Mill Creek Watershed Protection Plan

Developed by
The Mill Creek Watershed Partnership
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Cover photo of Mill Creek at FM-2429.

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Prepared for the

Mill Creek Watershed Partnership

by

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Statement of Purpose

Mill Creek is a vital resource in the area, supporting contact recreation and agricultural uses and providing habitat for a diverse array of plants and animals. It served as a source of water to Native Americans and early Spanish settlers. The creek also played a key role in the success of the first Anglo-American colony in Texas and was home to the first saw mill in the state, from which the creek derived its name. The land surrounding the creek has provided excellent agricultural and industrial opportunities. Agriculture remains a vital part of the local economy, and the most prevalent land use. In 2010, Mill Creek was listed by the State of Texas as having *E. coli* bacteria levels that impaired contact recreation use of the creek. In response, the Mill Creek Watershed Protection Plan was developed using a stakeholder process driven by public participation to provide a foundation for restoring water quality in Mill Creek and its tributaries. By identifying key water quality issues in the Mill Creek watershed and determining the factors contributing to these issues, management programs and public outreach efforts can be targeted to restore and protect the vital water resources of this watershed. The Mill Creek Watershed Protection Plan incorporates the analysis of existing water quality data and detailed investigation of potential pollutant sources based on local knowledge and experience to develop a strategy for addressing concerns related to water quality.

Stakeholders are any individual or group that may be directly or indirectly affected by activities implemented to protect water quality, such as citizens, 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 Mill Creek watershed and actively make a difference in the quality and health of their water resources through adoption of voluntary management practices. It helps focus restoration efforts, and enables financial and technical assistance to facilitate improvements in Mill Creek. 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 the stakeholders as they undertake active stewardship of the watershed.

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Executive Summary

Mill Creek is formed by two forks, East and West Mill Creek, in southwest Washington County which unite near Bellville, TX in Austin County to form the main stem. Mill Creek then flows 14 miles southeast to its confluence with the Brazos River. The 263,450-acre watershed is made up of 55 percent rangeland, 22 percent cropland (including managed pasture), 15 percent forest, and 8 percent developed land. Major agricultural uses include forage production and grazing lands with corn and cotton being grown on a small number of acres. The predominant livestock species in the watershed is cattle; however, there also are poultry, horses, domestic hogs, sheep, and goats in the area.

While the vast majority of the watershed is undeveloped or agricultural land, there are a few incorporated areas within the Mill Creek watershed. The City of Bellville is the largest city in the watershed and is located along the Boggy Creek tributary. Other incorporated areas in the watershed include the Cities of Burton and Industry. Additionally, very small portions of both Brenham and New Ulm lie within the watershed boundary.

In 2007 a Recreational Use Attainability Analysis (RUAA) was conducted on Mill Creek to determine if Mill Creek supports contact recreation uses. The Mill Creek RUAA was the first analysis of its kind in Texas and served as a model for RUAAs throughout the state. Results of the analysis concluded that Mill Creek historically supported contact recreation and continued to do so, affirming the primary contact recreation designated use assigned to Mill Creek by the Texas Commission on Environmental Quality.

Mill Creek (Segment 1202K) is identified as impaired on the 2014 Texas Integrated Water Report 303(d) list due to bacterial contamination. Data used for the 2014 Integrated Report were 26 samples taken during the 7-year period between December 2005 and November 2012 from the SH-36 monitoring station. The geometric mean of these data for E. coli bacteria was 192 colony forming units per 100 milliliters (cfu/100 mL), which exceeds the State standard of 126 cfu/100 mL for water bodies designated for primary contact recreation. Elevated levels of *E. coli* indicate the potential presence of pathogenic organisms.

The Texas State Soil and Water Conservation Board (TSSWCB) selected Mill Creek for development of a Watershed Protection Plan (WPP) based on criteria that included presence on the Texas Integrated Water Report 303(d) list, potential for success, ongoing activities, and level of stakeholder interest. Public meetings were held in Bellville and Brenham in November 2014, and shortly thereafter the Mill Creek Watershed Partnership was formed to guide the WPP development process. Led by the Steering Committee, the Partnership is working with citizens, businesses, public officials and state and federal agencies in the watershed to restore water quality in Mill Creek. The Partnership recognizes that success in improving and protecting water resources depends on the people who live, work, and recreate in the watershed. The Mill Creek Watershed Protection Plan created through these efforts, will serve as a guidance document for restoring and protecting local water quality.

The Partnership and Steering Committee dedicated significant time to the identification and location of potential sources of bacteria in the Mill Creek watershed. Potential sources identified are: urban runoff, dogs, cattle, goats, sheep, horses, domestic hogs, poultry, deer, feral hogs, and wastewater. While not of primary concern in this watershed, pollutants such as nutrients, sediment, pesticides and hydrocarbons (fuel, motor oil and grease) may also be present in runoff.

Through scientific analysis, researchers supporting the Partnership determined that Mill Creek requires a 43 percent reduction in bacteria concentrations in order to meet the state water quality standard. As part of this analysis, the Steering Committee 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 aimed at reducing bacteria levels in Mill Creek.

Based on the evaluation of existing water quality data and watershed characteristics, the Partnership and Steering Committee recommended management measures to reduce bacteria levels in Mill Creek.

Urban management measures focused on addressing potential sources of bacteria in existing urbanized areas of Bellville, Burton, Industry, and Brenham, coupled with plans for future growth and expansion. Dog waste and urban stormwater runoff were the two primary sources for which management measures were recommended. City ordinances and pet waste collection facilities are proposed to address dog waste. To address stormwater management, the Partnership will support cities in the watershed in seeking funding to conduct detailed engineering analyses to properly locate and design practices specific to each city.

The Partnership worked closely with both city and county personnel to identify wastewater management measures. In order to reduce the occurrence of illicit sanitary sewer system discharges, the Partnership recommends that cities participate in TCEQ's Sanitary System Sewer Overflow Initiative program. In addition, cities will work to extend sanitary sewer service to peripheral areas not currently served. Both Austin and Washington Counties will conduct education programs for homeowners on septic systems and seek funding to provide assistance to those who are unable to repair failing systems due to financial constraints.

Agricultural management measures identified by the Partnership included voluntary site-specific Water Quality Management Plans for individual operations. Enhanced planning and financial assistance will be provided to farmers and ranchers for development of management plans that reduce bacteria and nutrient losses and meet the needs of each farm operation. Activities including filter strips, nutrient management, and conservation easements are recommended as pollutant controls in the Mill Creek watershed.

To address concerns over feral hogs in the lower portion of the watershed, the Partnership will rely heavily on the expertise and resources of the Texas Wildlife Services for technical assistance, education, and direct control of feral hogs. In addition, the Partnership will support continued employment of a full-time, regional feral hog management position to provide direct technical assistance in the Mill Creek watershed.

As recommended management measures are implemented, it will be essential to monitor water quality and make any necessary adjustments to the implementation strategy. Routine water quality monitoring at the SH-36 monitoring station will continue throughout the implementation phase. In addition, nine sites will be monitored bi-monthly throughout the 10-year implementation period. 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 Mill Creek were developed based on complete implementation of the watershed protection plan and assume full accomplishment of pollutant load reductions by the end of the 10-year implementation period. The Partnership will evaluate progress towards achieving programmatic and water quality goals at years 3, 6, and 10. Reductions in the loadings 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 Mill Creek Watershed Partnership will continue to meet on a quarterly 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 Mill Creek for present and future generations.

Another important goal of the Mill Creek project was to demonstrate that Watershed Protection Plans can be developed with greater time efficiency without sacrificing quality, accuracy, or effectiveness. Thus, a 6-month timeline was created and executed for the Mill Creek plan development process. Through effective planning and management, and the dedication of the Partnership, this goal was met. Most importantly, by completing the process in a timely manner, stakeholder engagement was maintained and momentum optimized as the implementation phase begins.

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.

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.

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.

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 Mill Creek 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

GEOGRAPHY

Mill Creek is formed by two forks, East and West Mill Creek, in southwest Washington County which unite near Bellville, TX in Austin County to form the main stem. The almost 412-square-mile watershed (263,450 acres) lies within the larger Brazos River Basin. The headwaters of the East and West forks of Mill Creek begin in southwestern Washington County, just above SH-290 near Burton (Figure 2.1). The two forks parallel one another, flowing southeast and joining approximately 4 miles west of Bellville. Mill Creek then continues southeast for 14 miles to its confluence with the Brazos River (Figure 2.2). Much of Mill Creek is intermittent with pools during much of the year, until just above the confluence of the East and West forks. The upper and central portions of the watershed are characterized by rolling hills while the lower portion of the watershed transitions to a coastal prairie. Elevations in the watershed range from 551 feet in the upper reaches to 121 feet near the Brazos River. Incorporated areas within the watershed include the cities of Bellville, Burton, and Industry, which have populations of 4,097, 300, and 304, respectively (BOC, 2010).

Figure 2.1. Mill Creek flowing through a rural portion of the watershed. Image courtesy of H-GAC.

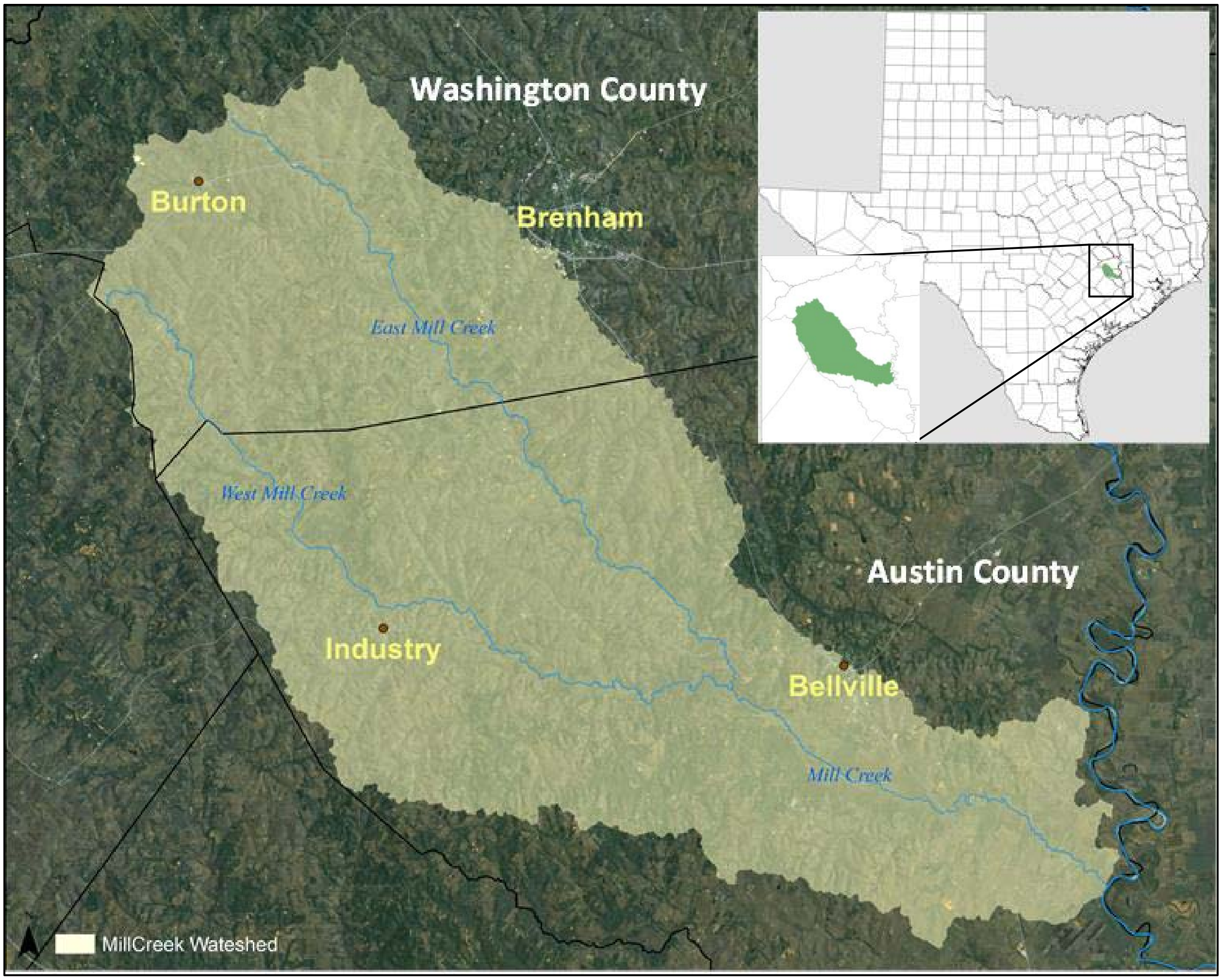

Figure 2.2. The Mill Creek watershed.

