1.0 Watershed Management

1.1 Watersheds and Water Quality

A watershed is the land area that drains water to a common point such as a stream, river, lake, wetland, or ocean. Watersheds can be very small, such as part of a park that drains to the creek in your neighborhood. Many of these small watersheds combine to form much larger watersheds, such as major river basins that drain large portions of states, and in some cases, cover large portions of countries or continents. For example, several subwatersheds make up the Eagle Mountain Lake watershed, which is part of the Trinity River basin (Figure 1-1).

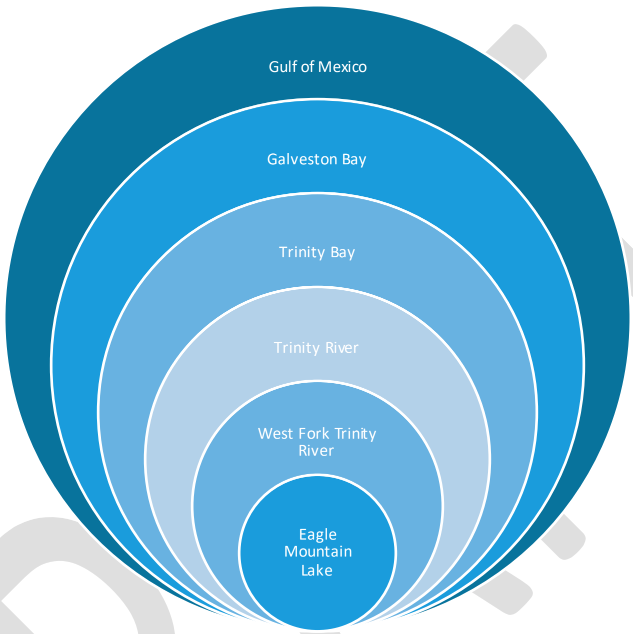


Figure 1-1. Conceptual interpretation of the EML watershed system

No matter where you are on Earth, you're in a watershed. As runoff water from storms flows across the landscape, it picks up and carries sediment and various other substances as it flows to a waterway. This means that everything we do on the land affects both water quality and quantity, and the cumulative effects can impact the function and health of the whole watershed.

An effective watershed management strategy will show a measurable effect on the water quality of the receiving water body. To accomplish this, the strategy must account for and examine the full scope of human activities and natural processes that occur within the watershed's boundary.

1.2 The Watershed Approach

Watersheds usually contain parts of many municipalities and counties and may even cross state lines. This often makes it difficult for any one entity to approach and solve water quality concerns on their own. To address this constraint, state and federal agencies have adopted a *watershed approach* for managing water quality, which involves assessing the sources and impacts of water quality impairments at the watershed level.

A key component of the watershed approach is input from stakeholders, which includes anyone that has an interest in the watershed. These stakeholders may offer unique insights and experiences gained from either working, living, or recreating in the watershed. These insights supplement water quality monitoring data to help inform management decisions. As users of the watershed, stakeholders have a vested interest in the water quality and will also be affected by the management decisions used to address water quality issues.

1.3 Watershed Protection Planning

A Watershed Protection Plan (WPP) is a watershed-based plan developed by the stakeholders to restore and/or protect water quality and designated uses of a waterbody through a combination of voluntary, non-regulatory water resource management measures. WPPs are an important part of the State's approach to managing nonpoint source (NPS) pollution. This plan was developed by stakeholders to address growing water quality issues in Eagle Mountain Lake and to protect this major drinking water supply from further degradation. The plan provides a comprehensive analysis and planning vehicle for restoring and protecting water quality in Eagle Mountain Lake (EML).

Via the WPP process, stakeholders help select, design, and implement management strategies best suited for the watershed from the standpoints of economic feasibility, social acceptability, and scientific credibility. Public participation is critical throughout plan development and implementation, as ultimate success of any WPP depends on stewardship of the land and water resources by local landowners, business, residents, and municipal leaders in the watershed.

To support stakeholders who wish to utilize this watershed approach, the Environmental Protection Agency (EPA) has developed a list of nine key elements (REF) necessary for developing a WPP capable of addressing water quality issues. WPPs are reviewed by either Texas Commission on Environmental Quality (TCEQ) or Texas State Soil and Water Conservation Board (TSSWCB) and then EPA to assess a plan's consistency with the nine elements. Acceptance of the WPP by EPA is necessary for implementation and future updates to be considered eligible for Clean Water Act (CWA) §319(h) funding. Details about these elements, as well as the WPP chapters they correspond to, are provided in Appendix A: Key Elements of Successful WPPs.

1.4 The Eagle Mountain Lake Watershed Protection Effort

Effective WPPs utilize local knowledge and expertise to guide the planning process, ensuring that the BMPs selected for implementation are relevant to the watershed's issues, applicable to the environmental setting of the watershed, and feasible for the watershed residents, given available resources. If this process is followed, local stakeholders are more likely to modify their behaviors and adopt the BMPs identified in the Plan.

The EML watershed protection effort was initiated to address water quality concerns in both EML and its tributaries. Drinking water from EML is part of an integrated regional water system that serves more than 2.4 million customers across 11 counties. Long-term analyses also indicate statistically significant relationships between nutrient and chlorophyll-a concentrations in Eagle Mountain Lake and other lakes in the region. This relationship between "causal" and "response" pollutants allows for the use of both chemical and biological data to establish comprehensive water quality goals for the lake, as well as implementation milestones for the watershed.

1.4.1 Structure

The general EML WPP stakeholder is open to public participation without formal membership. Anyone with an interest in the watershed and water quality in EML or its contributing streams is welcome to attend and provide input at in-person or virtual stakeholder meetings. Specifically-identified partners in Table 1-1 provided technical advice or develop technical materials such as modeling reports. To ensure that watershed interests are well-represented, there is a continued effort by the project team to maintain stakeholder representation that is well-distributed, both spatially throughout the watershed, and topically amongst multiple users with varying needs.

**Temporary note: contents of Table 1-2 will be adjusted as the WPP process progresses*

Table 1-1 EML WPP partners

Partner	Contributions

Natural Resources	
Texas A&M AgriLife Research	Modeling/Analytical Products
Texas A&M AgriLife Extension	Workshop support (ongoing)
Texas Water Resources Institute	Technical advice and workshop support
USDA-Natural Resources Conservation Service	Technical advice, data, and document review
Texas State Soil and Water Conservation Board	Technical advice, data, and document review
Soil and Water Conservation Districts	Data and technical advice
Texas Commission on Environmental Quality	Technical advice, data, and document review
Municipal	
North Central Texas Council of Governments	Data and coordination support
Non-Profit	
Save Eagle Mountain Lake	Community engagement
Businesses and Individuals	
Example	Document Review

1.4.2 Coordinated Development of the Watershed Protection Plan

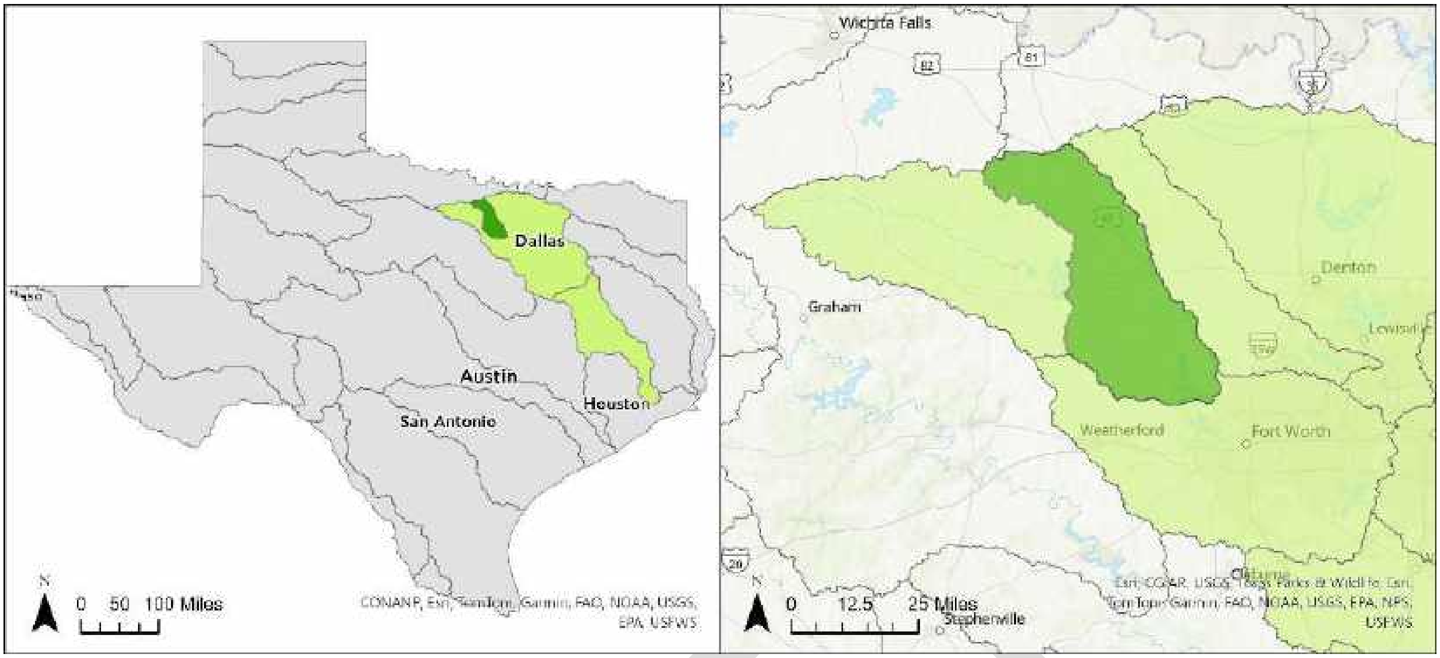
Partnership members were instrumental in identifying BMPs and strategies that proved useful from their diverse experiences. TRWD and its modeling partners at Texas A&M AgriLife used information from technical partners and general stakeholder meetings to recommend which BMPs were the best fit for the EML watershed and its residents.

Ultimately, this information was used to evaluate BMPs that should be implemented to achieve the desired water quality goals. This process involves continued communication between TRWD, its partners, and stakeholders as they identify measurable milestones and prioritize specific BMPs. Achieving improvements in water quality will not be a short-term effort and will continue long after the initial planning period is complete. Even after the Plan's water quality goals are achieved, continued preservation of these goals and long-term protection of the watershed is necessary. These programs and practices will require periodic evaluation of their results through continued water quality monitoring, which will be targeted to interim and long-term milestones. Through these evaluations, adaptive management techniques will be used to reassess the recommended strategies used in the watershed.

2.0 Watershed Overview

2.1 Geography

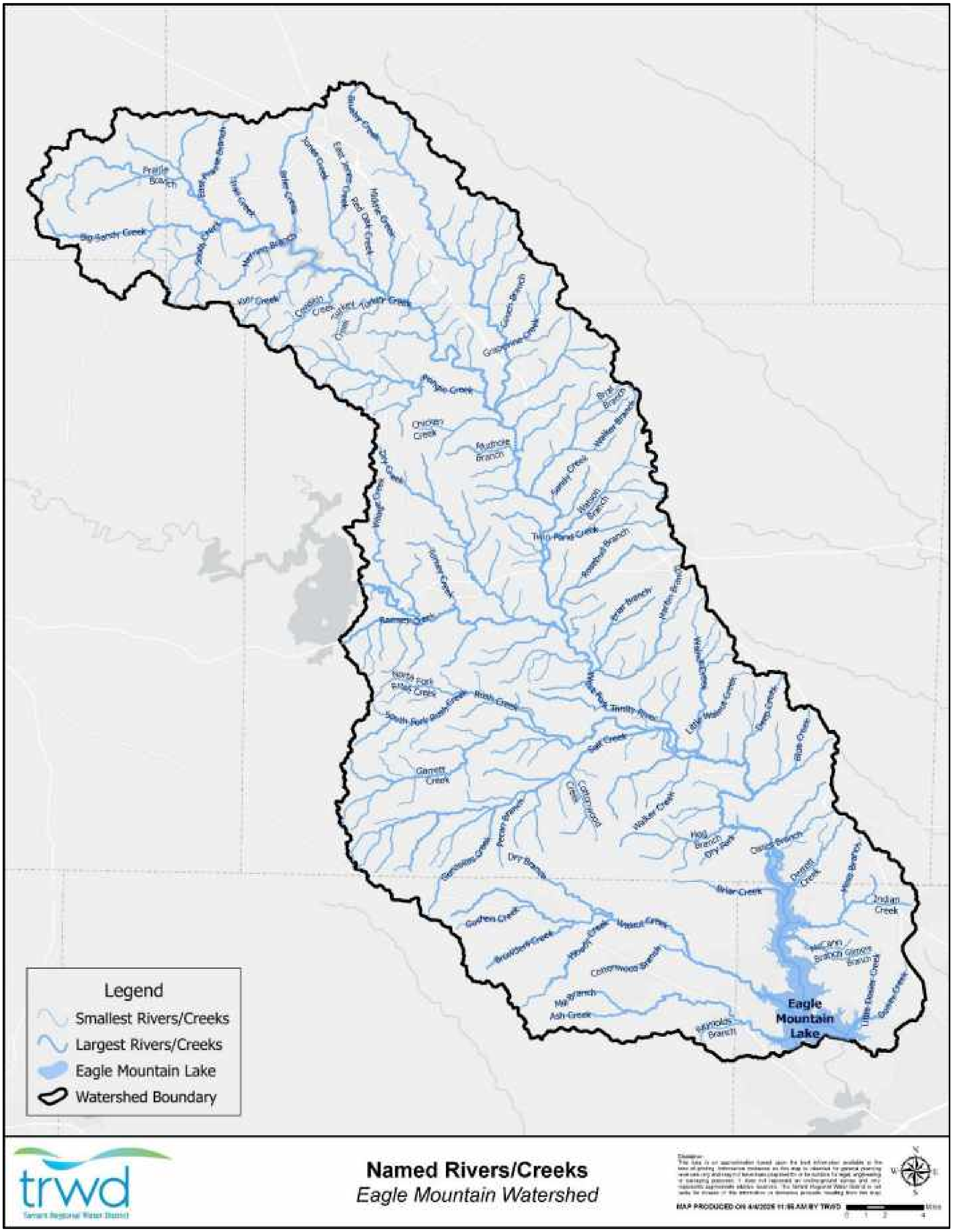
Permitted in 1928 for municipal, industrial, and irrigation use, Eagle Mountain Lake is one of four reservoirs owned by the Tarrant Regional Water District and operated for raw water supply, irrigation, flood control, and recreational purposes. Construction on the Eagle Mountain Lake dam was completed in 1932, impounding flows from a 1,970 square mile watershed that extends across portions of Tarrant, Parker, Wise, Montague, Jack, Clay, Young, and Archer Counties. Approximately 1,110 square miles of this watershed is impounded by the Lake Bridgeport dam in western Wise County, which controls inflows to Eagle Mountain Lake from the western 56% of the watershed. Although flows and water quality passing through Lake Bridgeport are considered in modeling efforts, the planning and implementation described in this WPP apply only to the 860 square mile (550,000 acre) portion of the watershed not controlled by the Lake Bridgeport reservoir.



Data source: TWDB and TCEQ.

Figure 2-1 Location of the EML watershed within the Trinity River Basin in Texas

EML receives flow from the West Fork of the Trinity River, which supported by releases from Lake Bridgeport. It also has numerous perennial tributaries, notably Big Sandy Creek, Derrett Creek, Dosier Creek, Martin Branch, Walnut Creek. The intermittent tributary Ash Creek is also notable due to water quality impairments. These many creeks flow into both the western and eastern sides of the lake, as well into the West Fork above EML (Figure 2-2). These incoming flows are comprised of stormwater runoff, as well as outfalls from 22 permitted municipal and privately owned.



Stream data source: NHD

Figure 2-2 Named rivers and creeks of the EML watershed

Databases maintained by TCEQ did not identify any discharges of cooling water, mining effluent, or concentrated animal feeding operation effluent in the watershed. Population estimates for the 18 municipalities throughout the watershed are shown in Table 2-1.

Table 2-1Population centers in the EML watershed

City	2020 Population Estimate[a]	% of City Limits in Watershed[b]	Population in Watershed[c]
Fort Worth	918,915	3%	23006
Azle	13,369	99%	13209
Bridgeport	5,923	98%	5798
Bowie	5,448	99%	5398
Decatur	6,538	69%	4511
Springtown	3,064	100%	3064
Reno	2,878	100%	2878
Pelican Bay	2,049	100%	2049
Boyd	1,416	100%	1416
Aurora	1,390	100%	1390
Alvord	1,351	100%	1351
Rhome	1,630	68%	1108
Newark	1,096	100%	1096
Chico	946	100%	946
Paradise	475	100%	475
Sanctuary	337	100%	337
New Fairview	1,386	8%	116
Lake Bridgeport	339	7%	25
(a) U.S. Census Bureau estimate based on 2020 census data. REF			
(b) Calculated using the Texas Department of Transportation 2022 city Transportation boundary dataset. REF			
(c) Assumes uniform population density.			

2.2 Geology and Soils

The majority of the watershed is underlain by units from the Trinity and Canyon groups. Soils vary across the watershed, but are overall dominated by sandy loams. Areas to the southeast edge of the watershed near EML have higher clay content. Intermittent zones of clay soils also occur in the western reaches of the watershed and past and present fluvial deposits result in narrow areas of silt-dominated soils (REF).

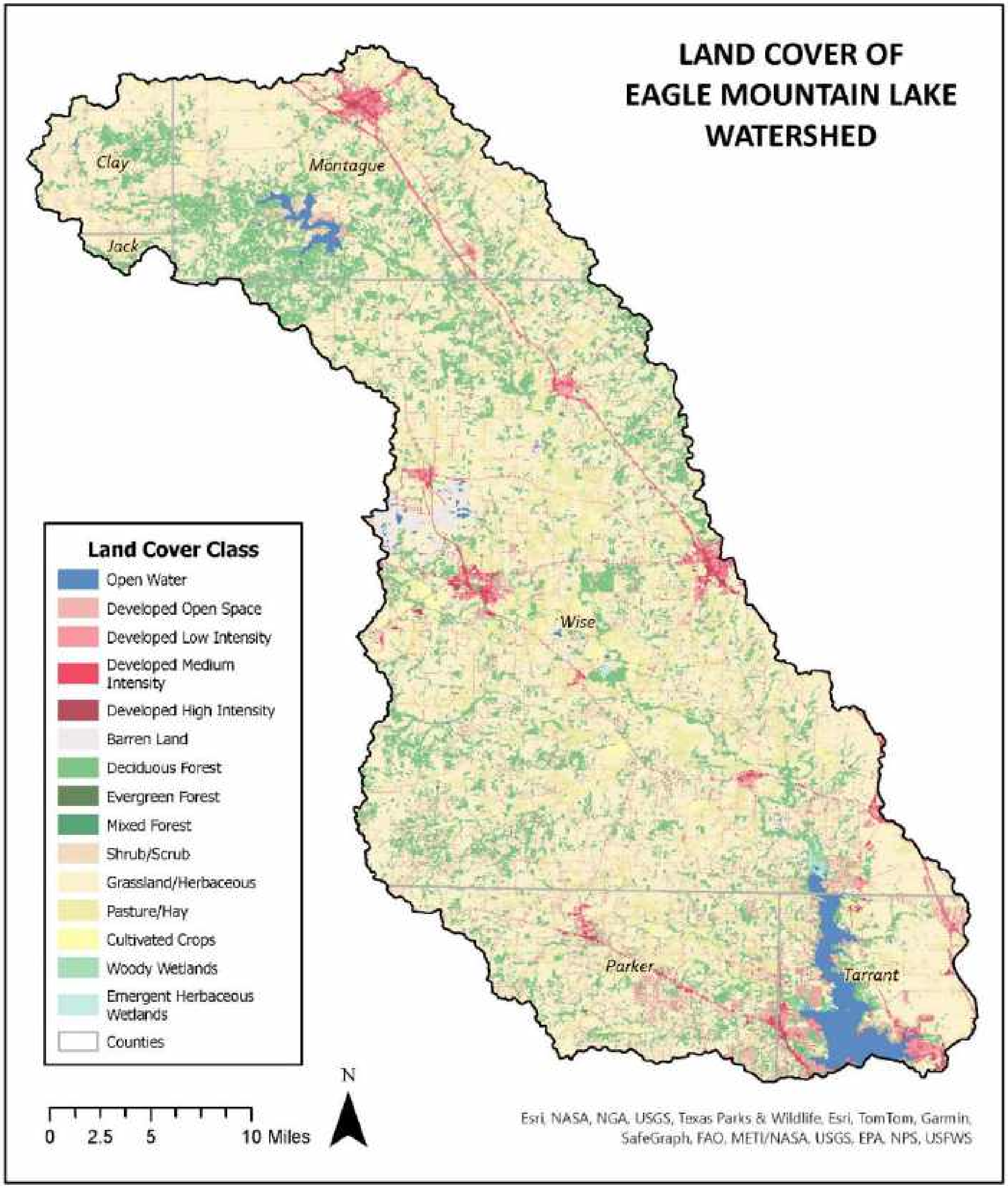
2.3 Land Use and Land Cover

Agricultural production is the dominant land use in the Eagle Mountain Lake watershed and is a leading driver of water quality in the Eagle Mountain Lake watershed. Early agricultural systems were primarily row crops, such as cotton. By 1920, serious erosion was occurring, much of the topsoil was gone, and gullying was rampant. It is assumed that this trend continued until the 50's and 60's at which time the NRCS began structural erosion control practices as well as non-structural land management practices in the basin. At the same time, the number of cropping operations declined owing to the depression in the 1930's and then poor yields and market value for crops following this period. In Wise County as of 1983, only 11 percent of the land was devoted to crops, with the majority in range and pasture. Current land cover maps classify 57% of the total land cover as grassland, 8% as pasture and hay, and just 2% in cultivated crops Table 2-2.

Table 2-2 Land cover types in the EML watershed

LULC Category	Acres			% Total Area
	Riparian	Upland		Total
Barren land (Rock/Sand/Clay)	93	3,357	3450	0.6%
Cultivated Crops	755	10,116	10871	2.0%
Deciduous Forest	8,087	77,796	85883	15.6%
Developed, High Density	29	1,863	1892	0.3%
Developed, Low Density	323	17,834	18157	3.3%
Developed, Med Density	116	6,335	6451	1.2%
Developed, Open Space	695	26,039	26734	4.8%
Emergent Herbaceous Wetlands	558	3,810	4368	0.8%
Evergreen Forest	8	206	214	0.0%
Grassland/Herbaceous	10,415	304,477	314892	57.1%
Mixed Forest	10	247	257	0.0%
Open Water	2,598	10,484	13082	2.4%
Pasture/Hay	3,397	41,370	44767	8.1%
Shrub/Scrub	785	8,935	9720	1.8%
Woody Wetlands	4,694	5,857	10551	1.9%
Total Composite Acreage	32,563	518,728	551291	100.0%

Although development is occurring in areas near the lake and around cities, developed land cover (including roadways) makes up less than 10% of the overall watershed area. These population centers compose most of the developed land in the area, which is shown as red areas in Figure 2-3. The EML watershed contains multiple parks, trails, and outdoor public spaces operated by various public and private entities including cities, Texas Parks and Wildlife Department, United States Forest Service, TRWD, and land trusts. Parks, trails, and open spaces provide multiple benefits to the watershed, but will also benefit from this WPP as the plan provides BMPs to reduce negative impacts to water quality.



Land data: USGS NLCD 2021

Figure 2-3 Land cover across the EML watershed

2.4 Ecology

The watershed is situated almost entirely within the Cross Timbers ecoregion, with a negligible portion in the far northwest portion of the watershed falling into the Central Great Plains. The Cross Timbers ecoregion includes swaths of prairie habitats with wooded habitat bands. It supports grassland species such as little bluestem, big bluestem, and Indiangrass. Taller woody species like post oak and American elm occur in forested bands to the east and thin out to isolated trees or clusters of live oaks, Eastern red cedar, and other shrubbier species in the drier west.

The lake itself also has ecological value as habitat for aquatic life and food source for animals that feed there. EML has little aquatic vegetation compared to some other lakes in the region. EML is home to several sport-fishing favorites, including white, spotted, and largemouth bass, as well as crappie and catfish.

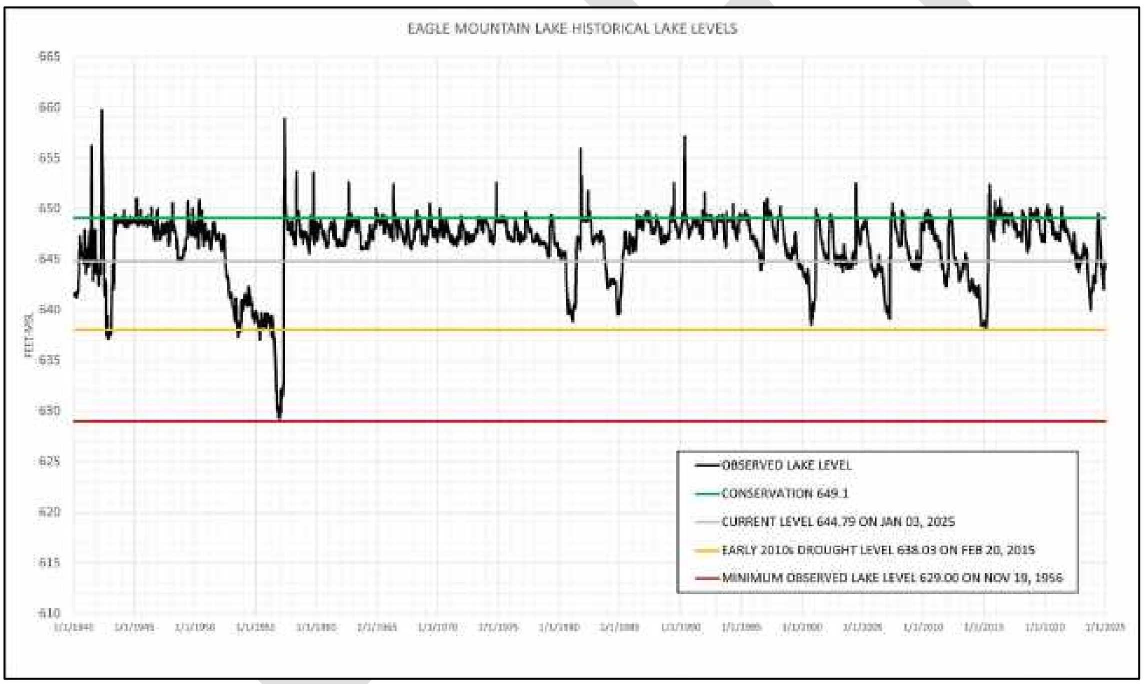
2.5 Climate

The mean annual daily temperature from the National Weather Service's DFW regional database (National Weather Service, 2025) is 66.6°Fahrenheit (F) for the current 30-year period of record (POR). Temperatures are generally lowest in January and highest in August. Annual precipitation is highly variable across North Texas, even within the Cross Timbers ecoregion. Totals range from about 35 inches in eastern part of the ecoregion, which is where EML is located, to 25 inches in the western parts.

2.6 Surface Water

2.6.1 Eagle Mountain Lake

The normal conservation pool elevation for EML is 649 ft above mean sea level (MSL) and the flood pool elevation is 668 ft MSL. Historical lake elevations from 1940 to 2025 are provided in Figure 2-5. At conservation level, EML holds 179,880 ac-ft of water (Texas Water Development Board, 2025).



Data source: TRWD

Figure 2-4 Observed water surface elevation in EML, 1940-2025

As noted above, EML receives flows from numerous sources: natural flow from the West Fork Trinity River and other creeks, as well as releases from Lake Bridgeport through the West Fork, and some effluent sources. In addition, EML receives water from other reservoirs in the TRWD water supply system to balance supply system-wide and ensure that water is where it needs to be for delivery to customers. Typically, this water comes from TRWD's larger reservoirs in the wetter eastern part of north Texas.

The lake is also used regularly for aquatic and waterfront recreation, including at two TRWD-owned and -operated parks, Twin Points Park (summer only with an improved beachfront) and Eagle Mountain Park (year-round access and managed for ecosystem quality).

2.6.2 Lake Tributaries

EML is fed by the West Fork of the Trinity River, its tributaries, and numerous smaller creeks flowing directly into the lake. The West Fork flows into the western side of the watershed out of Lake Bridgeport. To the north, the watershed is drained by Big Sandy Creek and its tributary Brushy Creek across mostly unincorporated land. The creeks that drain directly into the lake, including notable streams like Ash Creek and Walnut Creek flowing into the western side of the reservoir and Dosier and Derrett flowing into the eastern side, drain land areas including communities ranging from small enclaves to the fringes of the Fort Worth metropolitan area.

USGS monitoring stations on Big Sandy Creek above its confluence with the West Fork Trinity River, West Fork Trinity River near Boyd, and Walnut Creek near Reno provide flow data. Other flow data exist at other stations throughout the watershed within TCEQ Surface Water Quality Monitoring Information System (SWQMIS) that will be used to supplement the USGS dataset, where appropriate.

3.0 Water Quality Assessment

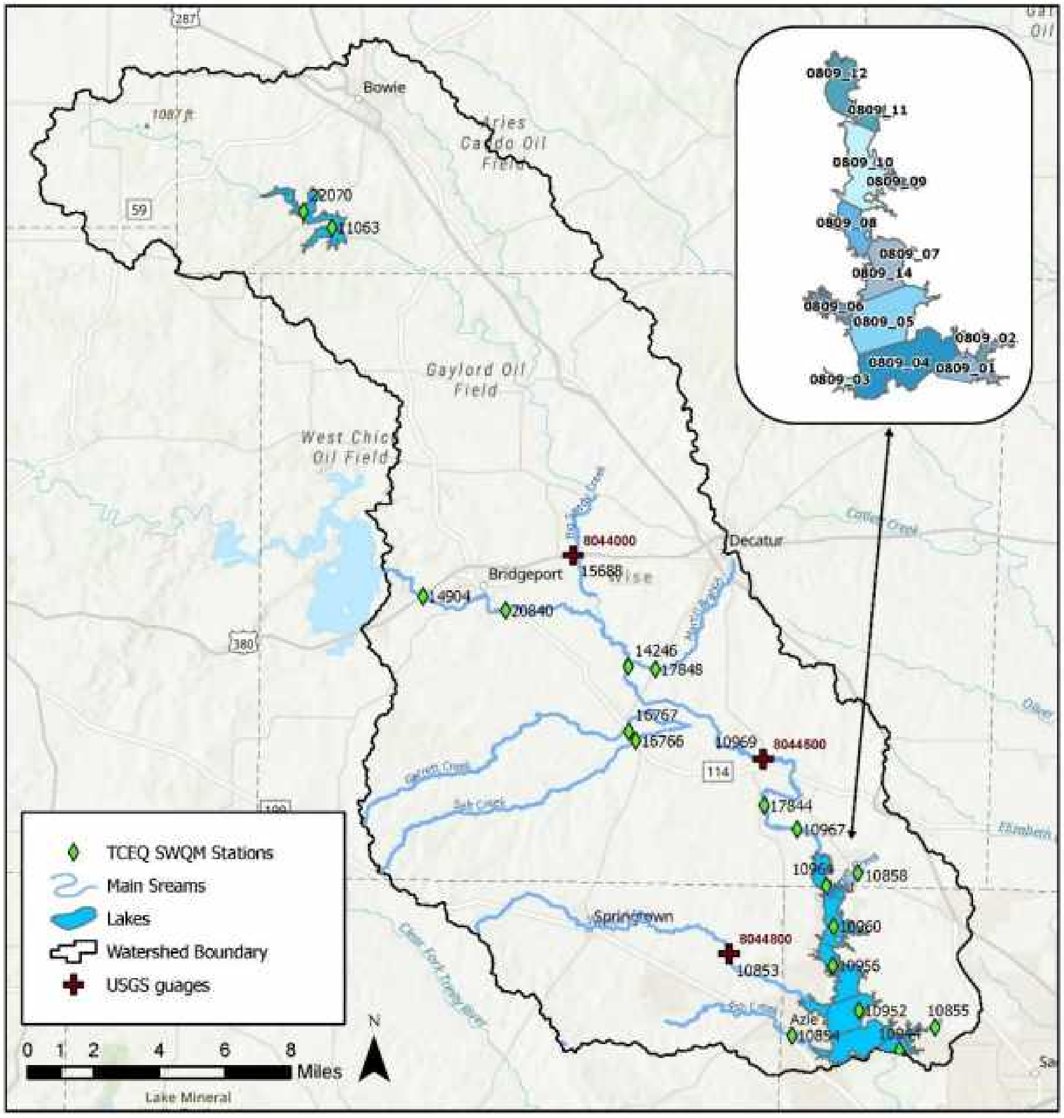
The EPA requires states to develop a list (commonly called the 303(d) List) describing water bodies in or bordering Texas for which effluent limitations are not stringent enough to implement water quality standards (REF 40 CFR § 130.7). In accordance with CWA (REF 33 USC § 1251.303), States may create and apply their own water quality standards, but these must first be approved by the EPA. In Texas, these water quality standards and the designated uses they are designed to support are defined in the Texas Water Code, in fulfillment of the requirements laid out by the CWA. Addressing waterways impaired by pollution and hazardous substances is at the heart of the CWA, which requires standards that: 1) maintain and restore biological integrity; 2) ensure that all waterbodies remain “swimmable and fishable” by protecting fish, wildlife, and recreational uses, and 3) assess the many uses of a water of the state (public water supply, agricultural, industrial, wildlife, recreation) from both a use and value standpoint.

EPA also requires that states develop acceptable strategies for restoring water quality in its impaired waterbodies (40 CFR § 130.7). One acceptable strategy is the use of a regulatory mechanism for developing total maximum daily loads (TMDLs) that sets budgets for pollutants in a water body. These budgets identify the water body’s maximum pollutant loading capacity and the reduction required to meet standards for applicable uses. TMDLs accomplish this by allocating the pollutant load budget to a variety of pollutant sources and establishing the maximum allowable loads from those sources. An alternative strategy involves the use of non-regulatory methods, such as a WPP. This allows stakeholders to identify and address water quality impairments, along with other water quality concerns in the watershed, with more autonomy in comparison to a TMDL. Due to the wider scope allowed with WPPs, established water quality goals may also include protections for unimpaired waters in addition to the goal of restoring impaired water bodies.

