surfaces
			Lack of education on pet waste impacts
Wildlife and Feral Hogs	Non-point	Bacteria, nutrients, and sediments directly deposited or through runoff into streams	Fecal matter direct deposition
			Erosion from degraded riparian zones
Domestic Livestock	Non-point, Point	Bacteria and nutrients directly deposited or through runoff into streams	Pasture manure runoff
			Overgrazing or overstocking
			Direct deposition into streams
OSSFs	Non-point, Point	Untreated sewage runoff into streams contributing bacteria and nutrients.	Poorly functioning or failing systems
			Improper design or abandonment
Permitted Discharges	Point	Untreated stormwater discharged carrying chemicals, sediments, nutrients, and bacteria directly into waterways	Construction related sediment runoff with storm events
			Transportation and manufacturing facilities, scrapyards, and other industrial activities
WWTFs and SSOs	Point	Untreated or partially treated sewage discharged or through runoff into streams contributing bacteria, nutrients, etc.	Aging infrastructure and lack of routine maintenance
			Overflow during large rain events
			Power failures

Water Quality Summary

Rowlett Creek watershed is mostly urban and because of this, most pollution in the watershed is picked up from overland flow due to impervious surfaces. Since the primary water quality concern for Rowlett Creek is bacteria impairment, reducing surface bacteria pollution and reducing overland flow by reducing runoff will have the greatest impact on reducing bacteria. Potential surface bacteria pollution in Rowlett Creek watershed likely includes pet waste, wildlife and feral hog waste, and permitted discharges from WWTFs (Table 3-3).

Chapter 4 Pollutant Source Assessment

Introduction

TCEQ has monitored and assessed water quality in Rowlett Creek since 1984 to satisfy requirements of Sections 305(b) and 303(d) of the CWA. Section 305(b) requires states to assess the health of surface water bodies every two years and submit a report summarizing results to EPA. Title 30, Chapter 307 of the Texas Administrative Code (30 TAC Chapter 307) describes the Texas Surface Water Quality Standards. These regulations specify designated uses (Table 4-1) of surface water bodies and establish water quality criteria to protect these uses (Table 4-2). When a water body fails to meet criteria associated with specific designated uses, it is placed on the state's 303(d) list of impaired water bodies (Table 4-2).

E. coli concentrations in Rowlett Creek have exceeded the Texas surface water quality standards established for contact recreation since 1998. Though nutrient levels do not have water quality standards established as of the date of this project, they are monitored as part of the Texas Integrated Report. Nutrient values are considered to be of concern if they exceed the screening values listed in Table 4-3 by 20%. This WPP was developed to address the bacteria impairments.

Table 4-1. The applied designated uses and impairment status of water segments according to the *2022 Texas Integrated Report of Surface Water Quality*.

Waterbody Name/Segment ID		Rowlett Creek/0820B
Designated Uses (X indicates if the use applies to segment)	Aquatic Life	X
	Recreation	X
	General	X
	Fish Consumption	X
	Domestic Water Supply	
	Oyster Waters	
TCEQ 2022 Report Listing	Impairment	Bacteria (Recreation)
	Concern	Nitrate (General)

Table 4-2. Water quality parameters criteria and assessed values reported in the *2022 Texas Integrated Report.*

Parameter	Assessment Method	Segment ID 0820B Criteria	AU 0820B_01 Reported Measures	Corresponding Designated Use
DO (mg/L)	Grab minimum	3	-	Aquatic life
DO (mg/L)	Grab screening level	4	-	
E. coli (MPN/100 ml)	Geomean	126	373.78	Contact recreation
pH range	Mean	6.5-9.0	-	General
Temperature (°F, °C)	Mean	95 /35	-	

Table 4-3. Nutrient screening levels vs reported values in AU 0820B_01 from the *2022 Texas Integrated Report*.

Parameter	Assessment Method	AU 0820B_01 Screening Level	AU 0820B_01 Reported Levels
Nitrate (mg/L)	Nutrient Screening Levels	1.95	5.87
Total Phosphorous (mg/L)		0.69	-
Ammonia (mg/L)		0.33	0.85

Pollutant Load Determination

Flow Duration Curve

A flow duration curve (FDC) demonstrates the flows of streams and rivers by predicting the frequency with which flows of various sizes will occur. They are also necessary in the development of LDCs, which can effectively demonstrate the relative loadings of constituents from different tributaries (Cleland, 2003).

FDCs were constructed using the calibrated SWAT Model described in Chapter 3, flow time series for the time when water quality data was available were modeled and obtained for each subwatershed. Flow data for a particular sampling location were then sorted in order and ranked from highest to lowest to determine the frequency of a particular flow in the stream. Flow data collected as part of routine water quality monitoring were used to develop FDCs for subwatersheds 1, 2, 3, 4, and 5 of Rowlett Creek. These results are used to create graphs of flow volume versus frequency, which produces a flow duration curve for each waterbody.

Load Duration Curve

FDCs and LDCs are not specific models, but data calculators. The calculation of FDC and LDC graphs have been shown to be an effective method for determining necessary load reductions (Cleland, 2003). A LDC is a graph that displays a given parameter's value that has been met or exceeded related to the percentage of time. The percentage of time is scaled ranging between 0 and 100. Pollutant loadings, point sources or non-point sources, for example, are displayed to enable the determination of patterns depending on the conditions of stream flow. Best management practices (BMPs) and implementation strategies can be determined based on the observed pattern in order to direct focus on a specific pollutant source. For example, a flow exceedance of less than 10% typically indicates that the stream flows are directly impacted by storm runoff events (Cleland, 2003). LDCs can be used as a method to evaluate current impairments in order to narrow the focus to non-point source or point source pollution.

The first step in developing FDCs and LDCs was to estimate continuous daily streamflows spanning multiple years at tributary sites in Rowlett Creek Watershed. Estimates of streamflow data for all tributary locations were derived using existing records from USGS 08061540 Rowlett Creek near Sachse, TX, near Site 5. Daily average discharge rates were downloaded from the nearest USGS station, sorted from highest cubic feet per second (cfs) to lowest cfs. The records from this gauge were then modeled to adjust for upstream flows for the contributing subwatershed to Site 5. FDCs indicate the percentage of time during which a certain value of flow is equaled or exceeded. The estimated streamflows record is January 1980 to December 2022.

Stream monitoring data for a pollutant also can be plotted on the curve to how frequency and magnitude of exceedances. Typically, flow regimes are identified as areas of the LDC where the slope of the curve changes because that correlates with a significant change in flow. These regimes reflect where a change in the slope of the LDC line is detected. In the LDCs for the Rowlett Creek watershed, there are three flow regimes: high (0-10th percentile flow), midrange (11th – 80th percentile flow), and low flows (81st -100th percentile flow). Pollutant data plotted on the LDCs for the Rowlett Creek Watershed in this report covered data collected from 1981 to 2022.

Pollutant Source Load Estimates

In figures 4-1 through 4-5, the red line indicates the maximum acceptable stream load for pollutants and the squares, triangles, and circles represent water quality monitoring data collected under high, mid-range and low flow conditions, respectively. Where the monitoring samples are above the red line, the actual stream load has exceeded the water quality standard, and a violation of the standard has occurred. Points located on or below the red line are in compliance with the water quality standard. In order to analyze the entire range of monitoring data, regression analysis is conducted using the monitored samples to calculate the "line of best fit" (blue line). Where the blue line is on or below the red line, monitoring data at that flow percentile is in compliance with the water quality standard. Where the blue line is above the red line, monitoring data indicate that the water quality standard is not being met at that flow percentile. Regression analysis also enables calculation of the estimated percent reduction needed to achieve acceptable pollutant loads. The green line indicates the 10% margin of safety (MOS) to account for uncertainty about pollutant loadings agreed on for this project.

GIS Analysis

A geospatial analysis was performed using geographic information systems (GIS) software to aid in the determination of the relative potential load contributions from each subwatershed within the watershed. The *E. coli* loads from all the sources were estimated across the five subwatersheds in combination with the other data sources outlined throughout this document in Chapters 2, 3, and 4. This data has spatially explicit information that is used to identify which subwatershed the sources are in. The analysis also considers the area of the subwatersheds, LCLU, and soil characteristics, described in Chapter 2, as these factors impact runoff and the potential source population estimates(Soil Survey Staff, 2022; USGS, 2023b). Potential load estimates are also based on 2022 U.S. Census ACS data for household numbers within each subwatershed (USCB, 2022).

Potential loads for the different identified sources for bacteria are summarized for each of the five subwatersheds. Figure 4-6 summarizes the estimated total daily *E. coli* loads by subwatershed. Prioritization of management measures to address the source loads are gained from this GIS analysis approach. This helps to apply a more targeted approach for each subwatershed and their sources of contribution. All numbers produced from these calculations are estimates based on reliably sourced data. Hence, the values from the calculations are meant to serve as reliable estimates but not representative of direct and real time measures.

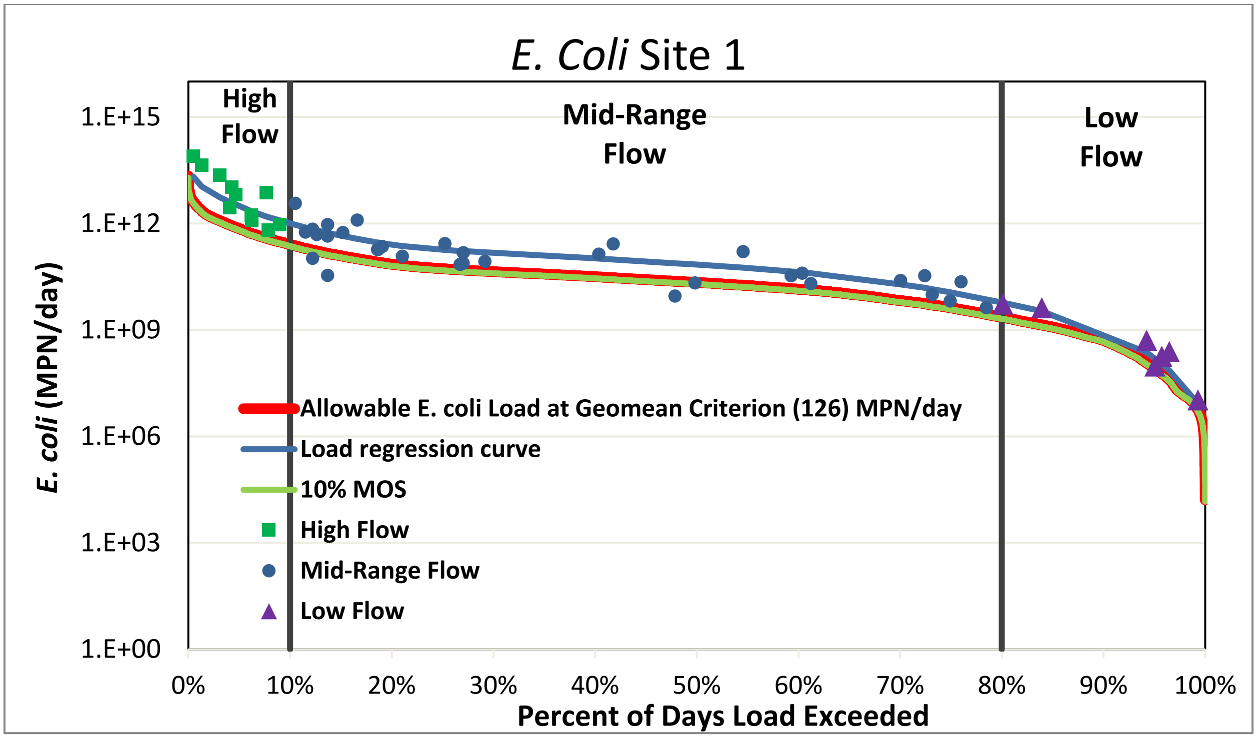

Figure 4-1. Load duration curve for *E. coli* at Site 1

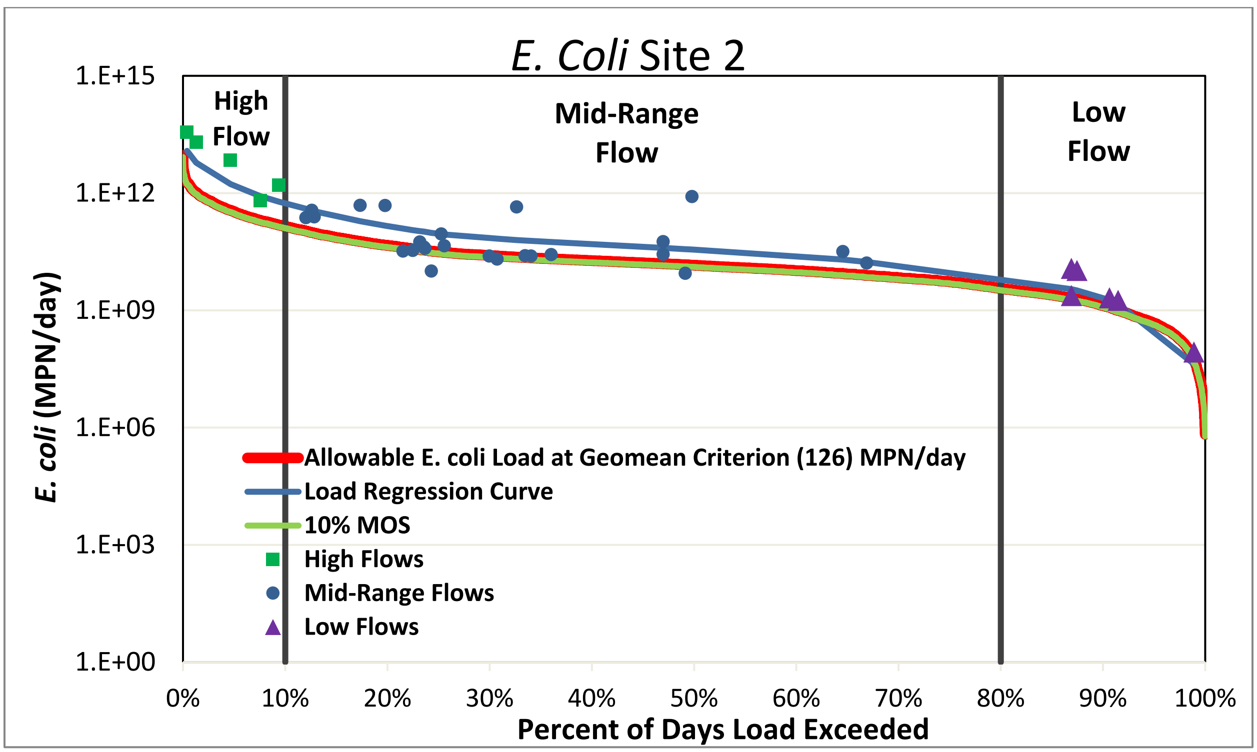

Figure 4-2. Load duration curve for *E. coli* at Site 2

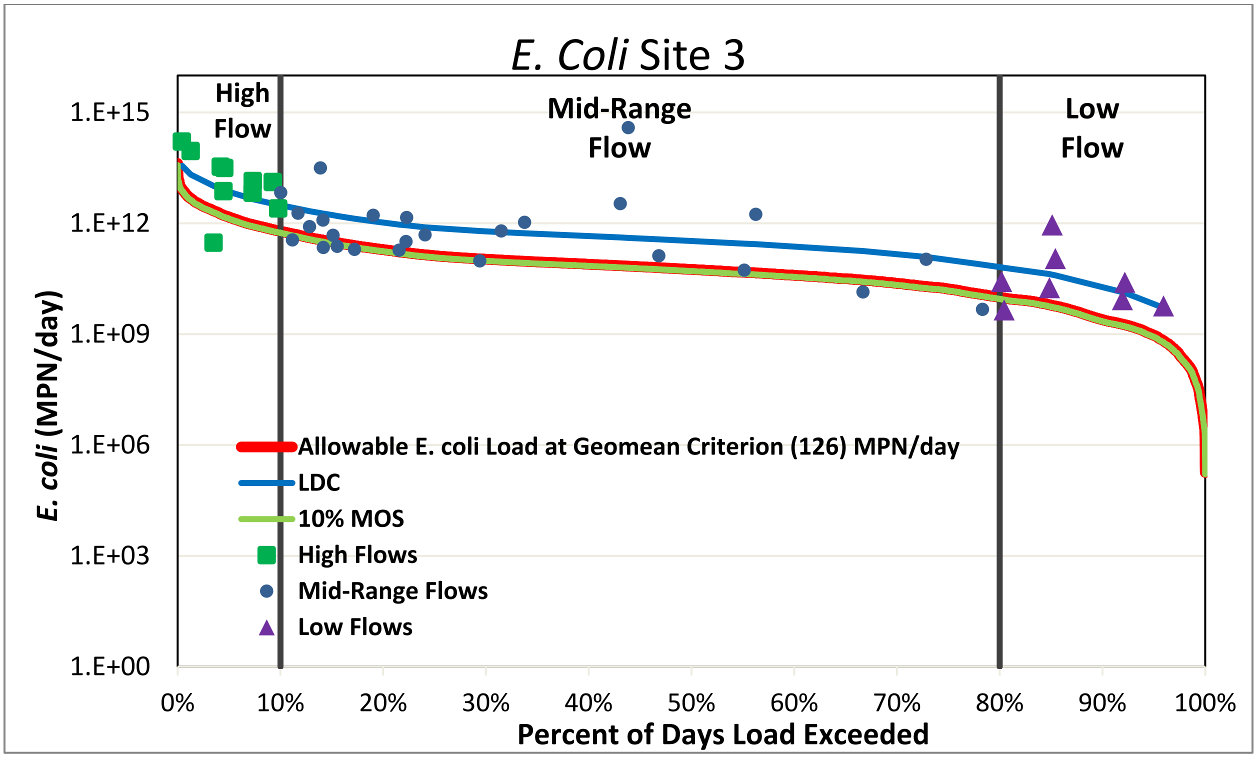

Figure 4-3. Load duration curve for *E. coli* at Site 3

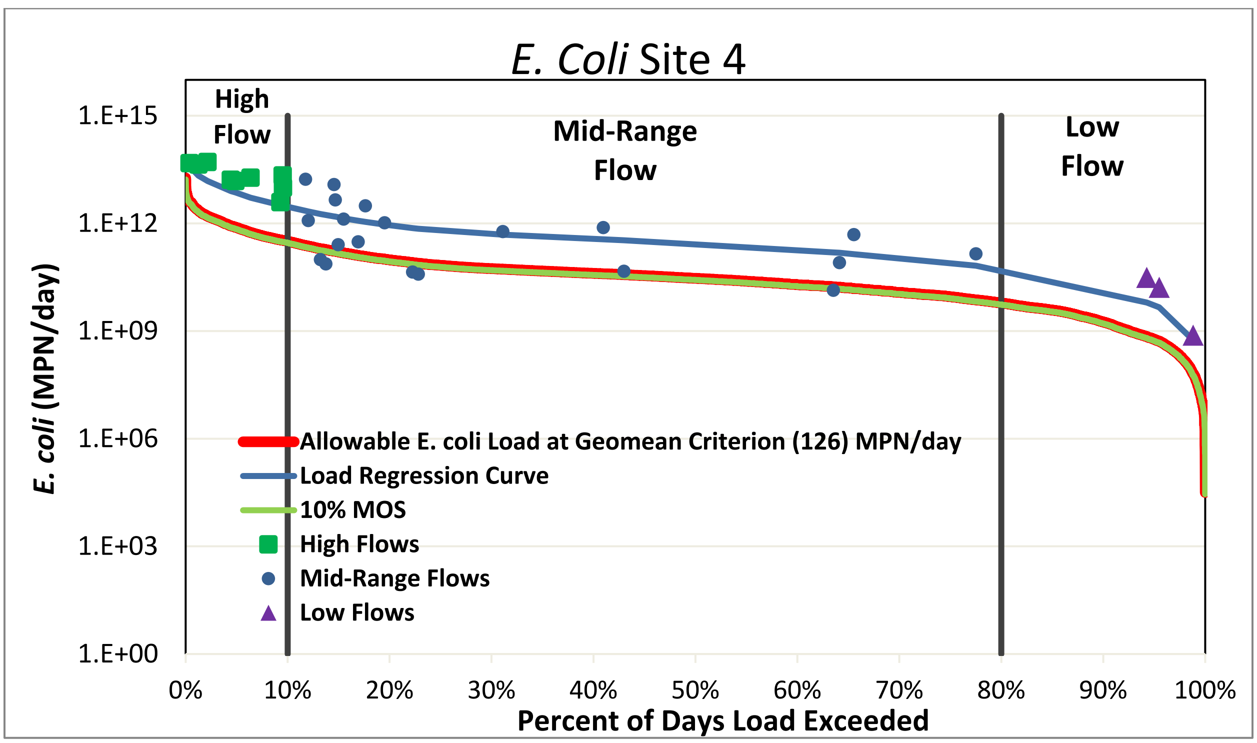

Figure 4-4. Load duration curve for *E. coli* at Site 4

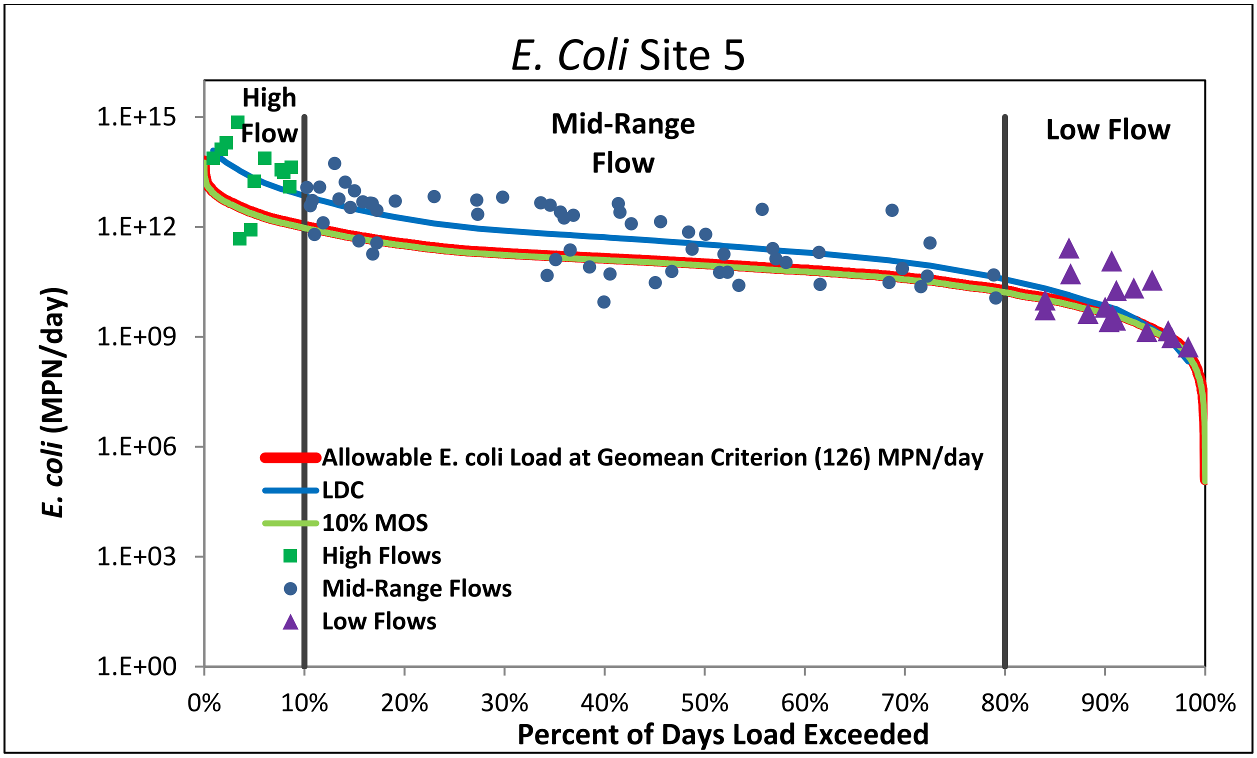

Figure 4-5. Load duration curve for *E. coli* at Site 5

E. coli

EPA has designated a standard *E. coli* concentration based on the geometric mean of a certain number of samples because the concentration can vary by orders of magnitude. The method for detection of *E. coli* is used as a proxy for the possibility of human illness when humans are recreating in water. The higher the concentration of *E. coli* the greater the possibility that there will be more toxic *E. coli* strains, other bacteria, or viruses that can be ingested while swimming, wading, or boating in waterbodies. Concentrations of *E. coli* samples often exceeded the maximum value able to be tested by the lab. There is, therefore, an artificial ceiling on values reported. For contact recreation in Texas, the geomean of *E. coli* must be below 126 cfu/100 mL (Table 4-2). Thus, the 10% MOS threshold concentration used in the LDC analysis was 113 cfu/100mL for bacteria.

All sites exceeded the allowable load in one or more of the ranges (Table 4-7). Site 1 (Figure 4-1) slightly exceeded the allowable load for high and mid-range flows and to a lesser extent for low flows. Site 2 (Figure 4-2) had a similar pattern to Site 1, with low flows being less above the allowable limit. Sites 3 (Figure 4-3) and 4 (Figure 4-4) were consistently above the allowable limit for all flows while Site 5 (Figure 4-5) was only above the allowable limits for the high and mid flows.

Percent reductions of *E. coli,* in Table 4-4 and Table 4-5, needed for each of the subwatersheds are similar, site ranging from 82% to 99%. The greatest reductions based on percentage are needed within subwatershed 5, an annual reduction of 4.03E+16 cfu/yr. Reductions needed in order of percent magnitude are as follows, subwatershed 2 reduction of 4.58E+15 cfu/yr, subwatershed 4 reduction of 9.53E+15 cfu/yr, subwatershed 3 reduction of 1.84E+16 cfu/yr, and subwatershed 1 reduction of 5.48E+15 cfu/yr. Since Site 5 is the furthest downstream of all the sites it is expected to have the greatest exceedance. Likewise, Site 3 is downstream of Sites 1 and 2 and should have a greater exceedance. The development of these *E. coli* load estimates and identification of their sources follow EPA guidance for developing pathogen total maximum daily loads (EPA et al., 2001).

Table 4-4. Estimated daily *E. coli* loads and reductions needed to meet the water quality standards for primary contact as determined by LDC analysis for each site.

Flow Condition	% Exceedance	Daily Load (cfu/day)	Allowable Daily Load (cfu/day)	% Reduction Needed	Daily Load Reduction Needed (cfu/day)
Site 1 (subwatershed 1)					
High Flows	0-10	1.59E+13	1.24E+12	92.2	1.47E+13
Mid-Range Flows	10-80	3.29E+11	4.08E+10	87.61	2.88E+11
Low Flows	80-100	1.52E+09	6.98E+08	54.08	8.22E+08
Site 2 (subwatershed 2)					
High Flows	0-10	1.30E+13	5.61E+11	95.68	1.24E+13
Mid-Range Flows	10-80	1.47E+11	2.53E+10	82.73	1.21E+11
Low Flows	80-100	4.78E+09	1.49E+09	68.76	3.29E+09
Site 3 (subwatershed 3)					
High Flows	0-10	3.60E+13	2.51E+12	93.03	3.34E+13
Mid-Range Flows	10-80	1.69E+13	1.05E+11	99.38	1.68E+13
Low Flows	80-100	2.22E+11	3.55E+09	98.4	2.19E+11
Site 4 (subwatershed 4)					
High Flows	0-10	2.52E+13	1.23E+12	95.12	2.40E+13
Mid-Range Flows	10-80	2.15E+12	5.38E+10	97.5	2.10E+12
Low Flows	80-100	1.63E+10	2.24E+09	86.24	1.40E+10
Site 5 (subwatershed 5)					
High Flows	0-10	1.12E+14	4.04E+12	96.38	1.07E+14
Mid-Range Flows	10-80	3.25E+12	1.85E+11	94.31	3.06E+12
Low Flows	80-100	3.26E+10	6.20E+09	80.96	2.64E+10

Table 4-5. Estimated annual *E. coli* loads and reductions needed to meet the water quality standards for primary contact as determined by LDC analysis for each site.

Flow Condition	% Exceedance	Annual Load (cfu/yr)	% Reduction Needed	Annual Load Reduction Needed (cfu/yr)
		Site 1 (subwatershed 1)		
High Flows	0-10	5.82E+15	92.2	5.37E+15
Mid-Range Flows	10-80	1.20E+14	87.61	1.05E+14
Low Flows	80-100	5.55E+11	54.08	3.00E+11
Total Annual		5.94E+15	92.17	5.48E+15
		Site 2 (subwatershed 2)		
High Flows	0-10	4.74E+15	95.68	4.53E+15
Mid-Range Flows	10-80	5.35E+13	82.73	4.43E+13
Low Flows	80-100	1.75E+12	68.76	1.20E+12
Total Annual		4.80E+15	95.42	4.58E+15
		Site 3 (subwatershed 3)		
High Flows	0-10	1.31E+16	93.03	1.22E+16
Mid-Range Flows	10-80	6.18E+15	99.38	6.14E+15
Low Flows	80-100	8.12E+13	98.4	7.99E+13
Total Annual		1.94E+16	95.14	1.84E+16
		Site 4 (subwatershed 4)		
High Flows	0-10	9.21E+15	95.12	8.76E+15
Mid-Range Flows	10-80	7.85E+14	97.5	7.66E+14
Low Flows	80-100	5.94E+12	86.24	5.12E+12
Total Annual		1.00E+16	95.30	9.53E+15
		Site 5 (subwatershed 5)		
High Flows	0-10	4.07E+16	96.38	3.92E+16
Mid-Range Flows	10-80	1.18E+15	94.31	1.12E+15
Low Flows	80-100	1.19E+13	80.96	9.63E+12
Total Annual		4.19E+16	96.27	4.03E+16

Nutrients

Nutrient LDCs and description of these watershed characterization results are available in Appendix B. The complete report on the nutrients can be found in the Rowlett Creek Watershed Characterization Report (Jaber et al., 2023), accessible on the [Rowlett Creek WPP webpage](https://agrilife.org/lid/rowlett-creek-watershed-protection-plan/)[1]. Three major forms of inorganic nitrogen are nitrite, nitrate and ammonium ion. Nitrogen compounds can be converted into forms that plants can use. However, too much nitrate can be harmful to aquatic systems and cause eutrophication. Nitrate is very abundant as an inorganic, oxidized form of nitrogen and nitrite is a less common, inorganic, oxidized form of nitrogen. Levels of inorganic nitrogen appear to be slightly increasing over time during routine sampling. Nitrate levels were at or below 10% MOS for all sites except low flows at Site 5. That could be influenced by backflows from the Lake. Sites 3 and 4 are nearly at 10% MOS indicating a potential concern for nitrate at those subwatersheds (See Appendix B for more details).

[1] https://agrilife.org/lid/rowlett-creek-watershed-protection-plan/

TKN is the measure of organic nitrogen plus ammonia nitrogen in a sample. TKN exceeded the allowable load for all sites with Sites 2, 3, and 4 noticeably higher than the limit. Ammonia levels in Rowlett Creek were below the allowable limit for all sites except site 4 during low flows. This indicates that high TKN values are mostly due to organic nitrogen.