PHYSICAL AND NATURAL FEATURES

Ecoregions

While the headwaters of Mill Creek begin in the Blackland Prairies ecoregion, the main stem flows through the Post Oak Savannah ecoregion. Also, the lower, southern end of the watershed extends slightly into the Gulf Coast Prairies & Marshes ecoregion (Figure 2.3). The Texas Blackland Prairies ecoregion is dominated by tallgrass species on uplands and by deciduous woodlands along riparian corridors (USDA, 1984). The Post Oak Savannah ecoregion is characterized by a mix of hardwoods, improved pasture, and rangelands while the Gulf Coast Prairies and Marshes ecoregion is a nearly level, slowly drained plain less than 150 feet in elevation. Native vegetation in the watershed consists of tallgrass prairies and post oak woodlands (TPWD, 1996). Post oak is the predominant hardwood species in the area but hickory, live oak, blackjack oak, elm, hackberry, black walnut, sycamore, cedar, juniper, pecan, loblolly pine, Chinese tallow, yaupon, huisache, and mesquite also are present. Animals native to the area include white-tailed deer, beaver, bobcat, coyote, fox, skunk, raccoon, squirrel, and a diverse array of other small mammals and birds (TPWD, 2007). In addition, feral hog (non-native, invasive species) populations in the lower end of the watershed are known to be significant.

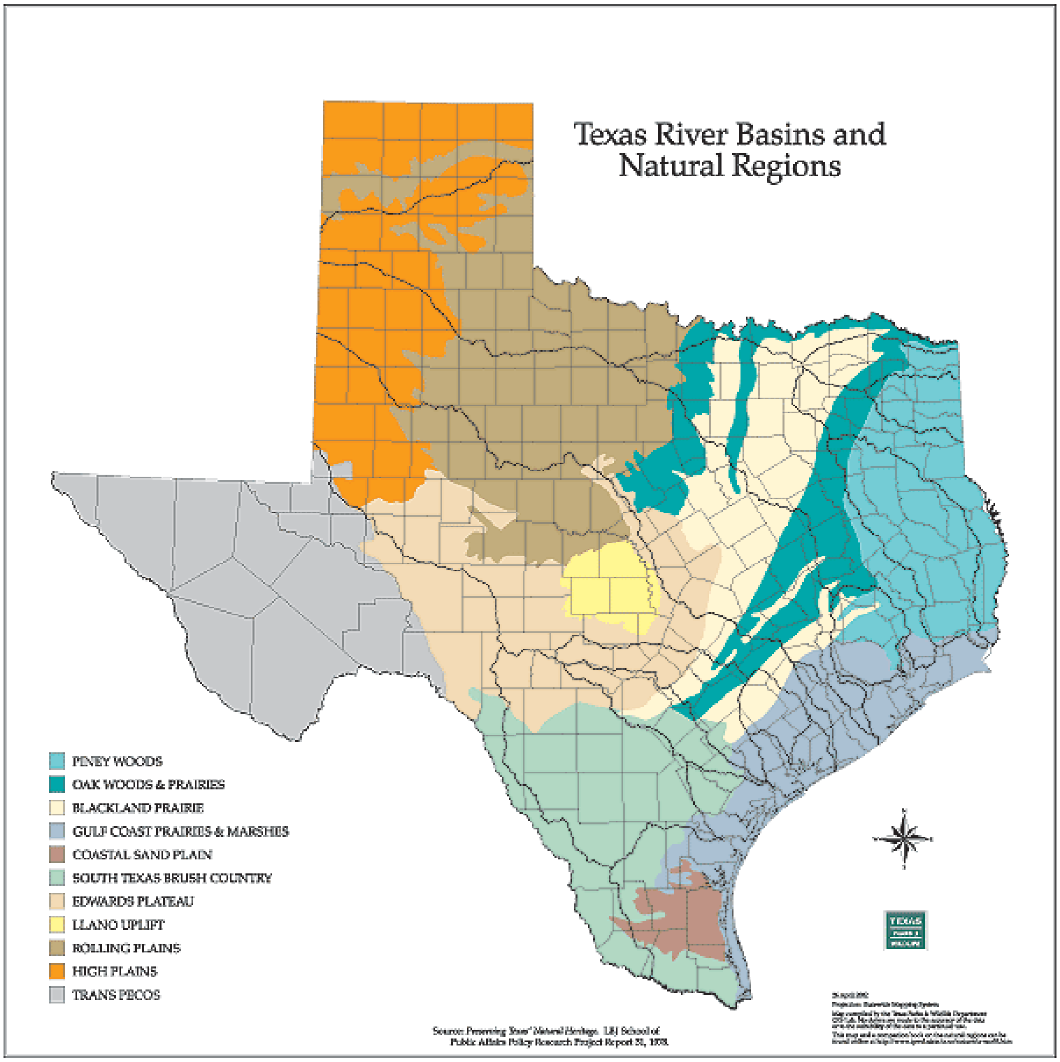

Figure 2.3. Ecoregions of Texas. Image courtesy of TPWD.

Soils

Soils in the upper end of the Mill Creek watershed generally are very deep clayey soils on rolling hills (Blackland Prairies zone), transitioning to loamy fine sandy soils on gently sloping prairies (Post Oak Savannah zone) towards the lower end of the watershed. However, soils across both ecological regions are highly varied (Figure 2.4). In the upper portions of the Mill Creek Watershed in Washington County, soils are primarily the Frelsburg series which consists of very deep, moderately well drained, clayey soils on uplands.

Bosque and Brenham series clay loam soils are common in the central watershed where Frelsburg series and similar clayey soils continue to be the dominant soil type. Both the Bosque and Brenham series are very deep, well drained, moderately permeable soils.

Near the confluence of the East and West forks of Mill Creek the watershed transitions into the Post Oak Savannah ecoregion where the soils are dominated by the Catilla and Trinity series. The Catilla series consists of very deep, moderately well drained, moderately slowly permeable loamy fine sands on uplands. The Trinity series consists of very deep, moderately well drained, slowly permeable clay soils found in riparian areas and in floodplains throughout the watershed (USDA, 1984).

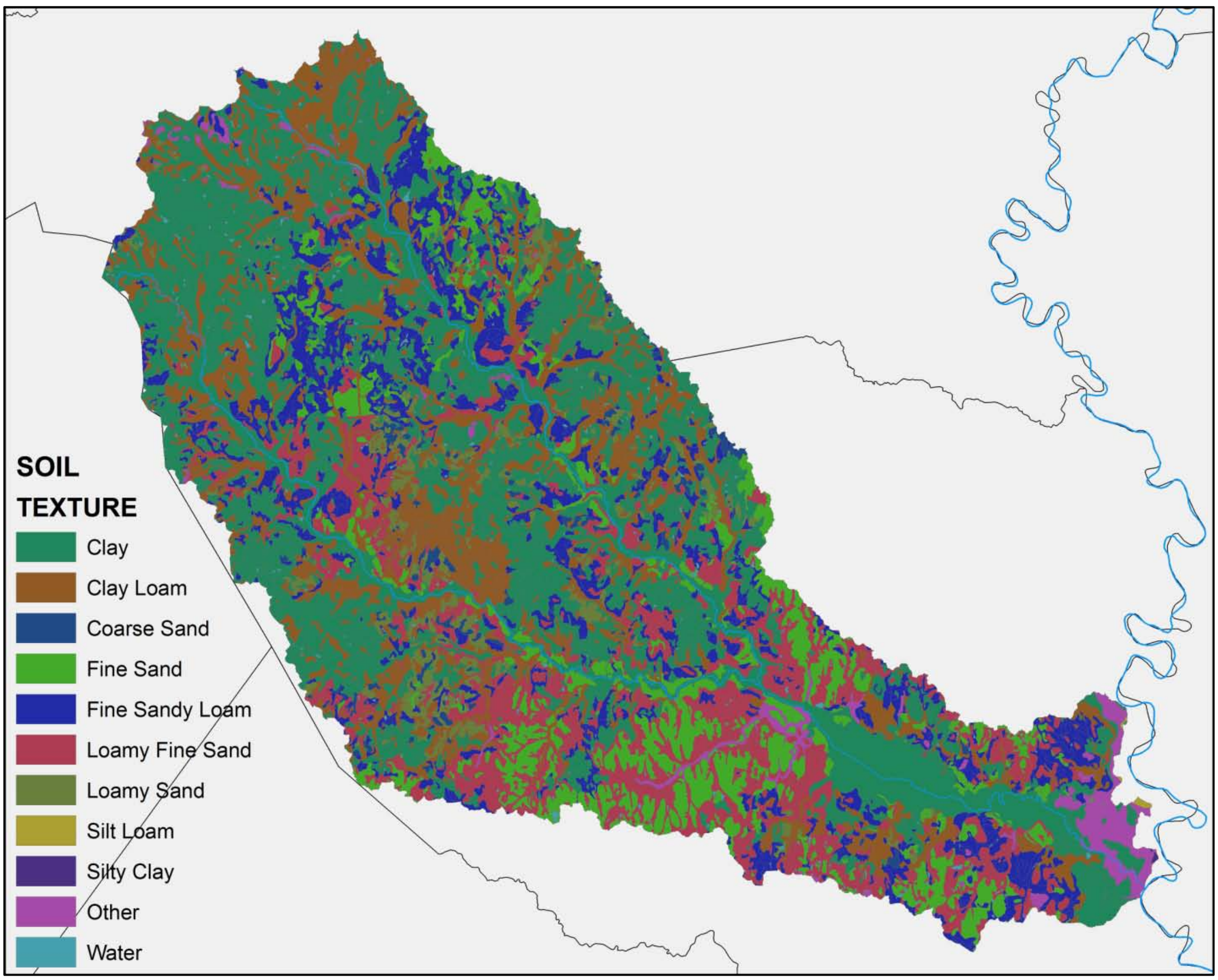

Figure 2.4. Soil textures of the Mill Creek watershed.

Water Resources

Flows in the upper reaches of the East and West Forks of Mill Creek are ephemeral, primarily occurring only during and immediately after rainfall events. Lower in the watershed before the East and West forks join, spring flows into the creek provide a more consistent supply of water.

Springs in the area originate chiefly from the northern part of Austin County. It has been noted that the East Fork of Mill Creek runs noticeable colder, likely due to baseflow from groundwater (PBS&J, 2007). However, the main stem of Mill Creek flows consistently throughout the year, receiving flows from the East and West Forks as well as from the Bellville wastewater treatment facility.

The principle water bearing strata under the study area are the Fleming Formation and Willis Sands, which are part of the Gulf Coast Aquifer. In addition, the Alluvium of the Brazos River and Mill Creek Alluvium are found adjacent to the water bodies for which they are named.

The chemical quality of the water from wells in the area is, in general, good for municipal, most irrigation, and most industrial purposes. Groundwater in the area typically ranges from moderately hard to very hard. Although most groundwater in the area meets all drinking water standards, fluoride has frequently been observed in less than optimum levels (TWDB, 1967). Water in the alluvial formations however is susceptible to contamination due to its shallow depth and should be carefully tested before using as a drinking supply.

Groundwater is the primary source of drinking supply for the vast majority of residents in the watershed. The Cities of Bellville, Burton, and Industry utilize water from the Gulf Coast aquifer for drinking supply and operate several wells located within or near city limits. The city of Brenham however uses water from Lake Sommerville, located approximately 14 miles northwest of Brenham in the adjacent Yegua Creek watershed, as its primary source of drinking water.

Fish and Benthic Macroinvertebrate Communities

Mill Creek has been identified by TPWD as an Ecologically Significant Stream Segment (ESSS) based upon its high water quality, exceptional aquatic life, and high aesthetic value. Furthermore, it has been noted that the creek supports a high degree of biodiversity and rare gammagrass-switchgrass species that grow in its bottomlands (Bayer et al., 1991; Moring et al., 1998). Fish species include channel catfish, common carp, spotted gar, and multiple species of sunfish and minnows. Common benthic macroinvertebrates collected during sampling include mayflies, midges, worms, and aquatic beetles.