3.1 Water Body Assessments

In compliance with Sections 305(b) and 303(d) of the CWA, TCEQ conducts biennial assessments of Texas waterbodies, with results provided in the Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d) List (REF Texas Integrated Report). A range of water quality conditions and assessment status is expressed by a level of support established in each assessment unit for each use and parameter combination. Support status reflects when (1) data are not sufficient to allow assessment, (2) only a concern can be established from limited data, and (3) the assessment can confidently establish the level of support.

The 2024 Texas Integrated Report for the Trinity River covers a seven- to ten-year assessment period through November 2024 (REF TCEQ, 2024). Water quality was evaluated according to the methods described in the *2024 Guidance for Assessing and Reporting Surface Water Quality in Texas* (REF).



Basemap: ESRI World Street Map; Stream data source: NHD; station data: TCEQ

Figure 3-1 Assessment units, segments, and surface water quality monitoring stations in EML watershed

3.2 Texas Surface Water Quality Standards

TCEQ is responsible for establishing numeric and narrative criteria for water quality in the state of Texas. These criteria are described in TCEQ's Texas Surface Water Quality Standards (TSWQS) which are codified in the Texas Administrative Code (TAC), Title 30, Chapter 307, hereto referred to as TAC 307 (REF TCEQ, 2018). The TSWQS are effective for Clean Water Act purposes when they are approved by the EPA.

Bacteria

The Primary Contact Recreation 1 (PCR1) use is evaluated using a numeric criterion of 126 cfu per 100 mL of water, although newer bacteria enumeration methods use MPN/100 mL metric. The two should be considered equivalent for the purposes of this project. The presumption of a PCR1 use and associated numeric criteria are applied to all freshwater systems in Texas unless site-specific standards have been developed. This numeric criterion is compared to the geometric mean (geomean) of the surface water quality dataset, which must include a minimum of 20 samples over a seven-year period (TCEQ, 2015a).

Total Dissolved Solids

Total dissolved solids (TDS) is a rudimentary measurement of all the dissolved ions within a water body, such as chloride, sulfate, and other dissolved salts. While it does provide a rough indicator of general water quality for evaluating aquatic life and public water supply uses, it cannot reveal the specific source or composition of the ions in the sample.

Other Measurements

Several additional parameters are often measured routinely to assess general use, support of aquatic life, and for public water supply use. These include DO, water temperature, pH, chloride, and sulfate. Chloride and sulfate are components of TDS, with excessive levels of each posing similar concerns for both aquatic life and public water supply uses.

Water temperature and pH are similarly important for a variety of uses. Healthy aquatic habitats in Texas typically fall within a pH range of 6.5-9.0. The pH values can be heavily dependent on water temperature, with excessively high water temperatures (>95 °F) indicating conditions that are stressful for aquatic organisms. This association is also evident with DO, which is vital to the survival of fish and other aquatic fauna, being affected by both temperature and nutrient concentrations.

Table 3-1 TCEQ site specific criteria for EML and tributaries

Parameter		0809 Eagle Mountain Reservoir	0810 West Fork Trinity River Below Bridgeport Reservoir
Chloride (Cl^{-1})	mg/L	75	100
Sulfate (SO_4^{-2})	mg/L	75	100
Total Dissolved Solids (TDS)	mg/L	500	300
Dissolved Oxygen (DO)	mg/L	5.0*	5.0*
pH Range	SU	6.5-9.0*	6.5-9.0*
E. coli	#/100 mL	126*	126*
Temperature	Degrees F	94	90
TAC 307 (TCEQ 2018) REF			
*site criteria matches standard criteria			

3.3 Nutrient Screening Levels and Reference Criteria

Currently, no numeric criteria have been adopted for nutrients in streams in the state of Texas. Numeric criteria for chlorophyll-*a* have been adopted by TCEQ and approved by EPA for 39 of 75 reservoirs in the state; however, EML is not one of these approved reservoirs. In such situations where no numeric criteria have been adopted or are in the process of being developed, controls such as narrative criteria and antidegradation considerations are often used. Despite this lack of numeric criteria, TCEQ continues to screen for parameters such as nitrogen, phosphorus, and chlorophyll-*a* as preliminary indicators for concern. To support this effort, nutrient screening levels and reference conditions are often used to compare a water body to reference values at a local, regional, or national level. Table 3-1 provides screening values from various sources. The Texas Nutrient Screening Levels are based on statistical analyses of Surface Water Quality Monitoring (SWQM) data. They are based on the 85th percentile values for each parameter in freshwater streams, tidal streams and reservoirs without numeric criteria throughout the state of Texas (REF TCEQ, 2015a).

The EPA Reference Criteria for streams are based on data from streams within specific ecoregion units and those for reservoirs are based upon nutrient criteria models (REF EPA, 2001a, 2020). While most EPA Reference Criteria are lower than those for state screening levels, surpassing them may not necessarily indicate a concern.

Table 3-2 TCEQ screening levels and EPA reference criteria for nutrients

Parameter		TCEQ Screening Levels		EPA Reference Criteria			
		Lake/Reservoir	Stream	Lake/Reservoir		Stream	
Total nitrogen (TKN)	mg/L	-	-	0.38[a]	0.41[b]	0.3[a]	0.4[b]
Nitrate (NO_3^-)	mg/L	0.37	1.95	-	-	-	-
Nitrite and nitrate, NO_x (NO_2^-+NO_3^-)	mg/L	-	-	0.017[a]	0.01[b]	0.125[a]	0.078[b]
Total phosphorous (TP)	mg/L	0.2	0.69	0.02[a]	0.019[b]	0.037[a]	0.038[b]
Ammonia (NH_3)	mg/L	0.11	0.33	-	-	-	-
Chlorophyll-*a*	µg/L	26.7	14.1	5.18[a]	2.875[b]	0.93[a]	1.238[b]
(a) Reference conditions for aggregate Ecoregion IX waterbodies, upper 25th percentile of data from all seasons, 1990-1999.							
(b) Reference conditions for level III Ecoregion 29 waterbodies, upper 25th percentile of data from all seasons.							

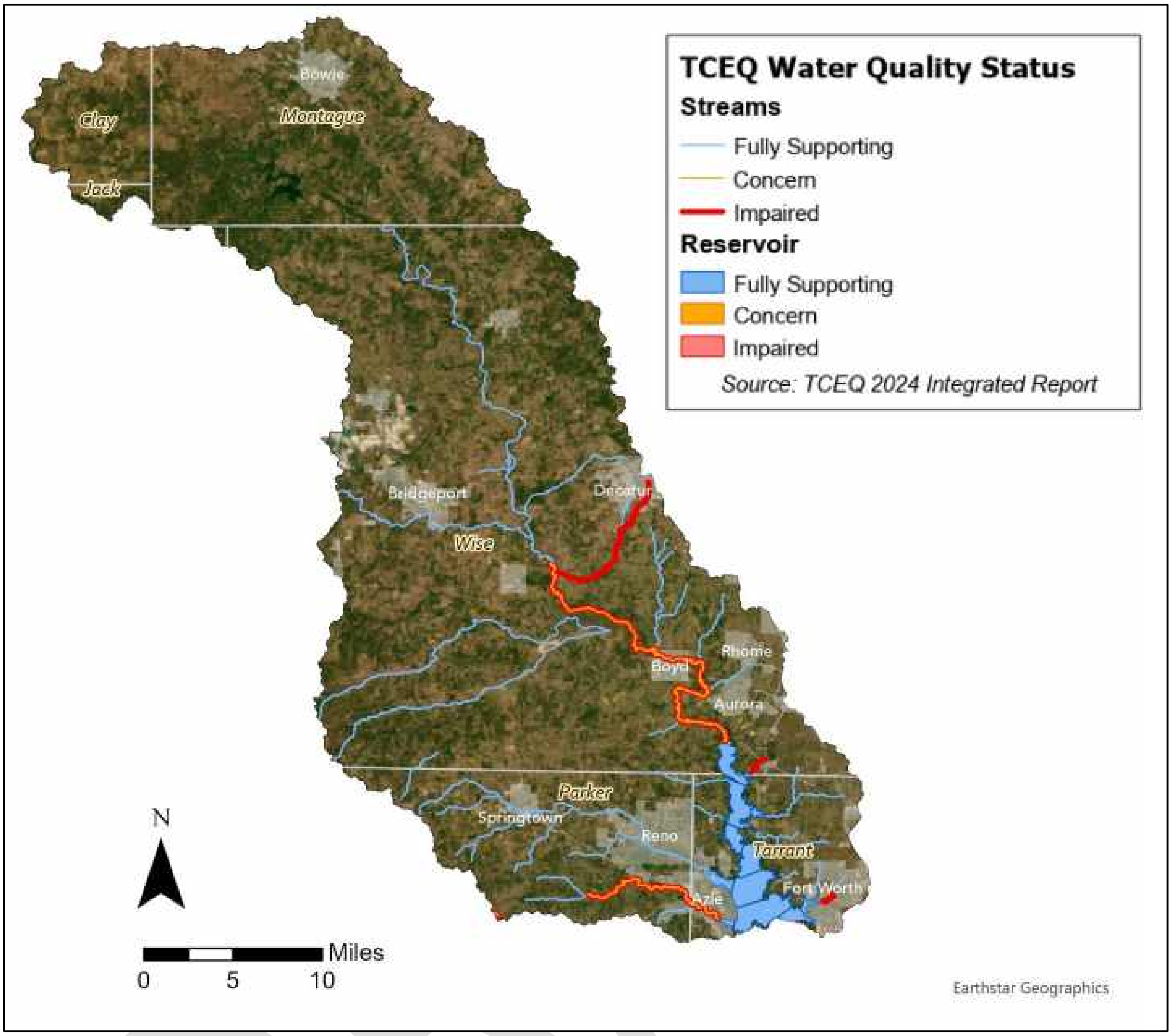
3.4 Segment Impairments and Concerns

When a sufficient number of elevated surface water quality measurements cause the water body to surpass the water quality criteria (min, max, average, or geomean), the waterbody is considered impaired and may not be supportive of one or more of its designated uses. The most recent assessment period covered by the 2024 Texas Integrated Report identified the impairments and concerns detailed in Table 3-3 and Figure 3-2.

If more than 20% of a water body's samples from the assessment period exceed a screening level, then on average, it will experience higher pollutant concentrations than 85% of the streams in Texas and thus is considered to have a concern for elevated nutrients.

Table 3-3 2024 Integrated Report impairments and concerns

Name	Segment(s)	Impairments	Concerns
Eagle Mountain Lake	0809_01 - 0809_14		
Walnut Creek	0809A		
Ash Creek	0809B	Bacteria (*E. coli*)	Nitrate (NO_3^-) (screening)
Dosier Creek	0809C	Bacteria (*E. coli*)	
Derrett Creek	0809D	Bacteria (*E. coli*)	
West Fork Trinity River Below Lake Bridgeport	0810_01	Bacteria (*E. coli*)	Chlorophyll-*a* (screening)
	0810_02		
Big Sandy Creek	0810A		
Garrett Creek	0810B		
Martin Branch	0810C	Bacteria	
Salt Creek	0810D		



Basemap: ESRI World Imagery; Stream data source: NHD; AU source: TCEQ

Figure 3-2 Impaired segments and water quality concerns in the EML watershed

4.0 Potential Pollutant Sources

Pollutants from human activities and natural processes can be grouped into two categories, based on their origin:

Point source pollution is a discharge that can be traced back to a single point of origin. This can be a pipe, drain, or outfall and is typically discharged directly into a waterway. Because point sources are tied to human activity, they regularly contribute flow to a system regardless of the native flow conditions. In fact, point sources may constitute most or all the baseflow in some systems, particularly in urban watersheds where large or regional wastewater treatment facilities (WWTFs) provide consistent effluent flows.

Point source pollution is regulated through a permitting process; in Texas this is administered through TCEQ. One example of a permitted discharge is effluent from WWTFs. Here, the treated effluent must remain within specific pollutant limits so that the facility's impact on the receiving water body is minimized. Other examples of point source include wastewater infrastructure issues, like a break in a wastewater pipeline, or a sanitary sewer overflow (SSO). These sources bypass WWTFs and can have either short-term or long-term effects on water quality depending on when they're identified and how quickly they're addressed.

Nonpoint source pollution, by contrast, tends to be more challenging to manage since it cannot be traced back to a single point of origin. Instead, pollutants that are dispersed over the land (either through human activity or natural processes) are carried into waterways with runoff from storm events. Several factors may influence the types and amounts of pollutants that ultimately end up in a waterway, but they are primarily dependent on land use and land cover (LULC). Sources of pollutants may include excess agricultural or residential fertilizers, fluids from leaking vehicles, pet waste from yards or urban public areas, or waste from wildlife, livestock, and feral hogs.

When considering the impacts of pollutant sources, it is important to account for the source's proximity to waterways. This is accomplished by estimating the percentage of the *E. coli* load that could realistically be transported from source to waterways through surface water or groundwater transport. In the EML WPP, weighted percentages for each source location were applied using the Spatially Explicit Load Enrichment Calculation Tool (SELECT). This approach weights riparian zones more heavily than those in upland zones to account for the increased impacts from sources in riparian zones. For additional information on SELECT and how source loads were calculated for both point and nonpoint sources, see Appendix C.

4.1 Prioritizing Pollutant Sources

Likely pollutant sources in the watershed were identified through the historical data review, water quality monitoring, and source identification/load calculation efforts. These results were interpreted and refined with the help of watershed stakeholders (Table 4-1). *[insert brief narrative of process after 7/9 meeting; table will be populated with info from meeting].* Further, sedimentation and flooding were also considered a water quality concern due to future growth, expansion, and development in the watershed but could not be included in the modeling and are outside the scope of this WPP. Stakeholders spent substantial time and effort considering these situations as they sorted through their collective priorities. They used a tiered approach to group priorities of similar urgency, based on perceived need, probability of success, and economic advantages.

Table 4-1 Summary of potential pollutant sources and management priorities

Source	Management Practices/Behavior Concerns	Potential Impacts	Rank[1]	Priority[2]
Livestock (Cattle, Sheep, Goats)	Increased runoff from overgrazing of upland areas	1. Direct or indirect bacterial loading; 2. Loss of natural pollutant mitigation	1	
	Manure transported to water body by runoff			
	Direct manue deposition in water body			
	Riparian buffer degradation/trampling			
OSSFs	Straightpipes" and other illegal wastewater discharges	1. Direct or indirect loading of untreated wastewater (bacteria, nutrients); 2. Groundwater quality degradation	2	
	Improperly treated aerobic effluent applied to land			
	Failure due to age, design, or lack of maintenance			
Pets (Dogs and Cats)	Improper disposal of pet waste	1. Indirect bacterial loading from yards, parks, and pet facilities; 2. Spread of disease	3	
	Disease trasnmission and public safety			
	Lack of education on impacts of proper disposal			
Wildlife	Manure transported to water body by runoff		4	

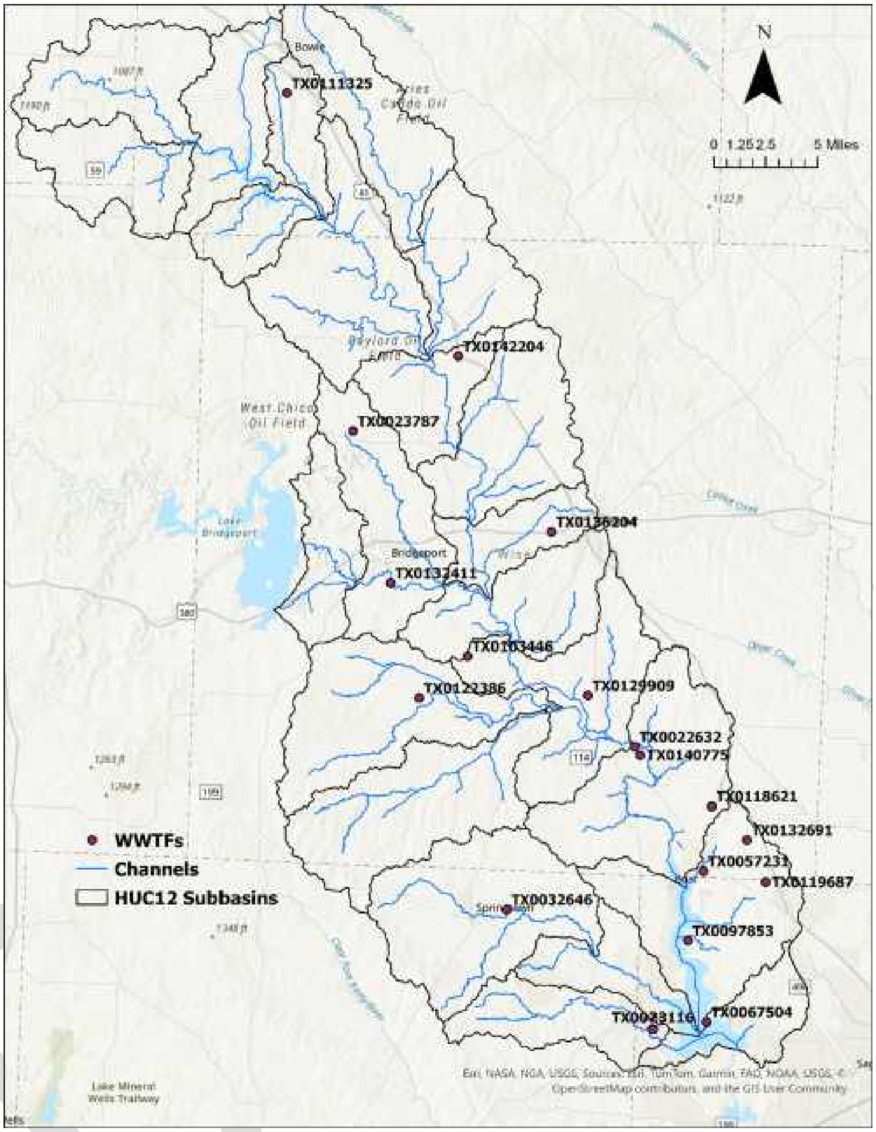
	Direct manue deposition in water body Riparian buffer degradation/trampling	1. Direct or indirect bacterial loading; 2. Loss of natural pollutant mitigation		
Feral Hogs	Manure transported to water body by runoff Direct manue deposition in water body Displacement/predation of native species Riparian buffer degradation/trampling	1. Direct or indirect bacterial loading; 2. Loss of natural pollutant mitigation; 3. Loss of biodiversity	*	
WWTF	Failure due to age, stormwater inflow and infiltration, or lack of maintenance Overloads from population growth or illicit connections	1. Direct or indirect loading of untreated wastewater (bacteria, nutrients)	*	
Yard Waste and Residue	Improper disposal of yard waste/clippings Excessive fertilizer, herbicide, or pesticide application	1. Direct or indirect bacterial, nutrient, and hazardous chemical loading; 2. Impacts to aquatic wildlife	-	
SSOs	Failure due to age, stormwater inflow and infiltration, erosion, or construction damage	1. Direct or indirect bacterial loading; 2. Human health hazards	-	
Illegal Dumping	Household/construction waste disposal in/near water body Animal carcass/hunting remains disposal in/near water body Disposal of large items (furniture, applicances, tires, vehicles)	1. Direct or indirect bacterial, nutrient, and hazardous chemical loading; 2. Human health hazards; 3. Flow obstruction/alteration	-	
Sediment and Flooding	Sediment loading and increased flooding in developing areas Loss of natural areas/green spaces	1. Impact to aquatic life; 2. Impact to water supply capacity and flood capacity in EML; 3. Direct or indirect bacteria and nutrient loading from reunoff/erosion events; 4. Human health and safety hazard; 5. Infrastructure damage	-	
(1) Relative impact on E. coli bacterial load as ranked by SELECT analysis. Sources noted by * were accounted for but represented a negligible load. Sources noted by - are not accounted for in SELECT.				
(2) Water quality restoration priorities as identified by stakeholder group.				

4.2 Point Source Pollution

4.2.1 Permitted Discharges

Wastewater facility outfall data was obtained from the Discharge Monitoring Report (DMR) database via EPA's Enforcement and Compliance History Online (ECHO) website (REF); see Appendix C for additional information. Thirteen total wastewater discharges exist in the EML watershed; four are inactive. Details about the active WWTFs and any associated permit limit exceedances for water quality parameters are provided in Table 4-2.

The significance of the WWTF locations in this watershed is EML and some of its tributaries contain some portion of wastewater effluent constituting their baseflow throughout the year (Figure 4-1). Stormwater inflow and infiltration (I/I) issues associated with the wastewater infrastructure connected to the WWTF can be the most common cause of elevated *E. coli* concentrations leaving facilities above the permitted effluent limits. This exceedance of treatment capacity can also be caused by unknown illicit connections delivering inconsistent additional flows, or from continued urbanization stressing the WWTF beyond its original design capacity.



Water body data source: TCEQ; outfall data: TCEQ

Figure 4-1 Wastewater Discharges to EML watershed

Table 4-2 Compliance history for active WWTFs in the EML watershed

NPDES Permit	Facility Name	Receiving Water body	Flow (daily average, MGD)		*E. coli* (daily average, MPN/100 mL)		Number of Exceedances(3)				Violations in Reporting Period4	
			Permitted	Reported(1)	Permitted	Reported(2)	*E. coli*	NH_3	BOD	TSS	Violation Identified	Significant/ Noncompliance
TX0023787	City of Chico	DRY CREEK, WEST FORK TRINITY RIVER	0.15	0.056	126	16.541	1	50	2	12	yes	yes
TX0132411	City of Bridgeport WWTP	WEST FORK TRINITY RIVER	0.84	0.525	126	3.811	0	13	16	0	yes	yes
TX0111325	City of Bowie WWTP	UNNAMED TRIB JONES CREEK	1.25	0.651	126	1.004	0	1	0	0	yes	no
TX0142204	City of Alvord WWTP5	UNNAMED DITCH; TRIBUTARY OF ELM CREEK	0.112	0.050	126	2.074	0	0	0	11	yes	yes
TX0136204	City of Decatur Water Plant	UNNAMED BRANCH; WAGGONER BRANCH	0.1	0.088	126	-	-	-	0	0	no	no
TX0122386	Camp Summit	WEST FORK TRINITY RIVER	0.00802	0.002	126	6.538*	0	0	0	0	no	no
TX0103446	Paradise ISD WWTP	WEST FORK TRINITY RIVER	0.03	0.009	126	32.658*	1	-	0	5	yes	yes
TX0129909	Ivy Hills WWTP	WEST FORK TRINITY RIVER	0	-	126	-	-	-	-	-	no	no
TX0022632	City of Boyd WWTP	WEST FORK TRINITY RIVER	0.24	0.089	126	301.547	11	-	6	11	yes	yes
TX0118621	Westside WWTP	WEST FORK TRINITY RIVER	0.15	0.083	126	7.718	0	20	0	7	yes	yes
TX0140775	Fairview Meadows WWTP6	FAIRVIEW MEADOWS WTF	0.2285	0.042	126	7.944	0	1	0	0	yes	no
TX0057231	City of Newark WWTP	DERRETT CREEK	0.15	0.060	126	1.000	0	0	1	0	yes	no

TX0097853	Eagle Mountain Rv Park WWTP	EAGLE MOUNTAIN RESERVIOR	0.006	0.003	126	79.692	1	-	0	0	yes	no
TX0119687	Chisholm Springs WWTP	UNNAMED TRIBUTARY; INDIAN CREEK	0.225	0.119	126	22.428	3	12	5	7	yes	yes
TX0132691	Rvr Water Reclamation & Amp Reuse Facility[7]	EAGLE MOUNTAIN RESERVOIR	0.15	0.058	126	61.749	3	13	0	6	yes	yes
TX0032646	City of Springtown WWTP	WALNUT CREEK	0.48	0.290	126	70.503	1	0	0	1	yes	no
TX0023116	Ash Creek WWTP[8]	REYNOLDS BRANCH, ASH CREEK	1.44	1.325	126	1.156	0	0	0	0	yes	no
TX0067504	Fort Worth Boat Club WWTP	EAGLE MOUNTAIN RESERVOIR	0.0158	0.003	126	1.000*	0	-	0	0	no	no

(1) 3-year average based on daily average measurements from EPA data, 04/30/2022 - 04/30/2025.

(2) 3-year geomean based on daily average measurements from EPA data, 04/30/2022 - 04/30/2025.

(3) ExceedanceExceedances based on daily average from available EPA data 04/01/2022 - 06/01/2025.

(4) Occurrence of Facility Statuses from EPA data, 04/01/2022 - 06/01/2025. Violation Identified is less serious than Significant Violation/Category I Noncompliance.

(5) Data for this facility from EPA data 09/01/2022 - 06/01/2025

(6) Newly permitted facility, data from EPA 10/01/2024 - 06/01/2025

(7) Data begins at 12/31/2023.

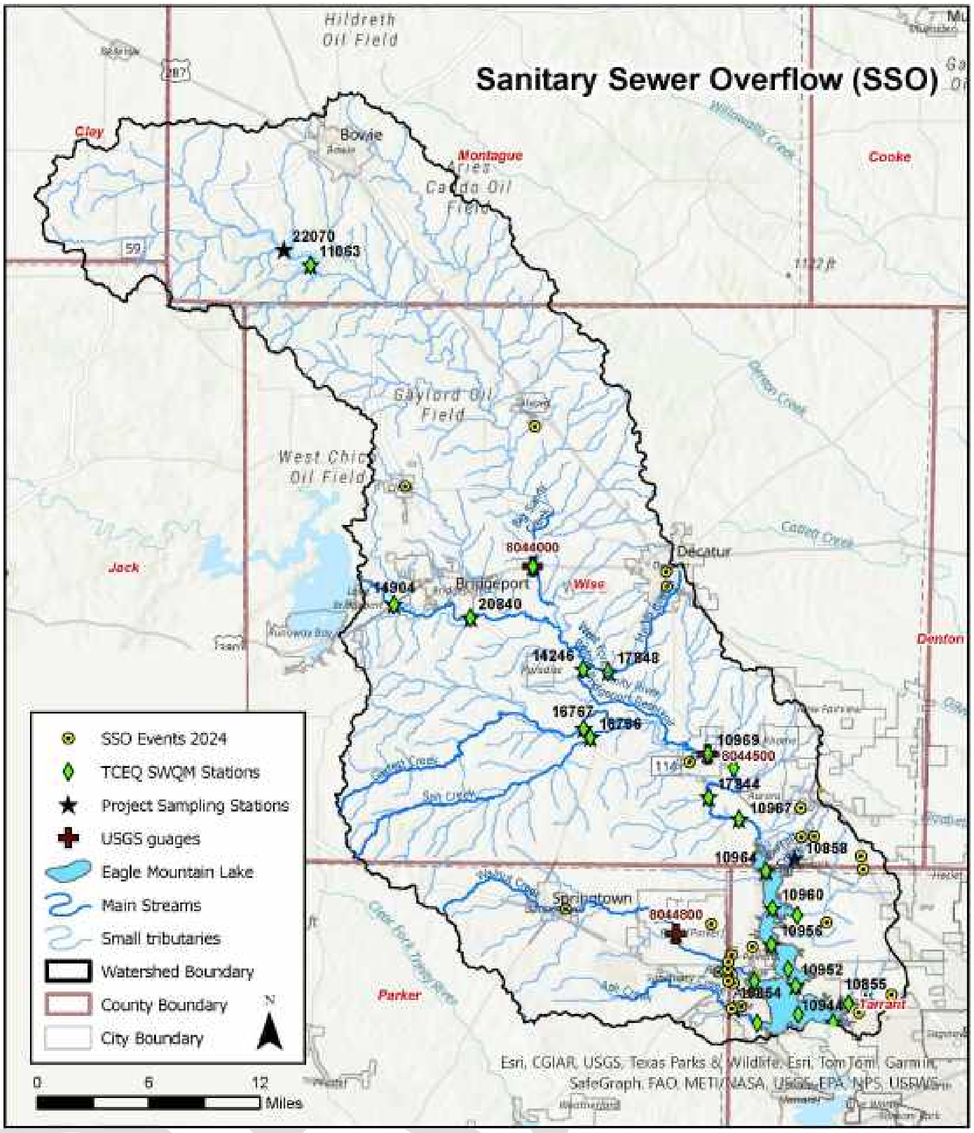
(8) Flow data recorded by EPA as "annual average" on monthly basis; flagged for potential coding issue.

*Daily averages reported on quarterly rather than monthly basis.

4.2.2 Sanitary Sewer Overflows

Being components of the wastewater conveyance system, many of the same issues encountered at WWTFs are caused by issues with the pipes and other infrastructure carrying wastewater from homes and businesses. SSOs occur when pipes are blocked, broken, or when deteriorating pipes and connections allow stormwater or groundwater infiltration into the wastewater system. These I/I issues often result in combined stormwater/wastewater volumes that exceed the design capacity of the pipes, causing backups that will eventually find a relief point, often a manhole cover or other surface access. From this relief point, untreated sewage can potentially reach streams and lakes if not contained properly or in a timely manner. For this reason, proximity of the SSO site to a water body must be accounted for when analyzing potential impacts. Older neighborhoods tend to be more prone to SSOs, as they tend to be serviced by older infrastructure that may be subject to the deterioration or design capacity issues mentioned previously. In addition, continued development can overshoot design capacity. In general, SSOs are combined with pet waste nonpoint sources and used as surrogates for urban runoff when calculating pollutant loads from urban sources.

The compendium of past reports of SSO occurrences was used to illustrate locations (Figure 4-2), overflow amount, cause of SSOs, and potentially determine impacts of SSOs on the day of occurrence. BMPs for SSOs require infrastructure assessments and proper maintenance that are usually built into a municipal separate storm sewer system (MS4) program as well as part of operations for any community with infrastructure.



Basemap: ESRI World Street Map; Stream data source: NHD; station data: TCEQ

Figure 4-2 Reported SSO events in the EML watershed 2024

4.2.3 Other Point Sources

Water Wells

Chemical or pollutant spills that occur in or near any water well can provide a direct route for pollutants to reach aquifers, bypassing the soil and rock substrata that usually provide some measure of remediation in natural systems. Plugged or destroyed wells, along with abandoned or otherwise unmaintained wells, are of particular interest. These wells are usually not closely monitored and potential contamination may go unnoticed for long periods of time. Well construction standards, along with regulation of abandoned or deteriorated water wells, are under the jurisdiction of the Texas Department of Licensing and Regulation. Complaints for such wells can be reported to the Texas Department of Licensing and Regulation through their website.

Underground Storage Tanks

Underground storage tanks are often used to store petroleum products and other hazardous liquids, most notably at gas stations. Most underground storage tanks are made of common steel and thus are subject to oxidation and rust over time. Excessive corrosion may lead to cracks or holes in the tank, which can result in groundwater contamination. TCEQ is the regulatory entity and current custodian of records related to leaking underground storage tanks in Texas.

Oil & Gas Exploration

Although several traditional oil and gas wells exist in the watershed, continued development of the Barnett Shale natural gas field has resulted in expansion of hydraulic fracturing activities, sometimes near the lake. Along with groundwater concerns, pad site construction may require a clearing of vegetation that can lead to increased runoff. If these pad sites are located near riparian buffer zones, the increased runoff may deliver higher pollutant loads to nearby waterways. The most recent EPA report on hydraulic fracturing (EPA, 2016) recommended that stakeholders focus on activities that are more likely than others to result in water supply impacts, including but not limited to:

- Water withdrawals in areas where groundwater is already scarce;
- Surface spills of chemicals or process water that may reach groundwater sources;
- Fluid injection into inadequately designed wells that allow for leakage into groundwater;
- Discharge of inadequately treated process water into surface water; or
- Disposal or storage of process water in unlined or improperly lined pits, allowing for groundwater contamination.

The Railroad Commission of Texas (RRC) has primary jurisdiction over drilling, exploration, and production activities related to oil and gas in the state of Texas. However, TCEQ does share some of the responsibilities for regulation and operation of oil and gas wells in upstream operations, particularly those that affect air/water quality, surface water management, and waste management (add REF to RG-482, Revised July 2023).

4.3 Point Source Pollution

Unless explicitly stated for each source, the contribution weights for the riparian buffer (90% contribution) and upland areas (50% contribution) mentioned previously are applied to the nonpoint sources analyzed for this project.

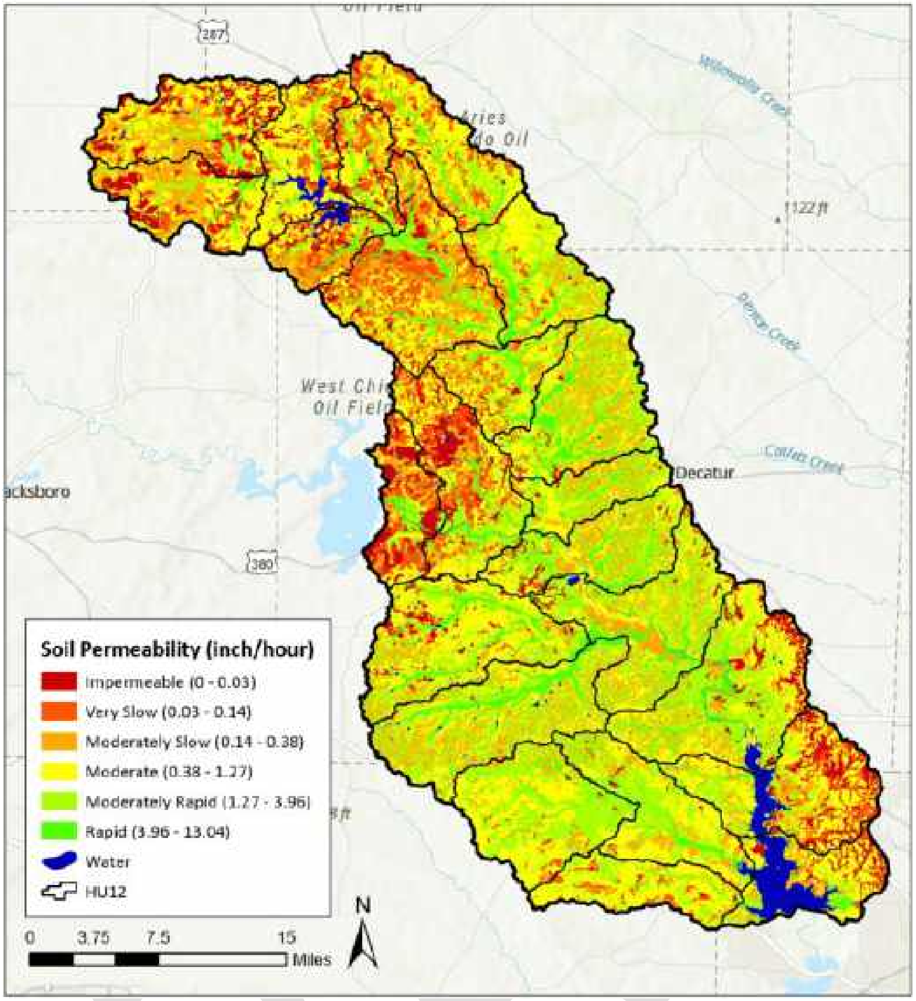
4.3.1 On-Site Sewage Facilities

The EML watershed is large and primarily rural, with widespread use of on-site sewage facilities (OSSFs) for wastewater treatment. When not functioning properly, OSSFs can become sources of pollution for *E. coli*, nutrients, and solids, both in groundwater and surface water bodies. A variety of causes can be to blame for reduced performance or malfunctions, including improper use, design/installation, lack of maintenance, unsuitable soil types, age of the system, and proximity to other systems.