TP is a parameter used to analyze a water sample for all forms of phosphorus. Forms of phosphorus include organic and inorganic forms as well as dissolved and particulate forms. TP levels were generally lower than the MOS for all sites. Notable exceptions are high flows at Site 3 and low flows at Site 4. The full detailed report with all the different parameters evaluated for the characterization of the Rowlett Creek watershed is available in Appendix B. The excess organic nitrogen runoff is indicative of fertilizer use and landscape plant matter. The sources of these in an urban landscape are typically from households, landscape businesses, and golf course grass clippings or leaf litter entering the stormwater systems.

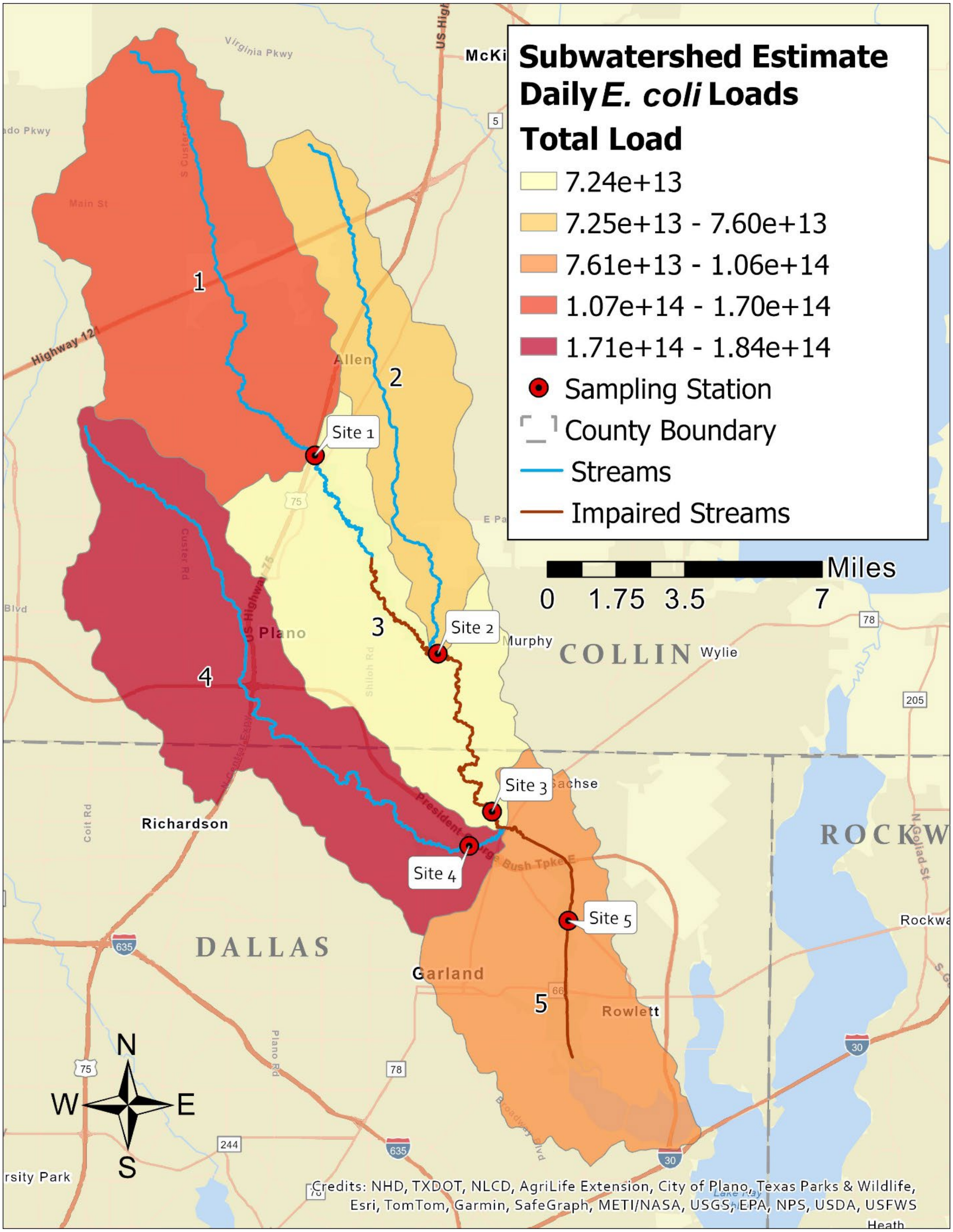

Figure 4-6. Estimated total daily *E. coli* loads by subwatershed.

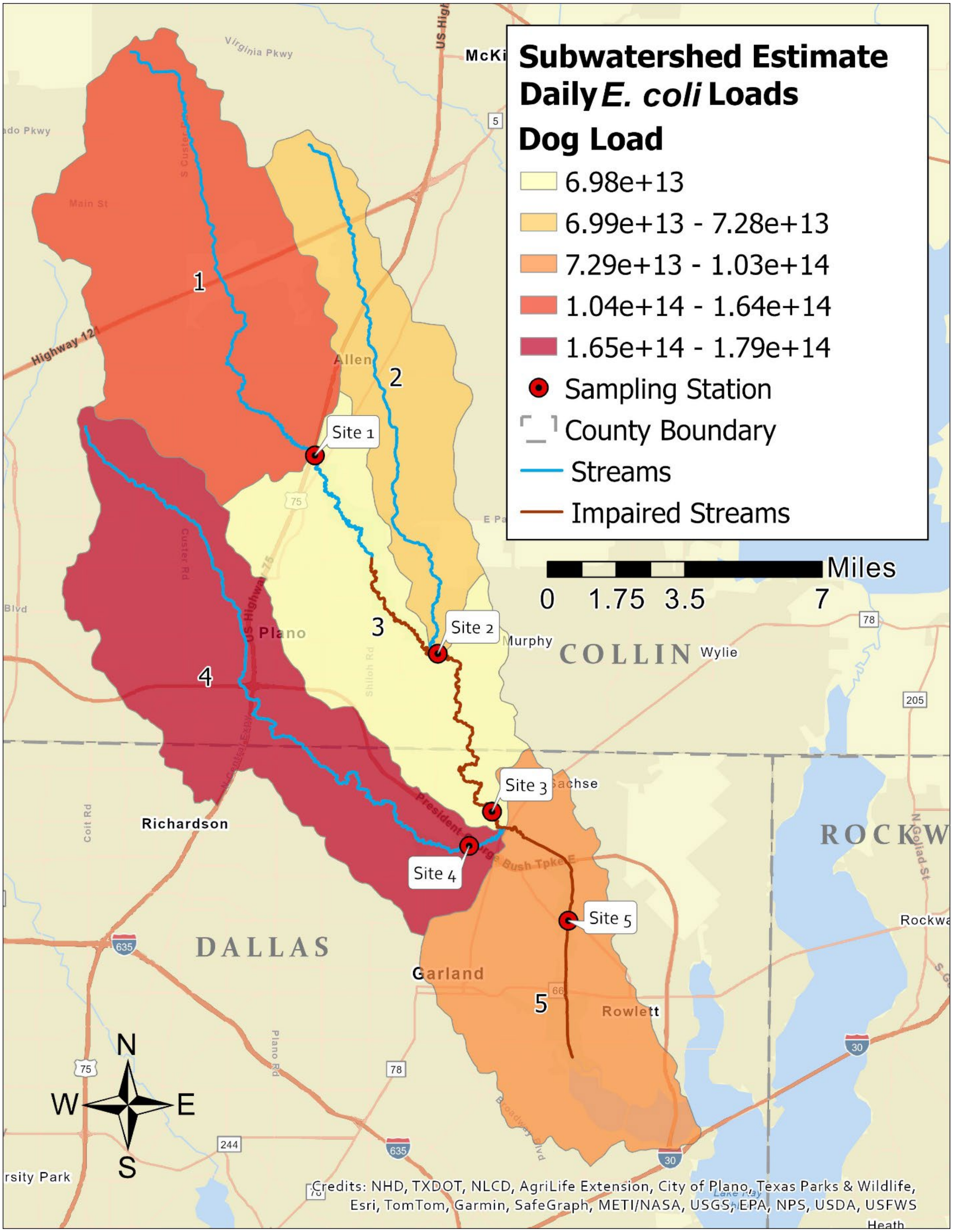

Figure 4-7. Estimated daily *E. coli* loads from dog waste by subwatershed.

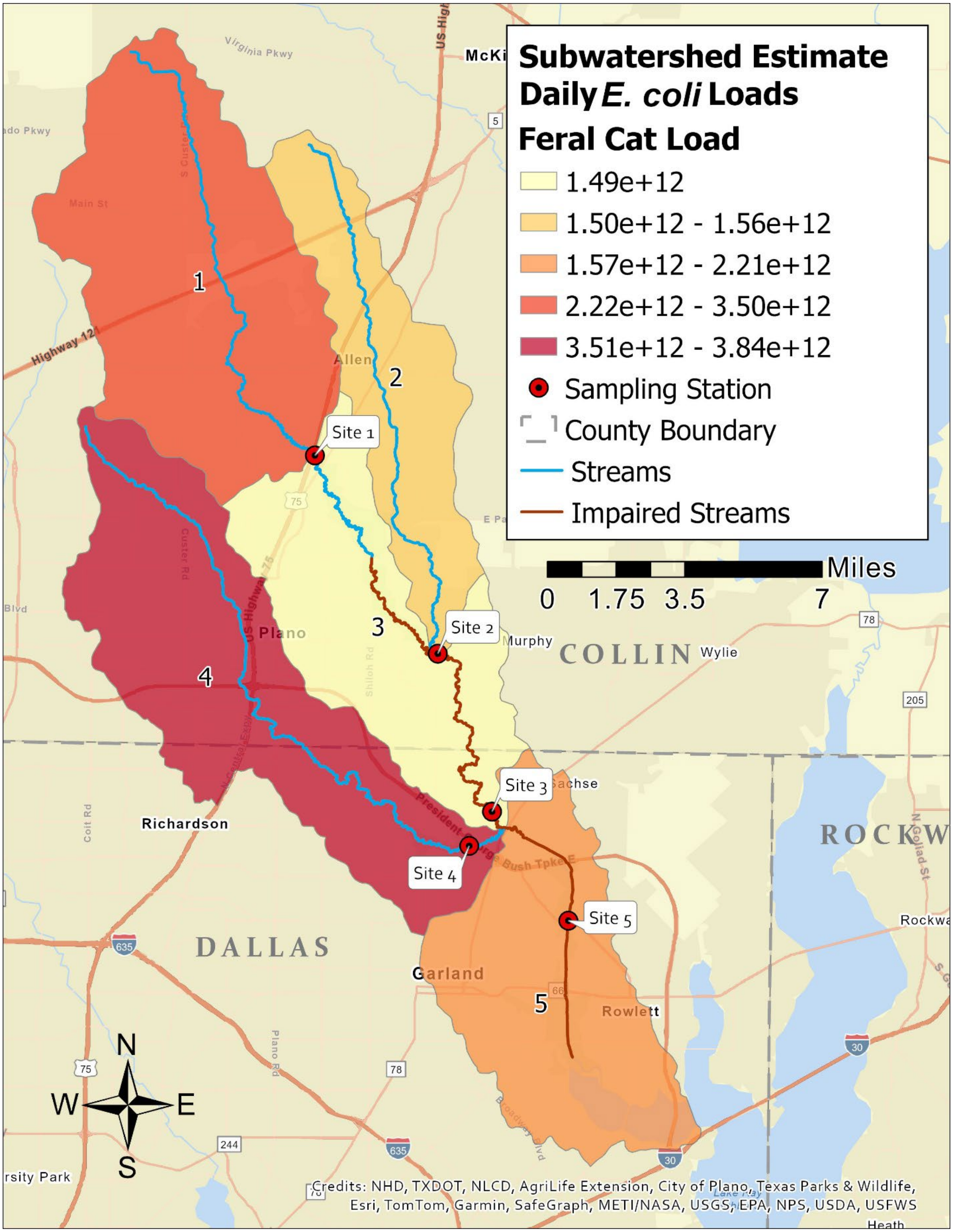

Figure 4-8. Estimated daily *E. coli* loads from feral cat waste by subwatershed.

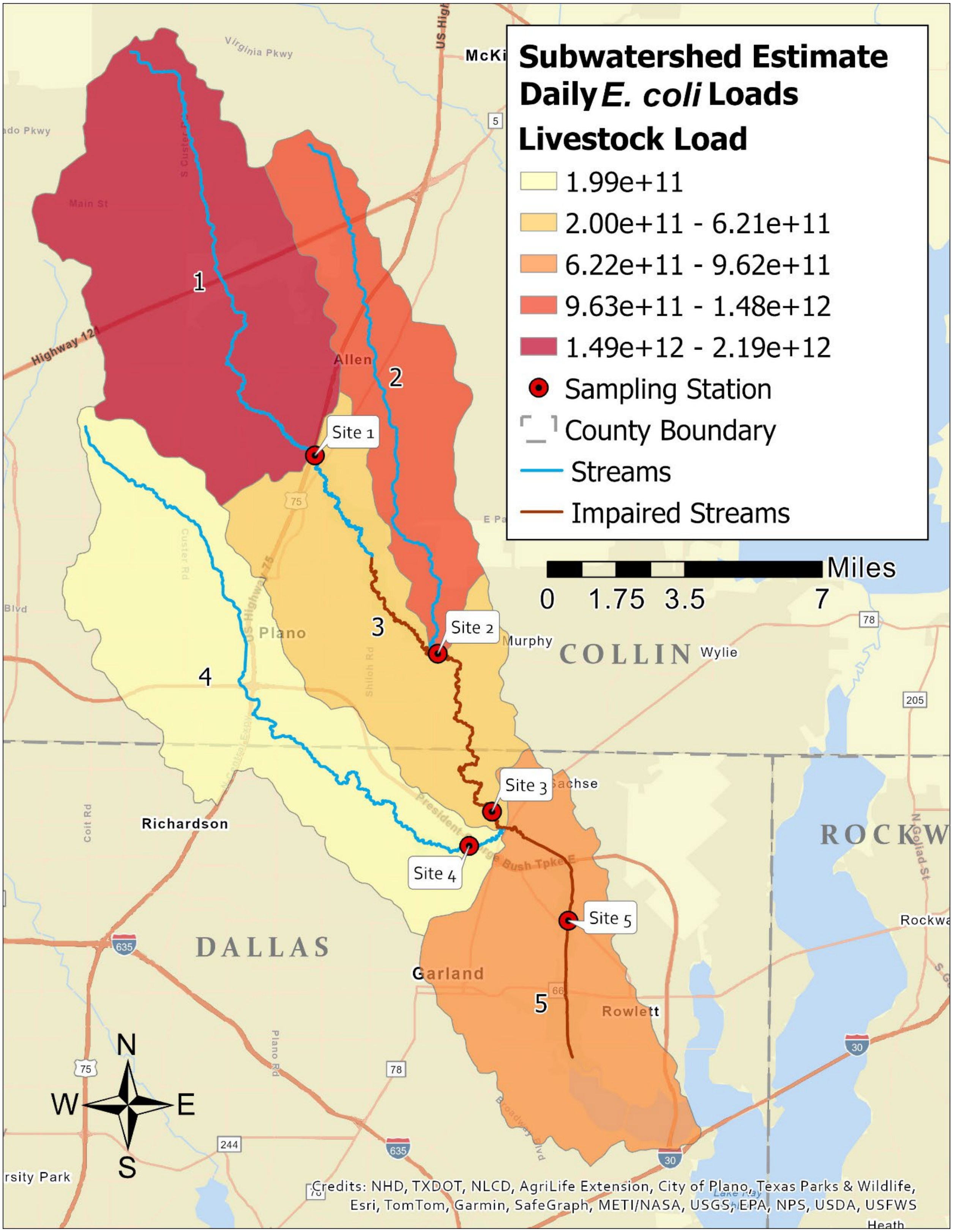

Figure 4-9. Estimated daily *E. coli* loads from livestock by subwatershed. Livestock waste includes cattle, chickens, horses, pigs, and sheep.

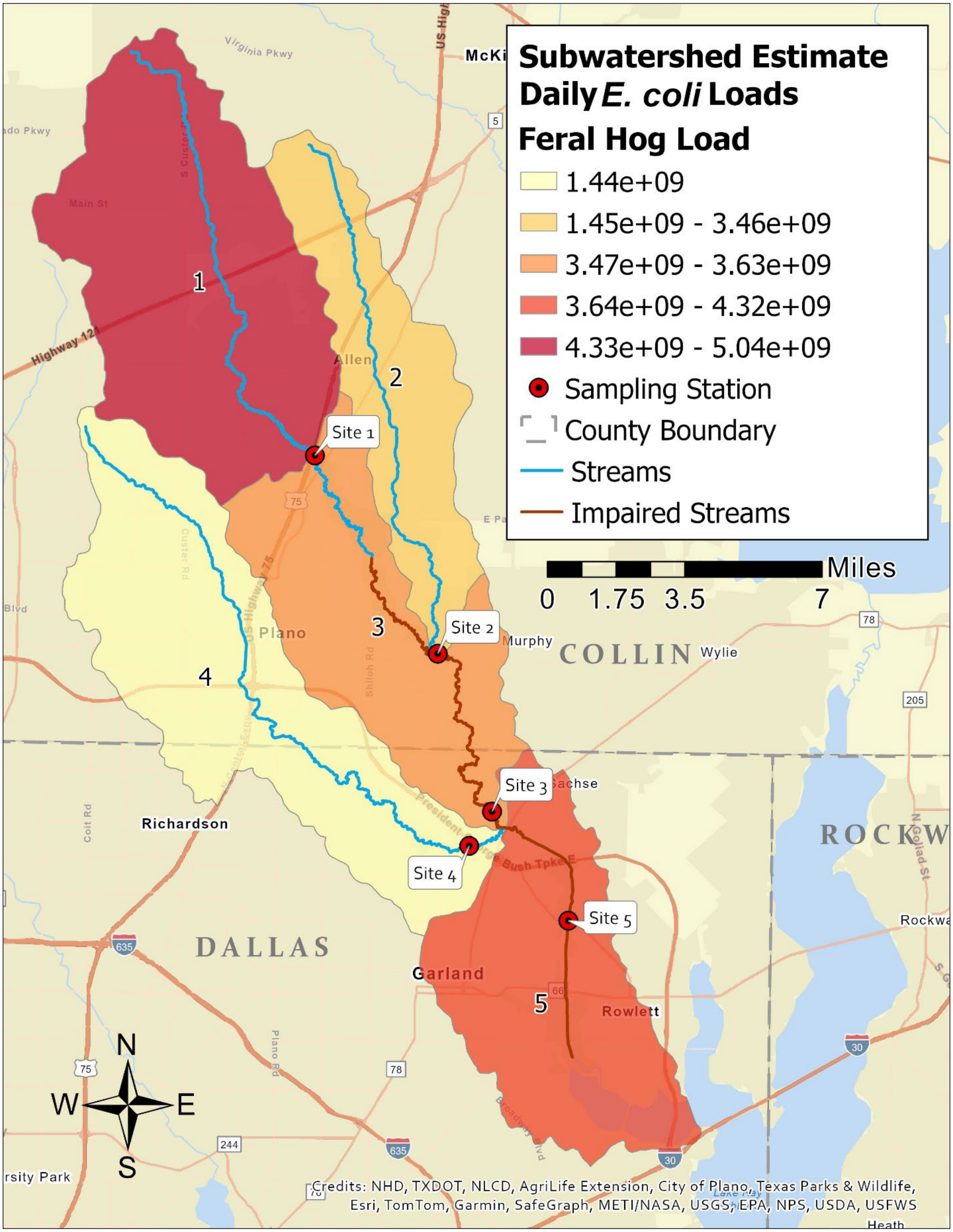

Figure 4-10. Estimated daily *E. coli* loads from feral hogs waste by subwatershed.

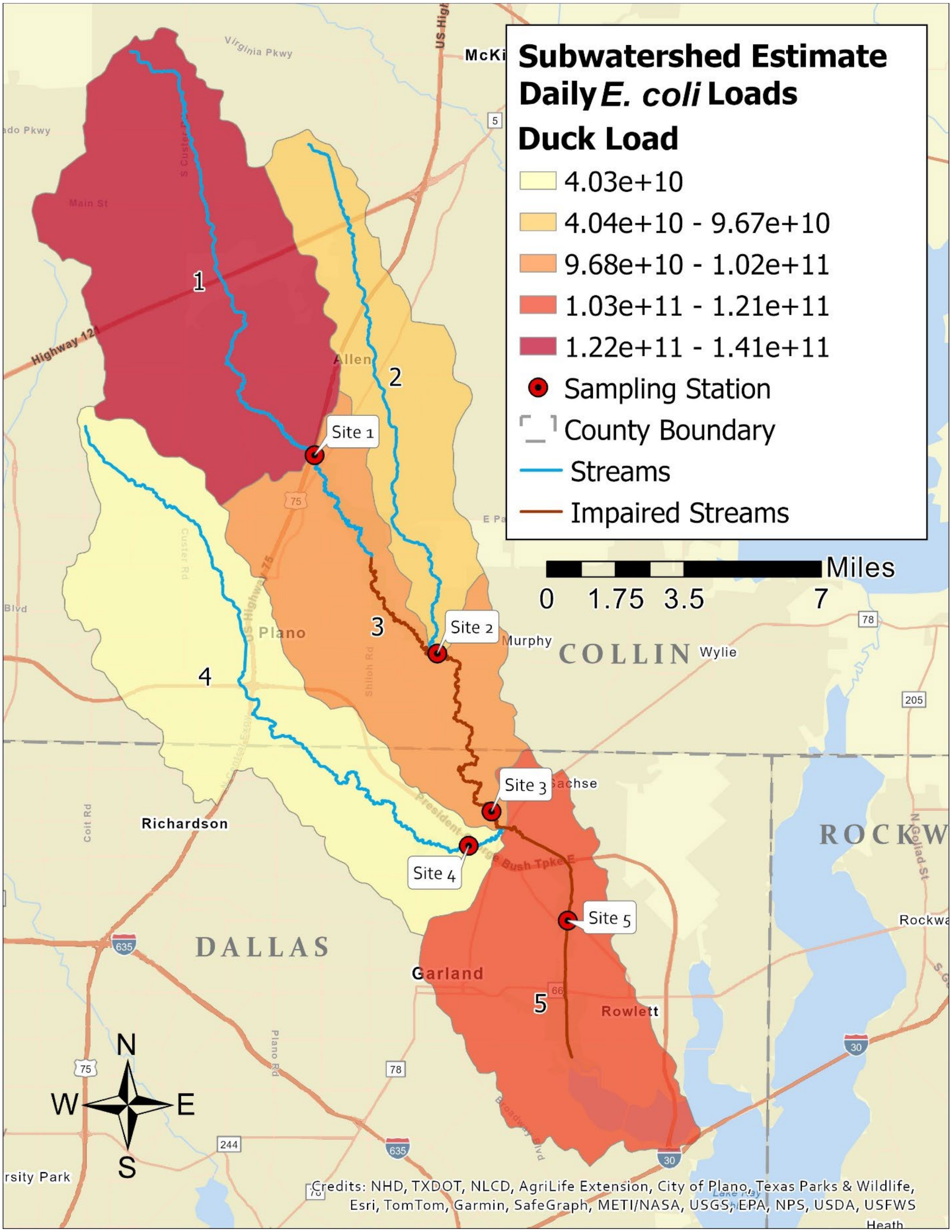

Figure 4-11. Estimated daily *E. coli* loads from duck waste by subwatershed.

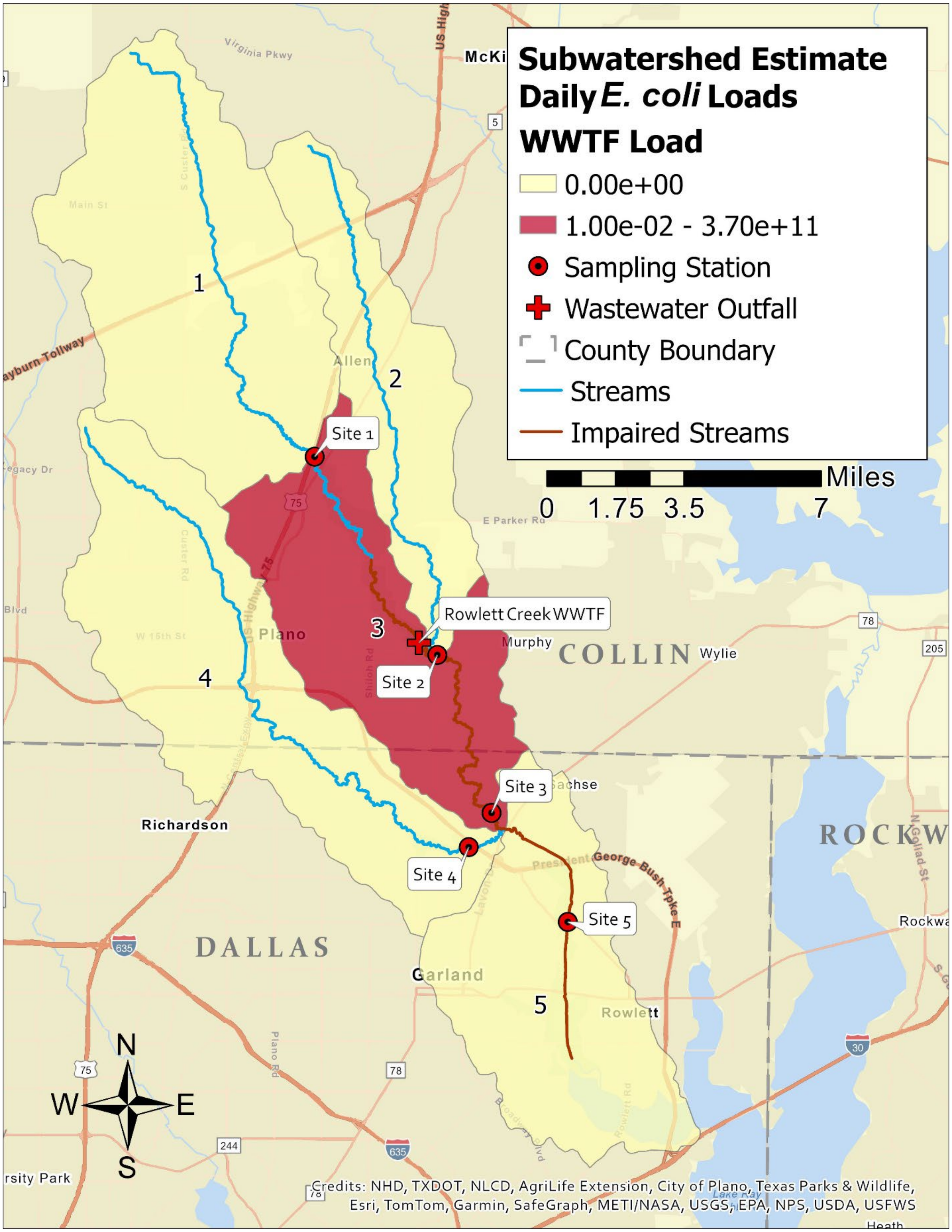

Figure 4-12. Estimated daily *E. coli* loads from WWTFs by subwatershed.

Domestic Pets

The majority of household domestic pet bacteria loading comes from dogs, as dogs almost exclusively deposit waste outdoors where if not properly disposed of it can easily enter the watershed via runoff. Across the entire watershed, it is estimated that total daily *E. coli* loads due to dogs are 5.89E+14 cfu/day. According to the *E. coli* source analysis performed here, dogs are the greatest contributor to the overall watershed. The daily contributions by subwatershed from dogs can be seen in Figure 4-7, subwatershed 4 experiences the greatest loading followed by 1, 3, 5, and 2. Feral cats in urban populations are an issue in this watershed area, described previously, as household cats primarily deposit waste indoors and are cleaned by the pet owners. For this analysis it was decided to exclude indoor/household cats and only focus on feral cats, because indoor cats are predominantly kept indoors and their waste is properly disposed by their owners. Feral cat total daily *E. coli* loads in the watershed were estimated to be 1.26E+13 cfu/day. The daily load contributions by subwatershed from feral cats can be seen in Figure 4-8, with subwatershed 4 experiencing the greatest loading, following the same pattern as dogs. Population estimates for dogs and feral cats are based on household numbers and within the subwatersheds. Pollutant sources are calculated using the estimated populations from Table 3-2. The approximate daily mean *E. coli* per unit of each of the sources used to calculate the daily load contributions. More details on the assumptions and equations used to estimate the potential bacteria loading in Rowlett Creek watershed can be found in Appendix A.

Table 4-6. The estimated daily mean *E. coli* contributions by source for each subwatershed.

Source	Daily mean *E. coli* per unit (cfu/day)	Subwatershed ID					Total Load	% of Total Load
		1	2	3	4	5		
Chickens	2.34E+08	1.96E+10	1.33E+10	7.71E+09	2.57E+09	1.75E+10	**6.07E+10**	**0.01%**
Cattle	5.39E+09	1.32E+12	8.94E+11	3.77E+11	1.08E+11	5.98E+11	**3.30E+12**	**0.54%**
Horses	2.29E+08	6.42E+09	4.35E+09	1.6E+09	4.58E+08	2.06E+09	**1.49E+10**	**<0.01%**
Pigs/Hogs	1.53E+10	7.66E+10	6.13E+10	1.53E+10	1.53E+10	1.53E+10	**1.84E+11**	**0.03%**
Sheep	3.65E+10	7.67E+11	5.12E+11	2.19E+11	7.31E+10	3.29E+11	**1.90E+12**	**0.31%**
Feral Hogs	9.53E+07	5.04E+09	3.46E+09	3.63E+09	1.44E+09	4.32E+09	**1.79E+10**	**<0.01%**
Ducks	1.41E+09	1.41E+11	9.67E+10	1.02E+11	4.03E+10	1.21E+11	**5.01E+11**	**0.08%**
Dogs	3.15E+09	1.64E+14	7.28E+13	6.98E+13	1.79E+14	1.03E+14	**5.89E+14**	**96.88%**
Feral cats	1.99E+08	3.50E+12	1.56E+12	1.49E+12	3.84E+12	2.21E+12	**1.26E+13**	**2.07%**
WWTF	3.79E+09	0.00E+00	0.00E+00	3.70E+11	0.00E+00	0.00E+00	**3.70E+11**	**0.06%**
Total Load	-	**1.70E+14**	**7.59E+13**	**7.24E+13**	**1.84E+14**	**1.06E+14**	**6.08E+14**	**100%**

Domestic Livestock

Runoff from pastureland is likely to carry *E. coli* deposited by cattle into Rowlett Creek. The potential loads from domestic livestock, cattle, chickens, horses, and sheep, were calculated based on population data from the USDA NASS and estimated per capita contribution of fecal coliform from Wagner & Moench (2009). Appendix A contains the assumptions and equations used to estimate the potential bacteria loading in Rowlett Creek watershed.

Across the entire watershed, it is estimated that total daily *E. coli* loads due to livestock are 5.46E+12 cfu/day or 1.99E+15 cfu/year. Table 4-6 shows the estimates broken down by their sources. It is estimated that total daily *E. coli* loads due to cattle were the greatest out of the livestock at 3.30E+12 cfu/day. The remaining livestock sources daily load estimates in order of greatest to least are as follows: sheep at 1.90E+12 cfu/day, pigs/hogs at

1.84E+11, chickens are 6.08E+10, horses are 1.49E+10. For all domestic livestock animal sources, the highest loads are in subwatersheds 1 and 2 (Figure 4-9).