CLIMATE

The Mill Creek watershed lies in a humid subtropical climate zone characterized by hot summers. Tropical maritime air masses predominate throughout spring, summer, and fall. Modified polar air masses exert substantial influence during winter and provide a continental type climate, characterized by considerable variations in temperature. Actual weather varies widely from year to year. For example, average annual rainfall is between 41-45 inches. However, the wettest year on record for the watershed was 1992, when the weather stations at Brenham and Bellville recorded total annual rainfall amounts of 57.3 and 64.4 inches, respectively. In contrast, total annual rainfall for those same stations in 2011 was 22.8 and 17.1 inches, respectively. The area experienced an "exceptional drought" (Category D4) that year and remained in drought conditions until 2014. Peak rainfall is usually the result of thundershowers in late spring. A secondary peak occurs in the fall. The prevailing winds are south and southeasterly most of the year. Winters are mild, with January mean temperatures of approximately 51°F. Summers are generally hot, with July mean temperatures of 83°F.

HISTORY

The earliest known settlers in the Mill Creek watershed were Indians belonging to the Tonkawa tribes, although archeological evidence suggests that human habitation in the area began as early as 7400 B.C. The Tonkawa were mostly nomadic, but evidence of their presence in the Mill Creek area is the number of arrowheads, tools and other artifacts found along the creek.

Early Spanish explorers referred to Mill Creek as Palmetto Creek, in reference to a species of dwarf palm trees which once grew along the lower reaches of the creek. By the late 1700's, Texas was under Spanish rule. Although several Spanish trade and military routes traversed the area, settlements were not established until the arrival of American colonists in the 1800's.

In January 1821, Moses Austin received permission from the Spanish to settle 300 families in Texas, but died only a few months afterward. Two years later his son, Stephen F. Austin, established the first American colony in the area under the Spanish grant his father had obtained. Austin settled in present day Austin County and chose a site just downstream of Mill Creek's confluence with the Brazos River to serve as the new colony's unofficial headquarters. In 1824, the Spanish governor for the province, Felipe de la Garza, proposed the site be named San Felipe de Austin, in honor of Stephen F. Austin and the governor's own patron saint.

Some of the first colonists to arrive with Austin were the Cummins family, who constructed a water-powered saw and grist mill near the mouth of Mill Creek in the mid-1820's, giving the creek its current name. The mill was the first industrial fixture in the area and is thought to be the first of its kind in Texas. Cotton gins also were established in the area around this time and San Felipe quickly became a hub for commerce, second only in Texas to San Antonio. By the 1830's, steamboats appeared in the lower Brazos, providing an alternative means for transporting goods to the Gulf coast.

Agricultural development increased exponentially over the next several decades with cotton and corn being the most prevalent crops. Oats, potatoes, and tobacco were also grown in significant quantities. During this time, livestock production increased with equal vigor. Herds of cattle, sheep, goats, hogs, and horses flourished on the lush coastal prairies.

Following the Civil War, economic development in the area was slow. However, a boost in immigration in the late 1800's marked an upturn for the region. By this time, the railroad had reached the area and continued to stimulate growth. Agriculture continued to dominate the local economy and would do so until present day.

Soon after the turn of the century petroleum was discovered in the county, although significant production did not begin until the 1920's with the opening of the Raccoon Bend oilfield northeast of Bellville. Production peaked in the early 1980's and declined steadily over the next few decades. Hydrocarbon production is still a significant component of the local economy and both oil and natural gas wells can be found in operation throughout the watershed.

Agriculture remains the chief economic driver in the area today. Beef cattle, hay, cotton, corn, and grain sorghum are the chief agricultural products. In recent years, an increase of absentee landowners has ushered in, to some degree, the conversion of agricultural lands to homesteads and those used primarily for wildlife management.

LAND USES

Land use in the Mill Creek watershed is predominately rural and agricultural. Rangelands and managed pastures account for over two-thirds of the watershed, most of which are utilized for livestock and hay production (Figure 2.5). Beef cattle are the dominant livestock species throughout the watershed but small numbers of sheep, goats, and horses also are raised. Native grasses 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 also are grown for hay and grazing including bahiagrass, johnson grass, bushy bluestem and KR bluestem.

Cotton, corn, rice and sorghum production take place in the lower watershed near the Brazos River. The sandy loam soils and availability of groundwater for supplemental irrigation in this part of the watershed make it ideal for row crop production. However, cultivated crops account for only one percent of the watershed, and are concentrated near the mouth of Mill Creek.

There is also a significant percentage of forest in the Mill Creek watershed. Deciduous, evergreen and mixed forest covers 10 percent of the watershed. These forested areas are found primarily in the western and southern ends of the watershed. Furthermore, near riparian forests account for an additional 5 percent of the watershed area. Most of the near riparian forest land is found in the large floodplain along the main stem of Mill Creek and the lower reaches of the East and West forks, where Trinity series clay soils are dominant.

Urban land represents a small portion of the watershed and is concentrated in the cities of Bellville, Industry, and Burton. A very small portion of Brenham's ETJ also lies within the watershed. Population growth and urban expansion in Bellville, Industry, and Burton have been slow since the 1990s, a trend which is estimated to continue (BOC, 2010). Brenham however has grown more steadily over the past several decades. Although the watershed encompasses very little of Brenham currently, future urban expansion may lead to a more significant concentration of urban land in the northeastern fringes of the watershed.

Figure 2.5. Row crop production in the Mill Creek Watershed.

PERMITTED DISCHARGES

Permitted discharges in the watershed include the City of Bellville, City of Industry, and City of Burton wastewater treatment facilities (WWTF). The City of Bellville WWTF (NPDES Permit ID TX0020621) is located approximately 1 mile southwest of downtown Bellville. It is permitted to discharge 0.95 million gallons/day (MGD) into the Boggy Creek tributary of Mill Creek. Boggy Creek joins the main stem of Mill Creek approximately 0.5 miles west of SH-36. The WWTF serving the City of Industry (NPDES Permit ID TX0116271) discharges into an unnamed tributary of West Mill Creek and is permitted to discharge 70,000 gallons per day. The discharge point is located approximately 0.75 miles upstream of the confluence of the unnamed tributary with West Mill Creek, which occurs 1.2 miles north by northwest of the city of Industry. The City of Burton WWTF (NPDES Permit ID TX0083089) is located approximately 0.1 miles north of US Hwy 290 on Indian Creek and is permitted to discharge 44,000 gallons per day (Figure 2.6). Indian Creek joins East Mill Creek approximately 7 miles to the southeast.

In addition, the Kieke egg farm (NPDES Permit ID TXG921138) located approximately 4.8 miles south by southwest of Burton, TX is the only permitted concentrated animal feeding operation (CAFO) in the watershed. It is permitted to apply poultry litter at a controlled rate to land management units located in the upper reaches of the Mill Creek watershed, and is estimated to generate a total of 10,209 tons of solid waste and 5.33 acre feet of wastewater annually.

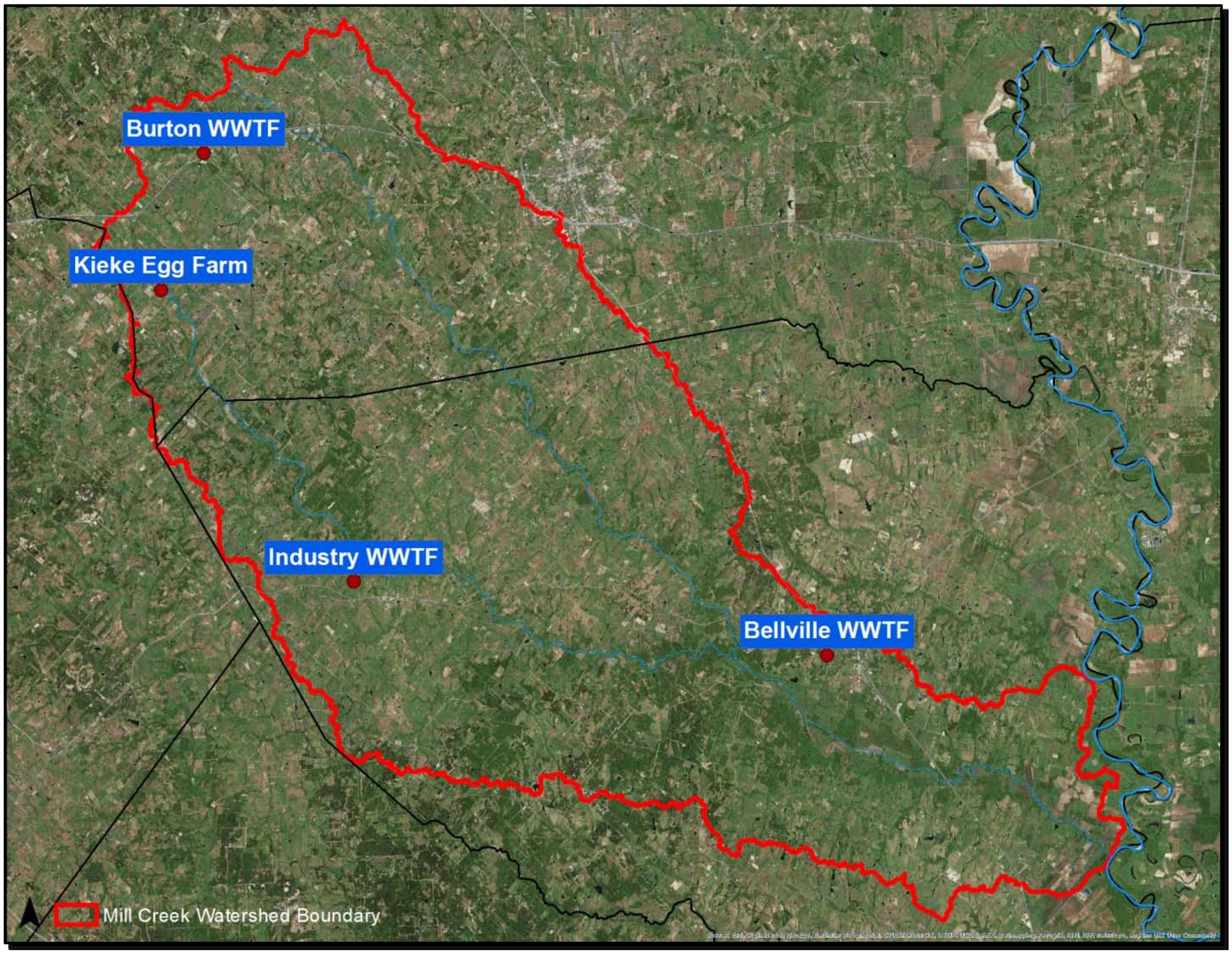

Figure 2.6. Permitted discharge locations in the Mill Creek Watershed.

WATER QUALITY

Mill Creek is identified as segment 1202K and has been monitored at the SH-36 crossing by the Texas Commission on Environmental Quality (TCEQ) under various programs since 1974 (Figure 2.7 and 2.8). Mill Creek was listed on the 2006 Texas Integrated Report of Surface Water Quality, formerly known as the Texas Water Quality Inventory and 303d list, with a concern for an impaired fish community in its downstream portion, and was listed again on the 2008 report. Additionally, Mill Creek appeared on the 2010 and 2012 Texas Integrated Reports as impaired for elevated levels of bacteria. All waters across the state are considered to have a contact recreation designated use. Stream segments are assessed by comparing the geometric mean of the *E. coli* bacteria data available from water quality monitoring over the previous seven years to a standard. In Texas, the *E. coli* bacteria standard 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. The 2010, 2012, and 2014 Texas Integrated Report 303(d) Lists identified Mill Creek as impaired for contact recreation because the geometric mean for *E. coli* bacteria exceeded the contact recreation stream standard established by the TCEQ.


Figure 2.7. Mill Creek at SH-36. Photo courtesy of H-GAC.

Since the data utilized for the Texas 303(d) List were from a limited geographic range, Texas A&M AgriLife Extension (Extension) engaged the Houston-Galveston Area Council (H-GAC) to initiate an extensive monitoring program on Mill Creek and its tributaries 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 the implementation strategy.

Data collection was conducted at 13 sites throughout the watershed (Figure 2.9 and Table 2.1). Following input from local stakeholders, the uppermost 4 sites were selected exclusively for biased stormwater monitoring, due to ephemeral stream conditions the upper reaches of the watershed. Routine sampling was conducted at the nine lowermost ambient sites on a monthly basis from September 2014 to June 2015. Biased monitoring was conducted at the four stormwater sites plus the nine ambient stations 3 times during this 10 month sampling period, when rainfall events generated measurable flow in the upper reaches of the watershed.

Figure 2.8. Water quality sampling on East Mill Creek. Photo courtesy of H-GAC.

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 13 sites. However, data collected during the 10 month sampling period seems to indicate that elevated bacteria levels are positively correlated to increased flow. Although the data show exceedances at several of the sites, the data does not conclusively identify any individual subwatershed as a leading contributor to bacteria pollution in Mill Creek.