Since 1989, Authorized Agents – including counties, some cities, and TRWD -- with agreements with TCEQ are responsible for maintaining records of permitted OSSFs. These must be inspected to ensure compliance with state regulations. Many of the systems in the watershed installed prior to 1989 are not tied to a current permit, indicating that they have not been recently inspected and/or may have been installed improperly or in areas where soils are less suitable for effluent loads (Figure 4-3) and thus have a higher likelihood for failure. Non-permitted systems have a failure rate of up to 50% (REF Reed et al 2001).

However, it is expected that even some permitted systems are currently in a state of failure, usually due to neglect or lack of homeowner knowledge regarding OSSF operation. Estimated failure rate in the EML watershed according to septic drainfield limitation class was assumed to be 15% (Appendix C). Proximity to a water body and proximity to other systems can negatively affect OSSF performance, particularly in areas where systems are densely spaced. In these situations, multiple failures are possible if one drain field exceeds its capacity and impacts adjacent fields, increasing the likelihood for drain field contaminants reaching waterbodies.

Based on estimates, there are approximately 11,762 permitted OSSFs within the watershed and 15,004 OSSFs constructed before permitting requirements were implemented. See Appendix C for details about how septic numbers were estimated across the EML watershed. Due to limitations in the available geographically explicit data, a 100% modeling contribution was assumed from all OSSFs regardless of riparian buffer.



Basemap: ESRI World Street Map; Soil permeability: USGS SSURGO

Figure 4-3 Soil permeability across EML watershed

4.3.2 Pet Waste

Feces from pets may also be a source of *E. coli* and nutrient loading to waterbodies via stormwater runoff. This may include dogs as well as cats that defecate outdoors, such as feral and barn cats. As with any nonpoint source, the severity of the contamination from an area is heavily influenced by the presence of impermeable soils (Figure 4-3) and increasing amounts of impervious cover (e.g., buildings, parking lots, Figure 2-3) associated with ongoing development in the watershed. These measurements are derived from human population data, so while there will be some contributions from rural areas, it is expected that urban areas will show the largest contributions.

Estimates for pets were made by extrapolating census data from the watershed and applying nationwide estimates for the number of dogs and cats per household. According to the American Veterinary Medical Association (AVMA), approximately 36.5% of U.S. households have dogs, and 30.4% own cats, and it is estimated that there are 1.6 dogs per household with dogs, an average of 0.614 dogs per household overall; 1.8 cats per household with cats, an average of 0.457 cats per household overall (REF AVMA, 2017).

4.3.3 Agricultural Activities

Free-roaming livestock can also be a contributor to nonpoint source *E. coli* loads, especially if they have direct access to waterbodies where they can defecate into or near them. However, poor land management practices can also affect the amount of manure *E. coli* that reaches waterbodies from upland areas by stormwater flows. If pastures are overgrazed, improperly tilled, or otherwise mismanaged, runoff potential increases, which can deliver larger loads of *E. coli*, nutrients, and pesticides/herbicides to waterbodies.

Initially, stocking rates for cattle, sheep/goats, and horses (Table 4-3), were estimated using data from the 2022 National Agricultural Statistics Survey (NASS), TPWD, or Texas A&M University data (USDA, 2022). Grazing was applied to all grassland and hay/pasture land cover types in both the SELECT tool and SWAT/HAWQS (Appendix C). Cattle population estimates were compared to United States Department of Agriculture (USDA) stocking rate recommendations, alongside technical guidance from local NRCS partners in the watershed. The most common livestock animal in the EML watershed is cattle, with approximately 50,000 head estimated across the watershed based on the 2022 NASS.

Table 4-3 Estimated animal stocking rates in EML watershed

Animal	Stocking Rate (acre/head)
Cattle	7.4
Sheep	173.2
Goats	110.5
Horses	123.2
Feral Hogs	50
Deer	39.4

In addition to *E. coli* and nutrient inputs from grazing livestock, production agriculture may also contribute other types of nonpoint source pollution to waterways, including nutrients from fertilizers, herbicides, and pesticides.

4.3.4 Wildlife

Wild animals tend to spend much of their life moving through riparian areas, so it is important to account for them as a pollutant source. Deer density data were sourced from Texas Parks and Wildlife's 2006 ecoregion-based estimates and applied to shrub/scrub, grasslands/herbaceous, hay/pasture, cultivated crops, forest, and wetland areas within the watershed. Feral hog density was based on planning-level estimates from Texas A&M AgriLife Extension and distributed across the same land use categories (Table 4-3).

4.3.5 Other Nonpoint Source Pollutants

Sediment is a pollutant source concern as well as an impact to the water supply and flood control capacity of EML. Land management practices that decrease root biomass or leave more soil surface exposed increase erosion potential and thus, sedimentation of EML. Future development will lead to increased impervious surfaces and shallow-rooted turfgrasses, in turn speeding up runoff velocities that will increase erosion. Sedimentation in the streams and the lake will impact aquatic life, harbor bacteria, affect recreational lake users, and impact the water supply capacity in EML. A sedimentation study conducted in 2008 showed that the lake had accumulated 15,861 acre-feet of sediment since its impoundment in 1934. Anecdotal evidence from stakeholders indicates that this is an ongoing issue in many areas of the lake.

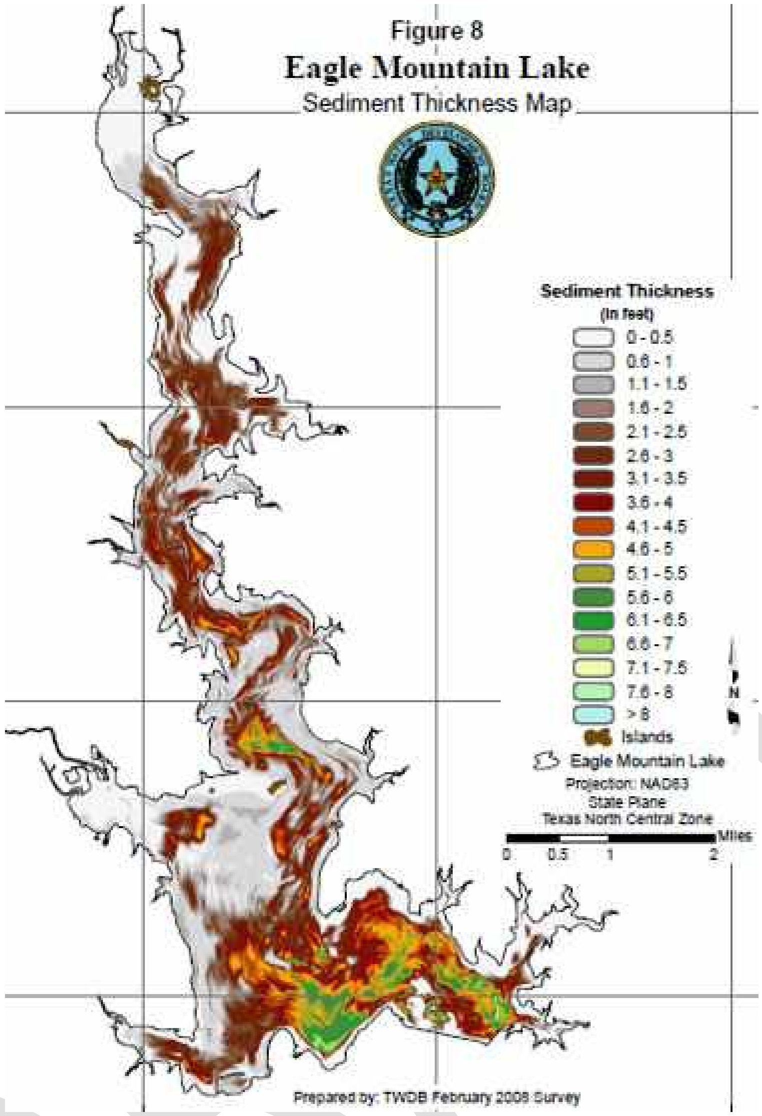


Figure 4-4 EML Sediment thickness map 2008

[The rest of this section is an opportunity for stakeholders to bring up additional concerns that may be tied to water quality or tied to the BMPs used to impact water quality, e.g. illegal dumping, litter, localized or macro-scale flooding, algal blooms/fish kills, specific chemical pollutants or pollutants associated with specific industries in the watershed, etc. Issues and associated BMPs that are written into the plan may be eligible for EPA 319 funding down the line.]

5.0 Pollutant Source Assessment

No one method of analysis is sufficiently accurate to provide a clear picture of the water quality impacts in a watershed on its own. To ensure that a thorough characterization of the watershed's status was achieved, pollutant loadings were assessed using a variety of methods utilizing both empirical data and estimations based on literature values from multiple sources. The methods used in this study included routine and flow-biased water quality data analysis, the Load Estimation program (LOADEST) Load Duration Curve (LDC) analysis based on collected data for multiple pollutants, Flow Duration Curves (FDCs), spatial analysis of potential *E. coli* sources using the SELECT analysis, and hydrological modeling using the Soil and Water Assessment Tool (SWAT).

SWAT has been the most widely used watershed-scale hydrology/water quality model in the world for over 20 years. The standard version of SWAT requires detailed inputs related to weather, climate, topography, soils, land use, water infrastructure, and point-sources of pollution. As a result, it can be difficult to build and calibrate SWAT models for specific watersheds and river basins. To overcome this problem, the TAMU Spatial Sciences Laboratory has worked closely with the EPA to develop the Hydrologic and Water Quality System (HAWQS).

HAWQS is a free, open-source, online platform using a point-and-click interface and powerful output visualization tools. HAWQS provides all input data (soils, weather, land use, topography, water bodies, point-sources of pollution, etc.) and graphical input/output interfaces for the contiguous 48 states. It requires no specialized software, hardware, or training in statistics or geographic information systems (GIS). The HAWQS platform allows users to customize SWAT inputs to create scenarios based on BMPs by modifying agricultural management, operations management, and conservation practices. Additional information about this analysis is provided in Appendix B.

Teague et al. (2009)REF developed SELECT to identify and estimate potential pathogen loads resulting from various fecal sources in watersheds. For EML, Texas specific databases were used based on stakeholder input. While the methodology used was from SELECT, this is now referred to as SELECT-TX. This tool can simulate potential pathogen loading in a watershed for various management scenarios based on user defined inputs. Inputs that can be modified based on BMPs include pet density, livestock and wildlife stocking rates, sources of OSSF numbers and amount of wastewater, daily *E. coli* and discharge values for WWTFs, and fecal coliform production rates and conversion to *E. coli* factors. Additional information about this analysis is provided in Appendix C. It should be noted that SELECT was designed specifically for calculating loads from *E. coli* sources, and thus cannot be used to calculate loads from other pollutants of interest to stakeholders, despite their relative importance.

5.1 Water Quality Monitoring

TRWD conducts routine water quality monitoring in EML and its tributaries (refer to Figure 3-1 for station locations). Water quality monitoring includes sample collection for pollutants that require laboratory testing and field-measured data (Table 5-1). This monitoring data is reported to TCEQ for inclusion in the SWQM-IS database.

Lake Monitoring Regime

TRWD water quality monitoring teams take measurements at 5 sites in EML on a quarterly basis, plus one additional sample during the critical water supply period of July through September. SWQM site numbers for TRWD monitoring are 10964, 10960, 10956, 10952, and 10944. Additional measurements are taken at the water supply intake (10944) during quarterly testing. Some sites are sampled at the surface and some are sampled at multiple depths, with more sites being sampled at multiple depths during the critical period. Water quality parameters sampled can be found in Table 5-1. In addition, weekly profiles are taken in the field with a sonde device at the EML intake from surface to bottom. This profile provides measurements across the depth profile of temperature, dissolved oxygen, oxidative reduction potential, pH, and conductivity.

Tributaries Monitoring Regime

TRWD water quality monitoring teams perform monthly testing at 5 SWQM sites: 10854 on Ash Creek, 10853 on Walnut Creek, 10969 on the West Fork Trinity River, 10858 on Derrett Creek, and 10855 on Dosier Creek. Water quality parameters sampled can be found in Table 5-1.

WWTFs Monitoring Regime

TRWD performs quarterly monitoring at the outfalls of 9 WWTFs near the lake on a rotating basis wherein each site ends up being sampled twice annually: Eagle Mountain RV Park, City of Decatur, City of Boyd, City of Newark, Eagle Mountain RV Park, Chisholm Springs, City of Springtown, Ash Creek, Fort Worth Boat Club, and Westside (City of Rhome).

Table 5-1 TRWD water quality monitoring summary

Sites	Total sites	Parameters tested	Frequency
All EML Sites	5	*Chlorophyll-a*, TSS, TDS, VSS, NH_3, No_x, TKN, TP, $DOPO_4$, TOC, DOC, Alkalinity, Chlorides, *E. coli*	Quarterly, with one extra during critical period
EML Intake additional	1	Calcium, Magnesium, Sodium, Potassium, Sulfate, Total Arsenic, Total Iron, Total Manganese, Total Silica, Dissolved Silica, Total Copper, Dissolved Copper	Quarterly, with one extra during critical period
EML Intake field profile	1	Temperature, DO, Oxidative Reduction Potential, pH, Conductivity	Weekly from April - October
EML Tributaries	4	TSS, VSS, NH_3, No_x, TKN, Dissolved TKN, TP, Dissolved TP, $DOPO_4$, TOC, DOC, *E. coli*, Chlorides	Monthly
West Fork Trinity River	10	*E. coli*	Quarterly
WWTF Outfalls	9	$CBOD_5$, TSS, VSS, NH_3, No_x, TKN, TP, $DOPO_4$, TOC, *E. coli*, Chlorides	Quarterly, 4 sites per quarter on rotating basis

5.2 Load Duration Curve Analysis

In watersheds where nonpoint sources are likely the primary source of pollutant loading, load duration curves (LDCs) are useful tools for illustrating the relationship between stream flow, pollutant concentration, and the resulting pollutant loads. The pollutant loads during each monitoring event can be compared to the maximum allowable load at that particular flow rate; this data can then be used to calculate the reduction needed to meet the water quality goal for each pollutant.

Although LDCs cannot be used to differentiate between specific sources (e.g., livestock, pets, OSSFs), they can be used to determine whether point sources or nonpoint sources are the primary concern by identifying whether exceedances occur within a specific flow regime. If exceedances are only observed during high flow or moist conditions associated with storm events, then nonpoint sources are the likely contributor. However, if exceedances are also present during dry conditions or low flow, then it is likely that point sources are also contributing to the overall load, becoming more prominent as flows decrease (Figure 5-1). Exceedances at high flows are usually attributed to flooding, and thus inherently unmanageable. Therefore, reductions demonstrated in the mid-range conditions flow regime are most appropriate for representing the water quality reduction goal at each site. A 10% margin of safety (MOS; REF USEPA 1999) was included for each water quality standard criterion. This means that 10% of the allowable pollutant load is intentionally set aside as a buffer to account for uncertainties in the modeling, data, or natural variability. This helps ensure that water quality standards are met even if there are unforeseen variations or errors in the analysis. Additional information regarding LDC development is provided in Appendix B.

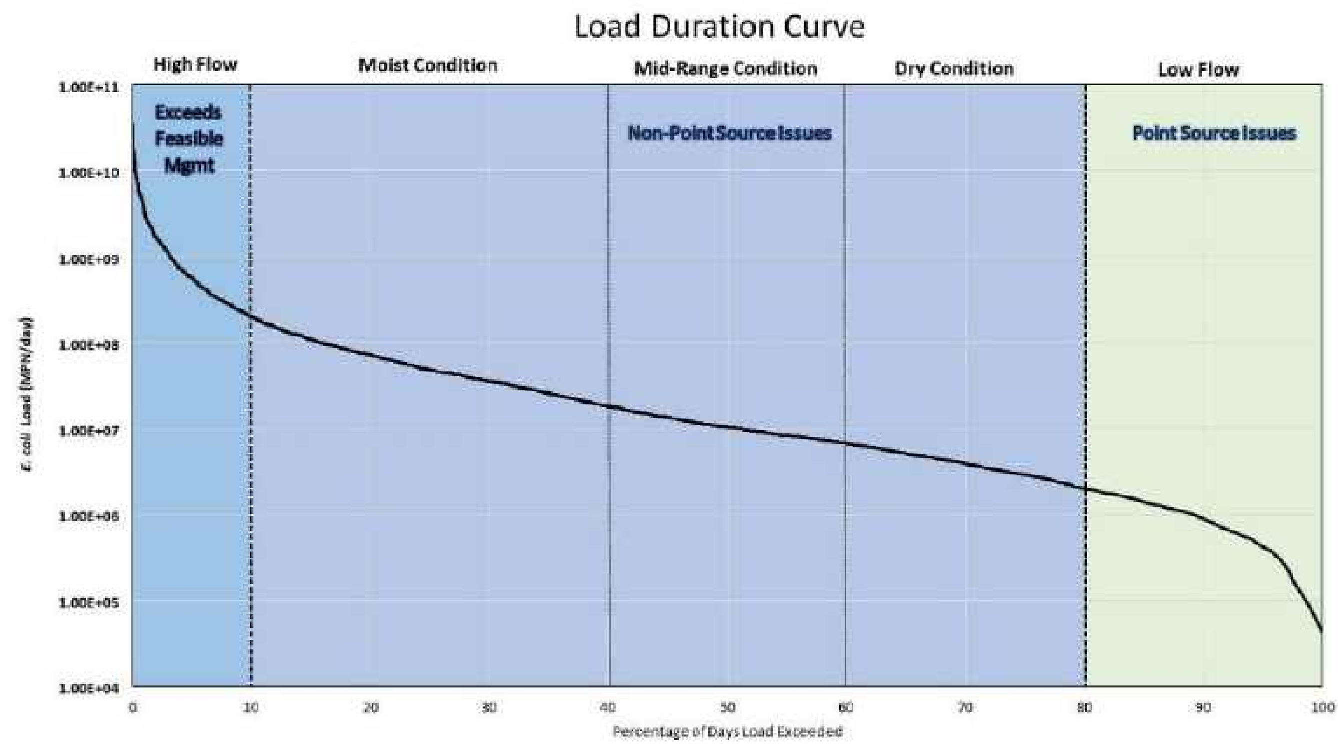


Figure 5-1 Flow categories and regions of likely pollutant sources in an example LDC

A minimum of 12 paired stream flow-pollutant concentration data points are required to properly execute the LDC analysis tool. LDCs were developed at three surface water quality monitoring stations with paired USGS flow gauges for three key constituents, *E. coli*, total phosphorous (TP), and nitrogen oxides (NO_X), which account for nitrate and nitrite ($NO_3^- + NO_2^-$). Stations are referred to by their SWQM station number. LDCs for both 10969 (West Fork Trinity River NE of Boyd near FM730) and 10854 (Ash Creek in Azle near SH199) had sufficient recent data to include in this plan. Station 17844 (West Fork Trinity River S of Boyd, below station 10969) was also assessed as part of SWAT calibration, but data concerns excluded it from use for load reductions (Appendix B).

For planning purposes, surface water quality monitoring station 10969 was selected for establishing pollutant load reductions. This station represents the most comprehensive available paired water quality and flow data with significant loading to EML. 10969 is also assumed to be far enough upstream from the lake to exemplify flowing conditions, not subject to lake backwater influence for the majority of the year. Its location near the lake on the West Fork means that it captures a majority of the watershed area, with exception of the numerous small tributaries that discharge directly into EML. Due to its heavier urban influence, 10854 presents interesting data that could drive projects in that area, but because it represents little overall flow or load to EML compared to 10969, it will not be assessed for meeting watershed load reduction goals.

5.2.2 *E. coli*

The LDC analysis indicates that elevated *E. coli* concentrations are associated with all flow conditions. At site 10969, exceedance decreases as flow decreases, indicating that E. coli loading is primarily due to nonpoint source inputs from runoff and/or resuspension of existing sediment bacterial colonies. However, at site 10854, loading exceedances are steady across all flow conditions, indicating that there may be a point source loading issue.

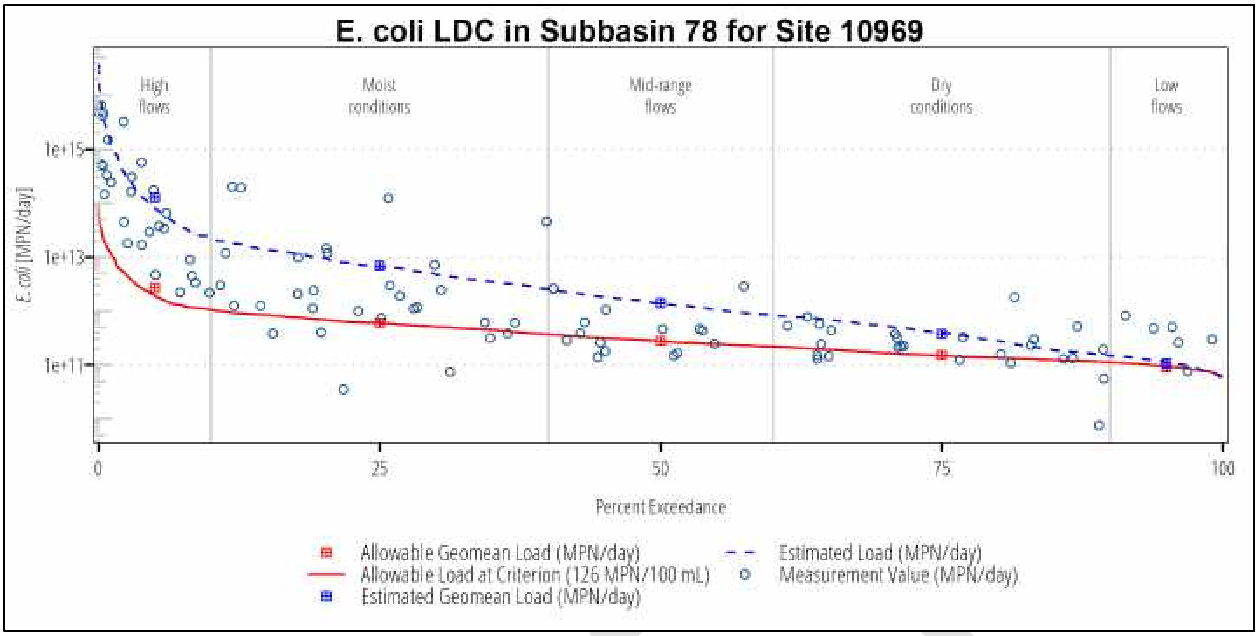


Figure 5-2 *E. coli* LDC and allowable load at site 10969

Table 5-2 *E. coli* reduction needed to meet allowable loading for each flow condition at site 10969

Flow Condition	Median Flow (m^3/day)	% of Time Flow Exceeds	Allowable Geomean Loading (MPN/day)	Estimated Geomean Loading (MPN/day)	Reduction Needed (MPN/day)	% Daily Load Reduction Needed
Highest Flows	1,723,680	0-10	2.71E+12	1.28E+14	1.26E+14	97.9
Moist Conditions	522,374	10-40	6E+11	6.88E+12	6.28E+12	91.3
Mid-range Conditions	**241,402**	**40-60**	**2.77E+11**	**1.4E+12**	**1.12E+12**	**80.2**
Dry Conditions	131,242	60-90	1.52E+11	3.71E+11	2.19E+11	59.0
Lowest Flows	84,033	90-100	9.17E+10	1.07E+11	1.53E+10	14.3

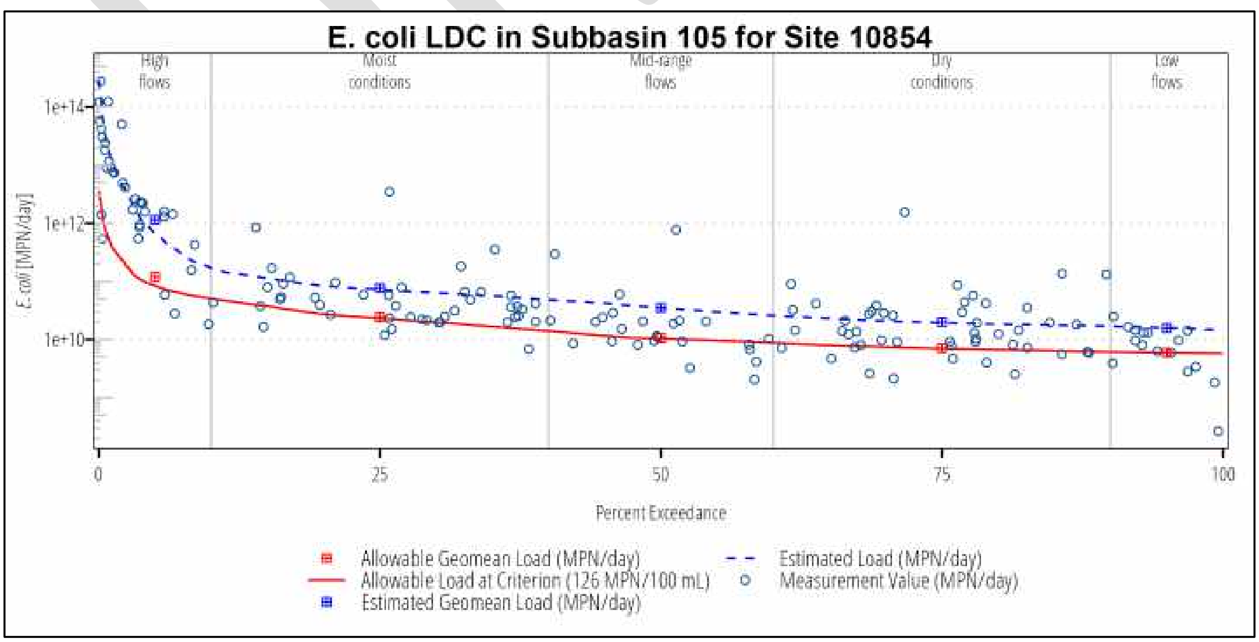


Figure 5-3 *E. coli* LDC and allowable load at site 10854

Table 5-3 *E. coli* reduction needed to meet allowable loading for each flow condition at site 10854

Flow Condition	Median Flow (m^3/day)	% of Time Flow Exceeds	Allowable Geomean Loading (MPN/day)	Estimated Geomean Loading (MPN/day)	Reduction Needed (MPN/day)	% Daily Load Reduction Needed
Highest Flows	74,451	0-10	1.2E+11	1.15E+12	1.03E+12	89.5
Moist Conditions	20,485	10-40	2.43E+10	7.75E+10	5.31E+10	68.6
Mid-range Conditions	**9,150**	**40-60**	**1.06E+10**	**3.54E+10**	**2.48E+10**	**70.1**
Dry Conditions	6,178	60-90	7.12E+09	2E+10	1.29E+10	64.4
Lowest Flows	5,238	90-100	5.94E+09	1.58E+10	9.82E+09	62.3

5.2.3 Nutrients

Nutrients are transient in flowing water bodies, but once they are delivered to a lake or reservoir, flow rates decrease significantly. This increased residence time leads to accumulation of nutrients, sediment, and other solids. Accumulation will continue in both the water column and lakebed sediments until they are used by organisms, removed by human means (typically through dredging), or resuspended and flushed downstream via the dam. Excessive accumulation in a lake can lead to algal blooms because nutrients are no longer a limiting factor on populations of photosynthetic organisms. This phenomenon is commonly referred to as lake eutrophication. Eutrophication does occur naturally, but it can be intensified by human activities, for example certain farm or ranch management practices and the proliferation of urban environments. In addition to the potentially harmful environmental effects, algal blooms may also cause taste and odor problems in municipal water taken from the lake and may impact recreational opportunities.

For this plan, nutrient reductions focus on nitrogen and phosphorous. Nitrogen enters water bodies in various forms from many potential sources throughout a watershed. NO_3^- is a common component of chemical fertilizers, which are used in both agricultural and urban settings. Ammonia (NH_3) is component of human and animal waste, entering water bodies via wastewater effluent, SSOs, OSSFs, or animal waste carried by runoff. NO_3^- can also be formed within the water body through oxidation of various nitrogen compounds. NO_3^- is highly soluble and moves readily through soil and water bodies. Phosphorous comes from many of the same sources, but it is more likely to bind to soil particles; therefore, mitigating erosion is a major component of controlling phosphorous loads. Typically, phosphorus is the limiting nutrient for algal growth in a water body.

LDCs were created based on monitoring data for total TP and NO_x . These pollutants do not have CWA-based impairment thresholds, so the LDCs were created using TCEQ screening level criteria for TP and using criteria for NO_3^- as a proxy for nitrogen oxides because NO_2^- typically exists in water bodies in trace amounts due to its tendency to oxidize to NO_3^-. There were no reductions needed for NO_x or TP at 10969 nor for TP at 10854 (Appendix B). However, site 10854 at Ash creek showed NO_x exceeding allowable loads at all conditions except for high flows (Figure 5-4 and Table 5-4).

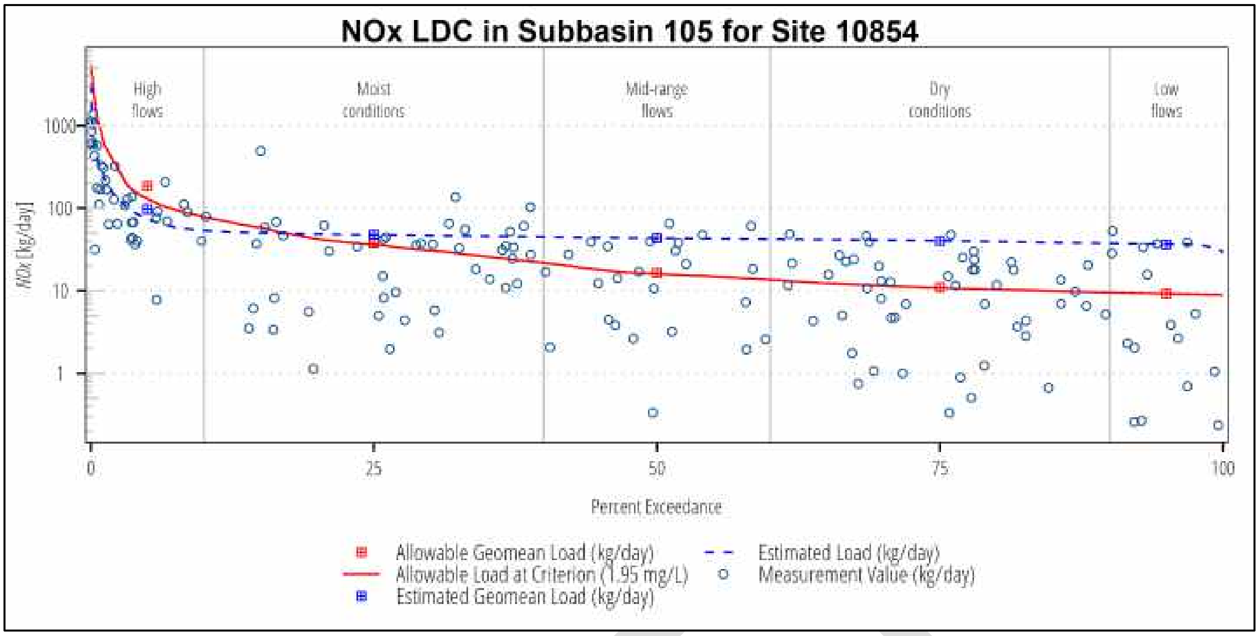


Figure 5-4 NO_x LDC and allowable load at site 10854

Table 5-4 NO_x reduction needed to meet allowable loading for each flow condition at site 10854

Flow Condition	Median Flow (m^3/day)	% of Time Flow Exceeds	Allowable Geomean Loading (kg/day)	Estimated Geomean Loading (kg/day)	Reduction Needed (kg/day)	% Daily Load Reduction Needed
Highest Flows	74,451	0-10	186.4	97.6	0.0	0.0
Moist Conditions	20,485	10-40	37.7	48.0	10.4	21.6
Mid-range Conditions	**9,150**	**40-60**	**16.4**	**43.6**	**27.2**	**62.3**
Dry Conditions	6,178	60-90	11.0	40.1	29.1	72.5
Lowest Flows	5,238	90-100	9.2	36.1	26.9	74.5

5.3 Spatial Analysis of *E. coli* using SELECT

Watershed prioritization and BMP recommendations were further refined with the use of the SELECT analysis, which distributes potential *E. coli* loads into 23 subwatersheds (Figure 5-5), based on likely *E. coli* sources as identified by watershed stakeholders. Potential point sources of E. coli were entered using their spatially explicit locations and permitted discharges (refer to 4.2 Point Source Pollution, pg 16 or Appendix C). Using a combination of GIS and spreadsheet tools, estimated populations of various warm-blooded animal species (humans, pets, livestock, wildlife) were distributed spatially throughout the watershed based on each population's applicability to different LULC characteristics (refer to 4.3 Nonpoint Sources, pg **Error! Bookmark not defined.** or Appendix C).

