Lavon Lake Watershed Protection Plan

Developed by
The Lavon Lake Watershed Partnership
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Cover photo of Lavon Lake.

Lavon Lake Watershed Protection Plan

Prepared for the

Lavon Lake Watershed Partnership

by

North Texas Municipal Water District

Texas A&M AgriLife Research & Extension Service

Texas State Soil and Water Conservation Board

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Statement of Purpose

Lavon Lake is a vital resource for the area, providing municipal water supply, flood control, wildlife habitat, and opportunities for recreation. Over 1.6 million North Texas residents rely on Lavon Lake as their primary source of drinking water. The land surrounding the lake supports a wide array of agricultural, industrial, and urban uses. Although the majority of the watershed is rural, the southwestern portion of the watershed is one of the most rapidly developing urban areas in the nation. Agriculture remains a vital part of the local economy, but the economic landscape in the watershed is changing as land uses shift from rural to urban.

In 2010, two tributaries to Lavon Lake were identified as impaired due to elevated levels of *E. coli* bacteria. The Lavon Lake Watershed Protection Plan was developed using a stakeholder process to provide a foundation for addressing these bacteria issues and to protect water quality in Lavon Lake and its tributaries from other pollutants of concern. By identifying key water quality issues and determining their contributing factors, management programs and public outreach efforts can be targeted to protect the vital water resources of this watershed. The Lavon Lake Watershed Protection Plan incorporates analysis of existing water quality data and investigation of potential pollutant sources to develop a strategy for addressing water quality concerns.

Stakeholders are any individual or group that may be directly or indirectly affected by activities implemented to protect water quality, such as citizens, civic organizations, businesses, municipalities, county governments, river authorities, soil and water conservation districts, agricultural committees, nonprofit organizations, and state and federal agencies. This Watershed Protection Plan is a means by which stakeholders can become more familiar with the Lavon Lake watershed and help protect the quality and health of their water resources through adoption of voluntary management practices. It helps focus protection efforts and enables financial and technical assistance to facilitate improvements in the Lavon Lake watershed. The plan is intended to be a living document, adjusted to include new data and modified as conditions in the watershed change over time. It will evolve as needs and circumstances dictate and will be guided by stakeholders as they undertake active stewardship of the watershed.

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Executive Summary

Lavon Lake is the uppermost reservoir on the East Fork of the Trinity River and is a primary source of raw water supply for the North Texas Municipal Water District. The 769-square-mile watershed (492,095 acres) includes parts of Collin, Fannin, Grayson, and Hunt Counties. The watershed consists of 40 percent rangeland, 20 percent forest, 21 percent cropland (including managed pasture), and 15 percent developed land. Major agricultural uses include forage production, grazing lands, and croplands that are primarily used to produce hay, wheat, corn, and sorghum crops. Cattle are the most prevalent livestock species in the watershed but significant populations of sheep, goats, poultry, and horses are also present.

The majority of the Lavon Lake watershed is undeveloped or agricultural land, but urban areas in the southwestern portion of the watershed are expanding rapidly. There are portions of twenty-nine incorporated communities in the watershed which range in population from a few hundred to over 150,000 people. The five largest cities in the watershed by population are McKinney, Frisco, Allen, Wyle, and Prosper. Population projections indicate that incorporated areas within the watershed will grow significantly over the next several decades.

Lavon Lake is supplied by four major tributaries, the East Fork of the Trinity River, Pilot Grove Creek, Sister Grove Creek, and Wilson Creek. The East Fork of the Trinity River and Wilson Creek were identified as impaired on the Texas Commission on Environmental Quality 2014 Integrated Report for Surface Water Quality due to elevated levels of *E. coli* bacteria. Elevated levels of *E. coli* indicate the potential presence of pathogenic organisms. Data used for the 2014 Integrated Report were 17 and 22 samples collected on The East Fork of the Trinity River and Wilson Creek, respectively, during the 7-year period between 2005 and 2012. The geometric mean of these data were 151 cfu/100mL in the East Fork of the Trinity River and 164 cfu/100mL in Wilson Creek, which exceed the state standard of 126 cfu/100 mL for water bodies designated for primary contact recreation. These segments were also listed as impaired for *E. coli* bacteria on the 2010 and 2012 Integrated Reports. The 2016 Integrated Report was not available at the time this watershed protection plan was developed.

In order to address these impairments, and to prevent other water quality issues from developing in the watershed, Lavon Lake was selected for the development of a Watershed Protection Plan (WPP). This decision was made through collaborative dialogue between the North Texas Municipal Water District (NTMWD), Texas State Soil and Water Conservation Board (TSSWCB), and Texas A&M AgriLife based on criteria that included the aforementioned tributaries having been identified on the Integrated Report, potential for success, ongoing activities, and level of stakeholder interest in protecting Lavon Lake from pollution.

Public meetings were held in both Wylie and McKinney in September 2016, and soon thereafter the Lavon Lake Watershed Partnership was formed to guide development of the Lavon Lake Watershed Protection Plan. Between November 2016 and June 2017 the Partnership met eight times to develop the Lavon Lake Watershed Protection Plan. Prior to the onset of these meetings, the North Texas Municipal Water District and Texas A&M AgriLife engaged city and county staff in the watershed to explain the goals of the project and convey the importance of watershed protection. Partnership meetings were open to the public and attendees consisted of citizens, businesses, public officials, and state and federal agencies. The Partnership recognized that success in improving and protecting water resources depends on the people who live, work, and recreate in the watershed. The Lavon Lake Watershed Protection Plan was developed to serve as a guidance document for protecting water quality at the local level.

The Partnership dedicated significant time to identifying potential sources of pollution and the reductions necessary to restore and maintain compliance with state water quality standards. Through scientific analysis, researchers supporting the Partnership determined that the East Fork of the Trinity River and Wilson Creek require a 33 and 49 percent reduction in bacteria concentrations, respectively, in order to meet the state water quality standard for primary contact recreation. As part of this analysis, the Partnership directed researchers to incorporate a 10 percent margin of safety to account for any inherent uncertainties. This information was used to set goals and milestones for the implementation of management measures to reduce bacteria levels in the Lavon Lake watershed. Since *E. coli* bacteria is the only cause of water quality impairment in the watershed, reduction goals for other pollutants were not established. However, recognizing the dynamic nature of the Lavon Lake watershed, the Partnership recommended measures to reduce pollution from sources of nutrients, sediment, and hazardous substances in order to prevent new water quality impairments from arising in the future.

Based on an evaluation of existing water quality data and watershed characteristics, the Partnership recommended management measures to reduce bacteria levels in the watershed and prevent pollution from nutrients, sediment, and hazardous substances from reaching harmful levels.

Urban management measures identified in the WPP focused on addressing potential sources of pollution in existing urbanized areas, coupled with plans for future growth and expansion. Management measures were recommended to supplement existing municipal stormwater and pollution prevention programs. Recognizing that many of the small communities in the watershed are projected to grow significantly in the coming decades, the Partnership identified a need to provide small communities with resources to help establish or expand stormwater management activities. These activities are intended to help communities accommodate new developments, protect environmentally sensitive areas, and mitigate potential downstream flooding during storm events. It was also recommended that training and continuing education opportunities be provided to city staff throughout the watershed regarding green infrastructure and low impact development. Outreach and education will also be targeted to urban residents about reducing pollution around their home and place of work.

Agricultural management measures identified by the Partnership include voluntary site-specific Water Quality Management Plans for individual operations. This may require providing enhanced planning and financial assistance to farmers and ranchers for development of management plans that reduce pollution and meet the needs of each farm operation. Activities including filter strips, nutrient management, and conservation easements are recommended as pollutant controls in the Lavon Lake watershed. Educational opportunities will also be offered to agricultural producers in the watershed on operational strategies for reducing pollution from farms and ranches.

Other key management measures identified by the Partnership were focused on septic system management, illegal dumping cleanup and enforcement, managing feral hog populations, and proper disposal of hazardous waste. Also, projects were recommended to restore degraded wetlands, streams, and riparian areas, and it was noted that nonprofit land trust organizations may provide a viable mechanism for protecting environmentally sensitive areas in the watershed.

As recommended management measures are implemented, it will be essential to monitor water quality and make necessary adjustments to the implementation strategy. Routine water quality monitoring of rivers, creeks, and Lavon Lake will continue throughout the implementation phase. In order to provide flexibility and enable adjustments to monitoring and implementation activities, adaptive implementation will be utilized throughout the process. This on-going, cyclic implementation and evaluation process serves to focus project efforts and optimize impacts. Adaptive implementation relies on constant input of watershed information and the establishment of intermediate and final water quality targets. Pollutant concentration targets for the Lavon Lake watershed were developed based on a 10-year implementation period. The Partnership will evaluate progress towards achieving programmatic and water quality goals at years 3, 6, and 10. Pollutant reductions will be tied to implementation of management measures throughout the watershed. Thus, projected pollutant targets will serve as benchmarks of progress, indicating the need to maintain or adjust planned activities. While water quality conditions likely will change and may not precisely follow the projections indicated in the WPP, these estimates serve as a tool to facilitate stakeholder evaluation and decision-making based on adaptive implementation.

The Lavon Lake Watershed Partnership will continue to meet on a periodic basis, or as needed, to receive updates on the progress of implementation efforts and guide the program though adaptive management actions. Ultimately, it is the goal of the Partnership to use this plan to improve and protect water quality in the Lavon Lake watershed for present and future generations.

1. Watershed Management

A watershed is an area of land that water flows across, through, or under on its way to a common point in a stream, river, lake, or ocean. Watersheds not only include water bodies such as streams and lakes, but also all the surrounding lands that contribute water to the system as runoff during and after rainfall events. The relationship between the quality and quantity of water affects the function and health of a watershed. Thus, significant water removals (such as irrigation) or water additions (such as permitted discharges) are important. Watersheds can be extremely large, covering many thousands of acres, and often are subdivided into smaller subwatersheds for the purposes of study and management.

1.1 – WATERSHEDS AND WATER QUALITY

To effectively address water issues, it is important to examine all natural processes and human activities occurring in a watershed that may affect water quality and quantity. Runoff that eventually makes it to a water body begins as surface or subsurface water flow from rainfall on agricultural, urban, residential, industrial, and undeveloped areas. This water can carry pollutants washed from the surrounding landscape. In addition, wastewater from various sources containing pollutants may be released directly into a water body. To better enable identification and management, potential contaminants are classified based on their origin as either point source or nonpoint source pollution.

Point source pollution is discharged from a defined location, such as a pipe, ditch, or drain. It includes any pollution that may be traced back to a single point of origin. Point source pollution is typically discharged directly into a waterway and often contributes flow across all stream conditions, from low flow to high flow. In Texas, dischargers holding a permit through the Texas Pollutant Discharge Elimination System (TPDES – see Appendix A for a complete list of acronyms) are considered point sources, and effluent is permitted with specific pollutant limits to reduce the impact on the receiving waterbody.

Nonpoint source pollution (NPS), on the other hand, comes from a source that does not have a single point of origin. The pollutants are generally carried off the land by runoff from storm water following rainfall events.

As runoff moves over the land, it can pick up both natural and human-related pollutants, depositing them into water bodies such as creeks, rivers, and lakes. Ultimately, the types and amounts of pollutants entering a water body will determine the quality of water it contains and whether it is suitable for particular uses such as irrigation, fishing, swimming, or drinking.

1.2 – BENEFITS OF A WATERSHED APPROACH

State and federal water resource management and environmental protection agencies have embraced the watershed approach for managing water quality. The watershed approach involves assessing sources and causes of impairments at the watershed level and utilizing this information to develop and implement watershed management plans. Watersheds are determined by the landscape and not political borders, and thus often cross municipal, county, and state boundaries. By using a watershed perspective, all potential sources of pollution entering a waterway can be better identified and evaluated. Just as important, all stakeholders in the watershed can be involved in the process. A watershed stakeholder is anyone who lives, works, or engages in recreation in the watershed. They have a direct interest in the quality of the watershed and will be affected by planned efforts to address water quality issues. Individuals, groups, and organizations within a watershed can and should become involved as stakeholders. Stakeholder involvement is critical for selecting, designing, and implementing management measures to successfully improve water quality.

1.3 – WATERSHED PROTECTION PLANNING

The United States Environmental Protection Agency (EPA) developed a list of nine key elements (see Appendix B) which serve as guidance for development of successful watershed protection plans (WPP). Using that guidance, plans are developed by local stakeholders with the primary goal being to restore and/or protect the water quality and designated uses of a water body through voluntary, non-regulatory water resource management. 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 landowners, businesses, elected officials, and residents of the watershed. The Lavon Lake WPP defines a strategy and identifies opportunities for stakeholders across the watershed to work together and as individuals to implement voluntary practices and programs that restore and protect water quality.

2. Overview of the Watershed

2.1 – GEOGRAPHY

Lavon Lake is the uppermost reservoir on the East Fork of the Trinity River and provides drinking water to over 1.6 million residents in North Texas (Fig. 2.1). The 769-square-mile watershed (492,095 acres) lies within the larger Trinity River Basin and includes parts of Collin, Fannin, Grayson, and Hunt Counties (Fig. 2.2). Elevations within the watershed range from 901 feet in the upper reaches of the East Fork of the Trinity River subwatershed in Grayson County to the conservation pool elevation of 492 feet in Lavon Lake. Incorporated areas within the watershed include twenty-seven towns and cities (Table 2.1). Notable tributaries to the lake include the East Fork of the Trinity River, Indian Creek, Pilot Grove Creek, Sister Grove Creek, and Wilson Creek, which are described in greater detail below. There are also a number of smaller, ephemeral streams which flow into Lavon Lake which include Elm Creek, Price Creek, Ticky Creek, and White Rock Creek.

<u>The East Fork of the Trinity River above Lavon Lake</u>

The headwaters of the East Fork of the Trinity River rise in Grayson County approximately 1.5 miles north-northwest of Dorchester, TX and flow south south-southeast for approximately 50 miles before draining into the western arm of Lavon Lake. Honey Creek is the primary tributary to the East Fork of the Trinity River above Lavon Lake. Honey Creek rises approximately 2.5 miles south-southeast of Gunter, TX and flows south-southeast for 21 miles before its confluence with the East Fork of the Trinity River approximately 0.6 miles southeast of the intersection of SH-75 and FM-543 near McKinney. Elevations in the East Fork of the Trinity River subwatershed range from 901 feet to the conservation pool of 492 feet in Lavon Lake. The East Fork of the Trinity River subwatershed drains approximately 136,958 acres (Table 2.2).

<u>Indian Creek</u>

Indian Creek rises in Trenton, TX in Fannin County and flows south for approximately 16 miles before its confluence with Arnold Creek, approximately 4.25 miles southeast of Blue Ridge, TX. Indian Creek then continues southwest for approximately 8 miles before draining into Pilot Grove Creek less than 2 miles upstream of its confluence with Lavon Lake. The headwaters of Arnold Creek rise approximately 3 miles south of Leonard and flow for 13 miles before joining Indian Creek. Another major tributary to Indian Creek is Bear Creek, which rises approximately 3 miles west of Leonard, TX and flows south for approximately 14 miles before joining Indian Creek 1 mile upstream of the confluence point of Indian and Arnold Creeks.

Pilot Grove Creek

The headwaters of Pilot Grove Creek rise approximately 2 miles east of Tom Bean, TX and flow south for 36 miles before draining into the eastern arm of Lavon Lake. The Pilot Grove Creek subwatershed is relatively long and narrow. Thus, save for the aforementioned Indian Creek subwatershed, there are no major tributaries to Pilot Grove Creek.

Sister Grove Creek

The west and east prongs of Sister Grove Creek rise 1 mile and 4 miles east of Howe, TX, respectively. These two prongs join approximately 3 miles east of Van Alstyne, TX to form the main stem of Sister Grove Creek. The creek then flows south for 29 miles before draining into the eastern arm of Lavon Lake.

Wilson Creek

The headwaters of Wilson Creek rise in Collin County approximately 2 miles east of Celina, TX and flow southeast for 29 miles until its confluence with the western arm of Lavon Lake. Wilson Creek flows through the heart of McKinney, TX and is by far the most urbanized of the Lavon Lake subwatersheds.

Figure 2.1. The East Fork of the Trinity River flowing through a rural portion of the watershed.

Table 2.1. Incorporated areas in the Lavon Lake watershed.

Name	BOC 2015 Population Estimate	County	Receiving Subwatersheds[1]	% of City Limit in Lavon Watershed[2]
Allen	98,143	Collin	Wilson Creek; Other	16.1%
Anna	11, 463	Collin	East Fk Trinity River; Sister Grove Creek; Pilot Grove Creek	100%
Blue Ridge	850	Collin	Pilot Grove Creek; Indian Creek	100%
Celina	7,697	Collin	Wilson Creek	9.2%
Dorchester	89	Grayson	East Fk Trinity River	73.6%
Fairview	8,438	Collin	Wilson Creek	99.9%
Farmersville	3,447	Collin	Elm Creek; Other	92%
Frisco	154,407	Collin	Wilson Creek	0.2%
Gunter	1,394	Grayson	East Fk Trinity River	40.8%
Howe	2,798	Grayson	East Fk Trinity River; Sister Grove Creek	28.8%
Lavon	2,889	Collin	Other	8.8%
Leonard	1,970	Fannin	Indian Creek	97.3%
Lowry Crossing	1,780	Collin	East Fk Trinity River	100%
Lucas	6,883	Collin	Wilson Creek; White Rock Creek; Other	70.8%
McKinney	162,898	Collin	Wilson Creek; East Fk Trinity River	81%
Melissa	7,436	Collin	East Fk Trinity River; Sister Grove Creek	100%
Nevada	1,008	Collin	Other	9.9%
New Hope	639	Collin	East Fk Trinity River	100%
Princeton	8,939	Collin	Sister Grove Creek; Ticky Creek; Other	100%
Prosper	15,967	Collin	Wilson Creek	30%
St. Paul	1,132	Collin	Other	60.3%
Tom Bean	1,055	Grayson	Sister Grove Creek; Pilot Grove Creek	42.8%
Trenton	628	Fannin	Indian Creek	78.2%
Van Alstyne	3,344	Grayson	East Fk Trinity River; Sister Grove Creek	100%
Weston	334	Collin	East Fk Trinity River	100%
Whitewright	1,633	Grayson	Pilot Grove Creek	NA[3]
Wylie	46,708	Collin	Other	49.6%[4]

[1] Other includes unnamed tributaries and areas that drain directly to Lavon Lake.
[2] Calculated using TxDOT 2015 city boundary dataset.
[3] City boundary not included in TxDOT dataset.
[4] According to dataset, a significant portion of Wylie city limits encompasses Lavon Lake itself; actual percentage of dry-land in watershed is much smaller.

Table 2.2. Lavon Lake subwatershed drainage areas and TCEQ Assessment Unit IDs.

Subwatershed	Percentage of Total	Acres	Sq. Miles	TCEQ AU
East Fork Trinity River	27.8%	136,958	214	0821D_01
Sister Grove Creek	15.6%	76,633	120	0821B_01
Pilot Grove Creek	11.1%	54,583	85	0821A_01
Indian Creek	15.7%	77,040	120	n/a
Wilson Creek	9.9%	48,929	76	0821C_01
Lavon Lake[1]	4.2%	20,559	32	0821_01 – 0821_04
All Others[2]	15.7%	77,393	121	n/a
Total	100.0%	492,095	769	n/a

[1] Surface area of Lavon Lake at conservation pool elevation.

[2] Includes all other streams and also areas that drain directly to Lavon Lake.

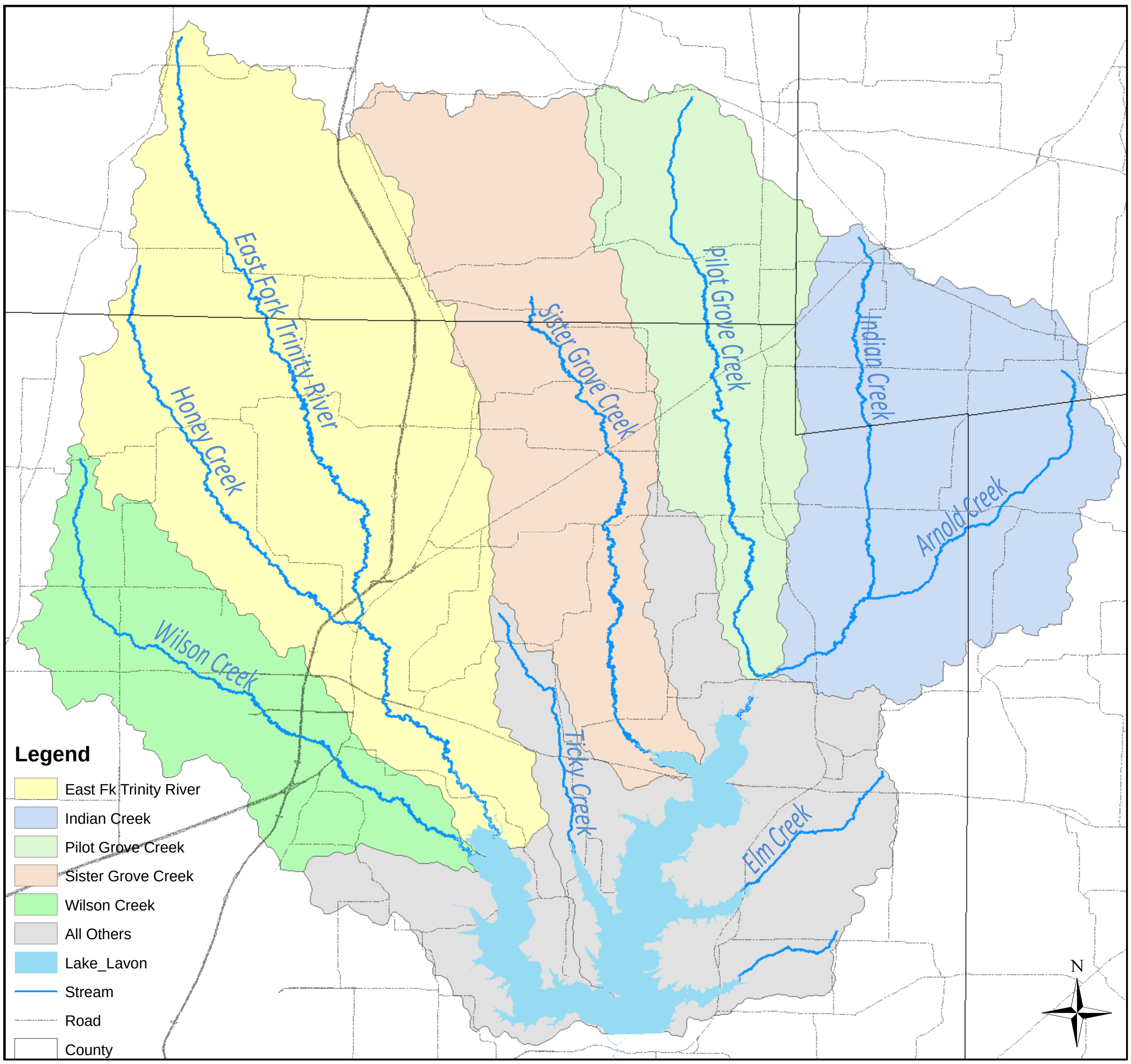

Figure 2.2. The Lavon Lake watershed.

2.2 – PHYSICAL AND NATURAL FEATURES

Ecoregion

The Lavon Lake watershed lies in the Blackland Prairies ecoregion (Figure 2.3). The Texas Blackland Prairies ecoregion is dominated by tallgrass species on uplands and by deciduous woodlands along riparian corridors (Auch, 2016). Native prairie vegetation in the watershed consists of big bluestem, little bluestem, switchgrass, sideoats, and other flora (Figure 2.4). Dominant hardwoods species include live oak, post oak, blackjack oak, American elm, winged elm, cedar elm, sugarberry, green ash, osage-orange, honey mesquite, and eastern redcedar. Pecan, black walnut, black willow, American sycamore, honey locust and bur oak can also be found in bottomlands throughout the region (TPWD, 2016). Animals native to the area include white-tailed deer, beaver, nutria, bobcat, coyote, fox, skunk, raccoon, rabbit, gopher, squirrel, and a diverse array of other small mammals and birds. In addition, feral hog (non-native, invasive species) populations are known to be significant.

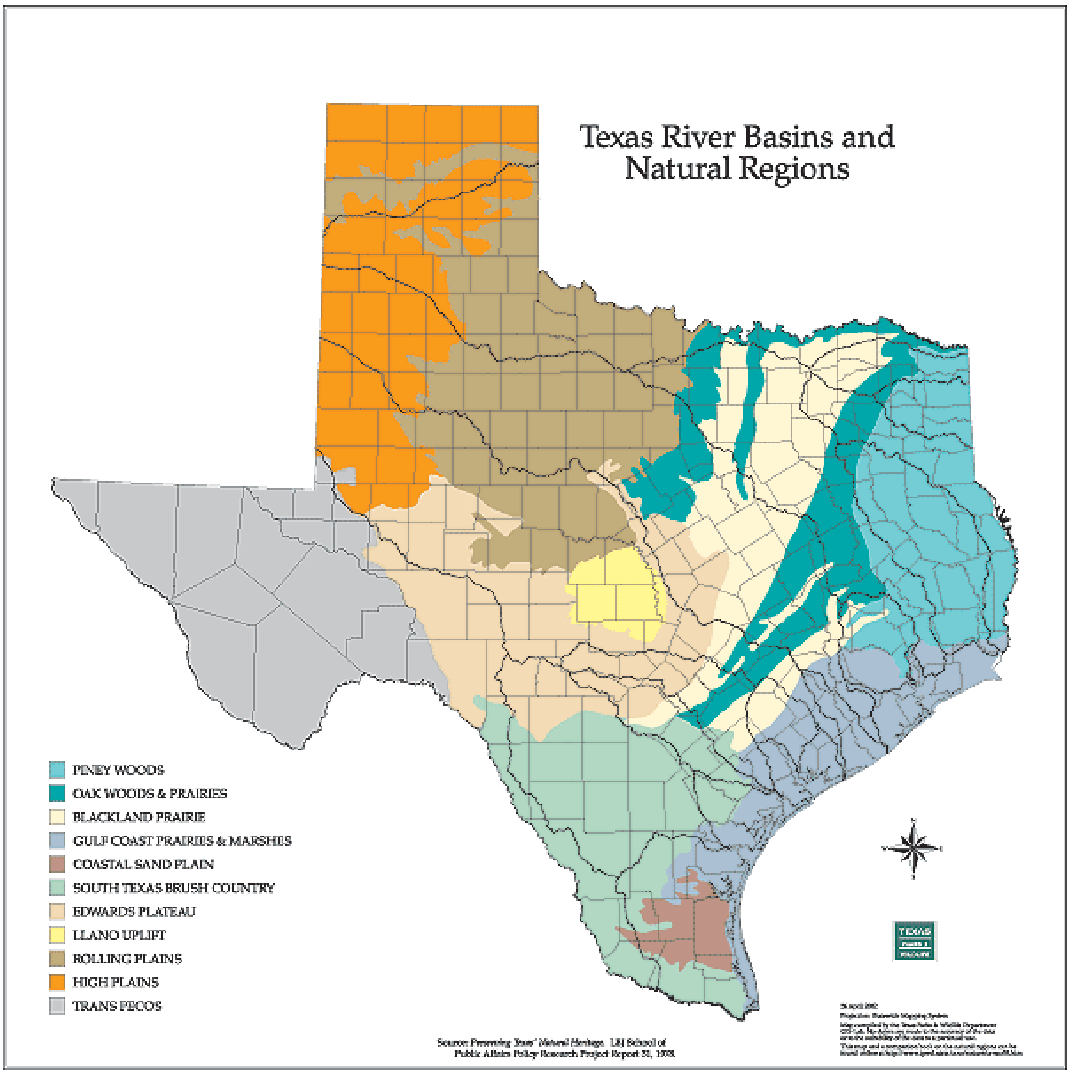

Figure 2.3. Ecoregions of Texas. Image courtesy of TPWD.


Figure 2.4. Tall grasses in the Blackland Praries ecoregion. Photo courtesy of Texas A&M AgriLife Extension.

2.2.1 – Soils

Soil textures in the northern and western portions of the watershed are generally heavy clays with intermittent silty clay and clay loam textures (Figure 2.5). Heavy clay soil textures dominate the remainder of the watershed but large clay loam aggregates can be found in the eastern portion of the watershed. Soil survey data in the Hunt County portion of the watershed largely describe mapping units which contain two or more soil types, known as soil complexes. Soil textures within a complex can vary, although heavy clays likely make up the majority of soil textures in these areas of the watershed. One exception however is the large concentration of fine sandy loam soil textures near the headwaters of Arnold Creek.

Houston Black, Austin, Fairlie, and Trinity series soils are the predominant soil associations found in the watershed. The Houston Black series consists of very deep, moderately well drained, very slowly permeable soils found on upland ridges and dissected plains. The Austin series consists of moderately deep, well drained, moderately slowly permeable soils found on nearly level to sloping erosional uplands. Fairlie series soils consist of deep, moderately well drained, very slowly permeable soils on level to gently sloping uplands. The Trinity series consists of very deep, moderately well drained, very slowly permeable soils that occur on river valley flood plains and dissected plains. Other soil associations found in the watershed include the Altoga, Aubrey, Bastrop, Bolar, Bunyan, Burleson, Callisburg, Crockett, Eddy, Elbon, Engle, Ferris, Frio, Heiden, Howe, Lamar, Lewisville, Lindy, Normangee, Stephen, Tinn, Vertel and Wilson series. (NRCS, 2016)

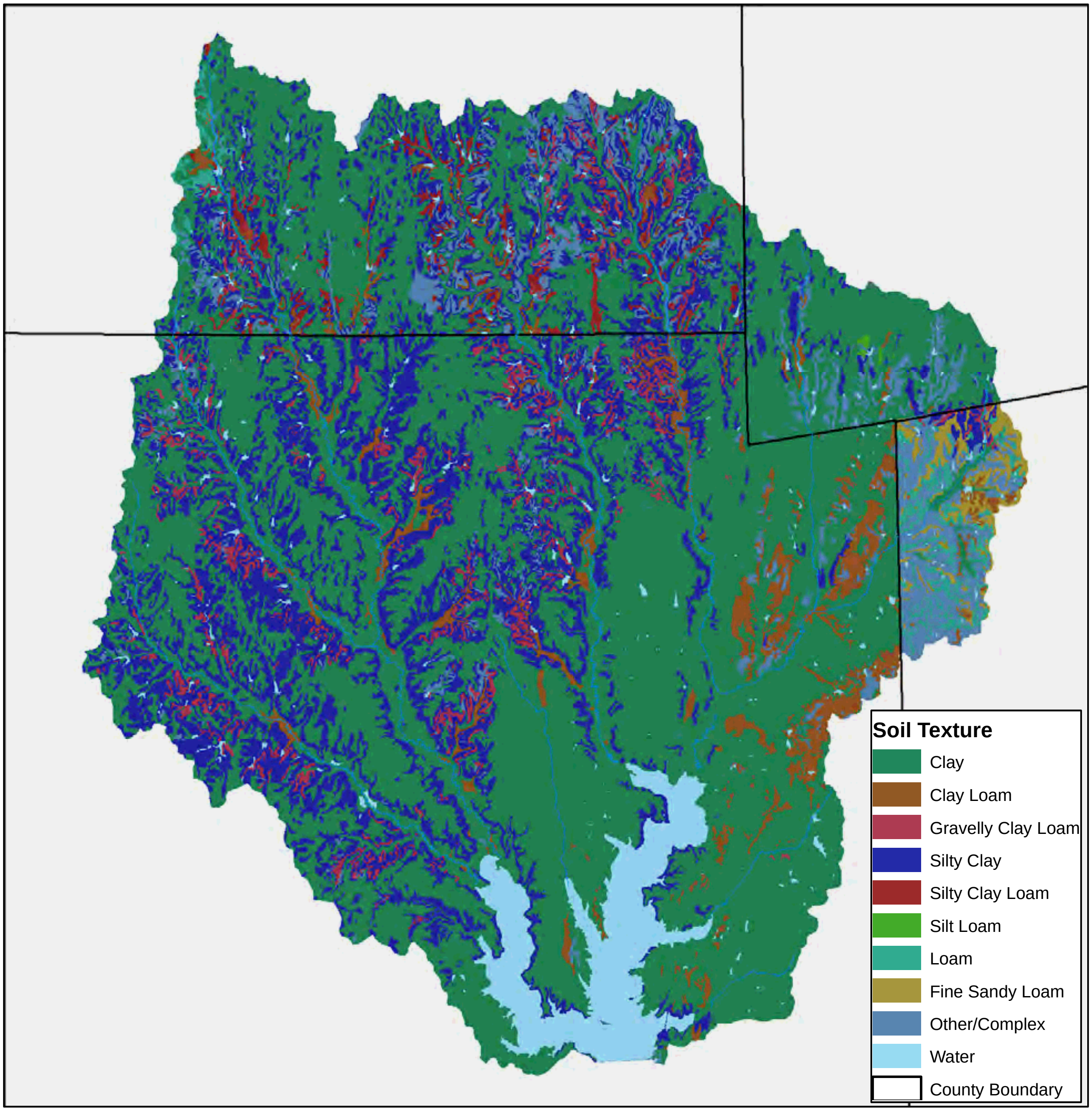

Figure 2.5. Soil textures of the Lavon Lake watershed.

2.2.2 – Water Resources

Flows in much of the watershed are ephemeral, primarily occurring only during and immediately after rainfall events. However, several of the larger tributaries to Lavon Lake have intermittent and perennial flows in their lower reaches. For example, the lower reaches of the East Fork of the Trinity River are perennial but the river transitions to intermittent and ephemeral flows upstream. Also, Wilson Creek, which is largely ephemeral, has consistent streamflow in its lower reaches most years; however, this may be due in part to runoff from municipal water uses such as landscape irrigation. There are also a number of small wastewater treatment plants (WWTP) in the watershed which discharge treated effluent to several streams in the watershed, but this is usually not enough to provide consistent baseflow.

The principle water bearing strata under the watershed are the Trinity and Woodbine aquifers. The Trinity Aquifer is a major aquifer that spans across central and northeast Texas and consists of limestones, sands, clays, gravels, and conglomerates. Water quality is generally good in much of the Trinity Aquifer but levels of total dissolved solids (TDS) can range from 1,000-5,000 mg/L, or slightly to moderately saline, in deeper parts of the aquifer. The average saturated thickness of the Trinity Aquifer in North Texas is approximately 600 feet. However, heavy usage has caused drastic declines in the Trinity Aquifer throughout many parts of the state. The Woodbine Aquifer is classified as a minor aquifer by the Texas Water Development Board and consists of sandstone interbedded with shale and clay that form three water-bearing zones. Water quality and yield vary with the depth of the Woodbine aquifer. For example, water extracted from above 1,500 feet generally contains less than 1,000 mg/L of total dissolved solids, while lower water-bearing zones generally produce water that is slightly to moderately saline (1,000-5,000 mg/L). Relative to other parts of these aquifers, there are not many wells in the Lavon watershed. This is largely due to the cost of extracting water and the presence of high salinity levels in some areas. Also, much of the watershed population relies on surface water sources for drinking supply, which has lessened the need for domestic wells. (TWDB, 2015)

Lavon Lake is a flood control and water conservation reservoir that serves as the primary drinking water source for most of the watershed and surrounding area (Figure 2.6). The lake has a maximum depth of 38ft and 275,000 acre feet of conservation storage capacity. The surface area of Lavon Lake at its normal elevation pool of 492 ft. msl is approximately 21,000 acres. Construction of the Lavon Lake dam was completed in 1953 and the dam was enlarged in 1975 to expand the lake's conservation storage capacity to its currently level. Both of these construction efforts were completed under the direction of the U.S. Army Corps of Engineers (USACE). The Lavon Lake dam and shoreline have been managed by the USACE since completion of the reservoir.

The North Texas Municipal Water District (NTMWD) holds water rights to 118,670 acre-feet per year from Lavon Lake (Figure 2.6) and is the primary water provider for the region. As a wholesaler, the district delivers treated water to 90 communities across North Texas that include more than 1.6 million residents. The NTMWD operates four water treatment plants in Wylie, TX and uses Lavon Lake as a collection point for water from several sources outside the watershed. Raw water from Lake Tawakoni and the East Fork Reuse Project is transported via pipeline and discharged into the eastern arm of Lavon Lake (Figure 2.7). Another pipeline carries raw water from Jim Chapman Lake to a discharge point located on the Hickory Creek tributary of Indian Creek, approximately 2.6 miles west of Merit, TX. The NTMWD has rights to a total of 51,201 acre-feet per year from Lake Tawakoni and 57,214 acre-feet per year form Jim Chapman Lake. However, much of the Tawakoni raw water supply is delivered to the Tawakoni water treatment plant to serve the cities of Terrell and Ables Springs, while any additional raw water withdrawn from Tawakoni continues on to Lavon Lake for use at the Wylie treatment facilities. Actual daily discharge into Lavon Lake from these sources varies greatly depending on municipal demand and current lake levels. For example, total discharges into Lavon Lake from Tawakoni were 23,245 acre-feet (AF) in 2014 and 19,582 acre-feet in 2015. Furthermore, water supply from the East Fork Reuse Project is contingent upon actual discharges from NTMWD wastewater treatment plants upstream of the intake point. Before entering the pipeline, water from the East Fork Reuse Project is filtered through a constructed wetland just east of Seagoville, TX that is designed to treat an average of 91 MGD, with peak flows of up to 165 MGD for brief periods. In addition to the aforementioned sources, the NTMWD obtains raw water from Lake Texoma, which is piped directly to its treatment facilities in Wylie. Also, the NTMWD is in the final stages of the permitting process for the proposed Lower Bois d'Arc Creek Reservoir in Fannin County, which will provide 120,000 acre-feet per year. Plans call for a pipeline to transport water from the Lower Bois d'Arc Creek Reservoir to the Leonard Water Treatment Plant before entering the NTMWD treated water distribution system.

Figure 2.6. Lavon Lake.

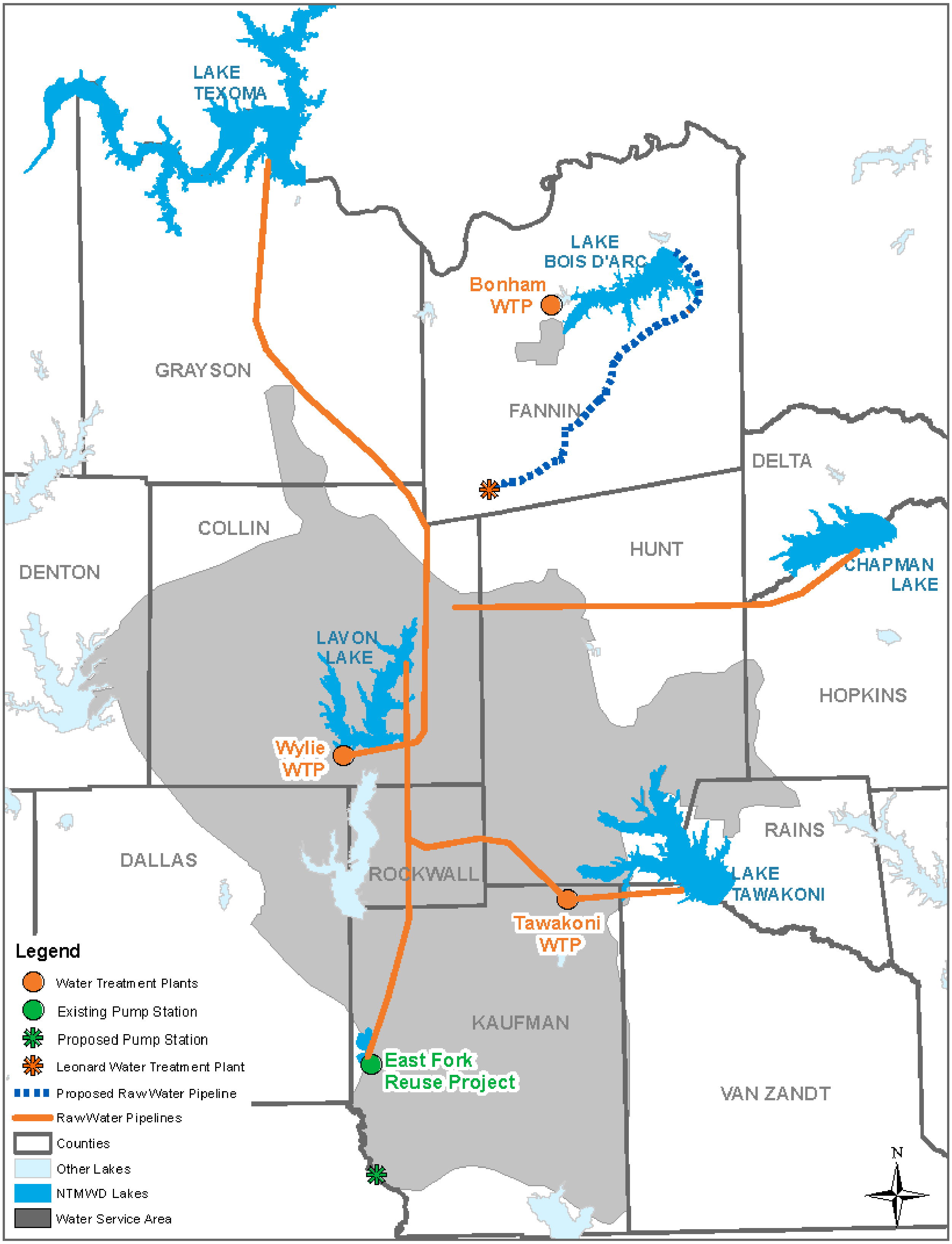

Figure 2.7. The NTMWD Water System.

2.2.3 – Fish and Benthic Macroinvertebrate Communities

Native Species

Fish species known to be common in Lavon Lake and its tributaries are bass, bluegill, blue catfish, channel catfish, carp, gar, sunfish, shad, suckers, and white crappie (USACE, 2016). Freshwater mussels that include giant floater, pink papershell, southern mapleleaf, and Texas liliput are also commonly found in the watershed. Common benthic macroinvertebrates collected during sampling include mayflies, caddisflies, dragonflies, damselflies, midges, worms, and aquatic beetles.

Invasive Species

A reproducing zebra mussel population has been documented in Sister Grove Creek. No reproducing populations have been documented in Lavon Lake but there is a high risk of establishment due to frequent boat traffic and recreational activities. Zebra mussels are known to attach to surfaces such as boat hulls and impellers and clog water intake pipes and treatment facilities. Furthermore, zebra mussels can compete for food sources with native aquatic species.

2.3 – CLIMATE

The Lavon Lake watershed lies in a humid subtropical climate zone characterized by hot, usually humid summers and mild to cool winters. Actual weather varies widely from year to year and the area is often prone to storms and brief extremes in weather. For example, average annual precipitation for the watershed is between 37-40 inches (FNEP, 2016). However, the watershed experienced “extreme” and “exceptional” drought (Category D3 and D4) in 2011 and remained in drought conditions until 2015. In 2011, weather stations in McKinney, Anna, and Trenton recorded total annual precipitation amounts of 24.81, 27.8, and 30.38 inches, respectively. In contrast, total annual rainfall for those same stations in 2015 was 66.97, 68.42, and 77.48 inches, respectively. Peak rainfall is usually the result of thundershowers in the late spring, with a secondary peak occurring in the fall. The prevailing winds are southerly most of the year however, strong winds from the north can occur frequently during the winter. Winters are mild, with January mean temperatures of approximately 44°F. Summers are generally hot, with mean temperatures of 85°F in July.

2.4 – HISTORY

The earliest known inhabitants in the area were Native Americans belonging to the Caddo tribes in the period from 1300 – 1600 A.D., although archeological evidence suggests that human habitation in the area began long before that. Specifically, it was primarily the Wichita group of the Caddoes that occupied the Red River Valley and headwaters of the Trinity River. These early inhabitants usually lived in permanent settlements and depended on agriculture and hunting for their livelihood. Pumpkins, sunflower, tobacco, beans, and corn were cultivated along with orchards of peach, plum, and fig trees. (Stambaugh, 1958)

By the late 1700's, Texas was under Spanish rule. Although it is thought that Spaniards traversed the Lavon Lake area as early as 1542, permanent settlements were not established until the arrival of American colonists in the 1800's. In fact, it wasn't until the 1840's that American settlers began arriving in earnest with the intention of establishing permanent homes, largely due to generous land grants offered by the newly formed Republic of Texas. When Collin County was established in 1846 the population was approximately 150 people. Early settlers established themselves near waterways where water and timber were abundant. However, the arrival of the railroad in the 1870's prompted much of the population to relocate closer to the new line. The railroad spurred significant growth in the area over the next fifty years. In particular, the easy access to markets provided by the railroad led to a drastic increase in farming in the region.

Populations in the watershed continued to rise until the 1920s. The mechanization of farms, and later the Great Depression, led to a downturn in the region that lasted through the 1940s. The Collin County Soil Conservation District was formed in 1946 and several years later, a number of flood retarding and sediment control basins were constructed throughout the watershed. These reservoirs were intended to mitigate downstream flooding and to prevent sedimentation of the Lavon Lake reservoir, which began construction in 1948 and was completed in 1953. Many of the communities in the area were instrumental in getting the Lavon Lake reservoir approved for domestic water supply, rather than the ACOE's original intention of it solely being a flood control reservoir. Consequently, the North Texas Municipal Water District was created in 1951 to provide treated water from Lavon Lake to its ten original Member Cities. By the time the first NTMWD water treatment plant came online in 1956, plans had already been made to obtain new water rights and expand treatment capacity to meet growing demand. (Sloan, 1994)

Populations continued to rise steadily over the next several decades and although agriculture was still important, the local economy had diversified by the 1980s to include significant retail, manufacturing, and wholesale businesses. As the Dallas metroplex grew steadily outward, many cities in the area began to experience significant increases in population. For example, during the twenty year period between 1990 and 2010, populations in the City of McKinney rose from 21,771 to 132,789, an increase of over 500 percent. This trend continued into the twenty first century and the NTMWD subsequently expanded to include three additional Member Cities and many more Customer Cities, bringing its population served to just over 1.6 million in 2016. Lavon Lake remains the primary drinking source for the region, as it has since its construction.

2.5 – LAND USES

Land use in the Lavon Lake watershed is predominantly rural and agricultural. Rangelands and managed pasture account for almost half of the watershed, a significant portion of which are used for livestock and forage production. Cattle are the most prevalent livestock species in the watershed but significant populations of sheep, goats, poultry, and horses are also present (NASS, 2012). Native grasses found in the watershed include Indian grass, tall bunchgrass, buffalograss, and bluestems. Bermudagrass is the predominant forage species produced in the watershed but a variety of cool and warm season grasses are also grown for hay and grazing, which include bahiagrass, johnson grass, bushy bluestem, and KR bluestem.

Cultivated crop production is present throughout the watershed (Figure 2.8). Estimates show that these areas account for over 17 percent of the watershed area. The majority of these lands are under hay and wheat production however, significant corn and sorghum production is also present. Although row crop production can be found throughout the watershed, the greatest concentrations of croplands are located in the East Fork of the Trinity River and Sister Grove Creek subwatersheds in a belt that spans from the Princeton area to Dorchester, TX.

There is also a significant amount of forest in the Lavon Lake watershed, with deciduous, evergreen, and mixed forests covering almost 20 percent of the land area. These forested areas are found primarily along riparian corridors with concentrations located in the lower reaches of several tributaries to Lavon Lake.

Urban lands are estimated to account for just over 15 percent of the watershed. Most of these urban areas are concentrated in the Wilson Creek and Lower East Fork of the Trinity River subwatersheds and along the U.S. Highway 75 and 380 corridors. According to recent U.S. Census Bureau (BOC) estimates, Collin County population grew by 16.8 percent between 2010 and 2015, making it the 23rd fastest growing county in the nation for this time period (BOC, 2015). Urban areas in this portion of the watershed are expected to continue growing in the coming years.