Wastewater Treatment Facilities

There is one wastewater treatment plant located in the Rowlett Creek watershed, Rowlett Creek Regional WWTF. The Rowlett Creek Regional WWTF is a permitted 24 MGD (million gallons per day) average daily flow plant located at 1600 Los Rios Boulevard in Plano, in subwatershed 3. The City of Plano originally constructed the Rowlett Creek WWTF in 1956 and operated the facility until the North Texas Municipal Water District (NTWMD) acquired it in October of 1975 after the city requested NTMWD take over operations. Wastewater discharges are regulated by TCEQ and the WWTF is required to report average monthly discharge flows and *E. coli* concentrations. An analysis of these reports from July 2003 to May 2023 shows that the mean daily loading is approximately 3.70E+11 (Figure 4-12). A review of these reports shows the plant is in working order with no illicit discharges reported. Therefore, the WWTF is not a significant contributor to elevated *E. coli* levels in Rowlett Creek.

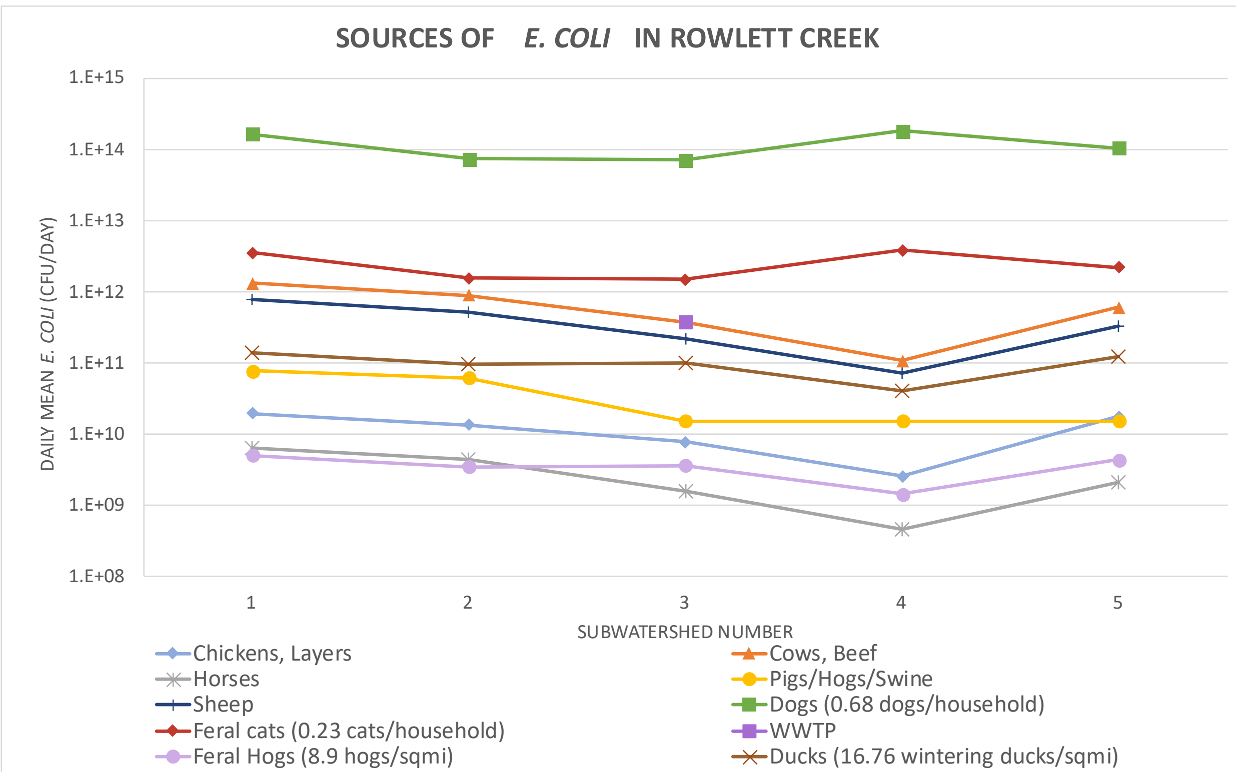

Figure 4-13. Estimates of daily mean *E. coli* (cfu/day) contribution by source for each subwatershed.

Wildlife and Feral Hogs

Wildlife in urban landscapes, such as in the Rowlett Creek watershed, predominantly refers to animals like racoons, skunks, coyotes, rodents, opossums, waterfowl and other birds. Tracking and management of these populations is difficult, and their fecal contributions are less commonly evaluated, with the exception of waterfowl. Estimates for waterfowl population were obtained using TPWD wintering waterfowl survey data from 2018, particularly for this analysis duck species were targeted as the more predominant subset of waterfowl species found in the watershed (Table 3-2). It can be noted that this estimate could be an inflated value since not all duck species are found year-round in the region and this survey targets their migratory season. The estimated daily E. coli contributions for ducks are 5.00E+11 cfu in the watershed. Feral hogs are likewise difficult to monitor populations, but methods are established to estimate them based on the existing suitable habitat (Timmons et al., 2012). According to the methodology used in this Texas study there are likely to be minimal, if any, feral hog numbers in the Rowlett Creek watershed. This is due to the intensity of urban development in and surrounding the watershed. Following a similar methodology, described above in potential sources, to obtain population estimates in the Rowlett Creek watershed, feral hogs potential daily E. coli loading is 1.79E+10 cfu. For detailed estimate descriptions and assumptions see Appendix A.

On-site Sewage Facilities

Few OSSFs are located in the watersheds due to the abundance of city sewer hook ups. OSSFs may contribute *E. coli*, nutrients, and solids to water bodies if not properly functioning. The number of OSSFs, their locations, ages, types, and functional statuses in the watersheds are unavailable, making it difficult to determine actual water quality impacts. To estimate OSSF numbers and approximate locations, an approach using PUCT CCNs, 911 address points, and U.S. Census data was used. First, the area serviced by municipal connected sewer systems was determined from PUCT and the NCTCOG data. This showed that nearly all the land within the Rowlett Creek watershed is serviced by a public utility with over 95% covered (Figure 3-3). Thus, contributions of OSSFs in the Rowlett Creek watershed can be deemed minimal enough to not measure as a quantifiable source.

Urban Stormwater Runoff

Impervious surfaces increase stormwater runoff which picks up pollutants and carries them to bodies of water. Two primary pollutants in urban runoff are bacteria and nutrients that come from improper application of fertilizers and improper disposal of animal waste. Stormwater runoff from lawns, parking lots, dog parks, and golf courses will wash fertilizers and waste into water bodies. Runoff from urban areas increases as population centers expand impermeable surface coverage in the watersheds (Jiang et al., 2007). Housing developments, shopping centers, and industrial and business parks are examples of urban expansion that increases impermeability within the watershed. Increased runoff from unmanaged urban development can affect water quality by accelerating creek erosion and habitat loss and by carrying more pollutants like bacteria, nutrients, metals, and hydrocarbons into surrounding water bodies.

Table 4-7. Ranking of greatest potential sources of annual *E. coli* loads (cfu/yr) contributions to the watershed.

Source	Potential Load (cfu/yr)	Highest priority subwatershed	Ranking
Dogs	2.15E+17	4, 1	1
Feral Cats	4.62E+15	4, 1	2
Cattle	1.20E+15	1,2	3
Sheep	6.94E+14	1, 2	4
Ducks	1.83E+14	1, 5	5
Total	**2.22E+17**	**4, 1**	

Load Reduction and Sources Summary

As each of the five sites corresponds to each of the five subwatersheds, it can be surmised that reductions are needed within each subwatershed and hence forth will be discussed as such. The LDCs (Figure 4-1 through 4-5) indicate that *E. coli* entering Rowlett Creek exceeds its capacity to meet water quality standards under all flow conditions, though the percent exceedance does generally decrease as flow rate decreases, except for Site 3. Additionally, TKN entering the watershed exceeded screening levels at all flows conditions, but ammonia, TP, and nitrate-nitrite levels generally did not exceed levels. This indicates that the sources of nutrients are from organic nitrogen caused by urban runoff. Based on these analyses, NPS pollution is determined to be the primary cause of the bacterial impairment and the nutrient concerns of AU 0820B_01 reported in the TCEQ 303(d) and 305(b) List. Management measures to attain the reductions needed for the watershed should target waste from dogs and feral cats (Table 4-7). Some agricultural activity from livestock also contributes bacteria and nutrients to this watershed, but these are a lower priority for management in the watershed. The LCLU data shows that agricultural related lands are also notable contributors.

The LDC analysis estimates on annual *E. coli* loads exceeded the standard at all flow levels in every subwatershed and the reductions needed can be seen in Table 4-5. The LDC reduction approach follows the logic that since low and high flows are rarer instances and cannot feasibly be managed under these conditions, reductions are based on the mid-range flows. Per the LDC approach, the watershed needs an *E. coli* load reduction of 8.18E+15 cfu/year to meet the water quality standards. All the subwatersheds measured more than an 80% exceedance of the standards so it is important to address the contributing sources within each subwatershed (Table 4-7). These analyses have identified that subwatersheds with a greater number of households are the largest contributors to the exceedance of *E. coli* and nutrients into AU 0820B_01 of Rowlett Creek. The LCLU data show that agricultural related lands are also notable contributors. Additionally, the detected excess organic nitrogen is indicative of fertilizer use and landscape plant matter running off from households, golf courses, and commercial businesses. Fertilizers can also contribute *E*. *coli* when they are made from animal manure. Chapter 5 includes recommendations for a variety of management measures to attain load reductions to meet water quality targets. These include the management based on sources outlined in this section and their related activities.

There are limitations to the data provided. All calculations performed for this analysis are not exact measures and therefore not meant to be deemed as representing exactly what is happening throughout the watershed. However, values are estimated using the best possible data available at the time from reliable sources and calculation methods approved by TCEQ and EPA.

Chapter 5 Watershed Protection Plan Implementation Strategies

Introduction

The watershed approach was used to develop implementation strategies (EPA & Browner, 1996). The guiding principles of this approach interlace partnerships with stakeholders of various backgrounds with science-backed management techniques for the specific watershed. An analysis was completed to identify major sources of *E. coli* in the watershed, their potential loading distribution, and estimated measured *E. coli* loads are outlined in Chapter 4. Recommended management strategies to achieve needed *E. coli* reductions in Rowlett Creek watershed were developed based on local knowledge, load estimations, and understanding of current water quality problems across the watershed. This combined information was used to make informed decisions regarding management measures to most effectively improve water quality in the watershed (EPA, 2018).

The WPP implementation strategies receive input from stakeholders to not only address the readily available data sources, but also the unmodeled sources of water quality degradation. Therefore, implementation focuses on the following sources: urban stormwater, pet waste, feral cats, livestock, agricultural runoff, lawn residue runoff, illegal dumping, and litter. These are not representative of all the sources of bacteria in the watershed but are the largest contributors that can practically be managed to mitigate the pollution.

Management Measures

The management measures detailed are suggestions with identified entities whose voluntary participation would be needed, or recommended, for the measure to be carried out. Because the watershed has multiple sources of *E. coli*, many different management options will be recommended to reduce the most *E. coli* from the greatest sources. Because a diverse approach was used, options can be chosen that are the most feasibly managed while also having the highest chance of producing *E. coli* reductions. This is not an exhaustive list of measures, but guidance to address the various known sources of pollution learned throughout this analysis to mitigate bacterial pollution. Many of the practices outlined can additionally help reduce the nutrient levels found in the segment to improve the overall stream health. The management measures described are:

1. Mitigate urban stormwater runoff problems
2. Reduce pet waste runoff and promote proper disposal
3. Expand and promote BMPs for feral cat populations
4. Promote the development of WQMPs or conservation plans
5. Conduct Urban NPS Pollution Education programs
6. Reduce illegal dumping and litter
7. Promote BMPs for urban lawn care management
8. Promote adaptive urban flood management
9. Expand and promote wildlife management BMPs

The loading estimates presented with each recommendation are based on the predicted worst-case scenario loadings that were defined in Chapter 4 at mid-range flow rates. Not all sources could be modeled so not all management measures can have a quantifiable *E. coli* load reduction. These measures are still known to have a potential reduction in water quality pollutants that further the objectives of reducing *E. coli* and nutrient concerns. The estimates cannot predict actual loadings or load reductions that are occurring in the streams of the watershed. Actual reductions depend on several factors that cannot all be accounted for thus adaptive implementation strategies may be needed. Future monitoring of Rowlett Creek sites as well as any BMPs that are constructed in response to this WPP would Financial and technical resources for these measures are included in Chapter 6.

Management Measure 1: Mitigate urban stormwater runoff problems

A major source of *E. coli* and nutrients entering water bodies in the watershed is stormwater generated in urban areas. Due to the high percentage of total land cover being developed in the watershed, the chances of bacteria loading from urban impervious surfaces are relatively high (Jiang et al., 2007; Schueler & Holland, 2000; Tate et al., 2004). The main objective of this management measure is to collaborate with local municipalities to identify and install green infrastructure (GI), also called Low Impact Development (LID), BMPs to manage stormwater runoff that can serve as demonstrations for stakeholders and residents throughout the watershed (Lombardo et al., 2000). An additional objective is to expand existing stormwater management education and outreach programs to educate residents and stakeholders on stormwater BMPs. GI BMPs can also be described as nature-based solutions or blue-green infrastructure, and these practices use nature-based or green engineering to mitigate stormwater pollution. Options include rain gardens, rain barrels/cisterns, permeable pavements, bioswales, bioretention, green roofs, and riparian buffers. Projects should include monitoring the effectiveness of the BMPs implemented and applying modifications as necessary to make sure water quality requirements are being met for the watershed (Dressing et al., 2016).

These BMPs can be designed based on the precipitation amount, amount of pollutant reduction needed, and location for implementation. Load reduction will depend on the location, size, and type of design installed. Thus, the most effective BMP can be installed based on each site selected under technical guidance. The entities involved in executing the recommendations include Texas A&M AgriLife, Texas A&M Forest Service, Texas Water Resources Institute, cities, counties, contractors, and property owners. Previous studies provided specific recommendations regarding the siting of such practices within urban developments (Jack et al., 2022; Heidari et al., 2023)). Table 5-1 shows suggested locations for the above-mentioned practices. The feasibility of installation of such practices is contingent on each site characteristics (e.g. land ownership (public or private, width of medians, proximity to stormwater outlets, access to site, etc.). Due to these factors and due to the fact that mapping every house, median, park, parking lot is not possible at the project area scale, it is recommended to use Table 5.1 and work with the local government and other stakeholders when deciding on a BMP in site for stormwater Management Table 5-2 summarizes management measures for urban stormwater management.

Table 5-1. Description and siting criteria for the stormwater BMPs.

Rain gardens	Rainwater Harvesting	Permeable Pavement	Bioswales	Bioretention	Green Roofs	Riparian Buffer
Description 6-8” depression with wetland facultative native plants	**Description** Cistern or barrel that collect water off roof tops	**Description** Pervious paving material such as pervious concrete or interlocking concrete pavers	**Description** Unlined stormwater conveyance that has vegetation and rocks to slow water	**Description** Similar to rain garden with 3-4’ of soil replaced with engineered soil. Usually includes a perforated pipe	**Description** Adding soil and plants on rooftops to capture water before it reaches downspouts	**Description** Vegetated buffer on streambanks to reduce erosion and capture pollutants
Potential Sites • House yards • Parks • Road medians • Public sidewalks	**Potential Sites** • Any structure with gutter and downspouts	**Potential Sites** • Parking lots • Street parking • Driveways • trails	**Potential Sites** • Sites replacing concrete channels	**Potential Sites** • Parking lot medians • Parks and trails • Road Medians	**Potential Sites** • Any structure with foundations that can carry the additional load (e.g. multiple floor buildings and overpasses	**Potential Sites** • Small creeks streambanks

Table 5-2 Management Measure 1: Mitigate urban stormwater runoff problems.

Pollutant Source: Urban Stormwater Runoff			
Problem: Fecal bacteria, nutrient loading, and erosion from stormwater runoff in developed areas			
Objectives: 1. Identify and implement green infrastructure (GI) (i.e., LID) BMPs in coordination with cities, counties, and property owners. 2. Organize general stormwater management education and outreach programs. 3. Educate residents about stormwater BMPs. 4. Monitor the effectiveness of BMPs.			
Location: Entire watershed (See Figure 4-6)			
Critical Areas: Urban areas of the watershed that are already developed			
Goal: Reduce *E. coli* loading associated with urban stormwater runoff through implementation of green stormwater infrastructure BMPs as appropriate and increase awareness of stormwater pollution and management.			
Description: Potential locations and types of GI BMPs for stormwater management demonstration projects will be identified in coordination with the local cities, counties, public works, and property owners. Examples of GI include green roofs, riparian buffers, vegetated bioswales, bioretention, permeable pavement, etc.			
Implementation Strategy			
Participants	**Recommendations**	**Period**	**Costs**
Cities, counties, property owners, contractors	Identify and install GI BMPs as funding becomes available	2025-2034	~$6-$45/sq. ft
Texas A&M Forest Service, cities, counties, TWRI	Conduct riparian, wetland, and/or stream restoration projects and monitoring	2025-2034	~$500,000/project
TWRI, AgriLife Extension, property owners, cities, counties, regional entities	Deliver education and outreach to property owners on stormwater BMPs, in multiple languages where applicable	2025-2034	N/A
Estimated Load Reduction			
Installation of stormwater GI BMPs that reduce runoff or treat bacteria will result in direct reductions of bacteria loading. Potential load reductions were not calculated because the size, type, and location of projects installed will determine the potential load reductions and these have not yet been identified.			
Effectiveness	Moderate to High: The effectiveness of GI BMPs at reducing bacteria and nutrient loadings is dependent on the design, site, and maintenance of the BMP		
Certainty	Moderate: Installation of GI BMPs requires sustained commitment from city officials or property owners.		
Commitment	Moderate to High: Urban stormwater management is a priority for cities.		
Needs	High: Support in the form of financial, technical, and educational resources is needed to identify the best application of and adoption of GI solutions.		

Management Measure 2: Reduce pet waste runoff and promote proper disposal

Due to the amount of developed urban space within the watershed, dog waste is a large potential contributor to *E. coli* loads in the watershed, and through analysis was identified as the greatest source. There are an estimated 186,994 dogs within the watershed. Most dogs live either in or near a human dwelling, or in an animal shelter, making their waste management much simpler than other potential sources in the watershed. If not properly managed, dog waste is transported downstream during storm events, mostly via overland flow. Picking up and properly disposing of pet waste is a simple and effective way to reduce *E. coli* and excess nutrients in the watershed. Recommendations for management include installing and maintaining pet waste collection stations in public areas like parks and trails and expanding education campaigns showing the environmental benefits of properly disposing of pet waste. Education and outreach should target residents that are renters living in multi-family housing complexes and the property managers since they have the densest pet populations and concentration of pet waste per land area. A further strategy is to develop and implement K-12 student education through educator programs to teach students who are pet caretakers; additionally, children usually share what they learned with family members and can access some hard-to-reach audiences. Pet waste stations for multi-family properties and homeowners' association (HOA)-managed dog parks should be supported with resources. Installing GI BMPs near dog parks, trails, and multi-family complexes close to the waterways can help further reduce bacteria and nutrient loading from pet waste. Table 5-3 summarizes management measures for reducing pet waste runoff.

Due to the large portion of contributions linked to dogs in the watershed, making up an estimated 57% of *E. coli* loading, measures to reduce pet waste will provide the greatest reductions. Assuming 12% of dog owners reached, change their behavior with a 75% effectiveness at removing bacteria, disposing of dog waste could result in an annual *E. coli* reduction of 1.93E+16 cfu. The complete explanation of the calculations and assumptions used for this estimate are in Appendix C.

Table 5-3 Management Measure 2: Reduce pet waste runoff and promote proper disposal.

Pollutant Source: Pet Waste (Dog)			
Problem: Improperly disposed dog waste is left on land surfaces and runoff leads to bacteria and nutrient loading into streams			
Objectives: 1. Expand education and outreach to residents on impacts of pet waste and need for proper disposal. 2. Stock, maintain, and install pet waste stations.			
Location: Entire watershed (See Figure 4-7)			
Critical Areas: Multi-family residences and other high pet concentration areas in close proximity to waterways			
Goal: Reduce the amount of dog waste in the watershed that may wash into water bodies during runoff events by providing educational and physical resources to increase stakeholder awareness of the water quality and potential health issues caused by excessive dog waste**.**			
Description: Expand distribution of educational messaging regarding the need to properly dispose of pet waste in the watershed. Specifically target renters, multi-family property management, K-12 educators, and general public. Install, stock, maintain, or replace existing dog waste stations in parks and other public areas to facilitate increased proper disposal of dog waste.			
Implementation Strategy			
Participants	**Recommendations**	**Period**	**Costs**
Cities, counties, property owners, HOAs, independent school districts (ISDs)	Develop and provide educational resources and outreach, in multiple languages where applicable	2025-2034	$50,000
Cities, counties, property owners, HOAs	Provide needed maintenance supplies for at least 50 pet waste disposal stations @ $85/station	2025-2034	$4,250
Cities, counties, property owners, HOAs	Install/replace 25 pet waste disposal stations @ $500/station	2025-2034	$12,500
Cities, counties, HOAs	Identify and install GI BMPs as funding becomes available for onsite treatment of runoff (See Table 5.1)	2025-2034	~$6- $45/sq. ft.
Cities, counties, HOAs	Develop/adopt and enforce proper pet waste disposal ordinances and by-laws	2025-2034	N/A
Estimated Load Reduction			
Load reductions resulting from this management measure are reliant on changes in people's behavior. Assuming 12% of targeted individuals respond by properly disposing of pet waste with a 75% effectiveness of removal, the annual load reduction would be approximately 1.93E+16 cfu of *E. coli* per year (Appendix C).			
Effectiveness	High: Collecting and properly disposing of dog waste is known to prevent *E. coli* and nutrients from entering local waterways and will directly reduce the quantity of *E. coli* in the watershed.		
Certainty	Low: Many dog owners already collect and properly dispose of dog waste. Those who do not may be a difficult audience to reach or convince that dog waste should be collected and discarded properly despite their respective reasons for not doing so.		
Commitment	Moderate: Most parks, trails, and residential complexes currently have pet waste stations. However, maintenance is less frequently conducted than needed. Meanwhile, little to no enforcement occurs to fine owners that do not pick up after their pets.		
Needs	Moderate to High: Pet waste stations are relatively inexpensive, and the additional work required to maintain stations should be minimal. Installation of GI BMPs need financial, technical, and educational resources support.		

Management Measure 3: Expand and Promote BMPs for feral cat populations

Due to the amount of urban area within the watershed, feral cat waste is another large potential contributor to *E. coli* loads in the watershed, and through analysis was identified as the second greatest source. There are an estimated 98,800 feral cats within the watershed, though this number can only be assumed based on some national estimates. Most feral cats live outdoors near a human dwelling and stay in what are referred to as colonies with populations of 10-200, making managing their waste more complicated than household pets. Implementing TNR style programs can reduce feral cat colony populations, though this requires intensive long-term (e.g., 10+ years) management to produce these results. Successful programs incorporate strong adoption/fostering efforts, coordinate with cat colony caregivers, make constant trapping efforts, and implement strategies to reduce pet abandonment. Providing financial resources for current TNR programs that are locally active, education and outreach on the BMPs for feral cat colonies and TNR programs can reduce the *E. coli* and nutrient loading in the watershed. Table 5-4 summarizes management measures for feral cat populations.

Recommendations include providing low-cost pet and feral cat sterilizations, providing cat traps for current or new programs, and educating pet owners and colony caregivers on BMPs. Some BMPs for managing feral cat colonies include increasing the number of trapped feral cats introduced into adoption programs if cat disposition is suitable for a household, rather than returning them outdoors. Several local operations support and provide these BMPs, including the Humane Society of North Texas, Feral Friends, City of Garland TNR Program, and Texas Coalition for Animal Protection. Additional resources on available programs can be found at the TNR website[2]. It's important to educate residents and other stakeholders about the impacts feral cats have on water quality and educational materials on BMPs should be developed in collaboration with local animal rescues and clinics, and TNR programs. Education and outreach should target residents who are renters living in multi-family housing complexes and property managers since they have dense populations and higher pet abandonment. Installing GI BMPs for waste runoff management near colonies, such as rain gardens or small sand pits where cats can eliminate waste without it running directly into stormwater systems. Some plants and substrates can be considered for these BMPs that can either act as a deterrent (e.g., lavender, Texas verbena/*Verbena halei*, horsemint/*Monarda citriodora*, pebbles) or attractant (e.g., sand, wood chips, catmint/*Nepeta x faassenii*). Clean Water Act §319(h) Nonpoint Source Grant Program funding managed by EPA Region 6 has a current policy that funds cannot be used for feral animal trapping efforts but can be used for the efforts of GI implementation, and education and outreach.

It must be stated that the efficacy of TNR programs has been highly debated, though several studies have shown they can be effective at reducing populations (Coe et al., 2021; Dutcher et al., 2021; Hostetler et al., 2020; Hughes, 2000; McCarthy et al., 2013). Assuming 57% of annual feral cat population are sterilized from four 14-day long capture events with a 3% success rate over 10 years brings a 25% successful population reduction, the estimated annual load reduction would be approximately 6.55E+13 cfu of *E. coli* per year. A more detailed explanation of the calculations and assumptions used for this estimate are in Appendix C.

[2] https://tnrtexas.com/north-texas

Table 5-4 Management Measure 3: Expand and promote BMPs for feral cat populations

Pollutant Source: Feral Cat Waste			
Problem: Fecal bacteria loading into streams through runoff in developed urban areas from feral cats			
Objectives: 1. Reduce fecal bacteria loading from feral cats through implementation of management programs. 2. Expand education and outreach to residents and stakeholders on BMPs. 3. Monitor the effectiveness of BMPs.			
Location: Entire watershed (See Figure 4-8)			
Critical Areas: Urban areas in close proximity to waterways			
Goal: Reduce the amount of feral cat waste in the watershed that may wash into water bodies during runoff events by providing educational and physical resources to manage feral cat population increase stakeholder awareness of the water quality and potential health issues**.**			
Description: Expand and implement Trap-Neuter-Return (TNR) type programs across the watershed to reduce feral cat colony populations over the course of 10 years of implementation. Educate residents and stakeholders on water quality impacts and the BMPs for managing cat colonies. Voluntarily implement efforts to reduce feral cat populations throughout the watershed by reducing food supplies, bait trapping feral cats, reducing pet abandonment, and increasing adoption.			
Implementation Strategy			
Participants	**Recommendations**	**Period**	**Costs**
Cities, property owners, HOAs, local rescues	Provide educational resources and outreach on BMPs to residents, in multiple languages where applicable	2025-2034	$50,000
Local vet clinics, local rescues, cities, counties, residents	Provide low-cost pet and feral cat sterilization for at least 400 cats @ $50/cat	2025-2034	$20,000
Local vet clinics, local rescues, cities, counties	Provide cat trapping supplies for 40 traps @ $120/trap	2025-2034	$4,800
Cities, counties, HOAs	Identify and install GI BMPs as funding becomes available for onsite treatment of runoff (See Table 5.1)	2025-2034	~$6-$45/sqft
Estimated Load Reduction			
Load reductions resulting from this management measure are reliant on assumed high trapping rates and changes in people's behavior. Assuming 57% of annual feral cat population are sterilized for 10-year program having a 25% effective reduction, the annual load reduction would be approximately 6.55+13 cfu of *E. coli* per year (Appendix C).			
Effectiveness	Moderate: Reduction in feral cat population will result in a direct decrease in bacterial loading to the streams. However, sterilizing enough cats to decrease their overall population will be difficult.		
Certainty	Low: Increasing resident participation, even after receiving education and related resources, in TNR programs is difficult and thus limits the program capacity. Feral cats can often be difficult to track and successfully capture.		
Commitment	Moderate to High: TNR programs already exist throughout the watershed and reducing feral cat populations is important to conservation groups, animal rescues/activists, and the public. Meanwhile, not all Department of Animal Services in this watershed have TNR programs or partnerships with non-governmental organizations (NGOs) that do.		
Needs	Moderate to High: Low-cost clinic programs are relatively inexpensive for providing services to cats as well as the educational resources and outreach needed. Significant funding is needed to expand shelter availability to increase adoptions.		

Management Measure 4: Promote the development of WQMPs or conservation plans

E. coli from livestock is a small contributor of *E. coli*, and a potential source of nutrients, in the watershed. Livestock waste is mostly transported during runoff events, from upland areas to downstream waters. With livestock, fecal deposition is dependent on the location of food, water, and shelter, and is therefore easier to control than other types of wildlife that aren't contained. Moving feeding locations and adjusting fencing to control their location can reduce *E. coli* runoff. Due to the potential *E. coli* load from livestock, these adjustments have the potential to reduce the amount of *E. coli* that ends up in runoff and into waterbodies within the watershed.

A water quality management plan (WQMP) or conservation plan (CP) is a site-specific plan developed through and approved by soil and water conservation districts (SWCDs) or NRCS for agricultural or silvicultural lands. The plan includes appropriate land treatment practices, production practices, management measures, technologies, or a combination of two or more practices (Brenner et al., 1996; Peterson, 2022). The purpose of WQMPs is to achieve a level of pollution prevention within state water quality standards (Osmond et al., 2012). NRCS, the Texas State Soil and Water Conservation Board (TSSWCB), and local SWCDs provide technical assistance for developing plans, some CPs offer financial assistance for landowners. There is a goal of developing and implementing up to 5 plans in the watershed. Agriculture lands are sparse in the watershed and are mainly found in subwatersheds 1, 2, and 5. The implementation of these plans estimate an annual *E. coli* reduction of 3.99E+13 cfu. The complete explanation of the calculations and assumptions used for this estimate are in Appendix C.

Several equestrian stables are found along Rowlett and Cottonwood Creeks. Depending on operation practices these may not qualify as agriculture use under some local government land appraisal districts. This also may apply to some small-scale or hobby farms that exist around the area. Thus, these operations may need different access to resources for implementing BMPs based on their uses. Educational, technical and financial resources for small-scale and urban agriculture[3] are provided by the NRCS. Some BMPs identified for stables include on-site composting of manure, vegetated filter strips, and bioswales to reduce bacteria and sediment loading into the waterways. Table 5-5 summarizes management measures for livestock.