Once distributed, species-specific *E. coli* load production values published in scientific literature were applied to each population, producing the *E. coli* loads that may eventually find their way to waterways (Figure 5-6). To account for the variety in the sizes of the subwatersheds, these loads were then normalized to a per-acre basis to ensure that contributions from larger subwatersheds did not overshadow those from several smaller ones. Finally, the separate, normalized sources were then aggregated to produce an overall normalized *E. coli* load for each subwatershed (Figure 5-8).

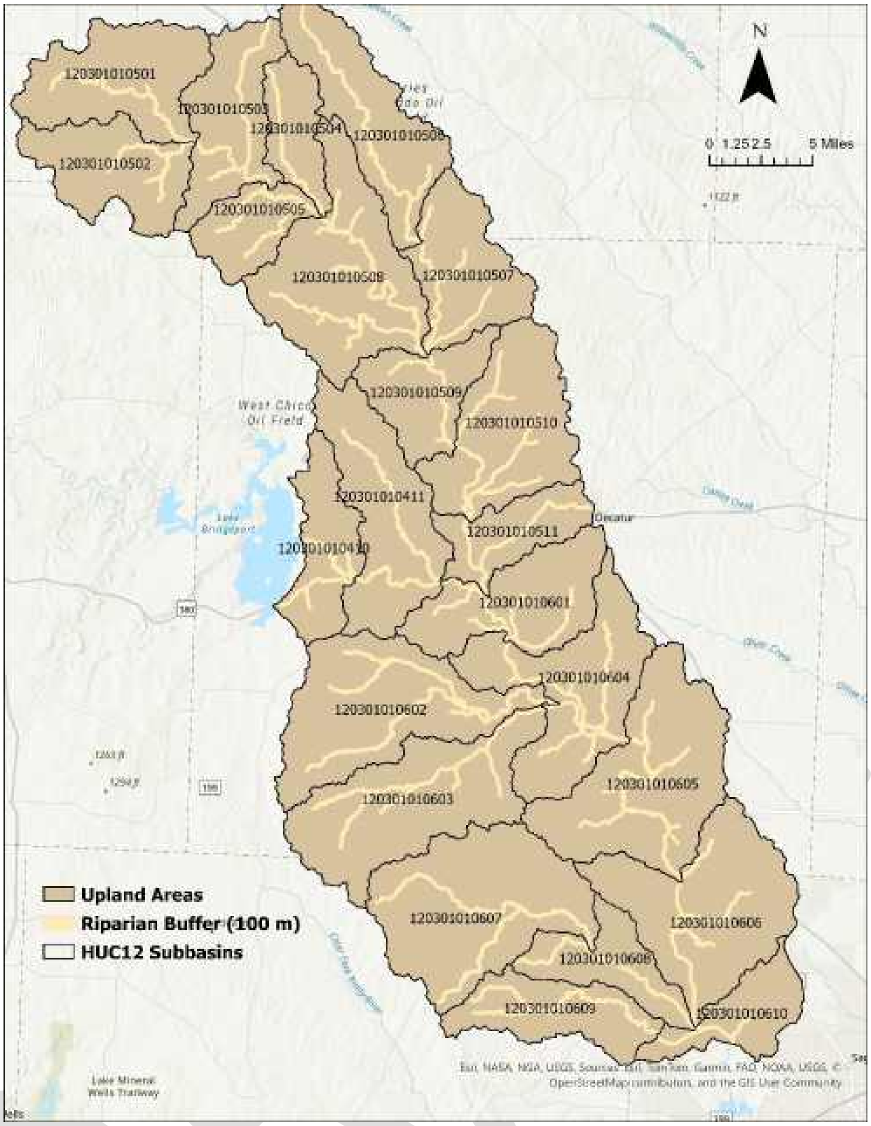


Figure 5-5 EML subwatersheds and riparian buffers used in SELECT analysis

Raw SELECT output is often seen as a “worst case scenario” for estimating *E. coli* loads, as the tool does not contain any built-in functionality that automatically adjusts for *E. coli* die-off, predation, soil entrainment, or other forms of mitigation between the time of deposition up to its introduction to a waterway. However, these processes can be partially accounted for by applying weights to the loads based on their distance to a waterway. For example, manure deposition within riparian buffer areas (< 100-m (330-ft) from a stream), carry more weight than deposition in an upland area (Figure 5-5). Use of this tactic will allow for further refinement of critical areas for BMP implementation. Details about weights used for each source can be found in 4.3 Nonpoint Sources (beginning on page **Error! Bookmark not defined.**) or in Appendix C.

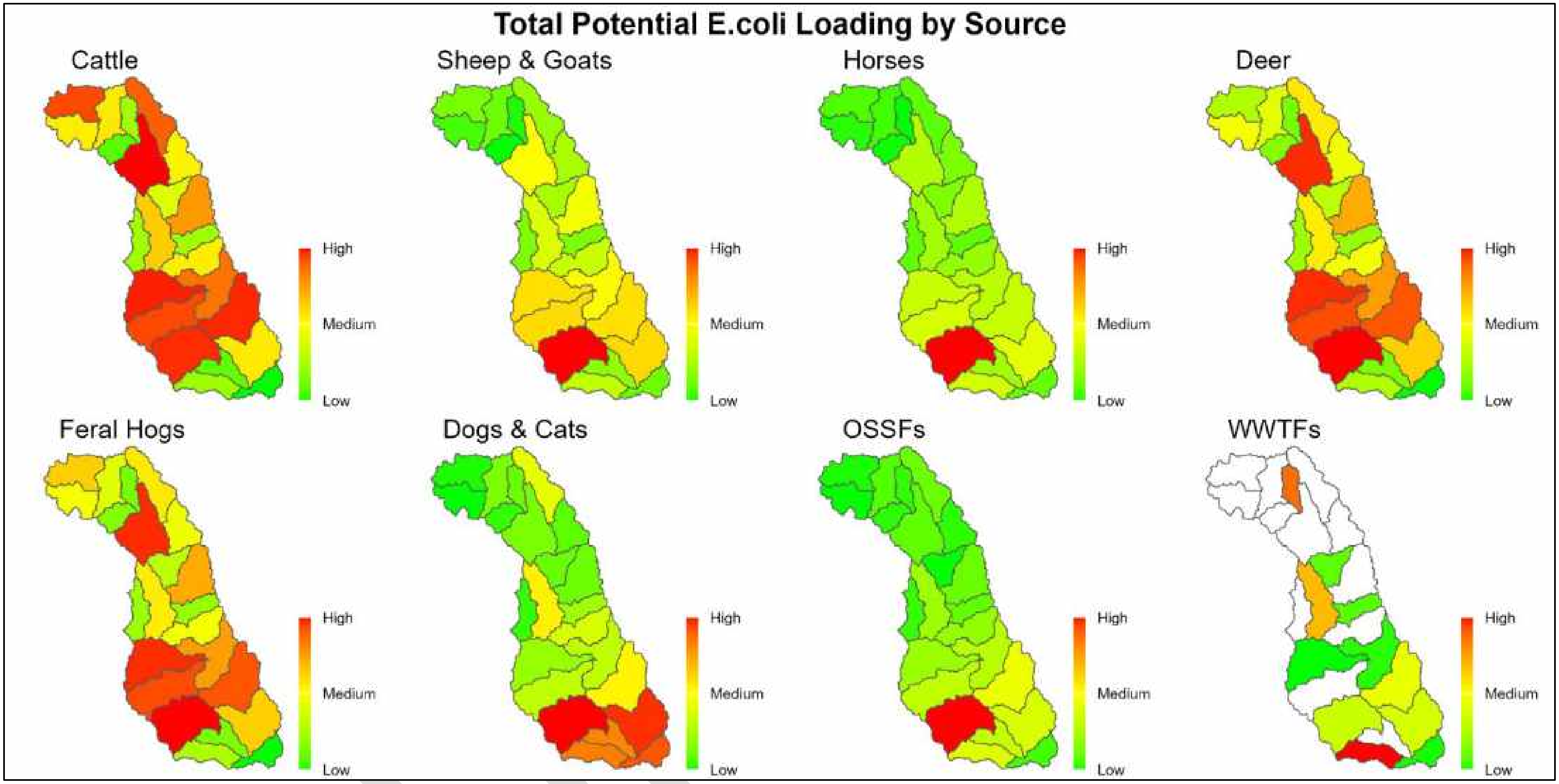
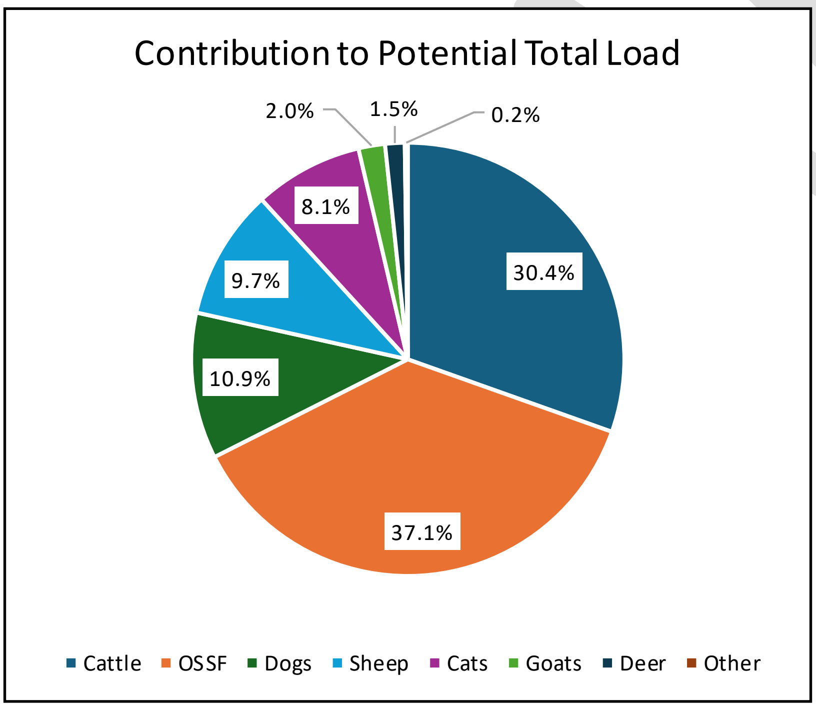


Figure 5-6 Potential *E.coli* loading by source from SELECT

Potential livestock *E. coli* loads were highest and most widespread throughout the watershed for cattle, compared to sheep and goats. Loading from smaller livestock and hobby livestock like sheep, goats, and horses is higher around the exurban fringes; this is especially true of horses. Similarly, OSSF loading is highest around the exurban fringes of Fort Worth's outer suburbs, especially in the Upper Walnut Creek subwatershed. This makes sense as many far-flung, lower-density suburbs are built without service to their most proximate city's utilities, but there is a higher load than the more truly rural areas in the northern parts of the watershed. Deer and feral hog loads follow a similar pattern wherein relative loads are high across much of the watershed except in more heavily urbanized areas. Dogs and cats are predictably producing the highest relative *E. coli* loads where human populations and therefore household pet populations are higher. Lastly, WWTF loads correspond directly to the size and number of treatment plants present in each subwatershed.

It is important to keep in mind that the maps in Figure 5-6 are relative within each source described. Figure 5-7 shows a more comprehensive picture of the total loads that each source contributes to the overall E. coli load within the EML watershed. Livestock (cattle, sheep, and goats) together account for 42.1% of the total potential load; OSSFs contribute 37.1%; household pets (dogs and cats) contribute 19%; deer contribute 1.5%; all other sources (horses, feral hogs, and WWTFs) contribute the remaining 0.2%. Figure 5-8 shows the spatial distribution of potential E. coli loads from all sources across the watershed.



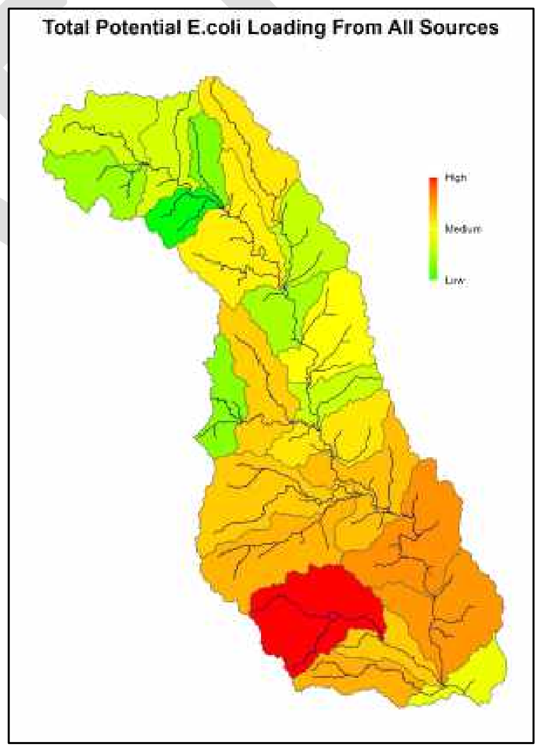


Figure 5-7 Total potential E. coli Loading by subwatershed (left)

Figure 5-8 Contributions to potential total *E. coli* load by source (right)

5.4 Conclusions

Based on these analyses, nonpoint source pollution is the main driver of water quality impairments in the EML tributaries, with the potential exception of small urban subwatersheds like Ash Creek, which may sustain consistently high E. coli loads from WWTFs. There are several significant sources of *E. coli*, nutrients, and other contaminants distributed throughout the watershed, thus focusing on one particular land use or location will not provide a viable solution to overall load issues.

Livestock, especially cattle, and OSSFs are likely the major contributors to *E. coli* issues and potentially also major contributors to nutrient issues in the EML watershed. Household pets are a distant third, but potentially heavy contributors in more urbanized areas. Several well-known and proven management strategies exist for all three source categories: grazing management practices implementation, OSSF maintenance education and funding programs, and pet waste management education and infrastructure can all help reduce both E. coli and nutrient loads. Additional BMPs put in place for several of the other source categories will provide additional flexibility for achieving the loading reduction of 1.12E+12 MPN/yr *E. coli*.

APPENDIX B: SWAT model setup and calibration for the Eagle Mountain watershed

Model Setup: HAWQS v2.0

Calibration: SWAT-CUP

Abstract

This report includes the information on SWAT model setup and calibration process for the Eagle Mountain Watershed.

SWAT

The United States Department of Agriculture (USDA) and Texas A&M University jointly developed the Soil & Water Assessment Tool (SWAT) and have actively supported the model for more than 25 years. SWAT is a small watershed to river basin-scale modeling software used to simulate the quality and quantity of surface and groundwater and predict the environmental impact of land use, land management practices, and climate change. SWAT is widely used in assessing soil erosion prevention and control, non-point source pollution control, and regional management in watersheds and cited in over 1,900 peer-reviewed journal articles (Center for Agriculture and Rural Development, 2023).

SWAT is physically based, requiring input about weather, soil properties, topography, vegetation, and land management practices occurring in the watershed. These data are available from various government agencies. SWAT uses these inputs to model physical processes associated with water movement, sediment movement, crop growth, nutrient cycling, etc. SWAT is a continuous time model which simulates long-term yields enabling users to study long-term impacts (*e.g.,* over several decades).

SWAT theoretical documentation and information on SWAT input and output files can be found on the documentation section of the TAMU SWAT website[1].

HAWQS

The Hydrologic and Water Quality System (HAWQS)[2] is a web-based interface that streamlines the development of SWAT watershed models by providing pre-loaded input data and modeling support capabilities for setting up models, running simulations, and processing outputs. SWAT is a commonly used public domain semi-distributed mechanistic watershed model that is used to evaluate the effects of land management and agricultural practices on water, sediment, and chemical fluxes across a wide range of watershed sizes, land uses, and physiographic provinces (Neitsch, et al., 2011). HAWQS provides pre-loaded national input data necessary to develop SWAT watershed models at resolutions that range from the 14-digit HUC (HUC14) to the 8-digit HUC (HUC8). The HAWQS platform was used to create the Eagle Mountain watershed SWAT model. Table 1 summarizes the input datasets used from HAWQS for the watershed.

Table 1. HAWQS v2.0 input data.

Input Dataset	Source	Specifications
Watershed Boundaries	National Hydrography Dataset Plus 2.0 (NHDPlus)	Scale: HUC14
Elevation	USGS National Elevation Dataset (NED)-Digital Elevation Model (DEM)	Resolution: 10-meter Year: 2019
Stream Network	NHDPlus 2.0	Year: 2019
Climate	Parameter-elevation Regressions on Independent Slopes Model (PRISM) 2.0	Period: 1981-2020 (Gridded) Resolution: ~4km Scale: Monthly

[1] https://swat.tamu.edu/docs/

[2] https://hawqs.tamu.edu/#/

Land Use (agricultural)	United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Cropland Data Layer (CDL)	Years: 2016 - 2018
Land Use (non-agricultural)	National Land Cover Database (NLCD)	Year: 2016
Soil	USDA Natural Resources Conservation Service (NRCS) Soil Survey Geographic Data (SSURGO)	Scale: County level Year: 2019
Point Sources	Water Quality eXchange (WQX) and National Pollutant Discharge Elimination System (NPDES)	Year: 2020
Ponds, Dams, and Reservoirs	National Inventory of Dams (NID) and NHDPlus 2.0	Year: 2018 and 2019
Management Data	USDA- NRCS crop management zone data	Year: 2010

TRWD HAWQS

A HAWQS platform was created for the Tarrant River Watershed District (TRWD)[3] to provide calibrated watershed to be used for watershed protection plans and analysis of various best management practices in the watersheds across the TRWD. The resulting calibrated Eagle Mountain watershed from this project will be available on the TRWD HAWQS platform for users to create and analyze.

Eagle Mountain Watershed

The SWAT model for the Eagle Mountain watershed was developed with the outlet at the Eagle Mountain Dam (32°52'27.3" N, 97°27'39.2" W) near Fort Worth, Texas. The hydrologic unit code (HUC14) boundaries within the delineated watershed area were considered as subbasin boundaries (Figure 1). The contributing area to Lake Bridgeport was not included in the delineated watershed due to the high regulated flow in the watershed from Bridgeport Dam. However, Lake Bridgeport Dam discharge was considered as a point source to the Eagle Mountain watershed along with the HAWQS point source databases (Table 1). As a result, the delineated watershed had a total area of 551,312 acres (2231.08 km^2) with 108 HUC14 subbasins. There was no land use threshold adopted when creating hydrologic response units (HRUs) which resulted in 10,239 HRUs across the watershed. Table 2 shows the distribution of land use in the Eagle Mountain watershed. The model outputs were simulated at monthly time-step from 2003 to 2020 with a 2-year warm-up period.

[3] https://trwd.hawqs.tamu.edu/

Table 2. Land use distribution within the Eagle Mountain Watershed.

Land use	Area (acres)	Percentage (%) of watershed area
Range-Grasses	327,427	60.47
Forest Deciduous	91,232	16.85
Pasture	47,352	8.74
Residential- Low density	19,182	3.54
Riparian Wetlands- Forested	11,278	2.08
Range- Brushes	9,501	1.75
Winter Wheat	7,672	1.42
Tall Fescue	6,659	1.23
Residential- Medium density	6,402	1.18
Others (under 1% each)	14,782	2.73

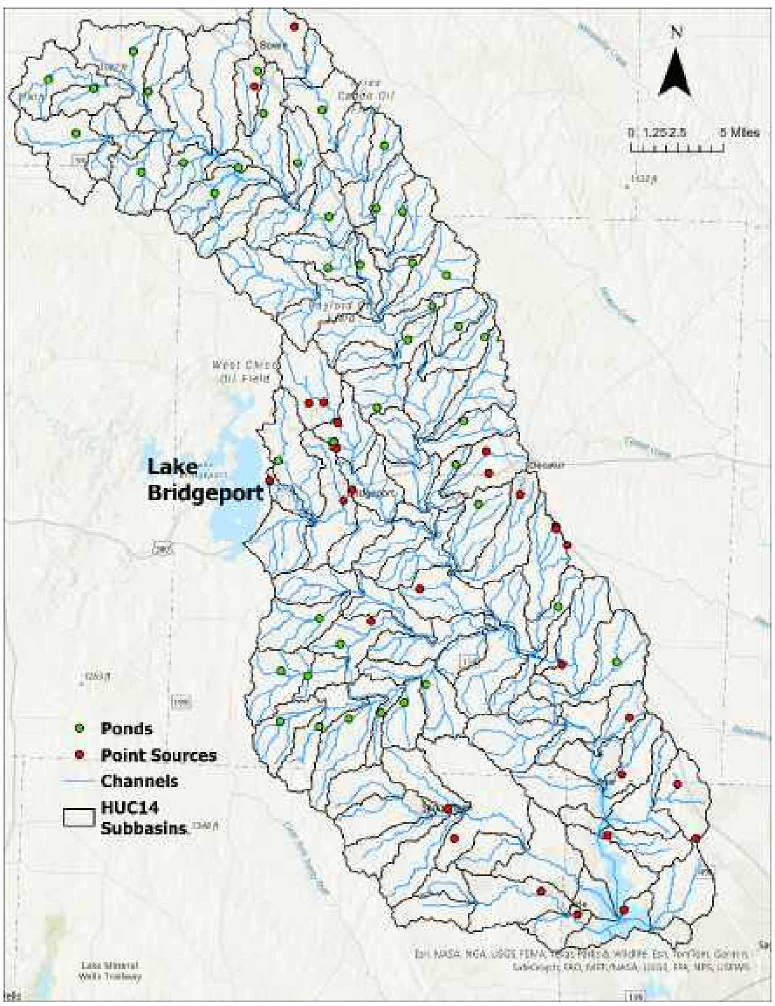


Figure 1. Eagle Mountain watershed at the HUC14 subbasin scale with Bridgeport Lake Dam as a point source.

Eagle Mountain Watershed Updates

Once the HUC14 model was created from the HAWQS platform, additional data was used to update the model to better represent current land development and management practices within the watershed.

Land Use

The HAWQS platform uses 2016 NLCD land use data as the default dataset. Since 2016, there has been extensive urbanization across the Eagle Mountain watershed. To account for this urbanization, the 2020 NLCD land use dataset was compared to the 2016 dataset to see if the urbanization increase was indeed evident in the land use dataset.

Overall, there was a 9.7% change (53,223 acres/215.4 km^2) in developed land use across the Eagle Mountain watershed when comparing the 2016 NLCD land use dataset to the 2020 NLCD land use dataset. This change was significant enough to update the land use data layer in the Eagle Mountain watershed to 2020. Figure 2 shows where the change in Developed land occurred in the watershed from 2016 to 2020.

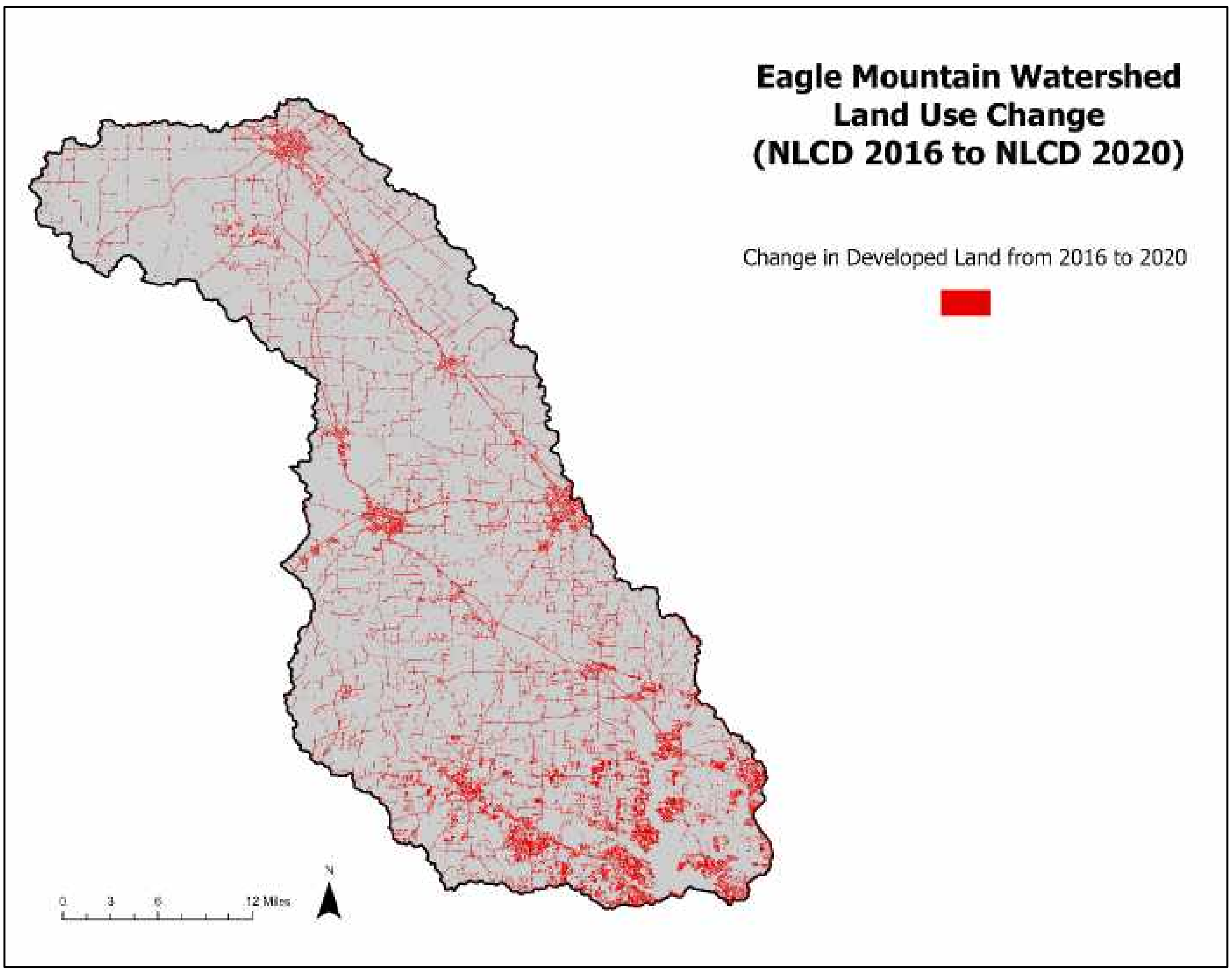


Figure 2. Developed land change in Eagle Mountain from 2016 to 2020 using NLDC Land Use layers.

Management Practices

To verify the model simulates current management practices across the watershed, historical Natural Resources Conservation Service (NRCS) data of best management practices (BMPs) implemented in the Eagle Mountain from 2008-2023 was analyzed. From the NRCS data, six management practices implemented within the watershed were chosen to simulate in the Eagle Mountain watershed model. Table 3 shows the management practices simulated in the watershed, and the area (or number of structures) of implementation.

Table 3. NRCS BMPs simulated in the Eagle Mountain watershed. The amount of land available, the amount of land receiving management, and the percentage of land applied.

Management Practices	Available Acres	Applied Acres	Percent of Land Applied
Grade Stabilization Structure		14*	
Brush Management	8,376	609	7.3%
Cover Crop	25,045	2,584	10.3%
Pasture Hay Planting	250,209	733	0.3%
Range Planting	159,429	381	0.2%
Prescribed Grazing	350,329	267,766	76.4%

* For grade stabilization structure, there were 14 different structures applied in the watershed.

SWAT can simulate various BMPs across a watershed. Some BMPs can only be simulated for the entire model run, while others can be simulated on the date of implementation. The grade stabilization structures were added to the SWAT model on the date and were implemented from the NRCS dataset. All locations prior to 2020 were included in the Eagle Mountain watershed resulting in 14 grade stabilization structures (Figure 3). In the SWAT model, these were simulated by creating a grass waterway in each HRU using the parameter values provided in Table 4. Each location and the corresponding HRU selected to simulate the structure are found in Table 5.

Table 4. List of variables adjusted to simulate Grade Stabilization Structures (grassed waterways) in the Eagle Mountain watershed.

Variable	Description	Value
GWATI	Flag to simulate grass waterways	1
GWATN	Manning's N value for overland flow	0.14
GWATL	Length of grassed waterway (km)	1
GWATW	Average width of grassed waterway (m)	15
GWATD	Depth of grass waterway channel from top of bank to bottom (m)	0.5
GWATS	Average slope of grassed waterway channel (m)	0.005
GWATSPCON	Linear parameter for calculating sediment in grassed waterways	0.005

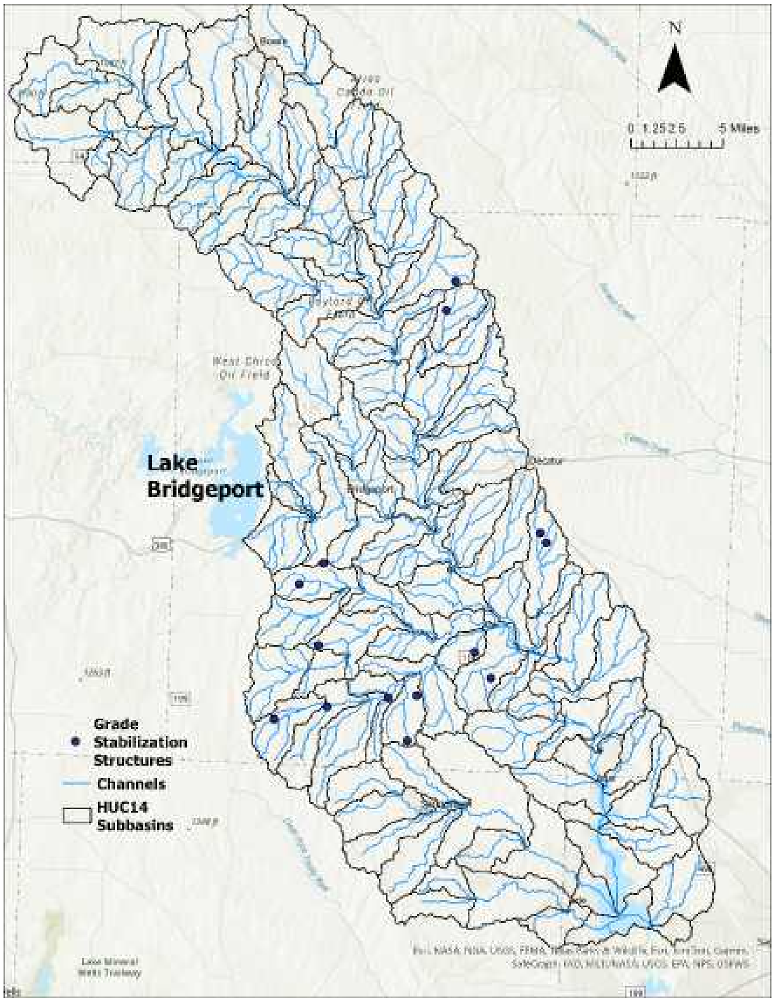


Figure 3. Grade Stabilization Structures added in the Eagle Mountain SWAT model. Implementation dates ranging from 2009-2018.

Table 5. Locations of Grade Stabilization Structures from NRCS and the corresponding HRU selected in the Eagle Mountain SWAT model.

NRCS Details				SWAT Location Used			
HUC12 Subbasin	Date	Area (acres)	Land Use	HUC14	Land Use	Soil Num	HRU
(120301010603) Salt Creek	11/9/2009	94	Pasture	12030101060307	RNGE	373644	000710021
(120301010604) Walnut Creek-West Fork Trinity River	5/7/2010	63.2	Pasture	12030101060402	FESC	373649	000730126
(120301010604) Walnut Creek-West Fork Trinity River	4/3/2012	13	Range	12030101060406	RNGE	373702	000770022
(120301010603) Salt Creek	4/12/2012	32.2	Pasture	12030101060303	RNGE	373667	000670010
(120301010603) Salt Creek	5/22/2012	26.5	Range	12030101060303	RNGE	373666	000670006

(120301010507) Lower Brushy Creek	7/6/2012	87	Range	12030101050704	UTRN (URLD)	373667	000330052
(120301010603) Salt Creek	7/16/2012	17.31	Pasture	12030101060304	RNGE	373678	000680016
(120301010604) Walnut Creek-West Fork Trinity River	5/17/2013	53	Pasture	12030101060402	PAST	373663	000730113
(120301010603) Salt Creek	6/26/2015	140	Range	12030101060301	RNGE	373666	000650014
(120301010510) Briar Branch-Big Sandy Creek	7/21/2015	14	Range	12030101051001	UTRN (URLD)	373702	000440041
(120301010602) Garrett Creek	5/2/2017	146	Range	12030101060206	FRSD (RNGE)	373679	000630019
(120301010602) Garrett Creek	5/2/2017	16	Range	12030101060206	RNGE	373642	000630003
(120301010602) Garrett Creek	6/11/2018	13	Range	12030101060202	FRSD (RNGB)	373704	000590025
(120301010603) Salt Creek	10/16/2018	8.2	Range	12030101060306	RNGE	373666	000700003

When simulating the other five management practices in SWAT, the same annual management was added within the selected HRUs for the entire simulation period (2005-2020). Since the amount of land receiving each management practice changed slightly over the period of the simulation, the annual average area within each HUC12 from the NRCS data was used. The annual average area for the watershed receiving each BMP is shown in Table 3.

The brush management BMP was simulated in the Eagle Mountain watershed by selecting RNGB (Range Brush) land use HRUs and converting them into RNGE (Range Grass) HRUs. This was done in the SWAT model by changing the initial land cover status to growing and defining RNGE as the plant type.

For the cover crop BMP, PAST (Pasture) HRUs were selected and either WWHT (Winter Wheat) or OATS (Oats) were planted as a cover crop. The Eagle Mountain watershed has more land with WWHT than OATS, so the HRUs selected for the cover crop BMPs were split with 75% simulating WWHT as the cover crop and 25% simulating OATS as the cover crop. The cover crop BMP was simulated in the SWAT model by changing the initial land cover status to growing and defining either WWHT or OATS as the initial plant type. Then, the management operations were set to harvest and kill at the end of March (03/31), plant BERM (bermudagrass) at the start of April (04/01), fertilize with 89 lbs/acre of nitrogen on 04/02, harvest only on 09/30, then plant the initial plant type again on 10/02.

To simulate pasture hay planting in the Eagle Mountain watershed, PAST HRUs were selected and updated with planting operations. This was done by adding in a heat unit operation where PAST was planted at heat units of 0.15, then auto fertilization of 89 lbs/acre of nitrogen was simulated with a trigger for application when the nitrogen stress factor falls to 0.75. Finally, a harvest and kill operation was set when the heat units reach 1.2.