Figure 2.8. Row crop production in the Lavon Lake Watershed.

2.6 – PERMITTED DISCHARGES

Permitted discharges in the watershed include thirteen active wastewater treatment plants (WWTP) (Table 2.3). The largest facility in the watershed is the Wilson Creek Regional WWTP, which is constructed to discharge an average of 56 million gallons/day (MGD), and permitted to expand to 64 MGD. It is currently in design phase to expand to the permitted capacity of 64 MGD, which is expected to be completed in 2019. Contrary to its name, the Wilson Creek Regional WWTP does not discharge into Wilson Creek, but rather directly into the western arm of Lavon Lake approximately 2 miles south of Lowry Crossing (Figure 2.9). The Wilson Creek WWTP is operated by the North Texas Municipal Water District, as are the Farmersville #1 and #2 WWTPs and the Seis Lagos WWTP, which are permitted to discharge an average of 0.225, 0.53, and 0.25 MGD, respectively. The remainder of the WWTPs in the watershed are all considered to be minor discharges by the TCEQ with capacities ranging from 0.02 MGD to 0.105 MGD. These facilities are owned and operated by the communities they serve.

In addition, Melissa Feeders (NPDES Permit ID TXG921248) is a cattle feedlot located approximately 4 miles east of Melissa, TX and is the only permitted concentrated animal feeding operation (CAFO) in the watershed. It is permitted to apply manure at a controlled rate to land management units located in the area near the feedlot. A portion of these land management units include a turf farm, which is owned and operated by Melissa Feeders. The feedlot is estimated to generate a total of 19,491 tons of solid waste and 89.37 acre feet of wastewater annually.

Table 2.3. Active WWTPs in the Lavon Lake watershed.

WWTP Name	NPDES Permit ID	Latitude Decimal	Long. Decimal	Permitted Avg. Daily Discharge	Receiving Waterbody
Collin County Adventure Camp WWTP	TX0126241	33.373974	-96.471335	0.032 MGD	Elm Grove Creek – Sister Grove Creek
Collin Park Marina WWTP	TX0057959	33.048258	-96.534406	0.02 MGD	Lavon Lake
Blue Ridge WWTP	TX0026808	33.295111	-96.416361	0.28 MGD	Pilot Grove Creek
Farmersville WWTP #1	TX0076091	33.155667	-96.374694	0.225 MGD	Elm Creek
Farmersville WWTP #2	TX0103497	33.155667	-96.374694	0.53 MGD	Elm Creek
Gunter WWTP	TX0129224	33.431381	-96.706539	0.08 MGD	Stanley Creek – East Fk Trinity
Leonard WWTP	TX0054208	33.370389	-96.239694	0.8 MGD	Arnold Creek
Seis Lagos WWTP	TX0024988	33.077222	-96.565278	0.25 MGD	Unnamed trib. to Lavon Lake
Slayter Creek WWTP	TX0056677	33.331641	-96.566739	0.25 MGD	Slayter Creek – East Fk Trinity
Tom Bean WWTP	TX0055212	33.515361	-96.478306	0.15 MGD	West Fork Pilot Grove Creek
Trenton WWTP	TX0026749	33.425361	-96.346083	0.105 MGD	Indian Creek
Van Alstyne WWTP	TX0026883	33.420917	-96.549649	0.95 MGD	Unnamed trib. to Sister Grove Creek
Wilson Creek Regional WWTP	TX0088633	33.182924	-96.613137	56 MGD	Lavon Lake

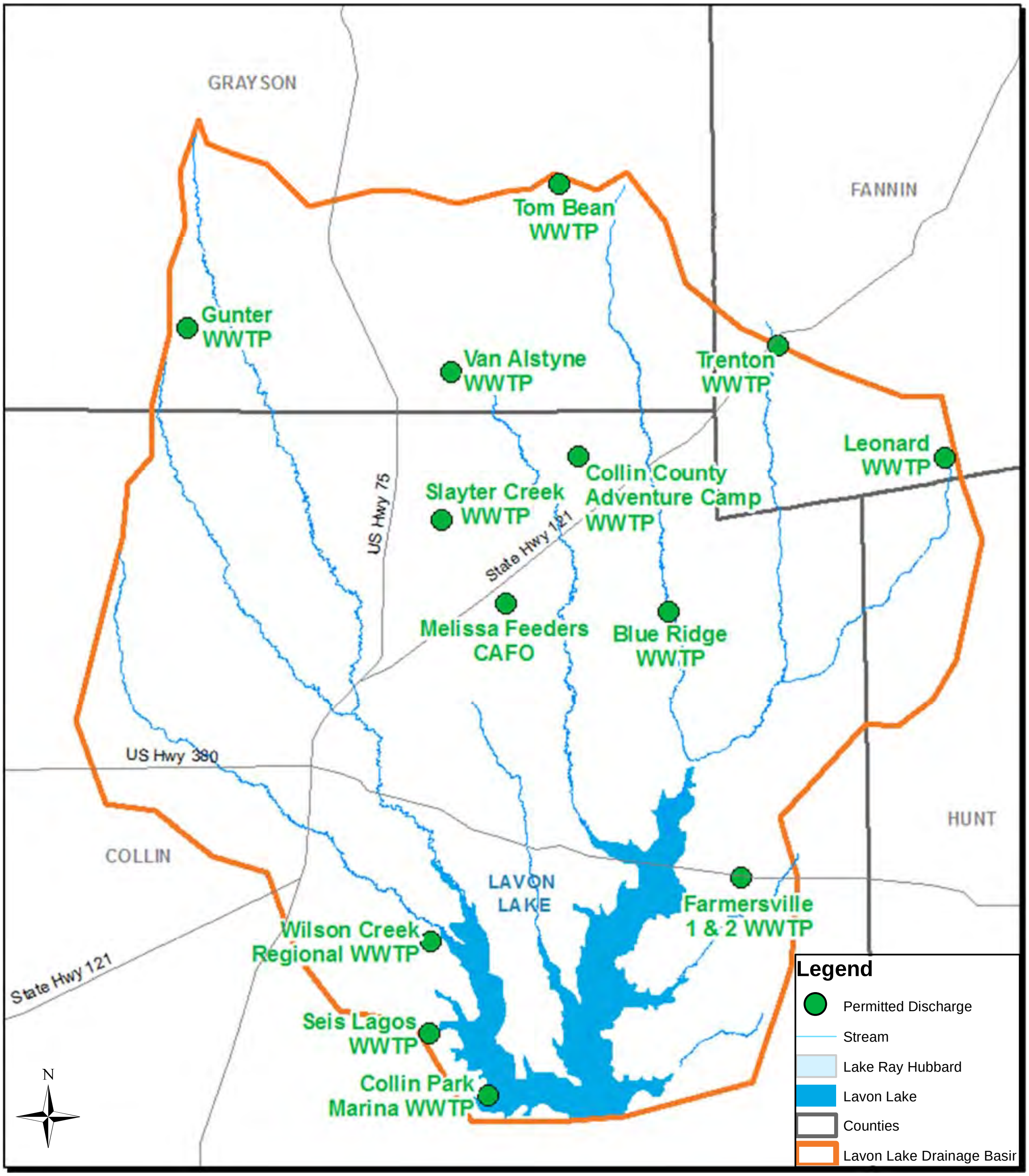

Figure 2.9. Permitted discharge locations in the Lavon Lake Watershed.

2.7 – WATER QUALITY

Lavon Lake is identified as segment 0821 and has been monitored by Texas Commission on Environmental Quality (TCEQ) and North Texas Municipal Water District under various state programs since 1971 (Figure 2.10). There are a total of 14 monitoring locations on Lavon Lake that are sampled monthly for water quality as part of the TCEQ Clean Rivers Program (CRP). In addition, there are single CRP monitoring locations located on the East Fork of the Trinity River, Pilot Grove Creek, Sister Grove Creek, and Wilson Creek. The East Fork of the Trinity River and Wilson Creek sites are sampled quarterly, whereas the Sister Grove Creek and Pilot Grove Creek sites are sampled monthly. Clean Rivers Program data from these locations are used to assess water quality against state and federal surface water quality standards. The Texas Integrated Report of Surface Water Quality, formerly known as the Texas Water Quality Inventory and 303d list, is prepared every two years by the TCEQ and describes the status of all water bodies sampled under the Clean Rivers Program during the most recent seven year period. Any water body not meeting state and federal water quality criteria for one or more of its designated uses is classified as impaired by the TCEQ. Designated uses which can be assigned to a waterbody in Texas include domestic water supply, categories of aquatic life use, recreational categories, and other basic uses. All waters in Texas are considered to have a primary contact recreation designated use unless demonstrated otherwise.

The East Fork of the Trinity River and Wilson Creek appeared on the 2010, 2012, and 2014 Texas Integrated Reports as impaired for elevated levels of bacteria (Table 2.4). Bacteria, specifically *E. coli* in freshwaters, are used to assess if a water body is attaining its contact recreation use. Stream segments are assessed by comparing the geometric mean of the *E. coli* bacteria data from the previous seven years to a standard. In Texas, the *E. coli* bacteria standard for primary contact recreation is 126 colony forming units per 100 milliliters (cfu/100mL). If the geometric mean of *E. coli* exceeds 126 cfu/100mL, the stream is impaired for bacteria. There are no other listed impairments in the watershed however, there is a concern for nitrate in Lavon Lake. It should be noted that although these issues persist, there is no concern for the quality of treated drinking water sourced from Lavon Lake.

Table 2.4. Bacteria impairments in the Lavon Lake watershed.

	Primary contact recreation standard	East Fork Trinity River *E. coli* geomean[1]	Wilson Creek *E. coli* geomean[1]	Date range used for data assessment
2010 Texas Integrated Report	126 cfu/100mL	150.19	174.29	2001 – 2008
2012 Texas Integrated Report	126 cfu/100mL	167.83	180.76	2003 – 2010
2014 Texas Integrated Report	126 cfu/100mL	150.62	164.25	2005 – 2012
2016 Texas Integrated Report	126 cfu/100mL	TBD	TBD	2007 – 2014

[1] All units are in cfu/100mL.

Figure 2.10. NTMWD staff collecting water quality data in the Lavon Lake watershed.

Since the data used to assess the tributaries draining into Lavon Lake were from a limited geographic range, the North Texas Municipal Water District, with support from Texas A&M AgriLife and the Texas State Soil and Water Conservation Board (TSSWCB), initiated an extensive water quality monitoring program in the Lavon Lake watershed as part of the WPP development process. The goal of this effort was to better characterize water quality across the watershed and to assist the Steering Committee and Partnership in developing an implementation strategy.

Data was collected at 20 sites throughout the watershed (Figure 2.11 and Table 2.5) and sampling was conducted at these sites on a monthly basis starting in April of 2016. Typically, a minimum of 7 years' worth of data is used to determine attainability of water quality standards. Therefore, additional data will be needed to fully assess water quality at each of the 20 sites.

Additionally, the NTMWD collects and analyzes water quality data on a monthly basis at the Lake Tawakoni, Jim Chapman Lake, and East Fork Reuse Project raw water intakes. This data is used to help ensure raw water from these sources will not cause detrimental effects to water quality when discharged to Lavon Lake. Although the East Fork of the Trinity River above the wetlands (Segment 0819) is listed as impaired for sulfate and total dissolved solids (TDS), the diluting effect of inputs from Lake Tawakoni, combined with the assimilative capacity of Lavon Lake, is thought to be sufficiently mitigating. However, further analysis may be needed fully assess the potential impact of TDS inputs on Lavon Lake. The TCEQ has also identified the Cowleech Fork of the Sabine River arm in Lake Tawakoni (Segment 0507_04) and portions of Jim Chapman Lake (Segment 0307) as impaired for elevated pH levels. According to the Texas Integrated Report, mean values for samples that exceeded the general use pH standard of 8.5 ranged from 8.6-8.68 in the six assessment units that make up Jim Chapman Lake. Also, it should be noted that the impaired portion of Lake Tawakoni is far from the NTMWD intake point. Nonetheless, water quality parameters, including pH, are monitored closely in and around NTMWD's Jim Chapman Lake and Lake Tawakoni pump stations.

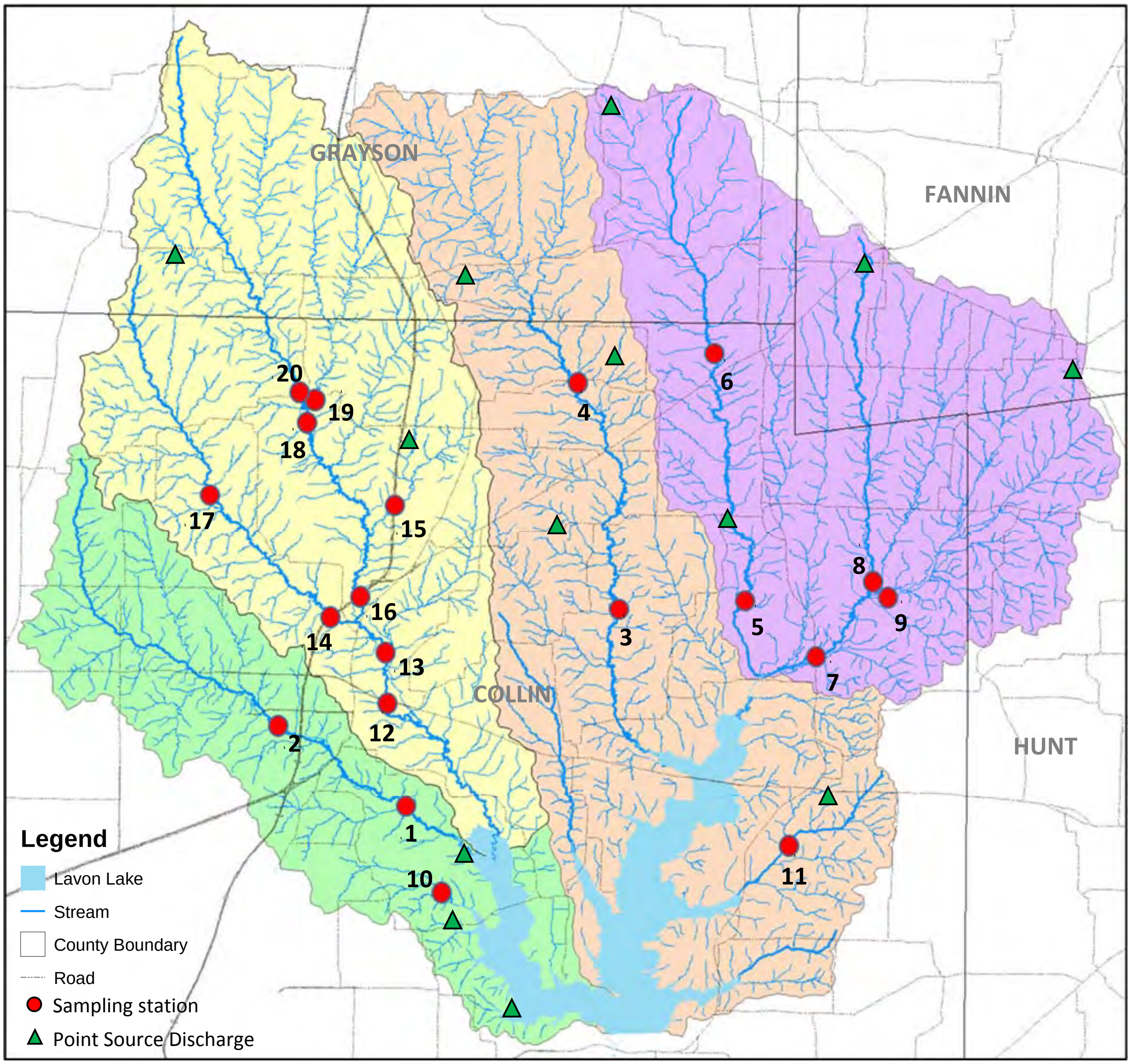

Figure 2.11. Water quality sampling stations in the Lavon Lake watershed.

Table 2.5. Sampling stations in the Lavon Lake watershed.

Site	Site Name	TCEQ Site ID	Latitude	Longitude	Description
1	Lower Wilson Creek	21764	33.14877222	-96.583.8611	WILSON CREEK AT CR317 NEAR MCKINNEY
2	Upper Wilson Creek	21765	33.18649722	-96.6448444	WILSON CREEK AT FOOT BRIDGE NEAR PARK VIEW AVENUE IN MCKIINEY
3	Sister Grove Creek	21766	33.24711944	-96.4746806	SISTER GROVE CREEK AT CR 470 APPROXIMATELY 6 MILES SW OF MELISSA
4	Headwaters Sister Grove Creek	21767	33.3676	-96.4946611	SISTER GROVE CREEK AT CR2862 APPROXIMATELY 4 MILES NE OF ANNA
5	Pilot Grove Creek	15692	33.253613	-96.412224	PILOT GROVE CREEK IMMEDIATELY DOWNSTREAM OF COLLIN CR 574 AND 3.2 MI SOUTH OF FM 5545 NEAR BLUE RIDGE
6	Headwaters Pilot Grove Creek	21768	33.38000556	-96.4249111	PILOT GROVE CREEK AT CR 584 APPROXIMATELY 2.5 MILES NE OF
7	Indian Creek	21769	33.22611389	-96.3734472	INDIAN CREEK AT SR 78 APPROXIMATELY 4.5 MILES NORTH OF FARMERSVILLE
8	Bear Creek-Indian Creek	21770	33.26345278	-96.3446444	BEAR CREEK AT CR 622 APPROXIMATELY 7 MILES NORTH OF FARMERSVILLE
9	Arnold Creek	21771	33.257575	-96.3357806	ARNOLD CREEK AT CR 664 APPROXIMATELY 6.5 MILES N. OF FARMERSVILLE
10	White Rock Creek	21772	33.10400278	-96.5649833	WHITE ROCK CREEK AT SNIDER LANE IN LUCAS
11	Elm Creek	21773	33.12769444	-96.3878917	ELM CREEK AT CR 605 APPROXIMATELY 3 MILES SW OF FARMERSVILLE
12	East Fork Trinity River 1	21774	33.20373333	-96.5959417	EAST FORK TRINITY RIVER AT US 380/EAST UNIVERSITY DRIVE NEAR MCKINNEY
13	East Fork Trinity River 2	21775	33.22430833	-96.5956056	EAST FORK TRINITY RIVER AT CR 331 NEAR MCKINNEY
14	Lower Honey Creek	21776	33.24653889	-96.6240861	HONEY CREEK AT US 75 NEAR MCKINNEY
15	Throckmorton Creek	21777	33.30101667	-96.5909	THROCKMORTON CREEK AT US 75 APPROXIMATELY 1.5 MILES NE OF MELISSA
16	East Fork Trinity River 3	21778	33.25772222	-96.6095917	EAST FORK TRINITY RIVER AT US 75 NE OF MCKINNEY
17	Upper Honey Creek	20932	33.31151	-96.68522	HONEY CREEK 40 M UPSTREAM OF COLLIN CR 170 4.3 KM SW OF WESTON AND 2.3 KM NORTHWEST OF INTERSECTION OF FM 543 AND COLLIN CR 170
18	East Fork Trinity River 4	21779	33.34946944	-96.6376056	EAST FORK TRINITY RIVER AT CR 210 APPROXIMATELY 1.8 MILES EAST OF WESTON
19	Whites Creek	21780	33.36174444	-96.6314944	WHITES CREEK AT CR 455 APPROXIMATELY 2.4 MILES NE OF WESTON
20	East Fork Trinity River 5	21781	33.36026667	-96.6403556	EAST FORK TRINITY RIVER AT CR 455 APROXIMATELY 1.8 MILES NE OF WESTON

2.8 – WATERSHED SELECTION

Lavon Lake was selected for WPP development due to three primary factors: 1) two of its tributaries had been listed as impaired due to bacterial levels in exceedance of the primary contact recreation use standard, 2) the identification of a nitrate concern in lower portion of the reservoir, and 3) its importance as a domestic drinking water source for the region. In order to support the WPP development process for Lavon Lake, the NTMWD partnered with Texas A&M AgriLife and obtained a State Nonpoint Source Program grant from the TSSWCB. These funds allowed for water quality data collection, watershed analysis, and facilitation of a Watershed Partnership to support WPP development.

Furthermore, in 2015, Texas A&M AgriLife, in coordination with the North Central Texas Council of Governments (NCTCOG), Texas Institute for Applied Environmental Research (TIAER), and the TCEQ, held the first meeting of the Upper Trinity River Basin Coordinating Committee (UTRBCC). This meeting was held as part of the 303(d) Vision Project in Texas, which outlines a strategy for improving on the TMDL approach by giving credit for the use of alternative methods for addressing water quality impairments, such as WPPs. Thus, two primary goals of the UTRBCC were to raise awareness about water quality impairments in the Upper Trinity Basin and facilitate the development of watershed plans. The UTRBCC identified a need for a watershed protection plan to address the bacteria impairments on the East Fork of the Trinity River above Lavon Lake and Wilson Creek, which furthered NTMWD's decision to develop a WPP for Lavon Lake.

3. The Lavon Lake Watershed Partnership

3.1 – PARTNERSHIP FORMATION

Local public involvement is critical for successful development and implementation of a WPP. To inform and educate citizens from across the watershed and engage them in the planning process, an information and education campaign was conducted at the outset of the project. Press releases were developed and delivered in the watershed in advance of the planning process using key media outlets including local newspapers and newsletters. Stakeholders were defined as those who make and implement decisions, those who are affected by the decisions made, and those who have the ability to assist with implementation of the decisions.

Following these efforts, two public meetings were announced and held on two dates in September 2016, with one in McKinney, TX and one in Wylie, TX. Seventy-eight stakeholders attended these public meetings where information was provided regarding conditions in the Lavon Lake watershed and the proposed development of a WPP. Participants were invited to become members of the Lavon Lake Watershed Partnership and asked to help notify other potential stakeholders that should be part of the process.

3.2 – PARTNERSHIP MEETINGS

Monthly public meetings facilitated by North Texas Municipal Water District and Texas A&M AgriLife Extension were held in the watershed (Figure 3.1). Technical issues were presented in detail to the Partnership for discussion and evaluation, and recommendations were developed and forwarded to the Steering Committee for consideration and approval. All meetings were open to the public, with announcements sent out via e-mail and news release, and posted on the project website. A total of six Partnership meetings were conducted during the plan development process.

Figure 3.1. Stakeholders participated in numerous Lavon Lake watershed meetings.

3.3 – PARTNERSHIP STRUCTURE

3.3.1 – Steering Committee Membership

A Steering Committee composed of stakeholders from the Lavon Lake Watershed was formed to serve as a decision making body for the Partnership. To obtain equitable geographic and topical representation, solicitations for Steering Committee members were conducted using three methods: 1) as part of the public meetings held in the watershed, 2) at meetings with various stakeholder interest groups and individuals, 3) and following consultation with Texas A&M AgriLife Extension Service County Agents, Soil and Water Conservation Districts in the watershed, and local and regional governments. Self-nomination or requests by various stakeholder groups or individuals were welcomed.

The Steering Committee was designed to reflect the diversity of interests within the Lavon Lake Watershed and to incorporate the viewpoints of those who will be affected by the WPP. Members include both private individuals and representatives of organizations and agencies. Size of the Steering Committee was limited to 15 members solely for reasons of practicality.

Types of stakeholders represented on the Steering Committee were:

- Land owners
- Business and industry representatives
- Agriculture producers
- Educators
- County and city officials
- Citizen groups
- Environmental and conservation groups
- Soil and water conservation districts

Ground rules were developed in order for the members to understand their roles and responsibilities, as well as, to provide guidance throughout the development and implementation of the WPP (Appendix C). Clear ground rules added structure and improved the efficiency of the group.

The Steering Committee considered and incorporated the following into the development of the WPP:

- Economic feasibility, affordability and growth;
- Unique environmental resources of the watershed;
- Regional planning efforts; and
- Regional cooperation.

Development of the Lavon Lake WPP required an 8-month period. However, achieving water quality improvements likely will require significantly more time, since implementation is an iterative process of executing programs and practices with evaluation of results and interim milestones and reassessment of strategies and recommendations. Because of this, the Steering Committee will continue to function throughout implementation of the WPP.

Committee members assisted with identification of the desired water quality conditions and measurable goals, prioritization of programs and practices to achieve water quality and programmatic goals, development and review of the WPP document, and communication regarding implications of the WPP to other affected parties in the watershed.

As an expression of their approval and commitment to successful implementation of the plan, Steering Committee members signed the final WPP.

3.3.2 – Technical Advisory Group

A Technical Advisory Group (TAG) consisting of state and federal agencies with water quality responsibilities provided guidance to the Steering Committee and Partnership. The TAG assisted with WPP development by serving as a technical resource and answering questions related to the jurisdictions of their agencies. The TAG included representatives from the following agencies:

- Army Corps of Engineers (ACOE)
- North Texas Municipal Water District (NTMWD)
- Texas Commission on Environmental Quality (TCEQ)
- Texas A&M AgriLife Extension Service (AgriLife Extension)
- Texas A&M AgriLife Research (AgriLife Research)
- Texas Department of Agriculture (TDA)
- Texas Parks and Wildlife Department (TPWD)
- Texas State Soil and Water Conservation Board (TSSWCB)
- Texas Water Development Board (TWDB)
- U.S. Environmental Protection Agency (EPA)
- U.S. Geological Survey (USGS)
- United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS)
- USDA Farm Service Agency (USDA-FSA)

4. Methods of Analysis

4.1 – LAND USE CLASSIFICATION

In order for the Lavon Lake Watershed Partnership to begin to analyze the water quality data, identify potential sources of pollutant loading, and make recommendations on possible management measures, an analysis of land use in the watershed was conducted (Figures 4.1 & 4.2).

The first step in development of the land use dataset was to select appropriately dated imagery for the Lavon Lake watershed. This was accomplished using aerial imagery available through the National Agriculture Imagery Program (NAIP), Texas Orthoimagery Project (TOP), and Landsat-8 databases. NAIP imagery used for this analysis were taken during 2014, while TOP and Landsat-8 imagery were taken during 2015. TOP, NAIP, and Landsat-8 images have a resolution of ½ meter, 1 meter, and 30 meters, respectively. Major land use types included in the classification were urban land, open water, rangeland, managed pasture, forest, and cultivated crops (Figure 4.2, See Appendix D for complete descriptions and a full explanation of land use data).

Figure 4.1 Example of rangeland in the Lavon Lake watershed.

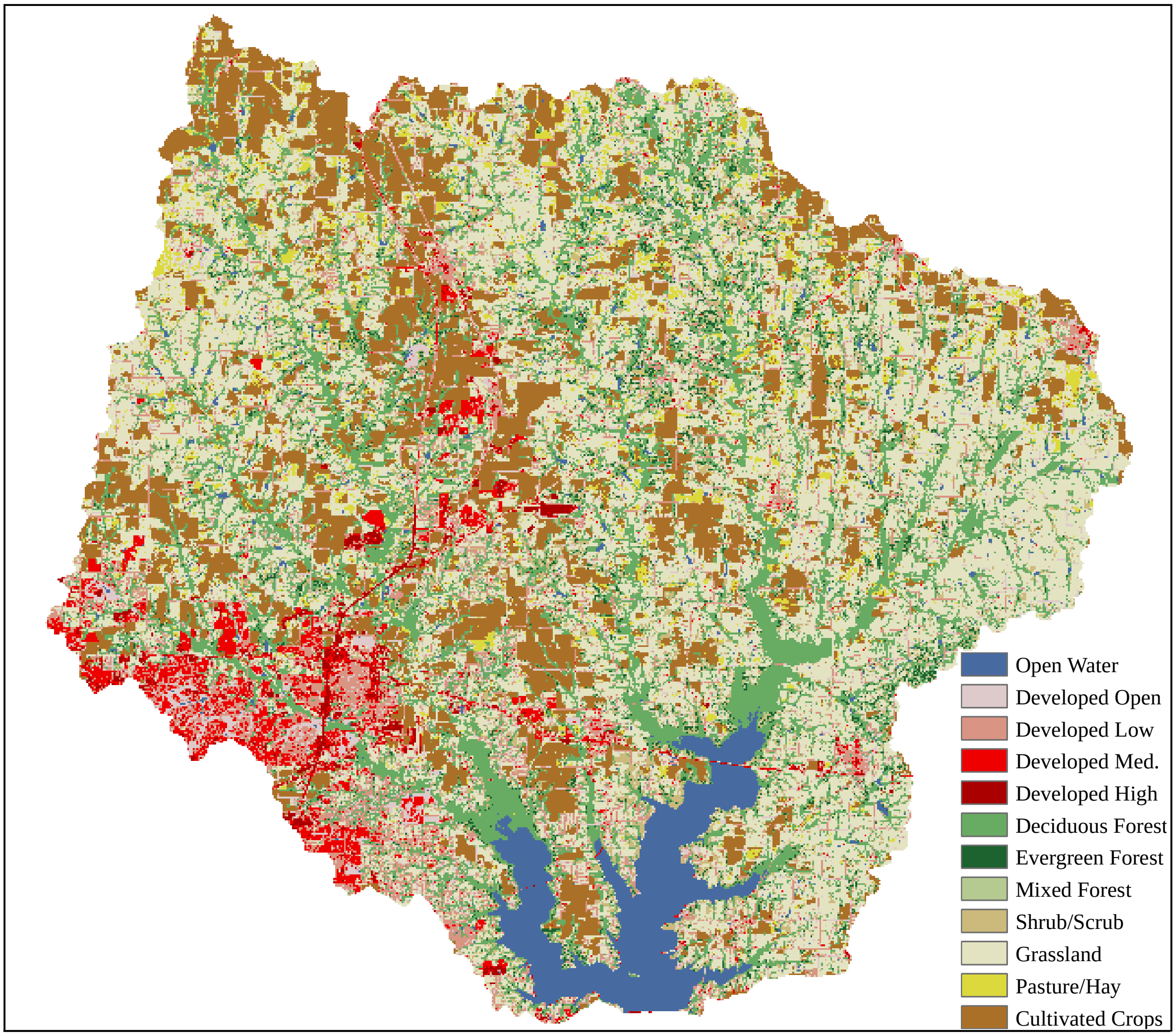

Figure 4.2. Lavon Lake watershed land use map.

Land parcels were assigned to classes based on attributes including vegetation, hydrology, and level of urban development. For descriptive purposes, similar land uses were aggregated where appropriate. For example, the urban land use category includes four subcategory land uses: open, low, medium, and high intensity urban development, and the rangeland category includes grassland and shrub/scrub. The watershed is made up of approximately 40% rangeland, 20% forest, 17% cultivated crops, 15% urban, and 4% managed pasture (Table 4.1).

Table 4.1. Summary of land uses in the Lavon Lake watershed.

Land Use	Percentage of Total	Acres
Rangeland	39.7	195,219
Forest	19.6	96,503
Cultivated crops	17.2	84,827
Urban	15.1	74,233
Open water	4.7	23,235
Managed pasture	3.7	18,078
Total	100.0	492,095

4.1.1 – Subwatershed Delineation

To enable closer examination of potential pollutant sources and as a tool to assist in focusing implementation efforts, the watershed was divided into 20 subwatersheds (HUC12) based upon elevation and hydrological characteristics (Figure 4.3).

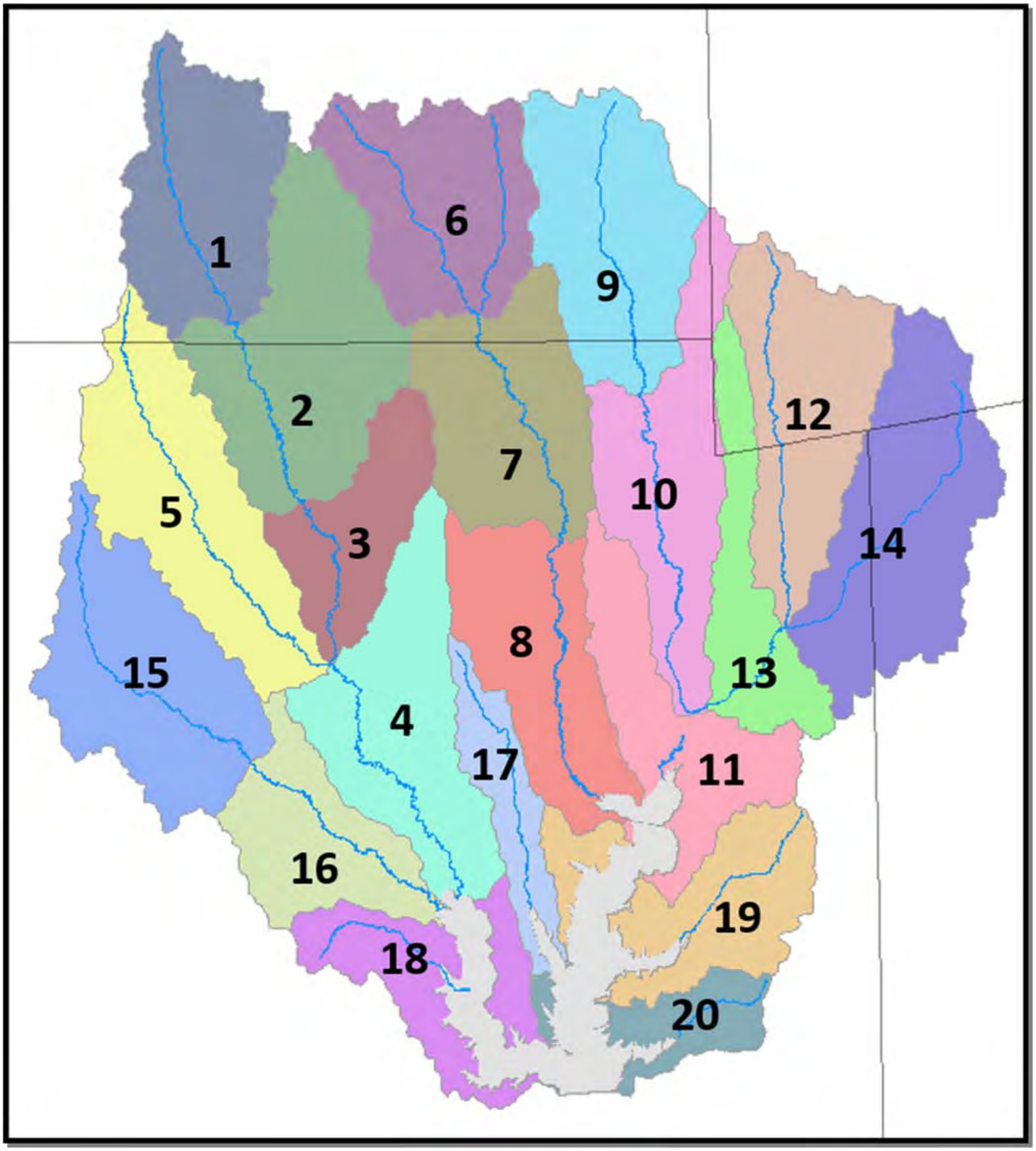

Figure 4.3. Subwatersheds of the Lavon Lake watershed.

4.2 – DETERMINING SOURCES OF POLLUTION

4.2.1 – Load Duration Curve

A widely accepted approach for analyzing water quality data is the use of a Load Duration Curve (LDC). A LDC enables determination and visual representation of pollutant loadings under different flow conditions. The first step in developing a LDC is construction of a Flow Duration Curve. Flow data for a particular sampling location are sorted in order and then ranked from highest to lowest to determine the frequency of a particular flow in the stream. These results are used to create a graph of flow volume versus frequency which produces the flow duration curve (Figure 4.4).

Step 1: Flow Duration Curve Calculation

Due to the inherent variability between monitoring locations, streamflow and water quality data used for LDC development must come from the same site. Although there are four USGS stream flow gages in the Lavon Lake Watershed that record daily streamflow, adequate water quality data for LDC development is not available at these locations. Thus, flow duration curves were developed using streamflow data that was collected at locations where routine water quality monitoring is conducted (Table 4.2 and Figure 4.5).

Streamflow data from these locations were analyzed to determine flow rate frequencies. For example, as shown in Figure 4.4, approximately 75% of flow observations in the East Fork of the Trinity River exceeded 1 cubic feet per second (cfs). It should be noted that the flow rates in Figure 4.4 are shown in logarithmic scale.

Table 4.2 Sampling sites used for LDC development

Waterbody Name	TCEQ Site ID	Year site was established	Data range used for analysis
East Fork of the Trinity River	13740	1981	1981-2016
Pilot Grove-Indian Creek	21717	2007	2007-2017
Sister Grove Creek	21396	2009	2009-2017
Wilson Creek	10777	1988	1988-2016

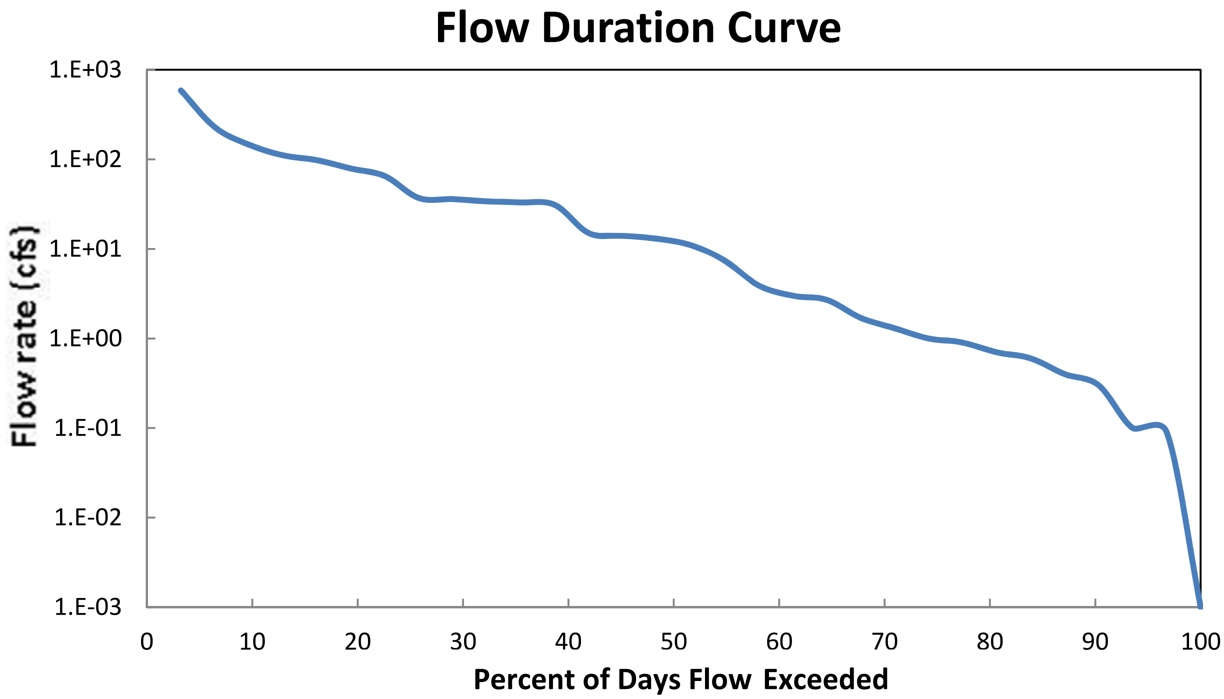

Figure 4.4. East Fork Trinity River flow duration curve. Historical stream flow data from TCEQ site 13740 were used to determine how frequently stream conditions exceed different flows (cfs = cubic feet per second).

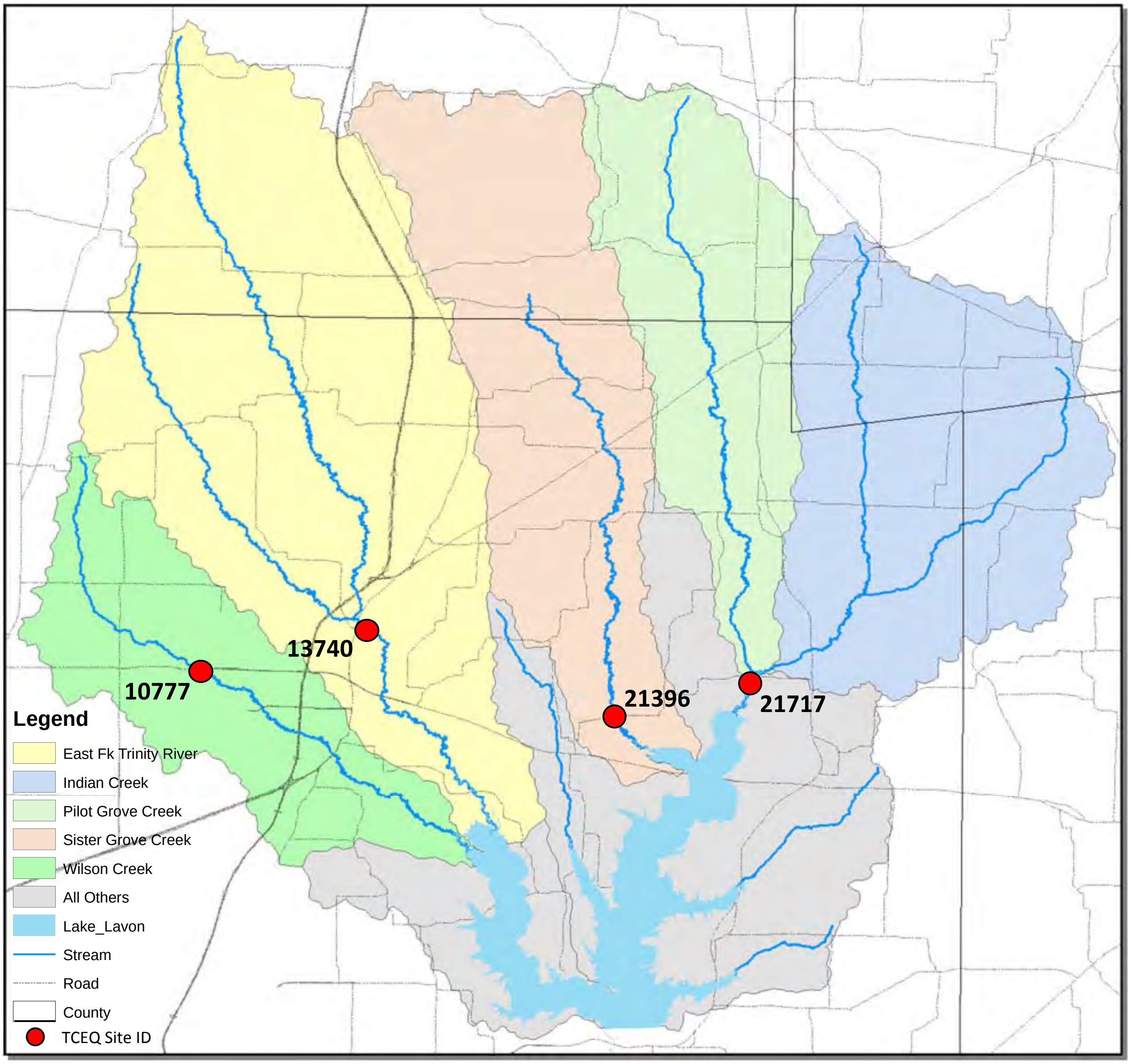

Figure 4.5 A Map of historical monitoring sites used for LDC development in the Lavon Lake watershed.

Step 2: Load Duration Curve Calculation

Next, data from these flow duration curves are multiplied by the water quality goal for the pollutant to produce the LDC (Figure 4.6). This curve shows the maximum pollutant load (amount per unit time; e.g., for bacteria, cfu/day; for nitrogen and phosphorus, grams/day) a stream can assimilate across the range of flow conditions (low flow to high flow) without exceeding the water quality goal. This pollutant load threshold is often referred to as a Total Maximum Daily Load (TMDL) calculation. Flow regimes typically are identified as areas of the LDC where the slope of the curve changes. In this example, as in the actual LDCs for the aforementioned tributaries to Lavon Lake, there are three flow regimes: high flows (0-10), mid-range (11-90), and low flows (91-100).

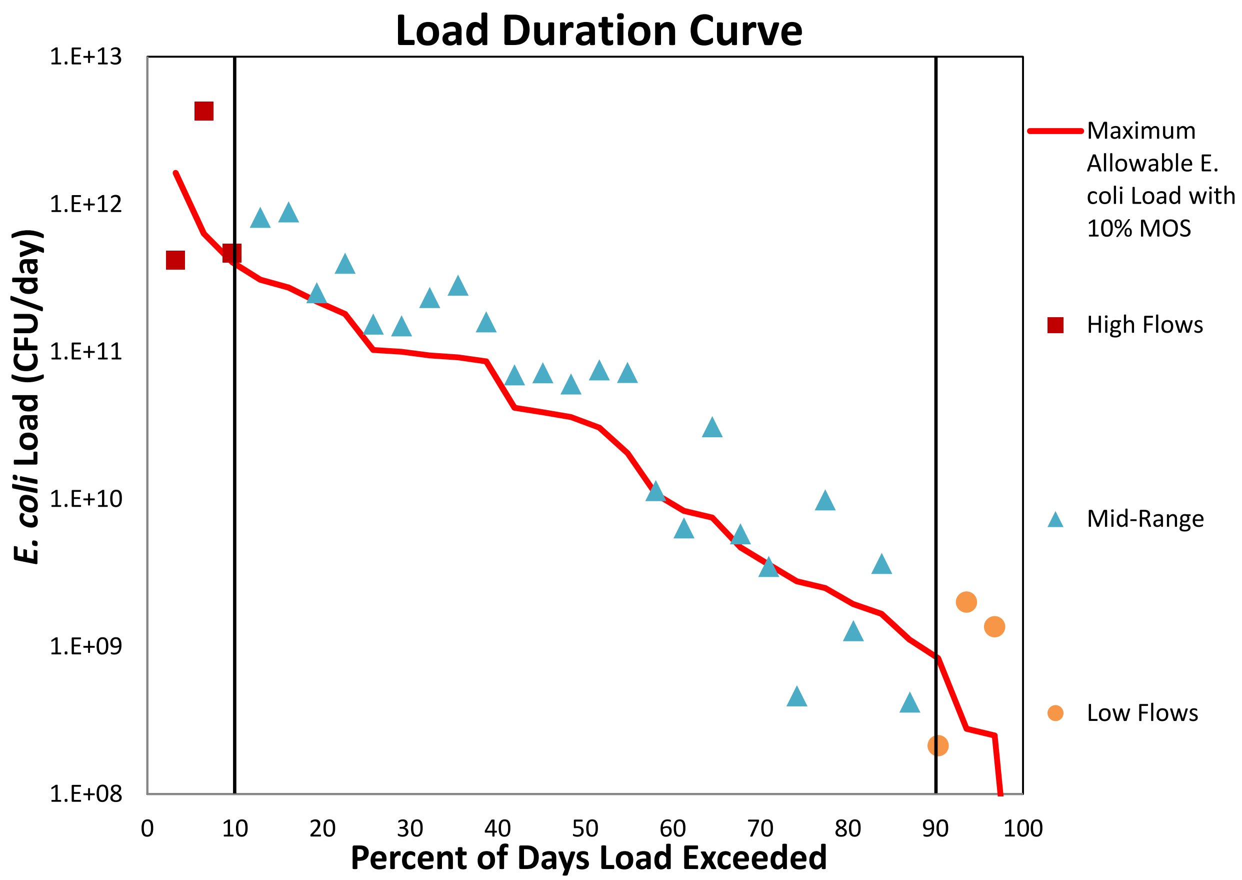

Figure 4.6. East Fork of the Trinity River load duration curve. Multiplying stream flow by pollutant concentration produces an estimate of pollutant load.