[3] https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/texas/small-scale-and-urban-agriculture-texas

Table 5-5 Management Measure 4: Promote the development of WQMPs & conservation plans (CP)

Pollutant Source: Livestock			
Problem: Direct and indirect fecal bacteria and nutrient loading due to livestock in streams, riparian degradation and overgrazing			
Objectives: 1. Work with landowners to develop property-specific CPs and WQMPs to protect water quality and provide technical and financial assistance. 2. Reduce fecal loading from livestock in riparian areas. 3. Educate producers, hobby farm owners, and equestrian stable managers on BMPs			
Location: Subwatershed 1, 2 and 5, and properties near waterways (See Figure 4-9)			
Critical Areas: Properties with creek and riparian zone access			
Goal: Reduce *E. coli* loading from livestock through education and developing WQMPs/CPs focused on minimizing the time spent by livestock in the riparian zones and better use of grazing resources across the property.			
Description: CPs and WQMPs will be developed with operators to implement BMPs that reduce water quality impacts from overgrazing, time spent in and near streams or riparian areas, and runoff from grazed lands. Practices will be identified and developed in consultation with NRCS, TSSWCB and local SWCDs as appropriate. Education program delivery to support and promote implementation adoption from livestock producers, hobby farm operations (i.e., small-scale farms), and equestrian stables.			
Implementation Strategy			
Participants	**Recommendations**	**Period**	**Costs**
Producers, NRCS, TSSWCB, SWCDs	Develop, implement, and provide financial assistance for up to 5 livestock WQMPs/CPs @ $30,000/plan	2025-2034	$150,000
AgriLife Extension, NRCS, SWCDs, cities, hobby farmers, stable managers	Deliver education and outreach programs and workshops to landowners, in multiple languages where applicable	2025-2034	N/A
Estimated Load Reduction			
Prescribed management will reduce loadings associated with livestock by reducing runoff from pastures and rangeland as well as reducing direct deposition by livestock. Implementation of 10 WQMPs and CPs is estimated to reduce annual loads from livestock by 3.99E+13 cfu of *E. coli* per year in the watershed (Appendix C). Reductions related to education and outreach for hobby farms and non-grazing equestrian stables are not quantified but will result in load reductions that vary by operation size and applicable practices.			
Effectiveness	High: Decreasing the time that livestock spend in riparian areas and reducing runoff through effectively managing vegetative cover will directly reduce nonpoint source contributions of bacteria and other pollutants to creeks.		
Certainty	Moderate: Landowners acknowledge the importance of good land stewardship practices and management plan objectives. However, financial incentives are often needed to promote WQMP and CP implementation.		
Commitment	Moderate: Landowners are willing to implement stewardship BMPs shown to improve productivity. Costs are often prohibitive, so financial incentives are needed to increase implementation rates.		
Needs	High: Financial costs are a major barrier to promoting implementation. Education and outreach are needed to demonstrate benefits of plan development and implementation to producers and BMPs to small-scale farms and equestrian stable owners.		

Table 5-6 Management Measure 5: Conduct Urban NPS pollution education workshops.

Pollutant Source: Landowners and Residents Without Education Resources			
Problem: Due to lack of knowledge about stormwater, pet waste, lawn, grazing lands, and water resource management, landowners and residents might not adopt BMPs for them.			
Objectives: 1. Promote and expand education and outreach efforts in the watershed. 2. Develop and expand education and outreach efforts for K-12 students in the area. 3. Provide technical assistance and training on watershed education.			
Location: Entire watershed (See Figure 4-6)			
Critical Areas: K-12 schools and colleges			
Goal: Educate landowners, residents, and students about sources of *E. coli* and other pollutants in the watershed and various ways to manage them.			
Description: Education delivery will mainly focus on BMPs for urban stormwater pollution using GI, pet waste, and landscape and water resource management. Work with local ISD educators to determine existing needs in their schools and what would be helpful. Develop or integrate existing educational materials for schools and provide training opportunities for teachers to learn the materials and how to administer them effectively.			
Implementation Strategy			
Participants	**Recommendations**	**Period**	**Costs**
AgriLife Extension, TWRI, Counties, Watershed Coordinators	Develop and deliver educational and outreach materials to residents, landowners, and colleges	2025-2034	N/A
AgriLife Extension, TWRI, ISDs, Watershed Coordinators	Develop and deliver education and outreach materials to K-12 teachers and students. Train teachers on watershed protection planning.	2025-2034	~$25,000
Estimated Load Reduction			
Load Reductions from this management measure were not quantified, though if behaviors change, they will reduce bacteria loading along with other related water pollutants – e.g., sediment and nutrients.			
Effectiveness	Low to Moderate: While there may not be a direct correlation to water quality improvement, education and outreach are effective tools to create awareness and behavior change.		
Certainty	Moderate: Predicting behavior change is difficult but can be tracked through surveys, tests, and other evaluation methods.		
Commitment	Moderate to High: There is a lot of interest in the watershed in GI and working with youth and the general public to develop environmental conservation programming.		
Needs	Moderate: Some financial and technical resources will be required to develop educational materials and coordinate training.		

Management Measure 5: Conduct Urban NPS Pollution Education Workshops

The main objective is to continue and expand the existing NPS Pollution Education workshops educating landowners and residents on identifying sources of *E. coli*, nutrients, and other pollutants in the watershed that originate from urban sources. Often, new or small acreage landowners and multi-family property managers may be unaware of BMPs and the resources available for implementation. Educating property managers, landowners, and residents to manage stormwater, pet waste, lawn, grazing lands, and water resource management is very important to prevent *E. coli* and nutrients from getting into nearby water bodies. A key aspect of conducting educational workshops is to expand these opportunities for K-12 schools to teach educators about urban NPS pollution and its BMPs, so these can be integrated into lessons delivered to students. These education workshops will further protect and improve local water resources by ensuring that appropriate people are informed about new techniques, requirements, and resources. Table 5-6 summarizes management measures for urban NPS pollution education.

Table 5-7 Management Measure 6: Reduce illegal dumping and litter.

Pollutant Source: Illegal Dumping and Litter			
Problem: Illegal dumping of waste and litter accumulation in and along waterways			
Objectives: 1. Promote and expand education and outreach efforts in the watershed. 2. Install and maintain trash receptacles in public areas and along water bodies. 3. Support cleanups and other efforts to reduce illegal dumping with various stakeholders.			
Location: Entire watershed (See Figure 4-6)			
Critical Areas: Focus on urban areas, trails, and bridges near waterways or riparian zones			
Goal: Reduce litter and illegal dumped waste that reaches the waterways throughout the watershed.			
Description: Education and outreach materials will be developed and delivered to residents throughout the watershed on the proper disposal of waste materials (both nonhazardous and hazardous). Working with various volunteer organizations and related stakeholders to support cleanup efforts and outreach to reduce illegal dumping and littering.			
Implementation Strategy			
Participants	**Recommendations**	**Period**	**Costs**
AgriLife Extension, cities, counties, nonprofits	Develop and deliver educational and outreach materials to residents, in multiple languages where applicable	2025-2034	~$5,000
Cities, counties, municipalities, HOAs	Expand enforcement of illegal dumping ordinances in common dumping areas, and install and maintain at least 15 trash receptacles on trails and walkways, or other identified problem areas @ $500-$1,000/receptacle	2025-2034	$7,500-$15,000
Cities, counties, nonprofits, HOAs, residents, regional entities	Coordinate multiple cleanup events and similar reducing illegal dumping program events	2025-2034	N/A
Estimated Load Reduction			
E. coli load reductions are likely minimal from this management measure and were not quantified. Though, preventing illegal dumping, especially animal carcasses or food products, near waterways can reduce bacteria loads as these attract wildlife that can directly deposit into streams.			
Effectiveness	Low: Preventing illegal dumping near waterways is likely to reduce bacteria loads by a small amount because, no noted instances were from animal carcasses.		
Certainty	Moderate: Anticipating changes in resident behavior due to education and outreach is difficult at best. Reaching residents that illegally dump is more difficult.		
Commitment	Moderate: Stakeholders indicate illegal dumping and littering occurs. However, enforcement can be difficult, and commitment of limited resources will likely remain low in some areas.		
Needs	Moderate: Some financial resources will be required to install and maintain trash receptacles and develop educational materials. Though, information could be incorporated into ongoing watershed/stormwater-related educational and outreach efforts.		

Management Measure 6: Reduce illegal dumping and litter

Based on stakeholder input, illegal dumping occurs in creeks within the watershed. The waste mostly consists of trash and debris that washes into and accumulates in the creeks. Figure 5-1 shows trash accumulated along portions of Rowlett Creek in the Rowlett Creek Preserve, located within subwatershed 5 approximately 2.25 miles upstream from the outfall of Rowlett Creek. Due to the nature of the materials being dumped, it is unlikely that it is a major contributor to bacteria loads in the watershed. Despite that, reducing all types of pollution in the watershed increases the overall health and water quality of the watershed, and should be addressed. The development and delivery of educational and community outreach materials on proper trash disposal could be constructive. Installing and maintaining trash receptacles in and around the local public trails, walkways, and parks will reduce the amount of trash accumulating into waterways. It is also recommended that coordinating multiple cleanup events along and in streams within the watershed will reduce pollutants entering the waterways. Table 5-7 summarizes management measures to reduce illegal dumping and litter.

Figure 5-1. Trash build-up in Rowlett Creek within the Rowlett Creek Preserve.

Management Measure 7: Promote BMPs for urban lawn care management

Nitrogen levels in the form of TKN, or organic forms, were found to be above screening levels. Though these are not required to be met, doing so can improve watershed health. Urban lawn residue and waste runoff carries grass clippings, leaf litter, fertilizers, and pesticides, making it a common contributor to excess nutrients, bacteria, and other pollutants in urban watersheds if not properly managed. Educating homeowners and property managers on the BMPs for lawn care management can reduce the pollutants impacting the Rowlett Creek watershed. BMPs include proper disposing of grass clippings and fallen leaves, soil testing before applying fertilizers, and installing GI BMPs in areas near creeks. Household lawns are likely a greater contributor to this source; however, there are several golf courses found on or next to the creeks of this watershed and are contributing sources. Conducting soil tests in both agricultural and urban areas can determine soil composition and nutrient levels existing. Therefore, soil testing is included to prevent nutrient runoff into nearby waterways by ensuring the proper rates and timing of fertilizer applications. This practice can also be applied to water resource management to create adaptive watering regimes so there is no excess used which increases the runoff. Installing or maintaining GI within golf courses can help reduce the loadings, as most properties in this watershed already implement the other practices. Similarly, the manicured or landscaped public parks can be high in fertilizer use as well. Table 5-8 summarizes management measures for urban lawn care BMPs.

Table 5-8 Management Measure 7: Promote BMPs for urban lawn care management

Pollutant Source: Lawn Residue and Waste			
Problem: Improper lawn care management in the form of excessive lawn residue waste, fertilizer, and pesticide runoff into streams leads to bacteria and nutrient loading			
Objectives: 1. Promote and expand education and outreach to landowners on lawn care BMPs.			
Location: Entire watershed (See Figure 4-6)			
Critical Areas: Urban areas and golf course properties near waterways			
Goal: Reduce bacteria, nutrient, and chemical runoff from lawns in the watershed that may wash into waterways during precipitation events**.**			
Description: Expand distribution of educational messaging on proper lawn care management to reduce excess runoff of bacteria and nutrients. Educate landowners on water resource management BMPs for lawn care and landscaping, proper disposal of lawn clippings, and proper application of fertilizers, pesticide, and other chemicals.			
Implementation Strategy			
Participants	**Recommendations**	**Period**	**Costs**
AgriLife Extension, TWRI, Regional Entities, HOAs	Develop and deliver lawn care education and outreach resources	2025-2034	N/A
AgriLife Extension, TWRI, Regional Entities, HOAs, golf courses, Cities, Counties,	Conduct workshops on soil testing, ways to determine nutrients application amounts, and water resource management	2025-2034	~$20,000
Landowners, Golf Courses, Cities	Conduct soil tests before applying fertilizer and watering regimes	2025-2034	~$12/test
Cities, counties, property owners, contractors	Identify and install GI BMPs as funding becomes available (See Table 5.1)	2025-2034	~$6-$45/sqft
Estimated Load Reduction			
Load reductions from this management measure were not quantified, but if behaviors change, they will reduce loads. No load reductions for nutrients are currently quantified, though a reduction will be beneficial to water quality and stream health as TKN and nitrate are above screening levels and a concern.			
Effectiveness	Moderate: Installation of GI BMPs can reduce bacteria and nutrient loadings but is dependent on the design, site, and maintenance of the BMP. Additionally, extra time and effort involved may hinder implementation.		
Certainty	Low: Anticipating changes in landowner behavior due to education and outreach is difficult.		
Commitment	Moderate: Many stakeholders indicate that soil testing is necessary; however, administration may be difficult in all areas. The issue is not a high priority and commitment of limited resources will likely remain low.		
Needs	Moderate: Some financial resources will be required to develop educational materials in languages other than English. Information could be incorporated into ongoing watershed related educational and outreach efforts.		

Management Measure 8: Promote adaptive urban flood management

Urban flooding occurs when a greater portion of the land is made up of impervious surfaces such as concrete and buildings, causing rainwater to travel across the ground faster and quickly accumulate. This can also be exacerbated by erosion which accumulates sediment and debris creating blockages in stormwater infrastructure. Increasing the surface area of green spaces can offset impervious surface areas and reduce stormwater runoff. Though no direct measures were calculated for the bacteria, these impacts do contribute to bacteria and nutrient loading in the watershed and BMPs can reduce these loadings (EPA et al., 2014; Jack et al., 2022). Promoting the development of local city Adaptive Flood Management Plans that incorporate aspects of water quality management can improve long-term management of water resources. By developing long-term adaptive management plans, city municipalities and utility districts can identify and outline measures to best manage urban stormwater infrastructure to reduce flooding and its water quality impacts triggered by increasing precipitation intensity and drought events over the coming decades. This should include guidance and implementation strategy on the number, location, and type of stormwater BMPs that not only mitigate flooding but also treat stormwater runoff pollution. Examples would include vegetated bioswales, stormwater tree trenches, and other blue and green infrastructure. Other recommendations include converting existing developed land into green spaces and implementing erosion control measures throughout the watershed. Table 5-9 summarizes management measures for urban adaptive flood management.

Table 5-9 Management Measure 8: Promote adaptive urban flood management.

Pollutant Source: Urban Flooding and Sediment			
Problem: Intense precipitation events in urban areas lead to flooding intensified by erosion, sediment buildup, impermeable surfaces and an increase in bacteria and nutrient loading			
Objectives: 1. Develop collaborative flood resiliency/adaptation plans that incorporate water quality concerns. 2. Identify and install GI BMPs in coordination with cities, counties, and municipalities. 3. Promote and expand education of flooding impacts on water quality and BMPs. 4. Monitor the effectiveness of BMPs.			
Location: Entire watershed (See Figure 4-6)			
Critical Areas: Urban areas with minimal green space and construction areas			
Goal: Reduce urban flooding throughout the watershed			
Description: Developing and implementing collaborative adaptive flood management plans that incorporate water quality concerns with holistic resource management strategies. Install and promote GI BMPs to mitigate flooding and erosion issues in identified areas of concern**.** Promote and expand education of urban flooding impacts on water quality to residents and stakeholders. These practices can also be used to mitigate the occurrence of illicit discharge of wastewater.			
Implementation Strategy			
Participants	**Recommendations**	**Period**	**Costs**
AgriLife Extension, TWRI, City Planners, Regional Entities, Watershed Coordinators	Coordinate with stakeholders to develop local adaptive flood management plans that incorporate water quality concerns	2025-2034	N/A
Cities, counties, Regional Entities, contractors	Identify and install GI BMPs as funding becomes available (See Table 5.1)	2025-2034	~$6-$45/sq.ft.
Cities, Counties, Regional Entities	Perform routine stormwater infrastructure assessments for identification of illicit discharges, proper storm drain management, and identify erosion and prevent erosion	2025-2034	$16,000
Estimated Load Reduction			
Installation of stormwater GI BMPs that reduce runoff or treat bacteria will result in direct reductions in bacteria loading. Potential load reductions were not calculated because the size, type, and location of projects installed will determine the potential load reductions and these have not yet been identified.			
Effectiveness	Moderate to High: The effectiveness of GI BMPs at reducing bacteria and nutrient loadings is dependent on the design, site, and maintenance of the BMP. Developing long-term planning strategies can reduce loading but it depends on adoption.		
Certainty	Moderate: Adoption of adaptive flood plans and installation of GI BMPs requires sustained commitment from city officials or property owners.		
Commitment	Moderate to High: Urban stormwater management is a priority for cities and regional entities.		
Needs	High: Support in the form of financial, technical, and educational resources is needed to identify the best application of and adoption/implementation of adaptive flood management planning and related GI solutions.		

Management Measure 9: Expand and promote wildlife management BMPs

Overpopulation of wildlife species can increase the loading of *E. coli* and nutrients across the watershed. Potential *E. coli* and nutrient loading from waterfowl and feral hogs across the watershed represents a small portion of the overall potential source contributions in the Rowlett Creek watershed. Habitat loss due to degradation and human development pushes wildlife into remaining green spaces which are often riparian zones and city parks in the case of highly urbanized areas, increasing impacts on water quality (Horton et al., 2023).

Habitat loss and human behaviors, for example feeding wildlife, can create ecological "traps" for migratory bird species leading to overpopulation of migratory waterfowl in urban detention ponds and water bodies which degrades water quality (Horton et al., 2023; Wildlife Center of Virginia, 2025). Local bird experts (e.g., TPWD, Trinity River Audubon Center, NRCS agents) can aid in conducting a census of waterfowls in local ponds and potential hotspots will aid in improving knowledge of the potential impact waterfowls have on water quality in the watershed. With the assistance of local bird experts, a series of recommendations on BMPs for managing healthy waterfowl populations can be developed and implemented across the watershed for public landowners and land managers to implement. The USDA (2025) has identified BMPs could include educating park visitors on the impacts of feeding waterfowl, adding tall shoreline vegetation and no-mow zones. It is advised to reach out to experts who can aid in developing and implementing BMPs to be sure they are in compliance with the Migratory Bird Treaty Act of 1918 (FWS, 2025). Education and outreach can be used to educate residents on BMPs for interacting with waterfowl to reduce feeding activities by humans.

Feral hogs are highly adaptable, allowing them to survive and maintain in suburban environments where they can travel into and through riparian corridors. Feral hogs have not been sighted within the watershed in recent years but are known to be in areas surrounding the watershed and are a concern of the stakeholders, therefore specific subwatersheds are being targeted for trapping and removal efforts of feral hogs. Removal of feral hogs can have an immediate impact on water quality, with an annual 10% removal effort loads could be reduced by and estimated 1.63E+11 *E. coli* cfu per year. A more thorough investigation into the potential presence of feral hogs would help to target locations for removal efforts and improve the success of this WPP for attaining water quality targets.

Removal techniques of feral hogs should be considered based on property owner and local hunting ordinances. The majority of land in the watershed is residential and within city limits, and much of the suitable land for feral hogs are owned and managed by municipalities. Education and outreach targeting private and public landowners on BMPs for managing feral hog populations in urban environments could lead to reductions in feral hog populations. Excluding feral hogs from supplemental feeding opportunities through fencing and proper storage is an effective management strategy that can be applied without reticence to urban areas. Education and outreach workshops can educate residents and landowners on BMPs for reducing feral hog populations and their access to food sources. AgriLife Extension [Feral Hog Management Program][4] has developed a variety of educational resources available.

Trapping and removal efforts on public land can be established with the proper authorizing agencies, cities and TPWD, with technical expertise from AgriLIfe Extension and TPWD. Through the implementation of a trap-share program partnering municipalities can pool resources to obtain and maintain live traps to capture and remove feral hogs throughout the participating entities areas of the watershed. Clean Water Act §319(h) Nonpoint Source Grant Program funding managed by EPA Region 6 has a current policy that funds cannot be used for feral animal trapping or eradication efforts but can be used for the efforts of GI implementation, and education and outreach. Table 5-10 summarizes management measures for urban waterfowl and feral hogs.

[4] https://feralhogs.tamu.edu/

Table 5-10. Management Measure 9: Expand and promote wildlife management BMPs.

<table>
<tr><th colspan="4">Pollutant Source: Urban Waterfowl and Feral Hogs</th></tr>
<tr><td colspan="4">Problem: Direct and indirect fecal bacteria and nutrient loading in city parks from waterfowl and riparian corridors from feral hogs</td></tr>
<tr><td colspan="4">Objectives: 1. Conduct surveys for waterbird species in perceived problem areas to establish population estimates. 2. Work with bird experts to develop and implement BMPs at identified areas. 3. Reduce easily accessible food sources for waterfowl and feral hogs. 4. Reduce fecal loading from feral hogs through trapping and population reduction. 5. Provide education and outreach to stakeholders on BMPs to deter the presence of feral hogs.</td></tr>
<tr><td colspan="4">Location: Entire watershed for waterfowl (See Figure 4-11); Subwatershed 1 and 5 for feral hogs (See Figure 4-10)</td></tr>
<tr><td colspan="4">Critical Areas: Focus on parks in close proximity to waterways and riparian zones</td></tr>
<tr><td colspan="4">Goal: Reduce wildlife (i.e., waterfowl and feral hogs) bacteria pollution in public use areas and riparian zones through the implementation of BMPs. Manage feral hog population to reduce current numbers by 10%.</td></tr>
<tr><td colspan="4">Description: Overpopulation of waterfowl in public use area ponds and lakes can worsen water quality problems. Establishing an estimate for the type (resident, migratory, etc.) and population numbers of waterfowl species helps experts develop a management plan that will improve water quality and bird population health in the watershed. Reduction of feral hog population through voluntary trapping implementation efforts to reduce populations in targeted subwatersheds. Provide education and outreach on BMPs for wildlife management.</td></tr>
<tr><th colspan="4">Implementation Strategy</th></tr>
<tr><th>Participants</th><th>Recommendations</th><th>Period</th><th>Costs</th></tr>
<tr><td>AgriLife Extension, cities, residents, TPWD, Trinity River Audubon Center</td><td>Conduct waterfowl census surveys; work with avian and stormwater experts to implement BMPs to manage populations; educate the public on BMPs</td><td>2025-2034</td><td>$10,000-$30,000</td></tr>
<tr><td>Public/Private Landowners and land managers, NRCS, AgriLife Extension</td><td>Voluntary identification of travel corridors, and deployment of trapping and hunting in these areas to reduce hog numbers; educate the public on BMPs</td><td>2025-2034</td><td>N/A</td></tr>
<tr><td>AgriLife Extension, TPWD, counties, cities</td><td>Provide support for a "trap share" program that will allow for two live traps to be shared amongst cooperating entities for placement in public greenspaces @ $5,000-$10,000/trap and @ $500/yr for support and maintenance for 10 years</td><td>2025-2034</td><td>$15,000-$25,000</td></tr>
<tr><th colspan="4">Estimated Load Reduction</th></tr>
<tr><td colspan="4">Reducing and maintaining reduced feral hog populations directly reduces fecal loading potential in the watershed. Reducing the total feral hog population by 10% of the current estimated population in the watershed is estimated to reduce potential loads by 1.63E+11 E. coli cfu per year. Implementing BMPs that reduce waterfowl year-round population can reduce E. coli potential loads, but the amount of reduction will vary depending on which management measures selected.</td></tr>
<tr><td>Effectiveness</td><td colspan="3">Moderate: Reduction in wildlife populations access to water bodies and riparian zones will result in a direct reduction in bacterial and nutrient loading to the water bodies.</td></tr>
<tr><td>Certainty</td><td colspan="3">Low to Moderate: Anticipating changes in resident behavior due to education and outreach is difficult at best. The target wildlife is highly adaptable to urban environments and difficult to manage.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate: Migratory bird and waterfowl health is a priority to many groups and stakeholders in the region. Landowners are aware of feral hogs and approve control measures.</td></tr>
<tr><td>Needs</td><td colspan="3">Moderate: Financial and technical resources will be required to implement feral hog and waterfowl population management strategies, surveys, and education and outreach efforts.</td></tr>
</table>

Table 5-11 Summary of estimated *E. coli* load reductions from management measure implementation

Management Measure	Potential *E. coli* Load Reduction (annual)
Dog waste management	1.93E+16
Feral cat population management	6.55E+13
Agricultural management	3.99E+13
Feral hog management	1.63E+11
Total reduction	**1.95E+16**
Total reduction needed[1]	8.18E+15

[1]Defined in Chapter 4, the total potential reduction exceeds reductions needed to help accomplish load reduction goals

Expected Loading Reductions

Reducing *E. coli* loads across the watershed and in Rowlett Creek is the goal of these management measures. The total estimated reduction from the management measures with calculated load reductions (2, 3, and 4) would reduce the annual load by 1.95E+16 cfu. Based on the LDC analyses, a combination of the management measures would reduce the annual *E. coli* loads by the needed 8.18E+15 cfu. The greatest expected load reductions will result from the measures recommended for pet waste, feral cats, and livestock, respectively (Table 5-11). The stormwater management measures recommended will result in load reductions; depending on the number, size, and type of GI BMPs designed and installed the load reductions could be significant while also addressing the high flow events that occur, which can be challenging for many of the other suggested management measures. The other recommendations, such as education and outreach, will result in load reductions from changes in people’s behavior, but are not easily quantified. Applying all these management measures can help meet the *E. coli* water quality standards and reduce nitrogen levels in the Rowlett Creek watershed.

Table 5-12 Management measures summary.

Management Measure	Participants	Estimated Unit Cost	Implementation goals (years after implementation begins) 0-1	2-3	4-5	6-7	8-9	10	Total Cost
Urban Stormwater Runoff									
Identify and install green infrastructure BMPs	Cities, counties, property owners, contractors	~$6-$45/sqft	As many as possible						Varies
Riparian, wetland, and stream restoration	Texas A&M Forest Service, cities, counties, TWRI	~$500,000/ project	As needed						Varies
Deliver education and outreach on stormwater BMPs	TWRI, AgriLife Extension, property owners, cities, counties, regional entities	N/A	As many as possible						N/A
Proper Pet Waste Disposal									
Develop and deliver education and outreach resources and materials	Cities, counties, property owners, HOAs, ISDs	$5,000/year	1	2	2	2	2	1	$50,000
Maintenance supplies for at least 50 pet waste stations	Cities, counties, property owners, HOAs	$85/station	5	10	10	10	10	5	$4,250
Install 25 pet waste stations	Cities, counties, property owners, HOAs	$500/station	5	5	5	5	5		$12,500
Identify and install GI BMPs	Cities, counties, HOAs	~$6-$45/sqft	As many as possible						varies
Pet waste disposal ordinances and by-laws	Cities, counties, HOAs	N/A	As needed						N/A
Feral Cat Management									
Develop and deliver educational resources and outreach	Cities, property owners, HOAs, local rescues	$5,000/year	1	2	2	2	2	1	$50,000
Feral cat and pet sterilization for at least 400 cats	Local vet clinics, local rescues, cities, counties, residents	$50/cat	40	80	80	80	80	40	$20,000
Provide cat trapping supplies for 40 traps	Local vet clinics, local rescues, cities, counties	$120/trap	10	20	10				$4,800
Identify and install GI BMPs	Cities, counties, HOAs	~$6-$45/sqft	As many as possible						varies
WQMPs and Conservation Plans									
Provide financial assistance for 5 WQMPs/CPs	Producers, NRCS, TSSWCB, SWCDs	$30,000/plan	1	2	2				$150,000

Deliver education and outreach workshops	AgriLife Extension, SWCDs, cities, hobby farmers, stable managers	N/A	As needed						N/A
Urban NPS Pollution Education									
Develop and deliver educational and outreach materials	AgriLife Extension, TWRI, Counties, Watershed Coordinators	N/A	As needed						N/A
Deliver K-12 educator workshops	AgriLife Extension, TWRI, ISDs, Watershed Coordinators	$5,000/event		2	2				~$25,000
Reduce Illegal Dumping and Litter									
Develop and deliver educational and outreach materials	AgriLife Extension, cities, counties, nonprofits	$500/year	1	2	2	2	2	1	~$5,000
Install and maintain at least 15 trash receptacles and enforce ordinances	Cities, counties, municipalities, HOAs	$500-$1,000/ receptacle			5	5	5		$7,500-$15,000
Coordinate cleanup events	Cities, counties, nonprofits, HOAs, residents, regional entities	N/A	1	2	2	2	2	1	N/A
Urban Lawn Care Management									
Develop and deliver education and outreach resources	AgriLife Extension, TWRI, Regional Entities, HOAs	N/A	As needed						N/A
Soil testing workshops	AgriLife Extension, TWRI, Regional Entities, HOAs, golf courses, Cities, Counties,	~$5,000/event		1	1	1	1		~$20,000
Conduct soil testing	Landowners, Golf Courses, Cities	~$12/test	As needed						Varies
Identify and install GI BMPs	Cities, counties, property owners, contractors	~$6-$45/sqft	As needed						varies
Adaptive Urban Flood Management									
Develop local adaptive flood management plans that incorporate water quality	AgriLife Extension, TWRI, City Planners, Regional Entities, Watershed Coordinators	N/A	1						N/A

Identify and install GI BMPs	Cities, counties, Regional Entities, contractors	~$6-$45/sqft	As many as possible						varies
Stormwater infrastructure assessments	Cities, Counties, Regional Entities	$800	2	4	4	4	4	2	$16,000
Wildlife and Feral Hog Management									
Conduct waterfowl surveys	AgriLife Extension, cities, TPWD, Trinity River Audubon Center	$10,000-$30,000	2						$10,000-$30,000
Develop BMPs for managing waterfowl populations, and deliver education and outreach materials	AgriLife Extension, cities, residents, TPWD, Trinity River Audubon Center		2						
Feral Hog management and removal workshops	AgriLife Extension, Watershed Coordinator	$7,500/each	2						$15,000
Feral hog removal	Public/private landowners and land managers	N/A	10% reduction						N/A
Trap share program - trap set-up purchases	Counties, cities, TPWD, AgriLife Extension	$5,000-$10,000/trap	2						$10,000-$20,000
Trap share program - trap maintenance	Counties, cities, TPWD, AgriLife Extension	$500/year	2	2	2	2	2	2	$5,000

Chapter 6 Plan Implementation

Introduction

A successful WPP requires implementation strategies and an outlined schedule to enact these different measures (Table 5-12). Additionally, a successful WPP needs multiple sources of support that vary depending on the level of their complexities and the BMPs being adopted. These sources include but are not limited to technical, financial, and educational outreach assistance. The implementation of this plan is an extended effort that will require active participation from various stakeholders and local entities outlined over a 10-year period.

To achieve this plan's goal of improving Rowlett Creek's water quality, it is important to identify the key sources of financial, technical and educational assistance. Working collaboratively with the existing water quality initiatives and other beneficial programs can best maximize the implementation of the management measures described in Chapter 5. The estimated costs and schedule for this WPP were made based on current best knowledge of the different BMPs. This chapter identifies the resources available to Rowlett Creek stakeholders for WPP implementation. A summary of the key stakeholders that should be engaged for the implementation of the management measures are found in Table 6-1.

Table 6-1. Rowlett Creek watershed stakeholders to engage throughout the implementation of the WPP.

Rowlett Creek Stakeholders	
Private Entities	Residents, landowners, businesses, HOAs, developers
Non-profit NGOs	Feral Friends Community Cat Alliance, TCAP, SNN, Friends of Rescue Animals, SPCA of Texas, DORBA
Local Governments	Collin and Dallas counties, Cities of Allen, Frisco, Garland, Murphy, Parker, Plano, Richardson, Rowlett, and Sachse, ISDs
State Agencies	TCEQ, TSSWCB, TWDB, TPWD, AgriLife Extension, TWRI
Regional Entities	NTMWD, TRA, NCTCOG, SWCDs (#535 and #519), ESC Region 10
Federal Agencies	USDA, NRCS
Colleges	Collin College Plano Campus, Dallas College Garland Center

Homeowner Association (HOA); Texas Coalition for Animal Protection (TCAP); Spay Neuter Network (SNN); Dallas Off-Road Bicycle Association (DORBA); Independent School Districts (ISD); Texas Commission on Environmental Quality (TCEQ); Texas State Soil and Water Conservation Board (TSSWCB); Texas Water Development Board (TWDB); Texas Parks and Wildlife Department (TPWD); Texas A&M AgriLife Extension Service (AgriLife Extension); Texas Water Resources Institute (TWRI); North Texas Municipal Water District (NTMWD) Trinity River Authority (TRA); North Central Texas Council of Governments (NCTCOG); Soil and Water Conservation District (SWCD); Education Service Center (ESC); United States Department of Agriculture (USDA); Natural Resources Conservation Service (NRCS)

Schedule, Milestones, and Estimated Costs

The implementation schedule of the Rowlett Creek WPP is set over a 10-year period. However, it can be expected to encounter challenges so additional management and time may be needed through adaptive management. The schedule, milestones, and estimated costs associated with planned implementation were discussed and developed in coordination with watershed stakeholders during the WPP development process. Management measures were selected for their ability to mitigate *E. coli* loading in the watershed and effectively manage the target sources at a reasonable cost.