The range planting BMP simulated in model was done like pasture hay planting. For the range planting, however, RNGE (Range Grass) HRUs were selected and the plant defined during the planting at the 0.15 heat unit was RNGE. The same auto fertilization of 89 lbs/acre of nitrogen with the 0.75 nitrogen stress factor was used as well as the harvest and kill operation at 1.2 heat units.

The last management practice added into the Eagle Mountain SWAT model was prescribed grazing. Using the NRCS data, and input from the NRCS Decatur Office, ~75% of the available PAST and RNGE land were used to simulate prescribed grazing. Additionally, the NASS Census data was used to determine the number of cattle, including cows within the watershed. The average number of animals from the Census data was 60,379. The NRCS Decatur office recommended using a factor of 1.2 animals to determine the animal units (AU) within the watershed. This resulted in 72,455 AU in Eagle Mountain and a stocking rate of 4.1 acres/AU (~5 acres/head), which was in line with the 2-4 acres/AU they recommended. NRCS Decatur also recommended simulating grazing from mid-April (04/15) through mid-November (~220 days). Modelers from the Blackland Research Extension Center (BREC) recommend that 1 AU typically eats 20 lbs/acre, tramples 10 lb/acre, and produces 5 lbs/acre of manure a day. These values were added into the selected PAST and RNGE HRUs selected along with a minimum biomass for grazing value of 1070.6 lbs/acre and harvest operation with a harvest efficiency of 0.8 on 12/01 (both recommended by BREC modelers).

After all the management practices were added into the Eagle Mountain SWAT model, the model was then calibrated against available flow and water quality data to ensure accurate simulation across the watershed.

Calibration Process

SWAT-CUP[4] is a program that performs calibration, validation, and sensitivity and uncertainty analysis for SWAT models. The program links the Sequential Uncertainty Fitting v2 (SUFI2) routine, the Particle Swarm Optimization (PSO), the Generalized Likelihood Uncertainty Estimation (GLUE), the Parameter Solution (ParaSol), and the Markov Chain Monte Carlo (MCMC) to SWAT models. For the Eagle Mountain watershed calibration, the SUFI2 algorithm was used since it is the most flexible algorithm and the only algorithm that can be run with parallel processing within the SWAT-CUP program. This algorithm measures two values: the p-factor and r-factor. The p-factor is the percentage of observed data enveloped by the 95 percent prediction uncertainty (95PPU). The r-factor is the thickness of the 95PPU. The objective of the SUFI2 algorithm is to have most observed values fall within a relatively small 95PPU. A comprehensive description of the SUFI2 algorithm can be found in Abbaspour et al. (2007). Within SWAT-CUP, there are 11 statistical tests that can be used to evaluate model performance. Model performance is evaluated against three basic statistical tests: Percent bias (PBIAS); Nash-Sutcliffe efficiency (NSE); and Kling–Gupta efficiency (KGE), which are described below.

Percent bias (PBIAS)

PBIAS measures the average tendency of the simulated data to be larger or smaller than their observed counterparts (Gupta, et al., 1999; Moriasi, et al., 2015). The optimal value of PBIAS is 0.0, with low-magnitude values indicating accurate model simulation. Positive values indicate model underestimation bias, and negative values indicate model overestimation bias (Gupta, et al., 1999; Moriasi, et al., 2015).

[4] https://swat.tamu.edu/software/swat-cup/

PBIAS is calculated with the equation below where PBIAS is the deviation of data being evaluated, expressed as a percentage.

$$PBIAS = \frac{\left[\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right) * (100)\right]}{\sum_{i=1}^{n}\left(Y_i^{obs}\right)}$$

Where Y_i^{obs} is the *i*th observation for the constituent being evaluated, Y_i^{sim} is the *i*th simulated value for the constituent being evaluated, and *n* is the total number of observations. Table 6 provides the range of acceptable values for PBIAS for flow, sediment, and nutrients consistent with current best modeling practices.

Table 6. General percent error calibration targets, applicable to monthly calibration (Donigian, 2002; Moriasi et al., 2007).

SWAT Output	Very Good	Good	Fair
Hydrology/Flow	<10	10-15	15-25
Sediment	< ± 15	± 15 to ± 30	± 30 to ± 55
Nutrients (TN & TP)	< ± 25	± 25 to ± 40	± 40 to ± 70

Nash-Sutcliffe efficiency (NSE)

NSE is a normalized statistic that determines the relative magnitude of the residual variance (“noise”) compared to the measured data variance (“information”) (Nash & Sutcliffe, 1970). NSE indicates how well the plot of observed versus simulated data fits the 1:1 line. NSE is calculated as:

$$NSE = 1 - \left[\frac{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n}\left(Y_i^{obs} - Y^{mean}\right)^2}\right]$$

Where Y_i^{obs} is the *i*th observation for the constituent being evaluated, Y_i^{sim} is the *i*th simulated value for the constituent being evaluated, Y^{mean} is the mean of observed data for the constituent being evaluated, and *n* is the total number of observations.

NSE ranges between negative infinity and 1.0, with 1.0 being the optimal value (a perfect model fit) and values <0.0 indicating that the mean observed value is a better predictor than the simulated value, thereby demonstrating unacceptable model performance. Good performance is indicated by values >0.5 and acceptable performance by values between 0.0 and 0.5 (Moriasi, et al., 2007).

Kling–Gupta efficiency (KGE)

KGE (Gupta, et al., 2009) is a performance indicator based on the equal weighting of linear correlation (r), bias ratio (β), and variability (γ), between simulated and observed data:

$$KGE = 1 - \sqrt{(r-1)^2 + (\gamma - 1)^2 + (\beta - 1)^2}$$

Where γ is the standard deviation of simulated/standard deviation of observed, β is the mean of simulated/mean of observed, and r is the linear regression coefficient between simulated and measured data. The calibration results range between negative infinity and 1.0, with 1.0 being a perfect model fit. KGE values larger than 0.5 are considered satisfactory (Moriasi et al., 2007).

KGE captures three additional statistics: mean, standard deviation, and r^2 (coefficient of determination). In most cases, evaluation of KGE encompasses the conclusions that can be made from evaluating PBIAS and, to a lesser extent, NSE. Therefore, KGE was used as the primary calibration metric to evaluate model performance in the Eagle Mountain watershed calibration.

Flow Calibration

The Eagle Mountain model was calibrated using monthly observed streamflow from two USGS gauge stations- 08044000 located on Big Sandy Creek near Bridgeport, Texas and 08044500 located on the West Fork Trinity River near Boyd, TX (Figure 4). The available observed monthly streamflow data for the 2005-2020 period (190 observations) was used to calibrate the model.

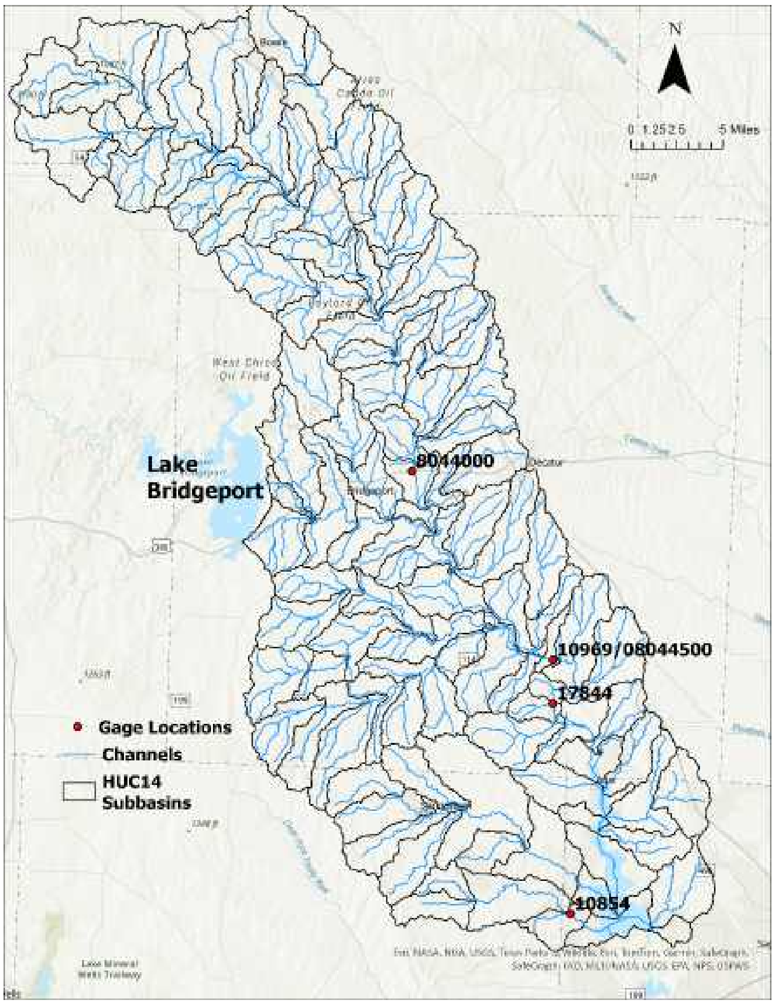


Figure 4. Flow and water quality gages used for calibration of the Eagle Mountain watershed.

Table 7 shows the best fitted parameter values for the calibrated Eagle Mountain SWAT model from SWAT-CUP. The resulting hydrographs for observed and simulated streamflow for the calibration period are shown in Figure 5 and Figure 6 and the flow calibration summary statistics are presented in Table 8. The USGS 08044000 gage on Big Sandy Creek is downstream of a large reservoir, the Soil Conservation Service Site 8 Reservoir. The observed flow at that gage is very low, 2.12 cms, and there was no release data available from the upstream reservoir, therefore the calibration at this gage was able to simulate the variability at the site, but the magnitude of the flow was larger than the acceptable range (PBIAS > +/-25%). The USGS 0804450 gage on the West Fork of the Trinity River is located on the main stem of the river, therefore the watershed calibration was prioritized at this gage. This gage is downstream of Lake Bridgeport Dam, which was used as a point source boundary condition in the model. As shown in Table 8 and Figure 6, SWAT-CUP was able to simulate both the variability (NS and KGE statistics) and the magnitude of the flow (PBIAS) very well.

Table 7. Flow calibration parameters used in the Eagle Mountain watershed and their range of acceptable values.

Value Type	Input File	SWAT Parameter	Description	Fitted Value	Range
Multiply	mgt	CN2	Initial SCS runoff curve number for moisture condition II	-0.074453	-0.1 to 0.1
Multiply	sol	SOL_AWC()	Available water capacity of all soil layer	0.000391	-0.05 to 0.05
Replace	HRU	CANMX	Maximum canopy storage	1.40625	0 to 20
Replace	HRU	ESCO	Soil evaporation compensation factor	0.372656	0.5 to 0.75
Replace	gw	ALPHA_BF	Baseflow alpha factor	0.134609	0.005 to 0.1
Replace	gw	ALPHA_BF_D	Alpha factor for ground recession curve of the deep aquifer	0.433594	0 to 1
Add	gw	GW_DELAY	Ground water delay time	21.171875	-30 to 90
Add	gw	GWQMN	Threshold depth of water in shallow aquifer required for return flow to occur	72.65625	-1000 to 1000
Add	gw	RCHRG_DP	Deep aquifer percolation fraction	0.005078	-0.05 to 0.05
Add	gw	REVAPMN	Threshold depth of water in shallow aquifer for “revap” or percolation to deep aquifer to occur	-378.906	-750 to 750
Replace	HRU	SLSOIL	Slope length of lateral subsurface flow	110.9375	0 to 200
Replace	HRU	LAT_TTIME	Lateral flow travel time	1.148438	0 to 14
Replace	gw	GW_REVAP	Groundwater “revap” coefficient	0.096172	0.02 to 0.1
Replace	rte	CH_K2	Effective hydraulic conductivity in main channel alluvium	4.453125	0 to 20
Replace	sub	CH_K1	Effective hydraulic conductivity in tributary channel alluvium	1.757813	0 to 20
Replace	HRU	EPCO	Plant uptake compensation factor	0.149219	0.1 to 1

**CANMX parameter was adjusted for Rangeland- brush, Forest- deciduous, Forest- evergreen, Forest- mixed.

Table 8. Flow calibration summary statistics from SWAT-CUP for the Eagle Mountain watershed.

Gage ID	NS	PBIAS	KGE	Simulation Mean (cms)	Observation Mean (cms)
USGS 08044000	0.8	-68.4	0.31	3.56	2.12
USGS 08044500	0.56	3.1	0.56	8.19	8.46

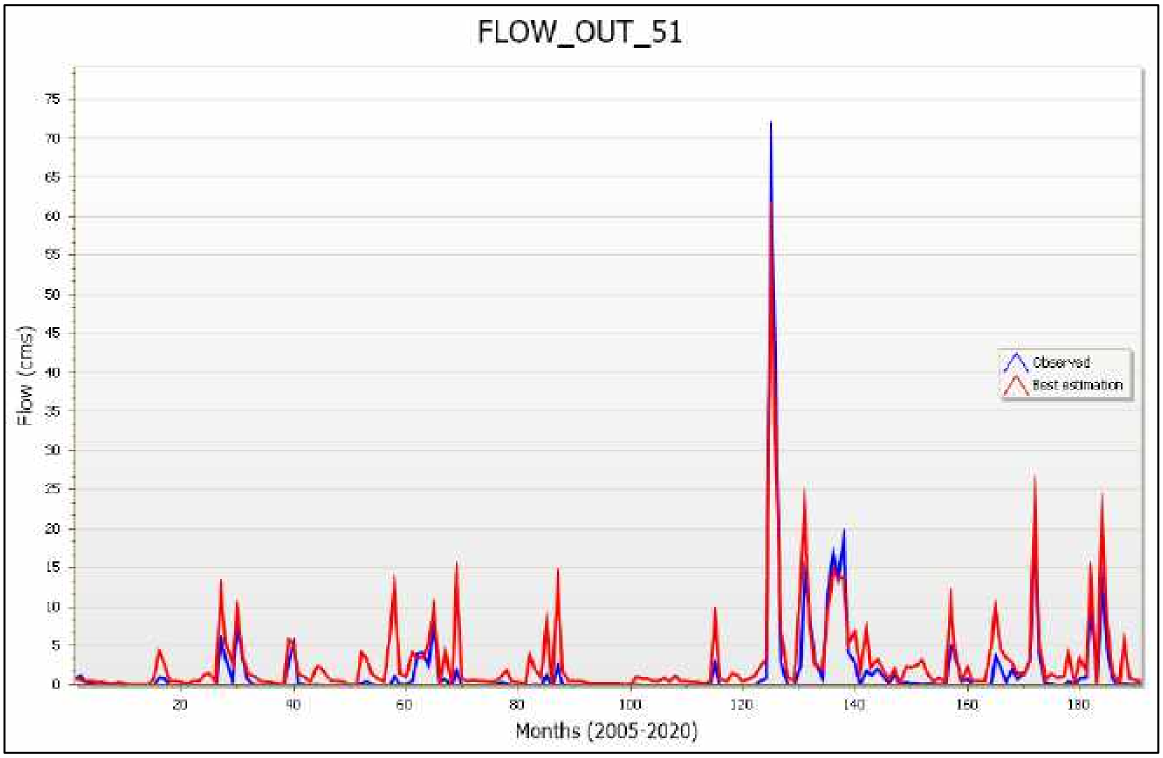


Figure 5. SWAT-CUP flow calibration results at USGS 08044000.

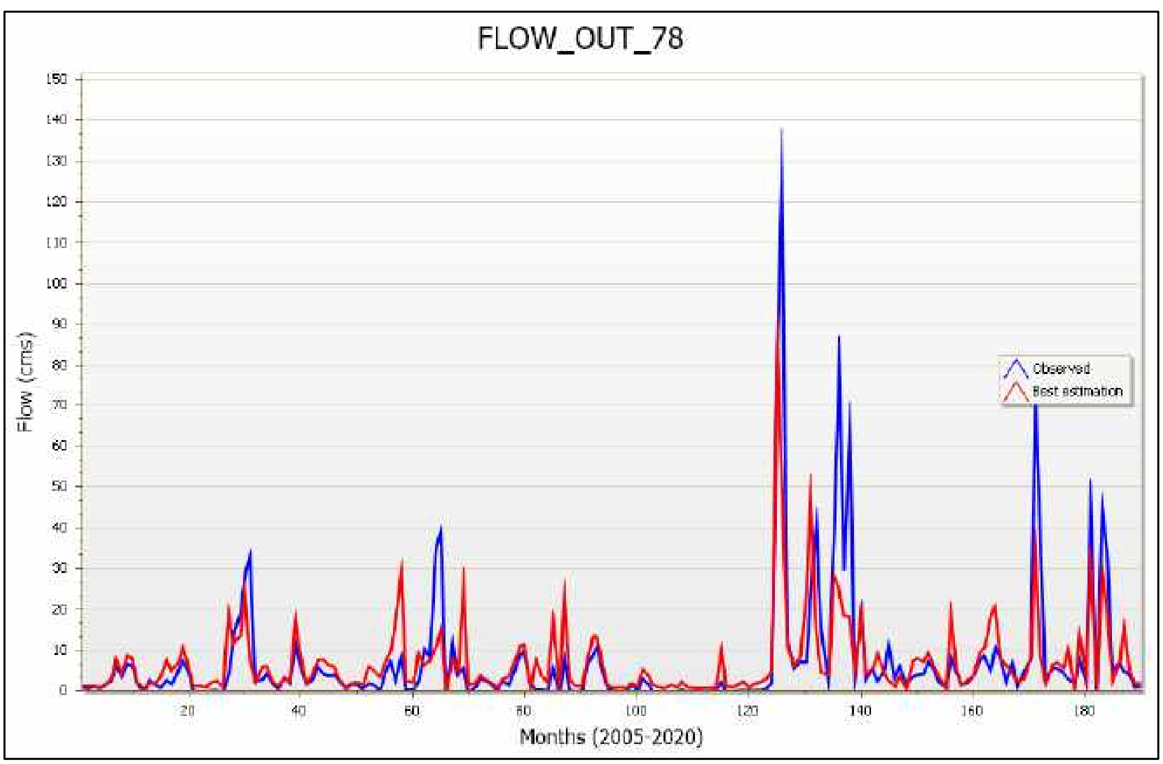


Figure 6. SWAT-CUP flow calibration results at USGS 08044500.

A flow duration curve for the USGS 08044500 gage on the West Fork Trinity River is shown in Figure 7. This illustrates that the high flow conditions happen less than 10% of the time, with dry to low flow conditions accounting for 40% of time. The remaining 50% of the flow is where BMPs can be successful in helping to reduce the amount of loading reaching the waterways.

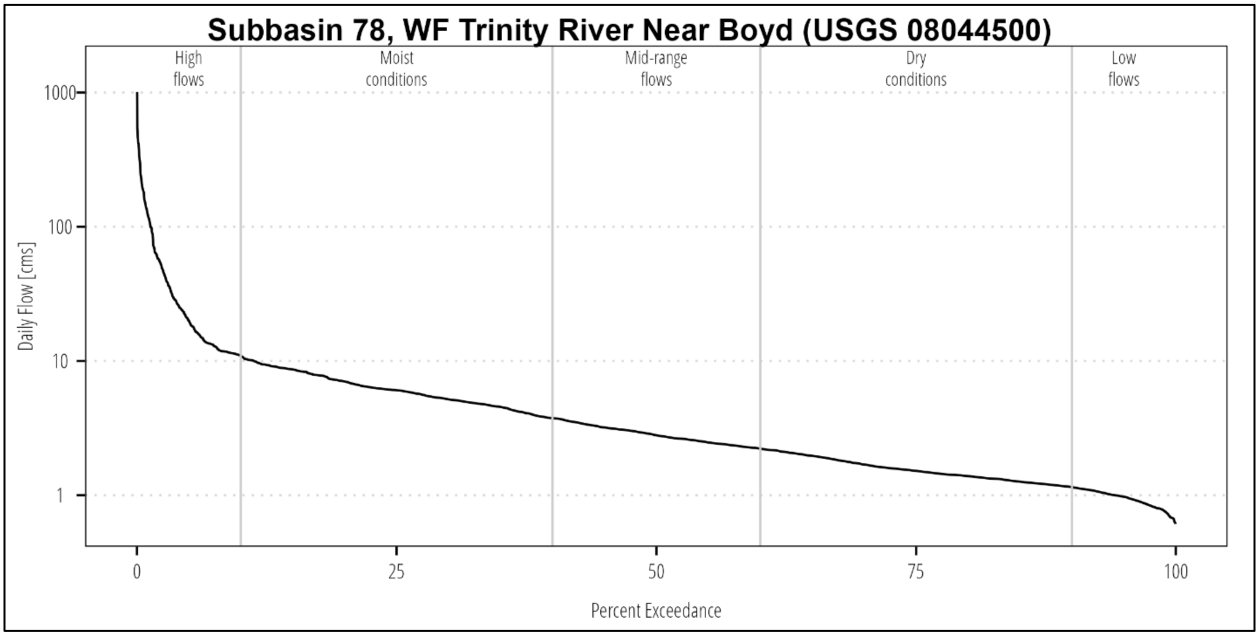


Figure 7. Flow duration curve for the West Fork Trinity River near Boyd.

Water Quality Calibration

Water quality (WQ) observations used in the calibration of the Eagle Mountain watershed, provided by the TRWD, are shown in Table 9. Site locations are shown in Figure 4.

Table 9. Monitoring sites used for calibration of the Eagle Mountain watershed.

Site Name	Site Number	Time Period	Data Available
Ash Creek	10854	2005-2020	TSS, NO2+NO3, NH3, TN, PO4, TP
WF @ FM730	10969	2011-2020	TSS, NO2+NO3, NH3, TN, PO4, TP
WF @ Bobo/4668	17844	2005-2010	TSS, NO2+NO3, NH3, TN, PO4, TP

LOADEST

The USGS LOADEST (Load Estimator) tool is a powerful and widely used software developed by the United States Geological Survey (USGS) to estimate the transport of sediment and nutrients in rivers and streams. LOADEST utilizes three statistical models to estimate the loads of sediment, nutrients, and other contaminants based on available WQ data. The Adjusted Maximum Likelihood Estimation (AMLE) and Maximum Likelihood Estimation (MLE) are appropriate when the calibration model errors (residuals) are normally distributed, and the Absolute Deviation (LAD) is an alternative when the residuals are not normally distributed.

For the Eagle Mountain watershed, the AMLE statistical model was used to generate the constituent load used for calibration. Time series of streamflow, dates and time of observations, and constituent concentration were input into LOADEST. The resulting estimation of constituent load was generated including the mean load estimates, standard errors, and 95 percent confidence intervals on a monthly timestep.

The summary statistics used to determine if the estimated load should be used for calibration were the Load Bias in Percent (B_p), where positive (negative) values indicate over (under) estimation. The model should not be used when the + or - bias exceeds 25%. The Partial Concentration Ratio (PCR) is another measure to show the amount of over or under estimation and is calculated using Bp.

$$\mathrm{PCR} = {(B_P + 100)}/{100}$$

PCR values > 1 indicate overestimation; values < 1 indicate underestimation. Finally, the Nash Sutcliffe Efficiency Index (E) (Nash and Sutcliffe, 1970). values range from -infinity to 1.0 with E = 1 a perfect fit to observed data, E = 0 the model estimates are as accurate as the mean of observed data, and E < 0; the observed mean is a better estimate than the model estimates. Table 10 shows the resulting LOADEST summary statistics for total phosphorus for each location across the Eagle Mountain watershed. All locations and constituents had acceptable LOADEST results except for NH3 at site 10854.

Table 10. LOADEST results for each station and WQ constituent. Red entries indicate poor LOADEST performance.

Station	Variable	Bp [%]	PCR	E
10969	Sediment (TSS)	-12.565	0.874	0.095
10969	NOx (NO2+NO3)	-2.899	0.971	0.096
10969	Ammonium-N (NH3)	-4.883	0.951	0.062
10969	Orthophosphate-P (OP4)	2.242	1.022	0.008
10969	Total Nitrogen (TN)	-1.128	0.989	0.215
10969	Total Phosphorous (TP)	-0.585	0.994	0.152
17844	Sediment (TSS)	1.457	1.015	0.155
17844	NOx (NO2+NO3)	5.922	1.059	0.071
17844	Ammonium-N (NH3)	-8.751	0.912	0.05
17844	Orthophosphate-P (OP4)	-0.424	0.996	0.085
17844	Total Nitrogen (TN)	-19.675	0.803	0.027
17844	Total Phosphorous (TP)	-0.739	0.993	0.406
10854	Sediment (TSS)	21.291	1.213	0.272
10854	NOx (NO2+NO3)	10.582	1.106	0.204
10854	Ammonium-N (NH3)	-13.911	0.861	-0.004
10854	Orthophosphate-P (OP4)	7.826	1.078	0.388
10854	Total Nitrogen (TN)	-6.434	0.936	0.093
10854	Total Phosphorous (TP)	11.082	1.111	0.171

Additionally, LOADEST was used to simulate continuous time series over the same time period for *E.coli* from the observations at each site. The summary statistics from LOADEST for *E.coli* are similar, but slightly different from the other WQ variables. *The E.coli* LOADEST tool provides R^2, Prob. Plot. Corr. Coeff. (PPCC), and serial correlation of residuals. The R^2 value indicates the percentage of variability in the observed *E. coli* loads that is explained by the model. Larger values indicate stronger fit, suggesting the model does a good job of predicting *E. coli* loads based on the input data. The PPCC assesses how well the residuals (differences between observed and predicted values) follow a normal distribution. A value close to 1 indicates that the residuals are normally distributed, which supports the validity of statistical assumptions in the model. The serial correlation of residuals measures how correlated the residuals are over time. A value of 0 would indicate no correlation over time, while values closer to ±1 indicate strong serial correlation. Table 11 provides the statistical results from the E.coli LOADEST for each station. All locations have strong fitted models (R^2 values), nearly normal distribution (PPCC) and mild positive autocorrelation (Corr. Residuals).

Table 11. LOADEST results for E.coli at each station.

Station	R^2	PPCC	Corr. Residuals
10969	82.12	0.9843	0.2287
17844	77.35	0.9885	0.0355
10854	81.3	0.967	0.1351

Results

For WQ calibration, SWAT-CUP was also used. First, SWAT-CUP was run to calibrate sediment. The best fitted value for each parameter used in the flow calibration (Table 7) was set as fixed values, and the parameters that calibrate sediment from Table 12 where used across their respective ranges to find the best fitted value. Next, the nitrogen was calibrated using a similar method of setting the previous calibration (flow and sediment) parameters as fixed and finding the best fitted value for the nitrogen parameter in Table 12. Finally, this process was completed for phosphorus resulting in a final calibrated model for all WQ constituents.

Table 12. Water quality calibration parameters used in the Eagle Mountain watershed and their range of acceptable values.

Value Type	SWAT Parameter	Input File	Description	Fitted Value	Range
Replace	SPCON	bsn	Maximum amount of sediment that can be reentrained	0.000417	0.0001 to 0.01
Replace	SPEXP	bsn	Sediment reentrained in channel sediment routing	1.380469	1 to 2
Replace	ADJ_PKR	bsn	Peak rate adjustment factor for sediment routing in the subbasin	1.858203	0.5 to 2
Replace	PRF_BSN	bsn	Peak rate adjustment factor for sediment routing in the main channel	0.417188	0 to 2
Replace	PPERCO	bsn	Phosphorus percolation coefficient	10.52734	10 to 17.5
Replace	PHOSKD	bsn	Phosphorus soil partitioning coefficient	199.2188	120 to 200

Replace	PSP	bsn	Phosphorus sorption coefficient	0.576016	0.01 to 0.7
Replace	SOL_P_MODEL	bsn	Soil phosphorus model	1	0 to 1
Replace	P_UPDIS	bsn	Phosphorus uptake distribution parameter	83.59375	20 to 100
Replace	CMN	bsn	Rate factor for humus mineralization of active organic nitrogen	0.001516	0.001 to 0.003
Replace	N_UPDIS	bsn	Nitrogen uptake distribution parameter	2.34375	0 to 100
Replace	NPERCO	bsn	Nitrogen percolation coefficient	0.242188	0 to 1
Replace	RSDCO	bsn	Residue decomposition coefficient	0.080625	0.02 to 0.1
Replace	CDN	bsn	Denitrification exponential rate coefficient	1.120313	1 to 1.2
Replace	SDNCO	bsn	Denitrification threshold water content	0.840625	0.6 to 1
Replace	AI2	wwq	Fraction of algal biomass that is phosphorus	0.013828	0.01 to 0.02
Replace	AI1	wwq	Fraction of algal biomass that is nitrogen	0.073594	0.07 to 0.09
Replace	AI0	wwq	Ratio of chlorophyll-a to algal biomass	86.640625	10 to 100
Replace	RS2	swq	Benthic (sediment) source rate for dissolved phosphorus in the reach at 20°C	0.076023	0.001 to 0.1
Replace	RS3	swq	Benthic source rate for NH4-N in the reach at 20°C	0.742188	0 to 1
Replace	RS4	swq	Rate coefficient for organic N settling in the reach at 20°C	0.089945	0.001 to 0.1
Replace	RS5	swq	Oranic phosphorus settling rate in the reach at 20°C	0.017242	0.001 to 0.1

Table 13 presents the water quality calibration results from SWAT-CUP. Calibrating the Eagle Mountain watershed as a whole ensures consistent representation of hydrologic processes and captures the interconnectedness between upstream and downstream areas. In contrast, adjusting channel processes at individual gage sites can lead to localized fixes that may ignore broader watershed dynamics and introduce inconsistencies. Among the sites, calibration at site 10969 yielded the most consistent and reliable results, possibly due to its more recent data availability (2011–2020). Site 17844, located slightly downstream on the West Fork Trinity River, had data only from 2005–2010 and showed the least favorable calibration. Site 10969, which overlaps with USGS gage 08044500 used for flow calibration, was prioritized during calibration. Site 10854, located on Ash Creek, contributes relatively low loading to Eagle Mountain Lake; thus, despite mixed calibration results, its impact on overall watershed loading is minimal. The SWAT model output separates NO2 and NO3, and during calibration, only one can be selected for calibration. The average annual loading of NO2 is 5% of NOx (NO2+NO3) at sites 10969 and 17844, and 6.7% at site 10854, therefore NO3 was used for the calibration of the NOx observations.

Table 13. Water quality calibration summary statistics from SWAT-CUP for the Eagle Mountain watershed. Bold values indicate acceptable calibration. TSS = metric tonnes, NO3, NH3, PO4, TN, TP = kilograms (kg).

Gage ID	Constituent	NS	PBIAS	KGE	Simulation Mean	Observation Mean
10969	TSS (tonnes)	0.63	2.9	**0.7**	10,095.86	10,394.62
10969	NO3 (kg)	0.36	-9.1	**0.65**	13,425.61	12,311.01
10969	NH3 (kg)	0.5	37.6	**0.35**	3,273.16	5,243.13
10969	PO4 (kg)	0.64	-4.8	**0.66**	5,727.16	5,464.76
10969	TN (kg)	0.52	31.5	**0.44**	42,854.48	62,547.68
10969	TP (kg)	0.54	-19.7	**0.7**	13,308.03	11,116.98
17844	TSS (tonnes)	0.75	9.6	**0.83**	6,125.54	6,773.68
17844	NO3 (kg)	-1.08	-98.4	-0.15	12,100.86	6,100.37
17844	NH3 (kg)	-5.47	-133.3	-1.21	3,323.82	1,424.43
17844	PO4 (kg)	-5.8	-184.5	-1.61	4,499.02	1,581.26
17844	TN (kg)	-0.28	-21.7	**0.3**	37,132.2	30,509.19
17844	TP (kg)	0.46	-26.4	**0.6**	9,134.45	7,226.91
10854	TSS (tonnes)	0.28	**52.1**	0.04	407.52	851.42
10854	NO3 (kg)	0.37	**-52**	0.23	1,508.92	992.53
10854	NH3 (kg)	-2.52	-305.6	-2.15	382.12	94.22
10854	PO4 (kg)	0.26	-13.8	**0.63**	153.21	134.65
10854	TN (kg)	**0.5**	-105.7	-0.06	3,945.85	1,918.03
10854	TP (kg)	0.16	**-70.3**	0.19	526.17	308.88

The resulting simulated WQ constituent time series at site 10969 on the West Fork Trinity River are shown in Figure 8 for sediment (TSS), Figure 9 for Nitrate (NO3), Figure 10 for Ammonium (NH3), Figure 11 for Orthophosphate (PO4), Figure 12 for Total Nitrogen (TN), and Figure 13 for Total Phosphorus (TP). As shown, both the variability over the time period (2011-2020) and the magnitude of each constituent is well simulated when compared to the observed data.

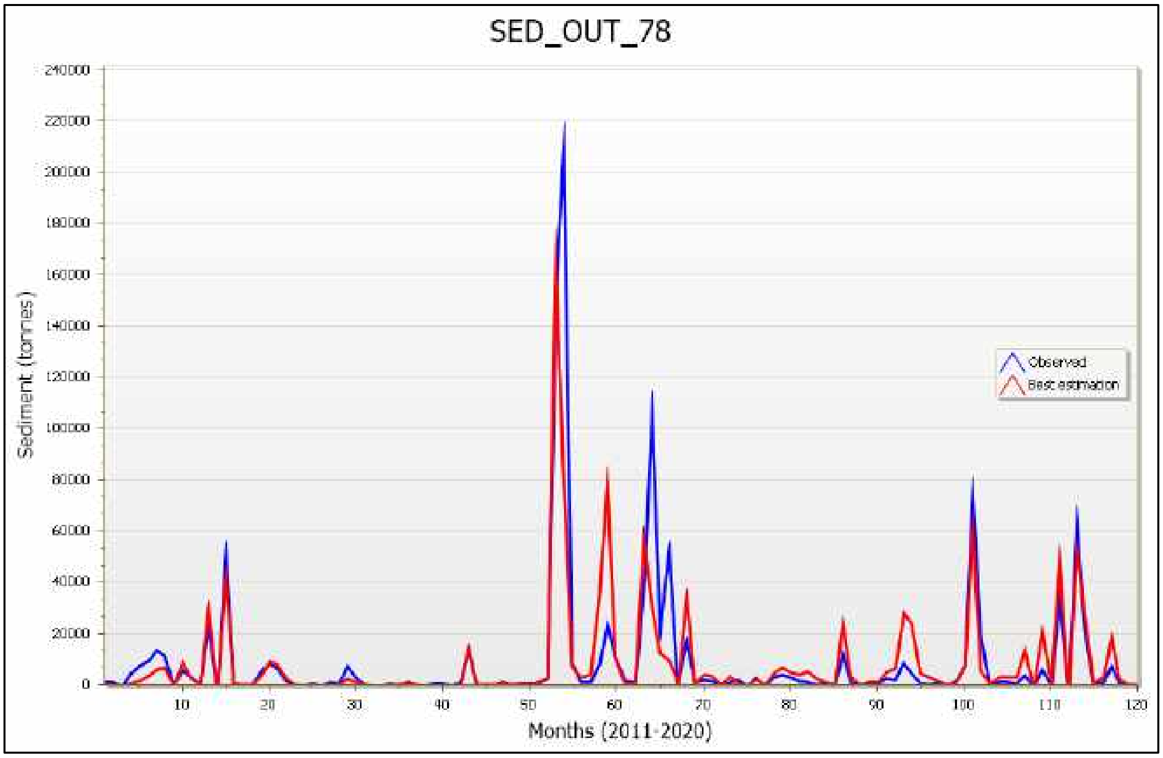


Figure 8. SWAT-CUP sediment calibration results for site 10969 on the West Fork Trinity River.