Stream monitoring data for a pollutant then can be plotted on the curve to show the frequency and magnitude of exceedances. In the example in Figure 4.6, the red line indicates the maximum acceptable stream load for *E. coli* bacteria, and the squares, triangles, and circles represent water quality monitoring data collected under high, mid-range, and low flow conditions, respectively. Where the monitoring samples are above the red line, the actual stream load has exceeded the water quality standard. Points located on or below the red line are in compliance with the water quality standard.

In order to analyze the entire range of monitoring data, regression analysis is conducted using the monitored samples to calculate the "line of best fit" (blue line). In Figure 4.7, where the blue line is on or below the red line, monitoring data at that flow percentile are in compliance with the water quality standard. Where the blue line is above the red line, monitoring data indicate that the water quality standard is not being met at that flow percentile. Regression analysis also enables calculation of the estimated percent reduction needed to achieve acceptable pollutant loads. In this example, load reductions of 54, 33, and 0% are needed at high, mid-range and low flows, respectively.

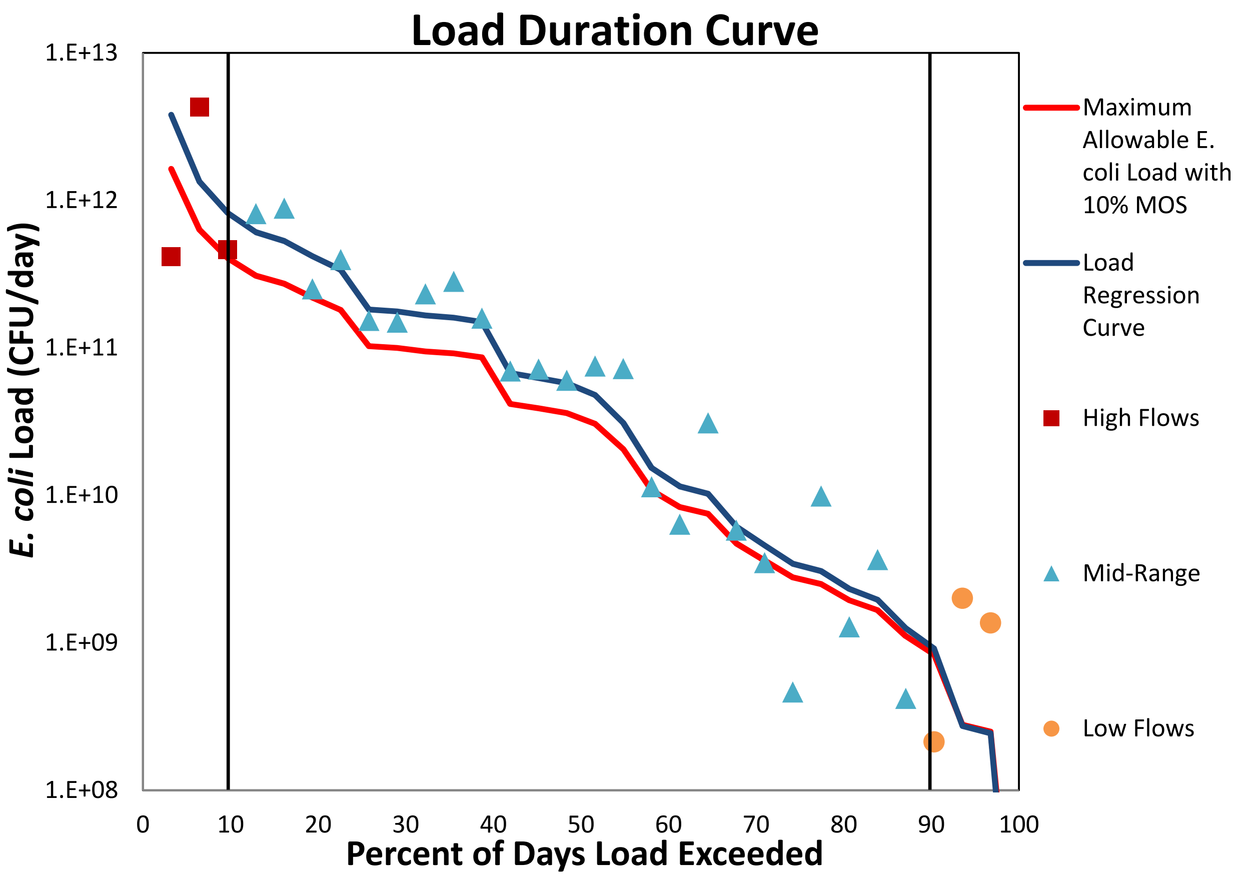

Figure 4.7. East Fork of the Trinity River load duration curve with monitored samples and calculated "line of best fit."

Typically, a margin of safety (MOS) is applied to the threshold pollutant concentration to account for possible variations in loading due to sources, stream flow, effectiveness of management measures, and other sources of uncertainty. The Steering Committee selected a 10% MOS for pollutants in this plan. For example, although the regular standard for *E. coli* bacteria is 126 cfu/100 mL, a more conservative threshold concentration of 113 cfu/100 mL [126 – (126 x 0.1)] was used in LDC analyses for the Lavon Lake watershed.

By considering the processes at work during high, mid-range, and low flows, it is possible to link pollutant concentrations with potential point or nonpoint sources of pollution. In general, if exceedances observed on the LDC only occur during high flows, nonpoint sources are likely to be the primary causes of impairment. This is because high flows typically are associated with higher rainfall events that generate surface runoff which can carry pollutants to the stream. In contrast, exceedances at low flows generally are attributed to point sources since no runoff is entering the stream and only direct discharges or deposition into the stream are contributing (see Appendix E for a more detailed explanation of a Load Duration Curve).

4.2.3 – Estimate of Pollutant Loads and Required Reductions

As previously mentioned, LDCs can be used to determine load reduction requirements by calculating the difference between the load regression curve for sampling data to the maximum allowable load for each percentile (i.e. TMDL). The TCEQ sites identified in Table 4.2 were used to determine load reduction goals for the watershed. These sites were selected because they are utilized by the TCEQ for assessment purposes as part of the Texas Integrated Report of Surface Water Quality. Also, these locations have historic water quality monitoring data available that is sufficient for LDC development.

4.2.4 – Spatially Explicit Load Enrichment Calculation Tool

To estimate the likely distribution of potential pollutant sources across the watershed and the degree of contribution by each, the Steering Committee utilized the Spatially Explicit Load Enrichment Calculation Tool (SELECT) developed by the Spatial Sciences Laboratory and the Biological and Agricultural Engineering Department at Texas A&M University. Each bacteria pollutant source identified by the Steering Committee was distributed across the 20 subwatersheds based on the best available data and information regarding its presence in a given subwatershed. Bacteria loads were estimated for each source in each subwatershed based on known pollutant production rates. By so doing, areas and sources with the greatest potential for impacting water quality were identified and targeted for implementation. A more complete explanation of the SELECT approach can be found in Appendix F.

It is important to note that SELECT evaluates the **potential** for pollution from the possible bacteria sources and subwatersheds, resulting in a relative approximation for each area. Sources with high loading potential are then evaluated to determine if necessary controls are already in place or if action should be taken to reduce pollutant contributions. It should also be noted that the sources of bacteria identified by the Steering Committee are also sources of nitrogen and phosphorus. Thus, even though SELECT is not capable of estimating potential nutrient loads, the resulting analysis can be used to make informed decisions about nutrient management measures in the watershed.

4.2.5 – Soil and Water Assessment Tool

The Soil and Water Assessment Tool (SWAT) is a river basin, or watershed, scale model developed to quantify and predict the impacts of land management practices on water, sediment, and agricultural chemical yields over a long period of time (AgriLife, 2016). Inputs to the SWAT model include weather, soil properties, topography, vegetation, land management practices, and much more. SWAT uses these inputs to simulate a number of complex watershed processes including, water movement, sediment movement, and nutrient cycling.

SWAT has been used as part of previous efforts to analyze sediment and nutrient loading in the Lavon watershed. Specifically, there have been three studies published since 2006 that used SWAT to evaluate sediment, nutrient, and pesticide loading in the Lavon Lake watershed (USDA, 2006; Wang, 2013; Lee, 2015). Results of these analyses were used to assess pollutant sources and make decisions about management measures in this plan.

In addition to these aforementioned studies, SWAT was used to simulate streamflow for LDC analysis on Sister Grove and Pilot Grove Creeks on days where measured streamflow data was not available. Streamflow measurements were not collected on these tributaries prior to 2016 and therefore, SWAT analysis was used to simulate many of the historic flow data used for LDC analysis on Sister Grove and Pilot Grove Creeks. SWAT was calibrated and validated using USGS stream gages in the watershed.

4.2.6 – Data Limitations

When evaluating the relationships between instream conditions and factors in the surrounding landscape, it is important to consider all potential sources of pollution and rely on the most dependable and current data available. In addition to receiving input from local stakeholders, information used in the analysis of the Lavon Lake watershed was gathered from a number of sources, including local and regional groups, river authorities, and county, state, and federal agencies.

It also is important to remember that information collected for the development of the Lavon Lake WPP represents a snapshot in time of a host of complex processes at work. Whether associated with human activities and urban growth, weather patterns, animal distribution, or other factors, the Lavon Lake watershed is very dynamic in nature, and conditions can change dramatically between years and within a given season. Furthermore, time lags often exist between population census counts and remapping, and updating of land cover and land information use. As a result, contributions from individual pollutant sources may vary considerably over time.

4.3 – DETERMINING BACTERIA LOADS

East Fork of the Trinity River

LDC analysis for TCEQ site 13740 indicates that the bacteria water quality standard is not supported at mid-range and high flows (Figure 4.8). Based on the regression analysis, reductions in *E. coli* loads of 54% and 33% will be required at high and mid-range flows, respectively, to achieve the water quality criterion for primary contact recreation.

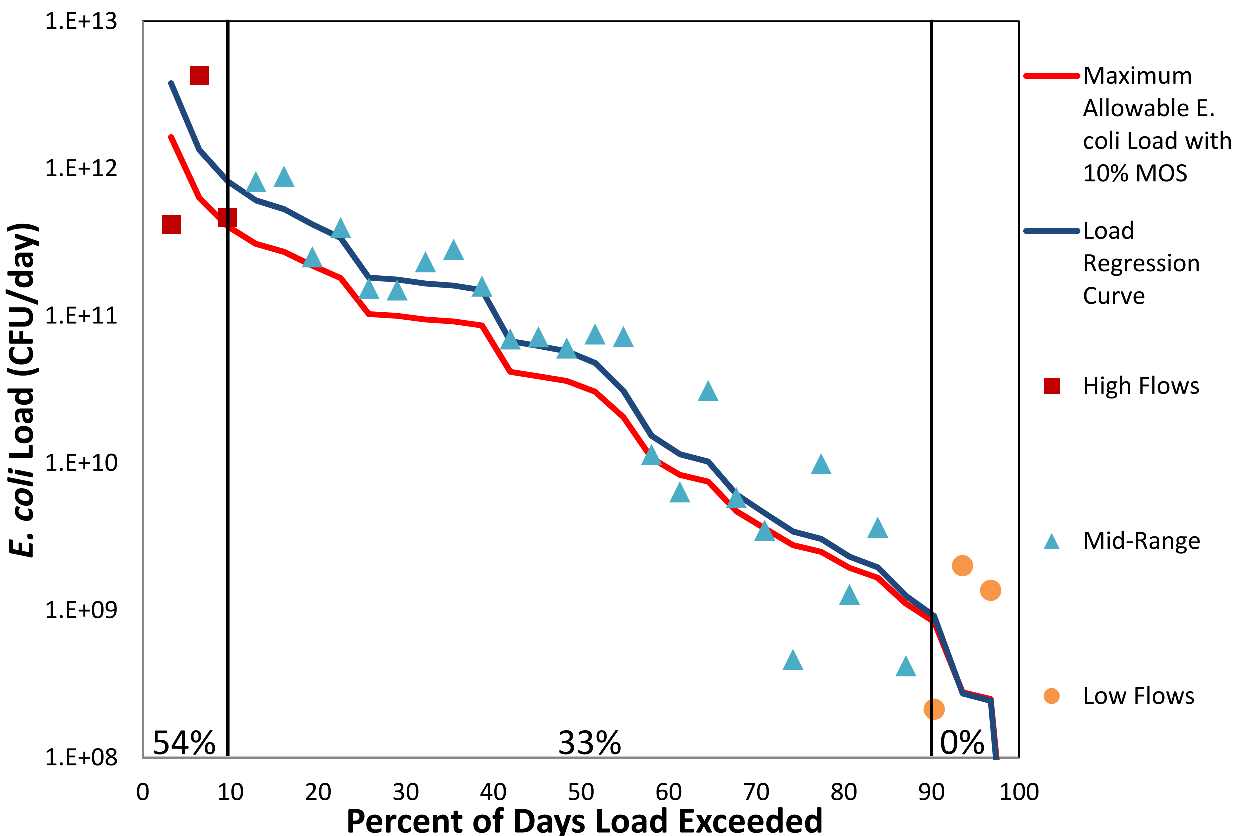

Figure 4.8. East Fork of the Trinity River load duration curve for *E. coli* at the TCEQ 13740 monitoring station. (2004-2016; n=31)

Pilot Grove-Indian Creek

Although Pilot Grove Creek has not been identified as impaired by the TCEQ, LDC analysis for TCEQ site 21717 indicates that the bacteria water quality standard is not supported at high and mid-range flows (Figure 4.9). A reduction in *E. coli* loads of 70% and 27% will be required at high and mid-range flows, respectively, to achieve the water quality criterion for primary contact recreation. It is important to note that analysis was conducted using a relatively small dataset from 2016-2017 due to a lack of historic *E. coli* data. Also, SWAT was used to simulate flows for this LDC analysis on days when measured streamflow data was not available. The sharp change in *E. coli* loads in the mid-range flow regime is due to SWAT analysis and field measurements indicating that Pilot Grove Creek experiences low-flow and no-flow conditions over 50% of the time. This is indicative of an ephemeral stream and is consistent with stakeholder observations.

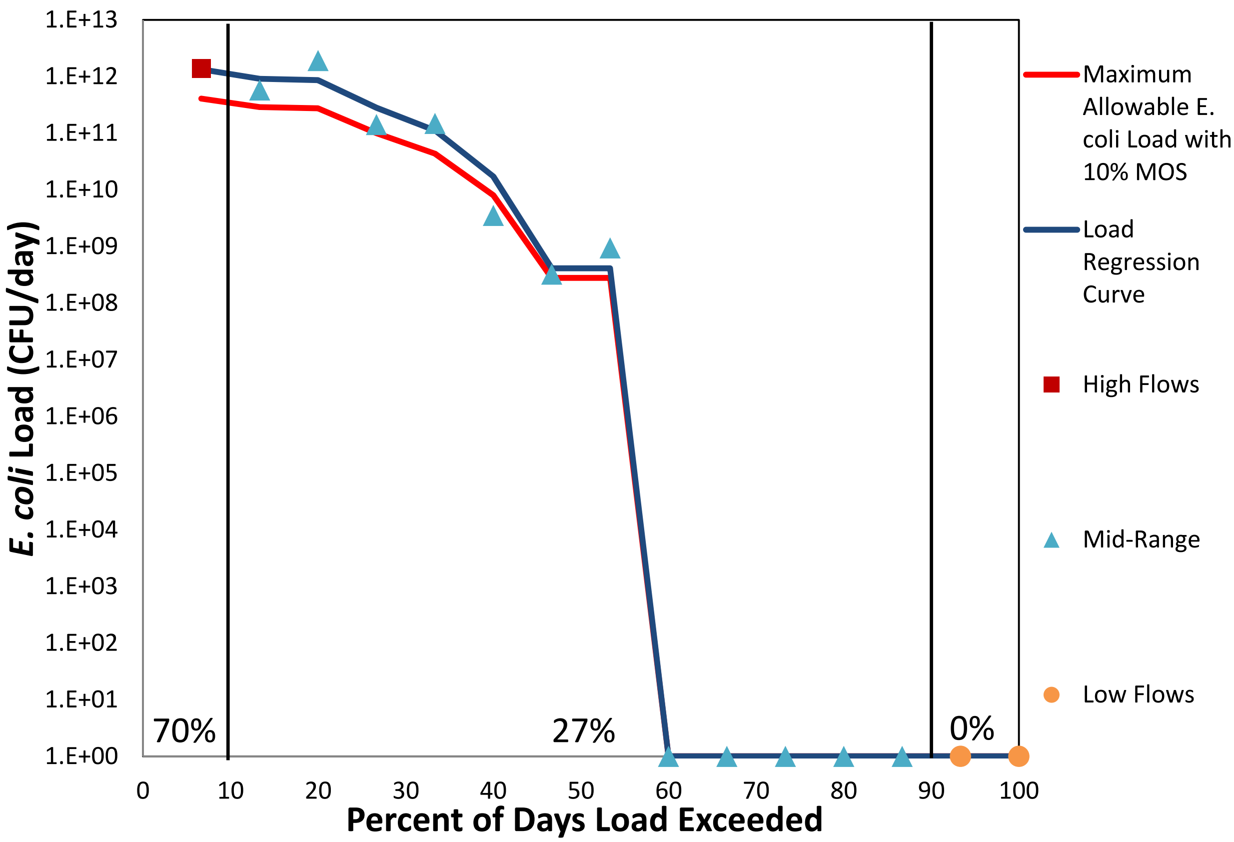

Figure 4.9. Pilot Grove Creek load duration curve for *E. coli* at the TCEQ 21717 monitoring station. (2016-2017; n=13)

Sister Grove Creek

Although Sister Grove Creek has not been identified as impaired by the TCEQ, LDC analysis for TCEQ site 21396 indicates that the bacteria water quality standard is not supported at high and mid-range flows (Figure 4.10). A reduction in *E. coli* loads of 66% and 23% will be required at high and mid-range flows, respectively, to achieve the water quality criterion for primary contact recreation. It is important to note that this analysis was conducted using a relatively small dataset from 2016-2017 due to a lack of historic *E. coli* data. Also, SWAT was used to simulate flows for this LDC analysis on days when measured streamflow data was not available. The sharp change in *E. coli* loads in the mid-range flow regime is due to SWAT analysis and field measurements indicating that Sister Grove Creek experiences low-flow and no-flow conditions approximately 50% of the time. This is indicative of an ephemeral stream and is consistent with stakeholder observations.

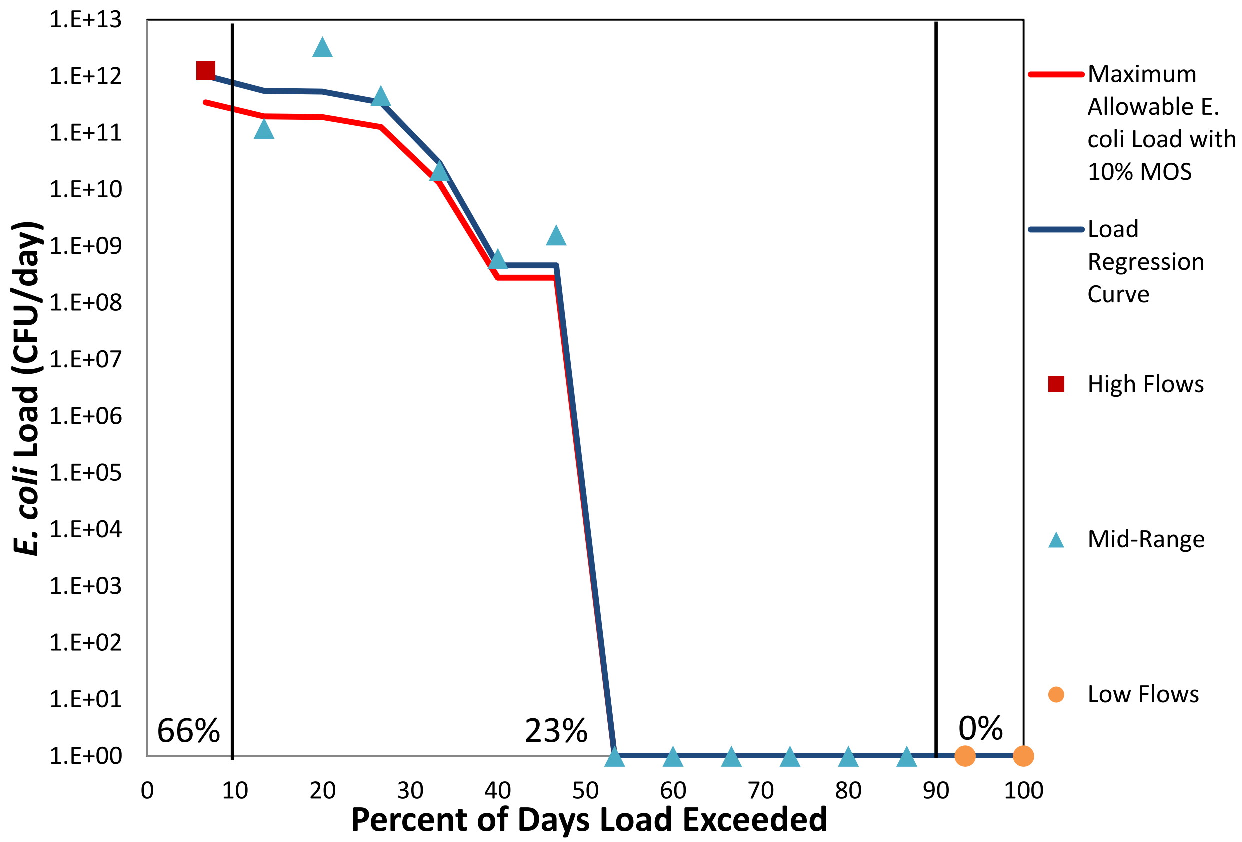

Figure 4.10. Sister Grove Creek load duration curve for *E. coli* at the TCEQ 21396 monitoring station. (2016-2017; n=14)

Wilson Creek

LDC analysis for TCEQ site 10777 indicates that the bacteria water quality standard is not supported at high and mid-range flows (Figure 4.11). A reduction in *E. coli* loads of 80% and 49% will be required at high and mid-range flows, respectively, to achieve the water quality criterion for primary contact recreation.

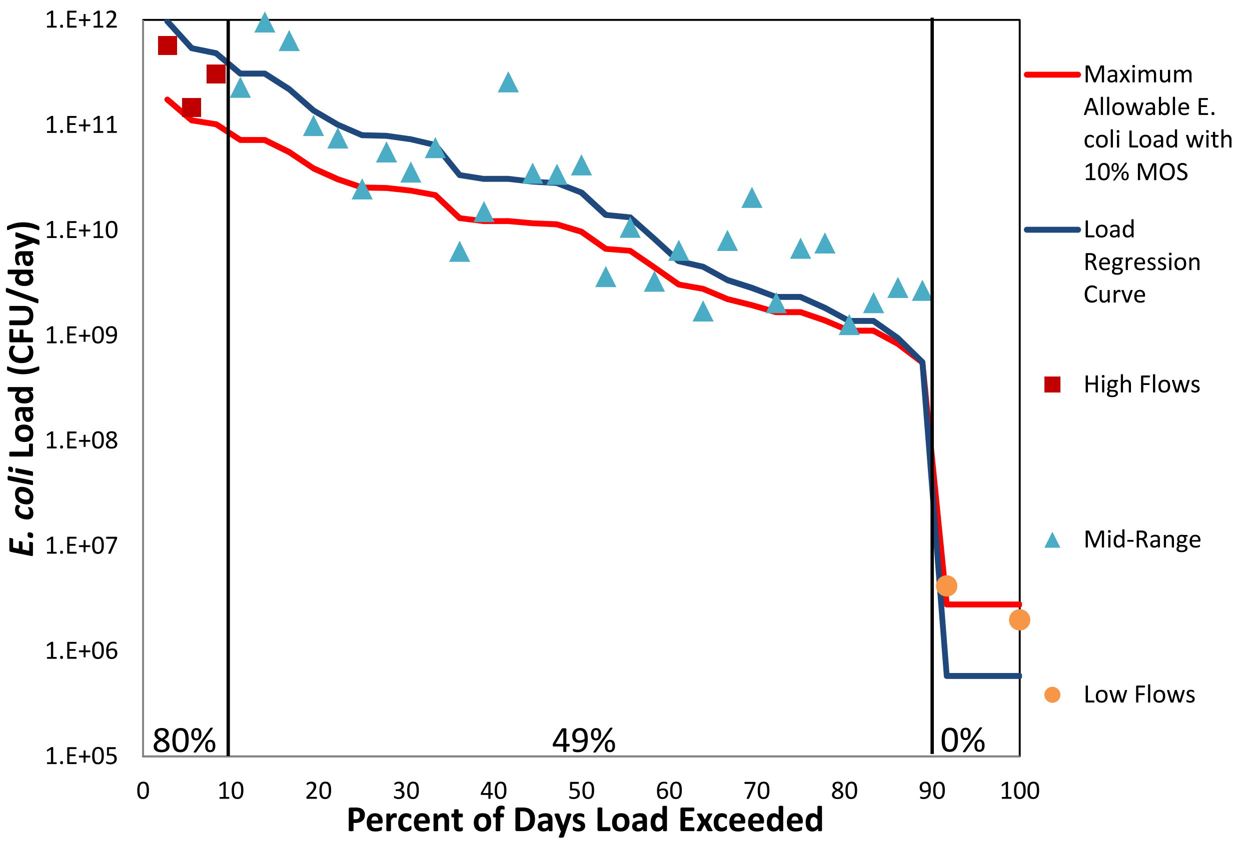

Figure 4.11. Wilson Creek load duration curve for *E. coli* at the TCEQ 10777 monitoring station. (2003-2016; n=36)

4.4 – DETERMINING SEDIMENT LOADS

LDC analysis was not performed for sediment loading in the watershed due to a lack of historic sampling data. However, estimates from previously conducted SWAT analyses provide enough information about sediment loading to Lavon Lake to make decisions about management measures.

Specifically, the work published by Wang et al. in the 2013 the Journal of Soil and Water Conservation evaluated streamflow and sediment loading into twelve major reservoirs in the Upper Trinity River Basin. This study utilized the SWAT model to predict long term sedimentation trends in these reservoirs, which includes Lavon Lake. As a result, the average daily sediment load to Lavon Lake was estimated to be 235 tons per day. This is a cumulative estimate of sediment loading that accounted for contributions from all tributaries to Lavon Lake under a range of flow conditions. Results of this analysis are discussed further in Section 5 of this plan.

4.5 – DETERMINING NUTRIENT LOADS

The state of Texas does not currently have numerical nutrient standards for surface waters. Historically, nutrient assessment of surface waters in the state has relied on screening criteria that include parameters such as dissolved oxygen and chlorophyll-a. These criteria can be used to assess the trophic status of surface waters, which is driven by nitrogen and phosphorus loading. Total Nitrogen (TN) and Total Phosphorus (TP) were selected for LDC analysis because they include both the organic and inorganic forms of these elements and therefore, represent a more conservative measure of nutrient loading. Like many other state environmental agencies, TCEQ is currently working with EPA to establish numerical standards for nitrogen and phosphorus. Once these standards are established, a TMDL for TN and TP can be calculated for comparison with the following load regression curves.

East Fork of the Trinity River

LDC analysis for TCEQ site 13740 indicates that generally, Total Nitrogen and Total Phosphorus loads increase linearly with high and mid-range flows but decrease sharply during low flows (Figure 4.12 & 4.13). This seems to indicate that nonpoint sources are the primary contributor to nutrient loading in the East Fork of the Trinity River.

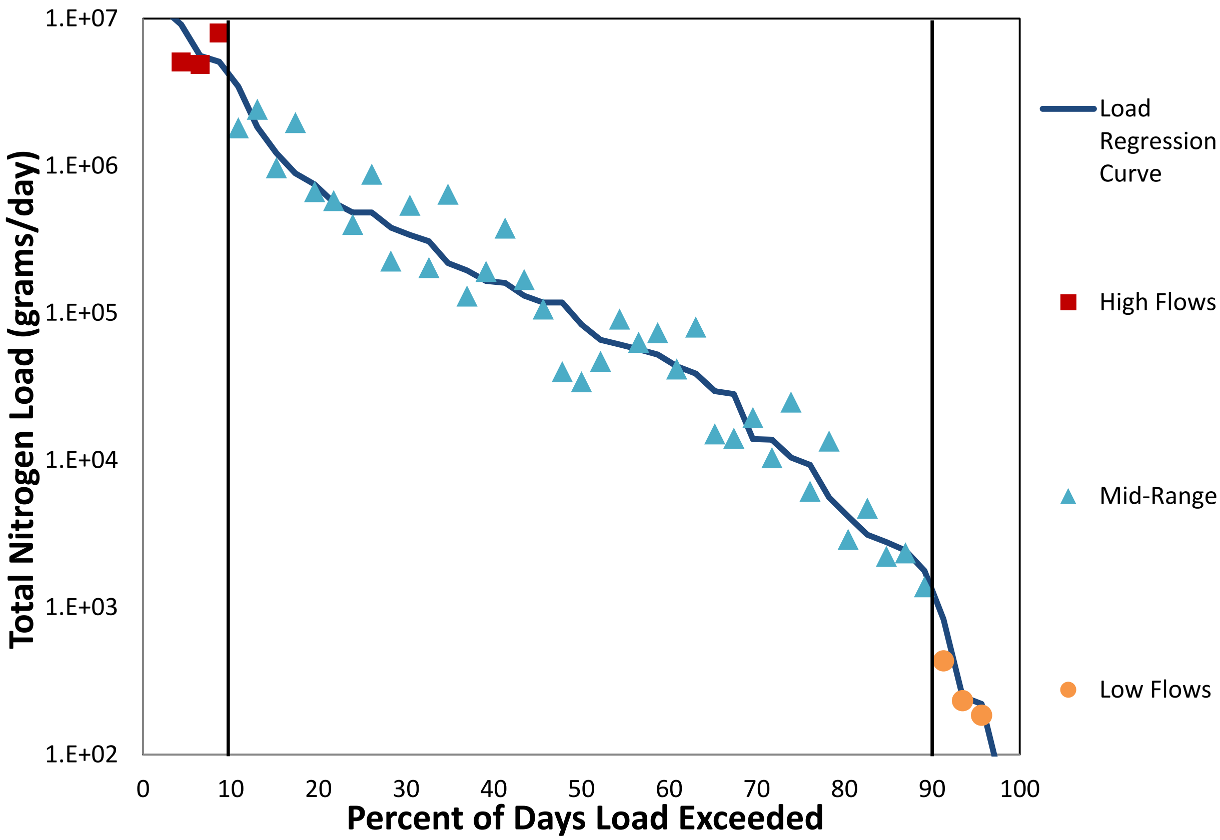

Figure 4.12. East Fork of the Trinity River load duration curve for Total Nitrogen at the TCEQ 13740 monitoring station. (1981-2016; n=46)

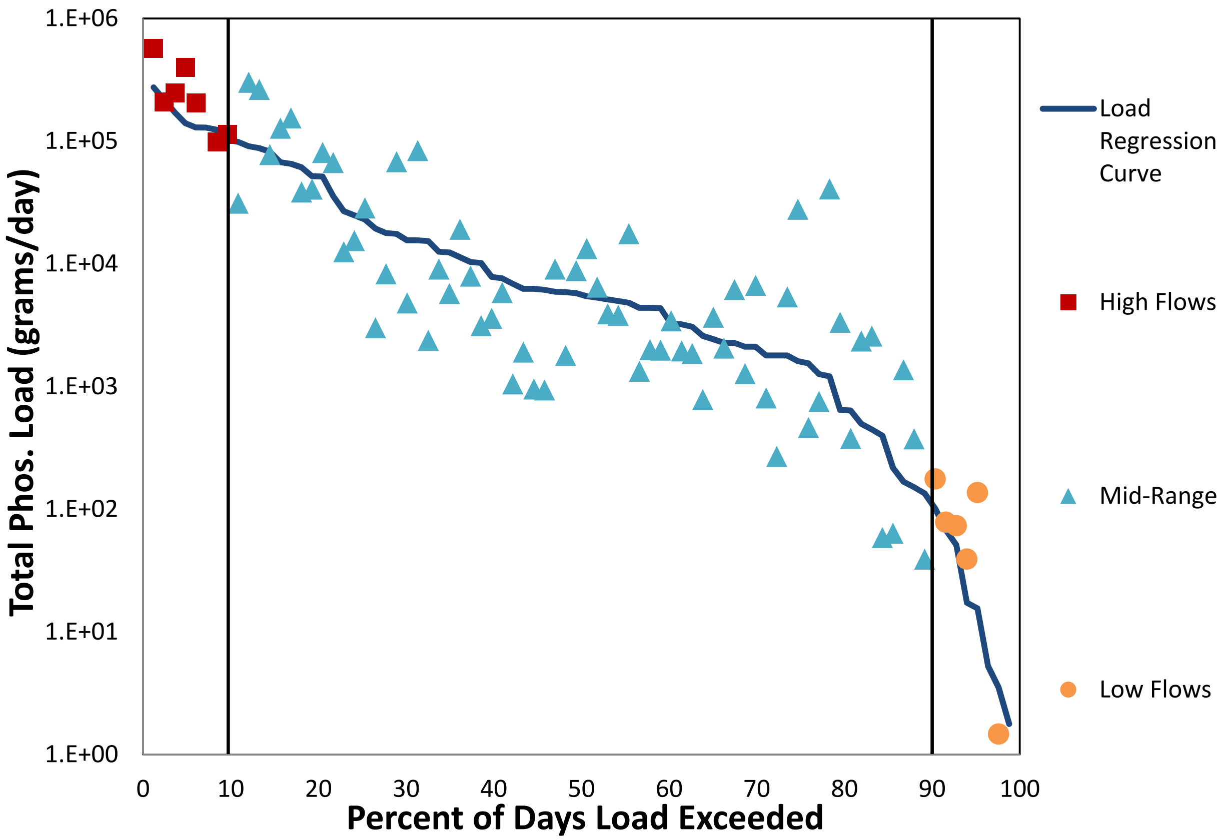

Figure 4.13. East Fork of the Trinity River load duration curve for Total Phosphorus at the TCEQ 13740 monitoring station. (1981-2016; n=83)

Pilot Grove-Indian Creek

LDC analysis for TCEQ site 21717 indicates that Total Nitrogen and Total Phosphorus loads increase sharply with higher streamflow in the mid-range flow regime (Figure 4.14 & 4.15). This seems to indicate that nonpoint sources are the primary contributor to nutrient loading in Pilot Grove and Indian Creeks. The sharp change in nutrient loads in the mid-range flow regime is due to the ephemeral nature of Pilot Grove Creek, which experiences low-flow and no-flow conditions approximately 50% of the time.

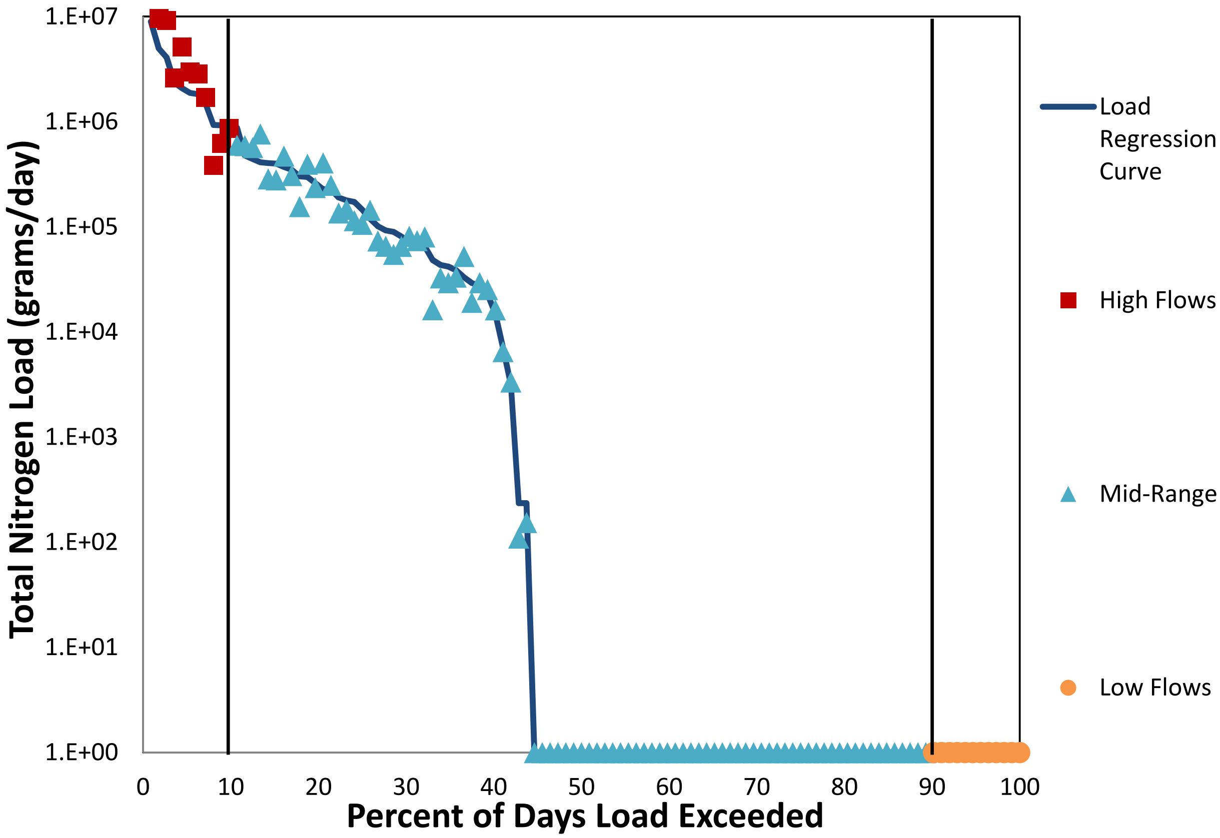

Figure 4.14. Pilot Grove Creek load duration curve for Total Nitrogen at the TCEQ 21717 monitoring station. (2007-2017; n=112)

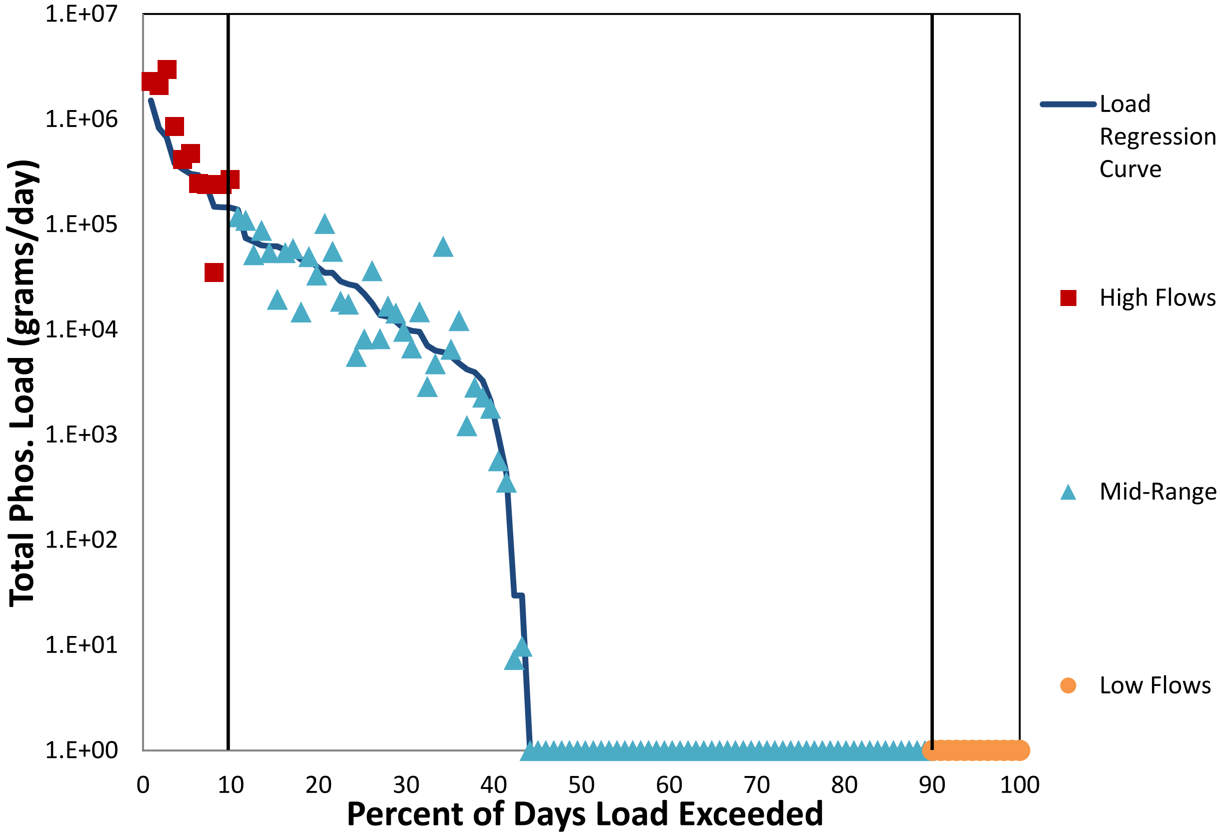

Figure 4.15. Pilot Grove Creek load duration curve for Total Phosphorus at the TCEQ 21717 monitoring station. (2007-2017; n=111)

Sister Grove Creek

LDC analysis for TCEQ site 13740 indicates that generally, Total Nitrogen and Total Phosphorus loads increase linearly with high and mid-range flows but decrease sharply during low flows (Figure 4.16 & 4.17). This seems to indicate that nonpoint sources are the primary contributor to nutrient loading in Wilson Creek. The sharp change in nutrient loads in the mid-range flow regime is due to the ephemeral nature of Pilot Grove Creek, which experiences low-flow and no-flow conditions approximately 50% of the time.

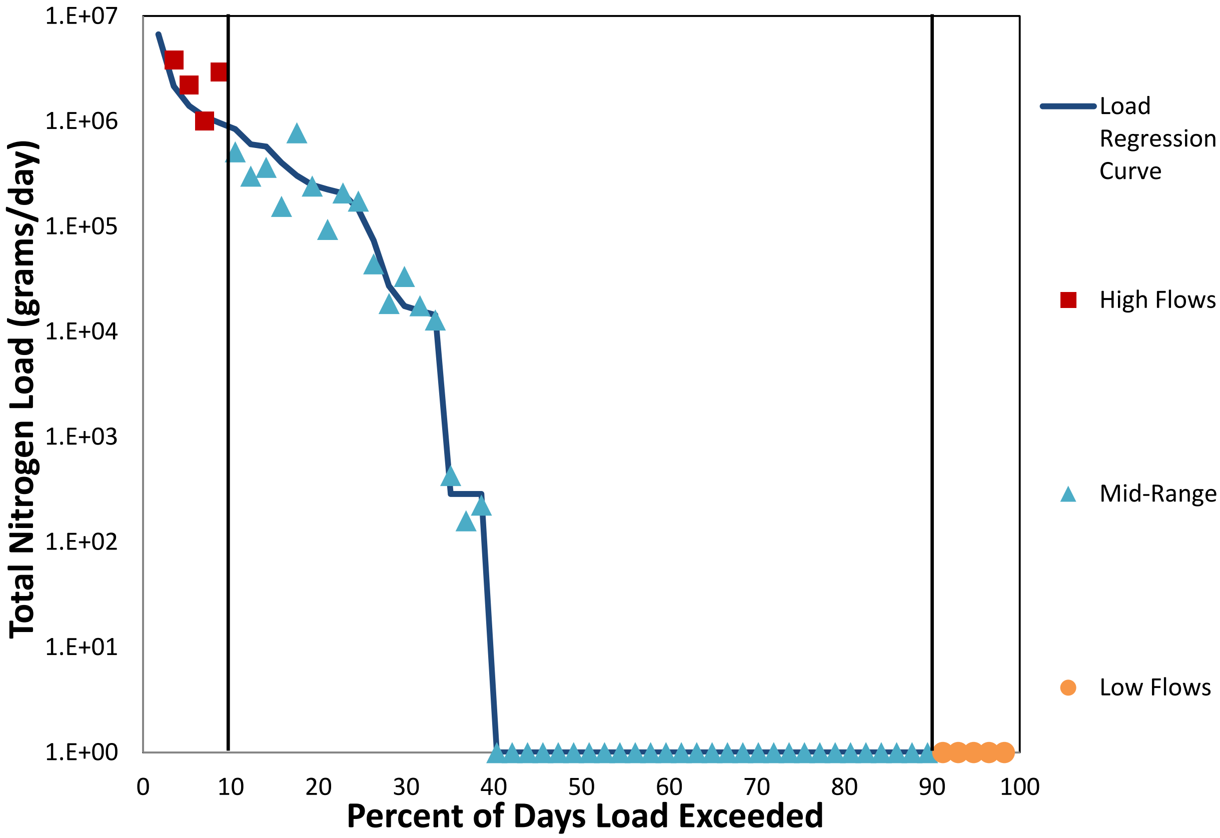

Figure 4.16. Sister Grove Creek load duration curve for Total Nitrogen at the TCEQ 21396 monitoring station. (2011-2017; n=56)

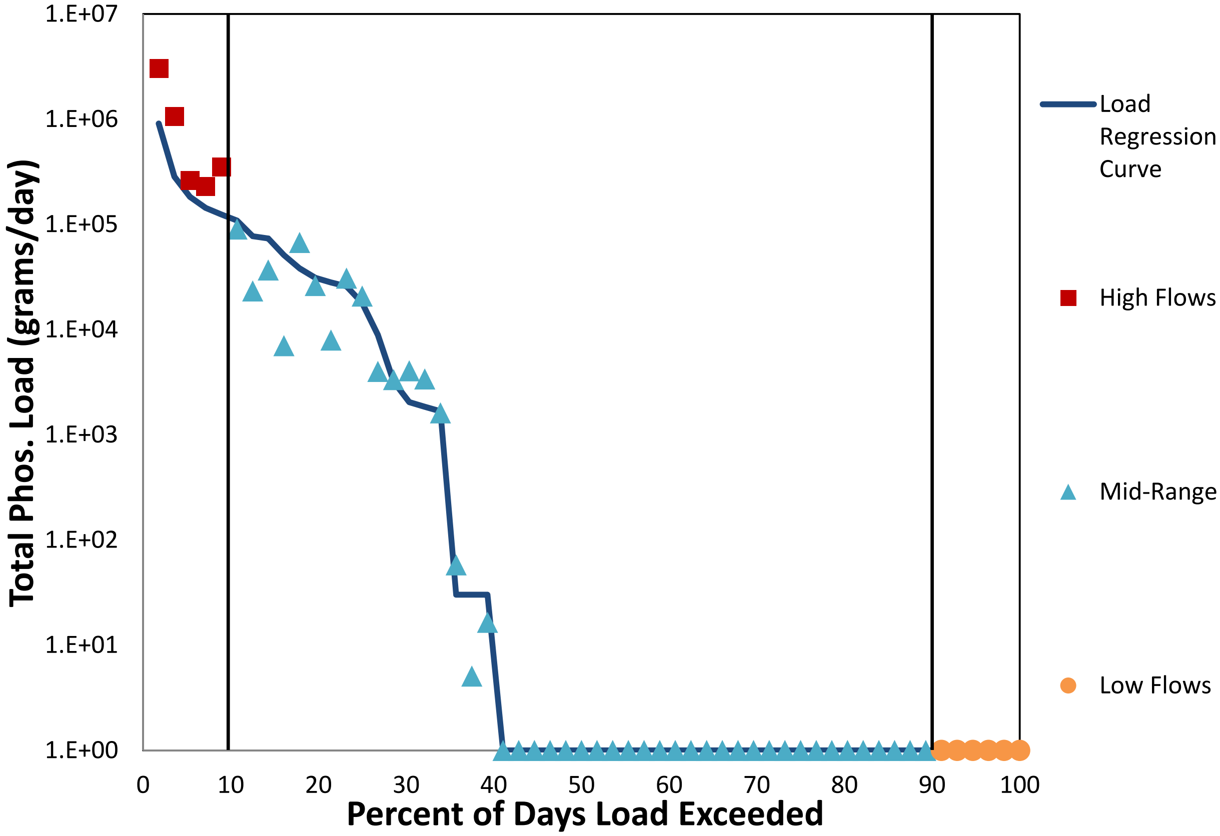

Figure 4.17. Sister Grove Creek load duration curve for Total Phosphorus at the TCEQ 21396 monitoring station. (2011-2017; n=56)

Wilson Creek

LDC analysis for TCEQ site 13740 indicates that generally, Total Nitrogen and Total Phosphorus loads increase linearly with high and mid-range flows but decrease sharply during low flows (Figure 4.18 & 4.19). This seems to indicate that nonpoint sources are the primary contributor to nutrient loading in Wilson Creek.