Mill Creek Water Quality Monitoring Stations

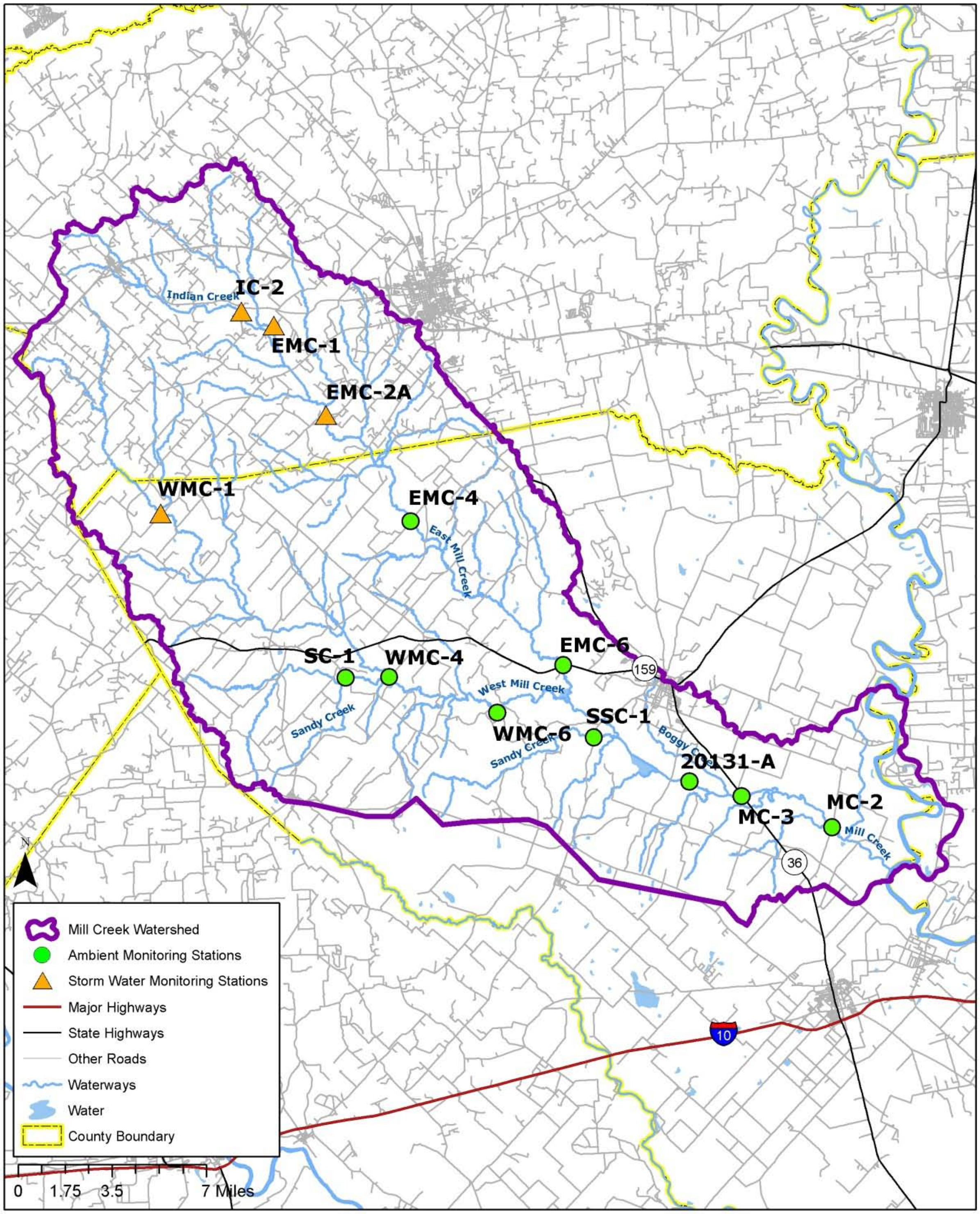

Figure 2.9. Mill Creek water quality sampling stations in the watershed.

Table 2.1. Sampling stations in the Mill Creek watershed.

Site	Site_ID	Latitude Decimal	Long Decimal	Description
13*	IC-2	30.154482	-96.514878	Indian Creek at CR 2/Beckermann Rd, 325 yards south of CR 25 and 5.6 miles west of Brenham.
12*	EMC-1	30.146670	-96.494839	East Mill Creek at Indian Creek Ln/CR 28A, 0.5 miles SW of intersection of CR 28 and Indian Creek Ln.
11*	EMC-2a	30.097393	-96.464984	East Mill Creek at FM332, 4.7 miles SW of intersection of FM332 and CR 389.
10*	WMC-1	30.046920	-96.567711	West Mill Creek at Wolfe Rd approximately 1.9 miles NW of intersection of FM 389 and Wolfe Rd.
9	EMC-4	30.039449	-96.413137	East Mill Creek at Bleiblerville Rd. About 1 mile northwest of TCEQ station ID 20133.
8	EMC-6	29.959612	-96.320151	East Mill Creek at FM 159/Old Nelsonville Rd, 1 miles west of intersection of Koy Rd and FM 159.
7	SC-1	29.955764	-96.455117	Sandy Creek at New Breman Rd approximately 3 miles southeast of the city of Industry.
6	WMC-4a	29.9557127	-96.4276336	West Mill Creek at Tiemann Rd, east of Industry.
5	WMC-6	29.935733	-96.360328	West Mill Creek adjacent to small lake between Artists Cir Dr and John Schoelikopf Rd approximately 4.8 miles west of the Mill Creek Rd and Kuykendall Rd
4	SSC-1	29.921135	-96.301334	Sandy Creek at Mill Creek Rd southwest of Bellville
3	20131-A	29.89679	-96.25499	Mill Creek at FM 2429 3.2 miles upstream of SH 36 and 3.26 miles downstream of Mill Creek Road approximately 3.6 miles south of Bellville in Austin County
2	MC-3	29.886502	-96.210053	Little Boggy Creek at Hwy 36 south of Bellville
1	MC-2	29.869637	-96.155232	Mill Creek at FM331, immediately downstream of bridge.

* Denotes storm water monitoring sites.

WATERSHED SELECTION

Mill Creek was selected for WPP development due to two primary factors: 1) it had been listed as impaired due to bacteria levels in exceedance of the recreational contact use standard, and 2) a Recreational Use Attainability Analysis (RUAA) had been conducted on Mill Creek in 2007. In addition, given the extent of agricultural production and lack of urban development, a watershed protection plan approach was deemed the best strategy for addressing water quality issues in Mill Creek.

The RUAA conducted on Mill Creek was the first such analysis conducted in the state, and became the template for future recreational use attainability analyses. It concluded that Mill Creek currently supports, and has historically supported, contact recreation. This affirmed that the contact recreation use designation and concurrent water quality standards assigned to Mill Creek were appropriate.

Mill Creek first appeared on the state's 303(d) list as impaired for elevated levels of bacteria in 2010, and also appeared on the 2012 and 2014 lists. Water quality data collected and used to assess Mill Creek for the 2010, 2012, and 2014 Texas Integrated Water Reports showed the geometric mean of bacteria concentrations was 200, 177, and 192 cfu/100mL, respectively.

After completion of two very successful watershed planning projects in the Guadalupe River Basin, the Plum Creek WPP and Geronimo & Alligator Creeks WPP, Extension obtained a State NPS Program grant from the TSSWCB to support the planning process in the Mill Creek watershed.

3. The Mill Creek Partnership

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 intensive 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 November 2014, with one in the upper (Brenham) and one in the lower (Bellville) portion of the watershed. Seventy-nine stakeholders attended these public meetings where information was provided regarding conditions in Mill Creek and the proposed development of a WPP. Participants were invited to become members of the Mill Creek Watershed Partnership and asked to help notify other potential stakeholders that should be part of the process.

PARTNERSHIP MEETINGS

Monthly public meetings facilitated by 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.

PARTNERSHIP STRUCTURE

Steering Committee Membership

A Steering Committee composed of stakeholders from the Mill Creek 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, Austin & Washington County Soil and Water Conservation Districts, and local and regional governments. Self-nomination or requests by various stakeholder groups or individuals were welcomed.

Figure 3.1. Stakeholders participated in numerous Partnership and Steering Committee meetings. Image courtesy of Beth Luedeker.

The Steering Committee was designed to reflect the diversity of interests within the Mill Creek 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 21 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 Mill Creek WPP required a 6-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.

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:

- 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

LAND USE CLASSIFICATION

In order for the Mill Creek 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 (Figure 4.1).

The first step in development of the land use dataset was to select appropriately dated imagery for the Mill Creek watershed. This was accomplished using aerial imagery with 1-meter resolution available through the National Agriculture Imagery Program (NAIP) and Landsat-8 databases. NAIP imagery taken during 2012 and Landsat-8 imagery taken during 2013 and 2014 were used for this analysis. 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 the managed pasture land use in the Mill Creek Watershed.

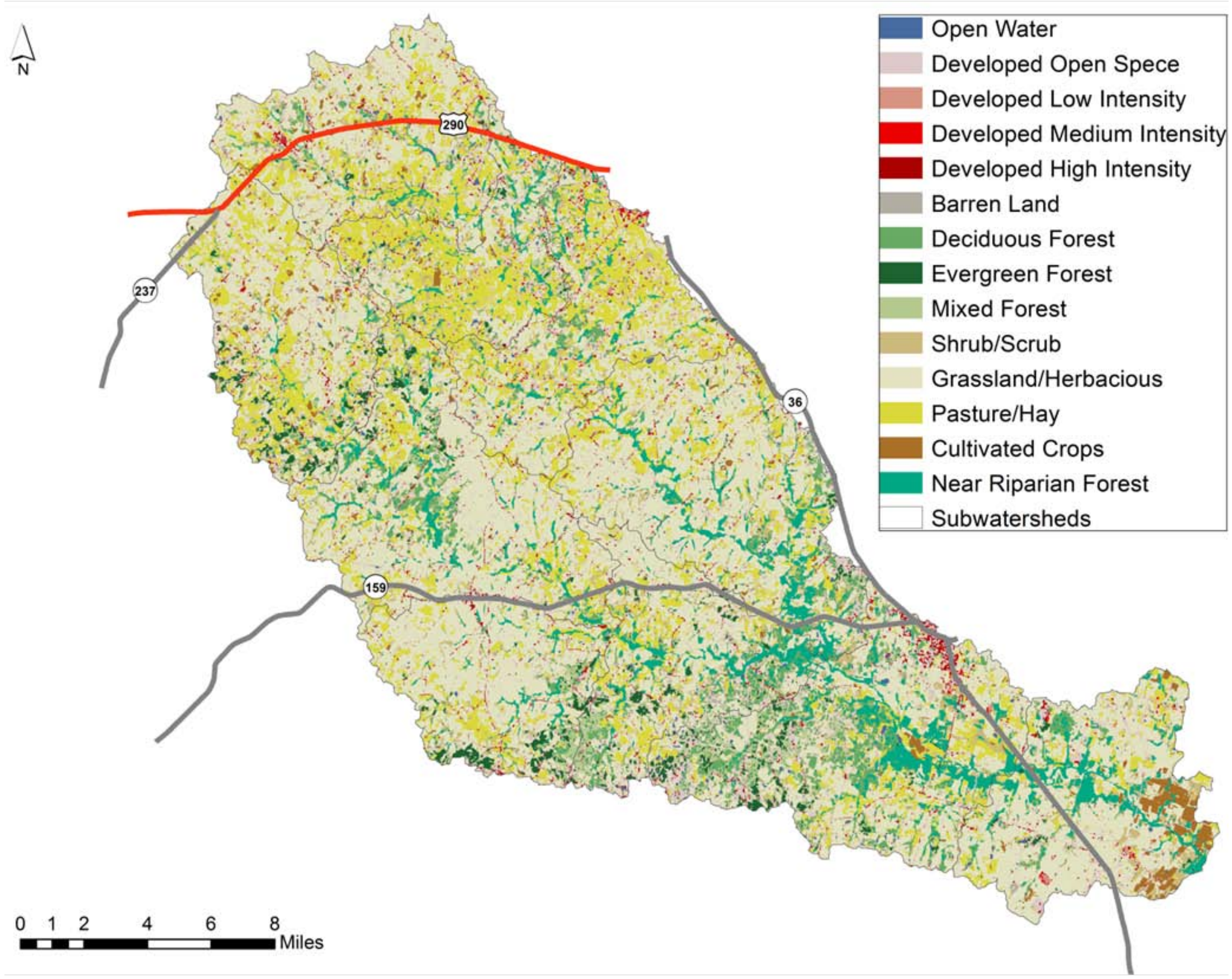

Figure 4.2. Mill Creek Watershed land use map.