A complete list of management measures, participating parties, estimated costs, and implementation goals are in Table 5-12. Implementation goals are included incrementally to reflect their anticipated implementation time frames. In many instances, acquiring funding, hiring personnel, or program initiation could delay implementation, which is why operating under the adaptive management approach is important. This approach sets incremental implementation objectives that can monitor and evaluate implementation progress. If sufficient progress is not made, adjustments will be made to increase implementation so that the established goals can be succeeded. Additionally, adaptive management can be employed to modify the approach if the initial strategy is no longer feasible. Additional monitoring of flow and water quality in the Creek and evaluation of the performance of implemented BMPs is crucial to evaluating the success of the plan implementation.

Education and Outreach

The success of WPP implementation heavily depends on education and outreach activities to enhance understanding and acceptance of BMPs for reducing pollutant loads, mainly *E. coli*, in the Rowlett Creek watershed. Nearly every management measure for this plan includes education and outreach components; the details can be found in Chapter 5. For effective outcomes, it is essential to provide stakeholders with continuous, well-organized, and relevant information and training tailored to the watershed's specific challenges. Educational programs will leverage resources and connections from various entities, utilizing local staff, topical experts, and industry specialists to deliver valuable content across different subjects. Existing programs related to identified pollutant sources in the WPP will be used, and where regional programming is insufficient, additional funding will be sought to develop new local-focused initiatives. Education and outreach should inform the public of the importance of achieving water quality standards, mainly reduction of *E. coli* in this WPP, and how the management measure or BMPs will advance this goal. Each physical BMP implementation project should prepare stakeholders for the continued proper operation and maintenance needed to maintain functionality once the project is completed in the form of educational materials and continued engagement. Though the main objective is *E. coli* reductions for this WPP, other topics such as nutrient reduction, eutrophication, GI, industrial/petrochemical contamination, illegal dumping, floatable trash, flooding, and water conservation will also be covered. It is also important to discuss these topics since they have an impact on water quality. Detailed information on the general and specific education and outreach resources for this WPP is provided in Table 6-2.

Hosting workshops in the watershed is an important part of successfully implementing education programs. These workshops provide residents and stakeholders with the opportunity to learn about the sources of potential pollutants, and feasible management strategies used to mitigate them and the resources to do so. Educational programs already exist for most of the management measures. Programs include Healthy Lawns and Healthy Water (HLHW), Active Community and Citizen Education for Science and Stewardship (ACCESS), the Texas Riparian and Stream Ecosystem Education Program, and the Take Care of Texas initiative (Table 6-2). Though educational resources exist, education and outreach program development are needed for feral cat management in urban areas related to water quality impacts, and for the construction and maintenance of GI (i.e., LID) BMPs to expand adoption. More details and resources on these efforts will be provided below.

Perhaps the most important component of ensuring successful WPP implementation is the role of the Watershed Coordinator. The Watershed Coordinator leads efforts to establish and maintain the working partnerships of stakeholders necessary for plan implementation. This individual also serves as the point of contact and facilitator for all WPP related development and implementation. The Watershed Coordinator is usually paramount for delivering education and outreach programs by engaging with the watershed residents to gain their participation and adoption of BMPs.

The stakeholder group along with the Watershed Coordinator will coordinate the transition from WPP development to implementation. Engagement can be sustained by continuing to host public meetings and educational programs, updating the website, participating in local events to promote WPP awareness, and applying for implementation funding. This can grow partnerships with key stakeholder groups that have yet to be engaged, like TNR organizations. Likewise, electronic newsletters, the project website, and news articles will be primary tools used to regularly communicate with watershed stakeholders. These communication tools will be developed to update readers periodically on implementation progress, new implementation opportunities, inform them on available technical or financial assistance, and other information related to the WPP effort.

Table 6-2. Summary of existing or needed education and outreach programs and the entities that provide it available to the Rowlett Creek watershed. This is not an exhaustive list of available resources.

Education Program	Description	Providing Participant
Lone Star Healthy Streams	Aims to protect Texas waterways from bacterial contamination from livestock operations and feral hogs that may pose serious health risk to Texas citizens.	AgriLife Extension
Water My Yard	Subscribers receive customized weekly watering advice specific to their lawn and irrigation system.	
ACCESS	Program that connects teachers and students to water education resources available in the state through workshops.	TWRI, Texas A&M Engineering Experiment Station
HLHW	Aims to improve and protect surface water quality by enhancing Texas residents' awareness and knowledge of BMPs for residential landscapes.	AgriLife Extension, TWRI
Texas Riparian & Stream Ecosystem Education	Aims to increase stakeholders' awareness and knowledge on the benefits of riparian zones and the BMPs that can be implemented to protect them while minimizing NPS pollution.	
Water 4 Otter	Engages with children in classrooms and provides online TEKS-aligned curriculum to increase family conversations and awareness around the One Water concept.	NTMWD
Take Care of Texas	Online only resources for K-12 educators to teach students on environmental pollutants and stewardship through pre-developed lesson plans.	TCEQ
Storm Drain Marking[1]	Collaboration between member cities to install storm drain markers with volunteering residents that educate residents not to dump into storm drains to increase stormwater protection.	Watershed Coordinator, member cities
E-Newsletters[1]	Electronic newsletters provide updates and upcoming actions on WPP implementation to stakeholders via email and webpage.	Watershed Coordinator
Trap-Neuter-Return[1]	Engages communities on the benefits of TNR programs and effective BMPs and the resources available while also educating residents on the importance of fixing their pets.	City of Garland, TCAP, Feral Friends
Blue-Green Infrastructure Network[1]	Aims to improve the adoption of blue-green infrastructure (i.e., GI or LID) practices by connecting, guiding, and educating professionals, academics, and communities.	TWRI, AgriLife Extension
Feral Hog Management Workshops	Educate landowners on the impacts of feral hogs, how to identify their presence, strategies to control the population and reducing attractants	TPWD, AgriLife Extension, counties, NRCS, SWCD, NRI
Small-Scale and Urban Agriculture	Educate landowners and community gardeners how to care for their farms soil, water, air, plant and animal health	NRCS, SWCD, AgriLIfe Extension
Urban Wildlife Workshops	Educate residents, homeowners, builders & developers, etc. on ways to manage wildlife, restoring habitat, and planning for healthy wildlife and human co-habitation	TPWD, AgriLife Extension, NRI

[1] Programs that need development. Texas Essential Knowledge and Skills (TEKS) Texas A&M Natural Resources Institute (NRI)

Technical Assistance

Various sources of technical assistance will be required to design, plan, and implement many of the management recommendations in this plan. Below lays out some of the available sources for each management measure. Some technical assistance relies on funding that may come from a variety of sources. Physical BMP implementation projects should prepare stakeholders for the continued proper operation and maintenance needed to maintain functionality once the project is completed in the form of educational or guidance materials and continued engagement. These materials can be provided or developed by the various technical assistants outlined in this section. A summary of the identified potential technical assistance sources is provided in Table 6-3.

Table 6-3. Summary of potential technical assistance sources available and related management measures

Management Measure	Technical Assistance Sources
1	Cities' public works departments, AgriLife Extension & Research, Texas A&M Forest Service (TFS), TWRI
2	Cities, Counties, TRA, AgriLife Extension, NCTCOG
3	City of Garland Animal Services, Feral Friends, TCAP, SNN, Alley Cat Allies, TWRI
4	TSSWCB, SWCDs, NRCS, Counties, AgriLife Extension
5	TCEQ, AgriLife Extension, TWRI, NTMWD, TRA, ISDs
6	City law enforcement, Texas Department of Transportation (TxDOT), TRA
7	AgriLife Extension, TWRI, NTMWD, TRA
8	TWDB, AgriLife Extension, TWRI, Cities public works and planning departments, NCTCOG, NTMWD, TRA, US Army Corp of Engineers, South Central Climate Adaptation Science Center
9	AgriLife Extension, TPWD, Trinity River Audubon Center

Urban Stormwater Runoff

Urban stormwater infrastructure and stormwater management efforts are well developed in the watershed but face challenges financially and technically to upkeep with rapid population expansion. Municipalities can benefit from technical assistance provided through education programs, BMP demonstrations, and public or privately funded projects. Specifically, this need is greatest for GI stormwater BMPs, as demand is higher than the available resources. GI BMP demonstrations provide physical and interactive teaching tools that also allow decision makers to see how GI BMPs look and function. TWRI, AgriLife Extension, TRA, and Texas A&M Forest Service (TFS) will coordinate with city and county officials to develop and implement GI demonstrations sites and full-scale projects. Lack of knowledge and understanding of GI BMPs for stormwater management is the largest barrier for adoption of these practices, and demonstrations help overcome this.

Technical assistance with education and outreach programming is available through AgriLife Extension, TFS, and TWRI. Stakeholders have expressed interest in expanding the current efforts on urban GI BMP implementation within the watershed. There are additional resources, such as the EPAs National Stormwater Calculator[5] web-based tool that can calculate estimates of the benefits and cost of implementing various GI at a desired location that uses SWMM for its computations. There is a need for an education and outreach program that removes the technical barriers (e.g., maintenance, design, and construction) that still hinder the widespread adoption of GI BMPs. One grass-roots local effort is the Blue-Green Infrastructure Network that actively works in the North Texas area to expand GI implementation for managing stormwater. This member-driven initiative has received inquiries about establishing GI BMP maintenance and construction workshops to remove the existing technical

[5] https://swcweb.epa.gov/stormwatercalculator/

barriers. In coordination with this network and the previously stated technical assistance providers, an education and outreach program with technical training workshops needs to be developed and implemented throughout the Rowlett Creek watershed.

Pet Waste

Currently technical assistance is widely available in the watershed to reduce pet waste runoff as part of municipalities' MS4 permitting requirements. Local programs are delivered by NTMWD, member cities, TRA, and NCTCOG from a shared campaign called "Doo the Right Thing". Expanding this program to deliver education and outreach resources to K-12 schools and multi-family residential properties (i.e., apartment complexes) to teach proper pet waste disposal practices is recommended, and this can be done in coordination of municipalities with ISDs and property managers. The EPA has additional resources on BMPs for pet waste management: Stormwater Best Management Practice, Pet Waste Management[6] (EPA, 2023). Due to the extensive urbanization of this watershed, pet waste runoff is the surmised leading cause of bacterial pollution, so the addition of GI and installation of pet waste stations can reduce the pollution by treating the runoff before it enters the waterways. This will require some planning ahead to identify the public or private spaces that need them most.

Feral Cat Management

Feral cat management TNR programs operate across the Dallas metroplex, including some in the Rowlett Creek watershed. However, not all TNR program resources are easily accessible to stakeholders in the Rowlett Creek watershed. The jurisdiction, location, and operating hours of TNR clinics vary which can limit the ability of residents to voluntarily contribute to TNR efforts, which is often essential for these programs to operate. The City of Garland's Animal Shelter and Adoption Center have partnered with Operation Kindness and Friends of Rescue Animals to offer their residents free spay/neuter and vaccination to community cats they bring on one day each month for the first 100 cats. Additionally, this program loans traps to colony managers bi-weekly on Mondays. This TNR program is a demonstration of how other municipalities in the watershed can expand and manage feral cat populations. Another local TNR program offers a low-cost clinic available to DFW feral cat caretakers through the TCAP Feral Fix Program[7]. Integrating existing non-profit programs with the city program would lead to the most effective implementation for reducing populations. An education and outreach program should be developed with the collaboration of the identified technical sources (Table 6-3) that educate stakeholders on the impacts that unmanaged feral cat colonies have on the watershed health. Additional resources on how to best manage feral cat colonies can be found by visiting Feral Friends Community Cat Alliance[8], and researched backed strategies and educational material can be accessed at the National Feline Research Council[9].

Agricultural and Livestock Management

Technical assistance to develop and implement BMPs to improve livestock management is offered by TSSWCB, SWCD, NRCS, and AgriLife Extension. Producers that are interested must request planning assistance, then these agencies will work with the producer to determine operation-specific management goals and objectives and develop a management plan in the form of WQMPs or CPs. The plans prescribe effective practices that will achieve the stated goals while also improving water quality.

Urban NPS Pollution Education

Education and outreach programs are currently deployed throughout the watershed. In partnership between municipalities and AgriLife Extension NPS educational workshops can be delivered to residents. These participating sources can also provide the necessary technical assistance for further development of educational materials if needed. TWRI, in collaboration with Texas A&M Engineering Experiment Station and TSSWCB, have

[6] https://www.epa.gov/system/files/documents/2023-01/bmp-pet-waste-management.pdf
[7] https://texasforthem.org/feral-fix-program/
[8] https://feralfriends.org/
[9] https://www.felineresearch.org/

developed the ACCESS program that connects K-12 teachers and students to water education resources available in the state to foster citizen science participation. This program involves workshops that educate teachers on opportunities in citizen science, GIS training, TEKS-aligned curriculum, and provides toolkits for classrooms.

Illegal Dumping and Littering

Efforts to reduce illegal and accidental dumping will focus on education and outreach with the inclusion of volunteer-based trash clean-up events. Technical assistance is extensively available for all cities with many active programs, nonetheless TRA and AgriLife Extension can provide technical assistance with education and outreach efforts when requested. Working with local outdoor stewardship non-profits, such as Scout Troops and the Dallas Off-Road Bicycle Association (DORBA), can help execute clean-up events. City law enforcement is the primary source of enforcement and monitoring activities associated with illicit dumping. Accidental discharge on roads and railways is under TxDOT jurisdiction.

Lawn Residue and Waste

Lawn residue and waste is a stormwater-related issue, thus there is considerable overlap between the entities that will manage this issue and provide technical assistance. Their expertise will be critical in implementing the management measures and engaging communities. AgriLife Extension provides an educational training program that aims to improve and protect water quality by increasing resident awareness and knowledge of BMPs for residential landscapes. This program is called Healthy Lawns and Healthy Waters, and it teaches BMPs for rainwater harvesting, turfgrass and landscape species selection, and soil testing for fertilizer application.

Adaptive Flood Management

Flooding and sediment erosion control GI BMP measures can be developed in step with urban stormwater management measures, as both are strongly linked. Many green stormwater BMPs can also offer flood mitigation so the implementation of these practices is the most beneficial. Technical assistance will rely heavily on municipal, regional, special district, higher education, AgriLife, TWRI, state, and federal staff to support investigation, identification, design, installation, operations, maintenance, and monitoring of GI throughout the watershed. A coordinated effort between these various entities can develop a watershed-level adaptive flood management plan that incorporates water quality management BMPs. An adaptive management plan at the watershed scale can provide guidance on identifying problematic flooding areas, areas impacting downstream flooding, and the design type/size and locations of various GI BMPs to implement. One such report this plan can model after was an Opportunity Analysis for Dallas, Texas, that indicates where green stormwater infrastructure can most effectively enhance urban flood resilience, developed by AgriLife Extension and The Nature Conservancy in collaboration with the City of Dallas and the Trust for Public Land (Jack et al., 2022). The development of this plan should include the allocation of municipality and city funds annually toward the implementation of the plan.

Wildlife and Feral Hog Management

Watershed stewards can benefit from technical assistance with waterfowl and feral hog control approaches, best practices, and regulations. AgriLife Extension, TPWD, and the Trinity River Audubon Center can provide technical and educational resources through programs and public events. The Trinity River Audubon Center[10] also hosts various educational, citizen science, and volunteer public events on their preserve grounds. More online resources for urban wildlife and feral hog management are available at: USDA-APHIS: Wildlife Services[11], Urban Wildlife Program - TPWD[12], and Feral Hogs in Texas[13].

[10] https://trinityriver.audubon.org/
[11] https://www.aphis.usda.gov/wildlife-services
[12] https://tpwd.texas.gov/wildlife/wildlife-diversity/urban-wildlife-program/
[13] https://feralhogs.tamu.edu/

Financial Assistance

Successful WPP implementation requires significant financial resources. Diverse funding sources will be sought to meet these needs of the Rowlett Creek WPP. Resources will be leveraged where possible to extend the impacts of acquired and contributed implementation funds. Grant funds will be relied upon to initiate implementation efforts. Grant funds are not a sustainable source of financial assistance but are necessary to assist in WPP implementation. Other sources of funding must be utilized and creative funding approaches that are applicable to this WPP will be sought as appropriate. Many funding opportunities are listed and described in this section, though other sources can be pursued (Table 6-4).

Table 6-4. Sources of potential financial assistance for WPP implementation.

Management Measure	Financial Assistance Opportunities
1	State CWA §319(h) Grants (TCEQ); Environmental Education Grants; State Water Implementation Fund (TWDB); Texas Water Development Fund (TWDB); Urban & Community Forestry Program (TFS); Texas Water Action Collaborative (TxBN); Cynthia and George Mitchell Foundation; Clean Water State Revolving Fund (TWDB); Five Star and Urban Waters Restoration Program
2	State CWA §319(h) Grants (TCEQ); Environmental Education Grants; Supplemental Environmental Projects Program (TCEQ); Recreation Grants (TPWD); Communities Foundation of Texas
3	Environmental Education Grants; American Humane; ASPCA Grants Program; Banfield Foundation; The Binky Foundation; Communities Foundation of Texas
4	Environmental Quality Incentives Program; Conservation Stewardship Program; Conservation Reserve Program; Urban Agriculture and Innovative Production Grants (USDA); National Integrated Water Quality Program; National Water Quality Initiative; Federal and State CWA §319(h) Grants; TSSWCB WQMP Program; Dixon Water Foundation;
5	State CWA §319(h) Grants (TCEQ); Environmental Education Grants; Supplemental Environmental Projects Program (TCEQ); Meadows Foundation; Cynthia and George Mitchell Foundation
6	State CWA §319(h) Grants (TCEQ/TSSWCB); USDA Water and Waste Disposal Loan and Grant Program; Supplemental Environmental Projects Program (TCEQ); Outdoor Recreation Grants (TPWD)
7	Environmental Education Grants; Meadows Foundation; Supplemental Environmental Projects Program (TCEQ)
8	Floodplain Management Services Program Technical Assistance; FEMA Flood Mitigation Assistance; Meadows Foundation; Flood Infrastructure Fund (TWDB); Texas Water Development Fund (TWDB)
9	Texas Farm and Ranch Lands Conservation Program (TPWD); State CWA §319(h) Grants (TCEQ/TSSWCB); Supplemental Environmental Projects Program (TCEQ); Outdoor Recreation Grants (TPWD)

Texan by Nature (TxBN)

Federal Funding Sources

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

Grant funding is provided to the State of Texas by EPA for implementation of projects that reduce nonpoint source pollution through the CWA §319(h) NPS Grant Program. These grants are administered by TCEQ and TSSWCB. Implementation measures included in WPPs that satisfy EPA's nine key elements of successful watershed-based plans and meet other program rules are eligible for funding though the 319(h)-grant program. Some commonly funded items include but are not limited to: development and delivery of education programs;

water quality monitoring; water body cleanup events; OSSF repairs and replacements; BMP installation and demonstrations. Further information can be found on the NPS Grant Programs websites for TCEQ Nonpoint Source Grant Program[14] and TSSWCB Texas Nonpoint Source Management Program[15]. Clean Water Act §319(h) Nonpoint Source Grant Program funding managed by EPA Region 6 current policy states that funds cannot be used for feral animal trapping or eradication efforts but can be used for the efforts of GI implementation, and education and outreach of the related BMP implementations.

Environmental Education Grants

Environmental Education grants[16] is a funding source by the EPA that seeks grant proposals from eligible applicants to support environmental education projects that promote environmental stewardship and help develop knowledgeable and responsible students, teachers, and citizens. This grant program supports projects that design, demonstrate, and/or disseminate environmental education practices, methods, or techniques as described in the solicitation notice.

Environmental Quality Incentives Program (EQIP)

The Environmental Quality Incentives Program (EQIP)[17] is provided by the USDA-NRCS with support from the local SWCDs and provides technical and financial assistance to agricultural producers and forest landowners to address natural resource concerns, such as improving and conserving soil, water, plant, animal, air, and other resources associated with agricultural land. Watershed stakeholders are strongly encouraged to participate in their local work group to promote the objectives of this WPP with the resource concerns and conservation priorities of EQIP.

Conservation Stewardship Program

The Conservation Stewardship Program[18] (CSP) is a voluntary conservation program administered by the NRCS. CSP encourages producers to address resource concerns in a comprehensive manner by undertaking additional conservation activities and improving, maintaining, and managing existing conservation activities. Conservation practices include prescribed grazing, nutrient management planning, precision nutrient application, manure application, and integrated pest management.

Five Star and Urban Waters Restoration Program

The Five Star and Urban Waters Restoration Grant Program's[19] goal is to meet the conservation needs of important species and habitats, providing measurable and meaningful conservation and educational outcomes. The program focuses on the stewardship and restoration of coastal, wetland, and riparian ecosystems across the country. The program requires the establishment or enhancement of diverse partnerships and an education/outreach component that will help shape and sustain behavior to achieve conservation goals.

State Funding Sources

Clean Water State Revolving Fund

TWDB provides low-cost financing for a variety of wastewater, stormwater, reuse, and other pollution control projects. Political subdivisions and private entities are eligible to apply for loans at lower than market rates to plan, design, acquire, or construct projects. The loans can spread project costs over a repayment period of up to 20 years. More information is available at the Clean Water State Revolving Fund[20] website.

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[14] https://www.tceq.texas.gov/waterquality/nonpoint-source/grants/grant-pgm.html
[15] https://www.tsswcb.texas.gov/programs/texas-nonpoint-source-management-program
[16] https://www.epa.gov/education/grants
[17] https://www.nrcs.usda.gov/programs-initiatives/eqip-environmental-quality-incentives
[18] https://www.nrcs.usda.gov/programs-initiatives/csp-conservation-stewardship-program
[19] https://www.nfwf.org/programs/five-star-and-urban-waters-restoration-grant-program
[20] https://www.twdb.texas.gov/financial/programs/CWSRF/index.asp

Supplemental Environmental Projects (SEP)

The SEP program is administered by TCEQ which directs fines, fees, and penalties for environmental violations toward environmentally beneficial uses. A respondent in an enforcement action may negotiate an agreement to perform a SEP to offset a portion of the assessed administrative penalty. The 3rd party administrators who can apply for SEP are non-profit or governmental organizations. Information can be found at the Supplemental Environmental Projects (SEPs) website[21].

Clean Rivers Program (CRP)

TCEQ administers a state fee-funded program that provides surface water quality monitoring, assessment, and public outreach with the CRP[22]. Allocations are made to 15 partner agencies throughout the state to assist in routine monitoring, special studies, and outreach efforts. The Trinity River Authority (TRA) is the CRP partner for the Rowlett Creek watershed and monitors the creek regularly.

Recreation Grants

The Recreation Grants[23] are administered by TPWD to support communities across Texas with their outdoor recreation needs through grant assistance and outreach programs. Providing grants to communities across Texas helps build access to outdoor experiences and encourages a connection with nature that is vital for promoting conservation and good environmental stewardship among Texans young and old.

Flood Infrastructure Fund (FIF) Program

The FIF program is administered by the TWDB to provide financial assistance in the form of loans and grants for flood control, flood mitigation, and drainage projects. The Flood Intended Use Plan, Flood IUP, details the structure of each funding cycle. Program eligibility for municipalities, counties, and other political subdivisions can be found on the FIF website[24].

State Water Implementation Fund for Texas (SWIFT)

The SWIFT program[25] helps communities develop and optimize water supplies at cost-effective rates. The program provides low-interest loans, extended repayment terms, deferral of loan repayments, and incremental repurchase terms for projects with state ownership aspects. Funding is available to municipalities, counties, river authorities, and water control and improvement districts.

Texas Farm and Ranch Lands Conservation Program

The Texas Farm and Ranch Lands Conservation Program[26] was established and is administered by TPWD to conserve working lands to protect water, fish, wildlife, and agricultural production that are at risk of future development. The program's goal is to educate citizens on land resource stewardship and establish conservation easements to reduce land fragmentation and loss of agricultural production.

Additional Sources

Private foundations, non-profit organizations, land trusts, and individuals can potentially assist with implementing some aspects of the WPP. Funding eligibility requirements for each program should be reviewed before applying. Examples of applicable additional funding sources include:

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[21] https://www.tceq.texas.gov/compliance/enforcement/sep
[22] https://www.tceq.texas.gov/waterquality/clean-rivers/index.html
[23] https://tpwd.texas.gov/business/grants/recreation-grants/
[24] https://www.twdb.texas.gov/financial/programs/FIF/index.asp
[25] https://www.twdb.texas.gov/financial/programs/SWIFT/index.asp
[26] https://tpwd.texas.gov/landwater/land/private/farm-and-ranch/

- Cynthia and George Mitchell Foundation[27]: provides grants for water and land conservation programs to support sustainable protection and conservation of Texas' natural resources.
- Dixon Water Foundation[28]: provides grants to non-profit organizations to assist in improving/maintaining watershed health through sustainable land management.
- Meadows Foundation[29]: provides grants to non-profits, agencies, and universities engaged in protecting water quality and promoting land conservation practices to maintain water quality and availability on private lands.
- Texas Land Conservancy[30]: funding provided by the trust assists communities, private landowners, governments, and other partners to protect Texas' natural areas.
- Partnerships with local industry in the watershed could provide in-kind donations or additional funding for implementation projects.

[27] https://cgmf.org/p/water-program.html
[28] https://dixonwater.org/grants/
[29] https://www.mfi.org/
[30] https://www.texaslandconservancy.org/

Chapter 7 Measuring Success

Introduction

Implementing the Rowlett Creek WPP will focus on addressing readily manageable bacteria sources in the watershed to reach water quality targets with the coordination of stakeholders over a 10-year period. This plan identified substantial financial resources, technical assistance, and educational resources required to achieve these targets. All management measures outlined in this WPP are voluntary and have support from watershed stakeholders at the recommended levels.

Measuring WPP implementation impacts on water quality through monitoring at critical locations and sometimes accompanying installations will provide data needed to document the progress toward water quality goals. While measuring improvements in water quality is the preferred measure of success, documenting implementation accomplishments can also be used. Combining water quality data and implementation accomplishments will facilitate adaptive management by illustrating which recommended measures are successful and which need modification. Documentation of these two aspects of success can be tracked along the timeframe outlined for WPP implementation in Table 5-12.

Water Quality Target

The selected goal for water quality in Rowlett Creek is the existing primary contact recreation standard for *E. coli* of 126 cfu/100 mL. This is the defined target for future water quality to allow for the necessary bacteria load reductions. This can be achieved by implementing the management measures over the course of the 10-year period. If there are revisions or adoption of new water quality standards, such as nutrients, it is recommended these targets be revised or amended as appropriate to attain the more conservative standard.

The LDC approach was used to calculate this water quality goal into the needed bacteria load reductions. Likewise, this approach was used to calculate water quality goals on nutrients if these become standards or of interest to any stakeholders to address. Five monitoring sites were established at each subwatershed junction in the creeks for this WPP. Each of the five sites were used in the LDC analysis to determine needed load reductions to meet the water quality targets listed above. Moreover, the mid-range flow conditions category was selected for the basis for identifying the needed amount of *E. coli* reduction.

Additional Data Collection Needs

Continuation of water quality monitoring in Rowlett Creek is necessary to track changes throughout the implementation of the WPP. This is an important process to ensure that the WPP implementation strategies are making progress to attain water quality standards. The current monitoring site distribution and data collection frequency across the watershed limits the scope of data accessibility Additional monitoring in the way of more intensive sampling in other stream segments within the watershed to identify potential pollutant sources is needed. The current monitoring setup limits the likely observation that may be needed to evaluate small changes in water quality that result from WPP implementation. Defining localized water quality changes from specific implementation activities will require targeted water quality monitoring efforts. These can be planned once specific implementation activities and locations are known and will demand funding support. Targeted water quality monitoring could include edge of field runoff analysis where different land use or management measures have been implemented, paired watershed studies, or multiple watershed studies. Data derived from these monitoring activities could demonstrate the applicability and efficacy of different BMPs within the watershed. Guidance for monitoring activities of different BMP implementation can be found through EPAs website or EPA developed materials such as *Monitoring and Evaluating Nonpoint Source Watershed Projects* (Dressing et al., 2016). At the minimum it is recommended that continuous monitoring is carried out at the five sites used in developing this QAPP. The average square mileage of watershed currently monitored by the five stations is 29.42, which is in line with other regional projects. Additional stations should be added to address any change in landuse or observed water quality impairments at a smaller scale.

Through the adaptive management method with WPP updates future water quality monitoring needs will be evaluated and adjusted as necessary. This could include adding new sites to address new concerns or areas of interest in the watershed. The data collected at new sites will be included in the quality assurance project plans developed with future monitoring efforts.

Data Review

Watershed stakeholders are responsible for evaluating WPP implementation impacts on instream water quality. Stakeholders will use TCEQ's statewide biennial water quality assessment approach, which uses a moving seven-year geometric mean of bacteria data collected through the state's CRP as a primary means of gauging implementation success. This assessment is published in the Texas Integrated Report and is available on the TCEQ Integrated Report webpage[31]. It is noted there is a two-year lag between data reporting and the assessment results in the Texas Integrated Report, therefore the 2028 or 2030 Texas Integrated Reports will be the earliest opportunity to include water quality data collected after the start of WPP implementation. Another method to evaluate water quality improvements is using the geometric mean of the most recent three years of water quality data reported within TCEQ's SWQMIS web tool[32]. This method can deliver more appropriate progress results for evaluating WPP implementation progress since the Integrated Report uses seven-year geometric means. To support data assessment as needed, trend analysis and other appropriate statistical analyses will be used.

Regardless of the method used, water quality changes resulting from WPP implementation will be difficult to determine and may be diminished by activity in the watershed that negatively influences water quality. Thus, data review will not be relied on exclusively to evaluate implementation effectiveness.

The Watershed Coordinator will be responsible for tracking implementation targets and water quality in the watershed. Implementation progress and data will be summarized and reported to watershed stakeholders at least annually. Implementation progress and water quality will be evaluated to describe the success of WPP implementation. Should implementation targets or water quality improvements lag significantly, adaptive management efforts will be initiated to reassess management recommendations and targets included in the WPP.

Interim Measurable Milestones

Rowlett Creek WPP implementation will occur over a 10-year period. Milestones are useful for incrementally evaluating the implementation progress of specific management measures recommended in the WPP. Milestones outline a clear tracking process for progression throughout implementation. Interim measurable milestones for management measures and education and outreach are addressed in Chapter 5 Table 5-11. Participants and estimated costs, where available, have been included in the schedule. In some instances, funding acquisition, personnel hiring, or program initiation may delay the start of some items. This approach provides incremental targets that can be used to measure progress. If sufficient progress is not made, adjustments will follow to increase implementation and meet established goals. Adaptive management may be used to adjust the planned approach if the original strategy is no longer feasible or effective in achieving the overall goal of water quality.