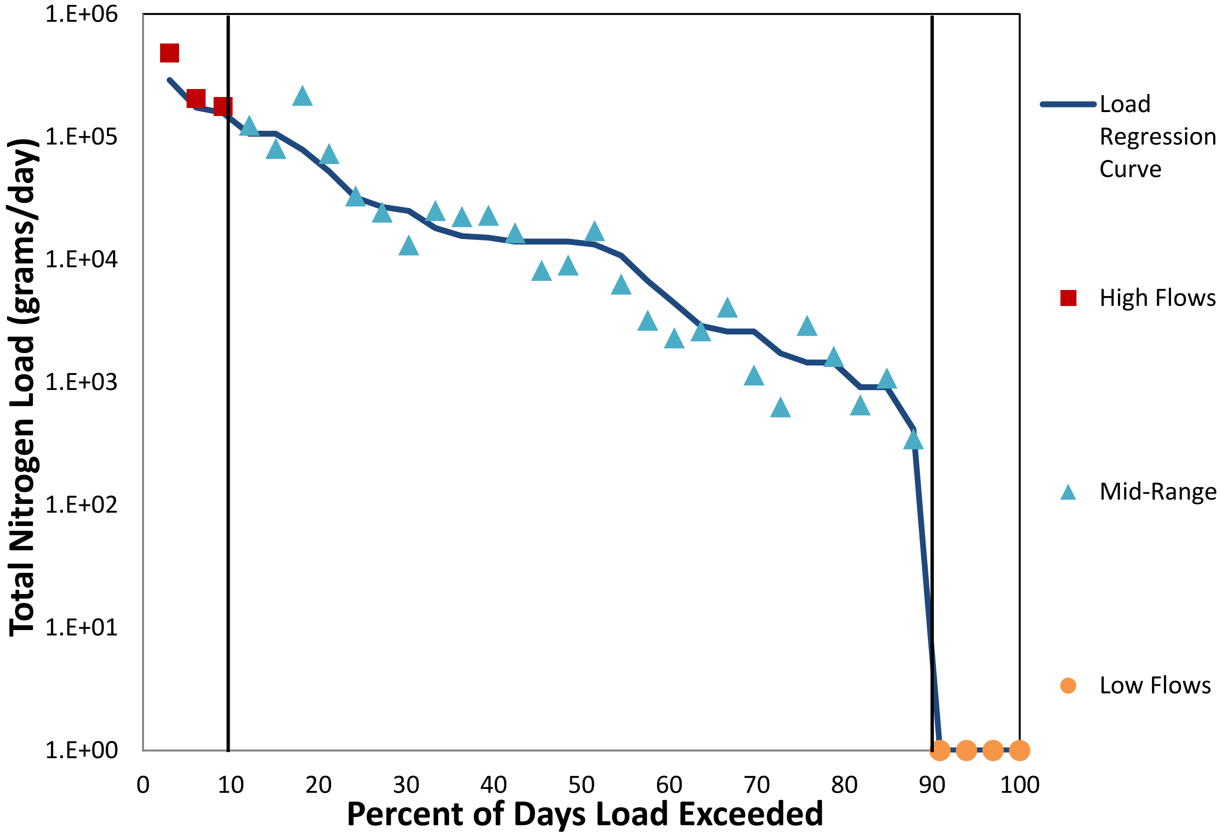

Figure 4.18. Wilson Creek load duration curve for Total Nitrogen at the TCEQ 10777 monitoring station. (1989-2016; n=33)

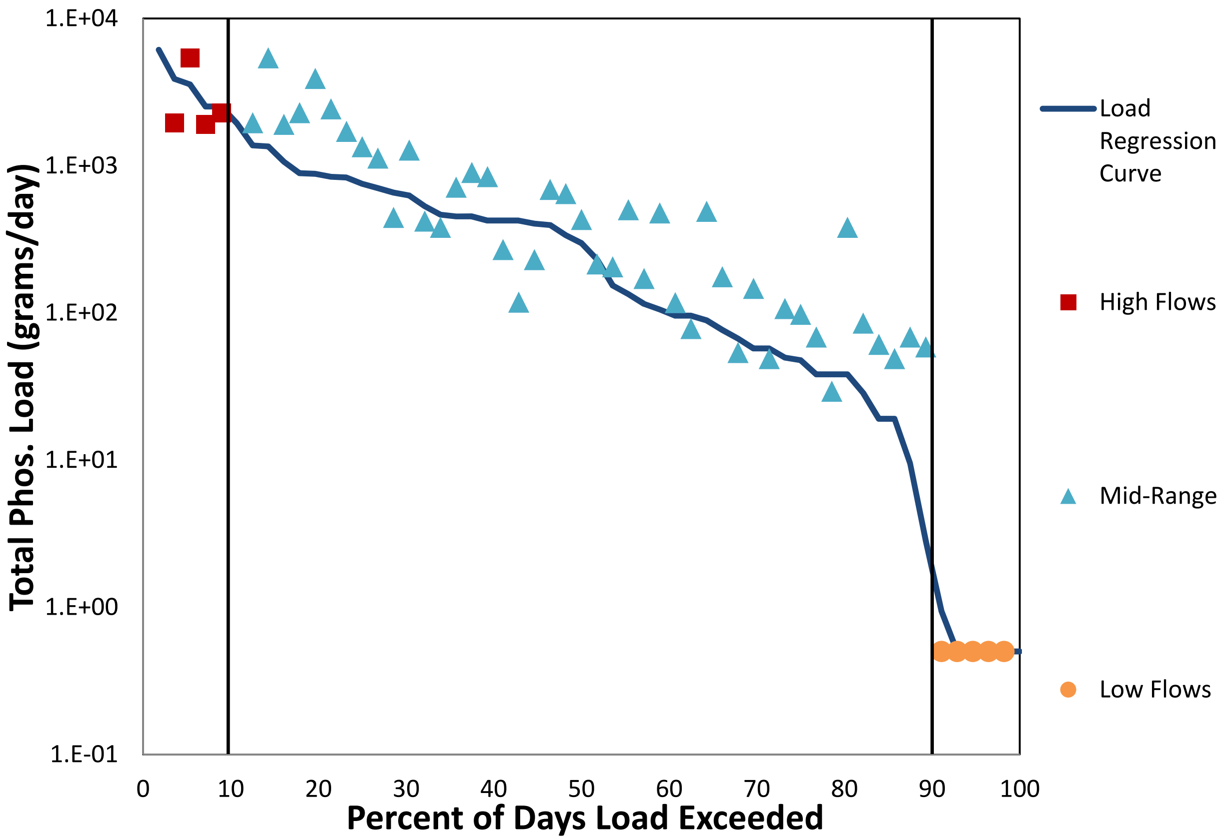

Figure 4.19. Wilson Creek load duration curve for Total Phosphorus at the TCEQ 10777 monitoring station. (1988-2016; n=56)

4.6 – RECOMMENDED PERCENT LOAD REDUCTION

Bacteria

The Steering Committee chose to use the load reduction goals identified in the LDC analysis for mid-range conditions. This represents a very conservative approach which will guide implementation efforts to not only achieve current water quality goals, but also will help to protect Lavon Lake into the future by considering increasing pressure on the watershed due to long-term population growth. These load reductions were applied, respectively, across the entire subwatershed for all sources and all flow regimes. For those subwatersheds where an LDC was not performed, the Steering Committee chose to apply a reduction goal of 27%.

Nutrients

Due to the absence of statewide numerical standards, TMDLs for nitrogen and phosphorus could not be calculated for the Lavon Lake watershed. Consequently, the Steering Committee chose to not to adopt a percent load reduction goal for nitrogen and phosphorus in the watershed. However, many of the management measures used to address bacteria also reduce nutrient loading.

Sediment

As previously noted, LDC analysis was not conducted for sediment. However, previously conducted SWAT analyses have provided information about the sources and amount of sediment loading in the watershed. Rather than adopt a percent reduction goal for sediment, the Steering Committee chose to identify management measures for sediment based on feasibility. It was noted that many of the management measures for bacteria and nutrients also function to provide erosion control and sediment capture.

4.7 – ANNUAL LOADS AND LOAD REDUCTIONS

Based on the LDC analysis, mean annual loads, and load reductions, target loads for *E. coli* bacteria (cfu/year), Total Nitrogen (grams/year), and Total Phosphorus (grams/year) were calculated (Table 4.3). Calculations for all pollutants were based on loading occurring between the 11th and 90th percentile flows, which is the range of flows for which the effective implementation of management measures is considered to be feasible.

Table 4.3. Mean annual loads, load reductions and target loads.

Name	Site ID	Pollutant	Mean Annual Load	Mean Annual Load Reduction	Mean Annual Target Load	Reduction Goal (%)
East Fk Trinity	13740	*E. coli* (cfu/year)	4.64×10^{13}	1.55×10^{13}	3.10×10^{13}	33
Pilot Grove-Indian Creek	21717	*E. coli* (cfu/year)	6.65×10^{13}	2.11×10^{13}	4.54×10^{13}	32
Sister Grove Creek	21396	*E. coli* (cfu/year)	4.64×10^{13}	1.22×10^{13}	3.24×10^{13}	27
Wilson Creek	10777	*E. coli* (cfu/year)	2.02×10^{13}	9.94×10^{12}	1.03×10^{13}	49

4.8 – HOW VARIABLE FLOWS INFLUENCE TRENDS IN POLLUTANT LOADS

Tables 4.4, 4.5, and 4.6 are a summary of the estimated annual average *E. coli* bacteria, Total Nitrogen, and Total Phosphorus loads categorized by flow condition. Increased pollutant loading during mid-range and high flows is indicative of contributions from nonpoint sources. High flow events occur in response to high rainfall runoff which transports pollutants greater distances across the landscape. However, these events occur only 10% of the time, and generally the runoff resulting from these extreme rainfall events cannot effectively be controlled by available best management practices (BMPs). In contrast, runoff events which result in mid-range stream flows are more common and considered more manageable using available BMPs. On that basis, the focus of implementation will be on management of loading that occurs during the mid-range flow regime (11-90th percentile flows). Pollutant loading at low flows are not of sufficient magnitude to cause nonattainment of state water quality standards.

Table 4.4. Estimated average annual *E. coli* loads under different flow conditions.

Waterbody Name	TCEQ Site ID	Loading by Streamflow Condition (cfu/yr)		
		High Flows	Mid-range Flows	Low Flows
East Fork Trinity River	13740	7.25×10^{14}	4.64×10^{13}	1.31×10^{11}
Pilot Grove-Indian Creek	21717	4.90×10^{14}	6.65×10^{13}	$3.65 \times 10^{2*}$
Sister Grove Creek	21396	3.75×10^{14}	4.46×10^{13}	$3.65 \times 10^{2*}$
Wilson Creek	10777	2.42×10^{11}	2.02×10^{13}	2.11×10^{08}

Table 4.5. Estimated average annual Total Nitrogen loads under different flow conditions.

Waterbody Name	TCEQ Site ID	Loading by Streamflow Condition (grams/yr)		
		High Flows	Mid-range Flows	Low Flows
East Fork Trinity River	13740	2.88×10^{9}	1.22×10^{8}	9.95×10^{4}
Pilot Grove-Indian Creek	21717	2.76×10^{6}	7.56×10^{4}	$1.00 \times 10^{0*}$
Sister Grove Creek	21396	2.46×10^{6}	8.05×10^{4}	$1.00 \times 10^{0*}$
Wilson Creek	10777	7.54×10^{7}	7.95×10^{6}	3.65×10^{2}

Table 4.6. Estimated average annual Total Phosphorus loads under different flow conditions.

Waterbody Name	TCEQ Site ID	Loading by Streamflow Condition (grams/yr)		
		High Flows	Mid-range Flows	Low Flows
East Fork Trinity River	13740	5.87×10^{7}	5.86×10^{6}	1.07×10^{4}
Pilot Grove-Indian Creek	21717	4.53×10^{5}	1.15×10^{4}	$1.00 \times 10^{0*}$
Sister Grove Creek	21396	3.29×10^{5}	1.04×10^{4}	$1.00 \times 10^{0*}$
Wilson Creek	10777	1.36×10^{6}	1.47×10^{5}	2.09×10^{2}

5. Pollutant Source Assessment

As noted previously, point sources in the watershed include thirteen WWTPs and the Melissa Feeders CAFO. However, these sources are managed by permits issued by TCEQ through the National Pollutant Discharge Elimination System (NPDES). Furthermore, LDC analysis indicated that nonpoint sources were the primary contributors of pollution in the Lavon Lake watershed. As a result, the majority of analysis will focus on nonpoint sources of pollution.

The Steering Committee identified several potential sources of bacteria and nutrients in the watershed, utilizing their knowledge of the area and information gathered from stakeholders. Based on this assessment, the major potential sources of bacteria and nutrient pollution were identified and are presented in Table 5.1. When identifying these sources, the Steering Committee noted there are several other, lesser sources of bacteria and nutrient pollution in the watershed (e.g. rodents, coyotes, etc.). These sources were excluded from analysis largely because of a lack of available population and distribution data. In addition, the Steering Committee recognized sediment loading as a significant water quality concern.

Table 5.1. Potential sources of pollution in the Lavon Lake Watershed identified by the Steering Committee.

Source Categories	Potential Sources	Bacteria	Nutrients
Urban	Urban Runoff	X	X
Wastewater	Septic Systems	X	X
	WWTPs	X	X
Agriculture	Cropland		X
	Cattle	X	X
	Domestic Hogs	X	X
	Horses	X	X
	Sheep/Goats	X	X
	Domestic Poultry	X	X
Wildlife and Nondomestic Animals	Deer	X	X
	Feral Hogs	X	X

Because bacteria are currently the only cause of impairment in the Lavon Lake watershed, more emphasis was put on analyzing sources of *E. coli*. SELECT analysis was performed for the sources of bacteria identified in Table 5.1, while assessment of nutrient and sediment sources relied on previously conducted SWAT analysis. However, since many bacteria sources also contribute nutrients, SELECT analysis of bacteria sources can also be used to make informed decisions about nutrient management measures.

5.1 – BACTERIA SOURCE ANALYSIS USING SELECT

Total estimated daily *E. coli* loads summed for the potential nonpoint sources in each of the 20 subwatersheds to Lavon Lake are presented in Figure 5.1. For this and similar SELECT figures in the WPP, red, orange, and yellow colors indicate subwatersheds with potential daily bacteria loads for a source that are comparatively higher, intermediate, and lower, respectively. Thus, subwatersheds 16 and 18 represent areas with the highest potential to contribute bacteria to Lavon Lake and its tributaries. This information will be useful in the targeting and planning of implementation efforts to achieve water quality goals.

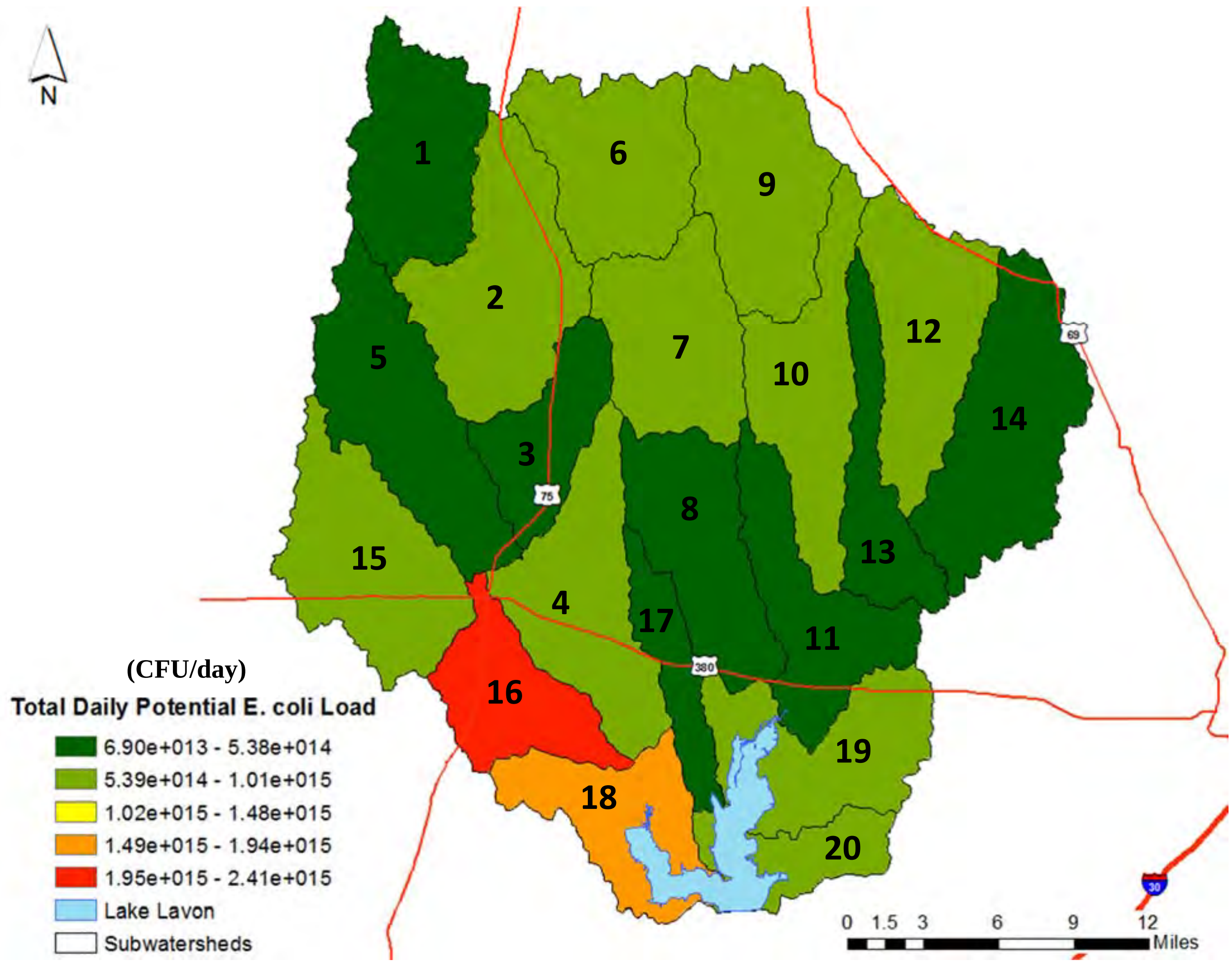

Figure 5.1. Average total daily potential *E. coli* contribution from all sources by subwatershed.

The following sections present and discuss results of the SELECT analysis for each of the potential bacteria sources identified in Table 5.1, which include urban runoff, septic systems, livestock, and wildlife. The Steering Committee noted that although cropland is generally not considered a major source of bacteria, and was therefore not included in the bacteria analysis for SELECT, these areas may still contribute some bacteria, especially when manure is applied as a fertilizer. Additional background information specific for each identified potential bacteria source in the watershed is located in Appendix F.

5.1.1 – Urban Runoff

The Partnership and Steering Committee utilized estimates of impervious surface cover from the land use analysis (see Appendix F) and bacteria loading estimates from a study conducted by the City of Austin, TX (PBS&J, 2000) to evaluate urban runoff. As would be expected, subwatersheds 4, 15, 16 and 18 have the most urban development and the greatest potential for urban-related pollution (Figure 5.2).

The City of Austin study showed that bacteria concentrations in urban runoff can be extremely high in areas with a high degree of impervious surface cover (rooftops, roads, and other hard surfaces) (PBS&J, 2000). Impervious cover causes more surface runoff and less water infiltration into the soil, increasing potential pollution from household pets, leaking wastewater collection systems, sanitary sewer overflows, and urban wildlife. Identifying the original source of pollution is extremely difficult since pollutants in runoff from urban areas potentially may come from any one source or a combination of several sources.

Variation exists in the level of urbanization between municipalities in the Lavon Lake watershed. For example, communities like Blue Ridge, Trenton, and Weston, with populations in the hundreds, have relatively little urban development compared to those with populations in the hundreds of thousands, such as McKinney and Frisco. Most of these urban areas are concentrated in subwatersheds 15, 16, and 18, and along the Hwy 75 and Hwy 380 corridors. The cities of Allen, Frisco, Lowry Crossing, Lucas, McKinney, New Hope, St. Paul, and Wylie, as well as Collin County, are currently under municipal separate storm sewer system (MS4) regulations as part of the National Pollutant Discharge Elimination System (NPDES). Several other growing communities in the watershed will soon fall under these regulations also, due to their exceedance of the urban area threshold set by EPA. The urban area threshold is defined by EPA as a land area comprising one or more place(s) and the adjacent, densely settled surrounding area that together, have a residential population of at least 50,000 and an overall population density of at least 1,000 people per square mile.

The latest NCTCOG projections estimate the number of households in Collin County will more than double in the 35 year period between 2005 and 2040. (NCTCOG, 2016) Although some of this growth will occur in existing high density areas, a significant amount of new residential and urban developments will be needed to accommodate this increase. Thus, pollutant contributions from urban stormwater are expected to increase over time. Additional analysis may be needed to fully assess the impact of urbanization on pollutant loading in the watershed.

Figure 5.2. Downtown Wylie is an example of the high intensity urban land use category in the Lavon Lake Watershed.

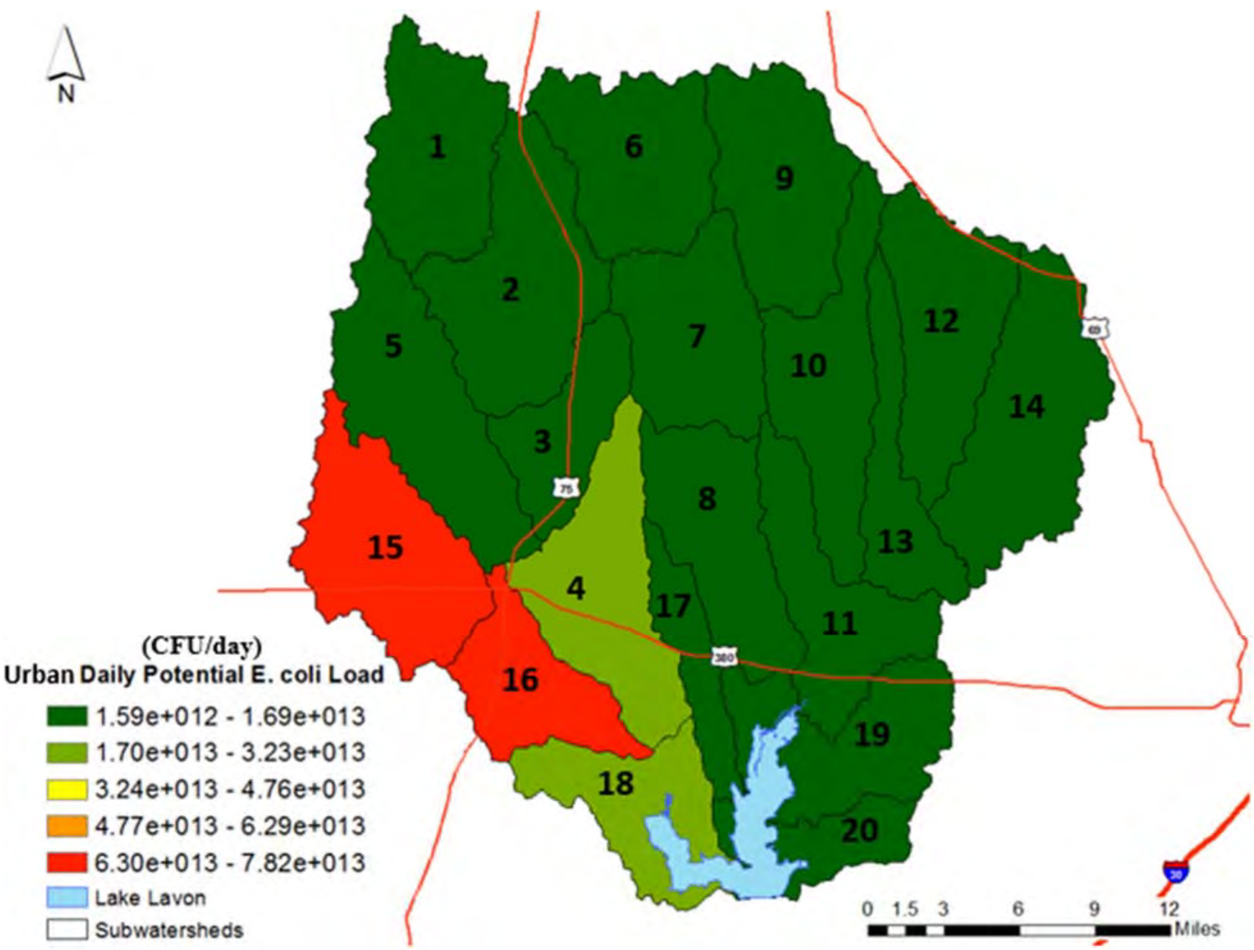

Figure 5.3. Average daily potential *E. coli* load from urban runoff by subwatershed.

5.1.2 – Wastewater

<u>Wastewater Treatment Plants</u>

As previously mentioned, there are thirteen municipal WWTPs in the watershed. Combined, these facilities discharge a total of 59.7 MGD, the vast majority of which comes from the Wilson Creek Regional WWTP (54 MGD). These facilities are required to treat discharge for bacteria below 126 cfu/100mL. Using this upper concentration limit of 126 cfu/100mL and the discharge rate for each facility, the combined daily bacteria load from WWTPs in the watershed was calculated to be 2.85E+11. Of course, the greatest potential for bacteria loading from WWTPs comes from subwatershed 16, which contains the Wilson Creek Regional WWTP (Figure 5.4).

A review of permit compliance history for these facilities showed several reportable non-compliance violations (RNC) over the past three years. However, many of these were relatively minor violations from the smaller facilities. According to EPA's online enforcement and compliance history database (ECHO), the Wilson Creek Regional WWTP only had a one violation that resulted in an enforcement action between 2014 and 2016.

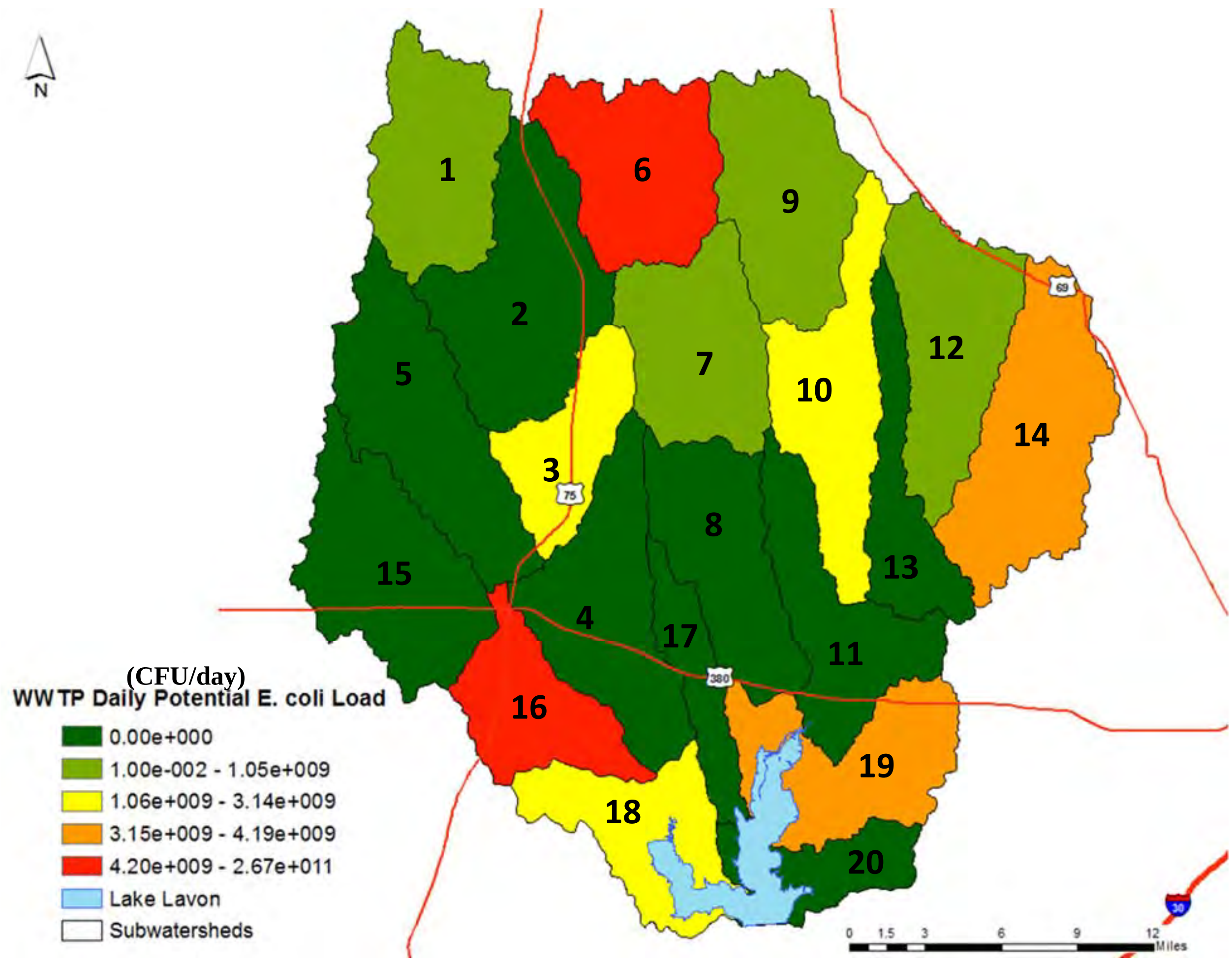

Figure 5.4. Average daily potential *E. coli* load from WWTPs by subwatershed.

Septic Systems

Rural residents across Texas rely on on-site sewage facilities (OSSFs), or septic systems, for disposal of household wastewater. New systems are installed when homes and businesses are constructed where centralized municipal sewer service is unavailable, which is typically outside city limits, but not necessarily. While WWTPs must be operated by trained personnel, septic systems are the responsibility of the individual homeowner or business owner. If regular and essential maintenance are not conducted, major problems can occur.

As with most types of NPS pollution, failing septic systems are found across the landscape. Those located nearest streams or drainage areas are most likely to impact water quality. A study funded by the Texas On-Site Wastewater Treatment Research Council (Reed et al., 2001) estimated that in the region of Texas containing the Lavon Lake Watershed, approximately 12% of existing septic systems are chronically malfunctioning, defined as "prone to failure from year to year." System failures in this region are due largely to the following four main factors, ranked in order from most to least important: soil suitability for the type of installed septic system, system age, a general lack of system maintenance knowledge among owners, and a lack of proper maintenance (Figure 5.5). Failure also can result from hydraulic overload of the system by adding additional homes to an existing system that was not designed to accept the increased load. Other factors that can contribute to system failure are improper installation and improper system design.

In Texas, installation of a septic system requires a permit based on state regulations passed in 1989. However, a septic system was "grandfathered" if it: 1) was installed before a local authorized program was established or before September 1, 1989, 2) has a treatment and disposal facility (tank and associated drain field), and 3) has had no significant increase in its use.

Figure 5.5. Surfacing effluent is a symptom of septic system failure that can be caused by several factors such as poor soil suitability, age of the system, or overloading. Photo courtesy of Texas A&M AgriLife.

The Steering Committee utilized an index based on soil type and age of system to predict septic system failure rates. Soil type was obtained from NRCS soil surveys, while system age was based on date of platting. Estimated failure rate categories were 8, 10, or 15%, based on the calculated index (see Appendix F for a complete explanation of the calculated index). This index of possible failure rates was used instead of the commonly utilized single estimated failure rate from Reed, Stowe, and Yanke (2001) due to its ability to more accurately estimate failure rates.

Incorporating estimated failure rates into the SELECT analysis, the greatest potential loading from septic systems occurs in the southwestern Lavon Lake subwatersheds (Figure 5.6; subwatersheds 16 and 18). As previously noted, these subwatersheds contain a relatively high number of homes. As populations continue to grow, these areas likely will become more heavily populated, resulting in an even greater number of septic systems.

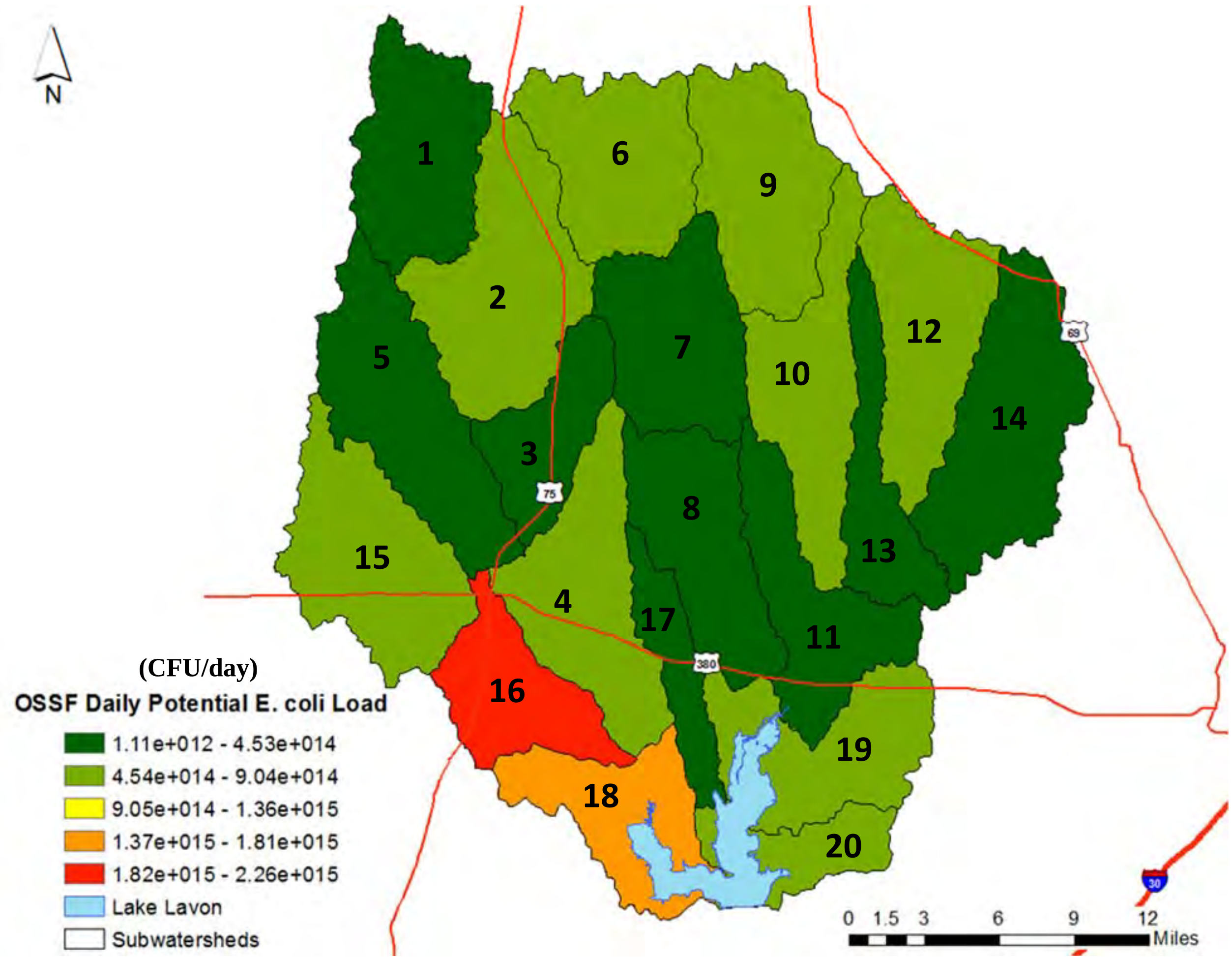

Figure 5.6. Average daily potential *E. coli* load from failing septic systems by subwatershed.

5.1.3 – Agriculture

The Partnership and Steering Committee identified several potential agricultural sources of bacteria, and helped develop animal population estimates used in SELECT analysis. It should be noted that these sources are dynamic, and can be affected significantly by factors such as weather and market prices. Also, many of these areas may be taken out of production over time as an increasing amount of land is converted for urban and residential use.

Livestock

Cattle, horses, goats, sheep, and domestic poultry were identified as the primary livestock raised in the area. Results of SELECT analysis for each of these classes of livestock are presented and discussed below.

Cattle

Based on USDA National Agricultural Statistics Service (USDA NASS) census data, cattle are the dominant livestock species in the watershed (Figure 5.7). Like all animals, waste products from cattle are sources of both bacteria and nutrients. After being deposited on the ground, these pollutants can be transported into streams during rainfall runoff events. The potential for impact increases where and when animals are grazed or confined near streams or drainage areas. Direct deposition in the waterbody also can occur when these animals are permitted access to riparian areas and/or the stream.

Figure 5.7. Cattle grazing in the Lavon Lake Watershed.

The Steering Committee chose to utilize 2012 USDA NASS data to estimate area stocking densities. According to NASS data, the total cattle population in the watershed was estimated at 34,037 head. The cattle population was distributed across land covers used for grazing, which includes rangeland and managed pasture, resulting in an average stocking density of 1 head of cattle per 7 acres. In general, most cattle grazing operations utilize several different land use types throughout the course of a year. Cattle grazing will occur on different land use types of varying carrying capacity, while the cattle population will remain somewhat constant. The analysis indicated that the largest potential source of loading from cattle is found in the northeastern portion of the watershed (Figure 5.8; subwatersheds 12 and 14). Additionally, subwatersheds in the central and northern portions of the watershed have significant potential for loading from cattle.

It should be noted that development of the cattle population estimates was conducted as this area of the state was emerging from a period of extreme drought, during which time most cattle operations were markedly reduced. Many operations were in the process of restocking when the 2012 USDA NASS Census was conducted. However, the Steering Committee indicated that this data reflected an average cattle population for the watershed.

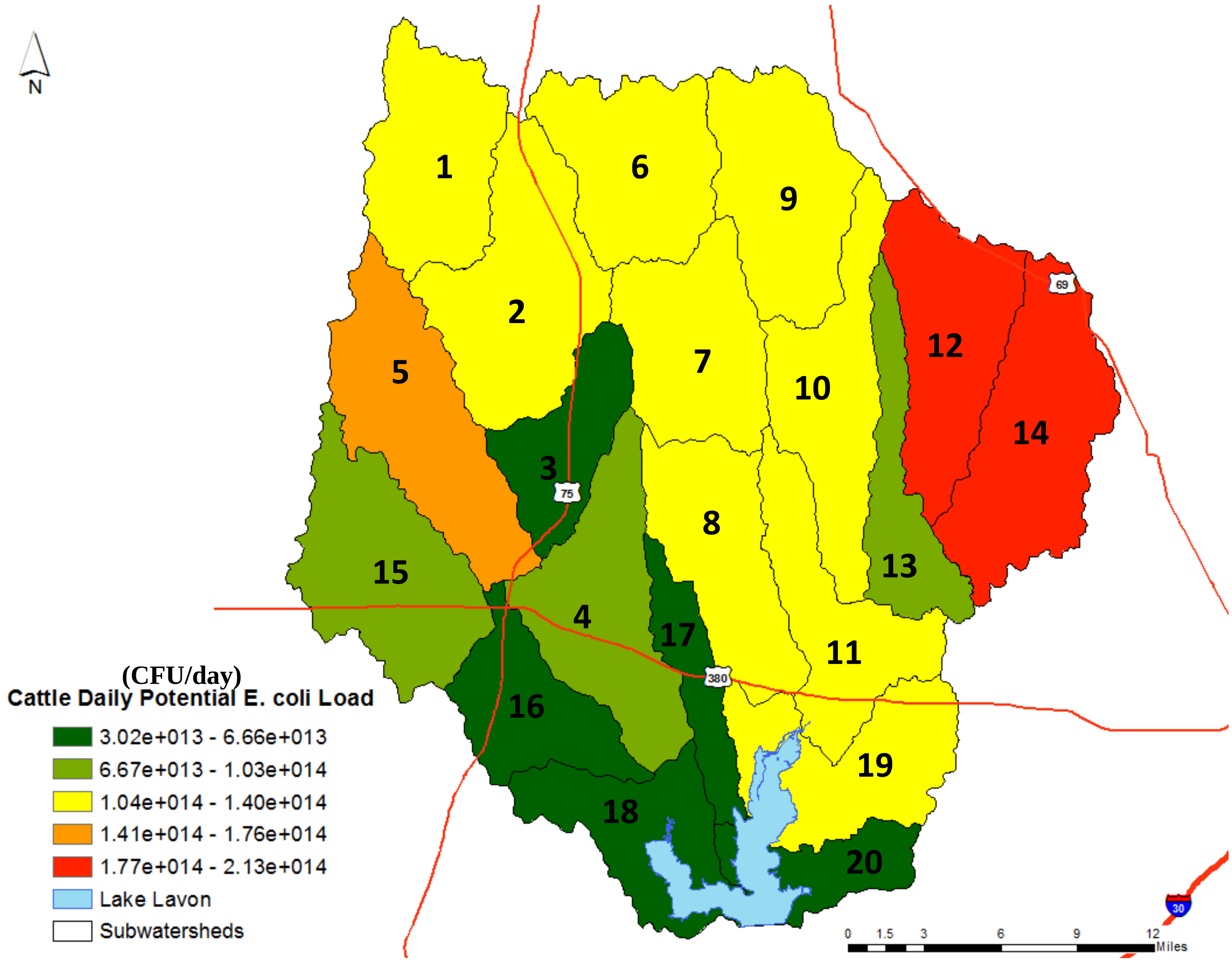

Figure 5.8. Average daily potential *E. coli* load from cattle by subwatershed.

Horses

The Partnership and Steering Committee based the horse population on 2012 USDA NASS county data which estimates there are approximately 4,025 horses in the watershed. This approach was used since stakeholders felt that it accurately estimated the horse population in the watershed. While the total population of horses in the watershed is low compared to cattle, management practices directly affect the potential for these animals to be contributors of bacteria. Stakeholders indicated that horses in the watershed are often kept on undersized acreages which results in overgrazing, and potentially increased runoff of fecal material. For this reason the horse population was distributed only the managed pasture acres in the watershed for SELECT analysis. The analysis indicates the greatest potential loadings are located in the East Fork of the Trinity River and Pilot Grove Creek portions of the watershed. (Figure 5.9; subwatersheds 2, 5, and 10).

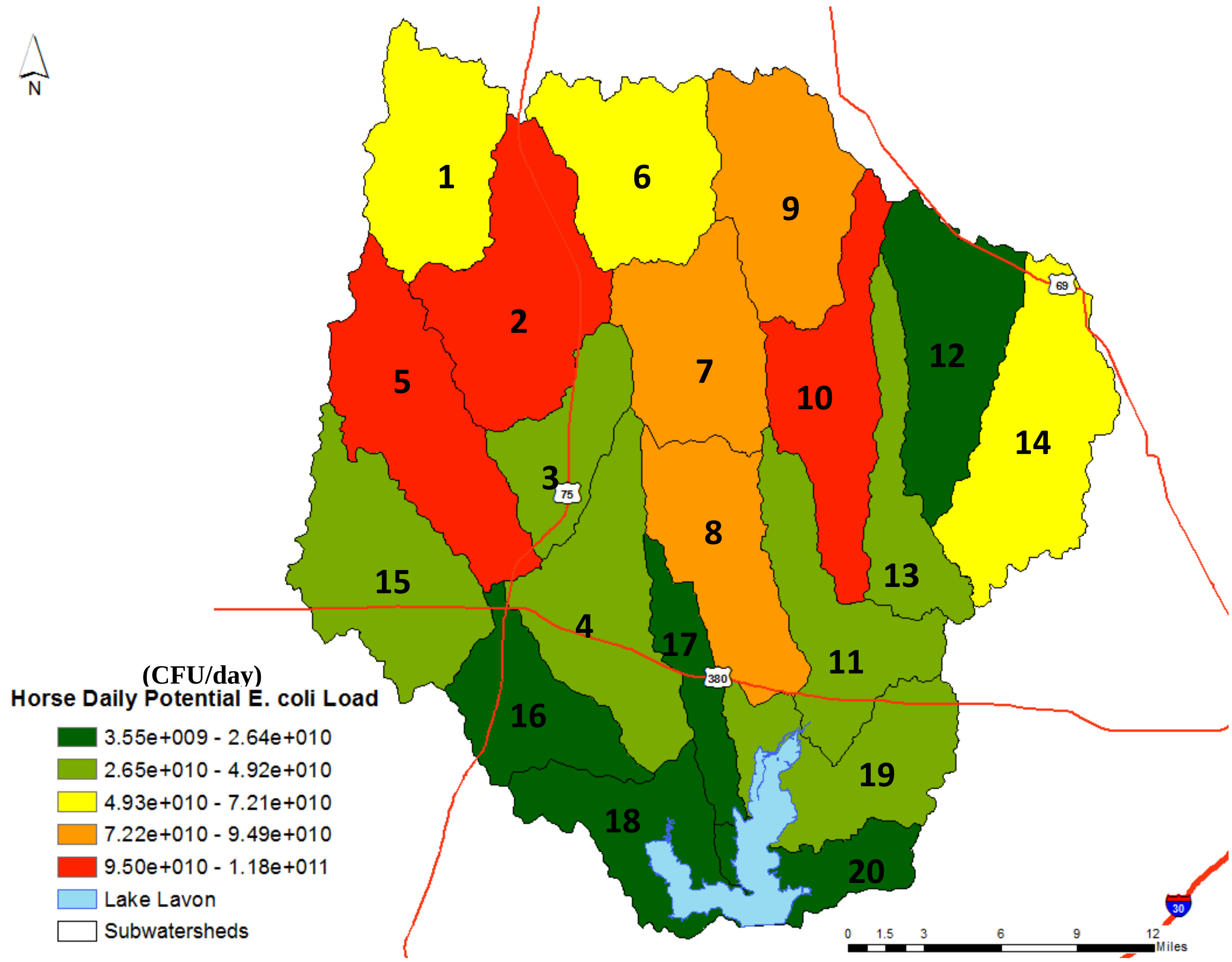

Figure 5.9. Average daily potential *E. coli* load from horses by subwatershed.

Goats

USDA NASS data from 2012 were utilized to create a baseline estimate of the goat population. The total watershed population was estimated to be 4,070 head of goats distributed on rangeland and managed pasture. SELECT analysis indicates the highest potential loading from goats is in the Honey Creek and Indian Creek subwatersheds. (Figure 5.10; subwatersheds 5 and 14).