Land parcels were assigned to classes based on attributes including vegetation, hydrology, and level of urban development. In order to simplify the map, similar land uses were aggregated where appropriate. For example, the urban land use category includes five subcategory land uses: open, low, medium, and high intensity urban development and barren land (Table 4.1). The watershed is made up of approximately 55% rangeland, 21% managed pasture, 15% forest, 8% urban, and 1% cropland areas.

Table 4.1. Summary of land uses in the Mill Creek Watershed.

Land Use	Percentage of Total	Acres
Rangeland	54.7	144,004
Managed pasture	20.6	54,323
Forest	15.2	40,021
Urban	7.9	20,677
Cultivated crops	1.1	3,025
Open water	0.5	1,400
Total	100.0	263,450

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 10 subwatersheds (HUC12) based upon elevation and hydrological characteristics (Figure 4.3).

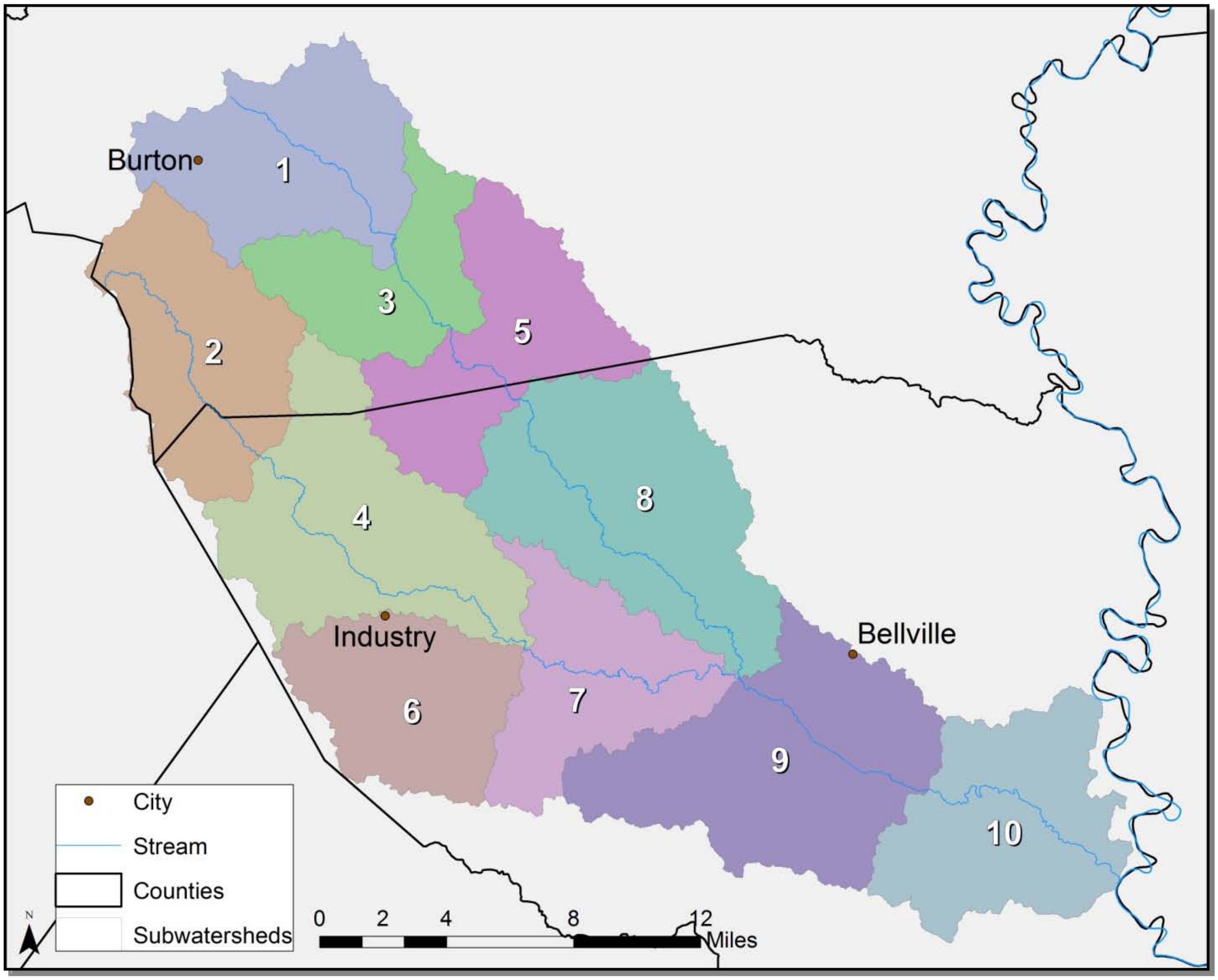

Figure 4.3. Subwatersheds of the Mill Creek Watershed.

DETERMINING SOURCES OF POLLUTION

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).

Developing a Load Duration Curve

There is a single stream flow gage (USGS 08111700) in the Mill Creek Watershed. The gage is located at SH-36 and Mill Creek. As previously noted, this is the same location at which TCEQ collects water quality data. Although stream flow data collection on Mill Creek began in 1940, it was not until 1963 that stream flow data were recorded on a daily basis. However, since water quality data were not collected at SH-36 and Mill Creek prior to 1982 only stream flow data from that point forward were used to develop the flow duration curve.

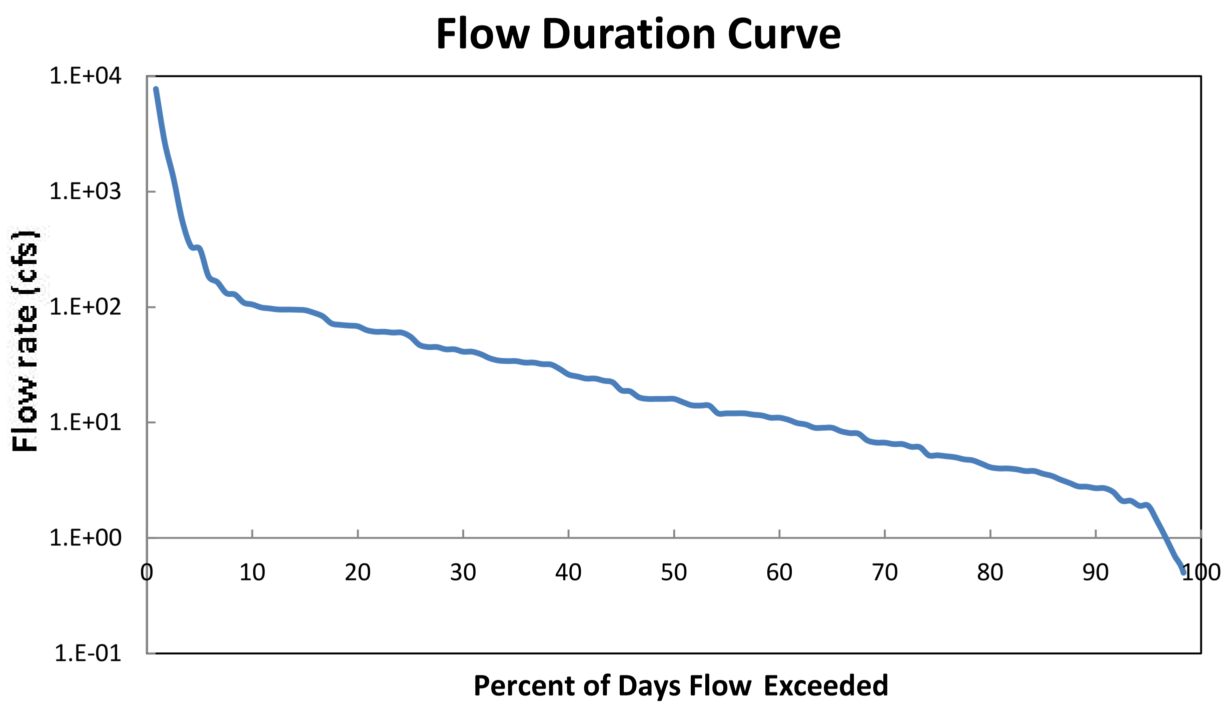

Figure 4.4. Mill Creek flow duration curve. Historical stream flow data from SH-36 were used to determine how frequently stream conditions exceed different flows (cfs = cubic feet per second).

Next, data from the flow duration curve are multiplied by the water quality goal for the pollutant to produce the LDC (Fig. 4.5). This curve shows the maximum pollutant load (amount per unit time; e.g., for bacteria, cfu/day) a stream can assimilate across the range of flow conditions (low flow to high flow) without exceeding the water quality goal. 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 Mill Creek, there are three flow regimes: high flows (0-10), mid-range (11-85), and low flows (86-100).

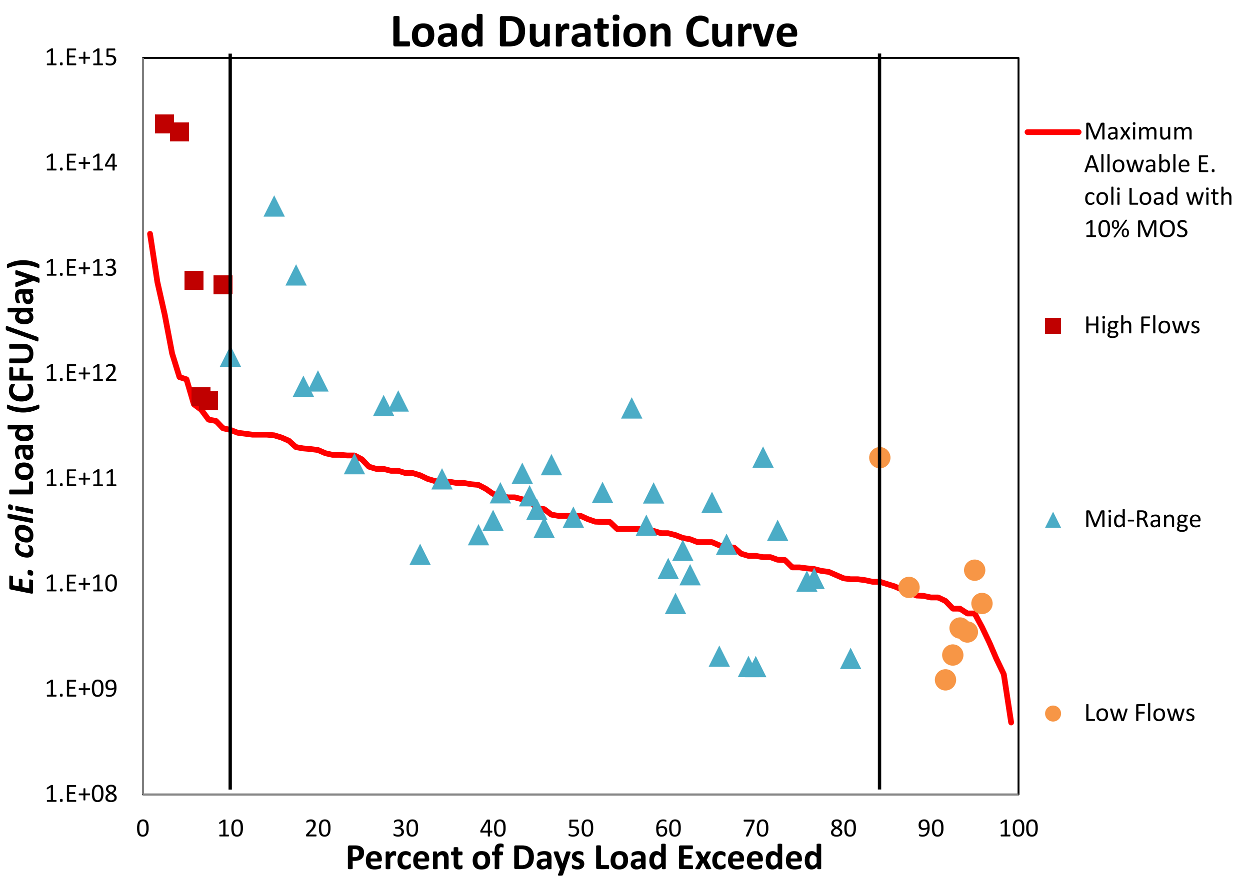

Figure 4.5. Mill Creek load duration curve. Multiplying stream flow by pollutant concentration produces an estimate of pollutant load.

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 4.5, 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 4.6, 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 83, 43, and 0% are needed at high, mid-range and low flows, respectively.