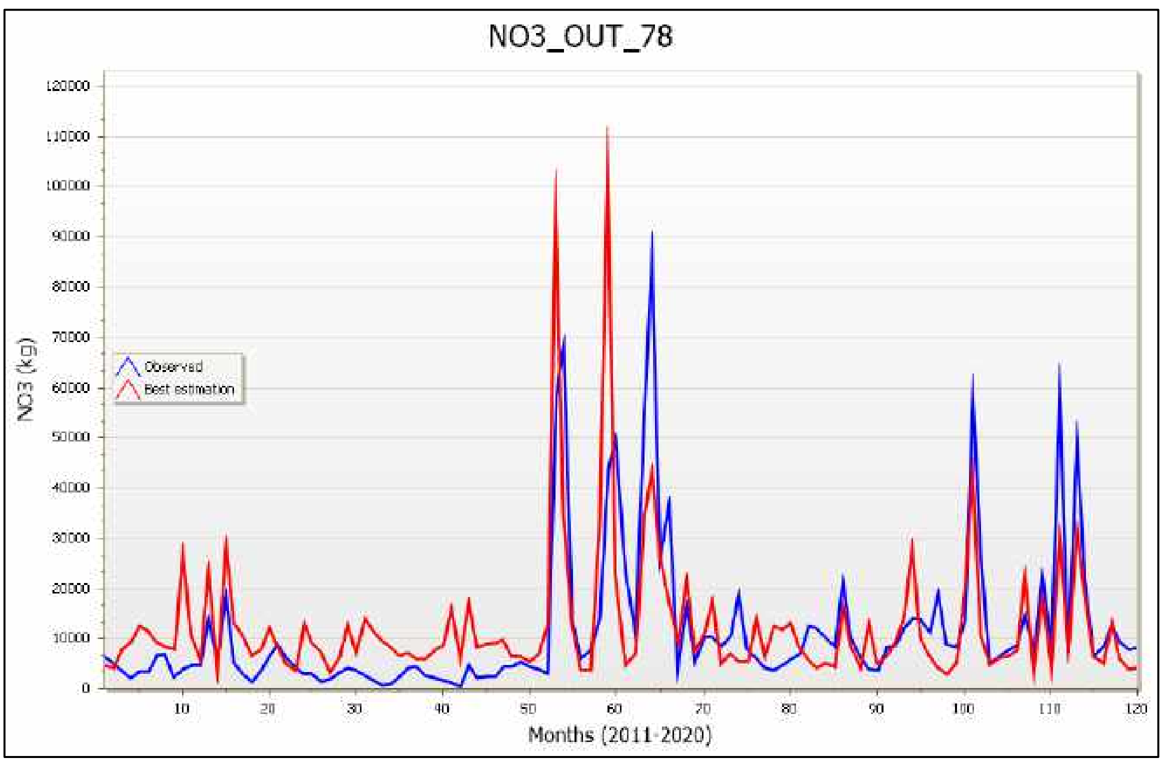


Figure 9. SWAT-CUP NO3 calibration results for site 10969 on the West Fork Trinity River.

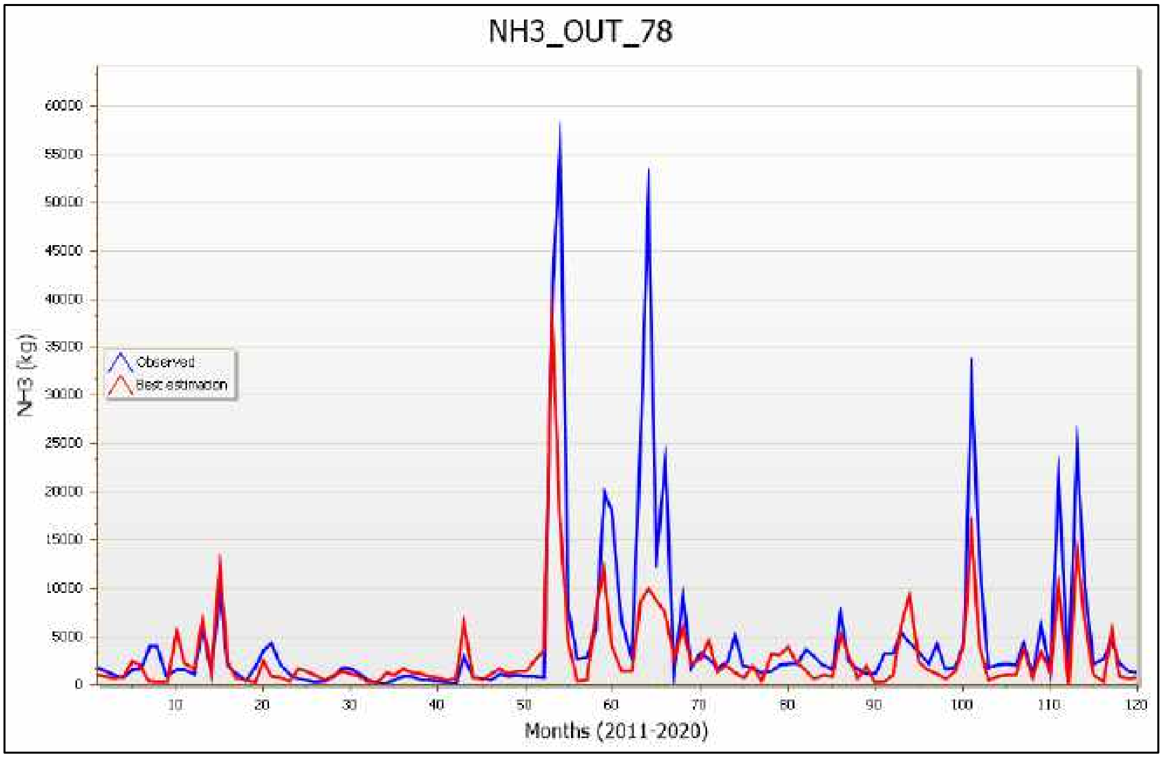


Figure 10. SWAT-CUP NH3 calibration results for site 10969 on the West Fork Trinity River.

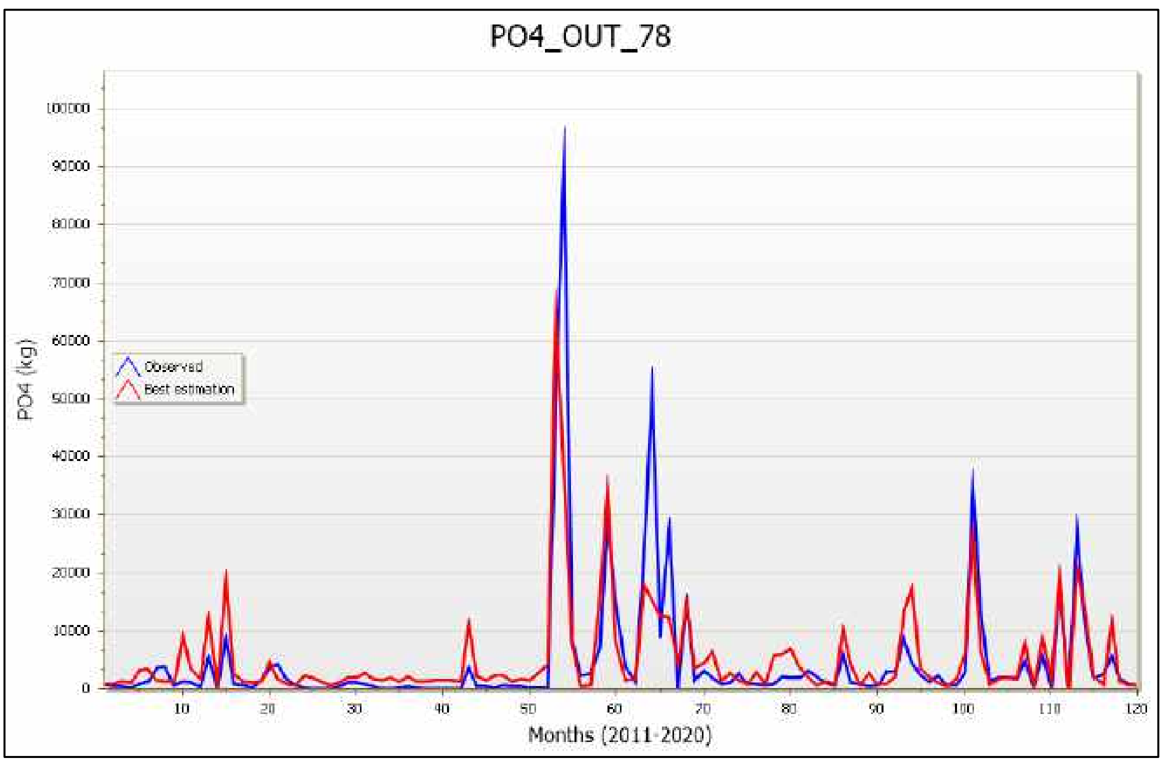


Figure 11. SWAT-CUP PO4 calibration results for site 10969 on the West Fork Trinity River.

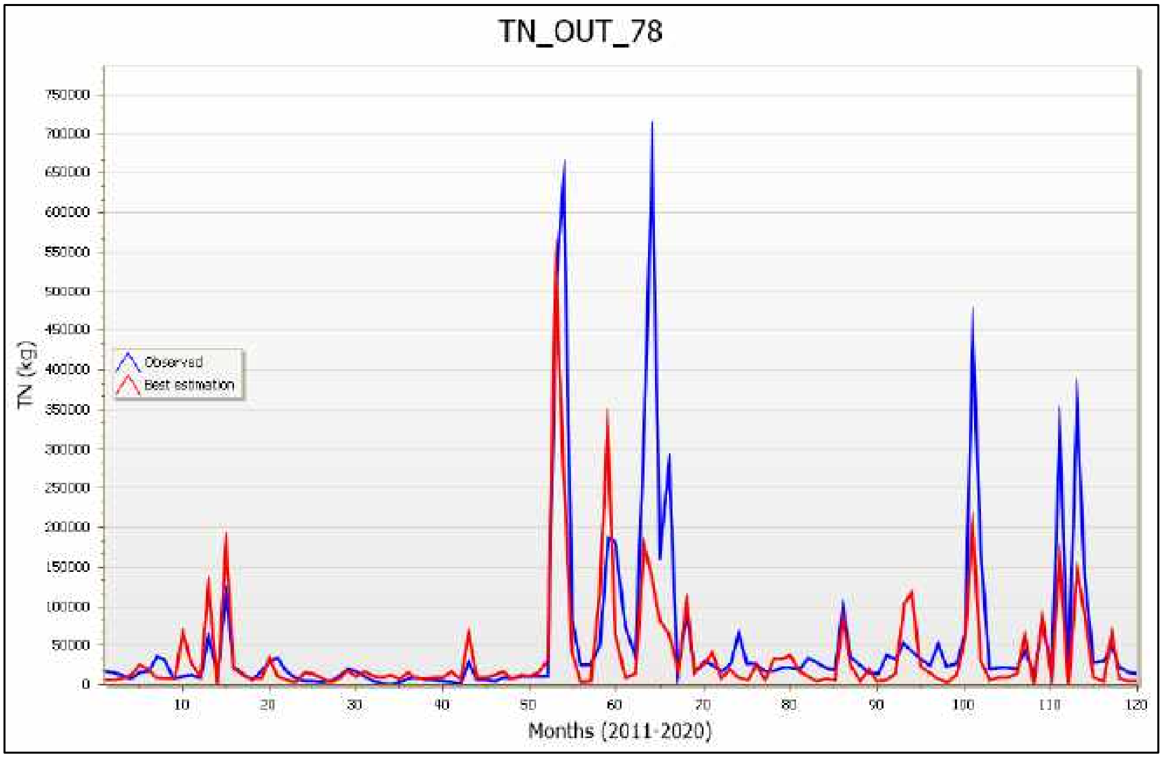


Figure 12. SWAT-CUP TN calibration results for site 10969 on the West Fork Trinity River.

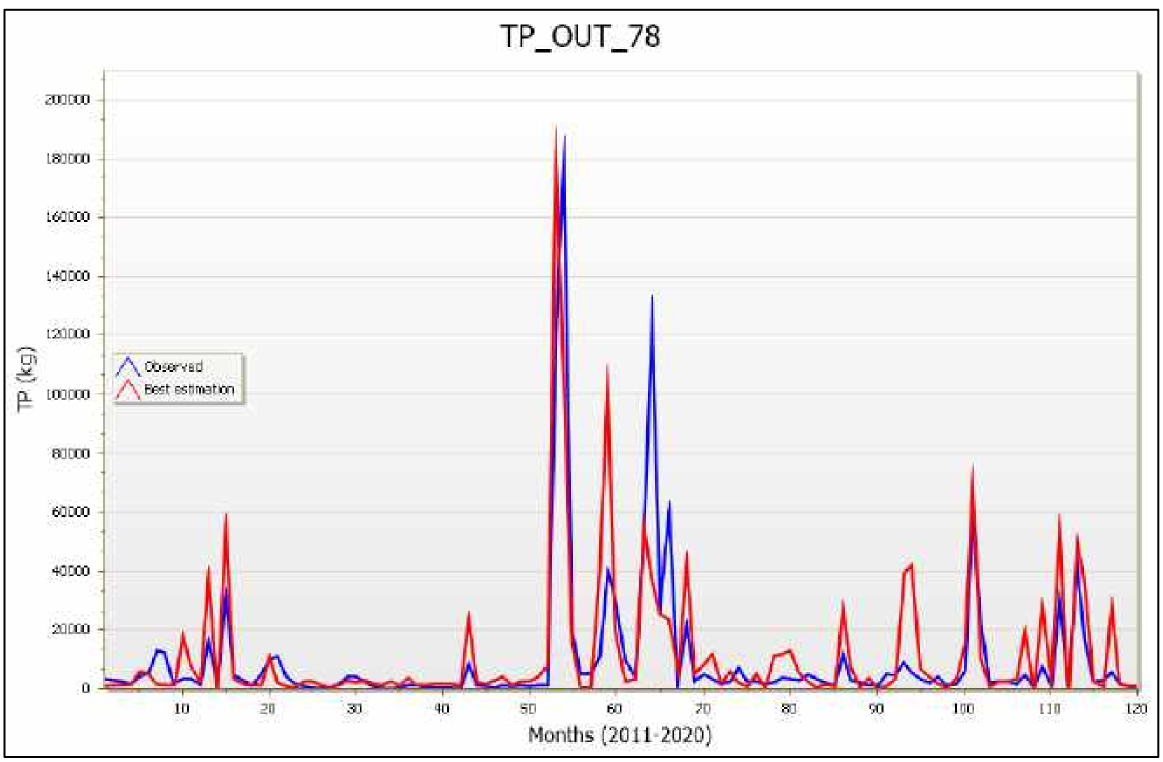


Figure 13. SWAT-CUP TP calibration results for site 10969 on the West Fork Trinity River.

Load Reduction

Texas Surface Water Quality Standards

The Texas Commission on Environmental Quality (TCEQ), set specific criteria for E. coli concentrations to protect recreational uses of surface waters. For contact recreation (e.g., swimming), the geometric mean criterion for E. coli is 126 CFU/100 mL. This standard helps assess water quality and guide watershed management efforts to reduce bacterial contamination.

TCEQ Screening Level

Currently, no numeric standards exist for nutrients in streams in the state of Texas. However, the TCEQ continues to screen for parameters such as nitrogen, phosphorus, and chlorophyll-a (chl-a) as preliminary indicators for waterbodies of possible concern for 303(d) impairments. To support this effort, nutrient screening levels are often used to compare a waterbody to screening levels that are set at the 85th percentile for those parameters of interest seen in similar waterbodies (Table 14). The Texas Nutrient Screening Levels are based on statistical analyses of Surface Water Quality Monitoring (SWQM) data (TCEQ, 2019).

Table 14. TCEQ water quality screening criteria for different constituents.

TCEQ Screening Levels	TKN (mg/L)	NH3 (mg/L)	NO2 (mg/L)	NO3 (mg/L)	NO2 +NO3 (mg/L)	TP (mg/L)	OP[d] (mg/L)	Chlorophyll-a[e] (µg/L)
Lake/Reservoir	-	0.11	-	0.37	-	0.2	0.05	26.7
Stream	-	0.33	-	1.95	-	0.69	0.37	14.1

(d) OP is no longer used for TCEQ screening purposes, as of the 2014 Texas Integrated Report.
(e) Chlorophyll-a, as measured by Spectrophotometric method with acid correction.

Load Reduction Curves

Using the calibrated Eagle Mountain SWAT model and the TCEQ screening criteria, load reduction curves (LDCs) were created for WQ constituents of interest in the Eagle Mountain watershed. A 10% Margin of Safety (MOS; USEPA 1999) was included for each water quality standard criterion. This means that 10% of the allowable pollutant load is intentionally set aside as a buffer to account for uncertainties in the modeling, data, or natural variability. This helps ensure that water quality standards are met even if there are unforeseen variations or errors in the analysis.

NOx

The observational data was available for NOx (NO2+NO3) at each site. The TCEQ only had a screening criterion for NO3, therefore that criterion was used as a proxy for the NOx LDCs. Figure 14 and Figure 15 show the LDCs for the two gages on the West Fork Trinity River. The corresponding geomean values from the figures are found in Table 15 and Table 16 respectively. There is no reduction needed at these two gauges to mean the screening criteria.

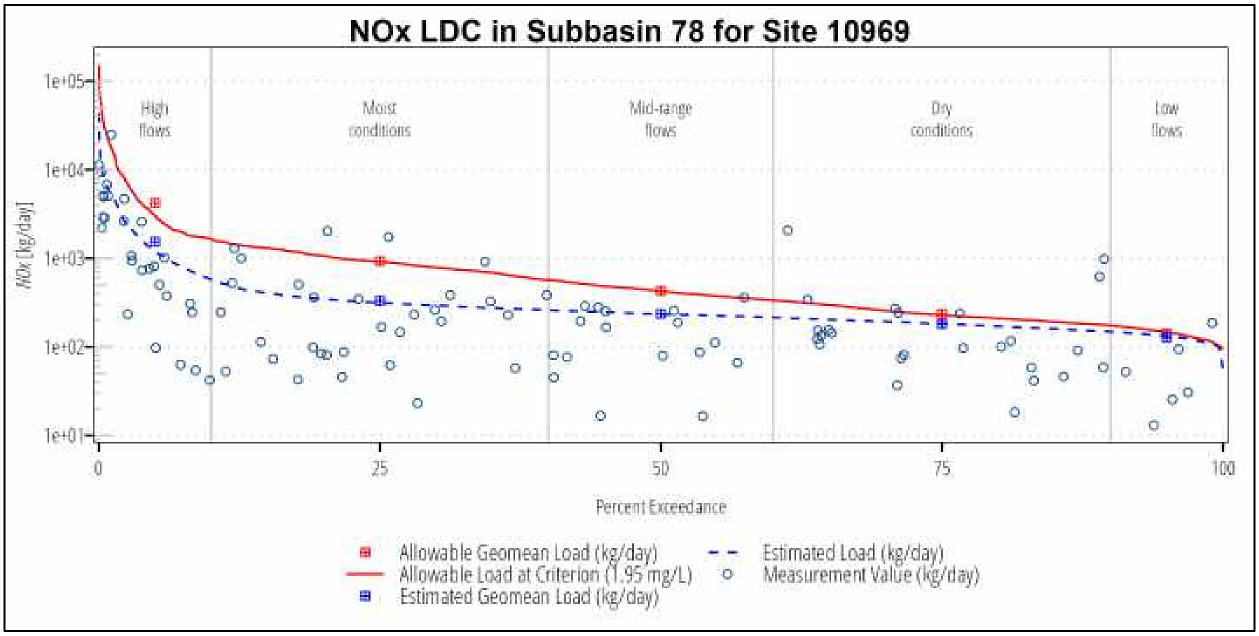


Figure 14. Nitrate (NOx) load duration curve and allowable load at site 10969.

Table 15. Nitrate (NOx) reduction needed to meet allowable loading at site 10969 for each flow condition.

Flow Condition	Median Flow (m^3/day)	% of Time Flow Exceeds	Allowable Geomean Loading (kg/day)	Estimated Geomean Loading (kg/day)	Reduction Needed (kg/day)	% Daily Load Reduction Needed
Highest Flows	1,723,680	0-10	4192.6	1535.8	0.00	0.0
Moist Conditions	522,374	10-40	927.8	331.7	0.00	0.0
Mid-range Conditions	241,402	40-60	429.2	235.9	0.00	0.0
Dry Conditions	131,242	60-90	235.5	180.5	0.00	0.0
Lowest Flows	84,033	90-100	141.9	127.2	0.00	0.0

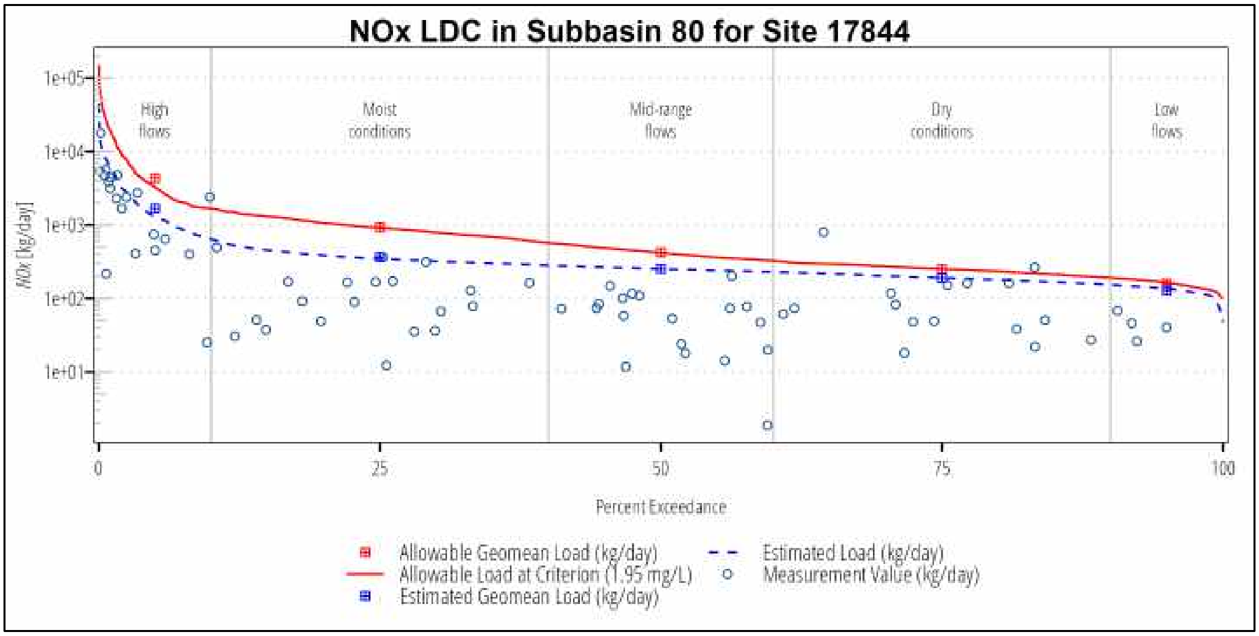


Figure 15. Nitrate (NOx) load duration curve and allowable load at site 17844.

Table 16. Nitrate (NOx) reduction needed to meet allowable loading at site 17844 for each flow condition.

Flow Condition	Median Flow (m^3/day)	% of Time Flow Exceeds	Allowable Geomean Loading (kg/day)	Estimated Geomean Loading (kg/day)	Reduction Needed (kg/day)	% Daily Load Reduction Needed
Highest Flows	1,882,656	0-10	4364.7	1678.2	0.00	0.0
Moist Conditions	518,400	10-40	936.0	365.6	0.00	0.0
Mid-range Conditions	237,082	40-60	422.6	252.7	0.00	0.0
Dry Conditions	143,770	60-90	250.4	190.0	0.00	0.0
Lowest Flows	93,442	90-100	157.8	128.1	0.00	0.0

The NOx LDC was also created for Ash Creek (site 10854) and show in Figure 16. The only flow condition that did not exceed the screening criteria was high flows. All other flow regimes exceed the criteria. Table 17 provides the amount of reduction needed during each flow regime to return loading below the screening criteria. However, the simulated loading at the site did over simulate, therefore the amount of reduction needed could be lower.

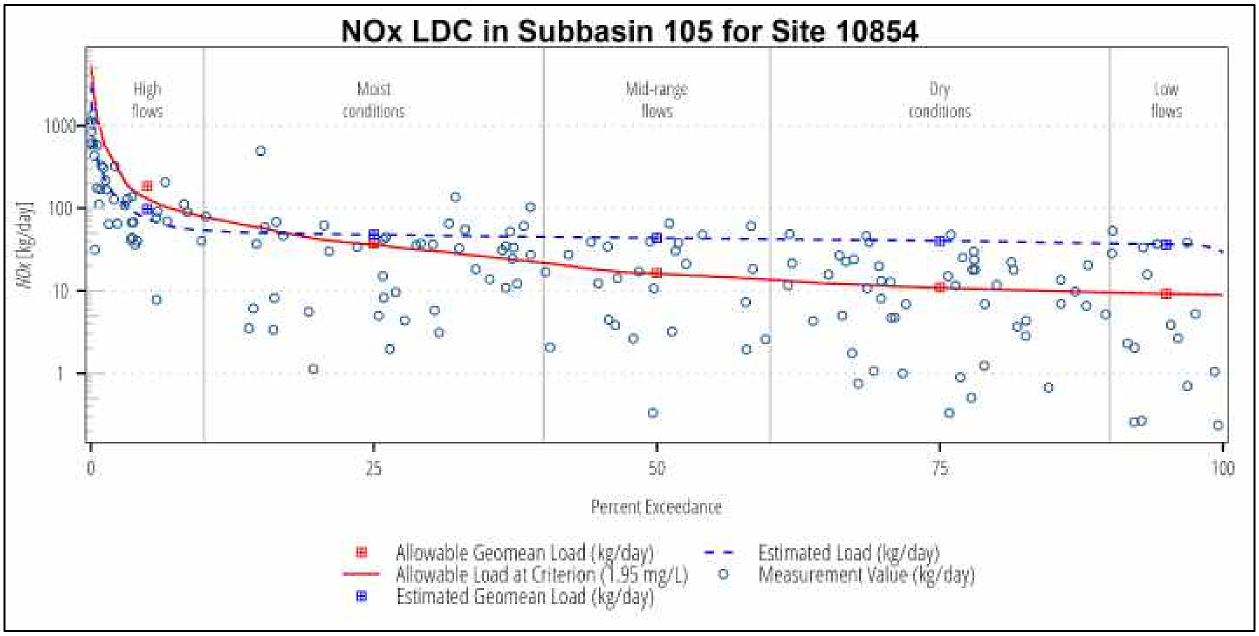


Figure 16. Nitrate (NOx) load duration curve and allowable load at site 10854.

Table 17. Nitrate (NOx) reduction needed to meet allowable loading at site 10854 for each flow condition.

Flow Condition	Median Flow (m^3/day)	% of Time Flow Exceeds	Allowable Geomean Loading (kg/day)	Estimated Geomean Loading (kg/day)	Reduction Needed (kg/day)	% Daily Load Reduction Needed
Highest Flows	74,451	0-10	186.4	97.6	0.0	0.0
Moist Conditions	20,485	10-40	37.7	48.0	10.4	21.6
Mid-range Conditions	9,150	40-60	16.4	43.6	27.2	62.3
Dry Conditions	6,178	60-90	11.0	40.1	29.1	72.5
Lowest Flows	5,238	90-100	9.2	36.1	26.9	74.5

TP

LDCs for TP were created using the TCEQ screening criteria. For all three sites, the loading did not exceed the screening criteria for any of the flow regimes (see Figure 17, Figure 18, and Figure 19; and Table 18, Table 19, and Table 20).

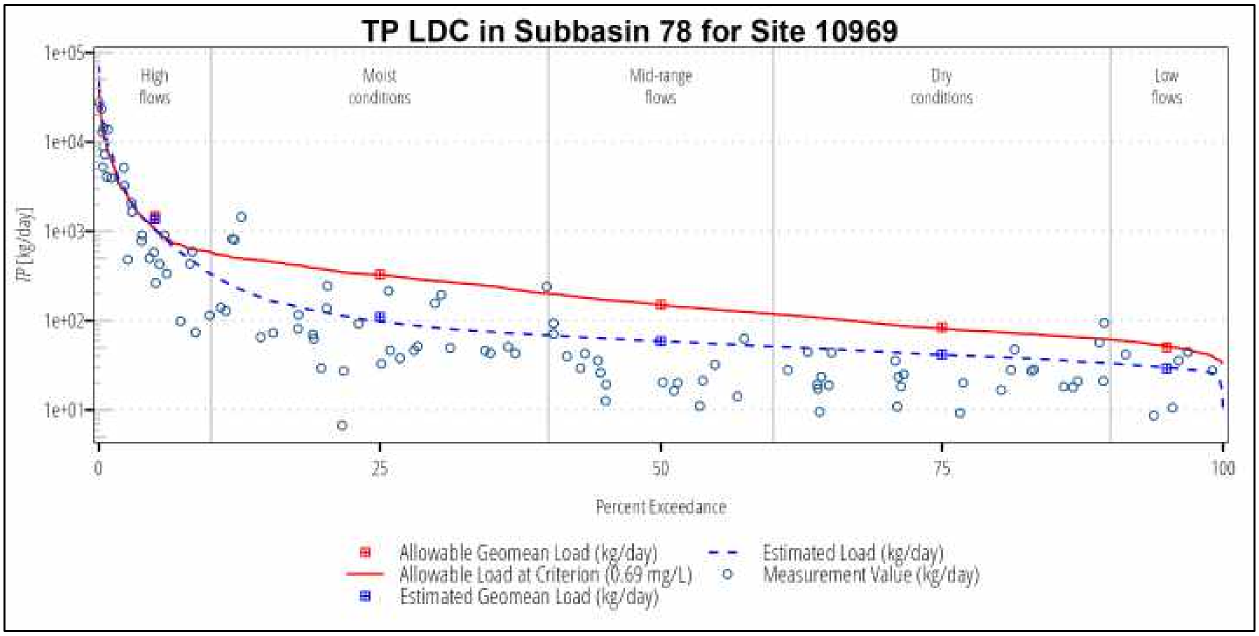


Figure 17. Total phosphorus (TP) load duration curve and allowable load at site 10969.

Table 18. Total phosphorus (TP) reduction needed to meet allowable loading at site 10969 for each flow condition.

Flow Condition	Median Flow (m^3/day)	% of Time Flow Exceeds	Allowable Geomean Loading (kg/day)	Estimated Geomean Loading (kg/day)	Reduction Needed (kg/day)	% Daily Load Reduction Needed
Highest Flows	1,723,680	0-10	1483.5	1378.3	0.00	0.0
Moist Conditions	522,374	10-40	328.3	110.9	0.00	0.0
Mid-range Conditions	241,402	40-60	151.9	59.1	0.00	0.0
Dry Conditions	131,242	60-90	83.3	41.8	0.00	0.0
Lowest Flows	84,033	90-100	50.2	29.2	0.00	0.0

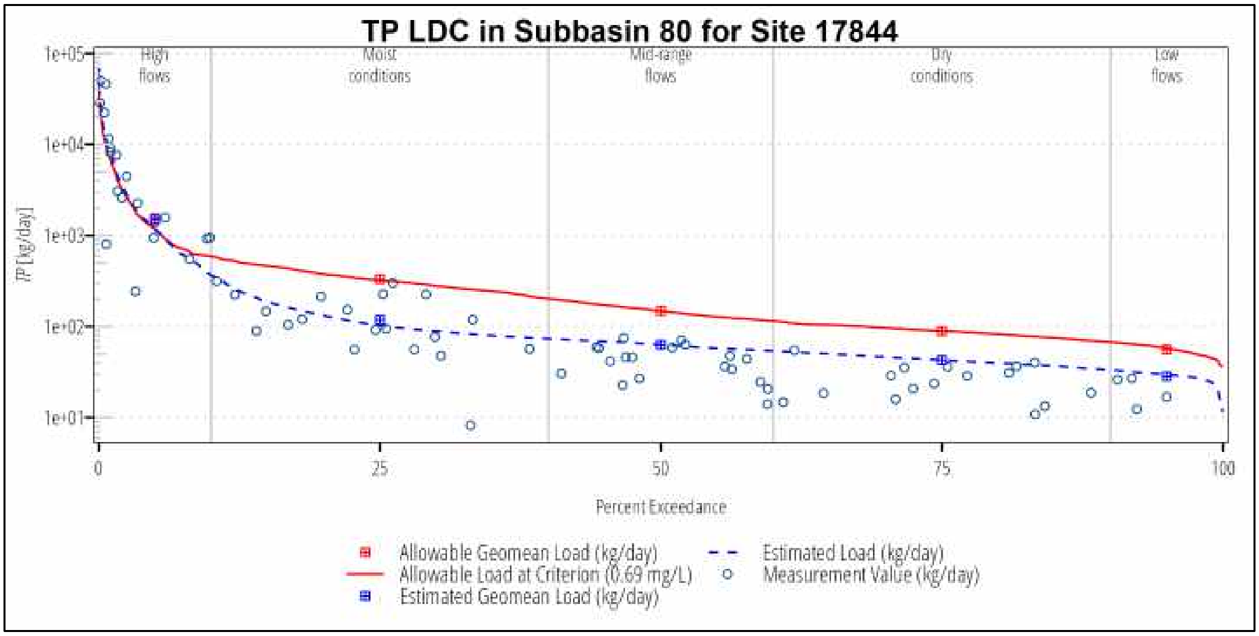


Figure 18. Total phosphorus (TP) load duration curve and allowable load at site 17844.