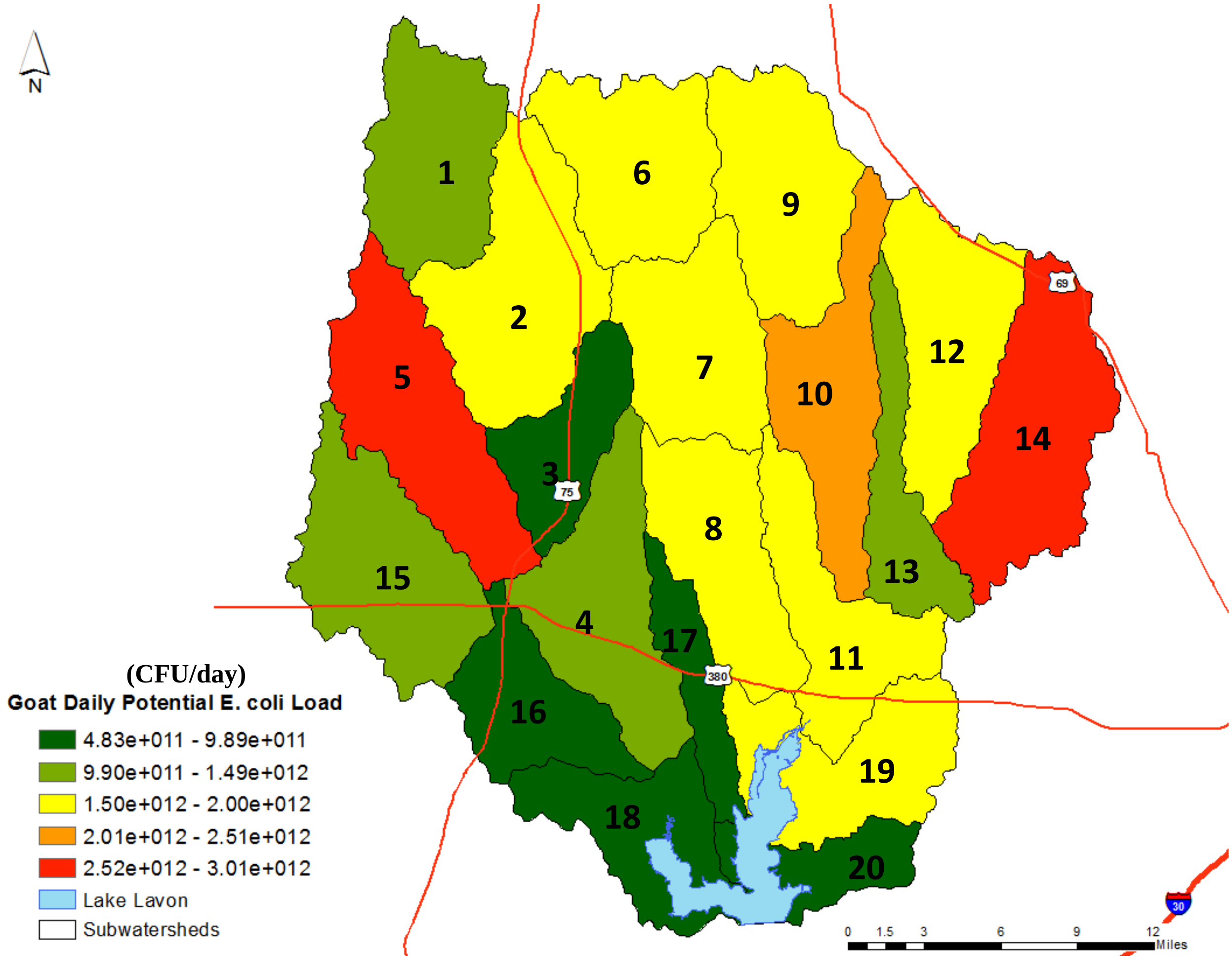

Figure 5.10. Average daily potential *E. coli* load from goats by subwatershed.

Sheep

USDA NASS data from 2012 estimates there are 1,222 sheep in the watershed. As with the SELECT analysis for goats, sheep populations were distributed across rangeland and managed pasture. The analysis indicates the highest potential loading from sheep is in the Honey Creek and lower Sister Grove Creek subwatersheds (Figure 5.11; subwatersheds 5 and 8).

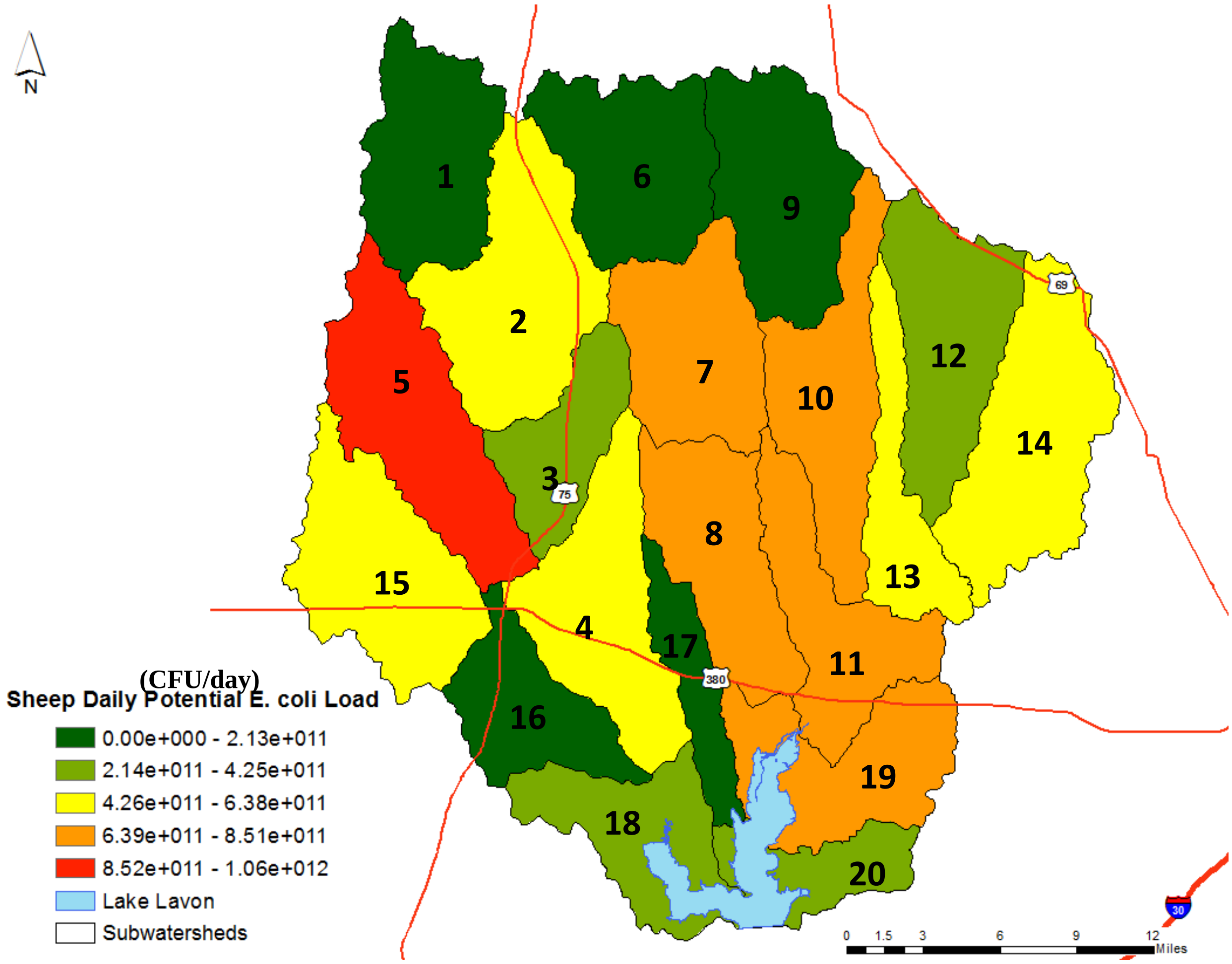

Figure 5.11. Average daily potential *E. coli* load from sheep by subwatershed.

Domestic Poultry

The 2012 USDA NASS county data shows there are approximately 7,022 domestic poultry in the watershed. Stakeholders indicated that domestic poultry are most often kept near the home or barn. For this reason, these poultry populations were distributed to rural households in the watershed for SELECT analysis. As a result, the analysis indicates the greatest potential loadings are located in the lower portions of the watershed (Figure 5.12; subwatersheds 4, 18, and 19).

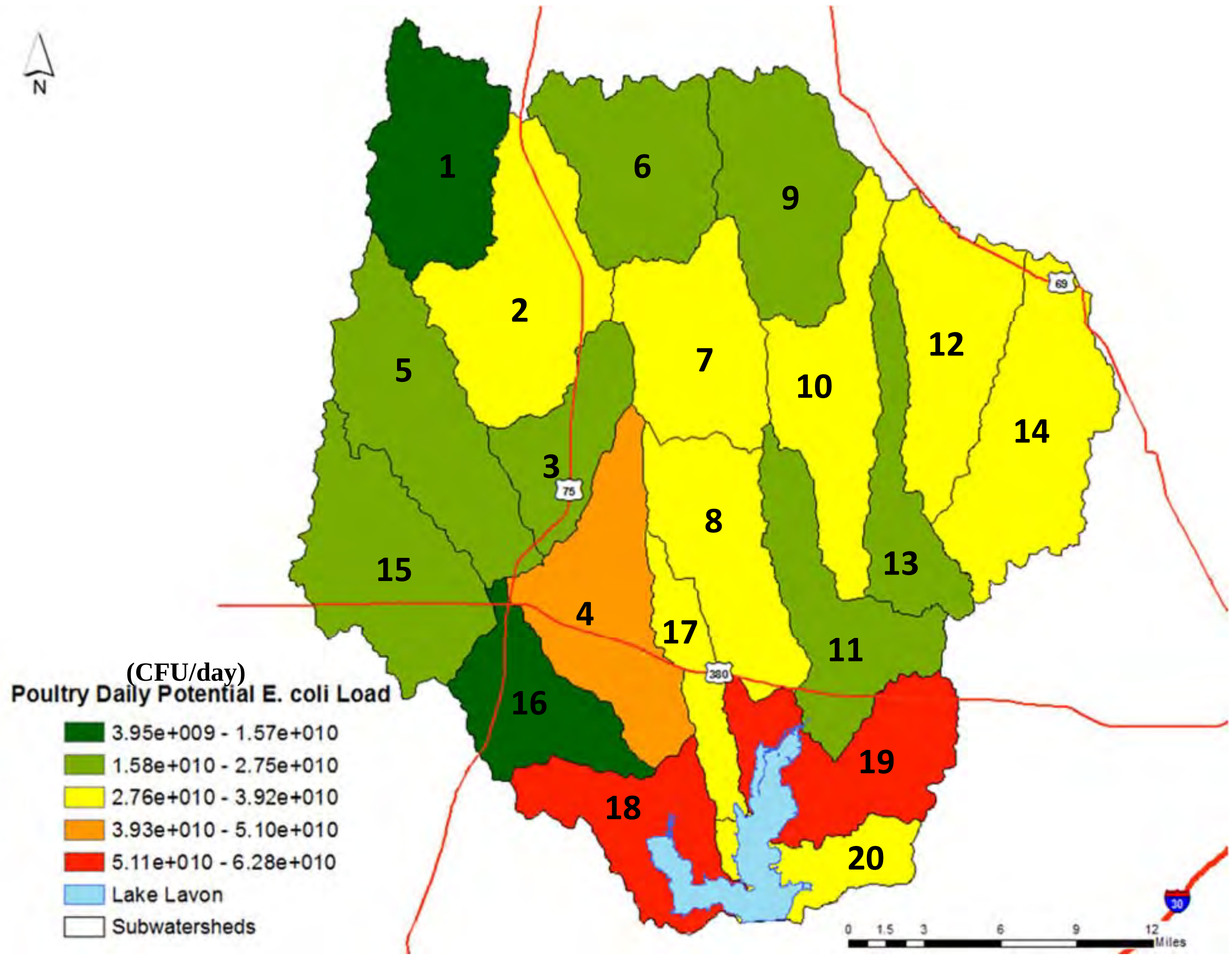

Figure 5.12. Average daily potential *E. coli* load from domestic poultry by subwatershed.

Row crops

Corn, sorghum, and wheat are the main crops grown in the watershed, while managed pasture serves to produce hay and forage crops for livestock. Fields that are grazed by livestock, including corn and sorghum stubble, wheat and managed pasture can be significant sources of both bacteria and nutrients. In contrast, row crops which are not grazed (cotton in all cases, and other crops harvested for grain, or as hay or silage) have much less of a potential to contribute bacteria, unless manure is used as a fertilizer. Thus, management measures targeting livestock will address all land uses where livestock are grazed. Bacteria management measures will also address agricultural operations that use manure as a fertilizer.

5.1.4 – Wildlife

In many watersheds across the country, *E. coli* inputs from wildlife contribute a considerable portion of the total stream bacteria load (EPA, 2002). Wildlife also can be a significant source of nutrients. This is particularly true where populations of riparian animals (raccoon, beaver, and waterfowl) are high. In one instance, raccoons were estimated to potentially deposit the most *E. coli*, followed by feral hogs, Virginia opossums, and white-tailed deer (Parker, 2010).

An assessment of watersheds within central Texas by the TCEQ included examination of bacteria sources in Peach Creek. Non-avian wildlife (wildlife other than birds) were responsible for almost 30% of the bacteria loading in that watershed (Di Giovanni and Casarez, 2006). This determination was made using Bacterial Source Tracking (BST). BST is a method for determining sources of fecal bacteria in water samples by identifying the genetic material of the bacteria found in the water sample and matching it to its source. The non-avian wildlife component includes animals such as raccoons, coyotes, deer, and other mammals. However, information on the abundance and contributions of most wildlife species is very limited. In Texas, the only wildlife species with routinely measured population estimates is the white-tailed deer (Figure 5.13). The Lavon Lake watershed has numerous bridge crossings, increasing the likelihood that deposition from bird bridge colonies could be a source of loading. In addition, the numerous small ponds, as well as Lavon Lake itself, attract significant populations of waterfowl which can contribute to bacteria and nutrient loads.

Detailed wildlife population and distribution estimates are not usually available for small wildlife, making load estimates for many of these species difficult. However, assessment of large wildlife species with reliable census data, such as deer, can be used to make inferences about the population and distribution of wildlife that share the same habitat and food sources. For this reason, SELECT analysis of wildlife focused on deer and feral hogs.

Figure 5.13. White-tailed deer are a potential source of bacteria in the Lavon Lake watershed.

Deer

White-tailed deer populations in the state of Texas are managed and their harvest is regulated by the Texas Parks & Wildlife Department (TPWD). There are many factors that are considered in the management of white-tailed deer in Texas, including carrying capacity of the land, recent population trends, hunter preferences, population densities, and competition with other species including native, domestic, and exotic animals (Richardson, 2008).

Waste products from deer, similar to livestock, can be a potential source of nutrients and bacteria. Deer spend a portion of their time almost daily in riparian areas in order to drink and remain hydrated, although daily water consumption may not be necessary depending on forage selection and climate conditions (Lautier, 1988; Richardson, 2008). As a result, both direct deposition into the stream and deposition of waste materials on the landscape in close proximity to the receiving water can occur.

The Steering Committee utilized information from local TPWD biologists in developing the deer population estimate for the watershed (Appendix F). The average density used for analysis was 62.5 acres per deer in the watershed. The total deer population was calculated by applying this density to all land uses except urban areas, cropland, and open water. This produced watershed population estimates of 1,175 deer. The deer population was then distributed to forestland, where local TPWD biologists estimate deer spend most of their time. SELECT analysis indicates the highest potential bacteria loadings from deer occur in the East Fork of the Trinity River and upper Pilot Grove Creek subwatersheds (Figure 5.14; subwatersheds 2, 4, and 9).

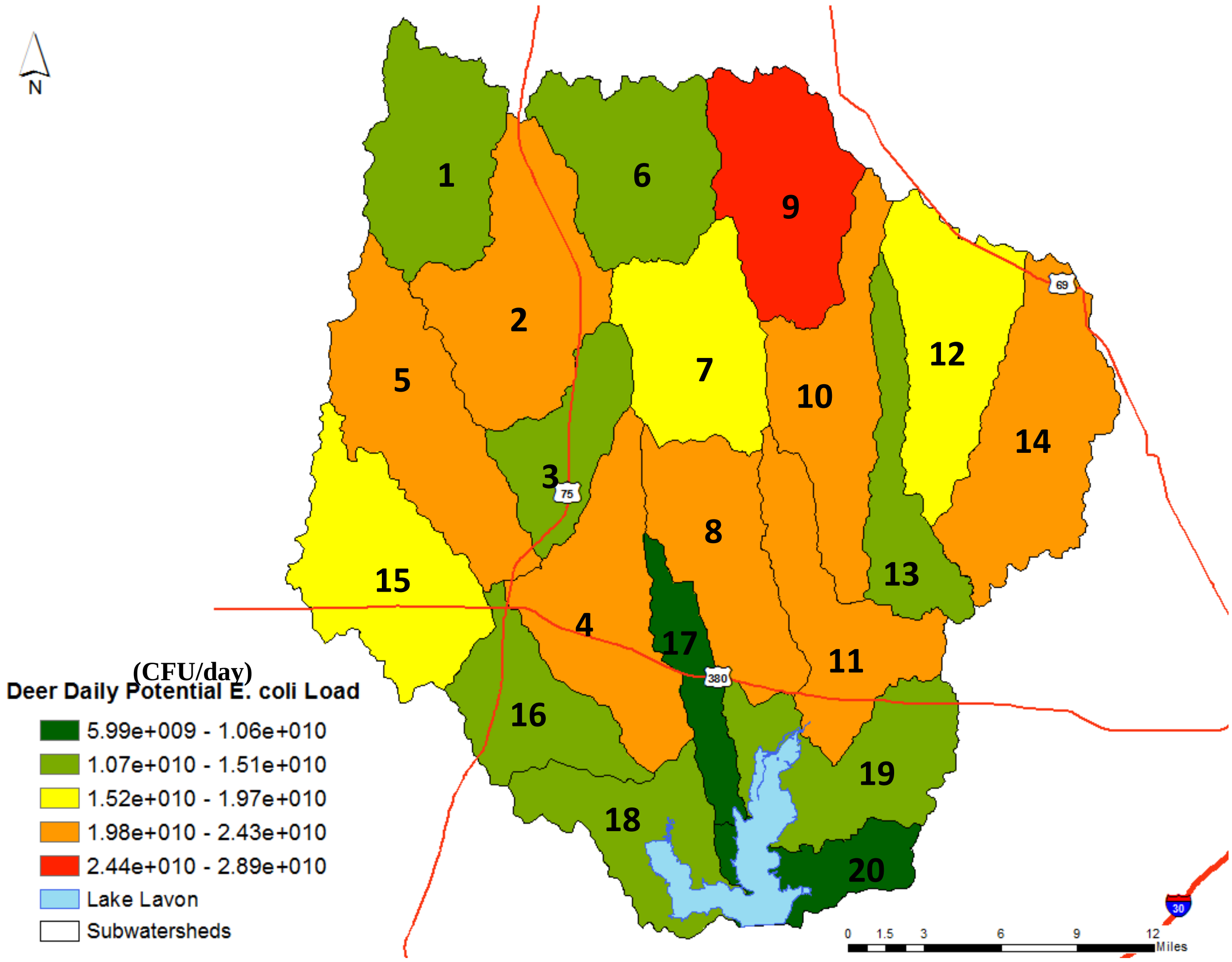

Figure 5.14. Average daily potential *E. coli* load from deer by subwatershed.

5.1.5 – Feral Hogs

In many watersheds across the state, and much of the southern United States, feral hogs are a concern (Figure 5.15). By definition, feral hogs are not wildlife, but are either domesticated hogs that have become feral, Russian boars, and/or hybrids of the two (Taylor, 2003). For this reason, feral hogs are not classified as game animals and are considered an invasive exotic species. In Texas, no regulation or coordinated massive abatement strategy is in place to control feral hogs. In order to hunt feral hogs, a hunting license is required, but there are no restrictions such as bag limits or closed seasons. Little data exist on their abundance and distribution. This is compounded by their high rate of reproduction and tendency to move in groups along waterways over large areas of a watershed in search of food.

Figure 5.15. Feral hogs are a potential source of bacteria and nutrients.

According to Texas A&M AgriLife Extension, feral hogs cause annual damages of nearly $400 million across all land uses in Texas, with over $52 million in agricultural crop and property damage alone (Timmons et al., 2012) (Figure 5.16). Particularly in periods of low flow and drought, hogs will congregate around perennial water sources to drink and wallow, and in the process deposit a portion of their waste directly in the stream. Extensive rooting activity also causes erosion. Feral hogs are predators of lambs, kid goats, baby calves, newborn fawns and ground-nesting birds, and compete for food and space with many native species of wildlife. They frequently damage or destroy urban yards, parks and golf courses, fencing, wildlife feeders and other property. In addition, vehicle collisions with feral hogs cause an estimated $1,200 in damage per collision, and create safety hazards for those involved (Mayer, 2007). As a result, stakeholders in watersheds across the state have recommended that efforts to control feral hogs be undertaken to reduce the population, limit the spread of these animals, and minimize their effects on property, other wildlife, natural resources, and water quality.

Though density and distribution data are scarce, studies estimate the hog population in Texas is between 1.8 and 3.4 million, with an average density of 1.3-2.5 hogs/ mile^2 (Timmons et al., 2012). However, historical research has shown that bottomland habitats feral hog population densities can be nearly 30 hogs/mile^2 (Tate, 1984 and Hone, 1990). Groups of feral hogs, called sounders, are mostly comprised of multiple generations of females, while males are more solitary, congregating with females primarily only during breeding. Mature sows can have as many as two litters per year with 10 to 13 piglets per litter. Typically, females can begin breeding at 8 to 10 months old, or much younger if food is abundant. The recent drought likely impacted the feral hog population in the watershed, but due to their prolific nature these animals have the capacity to recover quickly. The home range of feral hogs is based upon food availability and cover, and is usually less than 5,000 acres, but can range up to 70,000 acres (Taylor, 2003).

Figure 5.16. Property damage due to feral hogs.

The Steering Committee utilized information from local TPWD biologists to estimate the feral hog population in the watershed. A density of 25 feral hogs/mile^2 (1 hog/26 acres) was applied to all land use categories except urban and open water to determine the population estimate for the watershed. This resulted in a total population estimate of 15,900 feral hogs in the watershed. The feral hogs population was then distributed to the riparian corridors (within 328 feet of a stream), areas they are most likely to frequent and where known sightings have occurred (see Appendix F for a more complete explanation of feral hog distribution). SELECT analysis indicates that the majority of the potential bacteria impact due to feral hogs is located in northern and eastern portions of the watershed (Figure 5.17; subwatersheds 2 and 14).

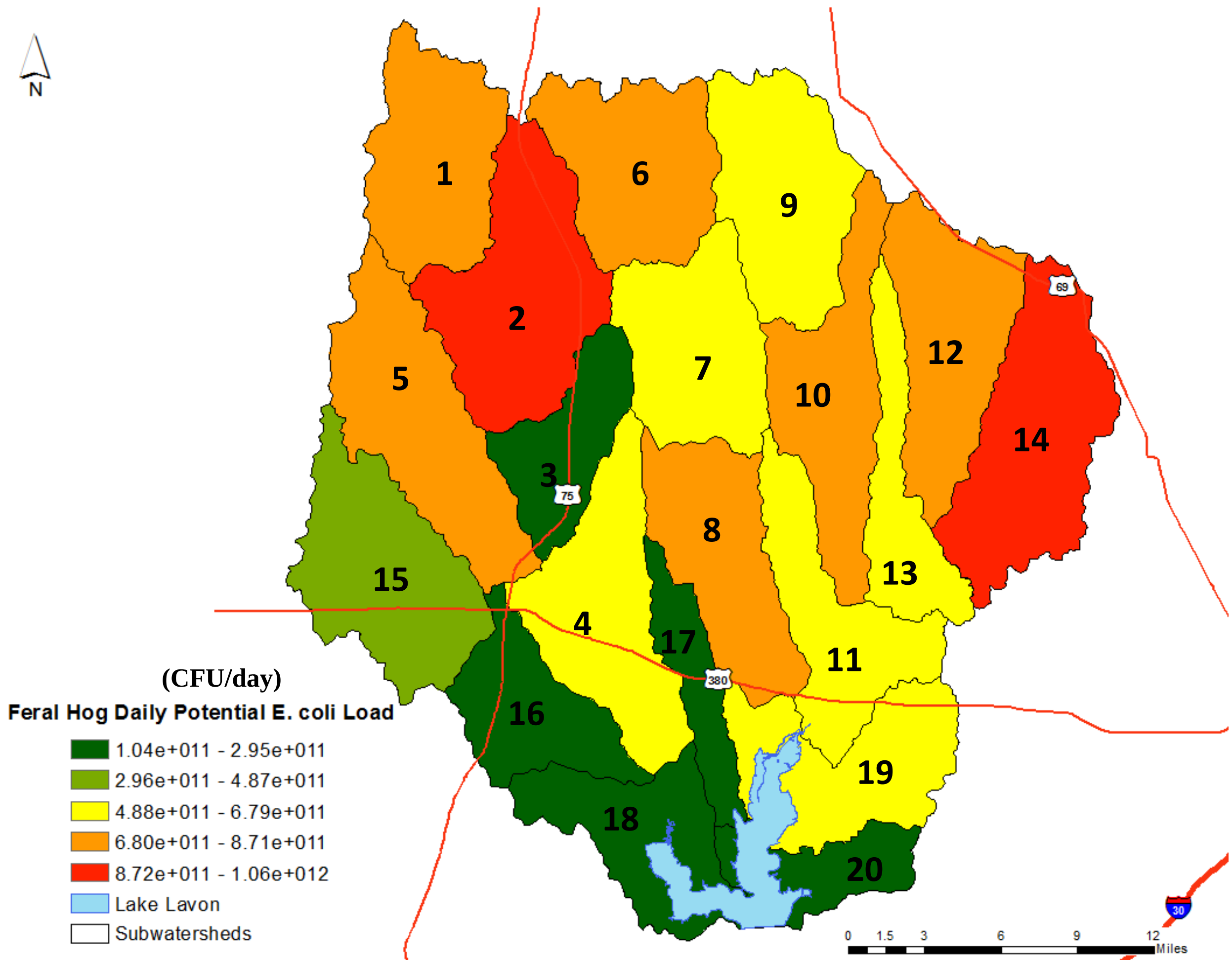

Figure 5.17. Average daily potential *E. coli* load from feral hogs by subwatershed.

5.1.6 – Relative Ranges of Bacteria Loading

Potential sources of bacteria have a range of average daily potential loads due to differences in population size and distribution, density, and daily production potentials. The relative ranges of bacteria loading across the subwatersheds of the identified potential sources are illustrated in Figure 5.18.

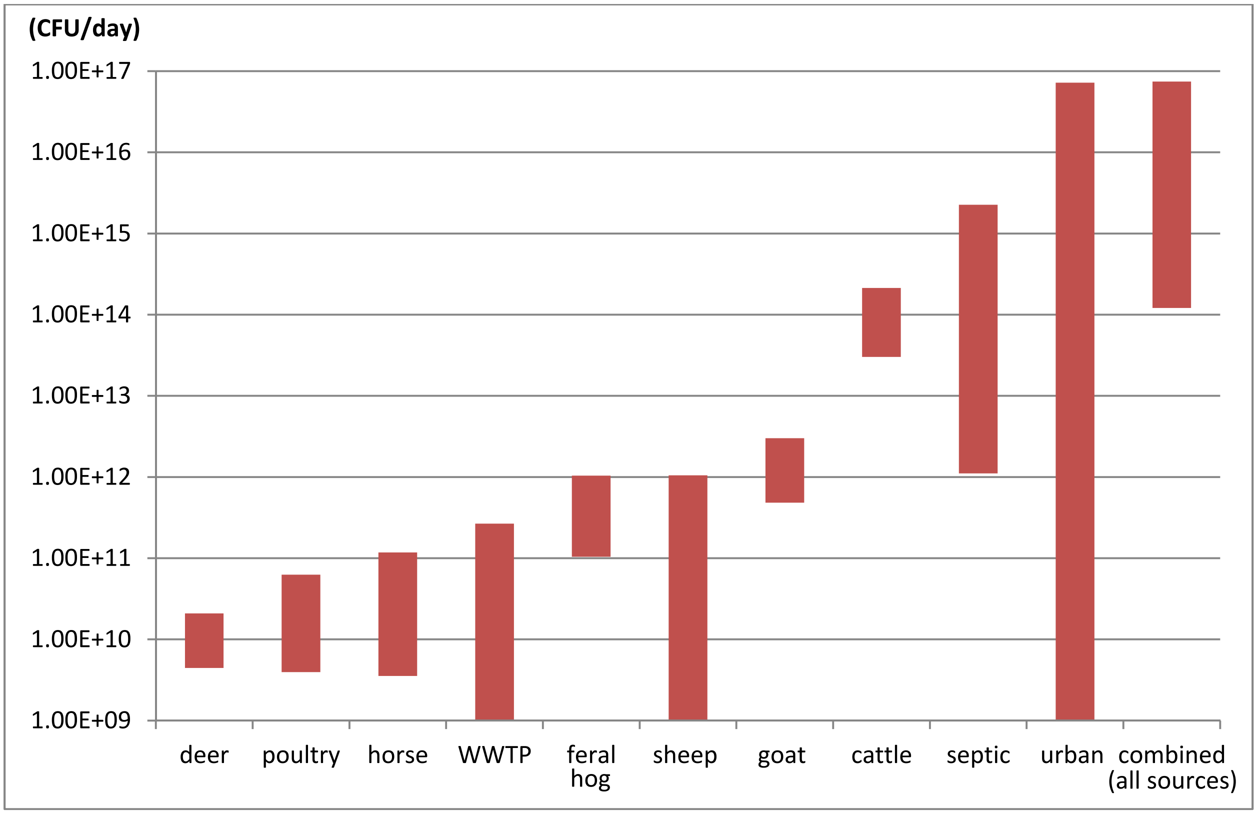

Figure 5.18. Relative ranges in loading by potential source across subwatersheds for Lavon Lake (cfu/day).

5.2 – SEDIMENT AND NUTRIENT SOURCE ANALYSIS USING SWAT

As mentioned, there have been several SWAT analyses previously conducted for the Lavon Lake watershed. Those studies analyzed sources of sediment, nutrient, and pesticide loading in the Lavon watershed. This information will be used in concert with results of the SELECT analysis to identify pollutant management measures. Results of the SWAT analyses conducted for the Lavon watershed are summarized below by pollutant category.

5.2.1 – Sediment

A USDA NRCS report released in 2006 described the results of a study that simulated sediment and atrazine loading in the Lavon Lake watershed using SWAT (NRCS, 2006). Three scenarios were modeled as part of the analysis: 1) baseline conditions (pre-1999); 2) current conditions (2006); 3) desired future conditions (i.e. application of water quality BMPs on all cropland in the watershed). This study was conducted as part of a joint effort between the USDA and TSSWCB.

Each of the three scenarios were evaluated at the farm, subwatershed, and watershed levels. Results of the analysis indicated that implementing BMPs on cropland in the watershed decreased sediment and atrazine concentrations by 88-100% and 69-97% at the farm level, 69-89% and 69-75% at the subwatershed level, and 80% and 71% at the watershed level, respectively. These results indicate that implementation of BMPs such as terracing, grassed waterways, conservation tillage, and filter strips can significantly reduce sediment and pesticide loading from cropland.

Another SWAT study was published by Wang et al. in 2013 to estimate flow and sedimentation for eleven reservoirs in the upper Trinity River Basin, including Lavon Lake. The analysis indicated that 51% of the sediment load entering Lavon Lake came from in-channel stream erosion, while the remaining 49% came from upland areas. The study also evaluated the effectiveness of sediment control ponds in the watershed by simulating their removal. There are a total of 144 sediment control ponds in the Lavon Lake watershed which capture drainage from approximately 34% of the watershed. The analysis conducted by Wang et al. estimated that these structures reduced sedimentation loadings to Lavon Lake by 19%. This indicates that in order to effectively manage sediment loading to Lavon Lake, a combination of upland and in-stream BMPs is necessary. Observations from local stakeholders and NRCS personnel indicate that many of the sediment control ponds may not be operating at their full capacity. For example, many of these structures have exceeded their 50-year operational design period, while others have issues that stem from improper design and construction. Further analysis may be needed to fully assess the current operational capacity of sediment control ponds in the watershed.

5.2.2 – Nutrients

In the 2015 Lee et al. study published in the Water Journal, SWAT was used to evaluate nutrient loading to Lavon Lake. This study built on the work previously conducted by Wang et al., 2013, which used SWAT to conduct flow and sediment modeling in the watershed. Baseline estimates for TN and TP were established and then, through scenario analysis, the effects of point source elimination and urbanization were analyzed.

Model estimates predicted that nutrient loading in the watershed was 640.3 kg/day for TN and 131.9 kg/day for TP. These estimates were based on land use data obtained from the 2001 National Land Cover Database. With this baseline established, researchers then simulated the impact of projected urban growth on TN and TP loading. Based on estimates for Collin County from the North Central Texas Council of Governments (NCTCOG), an increase in urban areas of 9% for the 30-year period between 2000 and 2030 was used to simulate urbanization of the watershed. Model estimates showed that this projected urban growth would result in a 9.2% increase in TN loading and a 14.4% increase in TP loading. One limitation of these results however is that the projected urbanization was applied to indiscriminately within each subwatershed, meaning the model distributed the 9% increase in urban areas uniformly in each subwatershed, with no consideration to where urban growth was likely to be concentrated. Regardless of these limitations, the analysis clearly indicates that urbanization will result in a substantial increase in nutrient loading to Lavon Lake.

The analysis also indicated that point sources are a significant source of nutrient loading in the Lavon watershed. The model projected a 56% reduction in TN loads and a 24% reduction in TP loads by removing all point sources of pollution in the watershed. It should be noted however that researchers did not use actual discharge data, but relied on permit limits, where available. In reality, it is not feasible to completely eliminate nutrient loading from these point sources. Nonetheless, the results of this study indicate the potential for a significant reduction in nutrient loading by implementing advanced effluent treatment technologies at point source facilities in the watershed.

Although nutrient loading from agricultural areas was not explicitly evaluated in the Lee et al. study, crop and livestock production is known to be a significant source of nutrient loading in Texas watersheds. The USDA study conducted in 2006 demonstrated the potential for significant reductions in sediment and atrazine loading from agricultural areas. Since nutrients share many of the same transport mechanisms as these pollutants, and because many of the management practices simulated in the USDA study also serve to address nutrients, it can be concluded that the application of BMPs on agricultural lands will also result in a significant reduction in nutrient loading.

5.3 – SUBWATERSHED MONITORING DATA

Starting in April, 2016, NTMWD began collecting monthly water quality samples at twenty locations in the Lavon Lake watershed. This data was intended to provide a higher degree of resolution and understanding about the extent of pollutant loads in the watershed and to identify any unknown, major sources of pollution.

Analysis of the data collected to-date was conducted to identify statistical differences between monitoring locations for *E.* coli, Total Nitrogen, and Total Phosphorus. In Table 5.2, sites with mean pollutant values that are statistically significant are designated with a plus symbol. For example, the mean TP values for samples collected at sites 21773 and 21777 are statistically different from one another and from all other mean values.

Although analysis showed a statistical difference in mean *E. coli* at site 21770, this was based on only three data points. This monitoring site is located on an ephemeral stream, which typically only flows for a short time following a period of rainfall. Consequently, the stream was dry for all but three of the monthly sampling attempts. The relatively high *E. coli* concentrations in these samples is likely due to the flushing of bacteria from upland areas that often occurs after a rainfall event. In fact, weather station data show that significant rainfall had occurred during the two week period prior to the collection of these samples. Nonetheless, additional data from site 21770 will be needed to confirm these conclusions.

Sites 21773 and 21777 are downstream of the Farmersville and Slayter Creek WWTPs, respectively. This may explain the elevated nutrient levels at these locations. Review of the NPDES permit data show there are limits in place for ammonia-nitrogen, but not for phosphorus at these facilities. However, further investigation will be needed to confirm upstream sources of nutrients at these monitoring locations.

With the exception of the three aforementioned monitoring sites, the data do not indicate the presence of any major, unknown sources of bacteria and nutrient pollution in the Lavon Lake watershed at this time.

Table 5.2. Statistical analysis of monthly subwatershed monitoring data.

Site Name	TCEQ Site ID	*E. coli* (cfu/100mL)			Total Nitrogen (mg/L)			Total Phosphorus (mg/L)		
		mean	p	n	mean	p	n	mean	p	n
Lower Wilson Creek	21764	354.5		15	8.25		14	0.08		14
Upper Wilson Creek	21765	537.8		16	1.21		15	0.06		15
Sister Grove Creek	21766	786.6		16	1.20		15	0.20		15
Upper Sister Grove Creek	21767	526.0		16	1.04		15	0.24		15
Pilot Grove Creek	15692	840.9		14	1.37		13	0.22		13
Upper Pilot Grove Creek	21768	1012.1	+	11	0.84		11	0.16		11
Indian Creek	21769	568.7		16	1.42		15	0.22		15
Bear Creek-Indian Creek	21770	1202.0	+	10	1.63		9	0.30		9
Arnold Creek	21771	779.9		15	1.33		15	0.26		15
White Rock Creek	21772	551.8		16	0.91		15	0.05		15
Elm Creek	21773	1009.8	+	16	43.3	+	15	1.94	+	15
East Fork Trinity River 1	21774	623.7		15	1.74		14	0.20		14
East Fork Trinity River 2	21775	371.4		15	1.69		15	0.21		15
Lower Honey Creek	21776	554.0		15	0.92		15	0.09		15
Throckmorton Creek	21777	382.0		14	10.1		13	0.90	+	13
East Fork Trinity River 3	21778	387.8		15	2.05		14	0.24		14
Upper Honey Creek	20932	508.3		16	0.71		15	0.07		15
East Fork Trinity River 4	21779	344.3		16	1.54		15	0.10		15
Whites Creek	21780	612.5		12	1.68		11	0.11		12
East Fork Trinity River 5	21781	437.6		16	1.48		15	0.06		15

1) Mean values designated with a + have statistically significant differences at $p<0.05$.
2) The number of data points used to calculate the mean is shown in the “n” column.

6. Management Measures

Based on a thorough evaluation of water quality data and supporting information characterizing the watershed, the Partnership and Steering Committee identified management measures that will be necessary to reduce pollutants entering Lavon Lake. Load duration curve analysis of historical data provided the basis for determining needed load reductions, and SELECT analysis enabled identification of target locations within the watershed to most efficiently achieve reduction goals. Management measures are proposed primarily to address bacteria concerns in the watershed. However, most steps taken to reduce bacteria loads also will result in reductions from other types of pollution.

The management measures discussed in this chapter represent the stakeholder's recommendations and plan to reduce and control the major potential sources of bacteria, nutrient, sediment, and hazardous substance loading within the watershed. Management measures were established under four general categories: Urban Nonpoint Source, Wastewater, Agricultural Nonpoint Source, and Wildlife and Nondomestic Animals (see Appendix H for Management Practice Efficiencies). Implementation of these management measures and expected load reductions are discussed further in Section 8 of this plan.

6.1 – URBAN NONPOINT SOURCE MANAGEMENT MEASURES

Management of potential sources of bacteria, nutrients, and sediment in existing urbanized areas, coupled with the potential for future growth and expansion, was the focus of urban nonpoint source management. Dog waste and general urban stormwater runoff are the two primary sources for which management measures were developed. A summary of recommended urban nonpoint source management measures common to all cities and community-specific measures is provided in Table 6.1.

Table 6.1. Summary of urban nonpoint source management measures.

Urban Nonpoint Source Management Measures

Common Goals

- Conduct detailed stormwater engineering assessments to determine the most effective types, design, and placement of structural control measures.
- Implement non-structural stormwater BMPs, where possible.
- Implement or expand pet and feral animal waste management activities.
- Provide guidelines and training for effective nutrient management on city property.
- Implement stormwater management activities.
    - Public education and outreach.
    - Public involvement or participation.
    - Illicit discharge detection and elimination program.
    - Manage construction site stormwater runoff.
    - Manage post-construction runoff.
    - Pollution prevention and good housekeeping practices for municipal operations.
    - Maintain streets and stormwater conveyance infrastructure.
- Provide training to watershed ISDs, city and county maintenance and parks departments, and other interested parties.
- Seek funding for maintenance and remediation of NRCS sediment control basins located in community jurisdictions.
- Seek funding for stream, streambank, and riparian restoration.
- Provide guidelines and training for development of stormwater management programs in small and growing communities.

Large Communities and MS4 Permit Holders (i.e. Allen, Celina, Fairview, Frisco, Lavon, Lowry Crossing, Lucas, McKinney, Melissa, New Hope, Princeton, Prosper, St. Paul, Wylie)

- Fully implement MS4 permit.
- Seek funding for implementation of targeted control measures.
- Encourage the use of green infrastructure and low impact development.
- Install pet waste stations and signage in neighborhoods and parks, where needed.
- Install storm drain markers and watershed signs.
- Expand education and outreach activities.

Table 6.1. Summary of urban nonpoint source management measures. (cont.)

Urban Nonpoint Source Management Measures
Small & Growing Communities (i.e. Anna, Blue Ridge, Dorchester, Farmersville, Gunter, Howe, Leonard, Nevada, Tom Bean, Trenton, Van Alstyne, Weston, and Whitewright) • Conduct detailed stormwater engineering assessments to determine the most effective types, design, and placement of structural control measures. • Develop and adopt city stormwater and development ordinances, where needed. • Develop and adopt stormwater drainage design criteria and construction standards. • Establish a schedule and plan for stormwater maintenance operations. • Seek funding for implementation of targeted control measures. • Install pet waste stations and signage in neighborhoods and parks, where needed. • Install storm drain markers and watershed signs. • Initiate education and outreach activities.

6.1.1 – Urban Stormwater Management

Stormwater Permitting

In Texas, regulation of stormwater from urban areas is managed by the TCEQ Municipal Separate Storm Sewer System (MS4) Permit program. For large urban areas with a population of 100,000 or greater (based on the latest census), a MS4 Permit is required.

Stormwater from smaller "urbanized areas", as defined by the U.S. Bureau of the Census as part of the decennial Census, is also regulated by the MS4 Stormwater Permit program. These small urbanized areas are defined as a land area comprising one or more central places and the adjacent densely settled surrounding urban fringe that together have a residential population density of at least 1,000 people per square mile. However, entities that serve less than 10,000 people may qualify for a MS4 permit waiver, provided they meet certain pollutant discharge criteria (EPA, 2012).

In order to qualify for a MS4 permit waiver, a small urban area must demonstrate that their discharges do not cause, or have the potential to cause, water quality impairment. The requirements for demonstrating this differ based on population size of the entity applying for the waiver. For applicants whose jurisdiction serves less than 1,000 people, they must demonstrate that their system does not contribute substantially to downstream pollutant loadings and, if their systems discharges to an impaired waterbody, that stormwater controls are not needed based on an EPA approved or established Total Maximum Daily Load (TMDL) allocation. In addition to these requirements, waiver applicants whose jurisdiction serves at least 1,000 but less than 10,000 people, must also demonstrate that future discharges from their system do not have the potential to result in water quality impairments.

MS4 Stormwater permits are intended to protect human life, health and property by providing flood control and drainage while also minimizing pollutant loading to receiving waterbodies. Management practices included in an MS4 permit typically address the following areas:

- Public education and outreach.
- Public involvement or participation.
- Construction site stormwater runoff control.
- Post-construction stormwater management in new developments and redevelopments.
- Pollution prevention and good housekeeping for municipal operations.
- Detection and elimination of illicit discharges.
- Industrial stormwater sources.

In addition to these activities, and to further reduce potential pollutant loading to Lavon Lake, cities also will work to adopt the following BMPs:

- Stormwater drain stenciling and watershed signage.
- Installation of stormwater detention facilities.
- Stormwater detention pond retrofits to enhance reduction of bacteria, nutrient, and/or sediment.
- Design a recognition program for voluntary pollutant reduction measures incorporated in new developments.
- Encourage the use of green infrastructure in urban areas. (Figure 6.1)

Figure 6.1. A rain garden captures and treats stormwater runoff from an adjacent parking lot. (Photo courtesy of Texas A&M AgriLife)

Small and Growing Communities

An initial goal of the Partnership will be to support communities to establish stormwater management programs in advance of future growth which may lead to MS4 permitting requirements. This will include assisting with the development of stormwater ordinances, the acquisition of funding to conduct detailed engineering analyses to properly locate and design stormwater management practices specific to each community, initiating public education and outreach efforts, and providing training for city staff. The Partnership will also seek to assist current MS4 permit holders to bolster their implementation efforts. Table 6.2 denotes which cities in the watershed are currently required to obtain a MS4 permit or waiver.

Table 6.2. MS4 Permit Status.

Name	MS4 Permit or Waiver Required	Permit Status
Allen	Yes	Active
Anna	No	n/a
Blue Ridge	No	n/a
Celina	Yes	Active
Collin County	Yes	Active
Dorchester	No	n/a
Fairview	Yes	Active
Farmersville	No	n/a
Frisco	Yes	Active
Gunter	No	n/a
Howe	No	n/a
Lavon	Yes	Active
Leonard	No	n/a
Lowry Crossing	Yes	Waiver
Lucas	Yes	Active
McKinney	Yes	Active
Melissa	Yes	Active
Nevada	No	n/a
New Hope	Yes	Waiver
Princeton	Yes	Active
Prosper	Yes	Active
St. Paul	Yes	Waiver
Tom Bean	No	n/a
Trenton	No	n/a
Van Alstyne	No	n/a
Weston	No	n/a
Whitewright	No	n/a
Wylie	Yes	Active

6.1.2 – Recommended Management Measures

Although MS4 stormwater permits are generally designed to minimize loading from all types of pollution, the Partnership recognizes that addressing bacteria, nutrient, and sediment pollution is of particular importance in the Lavon Lake watershed. Thus, the Partnership made specific recommendations for managing each of these nonpoint source pollutants in urban areas.

Bacteria

Population estimates from the American Veterinary Medical Association were used to estimate the total number of dogs in each subwatershed (AVMA, 2012). These numbers were then multiplied by the necessary bacteria load reductions in each subwatershed to estimate the minimum number of dogs that should be managed within each area. Results for the 20 subwatersheds are presented in Table 6.3. Based on these estimates, emphasis and resources will be directed primarily into the urbanized subwatersheds (15 &16). Management strategies will include spay/neuter programs, waste bag dispenser and collection stations, code enforcement, and intensive public outreach.

It is important to note that waste from other pet species can also contribute *E. coli* to nearby waterbodies. However, due to limited population data for the region, specific pet waste reductions were not recommended for other pet species. However, the dog population estimates provided in Table 6.3 can be used to direct implementation resources aimed at managing waste from other pet species.

Table 6.3. Recommended number of dogs under pet waste management practices.

Subwatershed	*E. coli* Reduction Goal	Total Dogs	Dogs Managed*
1	33%	660	218
2	33%	3,014	995
3	33%	4,835	1,596
4	33%	9,214	3,041
5	33%	2,479	818
6	27%	1,791	484
7	27%	1,816	490
8	27%	1,630	440
9	32%	1,423	455
10	32%	1,448	463
11	32%	1,051	336
12	32%	1,443	462
13	32%	515	165
14	32%	1,846	591
15	49%	25,178	12,337
16	49%	28,446	13,939
17	27%	3,675	992
18	27%	8,221	2,220
19	27%	3,438	928
20	27%	1,301	351
Total		103,426	41,329

* Refers to the number of dogs whose waste is managed by their owners picking up and disposing of it properly.

Spay/Neuter Programs

The Animal Friendly Grant Program offered by the Zoonosis Control Branch of the Texas Department of State Health Services (DSHS) provides funding to dog and cat owners to have pets spayed or neutered at little or no cost. Eligible participants are:

1. A private or public releasing agency (animal shelter);
2. An entity qualified as a charitable organization under Section 501c(3), Internal Revenue Code, that has animal welfare or sterilizing dogs and cats owned by the general public at minimal or no cost as its primary purpose; or
3. A local nonprofit veterinary medical association with an established program for sterilizing animals owned by the general public at minimal or no cost.