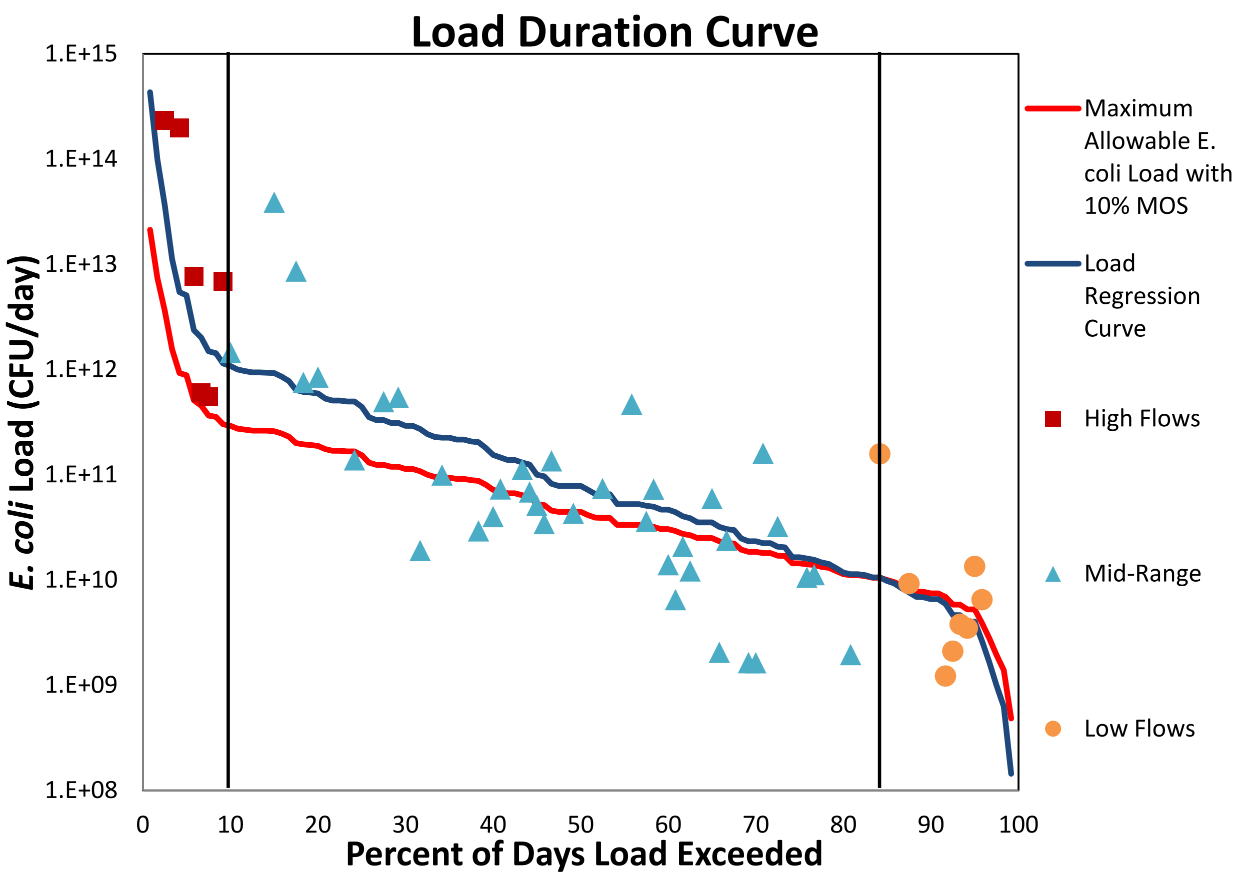

Figure 4.6. Mill Creek load duration curve with monitored samples and calculated "line of best fit."

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 bacteria in this plan. Thus, 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 the LDC analysis for Mill Creek.

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).

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 Mill Creek 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 potential pollutant source identified by the Steering Committee was distributed across the 10 subwatersheds based on the best available data and information regarding its presence in a given subwatershed. Pollutant 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 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.

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 Mill Creek 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 Mill Creek 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 Mill Creek watershed is very dynamic in nature, and conditions can change dramatically between years and even 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.

Estimate of Pollutant Loads and Required Reductions

The SH-36 site has served as the only routine monitoring station in the Mill Creek Watershed and is utilized by TCEQ for the 305(b) assessment of Mill Creek. Sampling began at the SH-36 location in 1974, thus the site has over 40 years of data. The site also represents approximately 91% of the total area of the watershed, with a drainage area of 376 square miles. For these reasons, the SH-36 sampling station was used to determine load reduction goals for the watershed.

BACTERIA LOADS

LDC analysis for the SH-36 monitoring site indicates the bacteria water quality standard is not supported above mid-range flows, while it is supported under dry conditions and low flows (Fig 4.7). Based on the regression analysis, reductions in *E. coli* loads of 83 and 43% will be required at high and mid-range flows, respectively, to achieve the water quality criterion for primary contact recreation.

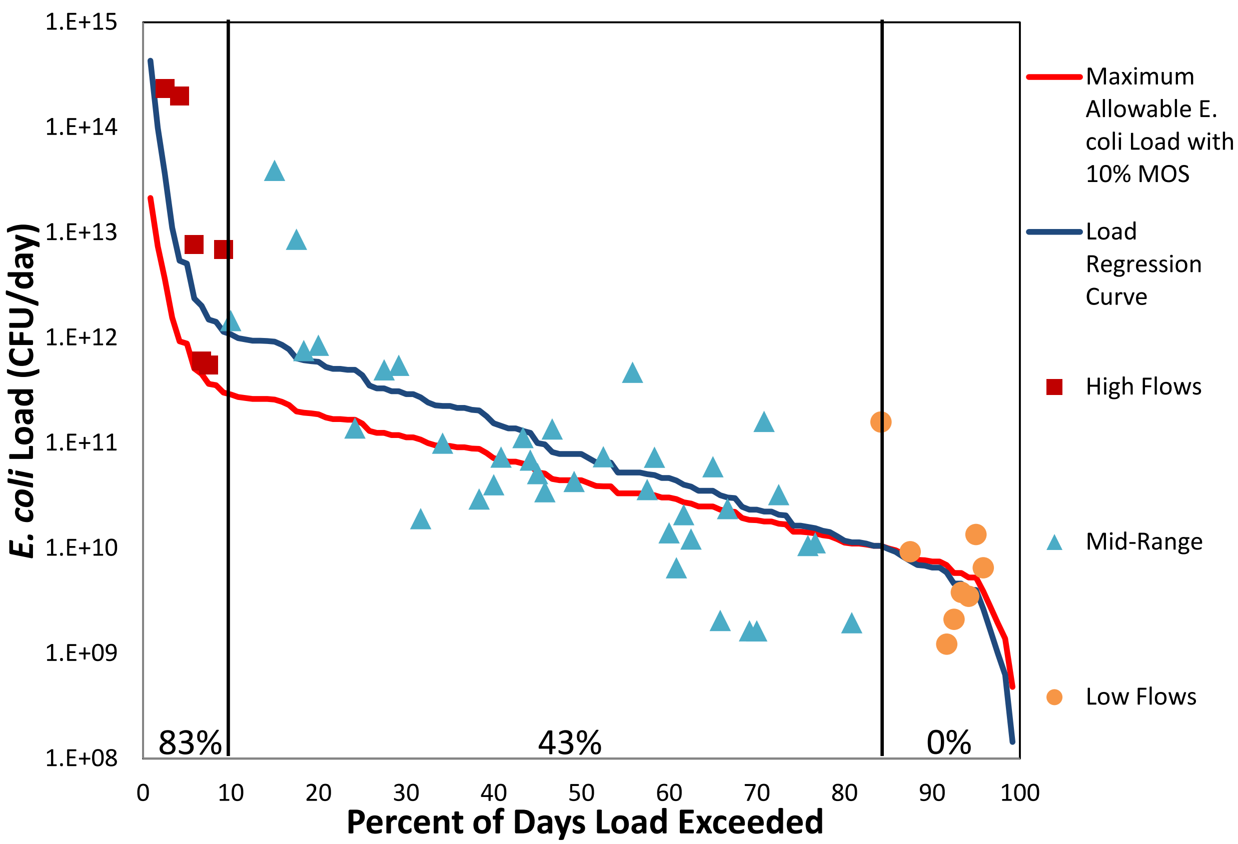

Figure 4.7. Mill Creek load duration curve for E. coli at the SH-36 monitoring station.

RECOMMENDED PERCENT LOAD REDUCTION

Based on the LDC analysis, the Steering Committee made the decision to use a load reduction goal of 43% as identified 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 Mill Creek into the future by considering increasing pressure on the watershed anticipated due to long-term population growth. This load reduction was applied across the entire watershed for all sources and all flow regimes.

ANNUAL LOADS AND LOAD REDUCTIONS

Based on the LDC analysis, mean annual loads, load reductions, and target loads for *E. coli* bacteria (cfu/year) were calculated utilizing data from the SH-36 monitoring station (Table 4.2). Calculations for bacteria were based on loading occurring between the 11th and 85th percentile flows, which is the range of flows for which the effective implementation of management measures is considered to be feasible.

Table 4.2. Mean annual loads, load reductions and target loads for the SH-36 monitoring station.

Pollutant	Mean Annual Load	Mean Annual Load Reduction	Mean Annual Target Load	Reduction Goal (%)
E. coli (cfu/year)	2.33×10^{11}	1.00×10^{11}	1.33×10^{11}	43

HOW VARIABLE FLOWS INFLUENCE TRENDS IN BACTERIA LOADS

Table 4.3 is a summary of the estimated annual average *E. coli* bacteria load categorized by flow condition for the SH-36 monitoring station. Nonsupport of the primary contact recreation use 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 and moist conditions 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 and moist conditions flow ranges (11-85th percentile flows). Bacteria loading at low flows are not of sufficient magnitude to cause nonattainment of the water quality standard for primary contact recreation (Figure 4.8).

Table 4.3. Estimated average annual *E. coli* loads under different flow conditions in Mill Creek based on water quality data at the SH-36 monitoring station.

Monitoring Station	Loading by Streamflow Condition (cfu/yr)		
	High Flows	Mid-range Flows	Low Flows
Mill Creek at SH-36	5.42×10^{13}	2.33×10^{11}	4.79×10^{9}

Figure 4.8. Contact recreation in Mill Creek. Photo courtesy of Frank Monk.

5. Pollutant Source Assessment

As noted previously, point sources in the watershed include WWTFs for the cities of Bellville, Burton, and Industry, and the Kieke Egg farm. However, these sources are managed by permits issued by TCEQ through the National Pollutant Discharge Elimination System (NPDES). As a result, implementation efforts will focus on nonpoint sources of bacteria pollution.

The Partnership and Steering Committee dedicated significant time to identification of potential nonpoint sources of bacteria in the watershed utilizing their knowledge of the area and information gathered from stakeholders. In addition, the Steering Committee recognized nutrients, specifically nitrogen and phosphorus, as a potential future water quality concern and included them in the source evaluation. Based on this assessment, the likely potential sources of pollutants were identified and are presented in Table 5.1.

Table 5.1. Potential pollutant sources in the Mill Creek Watershed identified by the Steering Committee.

Source Categories	Potential Sources	Bacteria	Nutrients
Urban	Urban Runoff	X	X
	Dogs	X	X
Wastewater	Septic Systems	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

The TCEQ does not currently have numerical nutrient standards in effect for surface waters in Texas. Regardless, water quality data collected at the SH-36 Clean Rivers Program monitoring site do not show cause for a nutrient concern in Mill Creek. Because elevated bacteria levels are the only current cause of impairment or concern in Mill Creek, the analysis focused on assessing potential sources of E. coli. However, pollutant sources that contribute bacteria inevitably also contribute nutrients.

SELECT ANALYSIS RESULTS

Total estimated daily *E. coli* loads summed for all potential sources in each of the 10 subwatersheds in Mill Creek 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 4, 8, and 9 represent area with the highest potential to contribute bacteria to Mill Creek. This information will be useful in the targeting and planning of implementation efforts to achieve water quality goals.