[31] www.tceq.texas.gov/waterquality/assessment
[32] https://www80.tceq.texas.gov/SwqmisPublic/index.htm

Adaptive Management

Watersheds are inherently dynamic systems with numerous variables influencing landscape processes, which results in an inherent degree of uncertainty. This consideration was central to the development of the WPP. As the WPP implementation progresses, it is essential to continuously monitor water quality and adjust the implementation strategies as necessary. The inclusion of an adaptive management approach within the WPP framework provides the necessary flexibility for such adjustments.

Adaptive management is a systematic approach based on the philosophy of improving management by learning from outcomes. Adaptive management is an iterative process that involves accumulating knowledge about the causes of impairment and the responses of water quality to implementation efforts. As these efforts progress, water quality is systematically tracked to assess their impact. This data guides the refinement of future implementation activities. This cyclical process of implementation and evaluation ensures that project efforts remain focused, and their impacts are optimized. Watersheds predominantly affected by nonpoint source pollutants, like Rowlett Creek watershed, are particularly suitable for adaptive management. Progress towards achieving established water quality targets will also be used to evaluate the necessity of adaptive management. An annual review of implementation progress and water quality trends will be presented to stakeholders during meetings, as discussed above. An update of activities presented in Table 5-11 will be provided to TCEQ at least once every five years.

Given the multitude of factors influencing water quality and the typical time lag between implementation efforts and observable improvements, it is crucial to allow adequate time for implementation before triggering adaptive management. In cases where progress towards water quality targets or milestones is deemed infeasible due to factors such as funding constraints or the scope of implementation, adaptive management provides an opportunity to revisit and revise the implementation strategy. If stakeholders determine that progress towards water quality improvement or milestones is insufficient, efforts will be intensified to increase the adoption of BMPs and adjust strategies or focus areas accordingly.

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Appendix A: GIS Analysis and Potential Load Calculations

Through a geospatial analysis of the watershed and its subwatersheds potential bacteria loads were estimated. This analysis utilizes estimates on potential sources calculated based on best available local public data provided by stakeholders, USDA, US Census Bureau, LCLU, and AVMA. This approach allows stakeholders to prioritize management implementation based on the results of the estimated potential loads by source and subwatershed (EPA et al., 2001). The GIS analysis provides an easy method to understand the relative contributions and spatial distribution across the watershed, without incorporating complex watershed modeling techniques that can increase uncertainty (EPA, 2018). The used approach calculates the estimates based on the spatial distribution of household or land cover data across the watershed within the five subwatersheds.

Dog Bacteria Loading Estimates

The dog population was estimated using latest AVMA (2024) statistics for the average number of dogs per household and the estimated number of households from Census block data (USCB, 2022). The estimated number of households for subwatershed 1 is 76,432; 2 is 33,998; 3 is 32,590; 4 is 83,798; and 5 is 48,172. While the estimated number of dogs for subwatershed 1 is 51,974; 2 is 23,119; 3 is 22,161; 4 is 56,983; and 5 is 32,757.

Table A-1. Assumptions used in calculating bacteria loading for dogs.

Description	Assumption
Average number dogs per household (AVMA, 2024)	0.68
Number of households (USCB, 2022)	274,990
Estimated number of dogs	186,993
Fecal coliform production rate of dogs (Horsley and Witten, 1996)	5.0×10^{9} cfu/day
Fecal coliform to *E. coli* conversion (Wagner & Moench, 2009)	0.63 *E. coli*/cfu fecal coliform

Using the assumptions in Table A-1, the potential annual bacteria load from dogs is estimated as:

$$PAL_d = N_d \times FC_d \times C \times 365 \text{ days/year}$$

Where:

PAL_d = Potential annual *E. coli* loading attributed to dogs

N_d = Number of dogs

FC_d = Fecal coliform loading rate of dogs

C = Fecal coliform to *E. coli* conversion rate

The estimated potential annual loading across the watershed due to dogs is 2.15×10^{17} cfu *E. coli*/year.

Feral Cat Bacteria Loading Estimates

According to the National Feline Research Council, Feral cat population in the U.S. best estimates suggests there are approximately 32 million with 72% living in urban areas (Rowan et al., 2019). Another study by Loss et al. (2013) estimated the feral cat population across the U.S. to be 30-80 million cats, with 131.4 million U.S. households that provides an estimated population rate of 0.23 – 0.61 feral cats per household. Local estimates within the Rowlett Creek watershed have not been assessed therefore, based on local stakeholders input the conservative estimate of 0.23 cats per household with the estimated number of households from Census block data was used to estimate feral cat population (USCB, 2022). The estimated number of households for subwatershed 1 is 76,432; 2 is 33,998; 3 is 32,590; 4 is 83,798; and 5 is 48,172. While the estimated number of dogs for subwatershed 1 is 17,579; 2 is 7,820; 3 is 7,496; 4 is 19,273; and 5 is 11,080.

To calculate the estimated fecal coliform production rate of feral cats per day the values of fecal bacterial density of 7.90E+06 cfu/gram from Schueler & Holland (2000) and fecal production rate of 40 grams/day from Dabritz et al. (2006).

Table A-2. Assumptions used in calculating bacteria loading for feral cats.

Description	Assumption
Average number of feral cats per household (Loss et al., 2013)	0.23
Number of households (USCB, 2022)	274,990
Estimated number of feral cats	63,248
Fecal coliform density (Schueler & Holland, 2000)	7.90 x10^6 cfu/gram
Daily fecal production rate per cat (Dabritz et al., 2006)	40 grams/day
Fecal coliform production rate of feral cats (see below as FC_c)	3.16x10^8 cfu/day
Fecal coliform to *E. coli* conversion (Wagner & Moench, 2009)	0.63 *E. coli*/cfu fecal coliform

Using the assumptions in Table A-2 the potential annual bacteria load from feral cats is estimated as:

$$FC_c = (7.90\text{x}10^6 \text{ cfu/gram}) \text{ x } (40\text{grams/day})$$

$$PAL_c = N_c \times FC_c \times C \times 365 \text{ days/year}$$

Where:

PAL_c = Potential annual *E. coli* loading attributed to feral cats

N_c = Number of cats

FC_c = Fecal coliform loading rate of cats

C = Fecal coliform to *E. coli* conversion rate

The estimated potential annual loading across the watershed due to cats is 4.60×10^{15} cfu *E. coli*/year.

Agricultural Bacteria Loading Estimates

To calculate the potential bacteria loads from livestock, estimates for livestock populations were calculated across the watershed. This was accomplished using the USDA & NASS (2022) Census of Agriculture by county, Collin and Dallas counties, and LCLU data within the watershed to derive estimates at the watershed and subwatershed-levels (USGS, 2023). Livestock populations from the census were gathered for cattle, sheep, horses, chickens, and hogs. For each, the population was divided by the amount of county agriculture land and then the ratio of animal per acre was multiplied by the acre area of farmland within the watershed. Finally, to standardize stocking rates based on relative livestock grazing patterns compared to one, 1,000-lb mature cow, the estimated numbers of animals in the watershed were converted to animal units (AnU). The assumptions used in this method are documented in Wagner & Moench (2009) and Borel et al. (2015), shown below in Table A-3.

Table A-3. Assumptions used in calculating bacteria loading for each livestock animal. AnU conversion factors and fecal coliform production rates are from Wagner & Moench (2009).

Animal	Estimated Number in Watershed	AnU Conversion factor	Fecal coliform production rate
Chickens	260	0.01	3.71×10^{10} cfu/AnU-day
Cattle	612	1	8.55×10^{9} cfu/AnU-day
Horses	65	1.25	2.91×10^{8} cfu/AnU-day
Hogs	12	0.25	9.73×10^{10} cfu/AnU-day
Sheep	52	0.2	2.90×10^{11} cfu/AnU-day
Fecal coliform to E. coli conversion rate			0.63 *E. coli*/cfu fecal coliform

Using livestock population estimates, the potential annual load across the watershed and for each subwatershed was calculated as:

$$PAL_l = N_l \times AnUC_l \times FC_l \times C \times 365 \text{ days/year}$$

Where:

PAL_l = Potential annual *E. coli* loading attributed to livestock

N_l = Number of animals

$AnUC_l$ = Animal units conversion factor

FC_l = Fecal coliform loading rate of animal

C = Fecal coliform to *E. coli* conversion rate

The estimated potential annual loading across the watershed due to cattle is 1.20×10^{15} cfu *E. coli*/year, sheep is 6.94×10^{14}, chicken is 2.22×10^{13}, hogs is 6.71×10^{13}, and horses is 5.44×10^{12}. The estimated potential annual loading across the watershed due to all livestock is 1.99×10^{15} cfu E. coli/year.

Wildlife Bacteria Loading Estimates

Wildlife populations were estimated using density rates of suitable wildlife habitat using a GIS analysis following Timmons et al. (2012). Suitable habitat for feral hogs and wildlife were sums of area of the following categories using 2021 LCLU data: all forest types, shrub/scrub, grasslands/herbaceous, pasture/hay, cultivated crops, woody wetlands, and emergent herbaceous wetlands. The area of suitable habitat was calculated to be 21.1 mi^2 and from Timmons et al. (2012) an estimated density rate of 8.9 hogs per mi^2 give an estimated population of 188 in the watershed. The daily fecal coliform production rate was estimated using Wagner & Moench (2009) as 1.21×10^6 cfu/AnU per day for feral hogs.

The latest available TWPD wintering waterfowl survey dataset is from 2018, looking at the Oak Woods/Blackland Prairie survey region there were an estimated 971,251 ducks, which includes 18 species of ducks. The survey area size is approximately 57,943.35 mi^2, which gives an estimated population density of 16.76 ducks/mi^2. The estimated population of 354 ducks in the watershed. The fecal coliform production rate for a duck was estimated using Schueler & Holland (2000) calculations as 2.25×10^9 cfu/duck per day, this source did not use AnU conversions, so the conversion factor is set to 1.

Table A-4. Assumptions used in calculating bacteria loading for feral hogs.

Description	Feral Hogs	Ducks
Area of wildlife suitable habitat (mi^2)	21.1	21.1
Average number of **animals per mi^2**	8.9	16.79
Estimated number of animals	187	354
AU Conversion	0.125 (Wagner & Moench, 2009)	1
Fecal coliform production rate	1.21×10^9 cfu/AnU-day (Wagner & Moench, 2009)	2.25×10^9 cfu/AnU-day (Schueler & Holland, 2000)
Fecal coliform to E. coli conversion rate (Wagner & Moench, 2009)	0.63	0.63

Using the assumptions in Table A-4, each wildlife potential annual load across the watershed and for each subwatershed was calculated as:

$$PAL_w = N_w \times AnUC_w \times FC_w \times C \times 365 \text{ days/year}$$

Where:

PAL_w = Potential annual *E. coli* loading attributed to animal

N_w = Number of animals

$AnUC_w$ = Animal units conversion factor

FC_w = Fecal coliform loading rate of animal

C = Fecal coliform to *E. coli* conversion rate

The estimated potential annual loading across the watershed due to feral hogs is 6.53×10^{12} cfu *E. coli*/year and for ducks is 1.83×10^{14} cfu *E. coli*/year.

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Appendix B: Watershed Characterization Modeling Report Pollutant Source Load Estimate Calculations

The pollutant source load estimates derived from the Rowlett Creek Watershed Characterization Report (Jaber et al., 2023). This data was used in the development of the Rowlett Creek WPP.

Load Duration Curve Analysis

A widely accepted approach for analyzing water quality is the use of a Load Duration Curve (LDC). A LDC allows for a visual determination of how stream flow may or may not impact water quality, in regard to a specific parameter. The first step in developing an LDC is the construction of a Flow Duration Curve (FDC).

Next, data from the FDC are multiplied by the concentration of the water quality standard for the pollutant to produce the allowable LDC. This curve shows the maximum load (amount per unit time; e.g., for bacteria CFU/day) a stream can carry across the range of flow conditions (low flow to high flow) without exceeding the water quality standard. Typically, a margin of safety (MOS) is applied to the threshold pollutant concentrations to account for possible variations in loading from potential sources, stream flow, effectiveness of management measures, and other sources of uncertainty. A 10% MOS for bacteria was selected for this plan.

Stream monitoring data for a pollutant also can be plotted on the curve to show frequency and magnitude of exceedances. Typically, flow regimes are identified as areas of the LDC where the slope of the curve changes because that correlates with a significant change in flow. In the LDCs for the Rowlett Creek watershed, there are three flow regimes: high (0-10th percentile flow), midrange (11th – 80th percentile flow), and low flows (81th -100th percentile flow). These regimes reflect where a change in the slope of the LDC line is detected. Pollutant data plotted on the LDCs for the Rowlett Creek Watershed in this report covered data collected from 1981 to 2022.

In the below figures, the red line indicates the maximum acceptable stream load for pollutants and the squares, triangles, and circles represent water quality monitoring data collected under high, mid-range and low flow conditions, respectively. Where the monitoring samples are above the red line, the actual stream load has exceeded the water quality standard, and a violation of the standard has occurred.

Points located on or below the red line are in compliance with the water quality standard. In order to analyze the entire range of monitoring data, regression analysis is conducted using the monitored samples to calculate the “line of best fit” (blue line). Where the blue line is on or below the red line, monitoring data at that flow percentile is in compliance with the water quality standard. Where the blue line is above the red line, monitoring data indicate that the water quality standard is not being met at that flow percentile. Regression analysis also enables calculation of the estimated percent reduction needed to achieve acceptable pollutant loads. The green line indicates the 10% margin of safety agreed on for this project.

Nitrate-Nitrite Nitrogen

Nitrogen in the forms of nitrite and nitrate measures inorganic nitrogen in the stream. Nitrate is very abundant as an inorganic, oxidized form of nitrogen and nitrite is not as common as an inorganic, oxidized form of nitrogen. Levels of inorganic nitrogen appear to be slightly increasing over time during routine sampling. Nitrate levels were at or below the 10% MOS for all sites except low flows at Site 5. That could be influenced by backflow from the Lake. Sites 3 and 4 are nearly at a 10% MOS indicating a potential concern for nitrate at those subwatersheds.

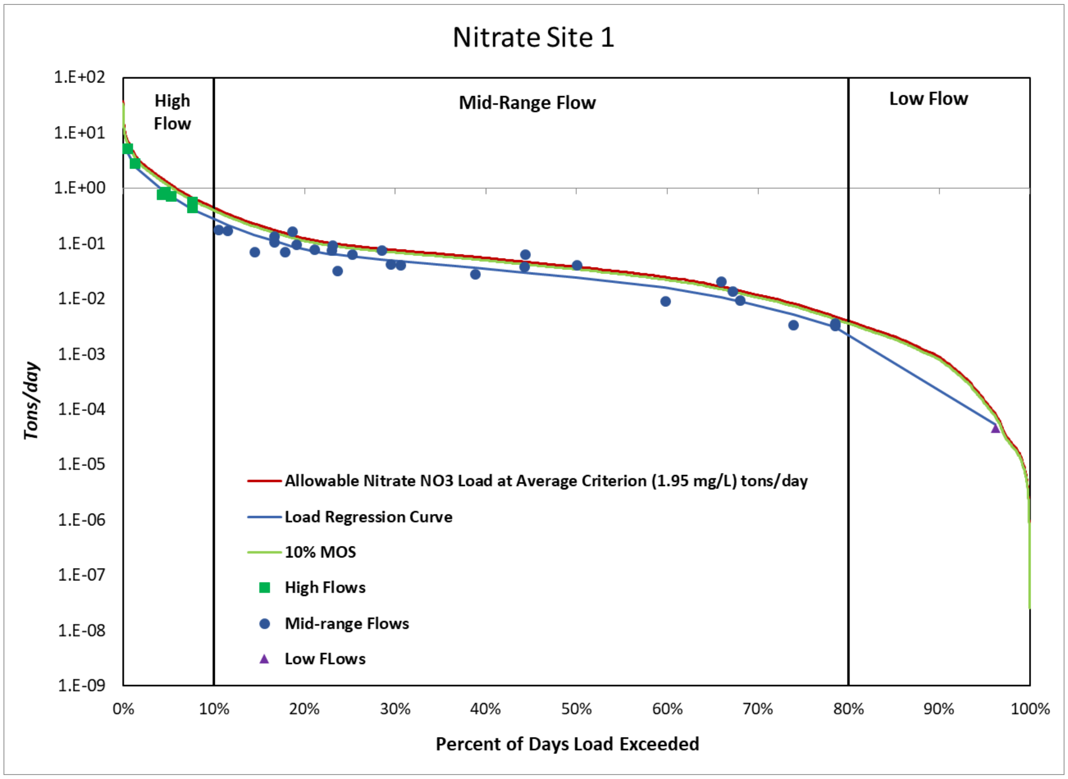

Figure B-1. Nitrate/nitrite load duration curve at Site 1 showing the allowable load and the 10% MOS.

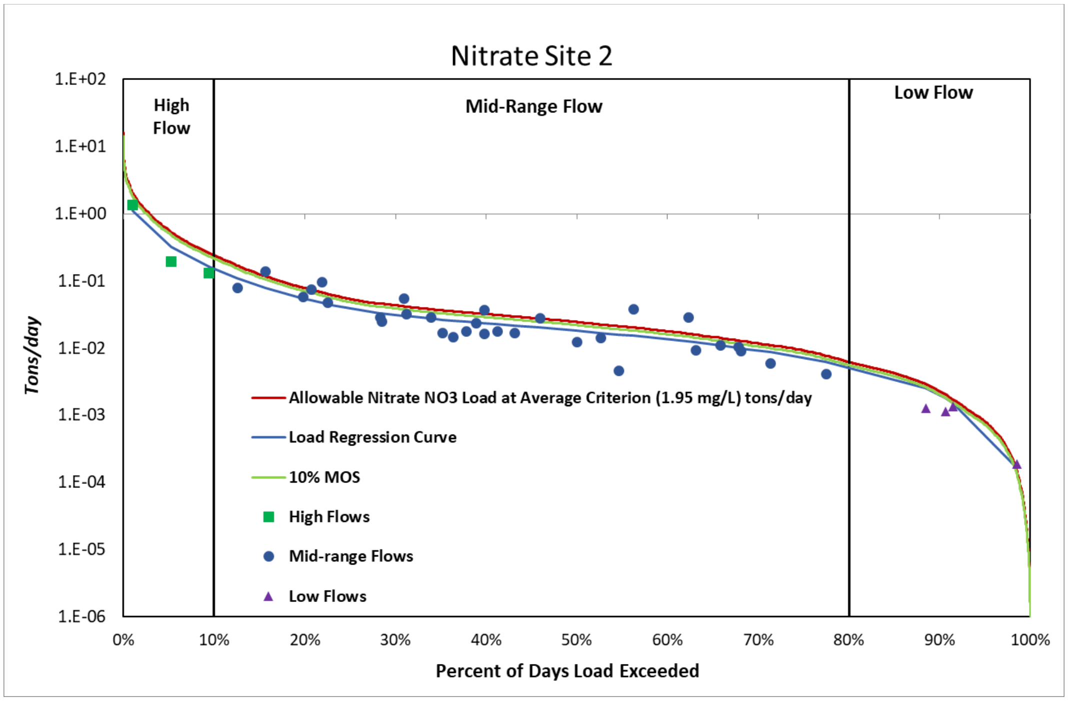

Figure B-2. Nitrate/nitrite load duration curve at Site 2 showing the allowable load and the 10% MOS.

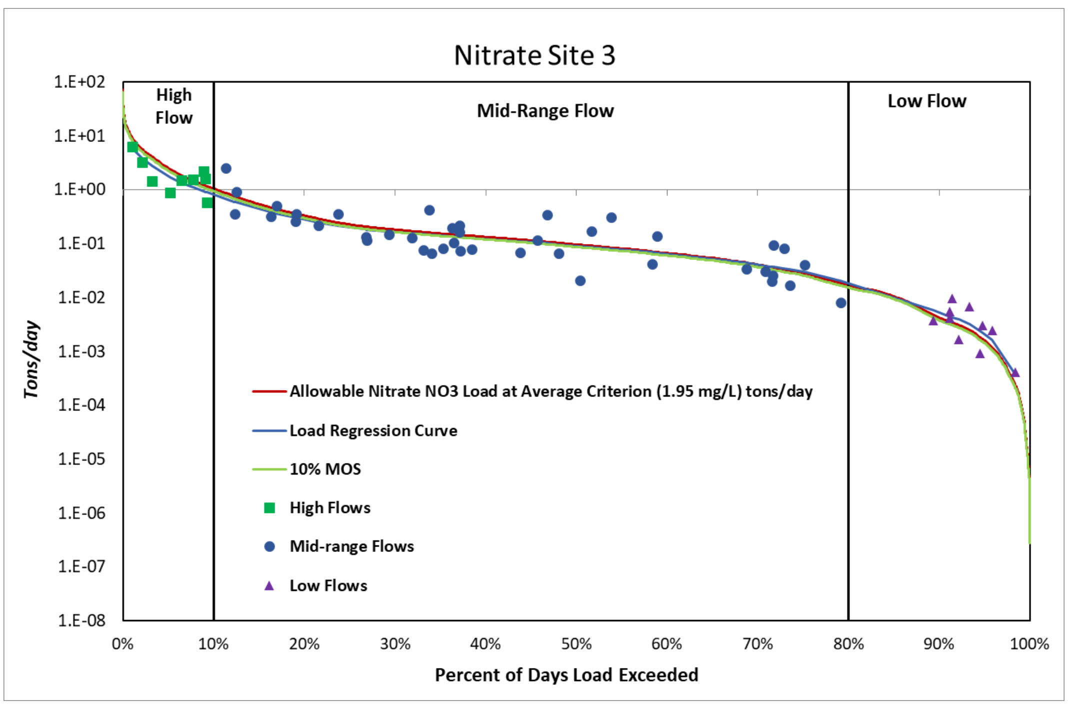

Figure B-3. Nitrate/nitrite load duration curve at Site 3 showing the allowable load and the 10% MOS.

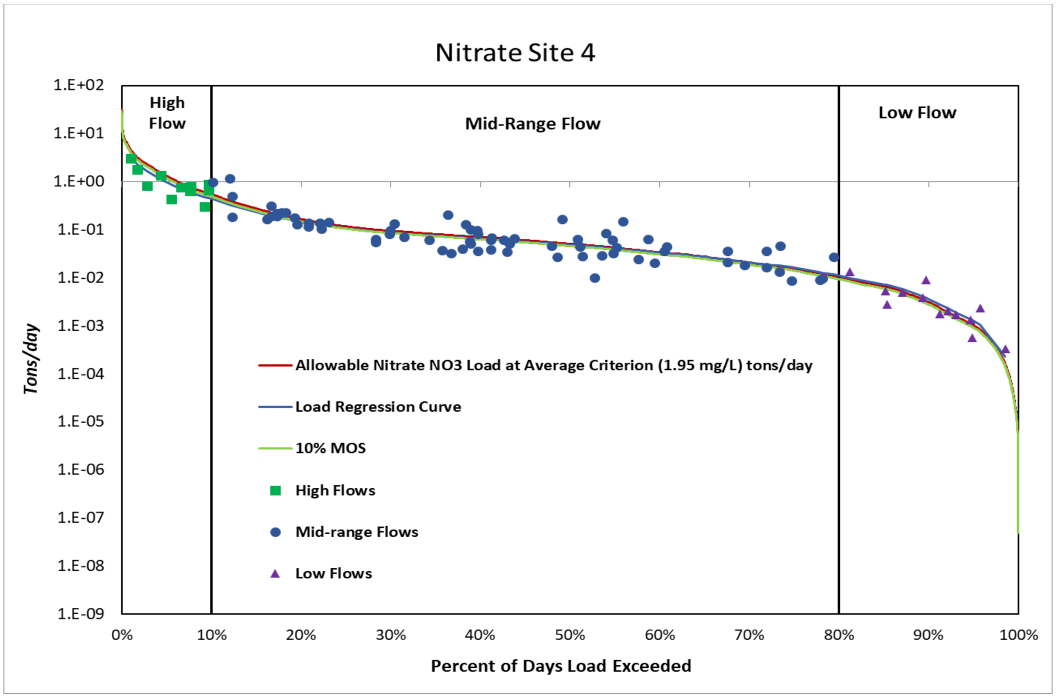

Figure B-4. Nitrate/nitrite load duration curve at Site 4 showing the allowable load and the 10% MOS.

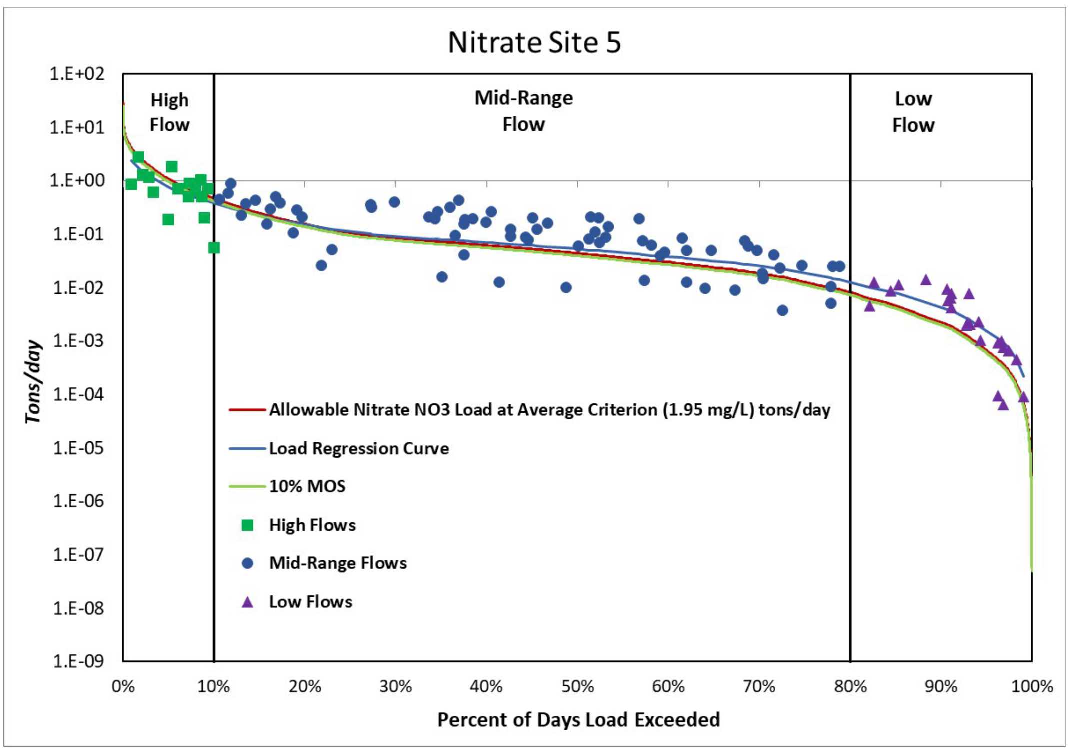

Figure B-5. Nitrate/nitrite load duration curve at Site 5 showing the allowable load and the 10% MOS.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is the measure of organic nitrogen plus ammonia nitrogen in a sample. TKN exceeded the allowable load for all sites with sites 2, 3 and 4 noticeably higher than the limit.

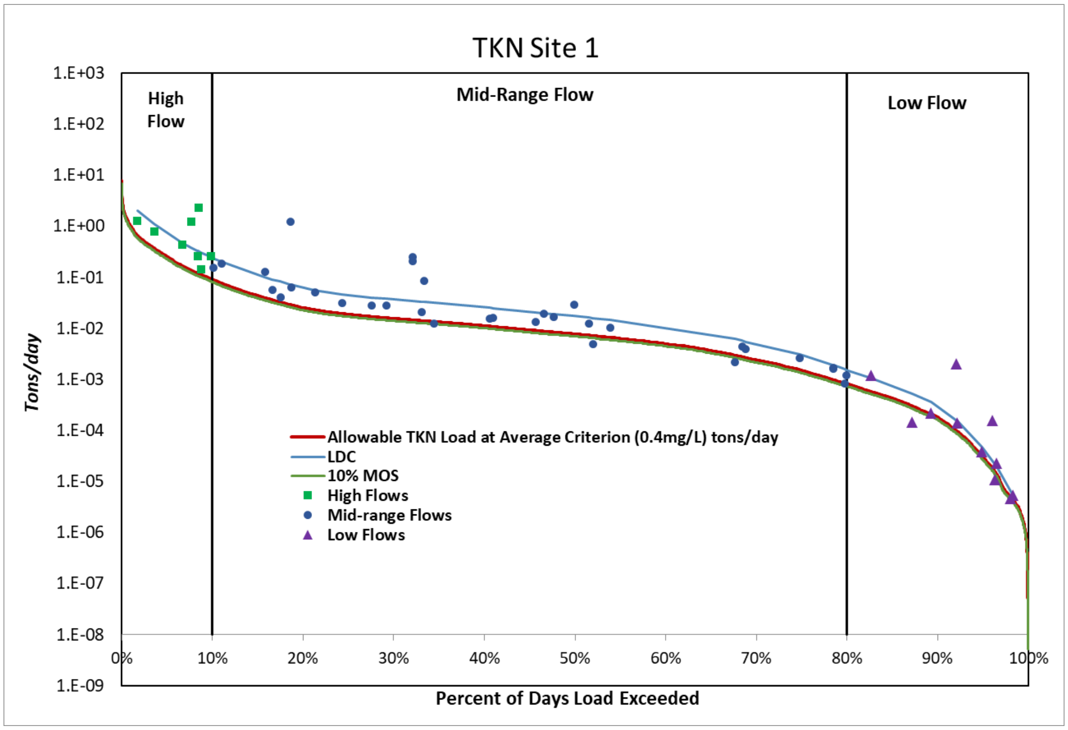

Figure B-6. TKN load duration curve at Site 1 showing the allowable load and the 10% MOS.

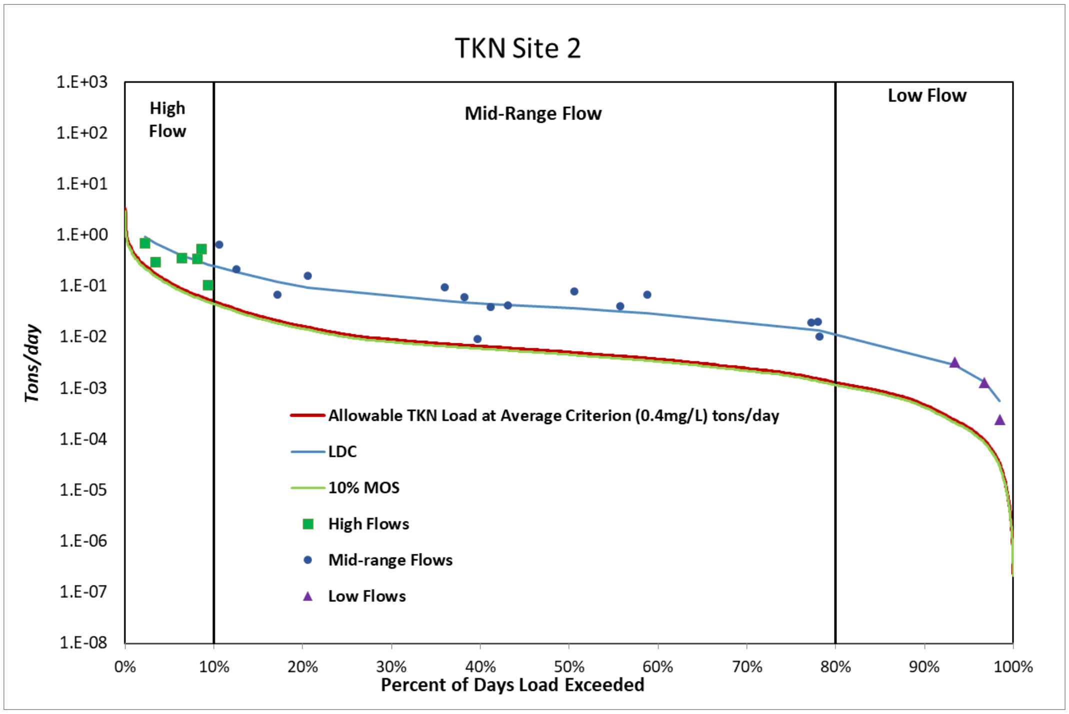

Figure B-7. TKN load duration curve at Site 2 showing the allowable load and the 10% MOS.