The DSHS request for proposals is announced biannually, and the grant cycle typically runs from September 1st to August 31st each year. Successful programs are usually offered a continuation grant for a second year.

There are also several organizations in the area which offer low-cost spay/neuter services to low income pet owners. Facilities in and near the watershed that offer these services include the SPCA of Texas office in McKinney, Humane Animal Hospital in Plano, and Cause for Paws in Greenville. In addition, there are a number of animal shelters, and city and county animal control departments that assist pet owners with finding affordable spay/neuter services. In fact, Collin County Animal Services offers low cost spay/neuter services on the first Friday and second Tuesday of every month.

The Partnership will facilitate participation between cities, counties, pet shelters, and veterinary clinics to implement spay/neuter programs in the watershed. It will also assist with acquisition of grant funding to support these activities.

Pet Waste Ordinances

A number of cities in the watershed have ordinances in place that require pet owners to pick up waste in public areas at all times, and on private property, if that waste is causing unsanitary, dangerous, or offensive conditions. Some cities even limit the number of pets per residence and require that pet owners carry the materials needed to remove and adequately dispose of pet waste when using public dog parks. However, code enforcement can be difficult, and require significant resources. Thus, in addition to code enforcement efforts, the use of signage, pet waste stations, and public education and outreach is important.

Several cities in the watershed promote the Doo the Right Thing program, developed by the NCTCOG. In addition, many parks and neighborhoods in the watershed have signage and/or pet waste stations. The Partnership will work to secure funding to purchase and install signage and pet waste stations in parks and neighborhoods, as needed, and to implement outreach campaigns to educate local citizens on the importance of pet waste management. The Partnership will also assist cities without pet ordinances with codifying language to address pet waste.

Nutrients

In addition to pet waste, landscape fertilizer application can be a significant source of nutrient loading from urban areas (He *et al*, 2014). Application of fertilizer is generally not regulated and thus, education and outreach are recommended for addressing nonpoint source pollution resulting from urban fertilizer applications in the watershed.

Outreach and education regarding landscape nutrient management will be targeted to homeowners in the watershed. This will include information about soil testing, and fertilizer selection, application, storage, and disposal.

Maintenance and Operations staff from all ISDs in the watershed, as well as city and county personnel will be offered SAFE Program (Sports and Athletic Field Education) training in nutrient management to reduce potential runoff losses of nutrients, and to take advantage of potential fertilizer cost savings. Similar training will be offered to golf course staff and city and county personnel responsible for landscape maintenance in public spaces, such as parks, roadsides, and medians.

Sediment

Urbanization has been shown to cause hydrologic change in watersheds that can result in sediment transport and deposition (EPA, 1984; Walsh et al., 2005). This is largely due to the disturbance of soil and vegetation during construction and maintenance activities, and from erosion caused by increased runoff from impervious surfaces. Although MS4 stormwater permits require cities to implement measures to mitigate these effects, space for stormwater control features can be limited.

Low impact development (LID) and green infrastructure involve incorporating stormwater controls into building and landscape design, and preserving critically important areas such as streambanks and floodplains. Utilizing green infrastructure and LID can reduce the peak flow and volume of stormwater flows to receiving waterbodies, while also reducing the amount of pollutants contained therein. More specifically, these practices can reduce sediment loading to receiving waterbodies, and the reduction in volume and peak flow can reduce erosion of streambanks and stream beds and banks.

As previously noted, a significant amount of sediment loading to Lavon Lake comes from the erosion of stream beds and banks. Although conventional stormwater controls and green infrastructure can help reduce stream channel erosion by reducing peak flow and volume, stabilization of stream beds and banks may be needed in some areas. This can include reestablishing vegetation, reshaping stream banks, and installing structural controls, such as culverts, rip-rap, and gabions.

Training will be offered to city and county staff, real estate developers, and elected officials about the benefits of incorporating green infrastructure and LID into communities. Additional trainings will be offered regarding riparian and stream restoration, and streambank stabilization. The Partnership will support the identification and implementation of activities to prevent erosion and sediment loss in the watershed, and provide assistance in acquiring grant funds for maintenance and remediation of NRCS sediment control ponds located in community jurisdictions.

Hazardous Substances

In addition to bacteria, nutrients, and sediment, hazardous substances from urban areas may also impact water quality in the Lavon Lake watershed. Hazardous substances include any material that can be harmful to humans and/or the environment. Common examples of hazardous substances include industrial chemicals, petroleum products, herbicides, pesticides, pharmaceuticals, and other household hazardous waste materials. The Partnership and Steering Committee recommend implementing education and outreach programs focused on the proper use, storage, and disposal of hazardous substances, as well as increased opportunities for hazardous waste collection events in the watershed.

6.1.3 – Education and Outreach Initiatives

All MS4 permits in the watershed include outreach and education activities. These include activities such as stormwater drain stenciling, educational workshops, outreach campaigns, and more. In addition to these activities, and to further reduce potential pollutant loading to Lavon Lake, cities also will work to adopt the following BMPs:

- Signage denoting the watershed boundary and environmentally sensitive areas.
- Design a recognition program for voluntary pollutant reduction measures incorporated in new developments.
- Encourage the use of green infrastructure and LID in the design of streets and sidewalks, real estate developments, and urban landscapes.

There are also several regional education and outreach efforts in the watershed which focus on water conservation and stormwater management. A brief description of these activities is provided below.

<u>Water IQ</u>

The NTMWD and a number of cities in the watershed participate in the Water IQ program, which is a statewide public awareness program developed by the TWDB. The goal of the Water IQ program is to provide resources and support to local entities in promoting conservation and awareness of water resources. Several participating cities in the watersheds have Water IQ program information on their websites and use the program logo on outreach materials. Also, the NTMWD has a dedicated Water IQ website (www.northtexaswateriq.org) which is focused on regional water supplies, including Lavon Lake.

<u>Water-My-Yard</u>

The Water-My-Yard (WMY) program was developed by Texas A&M AgriLife Extension as a tool to help homeowners make informed decisions about landscape irrigation applications. This online tool uses local weather station data to determine evapotranspiration (ET) rates and then sends out an irrigation recommendation to subscribers. The NTMWD has partnered with Texas A&M AgriLife to promote the WMY program, and maintains 15 weather stations and 12 rain gauges which supply local data for WMY subscribers in region. In 2017 the NTMWD launched a major outreach effort to encourage stakeholders to subscribe to WMY, use native plants, and conserve water. This campaign included radio, television, billboard, newspaper, and social media ads. The goal of the campaign is to increase WMY subscriptions in the region to 20,000 and encourage water conservation in urban landscapes.

AgriLife Landscape Management Trainings

The NTMWD has partnered with Texas A&M AgriLife to offer a series of Landscape Management trainings for homeowners in its member cities. These trainings consist of information related to irrigation, fertilizer, herbicide, and pesticide application, as well as the use of native plants and best management practices. The Partnership will support the offering of similar trainings to homeowners throughout the watershed.

NCTCOG

The North Central Texas Council of Governments provides a number of resources for protecting water quality and the environment. Through a variety of NCTCOG programs, cities and counties have access to publications, educational and outreach materials, and a number of other resources. A summary of several key NCTCOG resources is provided below.

- Water Quality Management Plan – Provides information to local stakeholders about current and project urban growth, and how that may impact water quality and wastewater management.
- Texas SmartScape Website – Designed to educate citizens about the ecological, economic, and aesthetic benefits of using native and adaptive plants.
- Stormwater – The Regional Stormwater Management program assists local governments in managing stormwater and meeting MS4 permit requirements.
- iSWM – The *i*ntegrated Stormwater Management (iSWM™) program focuses on site development and redevelopment through regionally developed criteria to help a community achieve their goals of water quality protection, streambank protection, and flood mitigation.
- BMP Library – Provides links to an array of resources related to stormwater.
- Trash Free Waters Project – Currently working to aid community cleanup efforts by developing an online tool to report and identify litter hotspots.
- Regional Ecosystem Framework – The REF geographic information system (GIS) tool allows users to identify areas of relative ecological importance.
- Committee Meetings – The NCTCOG hosts a number of recurring roundtable and committee meetings that focus on aspects of watershed and water quality protection.
- Annual Cooperative Purchase – Maximizes group savings on outreach and educational materials by combining orders.

6.2 – WASTEWATER MANAGEMENT MEASURES

The Partnership and Steering Committee worked with city, county, and NTMWD personnel to identify management measures that should be included in the WPP. Table 6.4 includes a summary of key measures and actions recommended by the Partnership.

Table 6.4. Summary of wastewater management measures for the Lavon Lake Watershed.

Wastewater Management Measures
• NTMWD and its regional wastewater (WW) members will develop and implement Capacity Management Operations and Maintenance (CMOM) and/or Sanitary Sewer Overflow (SSO) plans. • Municipal Utility Districts (MUD) and small WWTPs in the watershed will explore developing CMOM and SSO plans. • NTMWD and its regional WW member and customer communities will implement the Defend Your Drain outreach and education program. • Cities in the watershed will explore the possibility of participating in the SSO Initiative with TCEQ. • Cities in the watershed will work to extend sanitary sewer service to residents in marginal areas utilizing septic systems. • Counties will continue current inspection and enforcement programs for septic systems. • NTMWD and/or counties will conduct educational programs for homeowners on septic system management. • Funding will be sought to provide homeowners with assistance for repair/replacement/ upgrade of failing septic systems. • Funding will be sought to enable more frequent and expansive household hazardous waste and bulk waste cleanups in the watershed.

6.2.1 – Wastewater Treatment Facilities

As previously noted, thirteen wastewater treatment plants discharge in the Lavon Lake watershed. While all WWTPs must comply with site-specific regulations contained in a TPDES permit issued by the TCEQ, the Partnership recommends that facilities strive to exceed these requirements, where possible.

6.2.2 – Sanitary Sewer Collection Systems

Utilities manage the means of wastewater conveyance to WWTPs and are charged with the upkeep and maintenance of these systems, known as sanitary sewer collection systems. Sanitary sewer collection systems direct wastewater from homes and commercial businesses to a wastewater treatment facility for final treatment before discharge to waters of the State.

EPA has developed guidance for state inspectors, municipalities, and consultants to use for designing collection systems (EPA, 2005). Capacity, management, operations and maintenance (CMOM) are four important elements to consider when designing and maintaining a collection system.

Regional CMOM Program

In 2016 the NTMWD entered into a memorandum of understanding with its twelve regional wastewater member communities (i.e. Allen, Forney, Frisco, Heath, McKinney, Mesquite, Plano, Princeton, Prosper Richardson, Rockwall, and Seagoville) regarding development of a regional CMOM program. These communities have completed their CMOM plans, and development of a Regional CMOM Coordination Plan is underway. These plans include components that address the following aspects of the NTMWD's and communities' practices, assets, and programs:

- Emergency response and mitigation plan.
- Collection system cleaning program.
- Comprehensive fats, roots, oil, and grease (FROG) program.
- Condition assessment of force mains, lift stations, manholes, gravity sewers, and service laterals.
- Hydraulic modeling capacity assessment.
- Formalized operation and maintenance (O&M) training program including standard operating procedures and classroom training.
- Point of entry and flow metering program.
- Maintenance management system.
- Framework for identification and implementation of NTMWD and community capital project needs resulting from condition and capacity assessments.

Although some of the aforementioned communities lie outside of the Lavon Lake watershed, a portion of their wastewater is transported to the Lavon Lake watershed via NTMWD sanitary sewer systems. These sanitary sewer systems supply the Wilson Creek Regional WWTP, which accounts for approximately 94% of the permitted wastewater flow in the Lavon Lake watershed.

Sanitary Sewer Overflow Initiative

The TCEQ has developed a program called the Sanitary Sewer Overflow Initiative (SSO Initiative) to help collection system owners follow EPA guidance. SSOs are a type of unauthorized discharge of untreated or partially treated wastewater from a collection system or its components (manhole, lift station, or cleanout) before it has reached a treatment facility. The goal of the Initiative is to reduce the number of SSOs and address them before they harm human health, safety, or the environment, and/or become enforcement issues (TCEQ, 2008). This is accomplished by incorporating best practices into regular municipal operations and developing an SSO Plan. An SSO Plan identifies all high risk areas and documented problems in a collection system, and establishes a step by step plan to proactively address current and future issues.

The NTMWD's sanitary sewer collection system is comprised of four subunits which include the Upper East Fork Interceptor System, Muddy Creek WWTP Conveyance System, South Mesquite Regional WWTP Conveyance System, and the Sabine Creek WWTP Conveyance System. The Upper East Fork Interceptor System has been enrolled in the TCEQ SSO initiative since 2010. However, the NTMWD has developed a plan to enroll all of its collection systems in the SSO initiative. This plan will include activities such as the establishment of maintenance and inspection schedules, rehabilitation of aging infrastructure, and more.

Although the NTMWD collection systems account for the vast majority of wastewater flows in the watershed, there are a number of smaller sanitary sewer systems which operate independently. The Partnership will support the development of CMOM and SSO plans for these systems under this initiative.

6.2.3 – Defend Your Drain Program

The Defend Your Drain (DYD) program was developed by the City of Dallas to inform its citizens about the detrimental effects of certain products and substances on their plumbing, wastewater system, and the environment, in an attempt to reduce SSOs. The program was largely successful and has since been adopted by a number of entities in the North Texas region. In 2016 the NTMWD collaborated with its wastewater system member and customer communities to explore opportunities for outreach and education relating to proper disposal of personal care products, household chemicals, and fats, oils, and grease (FOG). As a result, these entities chose to adopt the Defend Your Drain program and have begun implementation. The Partnership will support implementation of the DYD program and other outreach and education efforts aimed at reducing SSOs and unauthorized wastewater discharges.

6.2.4 – Regional Wastewater System Study

The NTMWD is conducting a series of ongoing studies to explore options for meeting future wastewater treatment demands. These efforts are focused on meeting projected wastewater demands in the region over the next 50 years. Impact on the environment and water quality is a chief consideration in these studies. In fact, expanding regional wastewater treatment capacity will provide a number of benefits including reduced peak demand pressure on existing infrastructure, and the ability to extend service to marginal areas in the watershed. Marginal areas in the watershed include those that are currently serviced by small WWTPs and septic systems.

6.2.5 – Septic Systems

SELECT analysis was utilized to estimate the number of potentially failing septic systems in the watershed, and identify systems in close proximity (within 1,000 ft.) to Lavon Lake and its tributaries. These systems will be targeted for inspection and repair/replacement, where needed, due to their greater potential to impact water quality. Analysis included a variable failure rate, dependent upon soil type and age of the system. Calculated failure rates were applied to the total number of systems within each subwatershed to predict the number of systems that may require management, repair, or replacement (Table 6.5).

Table 6.5. Estimated number of septic systems, failing systems, and number of systems within 1,000 feet of a stream.

Subwatershed	Total Systems	Potential Failing Systems	Near-Stream Systems
1	330	49	239
2	759	111	641
3	1	0	1
4	1,037	152	744
5	389	57	298
6	694	100	530
7	661	96	506
8	357	51	273
9	1,007	148	529
10	746	109	540
11	542	79	417
12	794	117	569
13	412	60	324
14	422	62	357
15	191	28	140
16	3,402	502	2,218
17	68	10	33
18	1,676	242	1,156
19	825	121	599
20	842	123	593
Total	15,156	2,220	10,708

Based on estimated failure rate and proximity to a waterway, the greatest concentration of systems in need of management is in the southwestern portion of the watershed (subwatersheds 16 and 18) in Collin County. Inspection programs will initially focus on these areas, but over time will work to address all subwatersheds.

To assist with repair and replacement of failing septic systems, high risk areas within targeted subwatersheds will be identified through coordination with authorized agents and inspectors in Collin, Fannin, Grayson, and Hunt Counties. Critical areas that would benefit from more intense monitoring and inspection will be located based on GIS mapping, county data, and local knowledge. Education and assistance programs will then be targeted to these residents.

The aforementioned counties continue to update septic system permit information, compiling data on system age, location, and condition in electronic format for quick access. With incorporation of new information, these databases will allow patterns of system installation and failure to be monitored in order to predict, prevent, and respond to problems in the future.

In Texas, regional governments such as cities, counties, river authorities, and special districts are authorized to implement and enforce septic system regulations with approval and oversight by the TCEQ. All counties in the watershed have aggressive septic system enforcement procedures, and processes are in place with some local court systems for fast resolution of septic system violations. Septic system owners in the watershed must maintain a maintenance contract with a licensed provider at all times. However, counties in the watershed allow homeowners to forego this requirement and maintain their own system, provided the homeowner has attended a county-approved training and/or holds a county-approved professional license. Some counties in the watershed also have adopted more stringent requirements, including the need for a permit for all systems, lot size restrictions, floodplain determination, restrictions on items (such as picnic tables, play equipment, and barbeque pits) that can be placed within the surface application spray area of an aerobic system, and more.

County jurisdiction for septic systems typically does not include areas within incorporated cities. Although most cities in the watershed have policies in place aimed at reducing the number of households that are not connected to a centralized wastewater treatment system, there are some septic systems still present within city limits or extraterritorial jurisdictions.

Funding will be sought to assist homeowners with repair of failing septic systems and decommissioning old systems. Another goal of the WPP is to assist with identifying funding sources to support extending sanitary sewer service to areas not currently on a collection system. This is an expensive, multi-phase process, requiring extensive engineering analysis, financial planning, and a critical public outreach and education program. Areas will be identified and selected based upon the number of systems, estimated failure rate, and potential reductions in bacteria and nutrient loading (see Appendix F).

6.2.6 – Household Hazardous Waste

Several cities in the watershed have programs to deal with household hazardous waste (HHW) products and debris (Figure 6.2). These programs include year-round collection of certain HHW products, periodic HHW collection events, or both. There are however some restrictions on the types and amounts of products accepted through these programs. For example, collections are often limited to 50 lb. per deposit, and chemical containers over 5 gallons are not always accepted. In addition to these city programs, there are some local organizations that accept certain materials, such as the Collin County Habitat for Humanity organizations, which accept unused paint, appliances, and building materials. The Partnership will assist these entities in obtaining funding for expanding the frequency, types, and amount of materials currently accepted through these programs. In addition, the Partnership will support activities that increase public participation in these programs, such as education and outreach, and developing a comprehensive database of HHW programs in the watershed.

Figure 6.2. City of Frisco Environmental Services office and HHW collection center. (Photo courtesy of City of Frisco)

6.3 – AGRICULTURAL AND RURAL NONPOINT SOURCE MANAGEMENT MEASURES

The Partnership and Steering Committee recommended multiple agricultural BMPs be integrated, where appropriate, into local operations in order to address all potential agricultural-related sources of bacteria, nutrients, and sediment. They further recommend this can best be done by development of voluntary, site-specific management plans for individual farms. Both the NRCS and TSSWCB offer agricultural producers technical guidance as well as financial incentives for implementation of BMPs. To receive financial incentives from TSSWCB, the landowner must develop a Water Quality Management Plan (WQMP) with the local Soil and Water Conservation District (SWCD) that is customized to fit the needs of their operation. The NRCS offers options for development and implementation of both individual practices and whole farm conservation plans. To facilitate development and implementation of these management plans, the Lavon Lake Watershed Partnership will pursue funding to support a financial incentives program for the Collin County, Fannin County, Upper Elm-Red, and Upper Sabine SWCDs, and the creation of a new technician position to provide assistance in the watershed. This technician will serve the watershed by working one-on-one with local agricultural producers to develop and implement WQMPs.

6.3.1 – Livestock Operations

Based on 2012 USDA-NASS data, the average farm size was estimated to be 147 acres in the watershed. Local knowledge from NRCS, Extension, and agricultural producers indicates that livestock operations in the watershed maintain an average of approximately 50 animal units (cumulative cattle, sheep, goats, and horses) (Figure 6.3). Utilizing this information, along with results from the SELECT and LDC analyses, the number of comprehensive management plans necessary for livestock operations within each subwatershed was estimated and is presented in Table 6.5.

The estimated number of animal units in each subwatershed was divided by the average number of animal units per operation to determine the number of livestock operations within each subwatershed. Next, the bacteria reduction percentage was applied to the total number of livestock operations within each subwatershed to determine the number of operations that should undergo plan development (Table 6.6). Based on these estimates, the number of livestock operation management plans required for individual subwatersheds ranges from 5 to 23. A total of 253 management plans are necessary for the entire Lavon Lake watershed.

Figure 6.3. Livestock grazing in the Lavon Lake watershed.

Financial incentives and technical assistance programs will be directed to subwatersheds with the greatest potential for bacteria loading as identified by SELECT analysis. However, recognizing that livestock numbers within individual watersheds vary due to weather conditions and market economics, programs provided in the watershed will require flexibility. In addition, preference will be given to operations with the greatest number of animal units, particularly those located closest to streams and drainage areas.

Table 6.6. Recommended number of management plans for livestock operations by subwatershed.

Subwatershed	Animal Units	Number of Farms	Bacteria Reduction %	Recommended # of WQMPs
1	2,030	41	33%	13
2	2,607	52	33%	17
3	1,039	21	33%	7
4	1,592	32	33%	11
5	3,387	68	33%	22
6	2,490	50	27%	13
7	2,318	46	27%	13
8	2,282	46	27%	12
9	2,580	52	32%	17
10	2,685	54	32%	17
11	1,946	39	32%	12
12	3,290	66	32%	21
13	1,732	35	32%	11
14	3,789	76	32%	24
15	1,382	28	49%	14
16	531	11	49%	5
17	567	11	27%	3
18	847	17	27%	5
19	2,102	42	27%	11
20	802	16	27%	4
Total	39,998	2,049		253

6.3.2 – Cropland Operations

As previously noted, there are approximately 84,827 acres of cultivated corps in the watershed. The Partnership recommends developing water quality management plans for row crop operations. These plans will focus on mitigating nutrient and sediment loads, which are the primary pollutants from croplands (Figure 6.4), as well as herbicide and pesticide loads. Initial efforts will focus on subwatersheds 1, 2, 3, and 4, where the majority of cropland acres are found, and priority will be given to operations immediately adjacent to waterways.

Figure 6.4. Erosion from a wheat field following a period of significant rainfall.

6.3.3 – Management Measures

Due to the diffuse nature of nonpoint source pollution, a combination of BMPs is most commonly required to address nonpoint source pollution from agricultural operations (TWS Handbook, 2015). Selection of BMPs for WQMP development is site specific, and tailored to address the physical and operational characteristics of the property. Therefore, it is not feasible to quantify the extent of individual management measures for Agricultural and Rural lands in the watershed. However, in order to optimize the water quality benefits of plan development and implementation, management practices which most effectively control bacteria will be promoted and given top priority. Based on site-specific characteristics, plans should include one or more of the following management practices to reduce pollutant loads from agricultural lands:

- Residue Management: Management of the residual material left on the soil surface of cropland, for the purpose of reducing nutrient and sediment loss through wind and water erosion.
- Critical Area Planting: Establishes permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have physical, chemical or biological conditions that prevent the establishment of vegetation with normal practices.

- Filter Strips: Establishes a strip or area of herbaceous vegetation between agricultural lands and environmentally sensitive areas to reduce pollutant loading in runoff.
- Nutrient Management: Manages the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments to minimize agricultural nonpoint source pollution of surface and groundwater resources.
- Riparian Forest Buffers: Establishes an area dominated by trees and shrubs located adjacent to and up-gradient from watercourses to reduce excess amounts of sediment, organic material, nutrients, and pesticides in surface runoff and excess nutrients and other chemicals in shallow groundwater flow.
- Terraces: Used to reduce sheet and rill erosion, prevent gully development, reduce sediment pollution/loss, and retain runoff for moisture conservation.
- Grassed Waterways: Natural or constructed channel-shaped or graded and established with suitable vegetation to protect and improve water quality.
- Prescribed Grazing: Manages the controlled harvest of vegetation with grazing animals to improve or maintain the desired species composition and vigor of plant communities.
- Riparian Herbaceous Buffers: Establishes an area of grasses, grass-like plants, and forbs along watercourses to improve and protect water quality by reducing sediment and other pollutants in runoff, as well as nutrients and chemicals in shallow groundwater.
- Watering Facilities: Places a device (tank, trough, or other water-tight container) that provides animal access to water and protects streams, ponds, and water supplies from contamination through alternative access to water.
- Field Borders: Establishes a strip of permanent vegetation at the edge or around the perimeter of a field.
- Conservation Cover: Establishes permanent vegetative cover to protect soil and water.
- Stream Crossings: Creates a stabilized area or structure constructed across a stream to provide a travel way for people, livestock, equipment, or vehicles, improving water quality by reducing sediment, nutrient, organic, and inorganic loading of the stream.
- Alternative Shade: Creation of shade reduces time spent loafing in streams and riparian areas, thus reducing pollutant loading and erosion of riparian areas.

6.3.4 – Educational Opportunities

Agricultural Producers

The Partnership identified management topics that were most relevant for Ag Producers in the watershed. These included soil fertility management, conservation tillage, erosion control, integrated pest management, and grazing management. Initial implementation efforts will emphasize educational programs that focus on these areas, but will also include other aspects of agricultural operations (Figure 6.5).

Small Acreage and New Landowners

The Partnership described small acreage landowners as those having between 2 and 100 acres, often using the land for both residential and agricultural purposes. It is known that while these acreages are most often located in rural portions of the watershed, they may also be present in or near municipal areas. Furthermore, it was noted that these areas can often be susceptible to overgrazing. Thus, the Partnership recommends that educational opportunities be provided to small acreage landowners that focus on management of pastures, livestock, and wildlife, as well as proper maintenance of septic systems and water wells.

Figure 6.5. Landowners learn about soil fertility. (Photo courtesy of Texas A&M AgriLife)

6.4 – WILDLIFE AND NON-DOMESTIC ANIMAL MANAGEMENT MEASURES

Based on SELECT analysis, non-domestic animals are a significant potential contributor of pollutants to Lavon Lake. Feral hogs are a largely unmanaged, non-native species with growing numbers in the watershed. The Partnership and Steering Committee recommended that efforts be undertaken to reduce the feral hog population, limit the spread of these animals, and minimize their effects on water quality and the surrounding environment.

While native wildlife such as deer, raccoons, opossums, and bird species also are contributing pollutants, this is considered background nonpoint source pollution. TPWD manages native wildlife and oversees harvest of game species across the state. Active management of native wildlife for water quality purposes is generally not promoted in the State of Texas and will not be included in the Lavon Lake Watershed Protection Plan.

6.4.1 – Feral Hog Control

To determine the approximate number of feral hogs that should be removed, the estimated number of hogs in each subwatershed was multiplied by the necessary load reduction; results are presented in Table 6.7. Because the SELECT analysis used to determine total hog numbers also identified the most likely habitat zones based on land cover, initial management efforts will focus in those areas of highest concentration. These hog numbers represent initial goals over the course of the project, and as more information is gathered or if populations increase rapidly, these targets will be adjusted accordingly.

To address the feral hog issue, the Partnership will rely heavily on the expertise and resources of the Texas Wildlife Services (TWS), a division of the Texas A&M AgriLife Extension Service. This agency protects the resources, property, and well-being of Texans from damages related to wildlife. TWS serves rural and urban areas with technical assistance, education, and direct control for wildlife damage management of both native wildlife and non-domestic animals. In addition, the Partnership will coordinate with the Lone Star Healthy Streams Program (LSHS) to provide education and outreach in the watershed, focused specifically on feral hog management in the region. This program will work directly with landowners in the Lavon Lake watershed to provide technical assistance in managing feral hogs by means of snaring, trapping, and hunting.

To further enhance program targeting and success, the Partnership and Steering committee recommend development of a feral hog reporting website to enable reporting of the date, time, location, and approximate number of feral hogs observed in the Lavon Lake watershed. In addition, a landowner survey also will be conducted through local Extension offices to identify specific properties for participation in control programs and to better define feral hog populations and distribution. This will be supported by an annual or biennial Lone Star Healthy Streams feral hog management workshop to educate landowners regarding feral hog control strategies.

Table 6.7. Recommended number of feral hogs to be removed by subwatershed.

Subwatershed	Load Reduction	Total Hogs	Hogs To Be Removed
1	33%	987	326
2	33%	1,457	481
3	33%	419	138
4	33%	725	239
5	33%	1,134	374
6	27%	1,076	290
7	27%	920	248
8	27%	996	269
9	32%	795	254
10	32%	1,008	323
11	32%	830	266
12	32%	1,006	322
13	32%	715	229
14	32%	1,533	491
15	49%	571	280
16	49%	150	73
17	27%	266	72
18	27%	250	68
19	27%	779	210
20	27%	285	77
Watershed Total		15,900	5,029

Administered by the Texas Association of Community Action Agencies (TACAA), the Texas Hunters for the Hungry Program is a statewide wild game donation program that provides a healthy source of protein to Texans who need assistance obtaining well-balanced, nutritious meals. Through participating meat processors, game is processed for a nominal fee and then distributed to food banks and similar entities. Statewide, venison has been the staple for the Hunters for the Hungry Program, but other game such as feral hogs are accepted. Current regulations stipulate that feral hogs must be trapped live and transported to an approved facility for inspection prior to slaughter. This has historically limited the quantity of feral hogs processed for distribution through this program. The Partnership will work with TACAA, TDA, and other partnering groups to explore the feasibility of integrating management of nuisance animal populations with the generation of low-cost food products for community groups and low-income families. If successful, this will serve as a model for a statewide coordinated feral hog management and food assistance program.

6.4.2 – Wildlife Surveys

To identify other potential sources among local wildlife populations, the Partnership recommends additional surveys to further quantify wildlife contributions. In addition to this analysis, a complement of periodic avian and small mammal surveys could yield information on the distribution of wildlife species in the area to guide future implementation of additional wildlife management strategies. Additionally, assessment of fish and macroinvertebrate species can provide information on hydrologic and water quality conditions in the watershed.

6.5 – EDUCATION AND OUTREACH INITIATIVES

Water4Otter

Water4Otter (W4O) is a youth-education program launched by NTMWD in 2014. The initial goal of the W4O program was to educate youth about the importance of water conservation. However, the NTMWD is working to incorporate watershed protection and wastewater management concepts into the W4O curriculum. The program consists of a 45-minute presentation delivered at local elementary schools, and is designed to target grades K-2nd and 3rd-5th. To date, the program has reached nearly 17,500 students through 110 performances across North Texas. At each performance, children are provided educational materials to remind parents to conserve water. Future programs will also include educational materials promoting watershed protection and wastewater concepts, such as proper disposal of fats, oils, and grease.

Demonstration Area

The Partnership expressed a need to have an area in the watershed that showcases green infrastructure practices and water conservation techniques. This area should lend itself to education and outreach activities and, if possible, provide opportunities for academic research. Although a specific location has not been identified, the Partnership expressed that it should be easily accessible to stakeholders in the watershed. Furthermore, although water conservation and the use of native plants was identified as an important component of this proposed demonstration area, it was noted there should be an emphasis on including stormwater management features.

Watershed Signs

The Partnership identified watershed signs as an effective method for raising awareness about watershed protection. These may include roadside signs denoting the Lavon Lake watershed boundary, as well as signs denoting critical areas (e.g. riparian areas, boat ramps, shorelines). The Partnership will facilitate coordination between the ACOE, TxDOT, cities, and counties to gain approval to install watershed signs at identified locations, and explore funding options.

6.6 – JOHN BUNKER SANDS WETLAND CENTER

The John Bunker Sands (JBS) Wetland Center is located in the middle of the one of the largest constructed wetland in North America and provides education and research opportunities pertaining to water reuse and conservation, wetland systems, and wildlife management (Figure 6.6). These wetlands, also known as the East Fork Water Reuse Project, divert treated wastewater flows from the East Fork of the Trinity River and provide a level of filtration before it is returned to Lavon Lake and blended with other supplies for future treatment and use. The Bunker Sands Mitigation Bank, a 1,200 acre bottomland hardwood forest restoration area is located across the river from the John Bunker Sands Wetlands Center. Both the wetlands and forest provide valuable wildlife habitat and are home to a number of aquatic and terrestrial species throughout the year including a nesting pair of American Bald Eagles.

The John Bunker Sands Wetland Center is open to the public and provides a number of educational programs that relate to wetland ecology, water reuse and conservation, wildlife management and watershed protection. As part of an effort to expand educational opportunities, the JBS Wetland Center initiated a project in early 2017 to gather input on the strategic direction of the Center moving forward. Improvements and additions to existing facilities are being considered, as well as expanded educational opportunities for the public, which include water quality and watershed protection components.

Figure 6.6. A school group using the boardwalk at the John Bunker Sands Wetlands center.

6.7 – VOLUNTEER PROGRAMS

Master Gardeners and Master Naturalists

The Blackland-Prairie, Bluestem, and Bois d'Arc Master Naturalist Chapters, and the Collin, Fannin, Grayson, and Hunt County Master Gardener Associations are active volunteer groups in the watershed that have a significant focus on water quality and environmental protection. These organizations provide training to their members on water quality and environmental protection, and organize a number of volunteer events each year. Efforts will be made to coordinate with these organizations to bolster the activities of Master Naturalist and Master Gardener volunteers in the watershed.

Texas Stream Team

The Texas Stream Team (TST) is a network of trained volunteers that gather water quality data in lakes, rivers, streams, wetlands, bays, bayous, and estuaries throughout the state. Data collected by TST volunteers is uploaded to a central database and is available for public viewing online. This program is administered through a partnership between Texas State University, the TCEQ, and the EPA, and provides valuable information for local stakeholders and natural resource professionals about water quality. The Partnership supports making TST trainings and test kits available to volunteers in the watershed, as well as promoting participation in the program.

Cleanup Events and Illegal Dumping

There are a number of recurring community cleanup events that take place in the watershed. For example, the Cities of Allen, Frisco, Lucas, McKinney, and Wylie, all have annual, or bi-annual cleanup events. Many of these events are conducted as part of the Texas Trash-Off program, a statewide event sponsored by TxDOT and Keep Texas Beautiful. Funding to support these events typically comes from a combination of donations, state grants, and local city funds.

Additionally, Collin County participates in the NCTCOG Regional Stop Illegal Dumping Initiative, which utilizes a hotline to report illegal dumping, and maintains a map of known illegal dump sites. The Collin County Sheriff's office investigates illegal dumping reports in Collin County (Figure 6.7).

The Partnership will support activities that increase volunteer participation in existing cleanup events, and will support the establishment of new events in the watershed. Additionally, the Partnership will seek grant funding to support these events, as well as efforts to address illegal dumping throughout the watershed.

Figure 6.7. An illegal dump site in the Collin County portion of the Lavon Lake watershed.

6.8 – LAND TRUSTS

Land trusts are nonprofit organizations that work to protect the environment by conserving natural areas. This can be accomplished through outright purchase of the land, or by negotiating voluntary agreements with property owners to preserve natural areas and open space. These voluntary agreements, known as conservation easements, allow deed holders to retain ownership of the property and continue to live on and manage the land. Should the land ever be sold, these easements will typically apply

According to the Texas Land Trust Council, there are 841 acres in Collin County that have been conserved by Texas land trusts. This was facilitated by both regional and statewide land trust organizations. The Partnership will support these organizations in conserving natural areas and open space in the Lavon Lake watershed, with an emphasis on protecting critical areas such as floodplains and riparian areas.

6.9 – WATERSHED COORDINATION

Maintaining, adapting, and expanding ongoing and proposed implementation efforts is essential to the success of this project and the future of water quality in the Lavon Lake Watershed. As a result, the Steering Committee recommends that a local Watershed Coordinator position be maintained in the watershed. This position will facilitate the Partnership, lead in implementation efforts, engage with stakeholders, and maintain a high awareness of and involvement in water quality issues in the area through educational programs and effective use of the local media. The position will routinely interact with local city councils, county commissioner courts, SWCDs, NCTCOG, and other watershed interest groups to keep them informed and involved in implementation activities being carried out in the watershed.

The primary duties of the Watershed Coordinator will include, but are not limited to the following:

- Work with counties, cities, local boards, and businesses to identify management measures to improve water quality and develop funding mechanisms for putting them in place.
- Engage state and federal agencies and organizations, as appropriate, to bring technical and financial resources to the watershed.
- Pursue external funding to reduce or cover costs for the project through various federal, state, and local grants, loans, etc.
- Track and document implementation efforts to assess progress toward established goals.
- Evaluate water quality data to monitor progress and determine the need for new activities and approaches.
- Coordinate and conduct water resource and related environmental outreach education efforts across the watershed, including organizing training programs and participating in local community clean-up events.
- Develop publications (e.g. newspaper article, newsletter, factsheet) and website content to promote and communicate watershed efforts.
- Conduct regular stakeholder meetings throughout the watershed to gather and incorporate local input and encourage citizen participation.
- Provide counties, cities, and other partners with regular updates on progress, and seek their input and recommendations on needed activities.
- Continue to facilitate the Steering Committee and Partnership through regular meetings and communications regarding project activities.

7. Measures of Success

7.1 – ADAPTIVE IMPLEMENTATION

Due to the dynamic nature of watersheds and the many variables which experience highly complex interactions across watershed processes, some uncertainty is to be expected when a watershed protection plan is developed and implemented. As the recommended management measures of the Lavon Lake Watershed Protection Plan are put into action, tracking the water quality response over time will be necessary as needed adjustments are made to the implementation strategy for the purpose of reducing uncertainty. In order to provide flexibility and enable such adjustments, adaptive implementation will be utilized throughout the process..

Adaptive implementation is often referred to as "learning by doing" (Franklin, Helinski, & Manale, 2007). It is the on-going process of accumulating knowledge about the causes of water quality threats and impairments as implementation efforts progress, which results in reduced uncertainty associated with modeled pollutant loads. As implementation activities are instituted, water quality is monitored to assess impacts and guide adjustments to future implementation activities. This on-going cyclic implementation and evaluation process serves to focus project efforts and optimize impacts. Watersheds in which the impairment is dominated by nonpoint source pollutants, such as the Lavon Lake watershed, are good candidates for adaptive implementation in order to achieve watershed protection goals.

Adaptive implementation relies on near constant input of watershed information and the establishment of intermediate and final water quality targets. Pollutant concentration targets for major tributaries to Lavon Lake were based on implementing all aspects of the watershed protection plan and assume full accomplishment of pollutant load reductions by the end of the 10-year project period (Table 7.1). While some of the less complex management measures recommended here will be relatively simple to implement quickly, implementation of other measures will require more time, energy, and funding. For this reason, reductions in pollutant loads and associated concentrations may start out gradually. However, success in reducing the pollutant loads will be related to how effectively management measures are implemented throughout the watershed. Thus, these projected pollutant targets will serve as benchmarks of progress, indicating the need to maintain or adjust ongoing activities. The degree to which pollutant targets are achieved serve as a facilitation tool for stakeholder evaluation and decision-making based on adaptive implementation.

Table 7.1. *E. coli* bacteria target concentrations for TCEQ sites 10777 (Wilson Creek) and 13740 (East Fork of the Trinity River) during the 10-year implementation schedule.

Year	***E. coli* Concentration (cfu/100mL)**	
	East Fork of the Trinity River	**Wilson Creek**
2018	151	164
2021	138	147
2024	126	130
2027	113	113

7.2 – MONITORING AND WATER QUALITY CRITERIA

Water quality data will be analyzed using the 3-year geometric mean for *E. coli* bacteria to examine trends in the major tributaries to Lavon Lake. These values will be compared to the incremental reductions outlined in Table 7.1 to determine whether adjustments to the implementation strategy are necessary. The Partnership will review progress of implementation efforts outlined in the WPP each year, and especially at milestone years 3, 6, and 10, in order to make critical decisions on adaptive implementation of management measures. In addition, water quality data will be analyzed every 6 months to examine short-term trends and for comparison against the water quality criteria.

Current water quality monitoring efforts in the Lavon Lake watershed rely on the existing monthly routine monitoring stations on Sister Grove Creek (TCEQ Station 21396) and Pilot Grove Creek (TCEQ Station 21717), and quarterly routine monitoring stations on Wilson Creek (TCEQ Station 10777) and the East Fork of the Trinity River (TCEQ Station 13740). These location have been the main sampling locations used by TCEQ to conduct assessments for the Texas Integrated Report of Surface Water Quality, and will be an important part of continued efforts to track the success of implementation. In addition to these locations, the NTMWD will collect monthly data at TCEQ Station 21764 on Wilson Creek and establish a new monthly monitoring site on East Fork of the Trinity River at FM 546 (Figure 7.1).

Ambient in-stream data collected at these sites will include: flow, *E. coli*, nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, total dissolved solids, total suspended solids, pH, chlorophyll-a, sulfate, total phosphorus, total alkalinity, total organic carbon, temperature, turbidity, chloride, and dissolved oxygen.

Though not all of these measurements are necessary to assess current impairments or concerns, routine monitoring for this suite of parameters will potentially detect the development of additional water quality concerns should they begin to materialize, as well as measure progress toward the goals established in this plan.

7.2.1 – Targeted Water Quality Monitoring

To support WPP development, a special project funded by the TSSWCB and conducted by the NTMWD was implemented to increase the temporal and spatial resolution of sampling efforts to more effectively pinpoint the timing and sources of high pollutant loads. The project, entitled *Data Collection and Development of Essential Components to Support the Development of a Watershed Protection Plan for Lake Lavon*, utilized twenty routine sampling stations for an 18-month period between April 2016 and September 2017.

Prior to the onset of this project, very little subwatershed level water quality data had been collected in the Lavon Lake watershed. The Clean Rivers Program monitoring stations located at TCEQ Sites 10777 and 13740 on Wilson Creek and the East Fork of the Trinity River, respectively were the only sampling locations used in recent years to assess water quality in tributaries to Lavon Lake. However, the NTMWD began collecting monthly data on Sister Grove Creek and Pilot Grove Creek at TCEQ Sites 21396 and 21717, respectively, as part of the Clean Rivers Program in 2015.

Continued collection of subwatershed-level water quality monitoring data is needed to address key data gaps in the watershed. Although priority will be placed on collecting *E. coli* and flow data to monitor the effectiveness of implementation, it will also be important to collect nutrient and sediment data at these sites. If adequate resources are available, samples will be analyzed for the full suite of water quality parameters.

In addition to the aforementioned sites monitored as part of the Clean River Program, the NTMWD will collect monthly data from TCEQ Site 21764 on Wilson Creek and establish a new monthly monitoring site on the East Fork of the Trinity River at FM 546 near McKinney, TX. The NTMWD will also collect subwatershed water quality data at 10 sites quarterly for the duration of the proposed 10-year project implementation in order to assess trends and fill information gaps identified during development of the WPP (Figure 7.2). This intensive monitoring effort will refine the focus of management efforts as well as track performance of on-going implementation activities. Grant funding may be required to continue intensive monitoring throughout the 10-year period of implementation.

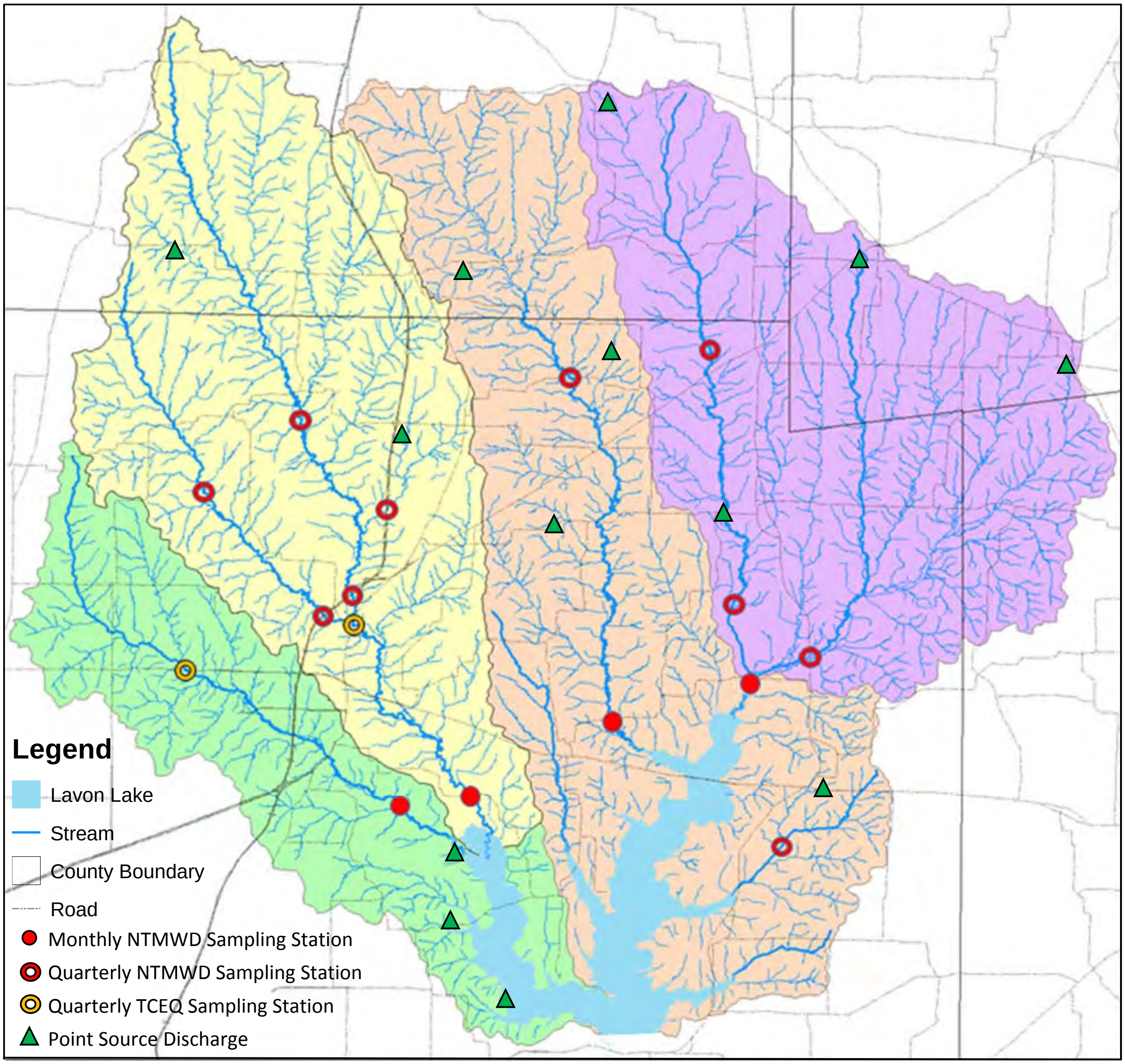

Figure 7.1. Routine water quality monitoring locations in the Lavon Lake Watershed during the 10-year implementation period.

7.2.2 – Stream Biological Assessments

In addition to water quality monitoring, biological and habitat assessments also should be conducted at the beginning of the implementation phase, and strategically thereafter at selected times after significant WPP implementation has occurred to assess any changes to biota and habitat. Surveys of the fish and macroinvertebrate communities in Lavon Lake and its tributaries, as well as the plant communities and physical characteristics of the environment adjacent to these waterbodies serve as indicators of changes in stream conditions. These surveys will determine if the stream is meeting current aquatic life use standards, and document measurable changes in the biological communities in the Lavon Lake watershed.

Figure 7.2. Sampling site 21764 on Wilson Creek at CR 317 near McKinney, TX.

7.3 – WATERSHED MODELS

7.3.1 – Spatially Explicit Load Enrichment Calculation Tool (SELECT)

SELECT was utilized to identify potential *E. coli* sources in the watershed and to estimate the distribution and level of contribution by each. As implementation of actions and activities outlined in Tables 8.1 and 8.2 moves forward, SELECT may be used to model changes within the watershed. During years 3, 6, and 10, stakeholders will evaluate changes in pollutant sources as affected by land use, animal numbers and distribution, changes in population and urban development, and other key inputs to develop possible recommendations. Integration of SELECT with both long-term water quality monitoring and the targeted sampling efforts will allow assessment of management measures. Some existing management practices may be modified, new practices added, and/or use of specific efforts may be adjusted to most effectively achieve overall project goals.