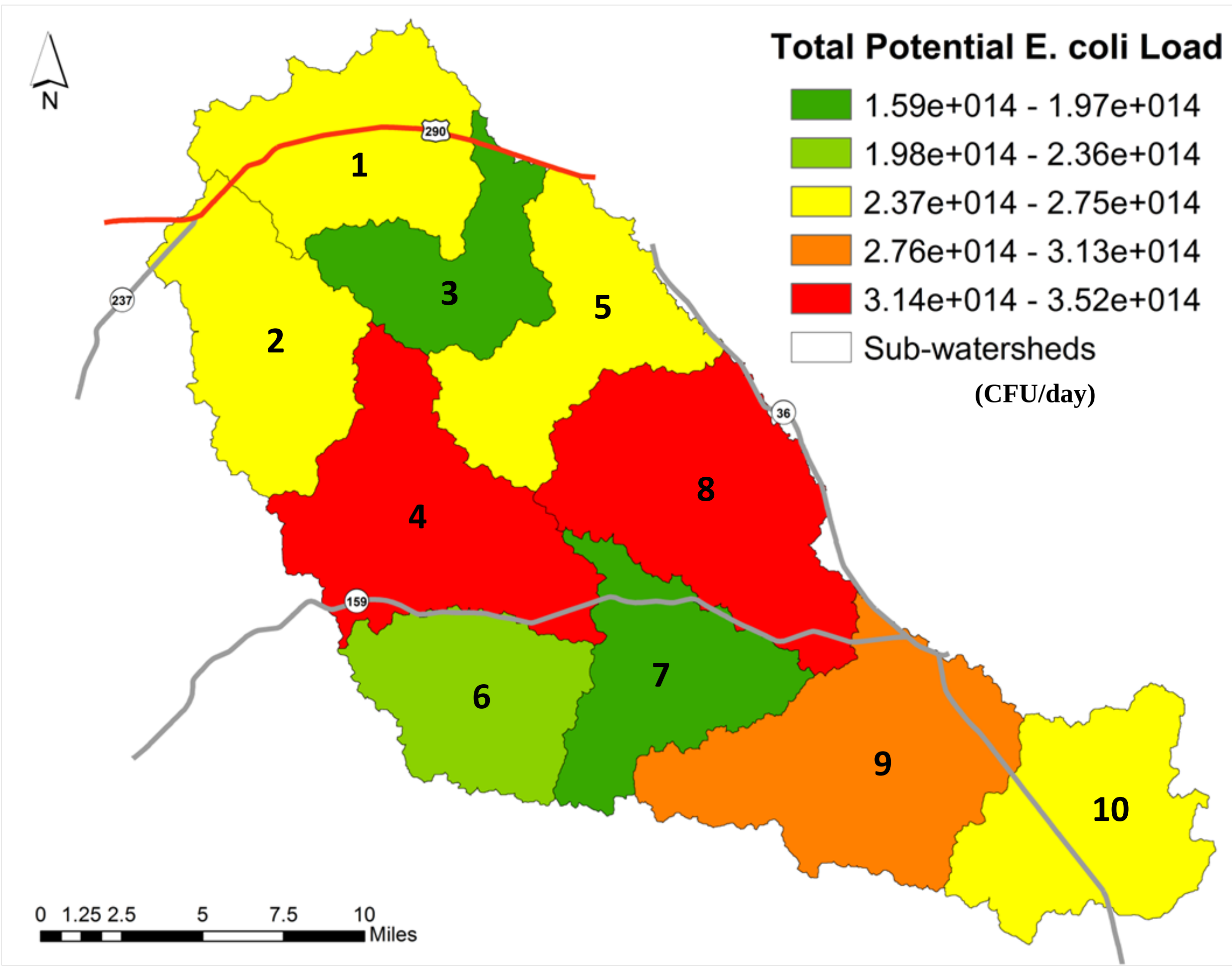

Figure 5.1. Average total daily potential *E. coli* contribution from all sources by subwatershed.

The following sections present and discuss results of the SELECT analysis for each of the potential nonpoint sources in the Mill Creek Watershed identified by the Steering Committee, which include urban runoff, domestic dogs, wastewater, livestock, and wildlife. Additional background information specific for each identified potential source in the watershed is located in Appendix F.

WASTEWATER TREATMENT FACILITIES

As previously mentioned, there are three municipal WWTFs in the watershed that serve the cities of Bellville, Industry, and Burton. These facilities discharge 0.95, 0.07, and 0.04 MGD, respectively. NPDES permit data show these facilities are required to treat discharge for bacteria below 126 cfu/100mL. A review of permit compliance history for these facilities showed no discharge violations over the past seven years. Using the permitted discharge concentration of *E. coli* (126 cfu/100mL) and the discharge rate for each facility, the combined daily bacteria load from WWTFs in the watershed is no more than 5.07E9. Thus, it was determined that due to the relatively low discharge rate of treated effluent from these facilities, potential loading from WWTFs in the watershed was much lower than any other source. Consequently, SELECT analysis was not performed for WWTFs.

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 (1997) to evaluate urban runoff. As would be expected, the subwatershed including the city of Bellville has 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). 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 Mill Creek watershed. Bellville, located at the intersection of SH-36 and SH-159 in the lower portion of the watershed, is by far the most urbanized area in the watershed. However, with a population of only approximately 4,170 and a moderate urban density its potential pollutant load is relatively low compared to other sources in the Mill Creek Watershed. The cities of Industry and Burton are both much smaller in terms of land area and population, and therefore do not represent a significant stormwater concern. Consequently, SELECT analysis was not performed for urban runoff. However, the analysis conducted for domestic dogs correlates directly to the distribution of urban areas in the watershed and was used to plan implementation efforts aimed at stormwater management. While the potential pollutant load is small compared to other sources in the watershed, the potential for pollutant contributions from these urban areas to increase with population does exist and is therefore discussed in more detail in the Management Measures chapter (Section 8).

Figure 5.2. The town square in Bellville is an example of the high intensity urban land use category in the Mill Creek Watershed.

DOMESTIC DOGS

Management of pet waste can have a substantial impact on the quality of stormwater runoff from areas with high pet populations. This category typically focuses on waste generated by dogs and cats. Fecal coliform production rates of dogs and cats are roughly twice that of humans (EPA, 2001). Dogs typically defecate outdoors and do not bury their waste, which if not collected from lawns, sidewalks, parking lots, and park areas can readily contribute to both bacteria and nutrient pollution. Management efforts for dog waste will focus on the entire watershed including both public and private property.

In contrast, domestic cats typically deposit fecal material indoors in litter boxes, which is disposed of in residential garbage collection or through the wastewater treatment system. Feral cats, as well as domestic cats allowed outside, usually bury their feces in shallow holes which substantially reduces potential loading in stormwater runoff. Also, little published information exists on feral cat populations. For these reasons, typically and in the case of this plan, cat waste is not considered when calculating potential loads and identifying management measures.

According to the American Veterinary Medical Association, the average American household owns 0.63 dogs (AVMA, 2008) and the average Texas household owns 0.8 dogs (AVMA, 2002). Local veterinarians suggested that the watershed dog population was higher than either of those averages, and recommended a dog ownership of 1.25 dogs/household. This conservative estimate was accepted by the Partnership and Steering Committee and used for planning purposes.

According to 2010 US Census population data for the watershed and using an average of 1.25 dogs/household, there are an estimated 9,111 dogs in the watershed. These animals are concentrated in urban areas, particularly Bellville, which have more households and a greater human population. Urban growth in Bellville has been slow, with the population increasing only 20% from 1990 to 2010, well below the national average. During that same period, the city of Industry experienced 48% population growth, rising from 206 to 304 persons, and the city of Burton slightly declined in population. Additionally, the upper portions of East Mill Creek contain a relatively high number of homes concentrated around SH-290 and FM-109 due primarily to the area's close proximity to Brenham. In contrast to other cities in the watershed, Brenham has experienced steady growth over the past two decades, increasing 30% from 1990 to 2010. Currently only a very small portion of the city of Brenham lies within the watershed; however, future urban growth could lead to an increase in population in the upper reaches of East Mill Creek. These population growth estimates are based upon 2010 Census data and city personnel estimates. Based on this information, the SELECT analysis indicates the greatest potential for pollutant loads from pets occurs in the relatively urbanized subwatersheds (Figure 5.3).

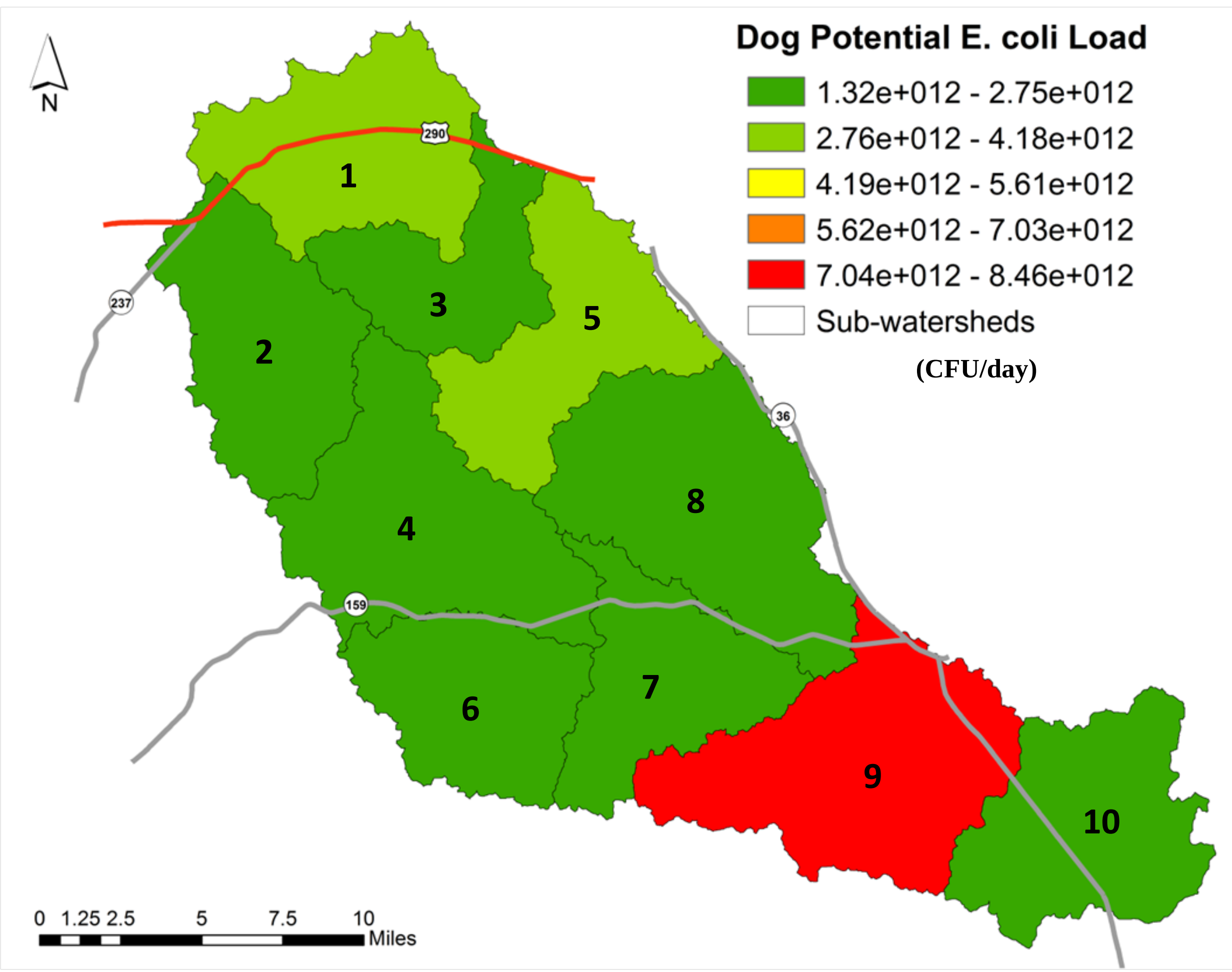

Figure 5.3. Average daily potential *E. coli* load from domestic dogs by subwatershed.

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 WWTFs 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 Mill Creek 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 education of septic system owners, and a lack of proper maintenance (Figure 5.4). 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 drainfield), and 3) has had no significant increase in its use.

Figure 5.4. 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 Ryan Gerlich.

The Partnership and 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 rate into the SELECT analysis, the greatest potential loading from septic systems occurs in the East Mill Creek subwatersheds (Figure 5.5; subwatersheds 1, 3, 5, and 8). As previously noted, the upper portions of East Mill Creek contain a relatively high number of homes, concentrated around SH-290 and FM-109. As Brenham continues to grow, these areas likely will become more heavily populated resulting in an even greater number of septic systems. Additionally, the upper portion of the main stem of Mill Creek has a relatively high potential for loading from septic systems. Like the East Mill Creek subwatersheds, a greater concentration of homes can be found in this area due to its proximity to the city of Bellville (Figure 5.5; subwatershed 9). Furthermore, the presence of a large floodplain composed primarily of Trinity Clay soils exacerbates the potential for bacteria loading from septic systems in this part of the watershed.