Table 19. Total phosphorus (TP) reduction needed to meet allowable loading at site 17844 for each flow condition.

Flow Condition	Median Flow (m^3/day)	% of Time Flow Exceeds	Allowable Geomean Loading (kg/day)	Estimated Geomean Loading (kg/day)	Reduction Needed (kg/day)	% Daily Load Reduction Needed
Highest Flows	1,882,656	0-10	1544.4	1500.6	0.00	0.0
Moist Conditions	518,400	10-40	331.2	118.6	0.00	0.0
Mid-range Conditions	237,082	40-60	149.5	63.0	0.00	0.0
Dry Conditions	143,770	60-90	88.6	42.9	0.00	0.0
Lowest Flows	93,442	90-100	55.8	28.5	0.00	0.0

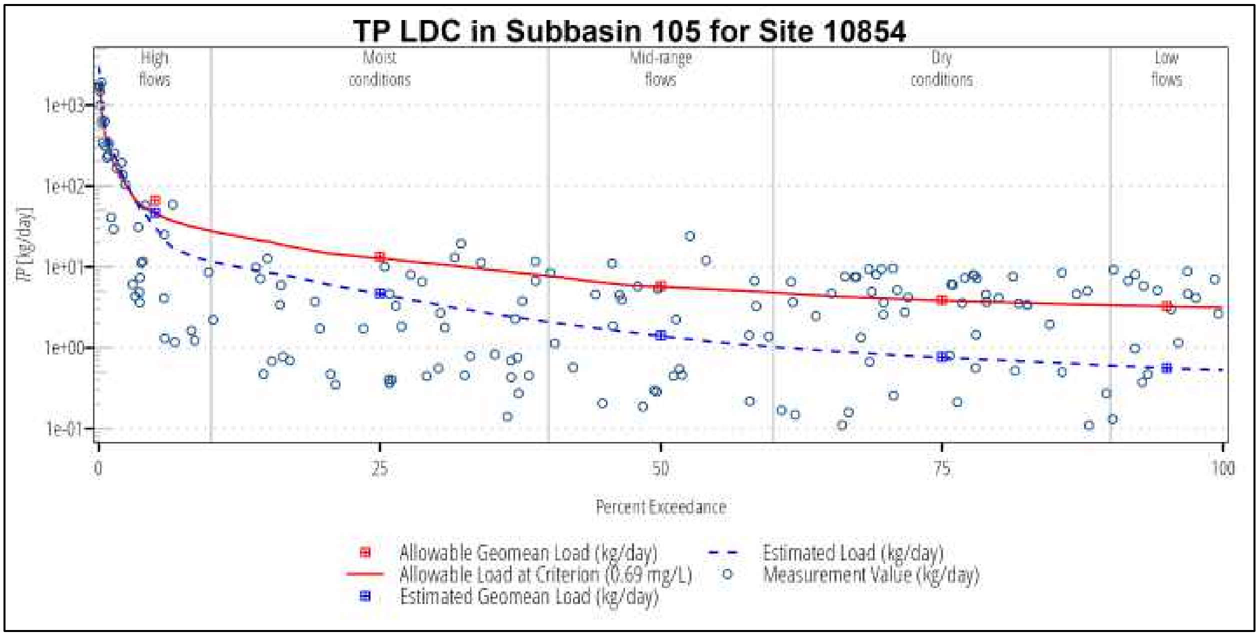


Figure 19. Total phosphorus (TP) load duration curve and allowable load at site 10854.

Table 20. Total phosphorus (TP) reduction needed to meet allowable loading at site 10854 for each flow condition.

Flow Condition	Median Flow (m^3/day)	% of Time Flow Exceeds	Allowable Geomean Loading (kg/day)	Estimated Geomean Loading (kg/day)	Reduction Needed (kg/day)	% Daily Load Reduction Needed
Highest Flows	74,451	0-10	65.9	46.5	0.0	0.0
Moist Conditions	20,485	10-40	13.3	4.7	0.0	0.0
Mid-range Conditions	9,150	40-60	5.8	1.4	0.0	0.0
Dry Conditions	6,178	60-90	3.9	0.8	0.0	0.0
Lowest Flows	5,238	90-100	3.3	0.6	0.0	0.0

E.coli

The SWAT model does not directly model *E.coli*. Therefore, the LDCs were created using the LOADEST generated time series from the provided observations. The two sites located on the West Fork Trinity River and the site located on Ash Creek all needed load reductions for every flow regime. Figure 20 and Table 21 provide the amount of reduction needed to reach the allowable load for site 10969. The allowable load is almost doubled during high flow conditions, and a smaller reduction during low flow conditions of ~14% is necessary.

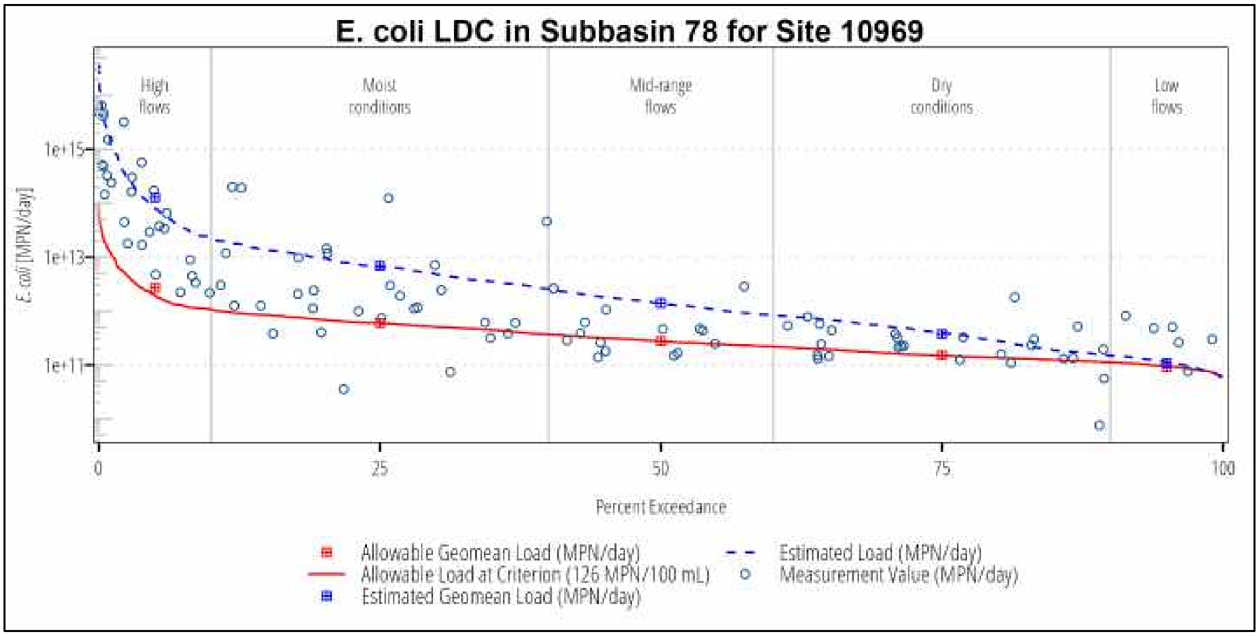


Figure 20. E.coli load duration curve and allowable load at site 10969.

Table 21. E.coli reduction needed to meet allowable loading at site 10969 for each flow condition.

Flow Condition	Median Flow (m^3/day)	% of Time Flow Exceeds	Allowable Geomean Loading (MPN/day)	Estimated Geomean Loading (MPN/day)	Reduction Needed (MPN/day)	% Daily Load Reduction Needed
Highest Flows	1,723,680	0-10	2.71E+12	1.28E+14	1.26E+14	97.9
Moist Conditions	522,374	10-40	6E+11	6.88E+12	6.28E+12	91.3
Mid-range Conditions	241,402	40-60	2.77E+11	1.4E+12	1.12E+12	80.2
Dry Conditions	131,242	60-90	1.52E+11	3.71E+11	2.19E+11	59.0
Lowest Flows	84,033	90-100	9.17E+10	1.07E+11	1.53E+10	14.3

For site 17844 (Figure 21 and Table 22) the reduction needed is smaller in all flow regimes. However, the observations used for this LDC were only available from 2005-2010, therefore when looking at BMPs to reduce the loading, it would be advisable to reach the load reductions of the upstream site 10969 which uses more recent observational data (2011-2020).

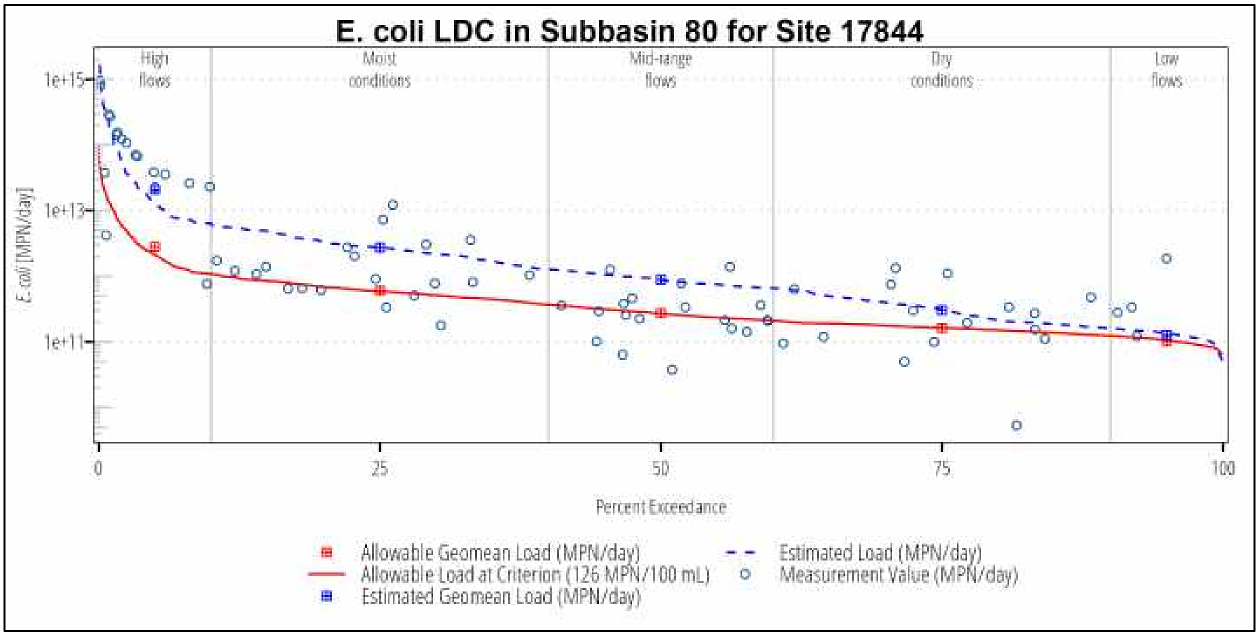


Figure 21. E.coli load duration curve and allowable load at site 17844.

Table 22. E.coli reduction needed to meet allowable loading at site 17844 for each flow condition.

Flow Condition	Median Flow (m^3/day)	% of Time Flow Exceeds	Allowable Geomean Loading (MPN/day)	Estimated Geomean Loading (MPN/day)	Reduction Needed (MPN/day)	% Daily Load Reduction Needed
Highest Flows	1,882,656	0-10	2.82E+12	2.08E+13	1.8E+13	86.5
Moist Conditions	518,400	10-40	6.05E+11	2.75E+12	2.15E+12	78.0
Mid-range Conditions	237,082	40-60	2.73E+11	8.91E+11	6.18E+11	69.4
Dry Conditions	143,770	60-90	1.62E+11	3.05E+11	1.43E+11	47.0
Lowest Flows	93,442	90-100	1.02E+11	1.27E+11	2.48E+10	19.6

For site 10854 again, reduction is needed for all flow regimes. Since there is a consistent amount of reduction needed (Figure 22 and Table 23) for all flow regimes, this could indicate that the *E.coli* loading in the Ash Creek may be from a point source instead of non-point source land processes which could be addressed with land management BMPs. To reduce the loading of *E.coli* at this site, point source information may be required.

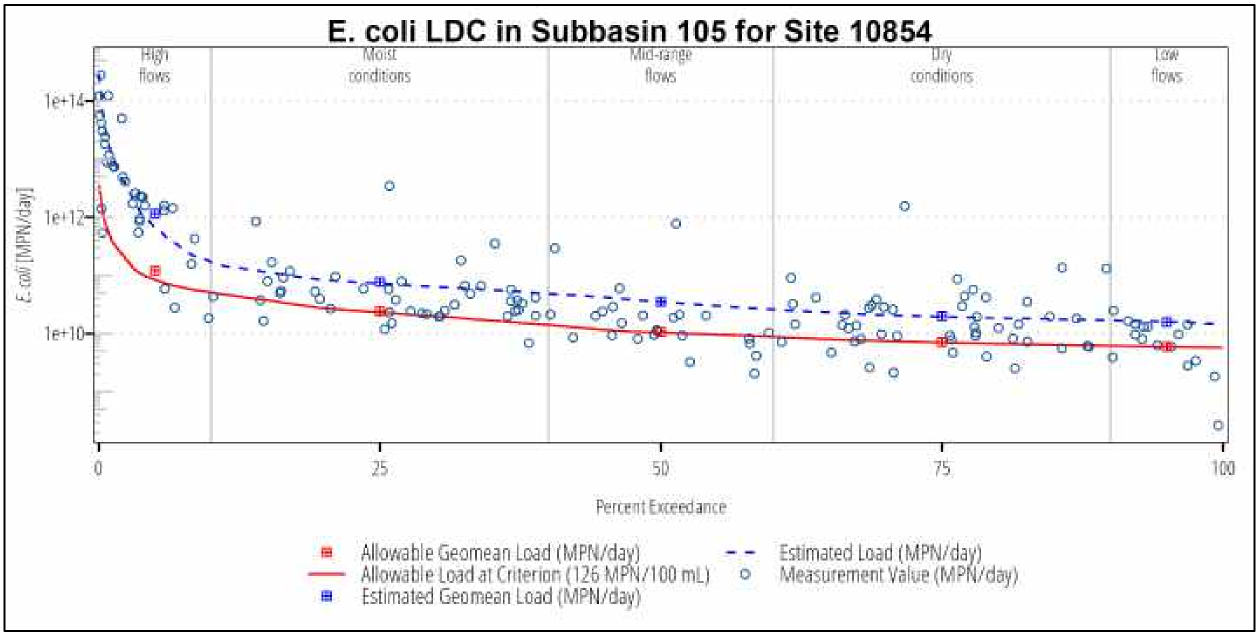


Figure 22. E.coli load duration curve and allowable load at site 10854.

Table 23. E.coli reduction needed to meet allowable loading at site 10854 for each flow condition.

Flow Condition	Median Flow (m^3/day)	% of Time Flow Exceeds	Allowable Geomean Loading (MPN/day)	Estimated Geomean Loading (MPN/day)	Reduction Needed (MPN/day)	% Daily Load Reduction Needed
Highest Flows	74,451	0-10	1.2E+11	1.15E+12	1.03E+12	89.5
Moist Conditions	20,485	10-40	2.43E+10	7.75E+10	5.31E+10	68.6
Mid-range Conditions	9,150	40-60	1.06E+10	3.54E+10	2.48E+10	70.1
Dry Conditions	6,178	60-90	7.12E+09	2E+10	1.29E+10	64.4
Lowest Flows	5,238	90-100	5.94E+09	1.58E+10	9.82E+09	62.3

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Load Reduction Strategies for the Eagle Mountain Watershed

Nutrients: SWAT

E.coli: TX-SELECT

Abstract

This report includes the information on the Best Management Scenarios simulated to reduce loading in Eagle Mountain watershed.

SWAT

The Soil and Water Assessment Tool (SWAT) was utilized to evaluate the potential effectiveness of various best management practices (BMPs) in reducing nutrient and sediment loads across the Eagle Mountain watershed. SWAT is a widely recognized, process-based watershed model capable of simulating the impact of land use, management practices, and climate on water, sediment, and agricultural yields in large and complex watersheds. In this study, SWAT was calibrated using observed streamflow and water quality data, as described in detail in the companion calibration document. The resulting model provided a reliable baseline representation of current watershed conditions and pollutant loads, serving as the foundation for evaluating the effectiveness of proposed BMPs.

Once the baseline model was established, a suite of BMP scenarios was simulated to assess their impact on reducing total nitrogen, total phosphorus, and sediment delivery throughout the watershed. These scenarios included management-based practices, such as cover cropping, nutrient management, and cattle stocking rate improvements. Each BMP was evaluated individually to understand its potential contribution to improving water quality. The simulation results allowed for watershed scale assessment to identify the potential for improvement of each BMP. This approach supports data-driven decision-making and helps stakeholders target resources efficiently to meet watershed conservation goals.

Load Reduction Strategies

Implementing nutrient and sediment load reduction strategies offers significant environmental benefits by improving water quality in streams, rivers, and downstream ecosystems. Excess nitrogen and phosphorus from agricultural runoff, wastewater, and urban sources can lead to harmful algal blooms, oxygen depletion, and loss of aquatic biodiversity. By adopting practices such as cover cropping, precision nutrient management, and improving cattle stocking rates, these pollutants can be significantly reduced at the source. This not only enhances aquatic habitat health but also helps maintain the integrity of drinking water supplies and supports recreational uses of water bodies.

Beyond environmental gains, nutrient and sediment reduction strategies contribute to long-term economic and social resilience. Healthier watersheds require fewer costly interventions for water treatment and infrastructure maintenance caused by sediment accumulation. Additionally, improved soil conservation supports agricultural productivity by preventing topsoil loss and enhancing soil fertility. These practices also demonstrate compliance with regulatory frameworks and help communities meet Total Maximum Daily Load (TMDL) goals, positioning them for future funding opportunities and partnerships. Overall, integrated load reduction strategies support sustainable land and water resource management while promoting community well-being.

The BMPs selected for modeling in the Eagle Mountain watershed were designed as enhancements to existing land management activities. Rather than introducing entirely new practices, the simulations focused on improving the effectiveness or increasing the extent of current practices already in use across the watershed.

Four distinct BMP types were evaluated; each applied at varying levels of implementation relative to the baseline scenario. These varying levels represent incremental changes in the adoption or intensity of the BMPs, allowing for an assessment of their potential impact on nutrient and sediment reduction under different management scenarios. Further details on each BMP and the modeled implementation levels are provided below.

Cover Crops

To assess the potential impact of increased cover crop adoption, additional land within the Eagle Mountain watershed was simulated to receive cover cropping treatments. Specifically, three levels of increased adoption were modeled—15%, 25%, and 40% above the current extent of cover crops in the watershed. These increases were applied to managed pasture areas using either oats (OATS) or winter wheat (WWHT) as the cover crop species using the same 25%/75% split, respectively, as the baseline model. Table 1 presents the total area under cover crops for each scenario, along with the corresponding average changes in nitrate (NO_3), total phosphorus (TP), and sediment yield (SYLD) across the watershed.

Cover crops offer numerous environmental and agronomic benefits, particularly when implemented on pasture land. Species such as oats and winter wheat provide soil cover during periods when fields would otherwise be bare, reducing erosion, improving soil structure, and enhancing infiltration. They also scavenge residual nutrients from the soil, particularly phosphorus, preventing leaching into nearby waterways. Over time, cover crops contribute to improved soil health through increased organic matter and microbial activity. In the Eagle Mountain watershed, expanding the use of cover crops on managed pastures not only helps reduce phosphorus and sediment loads but also supports long-term land productivity and resilience. Increasing the area of land receiving cover crops resulted in a slight increase in average NO_3 levels across the watershed. This outcome is attributed to the simulated application of nitrogen fertilizer on managed pasture land as part of the cover crop management. In the baseline scenario, pasture land did not receive nitrogen fertilizer, so the introduction of fertilization with the cover crop simulation represents a new source of nitrogen in the system.

While this fertilizer application supports cover crop establishment and productivity, it also introduces additional nitrogen that can contribute to leaching and runoff if not effectively taken up by the crops. This highlights the importance of carefully managing nutrient inputs when implementing cover cropping practices, particularly on land where fertilizer was not previously applied. Despite the increase in NO_3, the use of cover crops still provided measurable reductions in sediment and total phosphorus, underscoring their value as a conservation practice when integrated thoughtfully.

Table 1. Increase in cover crop area and corresponding average reductions in NO_3, TP, and sediment yield (SYLD) across the Eagle Mountain watershed.

Increase	Area (acres)	NO_3 % Change	TP % Change	SYLD % Change
15%	2,996	3.63%	-20.64%	-55.39%
25%	3,281	5.23%	-27.95%	-71.10%
40%	3,680	7.29%	-35.57%	-74.49%

Nutrient Management of Hay Planting

Nutrient management was also simulated as a best management practice (BMP) on pasture lands that received nitrogen fertilizer but did not include cover crops. This approach aimed to reduce excess nutrient application and improve the efficiency of fertilizer use. Specifically, the second BMP scenario focused on pasture land where bermudagrass (BERM) was planted and received nitrogen fertilizer. In these fields, the nitrogen fertilizer application rates were reduced by 15%, 25%, and 40% from the baseline application of 89 lbs/acre. These reductions were applied to approximately 733 acres of land distributed across the Eagle Mountain watershed. Table 2 presents the average changes in NO_3, TP, and SYLD resulting from each level of fertilizer reduction. Implementing nutrient management practices on hay fields helps align fertilizer inputs more closely with BERM nutrient requirements, minimizing losses to surface and groundwater. Reducing nitrogen application lowered the risk of NO_3 leaching however, there were slight increases in TP and SYLD.

This highlights the importance of implementing nutrient management as part of an integrated approach. While the reduction in NO_3 reflects improved nutrient efficiency and reduced leaching risk, the observed increases in TP and SYLD could be due to indirect effects, such as reduced plant biomass or ground cover, potentially increasing vulnerability to erosion. Combining nutrient management with complementary practices—such as cover crops or buffer strips—can help mitigate these unintended impacts. In this context, nutrient management remains a valuable BMP, especially when tailored to site-specific conditions and integrated within a broader conservation strategy to address multiple water quality concerns.

Table 2. Reduced nitrogen fertilizer application on hay fields and corresponding average reductions in NO_3, TP, and sediment yield (SYLD) across the Eagle Mountain watershed.

N Reduction	NO_3 % Change	TP % Change	SYLD % Change
15%	-10.68%	1.73%	5.64%
25%	-17.20%	2.53%	9.40%
40%	-26.77%	3.62%	15.30%

Nutrient Management of Range Planting

The third set of BMPs simulated nutrient management on range-planted areas where nitrogen fertilizer was applied in the baseline scenario. This involved reducing nitrogen application rates by 15%, 25%, and 40% from baseline levels on approximately 381 acres throughout the Eagle Mountain watershed. These scenarios aimed to evaluate the impact of more efficient fertilizer use on rangeland productivity and watershed nutrient dynamics. Table 3 summarizes the resulting changes in NO_3, TP, and SYLD across the watershed for each level of fertilizer reduction.

The results in Table 3 show a consistent reduction in NO_3 loading as nitrogen application decreased, demonstrating the effectiveness of nutrient management in minimizing nitrogen loss on rangeland. However, similar to the hay planting scenarios, there were slight increases in TP and SYLD. These increases were smaller in magnitude compared to the hay planting results, likely due to the smaller treatment area and differences in land cover or management intensity. Overall, these findings suggest that nutrient management on range-planted land can contribute to reduced nitrate levels but may require additional conservation practices to address potential increases in phosphorus and sediment transport.

Table 3. Reduced nitrogen fertilizer application on range fields and corresponding average reductions in NO_3, TP, and sediment yield (SYLD) across the Eagle Mountain watershed.

N reduction	NO_3 % Change	TP % Change	SYLD % Change
15%	-4.37%	1.69%	2.92%
25%	-10.06%	3.13%	5.67%
40%	-17.80%	5.12%	9.82%

Cattle Stocking Rate Modification

The final BMP simulated was the only practice that resulted in reductions across all three pollutants: NO_3, TP, and SYLD. This fourth BMP involved modifying the cattle stocking rate, which in this context means increasing the number of acres allocated per head of cattle—effectively reducing grazing pressure. The simulation modeled stocking rate increases by 15%, 25%, and 40% across approximately 267,901 acres of rangeland and pasture within the Eagle Mountain watershed. Table 4 presents the potential reductions in nutrient and sediment loads associated with each level of increased stocking rate. The stocking rate increase was calculated individually within each of the 23 subbasins across the Eagle Mountain watershed, allowing for spatially distributed adjustments based on local conditions. The watershed average is provided in Table 4.

Modifying the acreage per head of cattle can have significant positive impacts on watershed health. By reducing animal density, the land experiences less compaction, overgrazing, and vegetation loss, all of which contribute to erosion and nutrient runoff. Improved ground cover and root structure help stabilize soils and increase nutrient uptake, thereby reducing both sediment transport and nutrient leaching. In the Eagle Mountain watershed, these effects translated into measurable decreases in NO_3, TP, and SYLD. This BMP highlights the value of sustainable grazing management as a low-impact, landscape-scale strategy to enhance water quality and support long-term land productivity.

Table 4. Modification in cattle stocking rate and corresponding average reductions in NO_3, TP, and sediment yield (SYLD) across the Eagle Mountain watershed.

% Modification	Stocking Rate (acres/head)	NO_3 % Change	TP % Change	SYLD % Change
15%	8.7	-5.54%	-12.49%	-0.84%
25%	9.9	-8.91%	-20.71%	-1.76%
40%	12.4	-13.56%	-32.98%	-4.04%

TX-SELECT

TX-SELECT (Texas - Spatially Explicit Load Enrichment and Calibration Tool; Jain et. al. 2025) is an interactive web-based platform developed to support watershed management and planning efforts across Texas. This site uses an updated version of SELECT originally created by Teague et. al. 2009. The datasets used in the TX-SELECT are outlined in Table 1. The site was created to streamline access to spatially detailed information on nutrient and sediment loads, leveraging outputs from the HAWQS (Hydrologic and Water Quality System, HAWQS 2.0, 2023) model. TX-SELECT allows users to explore watershed-specific model results, visualize pollutant load estimates, and compare baseline and scenario conditions across the state. It is designed to assist stakeholders—including researchers, planners, and decision-makers—in identifying priority areas, evaluating best management practices (BMPs), and supporting data-driven water quality initiatives with a user-friendly interface and downloadable outputs.

Table 5. Description of datasets used in TX-SELECT.

Type	Data	Description	Source
GIS boundaries	Watershed	2-digit, 4-digit, and 12-digit Hydrologic Unit Code (HUC) boundaries	HAWQS 2023; Simley and Carswell Jr 2009
	Counties	County boundaries	USCB 2023
	Urban Area	2020 Census urbanized area polygons	USCB 2023
	CCN	Wastewater Certificate of Convenience and Necessity (CCN) digital mapping data	PUC 2023
Livestock	Livestock counts	NASS 2022 Census of Agriculture - county livestock counts	USDA NASS 2022
Wildlife	Deer density	TPWD ecoregions average deer densities	Lockwood 2006
	Ecoregions	EPA level IV ecoregions	Omernik and Griffith 2014
Demographic data	1990 Census	1990 Census block group level data on sewage disposal	Manson et al. 2023
	2020 Census blocks	2020 Census block polygons	USCB 2023
	2020 Census demographics	2020 Census block population and housing units	USCB 2023
	Address points	911 address points	Arctur 2018; USDOT
Watershed attributes	2021 NLCD	30-meter land cover raster from the 2021 national land cover database	Dewitz 2023
	SSURGO	30-meter SSURGO soil data	Soil Survey Staff 2023
	PRISM	4-km mean annual precipitation normals raster	Daly et al. 2008
Permitted discharges	WWTFs	Permitted discharges from the EPA Echo database	USEPA 2023

Water quality in a watershed is affected by two main categories of pollutant sources: **point sources** and **nonpoint sources**. Point sources are identifiable and localized, such as wastewater treatment facilities (WWTFs) and overflows from on-site sewage facilities (OSSFs). Nonpoint sources are diffuse and harder to trace, including urban and agricultural runoff containing nutrients from fertilizers, pesticides, crop residues, pathogens, and waste from livestock, pets, and households. In the Eagle Mountain watershed, potential sources of *E. coli* assessed in this report include waste from pets, livestock, OSSFs, wildlife, and WWTFs.

Pathogen load estimations are derived by multiplying the population counts of each source by their corresponding production rates (see Table 2). The OSSFs and household pets production rates were set to the highest fecal coliform production rates reported in the EPA guidelines (USEPA, 2001) Additionally, to estimate *E. coli* levels from fecal coliform figures, a conversion factor was applied. Based on the 2010 Texas surface water quality criteria for recreational uses, default conversion factors of 0.63 for *E. coli* was used.

Table 6. Fecal coliform production rates used to estimate daily potential bacteria load in TX-SELECT.

Source	Fecal coliform production rate	Reference
Cattle	8.55×10^9 cfu/head/day	Wagner and Moench 2009
Sheep	5.8×10^{10} cfu/head/day	
Goats	4.32×10^9 cfu/head/day	
Horses	3.64×10^8 cfu/head/day	
Deer	1.68×10^9 cfu/head/day	
Feral Hogs	1.51×10^8 cfu/head/day	
Dogs and Cats	5.0×10^9 cfu/head/day	USEPA 2001
OSSFs	10×10^6 /100 ml	

Raw SELECT output is often considered a "worst-case scenario" for estimating *E. coli* loads, as the tool lacks built-in functionality to account for natural mitigation processes such as *E. coli* die-off, predation, soil entrainment, or other reductions that occur between the point of deposition and entry into a waterway.

However, these limitations can be partially addressed by applying distance-based weighting to the estimated loads. For instance, manure deposited within riparian buffer zones (i.e., within 100 meters or 330 feet of a stream) is typically assigned a higher weight than manure deposited in upland areas farther from the waterway (see Figure 1).

Incorporating this approach allows for more refined identification of critical areas, thereby enhancing the effectiveness of Best Management Practice (BMP) implementation. Table 3 provide the amount of land across the Eagle Mountain watershed that falls within the riparian buffer zone, and the amount of land located in the uplands by land use category.

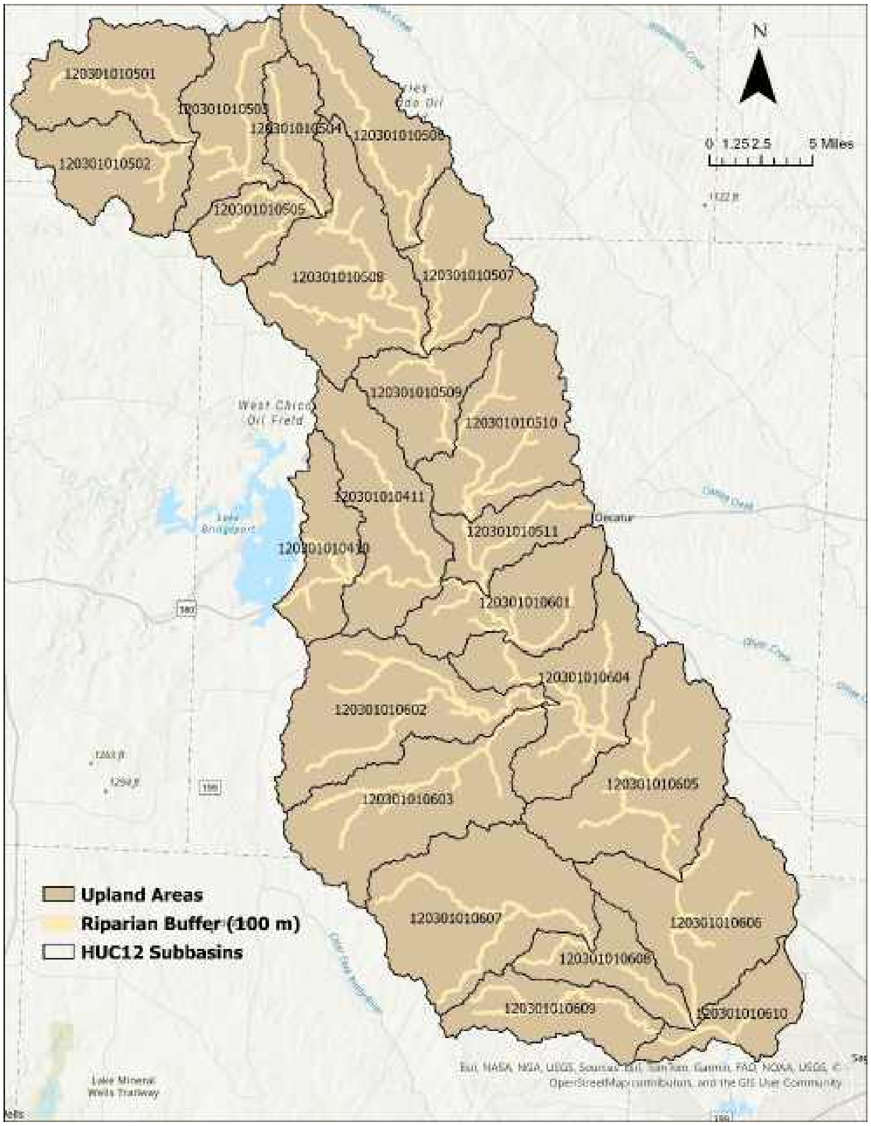

Figure 1. Upland area and 330 ft riparian buffer around the stream network in the HUC12 Eagle Mountain watershed.

Table 7. Acreage of riparian and upland area by land use type across the Eagle Mountain watershed.