7.3.2 – Nutrient Export Tool (NEXT)

The Biological and Agricultural Engineering Department at Texas A&M University is currently seeking funding to develop a GIS-based nutrient load estimation tool. This tool, known as the Nutrient Export Tool (NEXT), will function similarly to SELECT by identifying potential sources of nutrient pollution and the likely distribution of those sources in a watershed. This information can be used to better understand the impact of nutrient sources and help target implementation of management measures to areas that have the highest potential for contributing nitrogen and phosphorus loads. If developed, the Partnership will consider utilizing this tool to support adaptive implementation of nutrient management measures in the Lavon Lake watershed.

7.3.3 – Soil and Water Assessment Tool (SWAT)

As previously mentioned, the Soil and Water Assessment Tool has been used to estimate nutrient, sediment, and herbicide loading to Lavon Lake. During implementation of the Lavon Lake WPP, it may be necessary to repeat SWAT analysis to identify target locations for management measures and estimate their potential impact on water quality. If SWAT is utilized during implementation, the Partnership will consider making the calibrated model available for use by other entities (e.g. cities, counties, and councils of government) through the Hydrologic and Water Quality System (HAWQS), a web-based interactive modeling system that employs the Soil and Water Assessment Tool. HAWQS provides users with interactive web interfaces and maps, pre-loaded input data, and outputs that include tables, charts, and raw output data.

7.4 – BACTERIAL SOURCE TRACKING

The Lavon Lake Watershed Partnership and Steering Committee also recommended employing Bacterial Source Tracking (BST) techniques as an additional management tool at some point in the future, if deemed appropriate. These data could enhance and refine results from the SELECT analysis and also confirm and/or adjust ongoing and planned implementation efforts. Funding for targeted BST analysis may be pursued as a part of the adaptive implementation strategy. BST project costs have declined in recent years due to substantial investment by the TSSWCB for the development of a state BST library. At years 3, 6, and 10, based upon progress made towards implementation of actions and activities outlined in Tables 8.1 and 8.2, combined with an analysis of the latest water quality data, a recommendation will be made. BST may be employed if initial efforts to reduce bacteria loading are not as successful as anticipated.

8. Project Implementation

This chapter outlines needed technical assistance, a schedule for implementation of the recommended management measures, estimates of associated costs, potential sources of funding, and estimates of load reductions expected as a result of WPP implementation. Some management measures are part of ongoing budgeted operations of counties and municipalities. All management measures identified in the Lavon Lake Watershed Protection Plan are voluntary. The schedule for implementation is based on a combination of factors, such as available resources, financial resources, and regional priorities.

8.1 – TECHNICAL ASSISTANCE

Successful implementation of the Lavon Lake Watershed Protection Plan relies on active engagement of local stakeholders, but also will require support and assistance from a variety of other sources. The technical expertise, equipment, and labor required for many management measures are beyond the capacity of the local stakeholders alone. As a result, direct support from one or a combination of several sources will be essential for achieving water quality goals in the watershed. Focused and continued implementation of key restoration measures may require the creation of full-time equivalent positions in the watershed to coordinate and provide technical assistance to stakeholders.

8.2 – URBAN STORMWATER MANAGEMENT MEASURES

Structural and programmatic urban storm water controls are the responsibility of individual municipalities and other political subdivisions in the watershed. However, identification and design of specific improvements to storm water conveyances may be beyond the scope of many small communities in the watershed. Also, many of these communities may not have comprehensive ordinances and stormwater design criteria for accommodating rapid population growth and development effectively. To help in these situations, funding will be sought for engineering services related to structures and to support upgrades to existing storm water facilities, and to support the use and/or development of stormwater and urban development resources for small and growing communities in the watershed. Funding also will be sought to assist these communities with modifications to urban stormwater conveyance systems to enhance stormwater treatment before entering impaired waterways. Targeted implementation of recommended stormwater management controls, along with enhanced monitoring and management procedures and installation of pet waste collection stations, will enable achievement of needed urban pollutant load reductions. Throughout this process, the continued assistance and commitment of city officials and staff will be critically important.

8.3 – SEPTIC SYSTEM MANAGEMENT MEASURES

Active support and involvement of county inspection personnel will be essential to success in managing septic system issues. County inspection programs in Collin, Fannin, Grayson, and Hunt Counties initially will focus on the high priority subwatersheds identified by SELECT analysis, but over time will work to address all subwatersheds. Critical areas that would benefit from more intense monitoring and inspection will be located based on GIS mapping, county data, and local knowledge of residents and inspectors. Education and assistance programs also will be targeted to these residents.

8.4 – AGRICULTURAL MANAGEMENT MEASURES

Technical support from the TSSWCB, local SWCDs, and local USDA-NRCS personnel is critical for proper selection and placement of appropriate management measures on individual agricultural properties. However, due to the number of management plans needed, a new position dedicated specifically to WQMP development in the watershed may be warranted. The position would help develop information and resources to promote implementation of best management practices and provide direct assistance to agricultural producers, with emphasis on areas identified by SELECT analysis.

Targets for the number of WQMPs to be developed will be adjusted as plan implementation moves forward. Assistance from local Extension agents, other agency representatives, and landowners already participating in the WQMP program will be relied upon to identify and engage key potential agricultural producers.

8.5 – NON-DOMESTIC ANIMAL AND WILDLIFE MANAGEMENT MEASURES

Management of the feral hog control program will be coordinated through Texas A&M AgriLife, with support from a regional feral hog specialist. Animal number targets will be used as an initial measure of program effectiveness. In addition, feral hog surveys, the on-line reporting system, and supplemental wildlife assessments will be utilized to better define the extent and distribution of the problem and to help direct control efforts.

8.6 – SCHEDULE, MILESTONES, AND ESTIMATED COSTS

The implementation schedule, milestones, and estimated costs of implementation presented in Table 8.1 are the result of planning efforts of the Partnership and Steering Committee, in coordination with county and city officials, and other watershed stakeholders (Figure 8.1). A 10-year project timeline has been developed for the implementation of the Lavon Lake Watershed Protection Plan. Implementation periods are grouped in increments of years 1-3, 4-6, and 7-10, and estimated quantitative targets are provided for selected management measures as appropriate. This allows key milestones to be tracked over time so stakeholders can effectively gauge implementation progress and success. In the event that insufficient progress is being made toward achievement of a particular milestone, efforts will be intensified or adjusted as necessary. Multi-year increments also take into account the fact that many management practices will require the acquiring of funding, hiring of staff, and the implementation of new programs, all of which will have implementation time requirements. In addition, substantive changes in water quality often take time to detect following initial implementation of management measures, and may require several years to be discernible.

Figure 8.1 Stakeholders will meet to monitor progress throughout the implementation process.

Table 8.1. Implementation milestones and estimated financial cost for recommended management measures.

Management Measure	Responsible Party[1]	Unit Cost	Number Implemented			Total Cost
			Year			
			1-3	4-6	7-10	
Urban Stormwater Management Measures						
Pet Waste Collection Stations	Cities	$650/station; $85 annual per station	18	9	9	$46,180
Spay/Neuter Programs	Cities, Counties, and Local Partners	$50,000	3	3	4	$500,000
Implement MS4 Stormwater Permits	Cities	---	1			n/a[2]
Stormwater and Development Resources for Small and Growing Communities	Cities, Extension, NCTCOG, and NTMWD		1	---	---	$100,000
Comprehensive Urban Stormwater Assessment for Small Communities	Cities	$35,000/ survey	3	3	---	$210,000
Enhance Stormwater Management Practices	Cities					n/a[3]
Modify Stormwater Conveyance Systems	Cities					n/a[3]
Federally Assisted Floodwater Retarding Structure Rehab and Repair Projects	Cities, Counties, NRCS, Private Developers, and SWCDs	$500,000/ project	---	---	30	$15,000,000
Riparian, Wetland, and/or Stream Restoration Projects	Army Corps of Engineers, Cities, Counties, TCEQ, TPWD, and Local Partners	$500,000/ project; 1 project per subwatershed	---	---	20	$10,000,000
Lavon Lake Shoreline Stabilization Projects	Army Corps of Engineers and Local Partners	$250,000/ project	---	---	5	$1,250,000

Table 8.1. Implementation milestones and estimated financial cost for recommended management measures (cont.).

Management Measure	Responsible Party[1]	Unit Cost	Number Implemented			Unit Cost
			Year			
			1-3	4-6	7-10	
Wastewater Management Measures						
Implement CMOM and/or SSO plans	NTMWD and Regional WW System Member Cities	---	1			n/a[2]
Extend Sanitary Sewer Service to Marginal Areas	Cities and NTMWD	---	1			n/a[2]
Septic System Inspection Programs	Cities and Counties	---	1			n/a[2]
Expand OSSF Education Programs	Cities, Counties, NCTCOG, and Extension	$2,500/event	3	3	4	$25,000
Septic System Rehab and Repair	Homeowner	$5,000/system	277	833	1,110	$11,100,000
Septic System Replacement	Homeowner	$10,000/ system	15	15	15	$450,000
Septic System Decommissioning	Homeowner	$2,000/system	10	15	15	$80,000
Expand the Existing Household Hazardous Waste Programs	Cities, Counties, and NCTCOG	$20,000/event	2	3	4	$180,000

Table 8.1. Implementation milestones and estimated financial cost for recommended management measures (cont.).

Management Measure	**Responsible Party[1]**	**Unit Cost**	**Number Implemented**			**Unit Cost**
			Year			
			1-3	**4-6**	**7-10**	
Agricultural and Rural Management Measures						
WQMP Technician (New Position)	SWCDs	$75,000/year[4]	1			$750,000
Water Quality Management Plans	SWCDs	$15,000/plan	15	102	136	$5,385,000
Federally Assisted Floodwater Retarding Structure Rehab and Repair Projects	Counties, Landowners, NRCS, and SWCDs	$500,000/ project	---	---	123	$61,500,000
Lavon Lake Shoreline Stabilization Projects	Army Corps of Engineers, and Local Partners	$250,000/ project	---	---	5	$1,250,000
Non-Domestic Animal and Wildlife Management Measures						
Feral Hog Control (Existing Position)	Extension	$75,000/year[4]	1			$750,000
Feral Hog Control (Equipment)	Cities, Counties, and Extension	$500/trap	10	---	---	$5,000
Feral Hog Control (Equipment)	Cities, Counties, and Extension	$2,500/remote-trap and $20/month/trap for cell plan	4	---	---	$12,400
Regional Feral Hog Meetings and Online Resources	Extension and NCTCOG		1			$10,000

Table 8.1. Implementation milestones and estimated financial cost for recommended management measures (cont.).

Management Measure	Responsible Party[1]	Unit Cost	Number Implemented			Unit Cost
			Year			
			1-3	4-6	7-10	
Monitoring Component						
Water Quality Monitoring	Cities, NTMWD, and TCEQ	$50,000/year	3	3	4	$500,000
Comprehensive Stream Assessments	NTMWD, TCEQ, TPWD, and USGS	$2,500/ assessment	3	3	4	$25,000
Bacterial Source Tracking and Wildlife Surveys	NTMWD, TCEQ, and TPWD	---	---	---	1	$250,000

[1] Refers to the area in which implementation will take place and/or the party responsible for securing funding and/or coordinating implementation. This does not imply a financial obligation or requirement to take action. All management measures are voluntary.
[2] Funded through existing NTMWD and/or city programs.
[3] Extent and cost will be determined during implementation based on engineering assessments.
[4] Total includes salary and benefits (health insurance, annual/sick leave, etc.).

8.7 – OUTREACH AND EDUCATION

An aggressive outreach and education program will be vital to successful engagement of watershed stakeholders. This will require effective cooperation among personnel from the NTMWD, AgriLife Extension, TSSWCB, TCEQ, and other agencies and organizations involved in land and water resource management. In addition, city and county staff will play an important role in the dissemination of important information released through the Lavon Lake Watershed Partnership. Development of educational materials will be done by all these organizations and others. Some development, dissemination, and training activities will be accomplished through routine outreach efforts by these groups. However, additional funding will be required to enhance and sustain these efforts and will be sought from external sources including Clean Water Act Section 106 and 319(h) funds, as discussed below.

Table 8.2. Implementation milestones and estimated financial costs for outreach and education efforts.

Outreach, Education, and/or Volunteer Activity	Responsible Party[1]	Number Implemented Year			Total Cost
		1-3	4-6	7-10	
Broad-Based Programs					
Texas Watershed Steward Trainings	Extension	1	1	---	n/a[3]
Water 4 Otter Public School Education Program	NTMWD	1			n/a[2]
Develop and/or Implement Public School Watershed Curriculum Resources	Cities, Extension, Local Partners, and NTMWD	1	---	---	$50,000
Lavon Lake Watershed Protection Brochure and Newsletters	NTMWD	5	5	5	$10,000
Displays at Local Events	Cities, Counties, Extension, Local Partners, NCTCOG, NTMWD, TCEQ, and TSSWCB	6	6	6	$10,000
Nonpoint Source Pollution Educational Programs	Cities, Counties, Extension, Local Partners, NCTCOG, NTMWD, TCEQ, and TSSWCB	3	3	4	$50,000
Property Management Training and Educational Materials for Realtors	Extension	1	3	4	$15,000
Water IQ Program	NTMWD	1			n/a[2]
Water-My-Yard Program	Extension and NTMWD	1			n/a[2]
Watershed Tour	Extension, Local Partners, and NTMWD	1	1	1	$12,000
Stream/Watershed Demonstration Trailer	Extension and NTMWD	1	---	---	$50,000
Texas Stream Team Trainings	Extension and Meadows Center for Water and the Environment	2	3	4	n/a[3]

Table 8.2. Implementation milestones and estimated financial costs for outreach and education efforts (cont.).

Outreach, Education, and/or Volunteer Activity	Responsible Party[1]	Number Implemented			Total Cost
		Year			
		1-3	4-6	7-10	
Urban Programs					
Urban Sector Nutrient Education	Cities, Extension, and NTMWD	3	3	4	$25,000
Doo The Right Thing Pet Waste Program	Cities, Extension, NCTCOG, and NTMWD	1			$100,000
Urban Smart Growth Workshops	Cities, Counties, Extension, and NCTCOG	2	3	4	$10,000
Green Infrastructure and LID Workshops for Private Developers and City/County Staff	Cities, Counties, Extension, and NCTCOG	3	3	4	$10,000
Master Gardener and Master Naturalist Workshops	Extension	2	2	2	$5,000
Sports and Athletic Field Education (SAFE) Workshops	Cities, Counties, and Extension	3	3	4	$25,000
Landscape Management Training Sessions for Homeowners	Cities, NCTCOG, NTMWD, and Extension	6	6	8	$50,000
Master Composter Workshops	Cities and Extension	3	3	4	$20,000
Install Nutrient and Pesticide Management Kiosks and/or Signs at Local Retail Stores	Extension and NTMWD	2	3	4	$90,000
Install Green Infrastructure Demonstration Areas	Cities, Extension, and NTMWD	1	1	2	$600,000

Table 8.2. Implementation milestones and estimated financial costs for outreach and education efforts (cont.).

Outreach, Education, and/or Volunteer Activity	Responsible Party[1]	Number Implemented			Total Cost
		Year			
		1-3	4-6	7-10	
Wastewater Programs					
Advertise Septic System Online Training Modules	Extension and NCTCOG	1			$50,000
Septic System Workshops	Cities, Counties, Extension, and NTMWD	3	3	4	$25,000
Defend Your Drain Program	Cities, NCTCOG, and NTMWD	1			$100,000
Continuing Education for WW Operators	Cities and NTMWD	1			n/a[2]
Agricultural Programs					
Soil and Water Testing Campaigns	Extension	3	3	4	$75,000
Agriculture Nutrient Management Workshops	Extension, NRCS, and SWCDs	3	3	4	$10,000
Crop Management Seminars	Extension, NRCS, and SWCDs	3	3	4	$10,000
Agricultural Waste Pesticide Collection Days	Extension and TCEQ	2	3	4	$200,000
Livestock Grazing Management Workshops	Extension, NRCS, and SWCDs	3	3	3	$10,000
Lone Star Healthy Streams Workshops	Extension	1	1	1	n/a[3]
Non-Domestic Animal and Wildlife Programs					
Feral Hog Management Workshops	Cities, Counties, Extension, NCTCOG, and NTMWD	2	3	3	$10,000

Table 8.2. Implementation milestones and estimated financial costs for outreach and education efforts (cont.).

Outreach, Education, and/or Volunteer Activity	Responsible Party[1]	Number Implemented Year 1-3	4-6	7-10	Total Cost
Additional Programs					
Community Stream Cleanup Events	Cities, Counties, and Local Partners	2	3	4	$500,000
Rainwater Harvesting Workshops/ Demonstrations	Cities, Extension, and NTMWD	2	2	2	$25,000
Post "Don't Mess With Texas Water" Signage (H.B. 451, 82nd Legislative Session)	Cities, Counties, NTMWD, and TxDOT	4	4	4	$5,000
Post Lavon Lake Watershed Signage	Cities, Counties, NTMWD, and TxDOT	15	10	10	$10,000
Watershed Coordinator	NTMWD	1			n/a[2]

[1] Refers to the area in which implementation will take place, and/or the party responsible for securing funding and/or coordinating implementation. This does not imply a financial obligation or requirement to take action. All management measures are voluntary.
[2] Funded through existing NTMWD programs.
[3] Funded through existing CWA section 319(h) grants.

8.8 – PROGRAM COORDINATION

In addition to technical and financial assistance required for implementation of management measures and outreach programs, it is recommended that staff time be devoted to facilitatating continued progress. This may require participation from city, county, and NTMWD staff to oversee project activities, seek additional funding, organize and coordinate regular updates for the Partnership, maintain project websites, and coordinate outreach and education efforts in the watershed.

8.9 – SOURCES OF FUNDING

Acquisition of funding from multiple sources to support implementation of management measures will be critical for the success of the Lavon Lake Watershed Protection Plan. While some management measures require only minor adjustments to current activities, some of the most important measures require significant funding for both initial and sustained implementation. Discussions with the Partnership and Steering Committee, city officials, agency representatives, and other professionals were used to estimate financial needs. In some cases, funding for specific activities already has been secured either in part or full. Other activities will require funding to conduct preliminary assessments to guide implementation, such as in the case of urban storm water control. Traditional funding sources will be utilized where available, and creative new approaches to funding will be sought. Some of the key potential funding sources that will be explored are discussed below.

Agricultural Water Conservation Program

The Agricultural Water Conservation Program administered by the Texas Water Development Board provides grants and low-interest loans to political subdivisions and private individuals for agricultural water conservation and/or improvement projects. The program also provides a linked deposit loan program for individuals to access TWDB funds through participating local and state depository banks and farm credit institutions.

Agricultural Water Enhancement Program

The Agricultural Water Enhancement Program (AWEP) is a voluntary conservation initiative administered by NRCS that provides financial and technical assistance to agricultural producers to implement agricultural water enhancement activities on agricultural land for the purposes of conserving surface and groundwater and improving water quality. Grant funding is available to provide financial incentives for agricultural producers and other rural landowners to develop resource conservation plans and implement BMPs aimed at improving water quality (NRCS 2010b).

Clean Water Act State Revolving Fund

The Clean Water Act State Revolving Fund (SRF) administered by the TWDB provides loans at interest rates below the market to entities with the authority to own and operate wastewater treatment facilities. Funds are used for planning, design, and construction of facilities, collection systems, storm water pollution control projects, and nonpoint source pollution control projects.

Cooperative Watershed Management Program

The Cooperative Watershed Management Program (CWMP) is administered by the United States Bureau of Reclamation and provides funding for the development of watershed groups (Phase I) and implementation of watershed management projects (Phase II). Phase II watershed management project funds may be used for restoration activities, nonpoint source pollution control projects, and watershed monitoring, modeling, and mapping.

Coordinated Hog Out Management Program

The Texas Department of Agriculture (TDA) administers the Coordinated Hog Out Management Program (CHOMP) which provides funding to Texas counties to continue feral hog abatement activities. In order to be eligible for CHOMP funds, the applying county must have or develop a method to track the number of hogs taken during the one-year grant period.

Economically Distressed Area Program

The Economically Distressed Area Program is administered by the TWDB and provides grants, loans, or a combination of financial assistance for wastewater projects in economically distressed areas where existing facilities are inadequate to meet residents' minimum needs. While the majority of the watershed does not meet program requirements, small pockets within the area may qualify based on economic criteria. Entities representing these areas may pursue funds to improve wastewater infrastructure.

Environmental Restoration – Water Resources Development Act

Section 1135 of the Water Resources Development Act provides the U.S. Army Corps of Engineers the authority to plan, design, and build modifications to existing Corps projects, or areas degraded by Corps projects, to restore aquatic habitats for fish and wildlife. Projects are limited to $10 million in Federal cost.

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is administered by the USDA-NRCS as a voluntary conservation program that promotes agricultural production and environmental quality as compatible national goals. EQIP offers financial and technical assistance to eligible participants for the installation or implementation of structural controls and management practices on eligible agricultural land. This program will be engaged to assist in the implementation of agricultural management measures and the improvement of wildlife habitat in the watershed.

Environmental Education Grants

The grants program sponsored by USEPA's Environmental Education Division, Office of Children's Health Protection and Environmental Education, supports environmental education projects that enhance the public's awareness, knowledge, and skills to help people make informed decisions that affect environmental quality. USEPA awards grants each year based on funding appropriated by Congress. Annual funding for the program ranges between $2 and $3 million. Most grants are between $15,000 and $25,000.

Farm Service Agency – Conservation Reserve Program

The Conservation Reserve Program (CRP) is a voluntary program for agricultural landowners administered by NRCS. Individuals can receive annual rental payments and cost-share assistance to establish long term, resource conserving covers on eligible farmland. The program provides cost-share assistance for up to 50 percent of the participant’s costs in establishing approved conservation practices. By reducing water runoff and sedimentation, CRP helps protect and improve the condition of lakes, rivers, ponds, and streams.

Feral Hog Abatement Grant Program

TDA provides funding for practical, effective projects aimed at controlling the feral hog population across the state. The Feral Hog Abatement Grant Program is a one-year grant program focused on implementing a long-term, statewide feral hog abatement strategy. Currently, Texas A&M AgriLife Extension Service - Wildlife Services and the Texas Parks and Wildlife Department receive funding under this grant program.

Landowner Incentive Program

The TPWD Landowner Incentive Program (LIP) is designed to meet the needs of private landowners wishing to enact good conservation practices on their land. LIP targets projects aimed at creating, restoring, protecting, and enhancing habitat for rare or at-risk species throughout the State. The proposed conservation practices must contribute to the enhancement of at least one rare or at-risk species or its habitat as identified by the Texas State Wildlife Action Plan or the LIP Priority Plant Species List.

Outdoor Recreation Grants

Managed by the Texas Parks and Wildlife Department, this program provides 50% matching grant funds to municipalities, counties, municipal utility districts (MUD) and other local units of government with a population less than 500,000 to acquire and develop parkland or to renovate existing public recreation areas. There are two funding cycles per year with a maximum award of $500,000. Eligible sponsors include cities, counties, MUDs, river authorities, and other special districts.

Regional Water Supply and Wastewater Facility Planning Program

The TWDB offers grants for assessments to determine the most feasible alternatives to meet regional water supply and wastewater facility needs, estimate costs associated with implementing wastewater facility alternatives, and identify institutional arrangements to provide wastewater services for areas across the state.

Section 106 State Water Pollution Control Grants

Through the Clean Water Act, EPA provides assistance to states, interstate agencies, and eligible tribes to establish and implement ongoing water pollution control grant. Administered at the state-level by TCEQ, Section 106 Water Pollution Control Grants are used in conjunction with matching state funds to support state water quality programs, including water quality assessment and monitoring, water quality planning and standard setting, Total Maximum Daily Load (TMDL) development, point source permitting, training, and public information. The goal of these programs is the prevention, reduction, and elimination of water pollution.

Section 319(h) Federal Clean Water Act

The US EPA provides funding to states to support projects and activities that meet federal requirements of reducing and eliminating nonpoint source pollution. In Texas, both the TSSWCB and the TCEQ receive section 319(h) funds to support nonpoint source projects, with TSSWCB funds going to agricultural and silvicultural issues and TCEQ funds going to urban and other non-agricultural issues. Funding will be sought through TSSWCB to support WQMP implementation efforts, feral hog education programs, and continued facilitation of the Lavon Lake Watershed Partnership. Funding also will be sought from TCEQ through this program to support urban storm water assessments for municipalities in the watershed and implementation of stormwater measures that go above and beyond MS4 permit requirements. Funding will be sought from both agencies to support water quality monitoring.

Supplemental Environmental Projects Program

The Supplemental Environmental Projects (SEP) program administered by the TCEQ aims to direct fines, fees, and penalties from environmental violations toward environmentally beneficial uses. Through this program, a respondent in an enforcement matter can choose to invest penalty dollars in improving the environment, rather than paying into the Texas General Revenue Fund. In addition to other projects, funds may be directed to septic system repair and wildlife habitat improvement opportunities.

Texas Capital Fund

As part of the Community Development Block Grant, TDA administers the Texas Capital Fund which provides more than $10 million in competitive awards each year to small Texas cities and counties. The program provides funding for infrastructure projects that include water and sewer lines, and drainage improvements.

Texas Clean Rivers Program

The Clean Rivers Program (CRP) is a statewide water quality monitoring, assessment, and public outreach program funded by state fees. The TCEQ partners with 15 regional river authorities to work toward achieving the goal of improving water quality in river basins across the state. CRP funds are used to promote watershed planning and provide quality-assured water quality data. The Partnership will continue to engage this funding source to support and enhance surface water quality monitoring in the watershed.

Texas Farm & Ranch Lands Conservation Program

Established by Senate Bill 1273 in 2005, the Texas Farm & Ranch Lands Conservation Program provides grants to landowners for the sale of conservation easements that create a voluntary free-market alternative to selling land for development, which stems the fragmentation or loss of agricultural lands.

USDA Rural Development Program

The USDA Rural Development Program offers grants and supports low-interest loans to rural communities for water and wastewater development projects.

Water Quality Management Plan Program

The Water Quality Management Plan Program (WQMP) is administered by the TSSWCB as a voluntary mechanism by which site-specific plans are developed and implemented on agricultural and silvicultural lands to prevent or reduce nonpoint source pollution. Plans include appropriate treatment practices, production practices, management measures, technologies, or combinations thereof. Plans are developed in cooperation with local SWCDs, cover an entire operating unit, and allow financial incentives to augment participation. Funding from the WQMP program will be sought to support implementation of agricultural management measures.

8.10 – EXPECTED LOAD REDUCTIONS

Expected load reductions of *E. coli* bacteria at the TCEQ Stations 10777 (Wilson Creek), 13740 (East Fork of the Trinity), 21396 (Sister Grove Creek), and 21717 (Pilot Grove-Indian Creek) as a result of full implementation of the Lavon Lake Watershed Protection Plan are presented in Table 8.3. Estimates of attainable load reductions are difficult to determine, and may change over time due to significant changes in land use and pollutant sources. However, these estimates will be used to demonstrate expected improvement toward target water quality goals for the watershed. With active local stakeholder engagement and participation in plan implementation and continued support from cooperating groups and agencies, the activities outlined here will make significant progress toward improving and protecting water quality in the Lavon Lake Watershed.

Table 8.3. Estimated pollutant load reductions expected upon full implementation of the Lavon Lake Watershed Protection Plan.

Management Measure	**Expected *E. coli* Load Reduction**[1]			
	East Fork Trinity River	**Pilot Grove-Indian Creek**	**Sister Grove Creek**	**Wilson Creek**
Urban Stormwater Management Measures				
Pet Waste Collection Stations	3.30 x 10^{15}	2.36 x 10^{13}	1.34 x 10^{14}	8.13 x 10^{16}
Pet Waste Ordinance and Outreach and Education Program (e.g. Doo The Right Thing Program)				
Pet Spay/Neuter Programs				
Stormwater and Development Manual for Small and Growing Communities				
Comprehensive Urban Stormwater Assessments and Stormwater Conveyance Modifications				
Enhance Stormwater Management Practices				
Wastewater Management Measures				
Implement CMOM and/or SSO Plans	1.57 x 10^{9}	6.37 x 10^{9}	4.68 x 10^{9}	2.67 x 10^{11}
Extend Sanitary Sewer Service to Marginal Areas				
Septic System Workshops	1.92 x 10^{15}	2.76 x 10^{15}	1.21 x 10^{15}	2.39 x 10^{15}
Septic System Repair				
Septic System Replacement				
Septic System Inspections				
Expand the Existing Household Hazardous Waste Programs				
Agricultural Management Measures				
WQMP Technician (New Position)	5.54 x 10^{14}	8.96 x 10^{14}	3.78 x 10^{14}	1.05 x 10^{14}
Water Quality Management Plans				
Non-Domestic Animal Measures				
Feral Hog Control (Regional Position)	3.36 x 10^{12}	4.21 x 10^{12}	2.13 x 10^{12}	5.27 x 10^{11}
Feral Hog Control (Equipment)				
Total Estimated Reduction	5.78 x 10^{15}	3.68 x 10^{15}	1.72 x 10^{15}	8.38 x 10^{16}

[1] *E. coli* load reduction in cfu/day.

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Appendix A: List of Acronyms

7Q2	Minimum 7-Day, 2-Year Discharge
ACOE	U.S. Army Corps of Engineers
AI	Adaptive Implementation
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
BOC	U.S. Census Bureau
BOD	Biochemical Oxygen Demand
BST	Bacterial Source Tracking
CAFO	Concentrated Animal Feeding Operation
cfu	Colony Forming Units
CRP	Clean Rivers Program
CWA	Clean Water Act
DSHS	Department of State Health Services
ECHO	Enforcement and Compliance History Online
EDAP	Economically Distressed Area Program
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESRI	Environmental Systems Research Institute
ETJ	Extraterritorial Jurisdiction
GIS	Geographic Information System
LDC	Load Duration Curve
LSHS	Lone Star Healthy Streams
MGD	Million Gallons per Day
MS4	Municipal Separate Storm Sewer System
NAIP	National Agriculture Imagery Program
NASS	National Agricultural Statistics Service
NCTCOG	North Central Texas Council of Governments
NEMO	Nonpoint Source Education for Municipal Officials

NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source Pollution
NRCS	National Resources Conservation Service
NTMWD	North Texas Municipal Water District
OSSF	On-Site Sewage Facility
RNC	Reportable Noncompliance
RUAA	Recreational Use Attainability Analysis
SAFE	Sports Athletic Field Education
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SEP	Supplemental Environmental Project
SRF	State Revolving Fund
SWAT	Soil and Water Assessment Tool
SWCD	Soil and Water Conservation District
TACAA	Texas Association of Community Action Agencies
TAG	Technical Advisory Group
TAMU	Texas A&M University
TCEQ	Texas Commission on Environmental Quality
TDA	Texas Department of Agriculture
TFB	Texas Farm Bureau
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOP	Texas Orthoimagery Project
TP	Total Phosphorus
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TRA	Trinity River Authority
TSS	Total Suspended Solids
TST	Texas Stream Team
TSSWCB	Texas State Soil and Water Conservation Board

TWDB	Texas Water Development Board
TWS	Texas Wildlife Service
TxDOT	Texas Department of Transportation
USDA	United States Department of Agriculture
USGS	Unites States Geological Survey
WCSC	Watershed Coordination Steering Committee
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTP	Wastewater Treatment Plant
W40	Water for Otter

Appendix B: Nine Key Elements of Watershed Protection Plans

A. Identification of Causes and Sources of Impairment ***(Sections 2, 4, 5, and Appendices)***

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

B. Expected Load Reductions ***(Sections 5, 8, and Appendices)***

An estimate of the load reductions expected for the management measures proposed as part of the watershed plan. Percent reductions can be used in conjunction with a current or known load.

C. Proposed Management Measures ***(Sections 5, 6, and 8)***

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

D. Technical and Financial Assistance Needs ***(Section 8)***

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

E. Information, Education, and Public Participation Component ***(Sections 1, 3, 6, and 8)***

An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the appropriate NPS management measures.

F. Schedule ***(Section 8)***

A schedule for implementing the NPS management measures identified in the plan that is reasonably expeditious. Specific dates are generally not required.

G. Milestones ***(Sections 7 and 8)***

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

H. Load Reduction Evaluation Criteria ***(Sections 6, 7, 8, and Appendices)***

A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether the watershed-based plan needs to be revised. The criteria for loading reductions do not have to be based on analytical water quality monitoring results. Rather, indicators of overall water quality from other programs can be used. The criteria for the plan needing revision should be based on the milestones and water quality changes.

I. Monitoring Component ***(Sections 2, 4, 5, and 7)***

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

Appendix C: Partnership Ground Rules

The following are the Ground Rules for the Lavon Lake Watershed Partnership (hereafter referred to as the Partnership) agreed to and signed by the members of the Lavon Lake Watershed Partnership Steering Committee (hereafter referred to as the Steering Committee) in an effort to develop and implement a watershed protection plan.

GOALS

The goal of the Partnership is to develop and implement a Watershed Protection Plan (WPP) to improve and protect the water quality of Lavon Lake (Segment 0821). According to the 2014 Texas Integrated Report, there is a concern for nitrate in the lower portion of the Lavon Lake reservoir, and the East Fork of the Trinity River above Lavon Lake (Segment 0821D) and Wilson Creek (Segment 0821C) do not support their contact recreation use designation due to elevated bacteria concentrations.

The Steering Committee will consider and attempt to incorporate the following into the development and implementation of the WPP:

- Economic feasibility, affordability and growth;
- Unique environmental resources of the watershed;
- Regional water planning efforts; and
- Regional cooperation.

POWERS

The Steering Committee is the decision-making body for the Partnership. As such, the Steering Committee will formulate recommendations to be used in drafting the WPP and will guide the implementation of the WPP to success. Formal Steering Committee recommendations will be identified as such in the planning documents and meeting summaries.

The Steering Committee is an independent group of watershed stakeholders and individuals with an interest in restoring and protecting the designated uses and the overall health of the Lavon Lake Watershed.

The Steering Committee provides the method for public participation in the planning process and will be instrumental in obtaining local support for actions aimed at restoring surface water quality in Lavon Lake.

TIME FRAME

Development of the Lavon Lake WPP will require at least a 6-month period. The Steering Committee will function under a May 2017 target date to complete the initial development of the WPP. Achieving water quality improvement in the Lavon Lake watershed may require significant time as implementation is an iterative process of executing programs and practices followed by achievement of interim milestones and reassessment of strategies and recommendations. The Steering Committee may continue to function thereafter throughout implementation of the WPP.

STEERING COMMITTEE MEMBERSHIP SELECTION

The Steering Committee is composed of stakeholders of the Lavon Lake watershed. Initial solicitation of members for equitable geographic and topical representation was conducted using three methods: 1) consultation with the Texas AgriLife Extension Service County Agents, Soil and Water Conservation Districts in the watershed, and local and regional governments, 2) meetings with the various stakeholder interest groups and individuals, and 3) self-nomination or requests by the various stakeholder groups or individuals.

Stakeholders are defined as either those who make and implement decisions or those who are affected by the decisions made or those who have the ability to assist with implementation of the decisions.

STEERING COMMITTEE

Members include both individuals and representatives of organizations and agencies. A variety of members serve on the Steering Committee to reflect the diversity of interests within the Lavon Lake watershed and to incorporate the viewpoints of those who will be affected by the WPP.

Size of the Steering Committee is not strictly limited by number but rather by practicality. To effectively function as a decision-making body, the membership shall achieve geographic and topical representation. If the Steering Committee becomes so large that it becomes impossible or impractical to function, the Committee will institute a consensus-based system for limiting membership.

Steering Committee members are expected to participate fully in Committee deliberations. Members will identify and present insights, suggestions, and concerns from a community, environmental, or public interest perspective. Steering Committee members are expected to work constructively and collaboratively with other members toward reaching consensus.

Committee members will be expected to assist with the following:

- Identify the desired water quality conditions and measurable goals;
- Prioritize programs and practices to achieve water quality and programmatic goals;
- Help develop a WPP document;
- Lead the effort to implement the WPP at the local level; and
- Communicate implications of the WPP to other affected parties in the watershed.

Steering Committee members will be asked to sign the final WPP.

The Steering Committee will remain a facilitated group but may elect a spokesperson, if needed. The North Texas Municipal Water District (NTMWD), with support from Texas A&M AgriLife Extension (AgriLife Extension), will serve as the facilitator through a grant contract with the Texas State Soil and Water Conservation Board (TSSWCB).

In order to carry out its responsibilities, the Steering Committee has discretion to form standing and ad hoc work groups to carry out specific assignments from the Steering Committee. Steering Committee members can serve on work groups and represent that work group at Steering Committee meetings to bring forth information and recommendations.

WORK GROUPS

Topical work groups may be formed by the Steering Committee to carry out specific assignments. Each Work Group will be composed of at least 1 Steering Committee member and any other members of the Partnership, including the Technical Advisory Group, with a vested interest in that topic. There is no limit to the number of members on a work group. Each work group may elect a spokesperson.

Work Group members will discuss specific issues and assist in developing draft sections of the WPP, including implementation recommendations. The Steering Committee may set the scope of individual Work Groups and impose due dates for the delivery of recommendations.

Work Groups and individual Work Group members are not authorized to make decisions or speak for the Steering Committee.

TECHNICAL ADVISORY GROUP

A Technical Advisory Group (TAG) consisting of state and federal agencies with water quality responsibilities will provide guidance to the Steering Committee and participate in Work Groups. The TAG will assist the Steering Committee and Work Groups in WPP development by answering questions related to the jurisdiction of each TAG member. The TAG includes, but is not limited to, representatives from the following agencies:

- North Texas Municipal Water District
- Texas Commission on Environmental Quality
- Texas AgriLife Extension Service
- Texas AgriLife Research
- Texas Department of Agriculture
- Texas Parks and Wildlife Department
- Texas State Soil and Water Conservation Board
- Texas Water Development Board
- U.S. Environmental Protection Agency
- U.S. Geological Survey
- USDA Natural Resources Conservation Service
- USDA Farm Service Agency

REPLACEMENTS AND ADDITIONS

The Steering Committee may add new members if (1) a member is unable to continue serving and a vacancy is created or (2) important stakeholder interests are identified that are not represented by the existing membership. A new member must be approved by a majority of existing members. In either event, the Steering Committee will, when practical, accept additional members.

ALTERNATES

Members may identify a designated alternate. Designated alternates must be approval by a consensus of the Steering Committee. Members unable to attend a Steering Committee meeting (an absentee) may send their approved, designated alternate. An absentee should provide advance notification to the facilitator of the desire to send their designated alternate.

A designated alternate attending with prior notification from an absentee will serve as a proxy for that absent Steering Committee member and will have voting privileges. Should both the Steering Committee member and designated alternate be unable to attend a meeting, a non-designated alternate may be sent. Non-designated alternates attending with prior notification may serve as a proxy for the absent Steering Committee member but will not be allowed to vote on matters related to the changing of ground rules or the development of formal recommendations.

Absentees may also provide input via another Steering Committee member or send input via the facilitator. The facilitator will present such information to the Steering Committee.

ABSENCES

All Steering Committee members agree to make a good faith effort to attend all Steering Committee meetings; however, the members recognize that situations may arise necessitating the absence of a member. Three absences in a row of which the facilitator was not informed of beforehand or without designation of an alternate constitute a resignation from the Steering Committee.

DECISION MAKING PROCESS

The Steering Committee will strive for consensus when making decisions and recommendations. Consensus is defined as everyone being able to live with the decisions made. Consensus inherently requires compromise and negotiation.

If consensus cannot be achieved, the Steering Committee will make decisions by a simple majority vote. If members develop formal recommendations, they will do so by two-thirds majority vote.

Steering Committee members may submit recommendations as individuals or on behalf of their affiliated organization.

QUORUM

In order to conduct business, the Steering Committee will have a quorum. Quorum is defined as at least 51% of the Steering Committee (and/or alternates) present and an authorized representative of NTMWD present.

FACILITATORS

NTMWD, in coordination with AgriLife Extension, serves as the Facilitator for the Partnership, Steering Committee, and Work Groups. The Facilitator is an independent position that coordinates closely with the TSSWCB. Each has specific roles to perform in facilitating the Partnership and Steering Committee.

TSSWCB: The TSSWCB provides technical assistance to the stakeholders in developing the Lavon Lake WPP. The TSSWCB will ensure the planning process culminates in a WPP for Lavon Lake and ensure the Lavon Lake WPP satisfies the nine elements fundamental to a WPP as promulgated by the U.S. Environmental Protection Agency.

NTMWD Facilitators: The Facilitators will serve as an educator and facilitator to help the Steering Committee organize its work, run meetings, coordinate educational trainings and draft notes and other materials if requested, and work with the TSSWCB to facilitate the development of the plan. The Facilitators will co-lead the meetings and work with all of the members to ensure that the process runs smoothly. The role of the Facilitators includes working with the Steering Committee to prepare meeting summaries, assisting in the location and/or preparation of background materials, distributing documents the Steering Committee develops, conducting public outreach, moderating public workshops, providing assistance to Steering Committee members regarding Committee business between meetings, guiding the work of any standing or ad hoc Work Group, and other functions as the Steering Committee requests.

MEETINGS

All meetings (Partnership, Steering Committee, and Work Group) are open to the public and all interested stakeholders are encouraged and welcomed to participate.

Over the development period, regular meetings of either the Steering Committee or Work Groups will occur each month. The Steering Committee may determine the need for additional meetings. Steering Committee and Work Group meetings will be scheduled to accomplish specific milestones in the planning process; as such, if a meeting is not needed (as determined by the Steering Committee, the Facilitators, and/or TSSWCB) in any particular month it will not be scheduled.

Meetings will start and end on time. Meeting times will be set in an effort to accommodate the attendance of all Steering Committee members. The Facilitators will notify members of the Partnership, Steering Committee, and Work Groups of respective meetings.

OPEN DISCUSSION

Participants may express their views candidly, but without personal attacks. Time is shared because all participants are of equal importance.

AGENDA

NTMWD and TSSWCB, in consultation with Steering Committee members, are charged with developing meeting agendas. The anticipated topics are determined at the previous meeting and through correspondence. A draft agenda will be sent to the Steering Committee with the notice of the meeting. Agendas will be posted on the project website. Agenda items may be added by members at the time that the draft agenda is provided. The Facilitators will review the agenda at the start of each meeting and the agenda will be amended if needed and the Steering Committee (or Work Group) agrees. The Steering Committee (or Work Group) will then follow the approved agenda unless they agree to revise it.

MEETING SUMMARIES

The Facilitators will take notes during the meetings and may conduct audio recording (for the sole purpose of note taking). Meeting summaries will be based on notes and/or the recording. The Facilitators will draft meeting notes and distribute them to the Steering Committee or Work Group as needed. Meeting summaries will be posted on the project website, as appropriate.

DISTRIBUTION OF MATERIALS

The Facilitators will prepare and distribute the agenda and other needed items to the Partnership. Distribution will occur via email and websites, unless expressly asked to use U.S. Mail (i.e., member has no email access). To encourage equal sharing of information, materials will be made available to all. Those who wish to distribute materials to the Steering Committee or a Work Group may ask the Facilitators or TSSWCB to do so on their behalf.

SPEAKING IN THE NAME OF THE COMMITTEE

Individuals do not speak for the Steering Committee as a whole unless authorized by the Committee to do so. Members do not speak for the NTMWD, Texas A&M AgriLife or the TSSWCB. If Committee spokespersons are needed, they will be elected by the Steering Committee. Any materials or statements to be presented by the spokesperson are subject to prior approval from the Steering Committee.

DEVELOPMENT AND REVISION OF GROUNDRULES

These ground rules were drafted by NTMWD and TSSWCB and presented to the Steering Committee for their review, possible revision, and adoption. Once adopted, ground rules may be changed by two-thirds majority vote provided a quorum is present.

Appendix D: Methods Used for Land Use Classification

Three primary resources were utilized to conduct the land use classification analysis. The National Agriculture Imagery Program (NAIP), Texas Orthoimagery Project (TOP) and Landsat-8 databases provided imagery for the watershed. TOP, NAIP, and Landsat-8 images have a spatial resolution of ½ meter, 1 meter, and 30 meters, respectively. Ground control points and existing ancillary data were used to classify these images into land use land cover (LULC) classes. Ancillary data included the 2011 National Land Cover Database (NLCD), 2015 Cropland Data Layer (CDL).

Methods

Digital Ortho Quarter Quad tiles (DOQQs) from the 2014 NAIP (leaf on) and 2015 TOP (leaf off) were mosaicked and clipped to the watershed boundary in order to create complete coverage. During this process the TOP imagery is resampled from ½ meter to 1 meter. A single Landsat 8 tile covered the entire watershed with room for a large buffer if necessary. The watershed was then classified using a pixel-based threshold classification as well as an object-based classification. Thresholding is performed by identifying break points in image bands or band indices where values within the threshold are assigned to a class. Object-based classifications are performed by first segmenting an image based on a set of parameters. The segmentation process groups similar pixels into segments (objects). Segments are then classified based on training samples

Landsat 8 scenes which have been radiometrically calibrated to top-of-atmosphere reflectance in ENVI are extracted for the study area using the Lavon Lake watershed boundary with an additional 1 mile buffer. These images are then used to produce several band indices such as the Normalized Difference Vegetation Index (NDVI). NDVI and other indices can be evaluated for identifying pixel value thresholds for certain classes or as training inputs in later steps.

The Landsat 8 images and indices, threshold outputs, object-based classification, and ancillary data are combined to develop the final classification. Some outputs are filtered to reduce speckling. Outputs produced at 30 meters are left as is while outputs produced at 1 meter are summarized to 30 meters based on percent cover type rules. Once the outputs have been combined into a complete classification, an accuracy assessment is performed to determine if the classification meets requirements.

Results

Overall the classification resulted in a complete coverage of the study area with good accuracy based on visual assessment. Accuracy was assessed using control points independent from those used in the classification process. Overall accuracy is about 80% with some disagreement where the difference between pasture/hay, grassland, and cultivated crops is difficult to distinguish. In some cases, a rotation between pasture and crops may be to blame and in other cases the difference between managed and unmanaged grasses is simply difficult to identify.

Land Use Categories

Open Water - All areas of open water, generally with less than 25% cover of vegetation or soil.

Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in early successional stage or trees stunted from environmental conditions.

Grassland/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.

Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

Developed Open Space - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of the total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

Developed Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49% of the total cover. These areas most commonly include single-family housing units.

Developed Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79% of the total cover. These areas most commonly include single-family housing units.

Developed High Intensity- Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial areas. Impervious surfaces account for 80-100% of the total cover.

Forested Land - Areas dominated by trees generally greater than 16 feet tall, and greater than 50% of the total vegetation cover.

Mixed Forest - Areas dominated by trees generally greater than 16 feet tall, and greater than 20% but less than 50% of the total vegetation cover.

Appendix E: Load Duration Curve Explanation

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

The first step in developing an LDC is the construction of a Flow Duration Curve (FDC) (Figure E.1). Flow data for a particular sampling location are sorted in order and then ranked from highest to lowest to determine the frequency of a particular flow in the stream. Flow data collected as part of routine water quality monitoring were used to develop FDCs for the East Fork of the Trinity River, Indian Creek, Pilot Grove Creek, Sister Grove Creek, and Wilson Creek. These results are used to create graphs of flow volume versus frequency, which produces a flow duration curve for each waterbody.