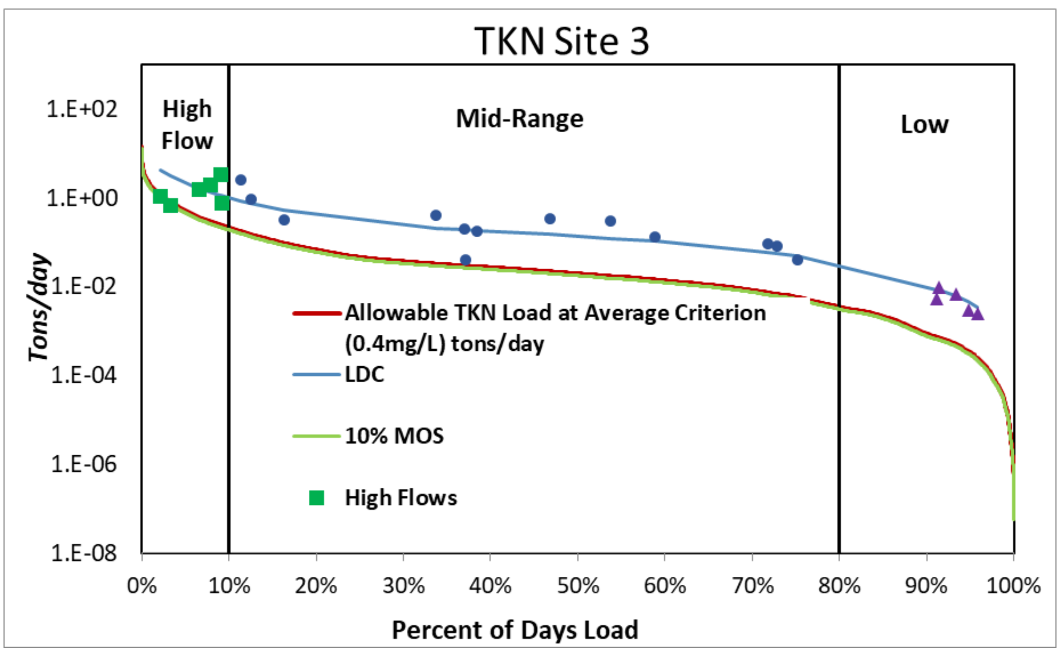

Figure B-8. TKN load duration curve at Site 3 showing the allowable load and the 10% MOS.

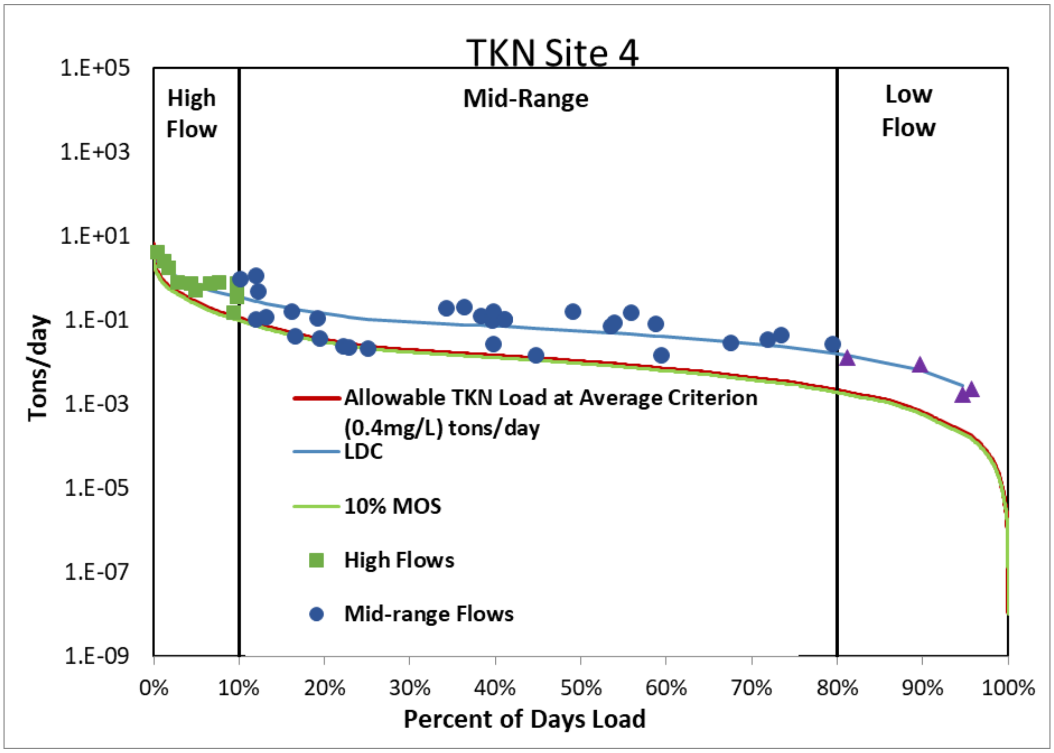

Figure B-9. TKN load duration curve at Site 4 showing the allowable load and the 10% MOS.

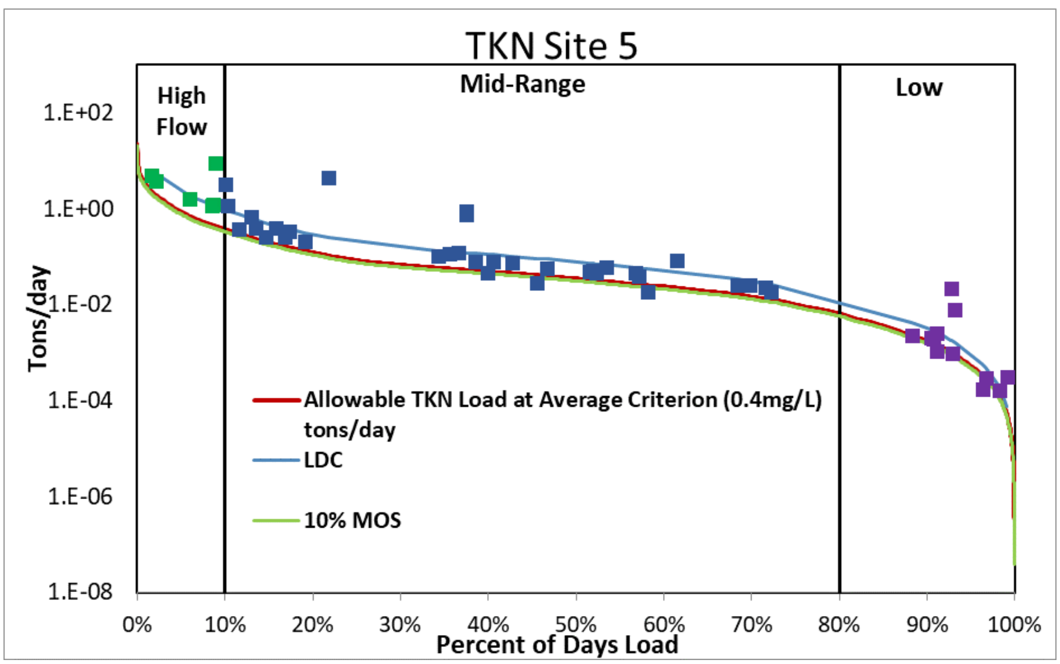

Figure B-10. TKN load duration curve at Site 5 showing the allowable load and the 10% MOS.

Ammonia Nitrogen

Ammonia levels in Rowlett Creek were below the allowable limit for all sites. This indicates that high TKN values shown above are mostly due to organic nitrogen. Notably, Site 4 had high ammonia loads at low flows.

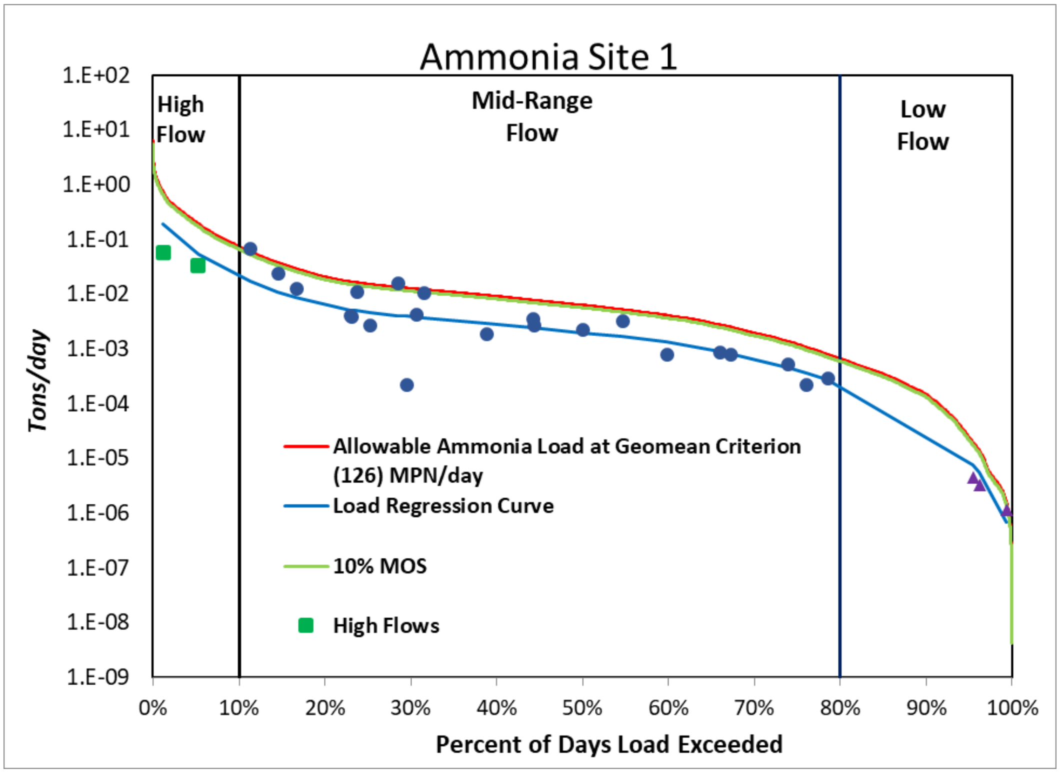

Figure B-11. Ammonia load duration curve at Site 1 showing the allowable load and the 10% MOS.

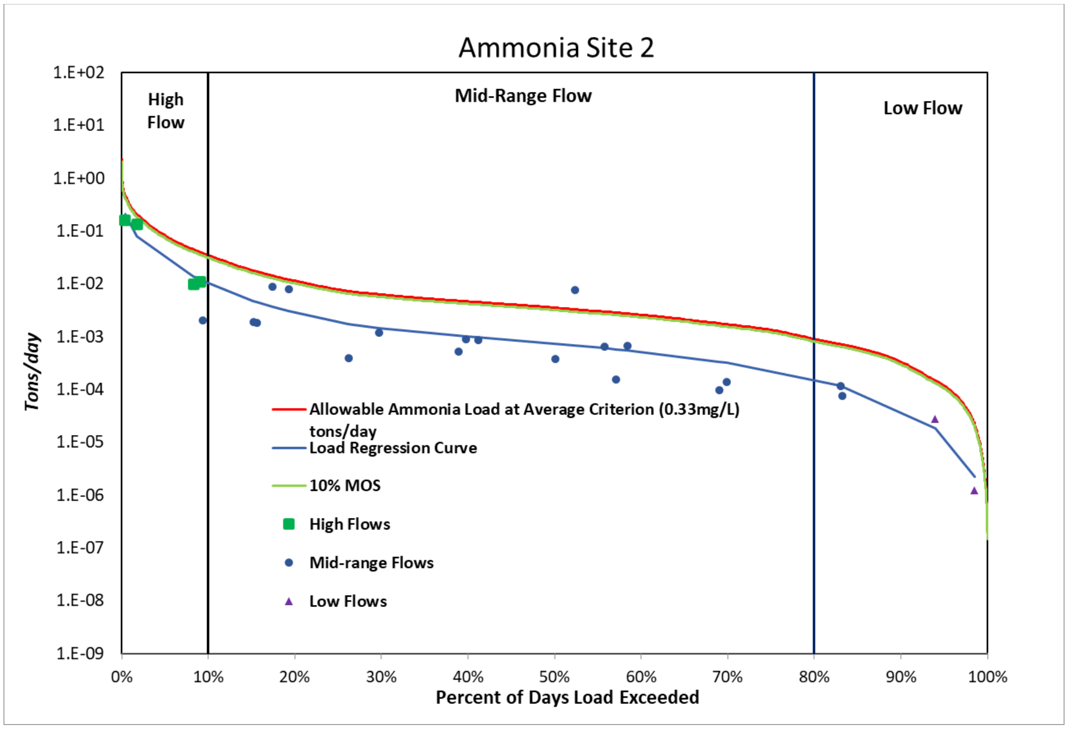

Figure B-12. Ammonia load duration curve at Site 2 showing the allowable load and the 10% MOS.

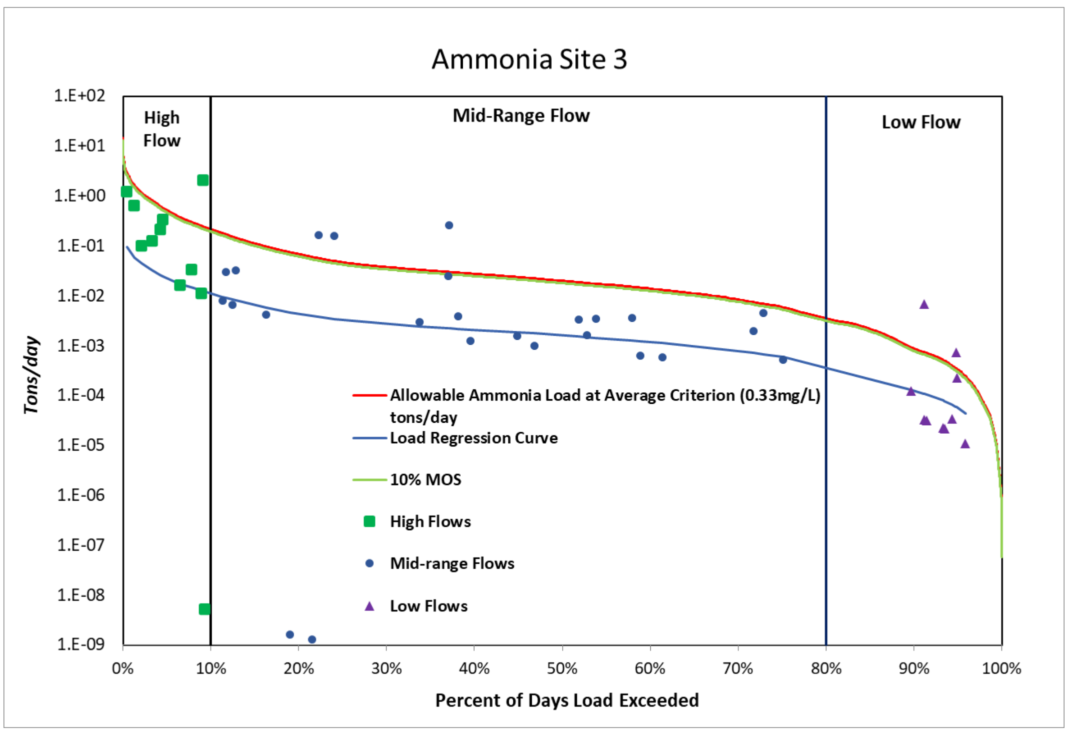

Figure B-13. Ammonia load duration curve at Site 3 showing the allowable load and the 10% MOS.

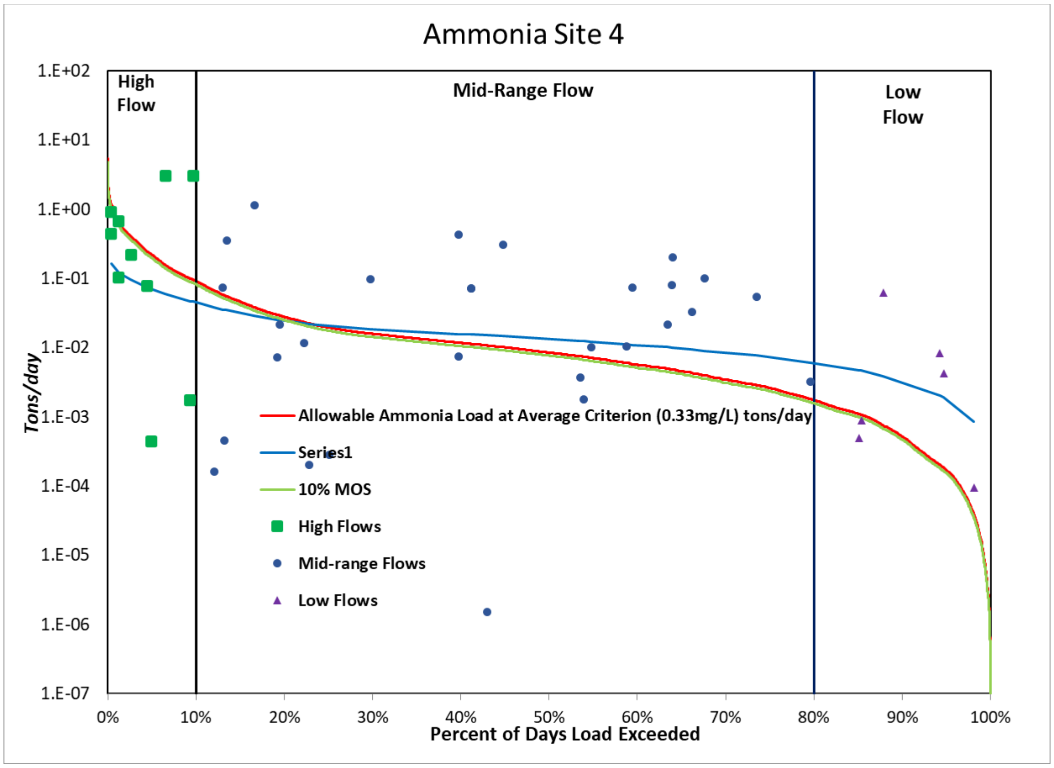

Figure B-14. Ammonia load duration curve at Site 4 showing the allowable load and the 10% MOS.

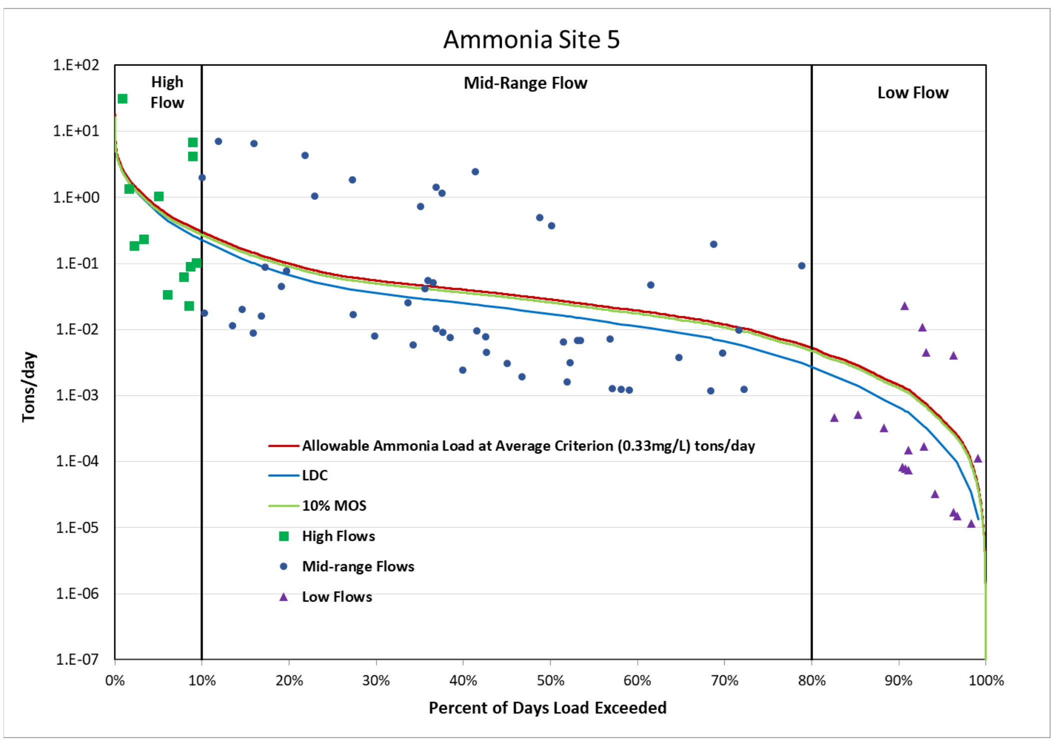

Figure B-15. Ammonia load duration curve at Site 5 showing the allowable load and the 10% MOS.

Total Phosphorus

Total phosphorus (TP) is a parameter used to analyze a water sample for all forms of phosphorus. Forms of phosphorus include organic and inorganic forms as well as dissolved and particulate forms. Total Phosphorus levels were in general lower than the MOS for all sites. A notable exception is high flows at Site 3 and low flows at Site 4.

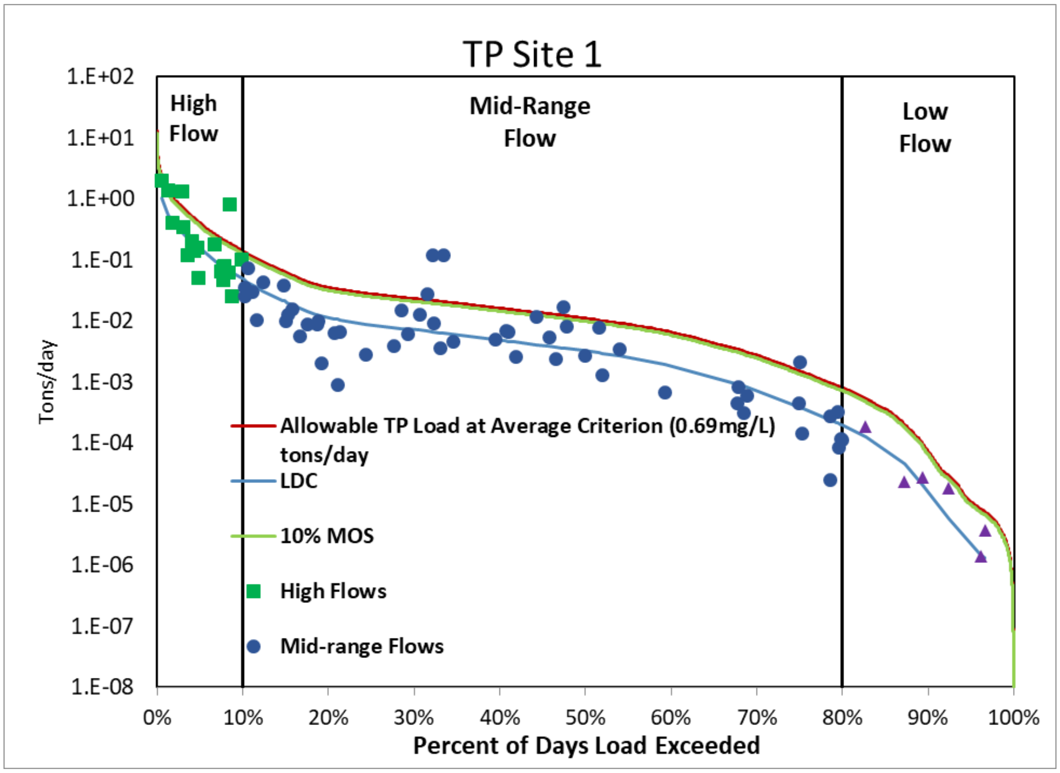

Figure B-16. Total Phosphorus load duration curve at Site 1 showing the allowable load and the 10% MOS.

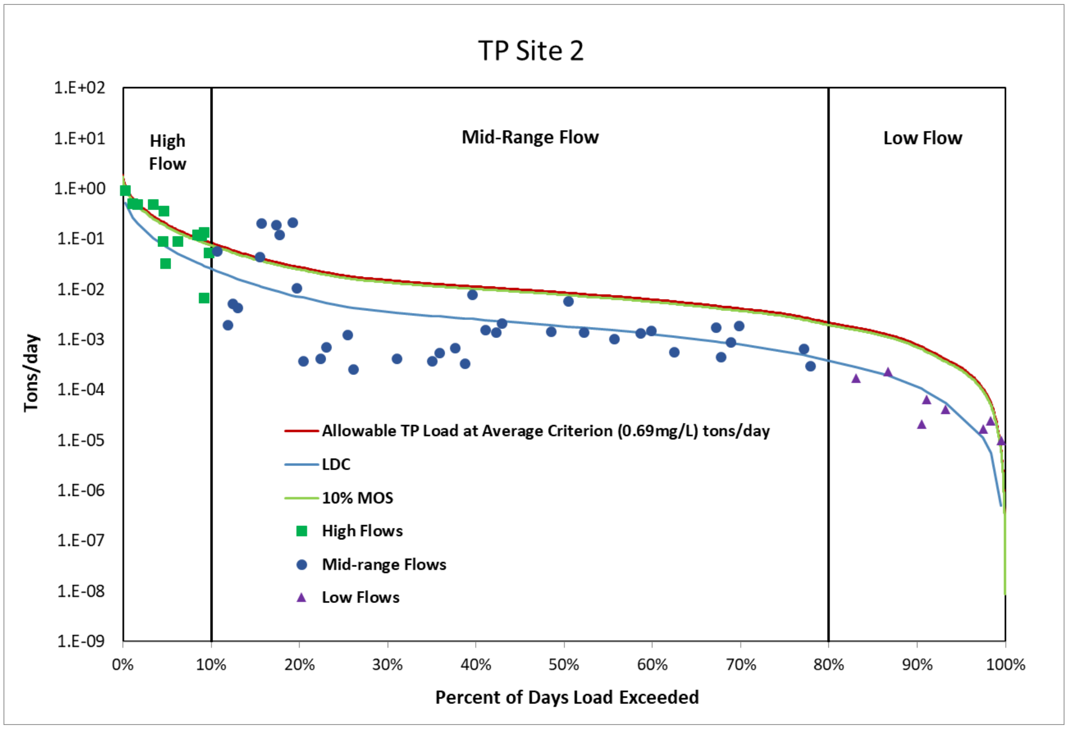

Figure B-17. Total Phosphorus load duration curve at Site 2 showing the allowable load and the 10% MOS.

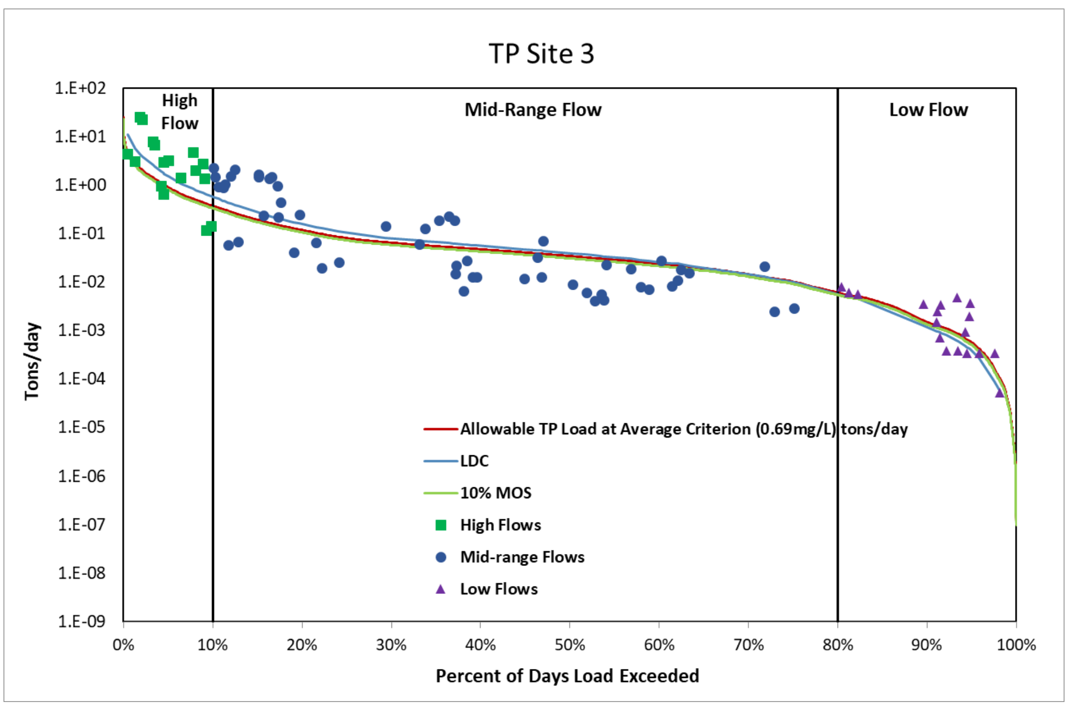

Figure B-18. Total Phosphorus load duration curve at Site 3 showing the allowable load and the 10% MOS.