LULC Category	Acres	
	Riparian	Upland
Barren land (Rock/Sand/Clay)	93	3,357
Cultivated Crops	755	10,116
Deciduous Forest	8,087	77,796
Developed, High Density	29	1,863
Developed, Low Density	323	17,834
Developed, Med Density	116	6,335
Developed, Open Space	695	26,039
Emergent Herbaceous Wetlands	558	3,810
Evergreen Forest	8	206

Grassland/Herbaceous	10,415	304,477
Mixed Forest	10	247
Open Water	2,598	10,484
Pasture/Hay	3,397	41,370
Shrub/Scrub	785	8,935
Woody Wetlands	4,694	5,857
Total Composite Acreage	32,563	518,728

TX-SELECT was used to create a model for the Eagle Mountain watershed at the HUC12 scale resulting in a 23 subbasin watershed. The land cover distribution is equivalent to the HAWQS generated Eagle Mountain watershed at the HUC14 scale, which is outlined in the calibration document.

Pets

The domestic pet population (dogs and cats) is estimated by multiplying a user-defined pet density per household by the total number of households in each subbasin. Household counts used in TX-SELECT are based on 2020 census block-level data. Default densities—0.614 dogs and 0.457 cats per household—from the 2017 U.S. pet ownership statistics from the American Veterinary Medical Association (AVMA) were used across the Eagle Mountain watershed. A 90% contribution was assumed to reach waterways within the 330-ft (100-m) riparian buffers, with a presumed 50% contribution from upland areas.

Wildlife

TX-SELECT includes both deer and feral hogs as potential sources of *E. coli* loading. Deer density data were sourced from Texas Parks and Wildlife's 2006 ecoregion-based estimates and applied to shrub/scrub, grasslands/herbaceous, hay/pasture, cultivated crops, forest, and wetland areas within the watershed. Feral hog density was based on planning-level estimates from Texas A&M AgriLife Extension and distributed across the same land use categories. Table 4 presents the average subbasin stocking rates for each species modeled in the watershed. To account for proximity to waterways a 90% contribution was assumed to reach waterways within the 330-ft (100-m) riparian buffers, with a presumed 50% contribution from upland areas.

Livestock

TX-SELECT accounts for livestock populations including cattle, sheep, goats, and horses. Livestock numbers are estimated by applying species-specific stocking rates (acres per head) to the total area of grazeable land within each subbasin. Grazeable land is defined by default to include NLCD land cover types of hay/pasture, grassland/herbaceous, and shrub/scrub. Stocking rates for each livestock type are derived from county-level headcounts reported in the 2022 Census of Agriculture by the USDA National Agricultural Statistics Service (NASS) for all counties overlapping the watershed, as detailed below.

$$Stocking\ Rate \left(\frac{acres}{head}\right) = \sum_{i=1}^{N} SR\ County_i\ x\ Proportaion\ of\ watershed\ grazing\ area\ in\ County_i$$

Where N is the total number of counties intersecting the subbasin and SR County is the grazeable land divided by the number of heads in the county.

The suggested stocking rates in TX-SELECT for cattle using 2022 USDA census values resulted in slightly lower rates than the average used in the SWAT model. The number of cattle in the watershed according to the 2022 Census was ~50,000 head of cattle whereas the average head of cattle from 2007-2017 was closer to 60,000. Additionally, the SWAT model only simulated cattle on hay/pasture and grassland, so only those land use types were selected for the Eagle Mountain watershed. Therefore, the results from TX-SELECT may be conservative but still consistent with the current management practices across the watershed. The stocking rate for cattle used in the Eagle Mountain watershed is also found in Table 4. Additionally, 90% of contribution was assumed to reach waterways within the 330-ft (100-m) riparian buffers, with a presumed 50% contribution from upland areas.

Table 8. Average stocking rate used in TX-SELECT for the Eagle Mountain watershed.

Animal	Stocking Rate (acre/head)
Cattle	7.4
Sheep	173.2
Goats	110.5
Horses	123.2
Feral Hogs	50
Deer	39.4

Wastewater treatment facilities (WWTFs)

Permitted wastewater treatment facilities within the Eagle Mountain watershed were identified using data from the U.S. EPA's ECHO database (2023). The geographic locations of these facilities are illustrated in Figure 2. To estimate daily pathogen loads (expressed in MPN/day), the most recent values for fully permitted discharge volumes and the corresponding allowable average daily pathogen concentrations (MPN/100 mL) were used, as calculated using the equation provided below.

$$Load = Dishcharge(MGD)\ x\ \frac{Daily\ E.coli\ limit\ (MPN)}{100\ mL}\ x\ \frac{10^6\ gal}{MGD}\ x\ 3758.2\frac{mL}{gal}$$

Table 5 provides a list of the WWTP facilities in Eagle Mountain along with the daily limit of *E.coli* and the discharge used to calculate the potential load for each facility. Since discharge from WWTPs typically flow directly into waterways, 100% contribution of loading from WWTPs was assumed across the Eagle Mountain watershed.

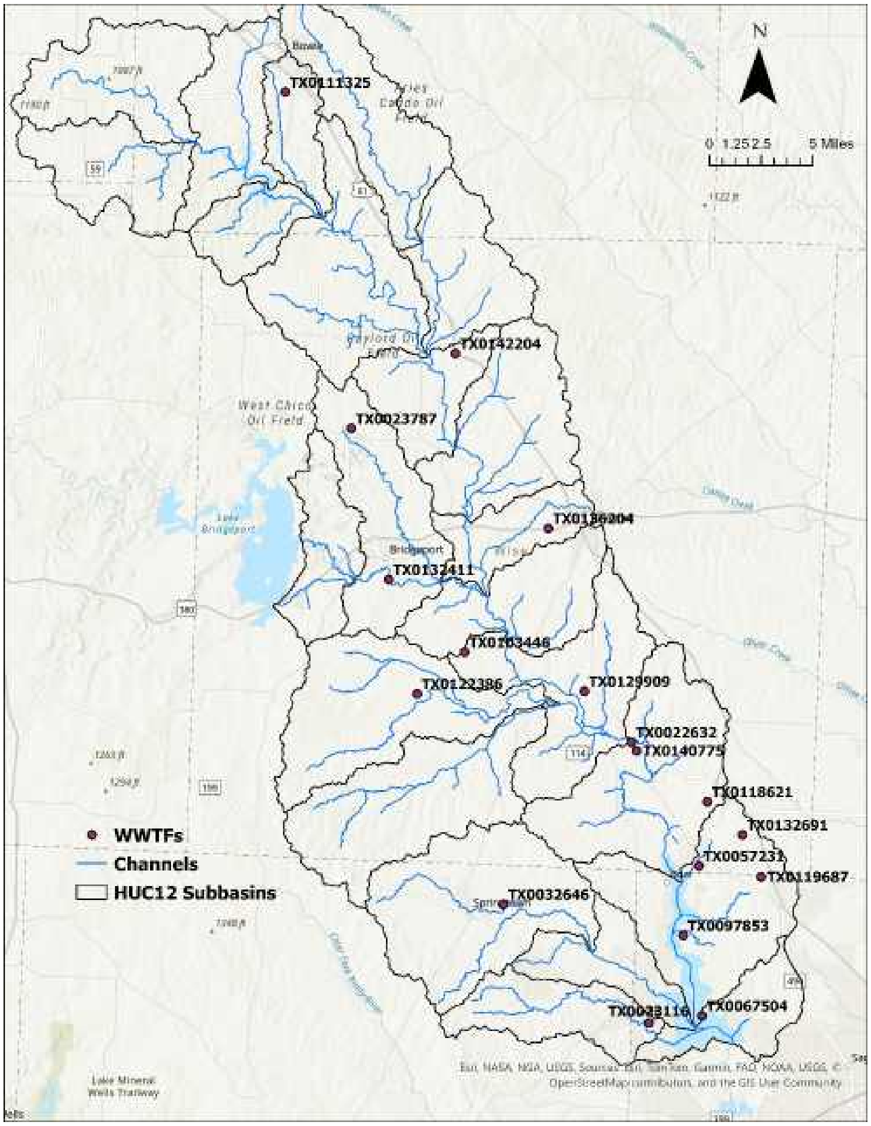

Figure 2. NPDES permitted WWTFs in the Eagle Mountain watershed.

Table 9.NPDES permitted WWTP facilities in the Eagle Mountain watershed along with the permitted daily average E.coli and flow.

NPDES Permit	Facility Name	City	*E.coli* Daily Limit, MPN/100 mL	Discharge Daily Average, MGD
TX0023787	City of Chico	Chico	126	0.15
TX0132411	City of Bridgeport WWTP	Bridge City	126	0.84
TX0111325	City of Bowie WWTP	Bowie	126	1.25
TX0142204	City of Alvord WWTP	Alvord	126	0.112
TX0136204	City of Decatur Water Plant	Decatur	126	0.1
TX0122386	Camp Summit	Paradise	126	0.00802
TX0103446	Paradise ISD WWTP	Paradise	126	0.03
TX0129909	Ivy Hills WWTP	Wise County	126	0

TX0022632	City of Boyd WWTP	Boyd	126	0.24
TX0118621	Westside WWTP	Rhome	126	0.15
TX0140775	Fairview Meadows WWTP	New Fairview	126	0.2285
TX0057231	City of Newark WWTP	Newark	126	0.15
TX0097853	Eagle Mountain Rv Park WWTP	Fort Worth	126	0.006
TX0119687	Chisholm Springs WWTP	Tarrant County	126	0.225
TX0132691	Rvr Water Reclamation & Amp Reuse Facility	Rhome	126	0.15
TX0032646	City of Springtown WWTP	Springtown	126	0.48
TX0023116	Ash Creek WWTP	Azle	126	1.44
TX0067504	Fort Worth Boat Club WWTP	Fort Worth	126	0.0158

On-site sewage facilities (OSSFs)

TX-SELECT offers three methods to estimate the number of on-site sewage facilities (OSSFs) in the Eagle Mountain watershed. One approach relied on 1990 Census records, which provided an estimate of approximately 15,004 OSSFs. Since permitting requirements did not begin until after 1989, this method was useful in identifying the likely number of non-permitted systems present before regulations took effect. Another estimation method used 911 address point data. While comprehensive, this approach tends to overestimate the number of OSSFs, as it includes a wide variety of address types beyond residential housing units—such as barns, electric poles, and other non-residential structures. This method produced an estimate of 38,222 OSSFs within the watershed. The third method utilized 2020 Census housing unit data to estimate the number of OSSFs by identifying housing units not connected to centralized wastewater treatment systems. This approach provided a more current and refined estimate, yielding approximately 26,958 OSSFs across the watershed.

To validate the estimates generated from these different methods, permitting data from the Texas Commission on Environmental Quality (TCEQ) was reviewed for the period 1992 through 2020. This data includes annual records of OSSFs permitted by county and TCEQ region. Using an area-weighted average from the county-level data, approximately 11,762 permitted OSSFs were identified within the watershed over this timeframe. When combined with the 15,004 estimated systems in place prior to the start of permitting, the total number of OSSFs in the watershed is estimated to be 26,766. This value is consistent with the estimate generated using the 2020 Census housing unit method, which identified 26,958 systems. Given this alignment and the relative reliability of the housing unit data, the 2020 Census Housing Units method was selected as the preferred basis for estimating the number of OSSFs in the Eagle Mountain watershed model.

OSSF failure rates for each subbasin are derived based on the predominant septic drainfield limitation class from the SSURGO Soil Surface Geographic database (2023). For the Eagle Mountain watershed, a default failure rate of 15%—corresponding to areas classified as "very limited"—was applied. These failure rates are then used to estimate the total number of malfunctioning OSSFs within each subbasin. The average number of individuals per household with a failing OSSF is determined by dividing the total population of the subbasin by the number of housing units. The resulting OSSF pathogen load (in MPN/day) is computed using the formula provided below.

$$Load = Failing\ OSSFs\ x\ PR\ x\ CF\ x\ \frac{70\ gal}{person.day}\ x\ \frac{Person}{Household}\ x\ 3758.2\frac{mL}{gal}$$

Where PR is the production rate of fecal coliform for OSSFs (Table 2) and CF is the conversion factor for *E.coli* (0.63).

Table 6 lists the estimated number of OSSFs and the average persons per household for each subbasin in the Eagle Mountain watershed, used to calculate potential daily *E.coli* loads.

Table 10. Number of OSSFs and potential daily loading per huc12 subbasin in the Eagle Mountain watershed.

HUC12 Subbasin	OSSFs	Failure Rate	Person/Household	Load (MPN/day)
120301010410	242	0.15	2.42	1.455×10^{12}
120301010411	1,168	0.15	2.81	8.148×10^{12}
120301010501	142	0.15	2.02	7.135×10^{11}
120301010502	88	0.15	1.94	4.251×10^{11}
120301010503	609	0.15	1.76	2.666×10^{12}
120301010504	213	0.15	2.27	1.203×10^{12}
120301010505	230	0.15	1.98	1.131×10^{12}
120301010506	794	0.15	2.12	4.193×10^{12}
120301010507	196	0.15	2.34	1.139×10^{12}
120301010508	626	0.15	2.15	3.353×10^{12}
120301010509	76	0.15	2.48	4.685×10^{11}
120301010510	639	0.15	2.51	3.981×10^{12}
120301010511	540	0.15	2.54	3.411×10^{12}
120301010601	1,165	0.15	2.47	7.165×10^{12}
120301010602	1,205	0.15	2.66	7.968×10^{12}
120301010603	1,835	0.15	2.57	1.173×10^{13}
120301010604	1,706	0.15	2.53	1.074×10^{13}
120301010605	2,654	0.15	2.59	1.712×10^{13}
120301010606	2,276	0.15	2.58	1.458×10^{13}
120301010607	5,930	0.15	2.58	3.804×10^{13}
120301010608	1,938	0.15	2.55	1.230×10^{13}
120301010609	2,358	0.15	2.56	1.503×10^{13}
120301010610	328	0.15	2.43	1.978×10^{12}

There was no information available for the actual number of "non-permitted" OSSFs across the Eagle Mountain watershed, therefore these potential sources of loading are not explicit in the TX-SELECT model. Non-permitted OSSFs tend to have a large failure rate, 50% (Reed et al., 2001) and not accounting for these could result in a lower representation of potential loading across the watershed from OSSFs. However, since exact OSSF locations across the watershed are undefined, a 100% contribution was assumed for modeling purposes.

Baseline Loading

Using all the criteria outlined above TX-SELECT was run to show locations of potential loading. For the Eagle Mountain watershed, the percentage of total contribution for each of the main categories are show in Figure 3. The “Other” category includes horses, feral hogs, and WWTFs and account for only 0.2% of the potential total loading.

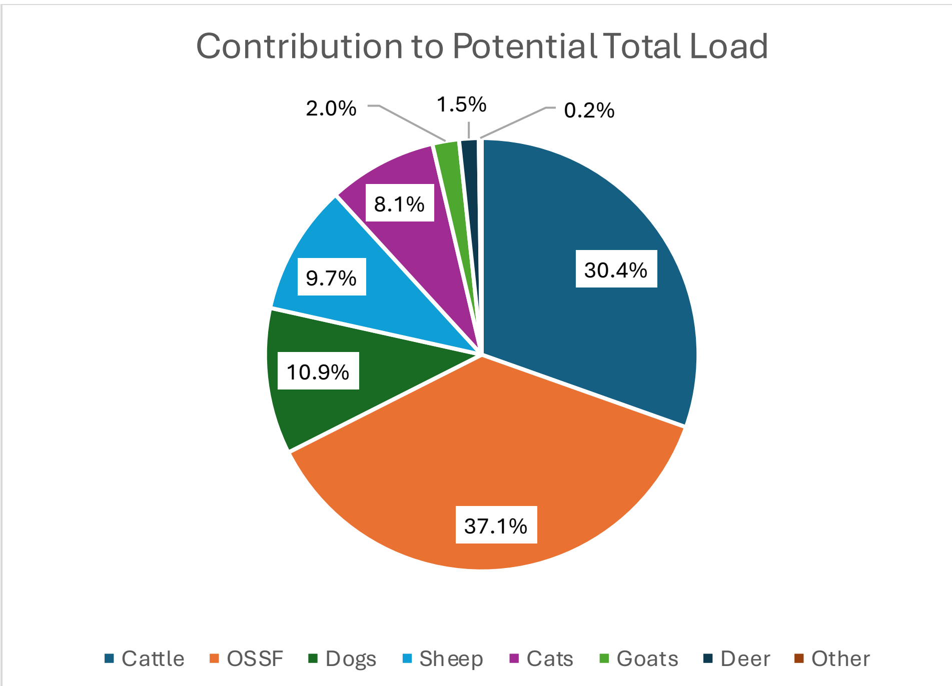

Figure 3. Potential sources of E.coli loading in Eagle Mountain watershed.

To see where in the watershed each potential source is contributing the most, each source was plotted in Figure 4. The color scale indicates the areas of low, medium, and high contributions for each source separately, and are not equivalent between categories.

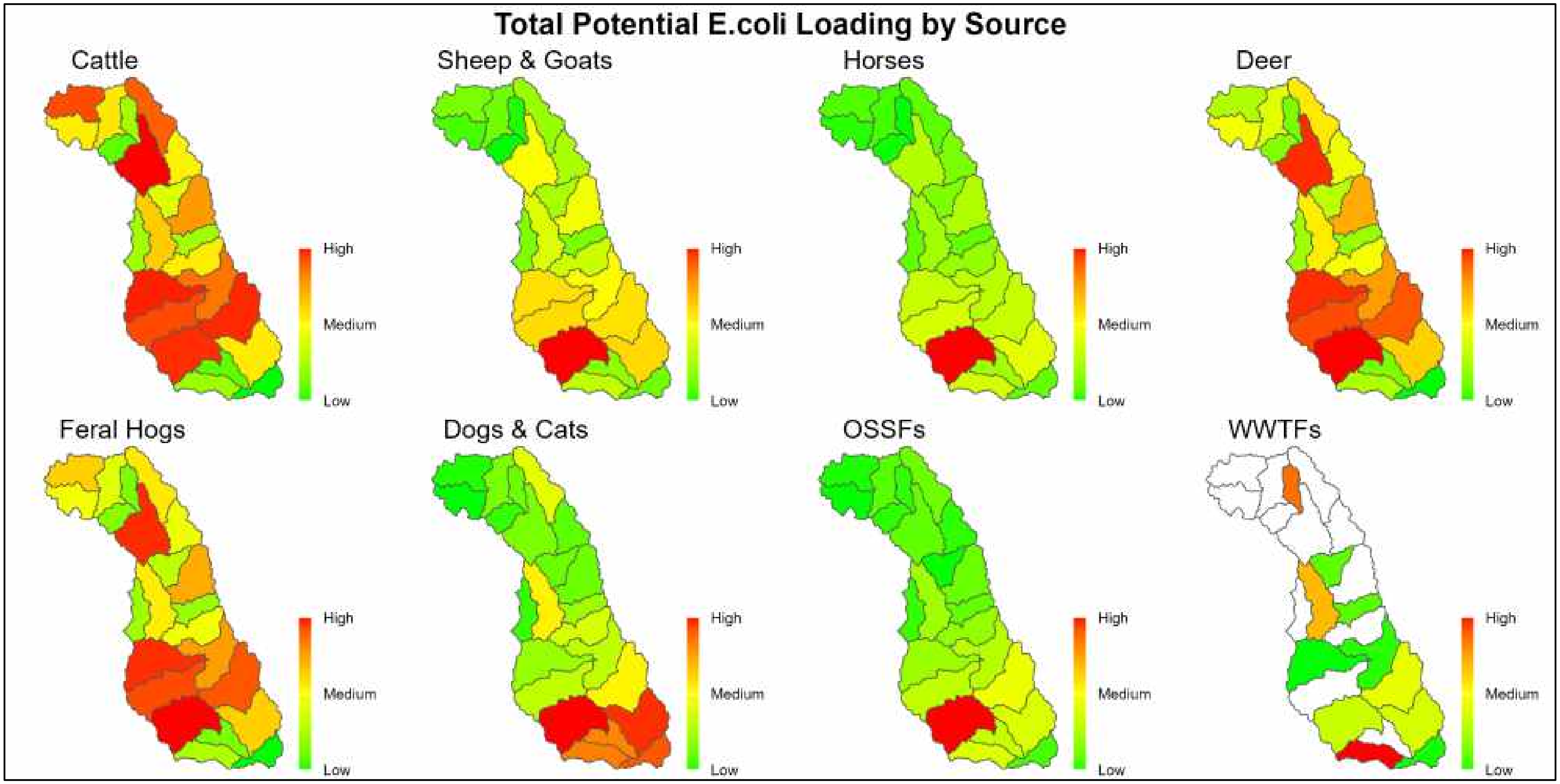

Figure 4. Potential E.coli loading by source from SELECT.

Reduction Strategies

The TX-SELECT tool can simulate potential reductions in loadings to get an idea of how impactful various BMPs would be at *E.coli* load reduction within the watershed. This is done by adjusting the input values in TX-SELECT and comparison the resulting output to the baseline loading scenario.

Cattle Stocking Rate

Cattle is the second largest source of potential loading in the Eagle Mountain watershed with a potential contribution of 30.4% of the total load. To see how much reduction is possible, the stocking rate of the cattle was modified (increasing the amount of land per animal) within the watershed. These values were used to simulate potential load reductions, not necessarily a realistic BMP for the watershed. First a 25% increase in the stocking rate was simulated, then a 50% increase, and finally a 75% increase. The stocking rate increase was calculated within each of the 23 subbasins across the watershed. The resulting subbasin average stocking rates (acre/head) are show in Table 7 along with the percentage of potential *E.coli* reduction at each monitored subbasin and for the entire watershed.

Table 11. The amount of potential reduction in loading for changes in cattle stocking rates in the Eagle Mountain watershed.

Average Stocking Rate		*E.coli* Reduction			
	Acre/Head	WF Trinity River Near Boyd	WF Trinity River at Bobo Bridge	Ash Creek	Watershed
Baseline	7.4				
25%	9.9	10.7%	10.2%	2.6%	7.6%
50%	14.9	21.4%	20.3%	5.1%	15.2%
75%	29.7	32.1%	30.5%	7.7%	22.8%

The largest increase in stocking rate (75%) results in an overall *E.coli* loading reduction of ~31% along West Fork of the Trinity River. This shows that modifying the stocking rate of cattle across the watershed alone, even beyond a reasonable amount, still will not reduce the amount of *E.coli* loading in the watershed to the amount necessary to meet the EPA requirements.

OSSF Failure Rate Improvement

The largest category of potential *E.coli* loading (37.1%) in the Eagle Mountain watershed is from OSSFs. To show the potential reduction of *E.coli* loading from OSSFs, the failure rate was deducted to 10% and 5%. The results of potential reduction for each monitored subbasin and the entire watershed are shown in Table 8.

Table 12. The amount of potential reduction in E.coli loading for reduced OSSF fail rates in the Eagle Mountain watershed.

OSSF Failure Rate Reduction	*E.coli* Reduction			
	WF Trinity River Near Boyd	WF Trinity River Near Bobo	Ash Creek	Watershed
10%	9.3%	10.1%	17.0%	12.4%
5%	18.5%	20.2%	34.0%	24.8%

Pet Reduction

The potential loading from pets (Dogs and Cats) in the Eagle Mountain watershed is the third largest source of loading contributing ~19% (10.9% for dogs, and 8.1% for cats). To simulate the amount of potential reduction of *E.coli* loading in the Eagle Mountain watershed, the density rate of dogs and cats were reduced. The baseline density of dogs was 0.614 and cats was 0.457. Two scenarios were simulated, one with a density reduction of 50%, and one with a density reduction of 80%. The densities used for dogs and cats for each reduction scenario, along with the resulting percentage of reduction at each monitored subbasin and the entire watershed are shown in Table 9.

Table 13. The amount of potential reduction in E.coli loading for various amounts of pet reduction in the Eagle Mountain watershed.

Pet Reduction			*E.coli* Reduction			
	Dog	Cat	WF Trinity River Near Boyd	WF Trinity River Near Bobo	Ash Creek	Watershed
50%	0.307	0.1228	6.7%	6.8%	15.2%	9.5%
80%	0.2285	0.0914	10.7%	10.9%	24.2%	15.2%

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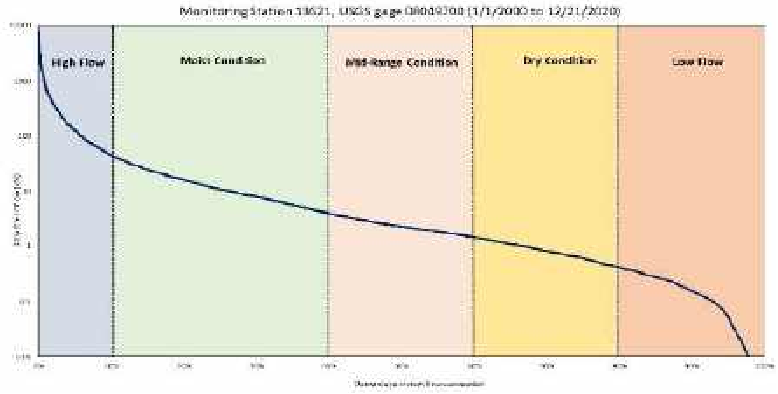
Load Duration Curve Explanation

LDCs allow for a visual interpretation of load exceedances in comparison to the allowable load at specific flow conditions. Using flow and *E. coli* data collected from a specific monitoring campaign, FDCs and LDCs can be built to further evaluate the contaminant sources. First, all flow values are aggregated and ranked from lowest to highest. This data is then graphically depicted to show the general flow regime, complete with the percentage of time that the water body is expected to be dry, as well as its response to storm flows (Figure B-1).

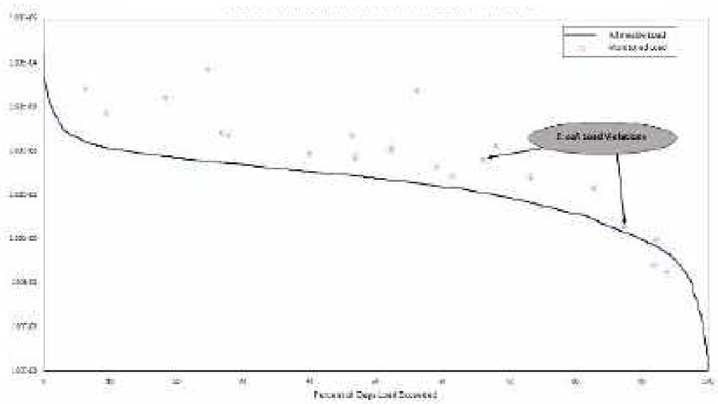


Source: FDC for streamflow conditions at monitoring station 13621 on Walnut Creek, near Mansfield, TX.

Figure B-1 FDC example from EML watershed (log scale Y-axis)

The FDC can then be used to develop an LDC for a specific pollutant of interest, given that there is pollutant concentration data that complements the flow data. Figure B-2 depicts an example LDC based on the FDC shown in Figure B-1. The first step in the process is to apply the pollutant's allowable limit concentration to all available flow values to produce the allowable load limit curve. In the case of bacteria, this value is 126 MPN/100 mL (solid line in Figure B-2) Then, the baseline monitoring data values for *E. coli* (also in MPN/100 mL) are also multiplied by their associated flow values to get loads for each data point (pink squares in Figure B-2). This can be developed further by performing regression analysis on the monitored data points, as depicted in Figure B-2. Here, the allowable load limit is depicted in red, while the regression line for the data points is depicted in blue.

LOAD DURATION CURVE FOR *E. COLI* AT MONITORING STATION 16433



Source: LDC at monitoring station 16433 on Hollings branch, near EML.

Figure B-2 LDC example from EML watershed (log scale Y-axis)

Regression analysis can be completed using one of many techniques. In this case, a USGS program known as Load Estimator (LOADEST) is utilized. A load reduction estimate can be calculated for each of the different flow regimes (High, Moist , Mid-range, Dry, Low). Achieving these reductions will become the one of the primary targets once the WPP moves into the implementation stage.

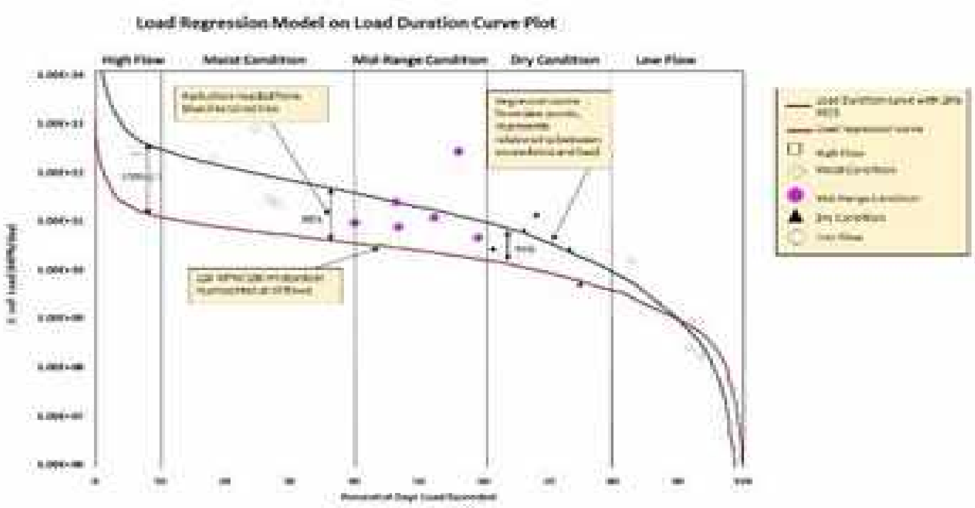


Figure B-1 LDC example for E. coli, with flow condition breakdowns and load reduction estimates (log scale Y-axis)

However, it is worth noting that some of these reductions, specifically those within the “High Flows” range, may not be achievable due to feasibility of applying management measures to storm flows that fall within the extreme range. It is therefore customary to focus efforts on the load reductions identified at the lower flow conditions, where it becomes easier to separate potential point source contributors from nonpoint source contributors. In most cases, if a water body exhibits high pollutant loads on the extreme right of the graph where low flows are represented (Figure B-2), it is highly likely that this may be attributable to a point source, such as a malfunctioning WWTF or leaking/failing wastewater infrastructure somewhere in the watershed. These types of contributions can typically be easily addressed and are worth investigating early in the process. Conversely, if pollutant loads tend towards the middle of the graph, it is likely that they are attributed to stormwater runoff during periods of normal or moderate rainfall. While typically not as easily addressed as point sources, these areas may also be targeted for watershed pollutant load reductions through BMP recommendations.

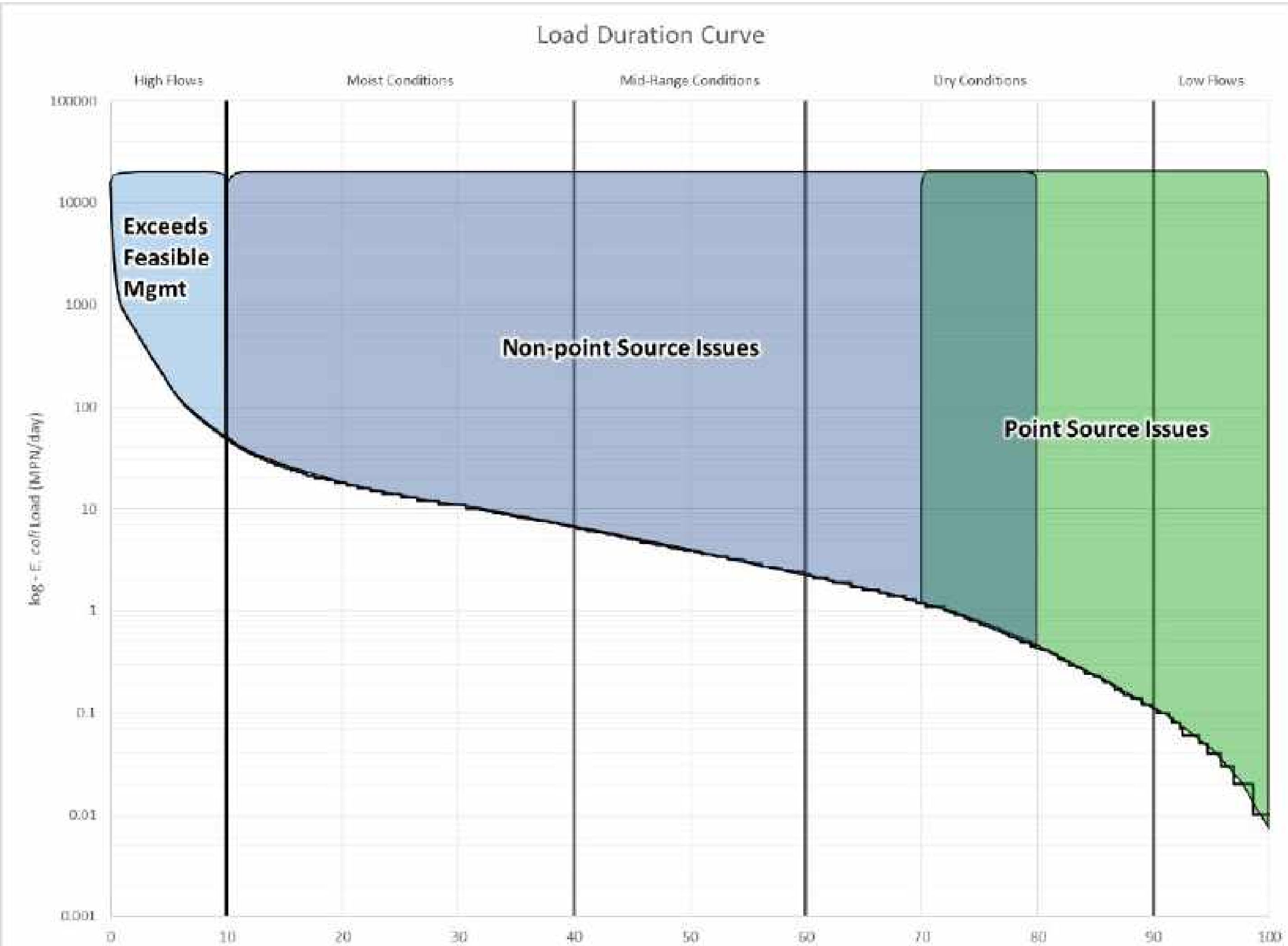


Figure B-2 Flow categories and regions of likely pollutant sources along an example load duration curve