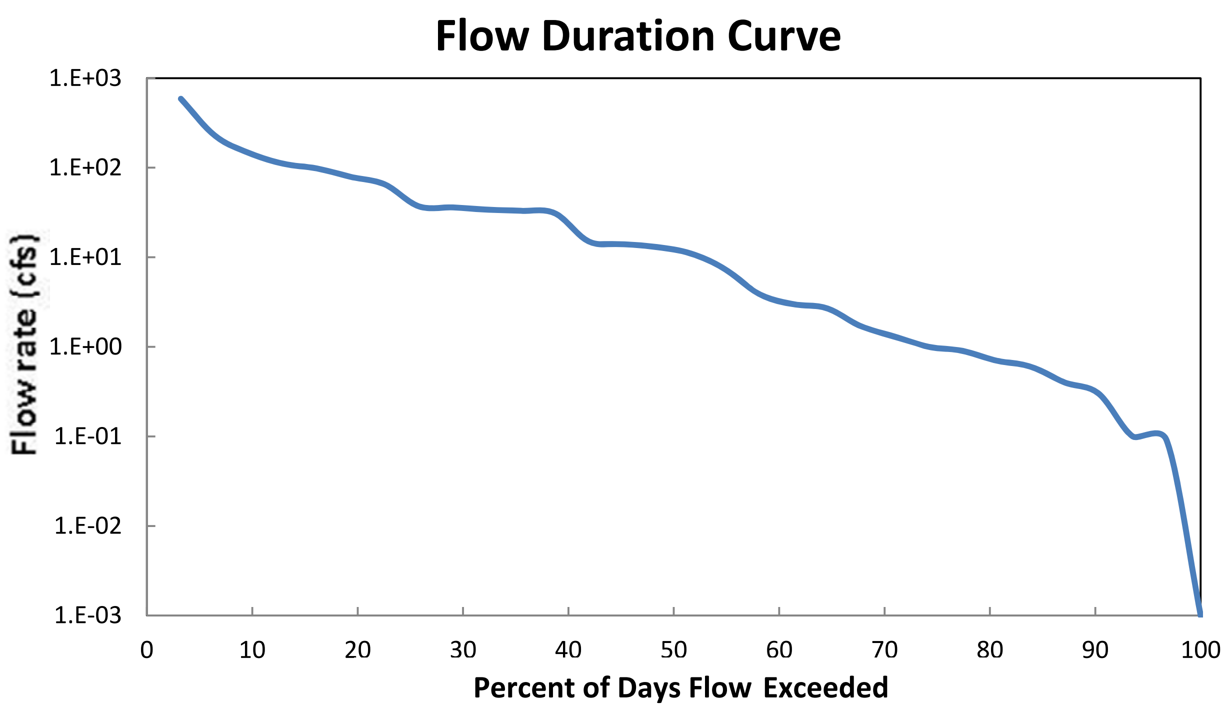

Figure E.1. The East Fork of the Trinity River above Lavon Lake flow duration curve.

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

For contact recreation in Texas, the geomean of *E. coli* must be below 126 cfu/100 mL. Thus, the threshold concentration used in the LDC analysis was 113 cfu/100mL for bacteria.

Stream monitoring data for a pollutant also can be plotted on the curve to show frequency and magnitude of exceedances. Typically, flow regimes are identified as areas of the LDC where the slope of the curve changes because that correlates with a significant change in flow. In the LDCs for the Lavon Lake watershed, there are three flow regimes: high (0-10th percentile flow), mid-range (11th – 89th percentile flow), and low flows (90th -100th percentile flow) (Table E.1). These regimes reflect where a change in the slope of the LDC line is detected. Bacteria data plotted on the LDCs for the Lavon Lake Watershed in this report covered data collected from 1981 to 2017. A regression line following the trend of the stream is plotted through the stream monitoring data using the USGS program LOAD ESTimator (LOADEST). LOADEST is used to determine load reductions for different flow regimes using the load reduction percentage (Babbar-Sebens and Karthikeyan, 2009). Load reduction percentage was calculated as (Loadest-TMDL/Loadest) × 100.

Table E.1 Flow ranges and regimes used for LDC development in cubic feet per second (cfs).

Waterbody Name	High flows (0-10th percentile)	Mid-range flows (11-89th percentile)	Low flows (90-100th percentile)
East Fk of the Trinity River	142.3 – 588.0	0.35 – 142.2	0.001 – 0.34
Indian Creek	*	*	*
Pilot Grove Creek	*	*	*
Sister Grove Creek	*	*	*
Wilson Creek	29.8 – 63.0	0.11 -29.7	0.001-0.1

*Analysis still in progress.

LOAD ESTimator (LOADEST) is a FORTRAN program for estimating constituent loads in streams and rivers. Given a time series of streamflow, additional data variables, and constituent concentration, LOADEST assists the user in developing a regression model for the estimation of constituent load (calibration). Explanatory variables within the regression model include various functions of streamflow, decimal time, and additional user-specified data variables. The formulated regression model then is used to estimate loads over a user-specified time interval (estimation).

The calibration and estimation procedures within LOADEST are based on three statistical estimation methods. The first two methods, Adjusted Maximum Likelihood Estimation (AMLE) and Maximum Likelihood Estimation (MLE), are appropriate when the calibration model errors (residuals) are normally distributed. Of the two, AMLE is the method of choice when the calibration data set (time series of streamflow, additional data variables, and concentration) contains censored data. The third method, Least Absolute Deviation (LAD), is an alternative to maximum likelihood estimation when the residuals are not normally distributed. LOADEST output includes diagnostic tests and warnings to assist the user in determining the appropriate estimation method and in interpreting the estimated loads.

In the following example, the red line indicates the maximum acceptable stream load for *E. coli* bacteria and the squares, triangles, and circles represent water quality monitoring data collected under high, mid-range and low flow conditions, respectively (Figure E.2). Where the monitoring samples are above the red line, the actual stream load has exceeded the water quality standard, and a violation of the standard has occurred. Points located on or below the red line are in compliance with the water quality standard.

In order to analyze the entire range of monitoring data, regression analysis is conducted using the monitored samples to calculate the "line of best fit" (blue line). Where the blue line is on or below the red line, monitoring data at that flow percentile is in compliance with the water quality standard. Where the blue line is above the red line, monitoring data indicate that the water quality standard is not being met at that flow percentile. Regression analysis also enables calculation of the estimated percent reduction needed to achieve acceptable pollutant loads.

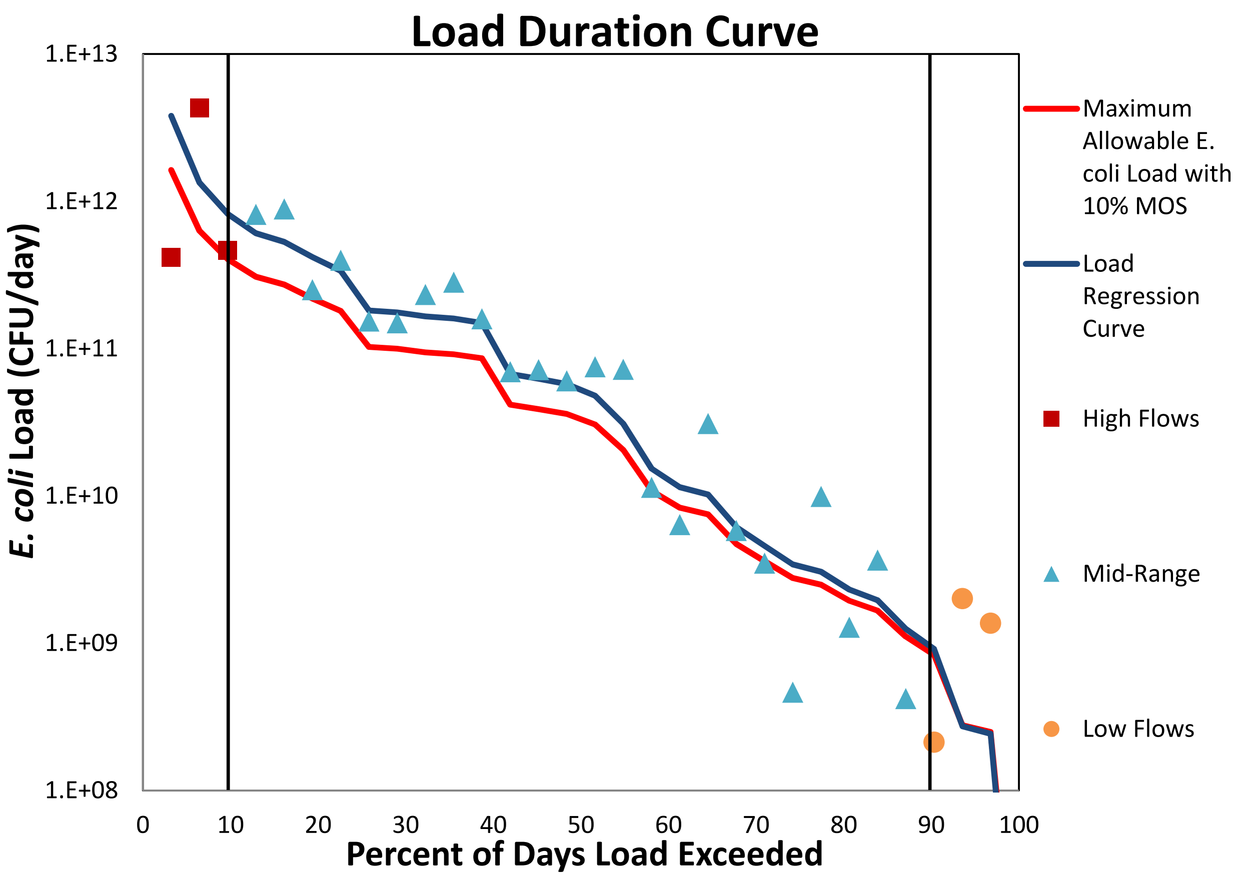

Figure E.2. The East Fork of the Trinity River Load Duration Curve for *E. coli* at TCEQ monitoring site 13740.

Appendix F: SELECT Approach Explanation

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) is an analytical approach for developing an inventory of potential pollutant sources, particularly nonpoint source contributors, and distributing their potential loads based on land use and geographical location. A custom land use classification was developed by the Texas A&M University Spatial Sciences Laboratory using 2015 National Agriculture Imagery Program (NAIP), Texas Orthoimagery Project (TOP), and Landsat-8 data, and a pixel-based classification system. The watershed was divided into 20 subwatersheds based on elevation changes along tributaries and the main segment of the water body. Since SELECT divides the watershed into a raster grid with a 30-meter cell size, the potential load is calculated over the entire watershed at a 30-meter cell size. The individual raster files for each source are then added together spatially to create a total load raster for the watershed that is divided into 30-meter grid cells.

Urban Runoff

Bacteria losses were based on a runoff curve number approach to estimate runoff (PBS&J, 2000). Data were generated on a subwatershed basis and then aggregated. *E. coli* bacteria numbers in runoff were calculated for each subwatershed separately. The spatial aspects of the model for each subwatershed were determined in ArcGIS and then exported into Microsoft Excel.

<u>*Mathematical Model*</u>

Percentage of impervious cover in each subwatershed was estimated using the subwatershed and urban area shapefiles based on the equation:

$$\text{Impervious Cover} = (\text{Urban Area})/(\text{Subwatershed Area}) * 100$$

Where:

Impervious Cover = Percent impervious area in subwatershed (%)

Urban Area = Urban area in subwatershed (acres)

Subwatershed Area= Subwatershed area (acres)

The percentage of impervious cover was found for each subwatershed for the PBS&J study to be utilized to find the amount of *E. coli* per subwatershed. The graph below (Figure 3) shows the relation of impervious cover and fecal coliform for City of Austin stormwater runoff.

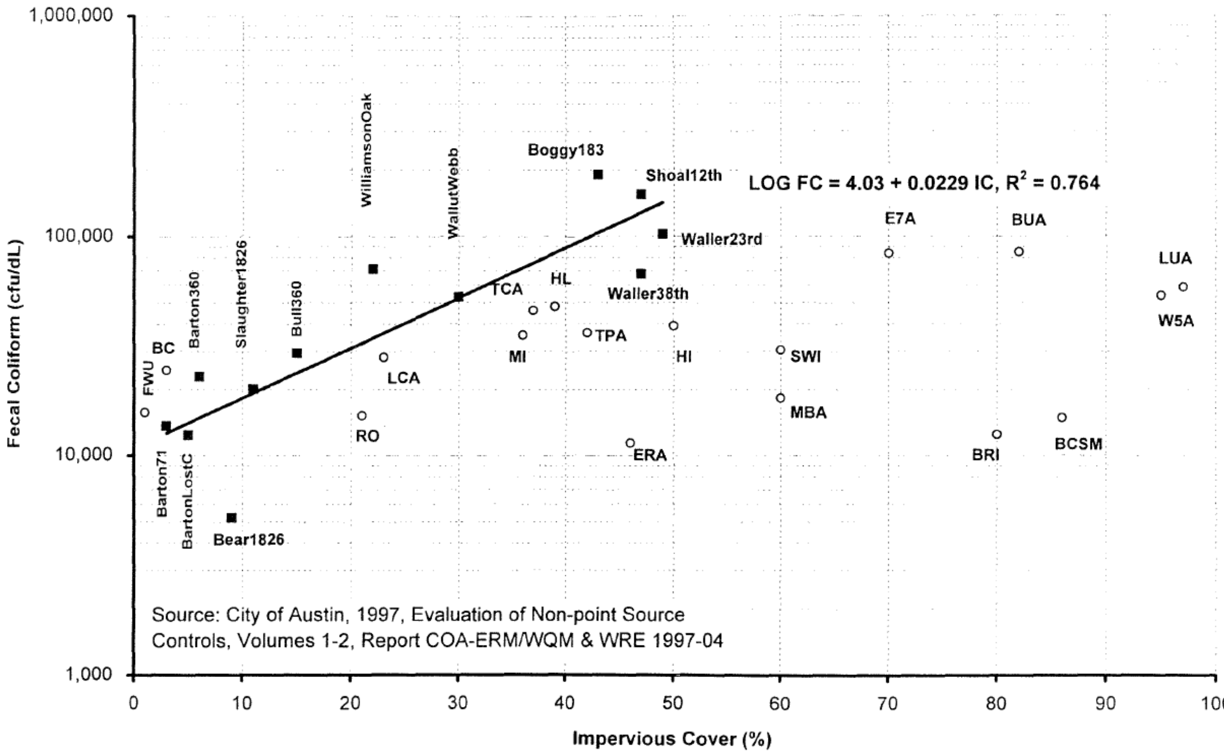

Figure 3. Fecal coliform mean EMCs for City of Austin stormwater runoff (PBS&J, 2000)

The percentage of impervious cover was then inputted into the equation below (PBS&J, 2000):

$$\text{LOG FC} = 4.03 + 0.0229\ \text{IC}$$

Where:

LOG FC = the log transformation of fecal coliform bacteria (colony forming units (CFU)/100 mL)

IC = Impervious Cover (%)

The equation was transformed from the log form to find the number of fecal coliform bacteria per 100 milliliters. The conversion rate of 0.63 *E. coli* bacteria to 1 fecal coliform bacteria was then used to convert from fecal coliform to *E. coli bacteria*. The 0.63 conversion rate is based on the ratio between the fecal coliform standard of 200 cfu/100 mL and the *E. coli* standard of 126 cfu/100 mL (126/200 = 0.63).

Curve Number Approach

The curve number approach was used to find the volume of runoff from the urban areas. The curve number approach is a method to estimate runoff volume for an area based on land use/land cover, soil type, soil moisture conditions, and precipitation (Haan, Barfield, & Hayes, 1994). Curve numbers can range from 0 to 100, with 0 having no runoff potential and 100 being an impervious area where there is a high runoff potential. The curve number is based on land use, hydrologic soil group, and antecedent moisture condition.

An assumptions made for this project in determining appropriate curve numbers was the use of antecedent moisture condition II. Antecedent condition II assumes normal soil moisture before the rainfall event as compared to dry or wet soil moisture. The curve numbers chosen for the specific land uses are presented in Table 1.

Table 1. Runoff Curve Numbers Utilized for Land Use Categories (Haan, Barfield, & Hayes, 1994).

Land Use	**Curve Number**
Open Water	0
Forest	83
Urban	98
Rangeland	89
Managed Pasture	80
Cultivated Crops	91

Worst case scenarios were used to select curve numbers for each land use due to limited specific information on individual land use types. For example, the forest curve number assumed a land use of wood or forest land with thin stand, poor cover, and no mulch. Rangeland assumed poor condition pasture or range land and managed pasture assumed good condition pasture or range land. Cultivated crops assumed cultivated land without conservation treatment. Urban assumed paved parking lots, roofs, and driveways. Areas designated as urban often had small portions of other land use categories included in those areas, so curve numbers were developed for all land use categories. Due to the variability within each of these designated urban areas, an area weighted curve number was then calculated for each urban area within a subwatershed using the formula below (Haan, Barfield, & Hayes, 1994):

$$CN = (\sum_i A_i CN_i)/(\sum_i A_i)$$

Where:

CN = the area-weighted curve number for mixed land uses

CN_i = the appropriate curve number for the part of the catchment having area A_i

A_i = the amount of area for the appropriate curve number

The curve number was then used in the formula below to find the maximum soil water retention parameter (Haan, Barfield, & Hayes, 1994):

$$S = (1000/CN) - 10$$

Where:

S = maximum soil retention parameter within each subwatershed (inches)

CN = the area-weighted curve number for each urban area within a subwatershed

The runoff depth was then calculated using the equation below for the urban area for each subwatershed (Haan, Barfield, & Hayes, 1994):

$$Q = (P - 0.2S)^2 / (P + 0.8S)$$

Where:

Q= the accumulated runoff volume or rainfall excess (inches)

P= the accumulated precipitation (inches)

S= maximum soil water retention parameter (inches)

An accumulated precipitation of 1.5 inches per day was based on the 90th percentile flow event in the area. This rainfall event was chosen because it is a small rainfall event that would regularly cause runoff in this region without causing flooding. The total runoff volume for each subwatershed was then calculated by multiplying the accumulated runoff by the amount of urban area. The volume of runoff was then converted to a daily potential *E. coli* load using the formula below:

$$E.\ coli\ \text{load} = E.\ coli * V * (102790\ \text{L}/1\ \text{acre-inches}) * (1000\ \text{mL}/1\ \text{L})$$

Where:

E. coli load = daily potential *E. coli* load for each subwatershed (CFU/day)

E. coli = Amount of *E. coli* calculated from equations 1 and 2 (CFU/100 mL)

V= volume of runoff calculated from equations 3, 4, and 5 (acre-inches)

Domestic Dogs

By multiplying the average number of dogs/household by the number of households in the watershed, the total dog population was estimated to be 98,049. The total potential daily bacterial load for each subwatershed was approximated using:

$$\text{DogLoad} = \text{\# Households} * (1.25 \text{ dog/household}) * (5*10^9 \text{ cfu/day}) * 0.63$$

Where $5*10^9$ cfu/day*0.63 is the average daily *E. coli* bacteria production per dog, converted from fecal coliform (EPA 2001).

Septic Systems

Using 2010 census block data from the U.S. Census Bureau the number and location of households in the Lavon Lake Watershed were determined. Census data were used to determine the average number of people per home and locations of households in the watershed. Homes within the city limits (CCN) were determined to be on city sewer facilities, and those outside city limits were assumed to rely on septic systems. The septic drainfield limitation classes were used to assign a potential malfunction rate (Table F.1and Figure F.1). Potential malfunction rate classifications were 8, 10, and 15% (Riebschleager 2012). Of the 15,286 systems, 74 were assigned an 8% malfunction rate, 876 were assigned a 10% malfunction rate, and 14,336 were assigned a 15% malfunction rate (Table F.2).

$$SepticLoad = SepticSystems * MalfunctionRate * People / Home * 3.08x10^{12}\, cfu / day * 0.63$$

Factors in the equation that determined potential loads from septic systems were: 3.08×10^{12} fecal coliform/person/day, and 0.63 is to convert fecal coliform to *E. coli* (EPA 2001).

Table F.1. Soil limitations classes.

Limitations Class	Percent Malfunction
Somewhat	10
Very	15
Not Rated	8

Table F.2. Results of classification by percent malfunction

Percent Malfunction	Ratio (#homes in each index category/total #homes)
8	74/15,268
10	876/15.268
15	14,336/15,268

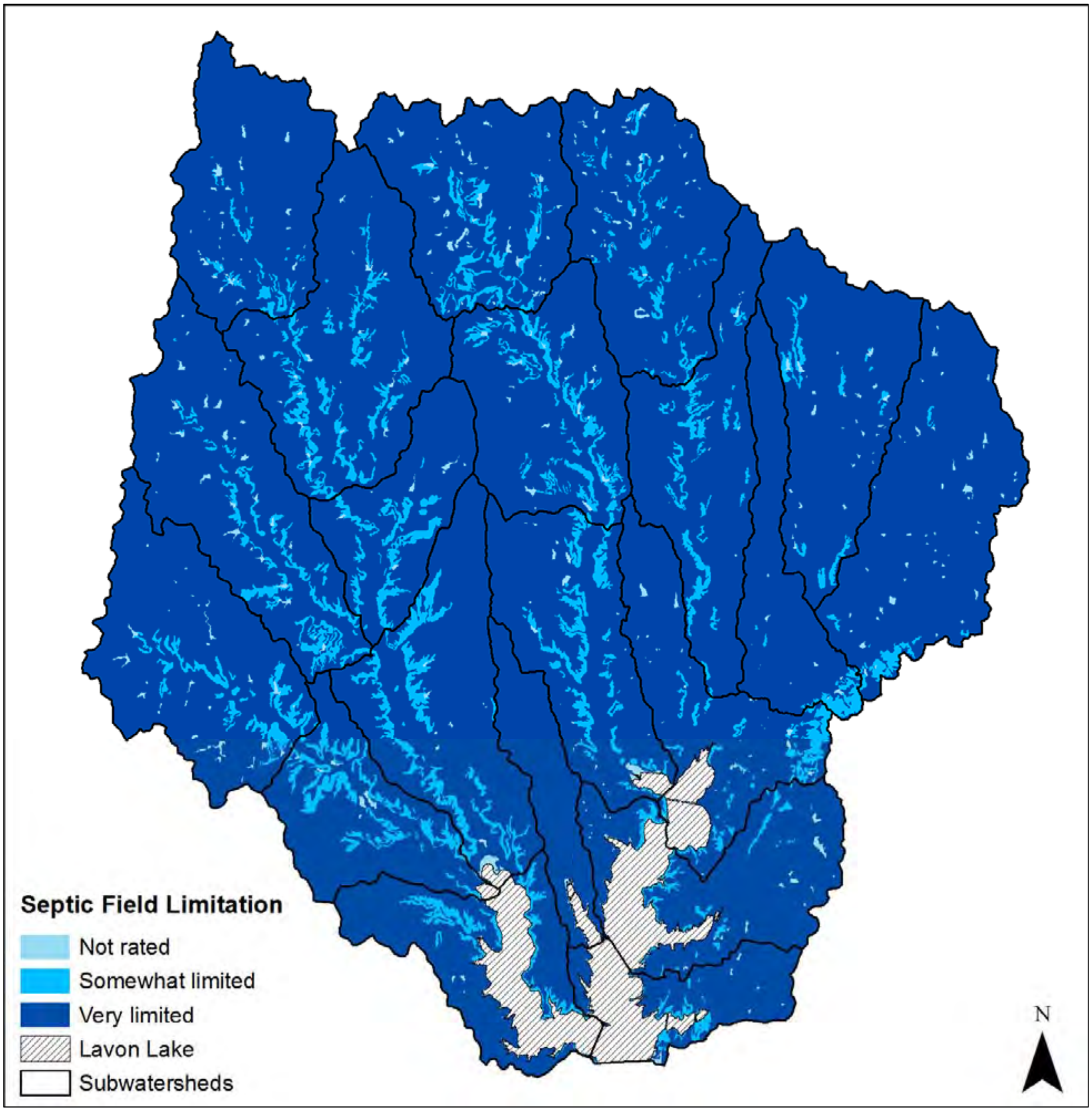

Figure F.1. Soil suitability for onsite sewage facilities in the Lavon Lake Watershed.

Livestock

To estimate livestock populations for input into SELECT, a combination of existing datasets along with stakeholder input was utilized. Livestock populations were initially estimated using agriculture census data from the USDA National Agricultural Statistics Service (NASS), then refined using current observations from stakeholders. The USDA-NASS conducts the census of agriculture every 5 years and provides estimates of production, supply, prices, and other operational characteristics. The 2012 census of agriculture was the most recent version available and was utilized by stakeholders as a baseline estimate of livestock populations in the Lavon Lake watershed.

Cattle

The average potential daily *E. coli* load for each subwatershed was estimated using:

$$\text{Cattle Load} = \#\ \text{Cattle}*1*10^{11}\ \text{cfu/day}*0.63$$

> Where $1*10^{11}$ cfu/day *0.63 is the average daily *E. coli* production per head of cattle (EPA 2001).

Horses

The potential daily *E. coli* load for each subwatershed was estimated using:

$$\text{Horse Load} = \#\ \text{horses}*4.2*10^{8}\ \text{cfu/day}*0.63$$

> Where $4.2*10^{8}$ cfu/day*0.63 is the average daily *E. coli* production per horse (EPA 2001).

Goats

The average potential daily *E. coli* load for each subwatershed was estimated using:

$$\text{Goat Load} = \#\ \text{goats}*1.2*10^{10}\ \text{cfu/day}*0.63$$

> Where $18*10^{9}$ cfu/day*0.63 is the average daily *E. coli* production per animal (EPA, 2001).

Sheep

The potential daily *E. coli* load for each subwatershed was estimated using:

$$\text{Sheep Load} = \#\ \text{sheep}*1.2*10^{10}\ \text{cfu/day}*0.63$$

> Where $1.2*10^{10}$ cfu/day*0.63 is the average daily *E. coli* production per animal (EPA 2001).

Domestic Poultry

The potential daily *E. coli* load for each subwatershed was estimated using:

$$\text{Domestic Poultry Load} = \text{\# poultry}*1.4*10^{8} \text{ cfu/day}*0.63$$

Where $1.1*10^{10}$ cfu/day*0.63 is the average daily *E. coli* production per animal (EPA 2001).

Wildlife and Nondomestic

The potential bacteria contributions from white-tailed deer and feral hogs in the Lavon Lake Watershed were estimated using population density estimates from local TPWD biologists. Based on the estimated number of deer and feral hogs per acre, total populations were calculated for each subwatershed. Deer populations were distributed to the forest land uses and feral hog population were distributed to rural riparian corridors. The total potential daily bacteria load in each subwatershed was then estimated using the *E. coli* production rate of Zeckoksi et al. (2005) and EPA (2001) for deer and feral hogs, respectively.

Deer

The daily potential *E. coli* load from deer was estimated using:

$$\text{Deer Load} = \text{\# deer}*3.5*10^{8} \text{ cfu/day}*0.63$$

Where $3.5*10^{8}$ cfu/day*0.63 is the average daily *E. coli* production rate per deer (Zeckoksi, 2005).

Feral Hogs

The daily potential *E. coli* load from feral hogs was estimated using:

$$\text{Feral Hog Load} = \text{\# hogs}*1.1*10^{10} \text{ cfu/day}*0.63$$

Where $1.1*10^{10}$ cfu/day*0.63 is the average daily *E. coli* production rate per hog (EPA, 2001).

A map of the most suitable habitat for feral hogs was constructed by identifying the 100 meter (328 foot) area surrounding streams in the watershed, but does not include urban areas that are located in the buffer (Figure F.3). It is understood that feral hogs are located outside of these areas as well.

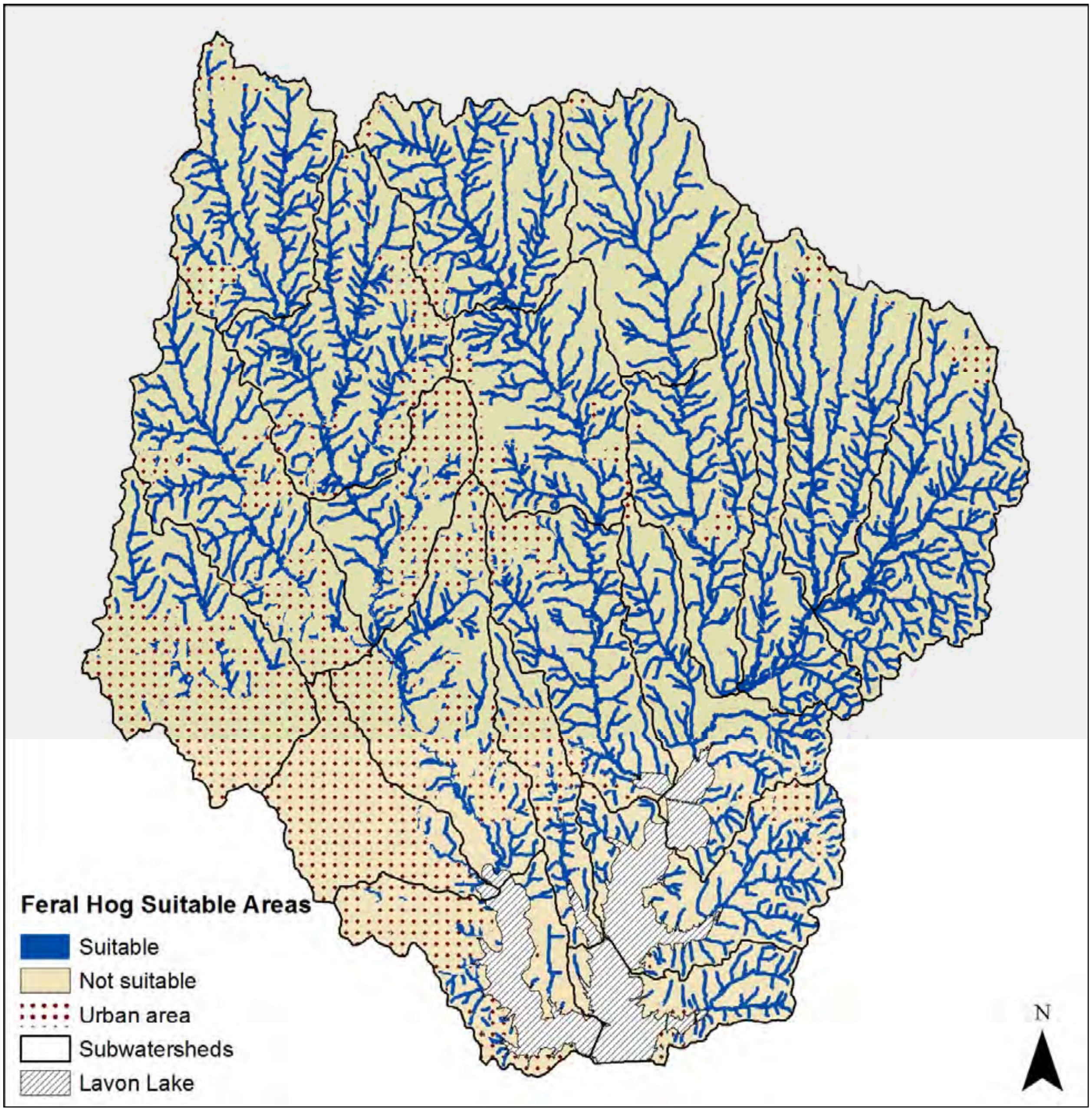

Figure F.3. The most suitable habitat for feral hogs.

Appendix G: Margin of Safety

EPA guidance states that a margin of safety (MOS) is a necessary component that accounts for uncertainty in the response of a waterbody to loading reductions. An MOS accounts for possible variation in loading from potential sources, stream flow variations, potential range of effectiveness of management measures, and other sources of uncertainty involved in projects of this nature. The MOS can be explicitly stated as an added or separate quantity, or implicit by being imbedded in conservative assumptions. In the development of the load reductions in this plan, both explicit and implicit MOS are utilized, and are so indicated. An explicit 10% MOS is employed in LDC calculations of the primary contact recreation standard by using a target *E.coli* geomean of 113 cfu/100mL rather than the primary contact recreation standard of 126 cfu/100mL. An implicit margin of safety was employed during development of several numeric SELECT inputs.

Appendix H: Management Practice Efficiencies

For use in determining optimal management practices for implementation in urban and agricultural areas, the following reduction efficiencies were assumed. All values are load reductions unless otherwise stated.

URBAN MANAGEMENT PRACTICES

Table H1. Load reductions for media filters.

TSS	TN	TP	Metals	Bacteria		
89%	17%	59%	72-86%	65%	Glick et al., 1998	Calif Handbook
95%	-[1]	41%	61-88%	-	Stewart 1992	
85%	-	4%	44-75%	-	Leif 1999	
85%	-	80%	65-90%	-	Pitt et al. 1997	
83%	-	-	9-100%		Pitt 1996	
98%	-	84%	83-89%	-	Greb et al. 1998	
70%	21%	33%	45%	76%(FC)	Galli, 1990	EPA Fact Sheet 1999
99%	38%	97%	94-99%	-	Hatt et al. 2008	
85%	35%	45%	-	-	NCDENR 2007	
82%	42%	49%	-	31%	N.P.R.D. 2007[2]	
70-90%	30-50%	43-70%	-	-	Bell et al. 1995; Horner & Horner 1995; Young et al. 1996	StormWater BMPs FHWA
75-92%	27-71%	27-80%	-	-	City of Austin 1990; Welborn & Veenhuis 1987	
90-95%	55%	49%	48-90%	90%	Claytor & Schueler 1996; Stewart 1992; Stormwater Management 1994	
66-95%	44-47%	4-51%	34-88%	-	USEPA 2004	

[1] No data.

[2] Reductions based on an average of multiple studies.

Table H2. Load reductions for wetlands.

Volume	TSS	TN	TP	Bacteria	Metals	BOD		
10%	45%	27%*	28%	31%[2]	-[5]	28%	Newman & Clausen 1997	
-	83%	26%,	43%	76%**[2]	36-85%	-	Winer 2000	EPA NPDES 2006
-	69%	56%	39%	-	80-63%	-		
-	71%	19%	56%	-	0-57%	-		
-	83%	19%	64%	78%[2]	21-83%	-		
-	-	37%	2%	-	-	-	Kovacic et al. 2000	
-	-	11%	17%	-	-	-	Raisin et al. 1997	
-	-	-	-	-	-	80%	Huddleston et al. 1999	
-	85%	85-90%	47%[4]	-	84%(Fe)	-	Lake Tahoe	EPA National Management Measures 2005
-	70%	-	-	-	-	-	Shop Creek	
-	94%	76%	90%	-	-	-	Lake Jackson	
-	55%	36%	43%	-	83%(Pb), 70%(Zn)	-	Orange County	
-	55-83%	36%	43%	-	55-83% (Pb, Zn)	-	Orlando	
-	50%	-	62%	-	-	-	Palm Beach	
-	71%	-	47%	-	-	-	Tampa	
-	86-90%	61-92%	65-78%	-	-	-	Des Plaines	
-	95-97%	-	82-91%	-	-	-	Long Lake	
-	95%	-	92%	-	-	-	St. Agatha	
-	96%	74%	78%	-	90%(Pb)	-	Spring Creek	
-	55%	24%	44%	76%[3]	-	-	N.P.R.D. 2007***	
-	65%	20%	25%	-	35-65%		USEPA 1993	StormWater BMPs FHWA
				99%[1]			Stenstrom and Carlander	
				93%[2]			de J. Quinonez-Diaz et al., Gerba et al., Khatiwada et al., Neralla et al, Rifai 2006	

* Total Kjeldahl-N Reduction.
** Based on fewer than 5 data points.
*** Based on an average of multiple studies.

[1] *E. coli.*
[2] Fecal coliform.
[3] Indicator species not specified.
[4] Particulate phosphorus reduction only.
[5] No data.

Table H3. Load reductions for bioretention structures.

Volume	TSS	TP	TN	Cu	Pb	Zn	Oil & Grease	Bacteria	
-[3]	97%	35-65%	33-66%	36-93%	24-99%	31-99%	99%	70%[2]	MD Envir. Service 2007
96.5%	60%	31%[2]	32%	54%	31%	77%	-	69%(FC) 71%(EC)	Hunt et al. 2008
-	-	-	40%	99%	81%	98%	-	-	Hunt et al. 2006
-	-	58-63%	47-88%	-	-	-	-	-	Passeport et al. 2009
-	-	65-87%	49%	43-97%	70-95%	64-95%	-	-	EPA BMP Menu
40%	-	35-50%	70-80%	-	-	-	-	97%(FC)*	Smith & Hunt
51%	-	16%	43%	-	-	-	-	-	Sharkey 2006
48%	-	-39%[2]	38%	-	-	-	-	-	
-	-	65-87%	49%	43-97%	70-95%	64-95%	-	-	Davis et al. 1997 ; EPA NPDES 2005
-	29%	-11%	44%	68%	-	23%	-	-	N.P.R.D. 2007**
-	75%	50%	50%	75-80%	75-80%	75-80%	-	-	StormWater BMP FHWA; Prince George's County 1993
-	80%	65-87%	49%	-	-	-	-	-	USEPA 2004
								97%(EC) 44%(FC)	Peterson et al. 2011

* Values based on only 6 collected samples, not a statistically significant finding.

** Reductions based on an average of multiple studies.

[1] Negative value represents an increase in pollutant concentration.

[2] Indicator species not specified.

[3] No data.

Table H4. Load reductions for infiltration trenches or basins.

TSS	TN	TP	Metals	Bacteria		
50%	-[2]	51%	52-93%	96%(FC)	Birch et al. 2005	
99%	60-70%	65-75%	95-99%	98%[1]	Schueler, 1987	Wisconsin Manual 2000
90%	60%	60%	90%	90%[1]	Schueler, 1992	EPA Fact Sheet
85%	-	85%	-	-	PA Stormwater Manual 2006	
75-99%	45-70%	50-75%	75-99%	75-98%[3]	Young et al. 1996	StormWater BMPs FHWA
75%	55-60%	60-70%	85-90%	90%[1]	USEPA 2004	

[1] Indicator species not specified.
[2] No data.

Table H5. Load reductions for dry ponds.

TSS	TN	TP	Metals	Bacteria		
61%	31%	19%	26-54%	-[3]	Schueler 1997	EPA BMP Menu
71%	-	-	26-55%	-	Stanley 1996	
47%	19%	21%	-	88%[2]	N.P.R.D. 2007**	
61%	19%	31%	26-54%	-	USEPA 2004	
-	-	-	-	90%[1]	BMP Database Project 3	

** Reductions based on an average of multiple studies.
[1] Fecal coliform.
[2] Indicator species not specified.
[3]No data.

Table H6. Load reductions for wet ponds.

TSS	TN	TP	Metals	Bacteria		
67%	31%	48%	24.73%	65%[1]	Schueler 1997	EPA BMP Menu
76%	31%	54%	-[2]	68%[1]	N.P.R.D. 2007**	
68%	55%	32%	36-65%	-	USEPA 2004	
-	-	-	-	47%(FC)	Rifai (2006),Gerba et al., Mallin	

** Reductions based on an average of multiple studies.
[1] Indicator species not specified.
[2] No data.

Table H7. Load reductions for swales.

TSS	TN	TP	Cu	Pb	Zn	Bacteria		
60-85%	10-90%	15-90%	45-80%	-[1]	68-88%	-	CRWA 2008	
81%	38% *	9%	51%	67%	71%	-	U.S. EPA Fact Sheet 1999	
-	51%, 41%	63%, 42%	70%, 49%	56%, 76%	93%, 77%	-	Yousef et al. 1987**	
30-90%	0-50%	20-85%	0-90%	0-90%	0-90%	-	City of Austin (1995)	StormWater BMPs FHWA
						-	Claytor & Schueler (1996); Kahn et al. (1992); Yousef et al. (1985); Yu & Kaighn (1995); Yu et al. (1993 & 1994)	
-	-	-	-	-	-	-388[2]	Randafi (2006), Dayton Ave Project [3]	

* Value reduction of nitrate only.
** Observations from two sites respectively.
[1] No data.
[2] Fecal coliform.
[3] MS Dept. of Marine Resources – http://www.dmr.state.ms.us/CMP/Storm/APPENDIX-C/Dayton%20Biofilter%20Grass%20Swale.pdf.

Table H8. Load reductions for street sweeping.

TSS	TP	TN	Metals	Bacteria		
55-93%	40-74%	42-77%	35-85%	-[1]	NVPDC 1992	StormWater BMPs FHWA

[1] No data.

Table H9. Load reductions for porous pavement.

Volume	TSS	TP	TN	Metals	Bacteria		
-[1]	82-95%	60-71%	80-85%	33-99%	-	MWCOG 1983 Hogland et al. 1987 Young et al. 1996	StormWater BMPs FHWA
-	82-95%	65%	80-85%	98-99%	-	USEPA 2004	
31-100%*	-	-	-	-	-	Smith et al. 2006	
66%**	-	-	-	-	-		
75%**	-	-	-	-	-		
81%**	-	-	-	-	-		
53%**	-	-	-	-	-		

* Represents the range of reduction for 4 types of porous pavement from 17 rainfall events.

** Represents an average reduction for one of the 4 types of porous pavement tested from 17 rainfall events.

[1] No data.

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Table H10. Load reductions for filter strips.

Sediment/Solids	N	P	Fecal Coliform*	Length of Strip		
97.6%	95.3%	93.6%	-[1]	18.3m	Load(kg/ha)	Lim et al. 1998
91.9%	90.1%	83.8%	-	18.3m	Conc.(mg/L)	
77.3%	86.9%	92.6%	-	21m	Load(kg/ha)	Chaubey et al. 1994
92.1%	94.6%	96.9%	86.8%	21m	Conc.(mg/L)	
95%	80%	80%	-	9.1m	Load(kg/ha)	Dillaha et al. 1988
99%	-	-	74%	9m	Load(kg/ha)	Coyne et al. 1995
79%	84%	83%	69%		Conc.(cfu/mL)	Young et al. 1980
-	-	-	95%	1.37m	Conc.(cfu/mL)	Larsen et al. 1994
-	-	-	FC-54% EC-13%	-	-	Rifai (2006),Goel, et al.
-	-	-	FC-30-100% EC-58-99%	-	-	Peterson et al. 2011

* Concentration reductions are for fecal coliform unless otherwise labeled.
[1] No data.

Table H11. Load reductions for riparian herbaceous buffers.

Sediment/Solids	N	P	Fecal Coliform*	Width	
79%	84%	83%	69%	27m	Young et al. 1980
84%	73%	79%	-[1]	9.1m	Lee et al. 1999
66%	0%	27%	-	4.6m	Magette et al. 1999
70%	50%	26%	-	4.3 & 5.3m	Parsons et al. 1991
99%	-	-	-	5-61m	Dosskey et al. 2002
67%	-	-	-	5-61m	Dosskey et al. 2002
59%	-	-	-	5-61m	Dosskey et al. 2002
41%	-	-	-	5-61m	Dosskey et al. 2002
-	-	-	95%	1.37m	Larsen et al. 1994

* Concentration reductions in cfu/mL.
[1] No data.

Table H12. Load reductions for field borders.

Sediment/Solids	N	P		
57%	55%	50%	Load(kg/ha)	Arabi 2005
45%	35%	30%	Load(kg/ha)	Arabi 2005
50%	45%	25%	Load(kg/ha)	Arabi et al. 2006
48%	45%	24%	Load(kg/ha)	Arabi et al. 2006
81%	32%	-[1]	Load(kg/ha)	Tate et al. 2000

[1] No data.

Table H13. Load reductions for grassed waterways.

Sediment/Solids	N	P	Fecal Coliform		
97%	-[1]	-	-	Load(kg/ha)	Fiener & Auerswald 2003
77%	-	-	-	Load(kg/ha)	Fiener & Auerswald 2003
95%	-	-	-	Load(t/ha)	Chow et al. 1999
-	-	-	95%	Conc.(cfu/mL)	Larsen et al. 1994
-	-	-	16%	Conc.(cfu/mL)	Dickey and Vanderholm, 1981

[1] No data.

Table H14. Load reductions for riparian forest buffers.

Sediment/Solids	N	P		
97.2%	93.9%	91.3%	Load(kg/ha)	Lee et al. 2003
76%	-[1]	-	Mass(g/event)	Schoonover et al. 2005
61.3%	-	-	Conc.(mg/L)	Schoonover et al. 2005
90%	-	-	Conc.(mg/L)	Peterjohn & Correll 1984
-	89%	80%	Load(kg/ha)	Peterjohn & Correll 1984

[1] No data.

Table H15. Load reductions for alternative watering facilities.

Sediment/ Solids	N	P	Bacteria	Reduction in Time Spent in Stream	Reduction in Time Spent Near Stream	Reduction in Time Spent Drinking From Stream		
96.2%	55.6%	97.5%	-[3]	-	-	92%	Load (kg/ha)[1]	Sheffield et al. 1997
90%	54%	81%	FC-51%	-	-	92%	Conc. (mg/L)[2]	Sheffield et al. 1997
-	-	-	-	85%	53%	73.5%	-	Clawson 1993
-	-	-	-	-	75%	-	-	Godwin & Miner et al. 1996
-	-	-	-	90%	-	-	-	Miner et al. 1992
77%*	-	-	EC-85% FC-51-94%	-	-	-	-	Peterson et al. 2011

* Estimated reduction in stream bank erosion.
[1] Load Reductions based on measurements taken only from the watershed outlet.
[2] Concentration reduction based on measurements averaged from all 5 sample sites in the studied watershed.
[3] No data.

Table H16. Load reductions for nutrient management.

N*	NO_3-N**	P*	Management Practice	
-[1]	47%	-	Variable Rate Application	Delgado & Bausch 2005
-	59%	-	Nitrification Inhibitor	Di & Cameron 2002
-	-	12-41%	Variable Rate Application	Wittry & Mallarino 2004

* Reductions in nutrient applied to crop and continuing to maintain yield.
** Reduction in residual soil NO3-N and NO3-N leaching potential.
[1] No data.

Table H17. Load reductions for conservation cover.

Sediment/Solids	N	P	Bacteria	
71%	-[1]	-	-	USEPA 2009 STEPL BMP Efficiency Rates
90%	-	-	-	Grace 2000
99%	-	-	-	Robichaud et al. 2006
89%	-	-	-	Robichaud et al. 2006

[1] No data.

Table H18. Load reductions for prescribed grazing.

Consumption of Weed Species	Reduction of Weed Population	Reduction of Stem Density	Increase in Population of Preferred Veg.	Weed Species	Livestock Species	
40-90%	-[1]	-	-	Tall larkspur	Sheep	Ralphs et al. 1991
-	-	98%*	-	Leafy Spurge	Goats	Lym et al. 1997
-	93%	-	13%	Leafy Spurge	Sheep	Johnston & Peake 1960
-	90%	-	-	Barley	Sheep	Hartley et al. 1978
-	100%	-	-	Bull Thistle	Goats	Rolston et al. 1981
-	90%	-	-	Leafy Spurge	Sheep	Olson & Lacey 1994

* Reduction achieved in combination with herbicide application.

[1] No data.

Table H19. Load reductions for prescribed grazing.

Sediments / Solids	N	Bacteria	Runoff Volume*	Livestock Species	
8%	34%	EC – 66-72% FC – 90-96%	[1]Mod. Grazed—29% [2]Lightly Grazed—89%	Cattle	Peterson et al. 2011

* Reduction as compared to heavily grazed (1.35 AUM/acre).

[1] (2.42 AUM/acre)

[2] (3.25 AUM/acre)

Table H20. Load reductions for stream crossings.

Sediments / Solids	N	P	Bacteria*	
18-25%	18-25%	18-25%	EC—46% FC—44%-52%	Peterson et al. 2011
-[3]	35%[1]*	78%[2]*		

* Concentration reductions.
[1] Nitrate nitrogen.
[2] Particulate phosphorus.
[3] No data.

Table H21. Load reductions for alternative shade.

Sediments / Solids	N	Bacteria	
-[1]	-	EC – 85%*	Peterson et al. 2011

* When combined with an off-stream water source.
[1] No data.

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