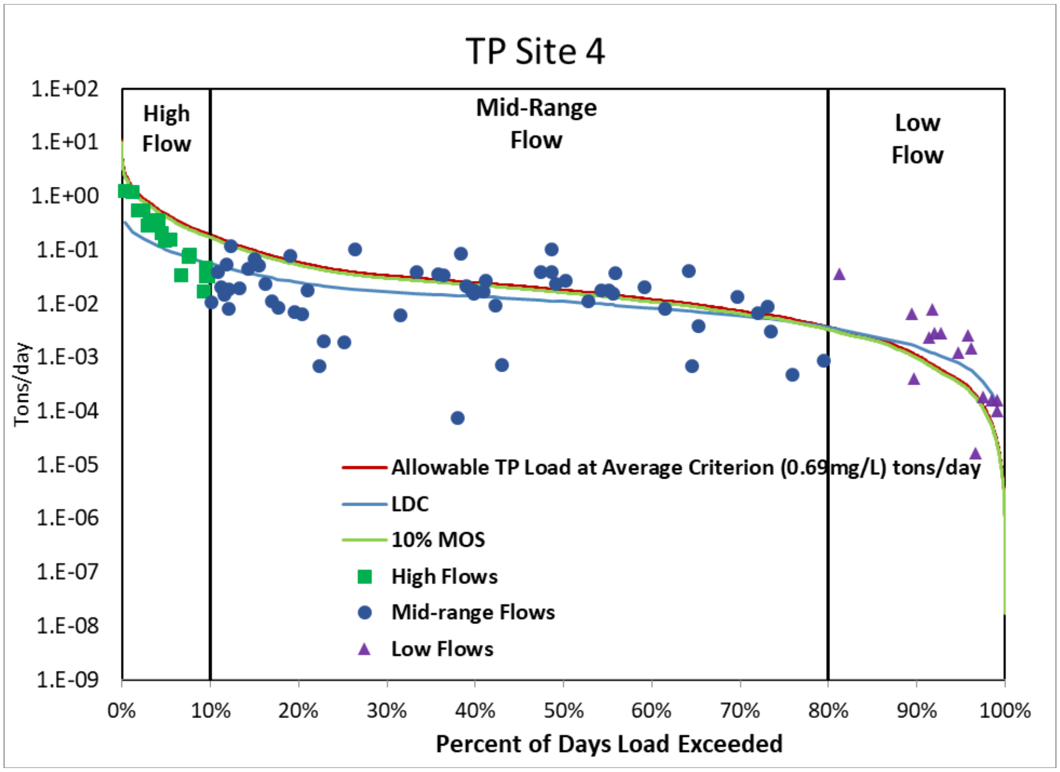

Figure B-19. Total Phosphorus load duration curve at Site 4 showing the allowable load and the 10% MOS.

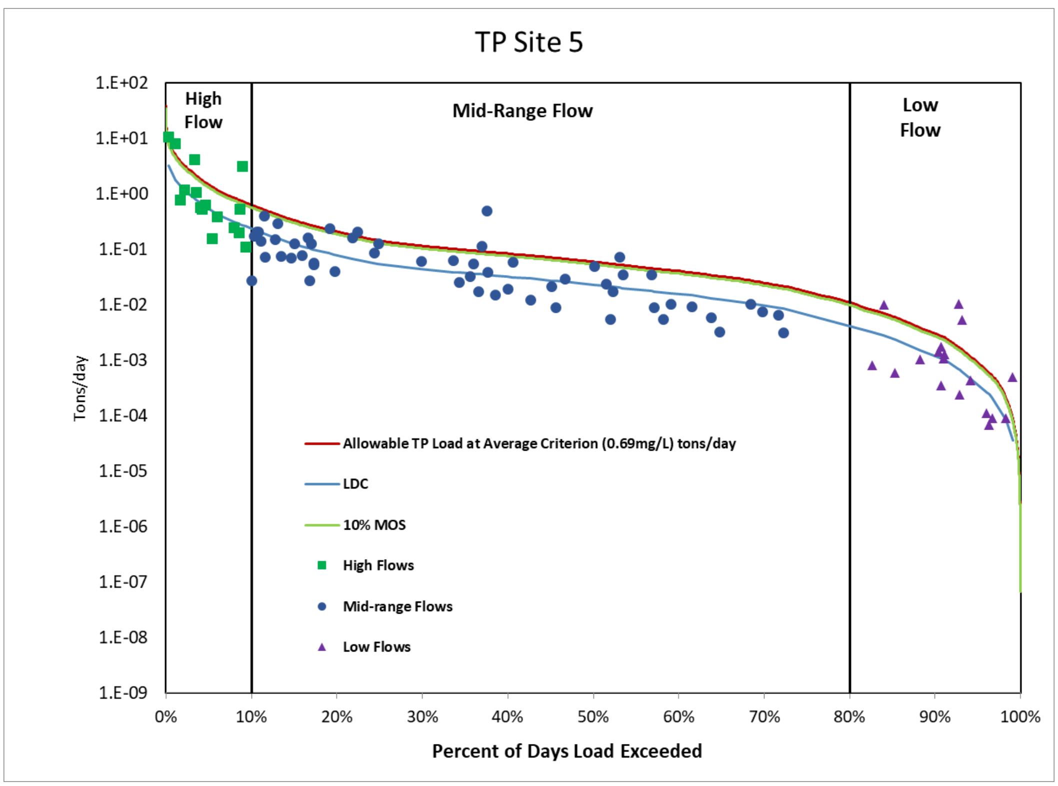

Figure B-20. Total Phosphorus load duration curve at Site 5 showing the allowable load and the 10% MOS.

Total Suspended Solids

Total suspended solids (TSS) are suspended particles in a water column that, when sampled, are not capable of passing through a specific pore sized filter. Solids are made up of organic matter that can include algal, bacterial cells or organisms as well as inorganic matter that includes soil sediments due to erosion. Suspended solids reduce water clarity and light penetration, slowing the growth of beneficial aquatic plant life. Fish are directly affected by sedimentation through the loss of insect prey, clogging and abrasion of gills and skin, and loss of species diversity. TSS loadings for the subwatersheds sizes were low at sites 1 and 2. These loads were significantly higher at Site 3 and to a lesser extent Site 4. Site 5 was a little lower than Sites 3 and 4 but the range of values was notably wider (large standard deviations). Such variability might be caused by the lake effects as Lake water levels sometimes impacted this site.

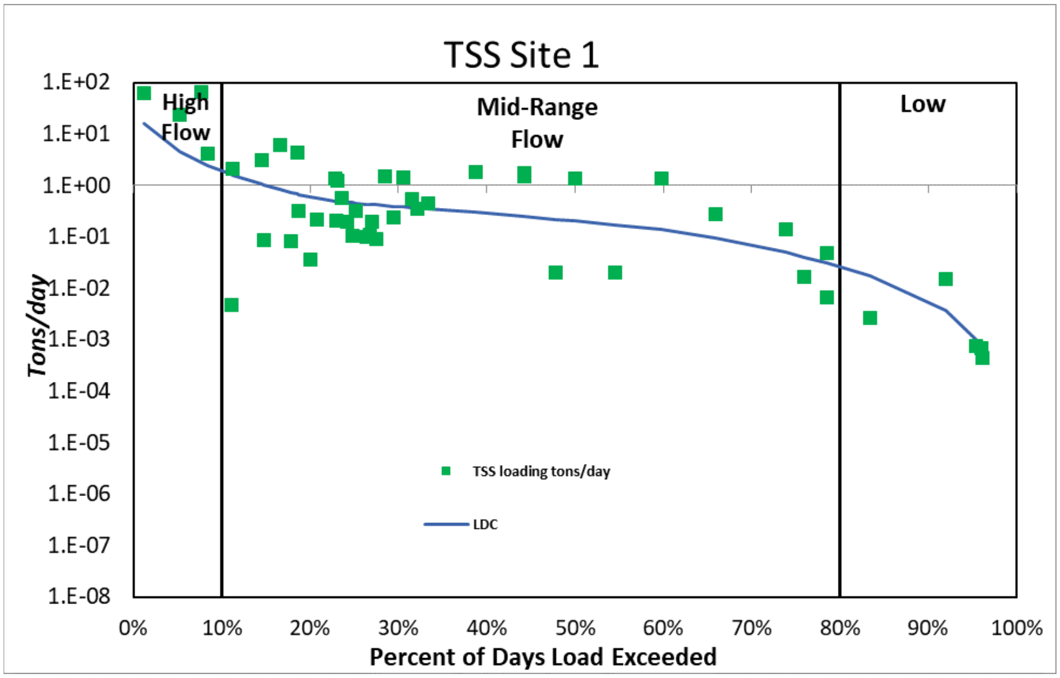

Figure B-21. Total suspended solids load duration curve at Site 1

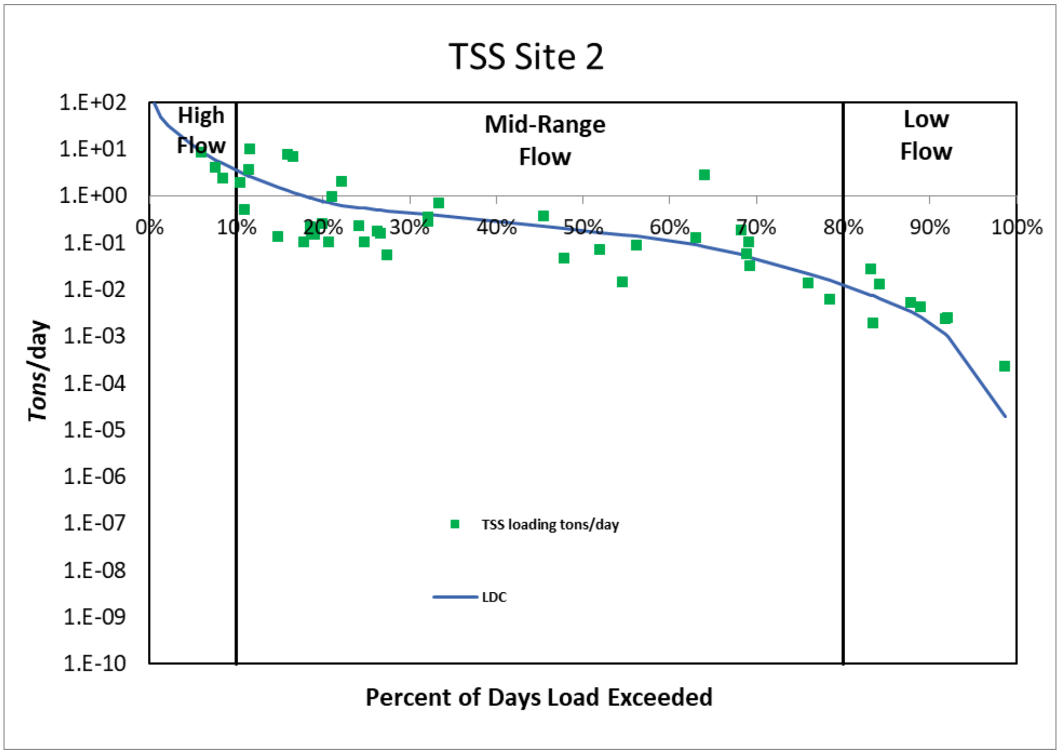

Figure B-22. Total suspended solids load duration curve at Site 2

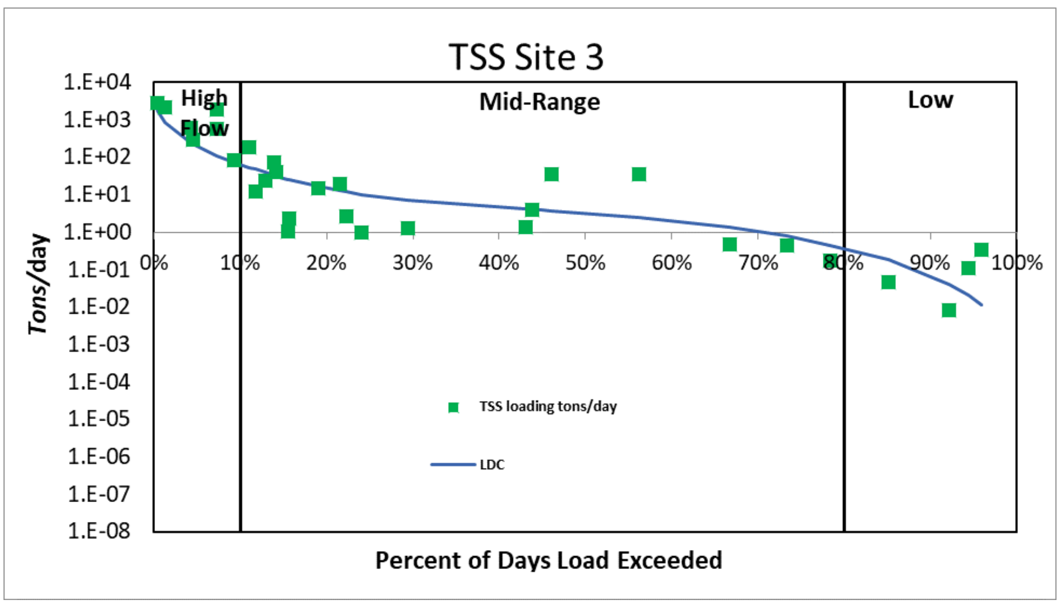

Figure B-23. Total suspended solids load duration curve at Site 3

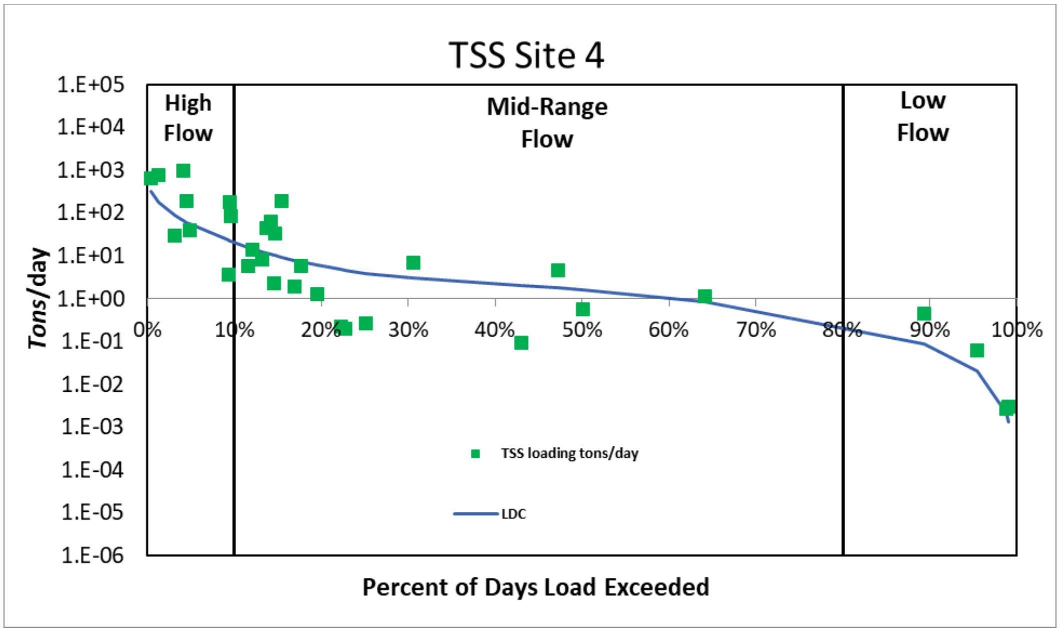

Figure B-24. Total suspended solids load duration curve at Site 4

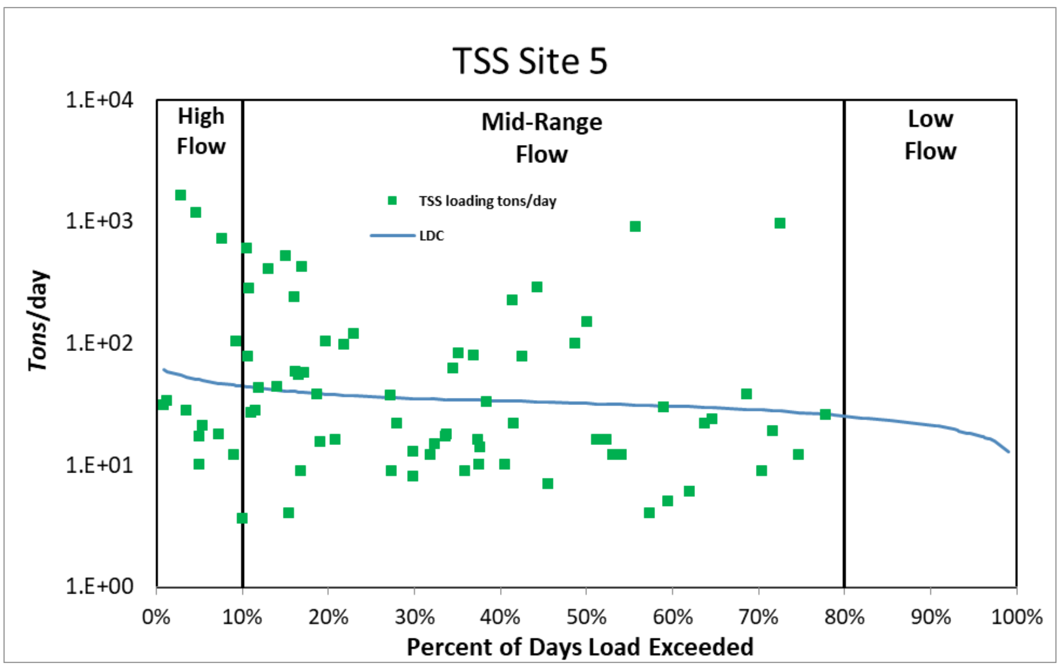

Figure B-25. Total suspended solids load duration curve at Site 5.

References

Jaber, F., Mehta, T., Firn, H., & Sun, W. (2023). *Rowlett Creek Watershed Characterization Project: Modeling Report*. https://agrilife.org/lid/rowlett-creek-watershed-protection-plan/

Appendix C: Calculations for Potential Bacteria Load Reduction Estimates

Estimates for bacteria load reductions in the Rowlett Creek watershed are based on the best available information regarding the effectiveness of management measures agreed upon by local stakeholders (EPA, 2008, 2010; EPA et al., 2001). The real-world conditions where implementation is completed will ultimately determine the actual load reduction achieved, which may differ from the estimated values. Stakeholders determined the types and numbers of management measures to be implemented over a 10-year period based on perceived local acceptability, effectiveness, and available resources.

Pet Waste Load Reductions

Potential load reductions for pet waste depend on the number of pets that contribute loading and the amount of pet waste that is picked up and disposed of properly (EPA, 2023). Assessing the number of dog owners who do not pick up waste or who would change behavior based on education or availability of pet waste stations is fundamentally difficult. Thus, only estimates of potential reduction can be made through the best available knowledge. If we assume that 50% of dog owners walk their dogs, 40% of those walkers do not pick up pet waste, and of those 40%, about 60% would be willing to change their behavior then 12% (0.5 × 0.4 × 0.6 = 0.12) of dog walkers can be assumed to change their behavior to begin picking up after their pets, and that 75% of the waste was disposed of properly (Center for Watershed Protection, 1999).

Table C-1. Bacteria load reduction assumptions for dogs.

Description	Assumption
Estimated number of dogs	186,994
Percent of dogs managed (Center for Watershed Protection, 1999)	12%
Practice Efficiency (Center for Watershed Protection, 1999)	75%
Fecal coliform production rate (EPA et al., 2001)	5.00×10^9 cfu/animal-day
Fecal coliform to E. coli conversion rate (Wagner & Moench, 2009)	0.63 *E. coli*/cfu fecal coliform

Using the assumptions in Table C-1, the potential annual bacteria load from dogs is estimated as:

$$LR_d = N_d \times M_d \times FC_d \times C \times 365 \frac{days}{year} \times E_d$$

Where:

$$LR_d = Potential\ annual\ E.coli\ loading\ reduction\ attrubutied\ to\ proper\ dog\ waste\ disposal$$

$$N_d = Number\ of\ dogs$$

$$M_d = Percentage\ of\ dogs\ managed$$

$$FC_d = Fecal\ coliform\ laoding\ rate\ of\ dogs$$

$$C = Fecal\ coliform\ to\ E.coli\ conversion\ rate$$

$$E_d = Assumption\ of\ percent\ efficiency\ of\ proper\ dog\ waste\ disposal$$

The estimated potential annual load reduction across the watershed attributed to proper dog waste disposal is 1.93×10^{16} cfu *E. coli*/year. Additionally, it can be anticipated that nutrient load reductions will accompany these *E. coli* reductions. The Tres Palacios and Carancahua Bay WPPs estimated annual load reductions between 0.8 - 1.0 pounds of nitrogen, and 0.2 pounds of phosphorus per additional dog managed (Schramm et al., 2017, 2019).

Feral Cat Load Reductions

Potential load reductions for feral cat waste depend on the number of cats that contribute loading, and the number of feral cats managed annually through trap-neuter-return (TNR) programs. Since TNR programs vary in effectiveness based on the management strategies implemented and the length of time implemented, assessing the amount of waste load reduction is fundamentally difficult (Dutcher et al., 2021). Thus, only estimates of potential reduction can be made through the best available knowledge and models which simulate trapping effectiveness. If we assume four trapping periods lasting 7-days each year leads to 57% of feral cats being successfully trapped and fixed annually, then over the course of 10 years this will lead to a reduction of the feral cat population by 25% (McCarthy et al., 2013).

Though the model is exponential, for simplicity it was further assumed that there would be an equal cumulative annual effectiveness of 2.5% (0.25/10-years = 0.025) reduction in feral cat population. The assumptions were developed based on the moderate-high management control measures being implemented and does not account for potential inflow of new cats from abandonment and roaming, or cats being completely removed from the outside to be placed for adoption or humanely euthanized for health reasons (Coe et al., 2021; McCarthy et al., 2013; Spehar & Wolf, 2018).

Additionally, to calculate the estimated fecal coliform production rate of feral cats per day the values of fecal bacterial density of 7.90E+06 cfu/gram from Schueler & Holland (2000) and fecal production rate of 40 grams/day from Dabritz et al. (2006).

Table C-2. Bacteria load reduction assumptions for feral cats.

Description	Assumption
Estimated number of feral cats	63,248
Percent of feral cats managed (McCarthy et al., 2013)	57%
Practice Efficiency (McCarthy et al., 2013)	25%
Fecal coliform density (Schueler & Holland, 2000)	7.90 x10^6 cfu/gram
Daily fecal production rate per cat (Dabritz et al., 2006)	40 grams/day
Fecal coliform production rate	3.16x 10^8 cfu/animal-day
Fecal coliform to E. coli conversion rate (Wagner & Moench, 2009)	0.63 *E. coli*/cfu fecal coliform

Using the assumptions in Table C-2, the potential annual bacteria load from cats is estimated as:

$$FC_c = (7.90\text{x}10^6 \text{ cfu/gram}) \text{ x } (40\text{grams/day})$$

$$LR_c = N_c \times PM_c \times FC_c \times C \times 365 \frac{days}{year} \times \frac{E_c}{10\ years}$$

Where:

$LR_c = Potential\ annual\ E.coli\ loading\ reduction\ attrubutied\ to\ feral\ cat\ waste\ disposal$

$N_c = Number\ of\ feral\ cat$

$PM_c = Percent\ of\ feral\ cats\ managed$

$FC_c = Fecal\ coliform\ loading\ rate\ of\ cats$

$C = Fecal\ coliform\ to\ E.coli\ conversion\ rate$

$$E_c = Assumption\ of\ percent\ efficiency\ of\ feral\ cat\ population\ management$$

The estimated potential annual load reduction across the watershed attributed to feral cat population reduction through management (TNR) is 6.55 x 10^{13} cfu *E. coli*/year.

Agricultural Nonpoint Source Load Reductions

The potential agricultural load reductions that are achieved through conservation planning and water quality management planning will depend on the specific management practices implemented by landowners. The load reduction will vary based on the type of practice implemented, existing land condition, number of cattle in each operation, and proximity to water bodies. Substantial research has been conducted on bacteria reduction efficiencies of practices, following other WPP development guidance's within Texas a median 62.8% load reduction effectiveness rate for conservation planning (Table C-3) was used in the calculations described below (Table C-5). Potential bacteria load reductions for livestock management measures were calculated first based on the assumed average number of grazing livestock per operation, average fecal coliform production rates, and standard conversions, conservation practice effectiveness, and proximity factor of practice to water body (Table C-4, Table C-5). The assumed number of operations and their number of grazing livestock were calculated using the USDA 2022 NASS county level data through spatial analysis. The proximity factor is an estimated impact factor that accounts for an assumed stream impact based on the location of a practice to the stream. Practices closer to a stream are assumed to have a higher potential load reduction impact while those further away have a lower impact. Since actual practices and locations are unknown a proximity factor of 25% was assumed, like used in other WPPs (Monroe et al., 2023).

Table C-3. Estimated effectiveness of conservation practices.

Conservation Practice	Effectiveness		
	Low	Median	High
Exclusion Fencing[a]	30%	62%	94%
Prescribed Grazing[b]	42%	54%	66%
Watering Facility[c]	51%	73%	94%

[a] (Brenner et al., 1996; Cook, 1998; Hagedorn et al., 1999; Line, 2002, 2003; Lombardo et al., 2000; Meals, 2004)
[b] (EPA, 2010; Tate et al., 2004)
[c] (Byers et al., 2005; Hagedorn et al., 1999; R. E. Sheffield et al., 1997)

Table C-4. Bacteria load assumptions for grazing livestock per operation (animal unit (AnU)) used to calculate the total daily load per farming operation.

Animal	Estimated AnU in Watershed (USDA & NASS, 2022)	AnU per operation (Wagner & Moench, 2009)	Fecal coliform production rate (cfu/AnU-day) (Wagner & Moench, 2009)
Cattle	612	16.34	8.55 x 10^9
Horses	81.25	2.17	2.91 x 10^8
Sheep	10.4	0.28	2.90 x 10^{11}

Table C-5. Bacteria load reduction assumptions for grazing livestock.

Description	Assumption
Number of farming operations (USDA & NASS, 2022)	37.5
Total daily load per operation	1.39 x 10^{11} cfu/operation-day

Practice Efficiency	62.8%
Water body proximity factor (Monroe et al., 2023)	25%
Fecal coliform to E. coli conversion rate (Wagner & Moench 2009)	0.63 *E. coli*/cfu fecal coliform

Using the above assumptions, the potential daily E. coli load per operation was estimated by:

$$PDL_o = \sum \frac{AnU_1}{N_o} \times FC_l \times C$$

Where:

$PDL_{ol} = Potential\ daily\ E.coli\ loading\ of\ all\ livestock\ per\ operation$

$AnU_l = Animal\ units$

$N_o = Number\ of\ operations$

$FC_l = Fecal\ coliform\ loading\ rate\ of\ animal$

$C = Fercal\ coliform\ to\ E.coli\ conversion\ rate$

Using the above assumptions and previous calculation, the potential annual load reduction was calculated as:

$$LR_l = N_p \times PDL_o \times 365\ days\ /\ year \times E_l \times P$$

Where:

$LR_l = Potential\ annual\ E.coli\ load\ reduction$

$PDL_{ol} = Potential\ daily\ E.coli\ loading\ of\ all\ livestock\ per\ operation$

$N_p = Number\ of\ plans$

$E_l = Median\ efficancy\ rate$

$P = Proximity\ factor$

The recommended number of WQMPs or CPs to be implemented is 5, resulting in a total potential annual load reduction of 3.99×10^{13} cfu E. coli/year across the watershed. The estimated potential annual loading across the watershed due to all livestock is 1.99×10^{15} cfu *E. coli*/year. Additionally, it can be anticipated that nutrient load reductions will accompany these *E. coli* reductions. The Tres Palacios and Carancahua Bay WPPs estimated annual load reductions between 733 – 983 pounds of nitrogen, and between 276 – 511 pounds of phosphorus per WQMP or CP depending on the size and type of operation (Schramm et al., 2017, 2019). Though it can be more appropriately assumed that given the smaller size of these operations (e.g., less than 19 AU/operation) compared to the ones described, the reductions may be much less.

Feral Hog Load Reductions

Load reductions for feral hogs assume that the estimated feral hog populations can be reduced and maintained by a certain amount on an annual basis. Moreover, assumptions that the existing feral hog population are present in the watershed, though no sightings in the past several years have been present in the watershed there are confirmed sightings in areas surrounding the watershed and are a concern of the stakeholders. Removal of feral hogs from the watershed is assumed to completely remove potential bacteria loads generated by that feral hog. Based on a GIS analysis, 187 feral hogs are estimated to be in the watershed (see Appendix A). A goal was established to reduce and maintain the feral hog population by 10% below current population estimates to reduce their potential loading. The proximity factor is assumed based on the proximity of the management measure to water bodies.

Table C-6. Assumptions used in calculating bacteria loading for feral hogs.

Description	Assumption
Estimated number of feral hogs	187
Percent of feral hogs managed	10%
Proximity factor (Wagner & Moench 2009)	25%
Fecal coliform production rate (Wagner & Moench 2009)	1.21 x 10^9 cfu/AnU-day
Fecal coliform to E. coli conversion rate (Wagner & Moench 2009)	0.63 *E. coli*/cfu fecal coliform

Using the above assumptions in Table C-6 and previous calculation, the potential annual load reduction was estimated as:

$$LR_h = N_h \times PM_h \times AnU_h \times FC_h \times C \times 365 \frac{days}{year} \times PF_h$$

Where:

$LR_h = Potential\ annual\ E.coli\ loading\ reduction\ attrubutied\ to\ feral\ hog\ removal$

$N_h = Number\ of\ feral\ hogs$

$PM_h = Percent\ of\ feral\ hogs\ managed$

$AnU_h = Animal\ units$

$FC_h = Fecal\ coliform\ loading\ rate\ of\ feral\ hogs$

$C = Fecal\ coliform\ to\ E.coli\ conversion\ rate$

$PF_h = Assumed\ proximity\ of\ the\ management\ measure\ to\ water\ bodies\ as\ percentage$

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Appendix D: EPAs Elements of a Successful Watershed Protection Plan

The EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (USEPA, 2008) describes the nine elements critical for achieving improvements in water quality that must by sufficiently included in the WPP for it to be eligible for implementation funding through the CWA Section 319 funds. These elements do not preclude additional information from being included in the WPP. Below are the nine elements briefly described and references to the chapters and sections that fulfill each element.

A. Identification of Causes and Sources of Impairments

Identify the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan, and to achieve any other watershed goals identified in the watershed-based plan. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed. Information can be based on a watershed inventory or extrapolated from a subwatershed inventory, aerial photos, GIS data, or other sources.

See Chapters 1, 3, 4, Appendix A, and B.

B. Estimated Load Reductions

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

See Chapter 4 and Appendix C.

C. Proposed Management Measures

Describe the management measures that will need to be implemented to achieve the estimated load reductions and identification (using a map or description) of the critical areas in which those measures will be needed to implement the plan. Proposed management measures are defined as including BMPs and measures needed to institutionalize changes. A critical area should be determined for each combination of source BMP.

See Chapter 5 and Appendix C.

D. Technical and Financial Assistance Needs

Estimate the amounts of technical and financial assistance needed, associated costs and/or the sources and authorities that will be relied upon to implement this plan. Authorities include the specific state or local legislation that allows, prohibits, or requires an activity.

See Chapter 6.

E. Information, Education and Public Participation Component

Information/education components will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the appropriate nonpoint source pollution management measures.

See Chapter 6.

F. Implementation Schedule

Schedule implementing the nonpoint source pollution management measures identified in the plan that is reasonably expeditious.

See Chapter 5.

G. Milestones

Provide a description of interim, measurable milestones for determining whether nonpoint source pollution management measures or other control actions are being implemented. Milestones should be tied to the progress of the plan to determine if it is moving in the right direction.

See Chapters 5 and 7.

H. Load Reduction Evaluation Criteria

Determine a set of criteria that can be used to determine whether loading reductions are being achieved over time and if substantial progress is being made toward attaining water quality standards. If not, it is also the criteria for determining if the watershed-based plan needs to be revised. The criteria for the plan needing revision should be based on the milestones and water quality changes.

See Chapters 5 and 7.

I. Monitoring Component

Include a monitoring component to evaluate the effectiveness of the implementation efforts over time that is measured against the evaluation criteria. The monitoring component should include required project-specific needs, the evaluation criteria, and local monitoring efforts. It should also be tied to the state water quality monitoring efforts.

See Chapter 7.

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