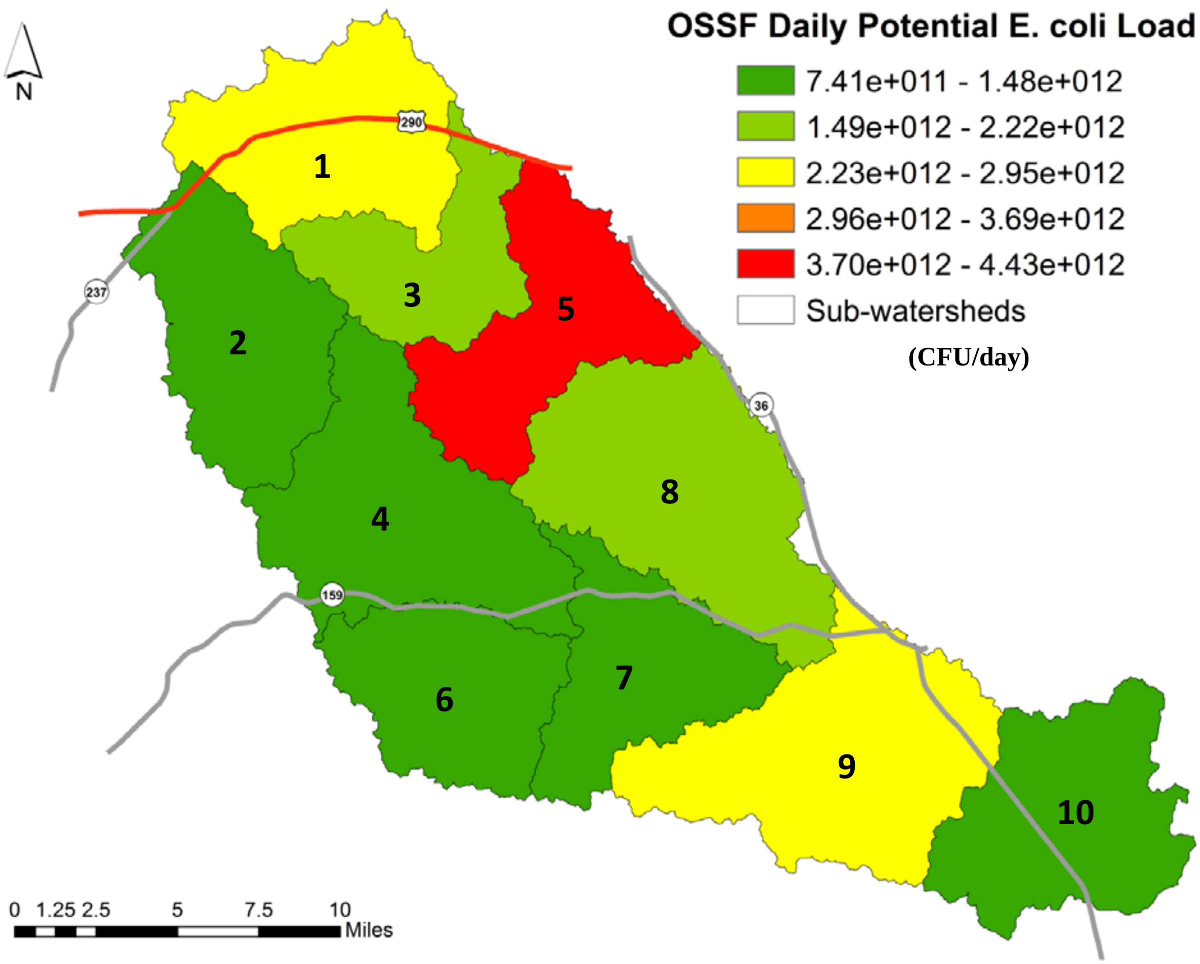

Figure 5.5. Average daily potential *E. coli* load from failing septic systems by subwatershed.

AGRICULTURE

The Partnership and Steering Committee identified several potential agricultural sources of bacteria, and helped develop animal population estimates used in SELECT analysis.

Livestock

Cattle, horses, goats, sheep, domestic poultry, and domestic hogs 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 5.6). Like all animals, waste products from cattle are sources of both bacteria and nitrogen. 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).

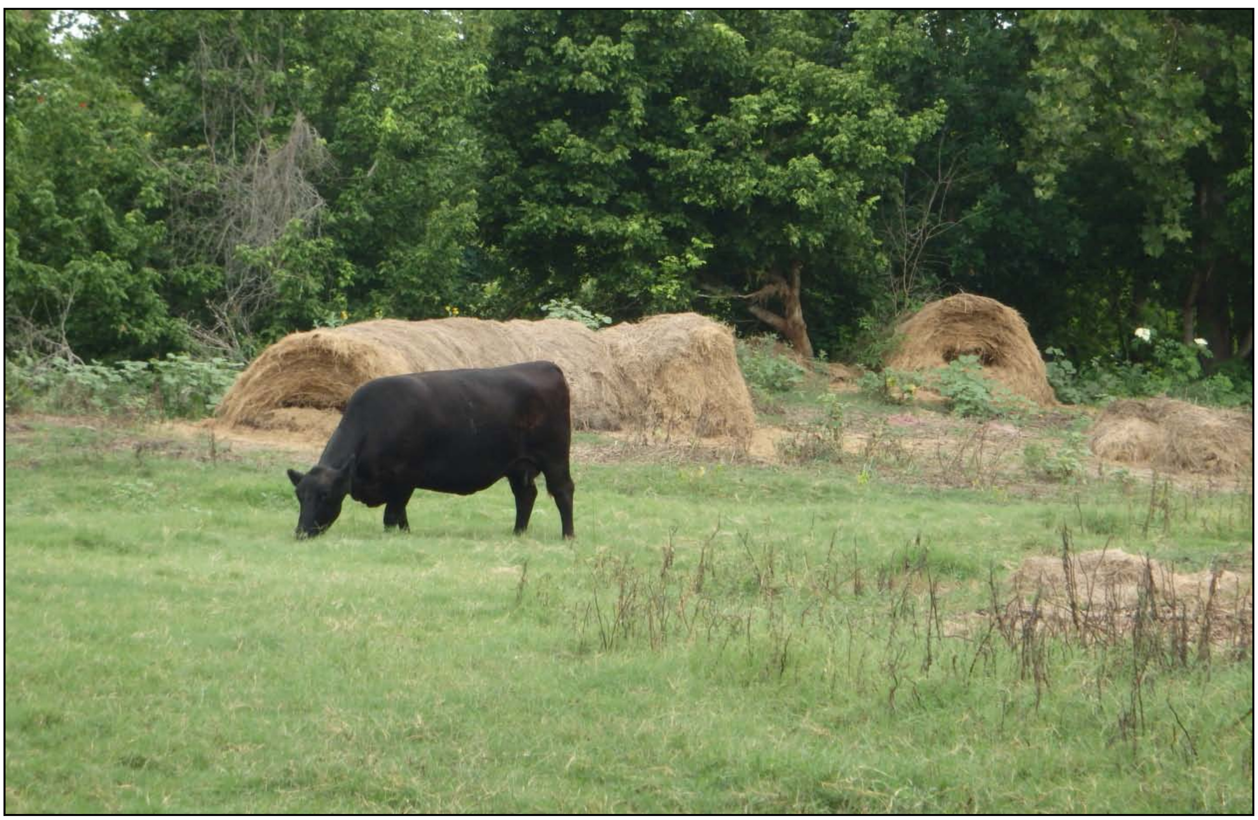

Figure 5.6. Cattle in the Mill Creek Watershed. Photo courtesy of H-GAC.

The Partnership and 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 38,299 head. The cattle population was distributed across land covers used for grazing in each county, which include rangeland and managed pasture. 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. Based on this information, an average stocking density of 1 head of cattle per 5.2 acres was applied to the selected land uses to determine cattle population and distribution for SELECT analysis. The analysis indicated that the largest potential source of loading from cattle is found in the central portion of the watershed (Figure 5.8; subwatersheds 4 and 8). Additionally, the uppermost subwatersheds of the East and West Mill Creek as well as those along the main stem of Mill Creek have significant potential for loading from cattle.

Figure 5.7. A cow in Mill Creek.

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 Partnership and Steering Committee indicated that the 2012 USDA NASS data accurately reflected an average cattle population for the watershed. There are no concentrated animal feeding operations for cattle in the watershed, such as feedlots or dairies.

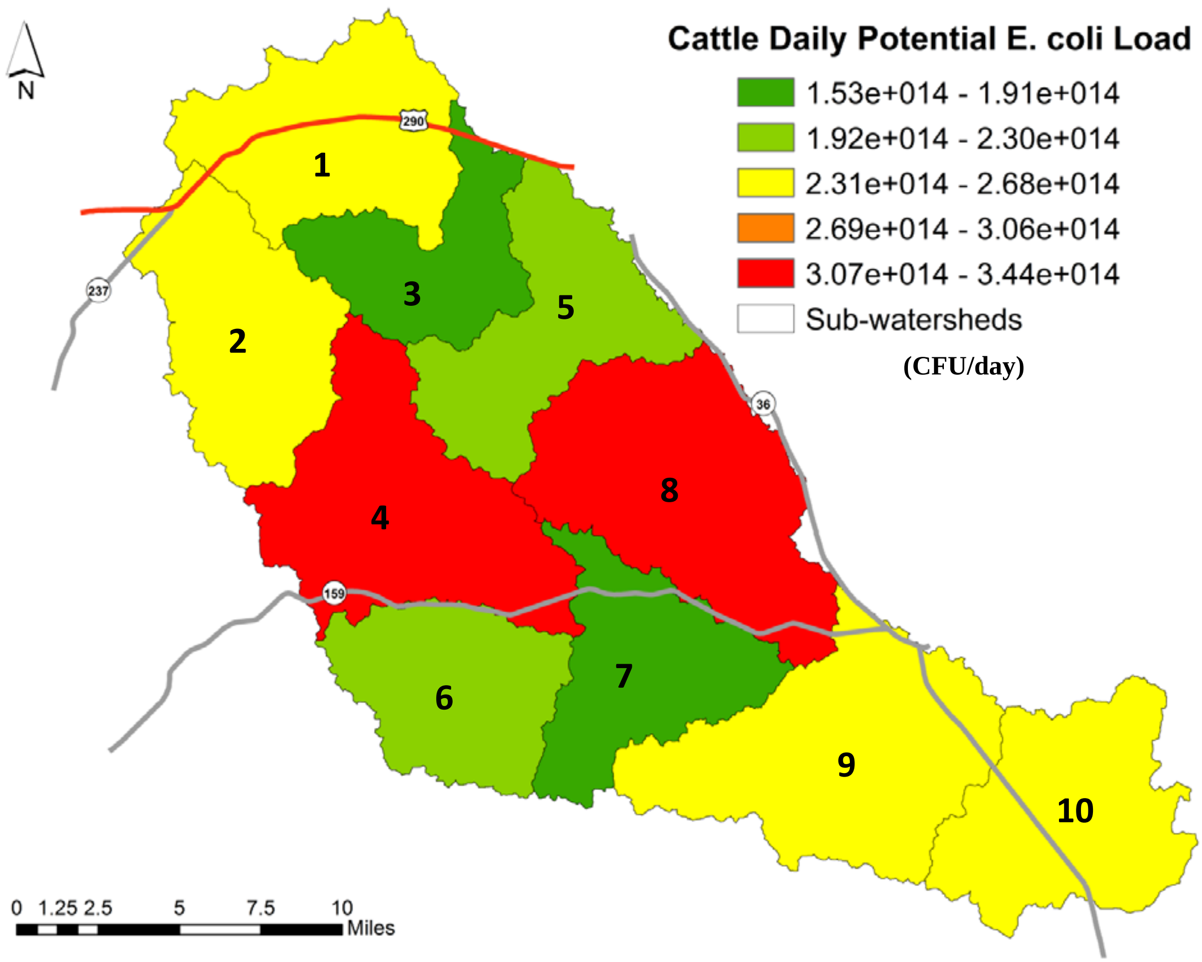

Figure 5.8. Average daily potential *E. coli* load from cattle by subwatershed.

Horses

The Partnership and Steering Committee based the horse population 2012 USDA NASS county data which estimate there are approximately 2,251 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 across only the managed pasture acres in the watershed for SELECT analysis. The analysis indicates the greatest potential loadings are located in the central and lower portions of East Mill Creek and in the central portion of West Mill Creek (Figure 5.9; subwatersheds 4, 5, and 8).

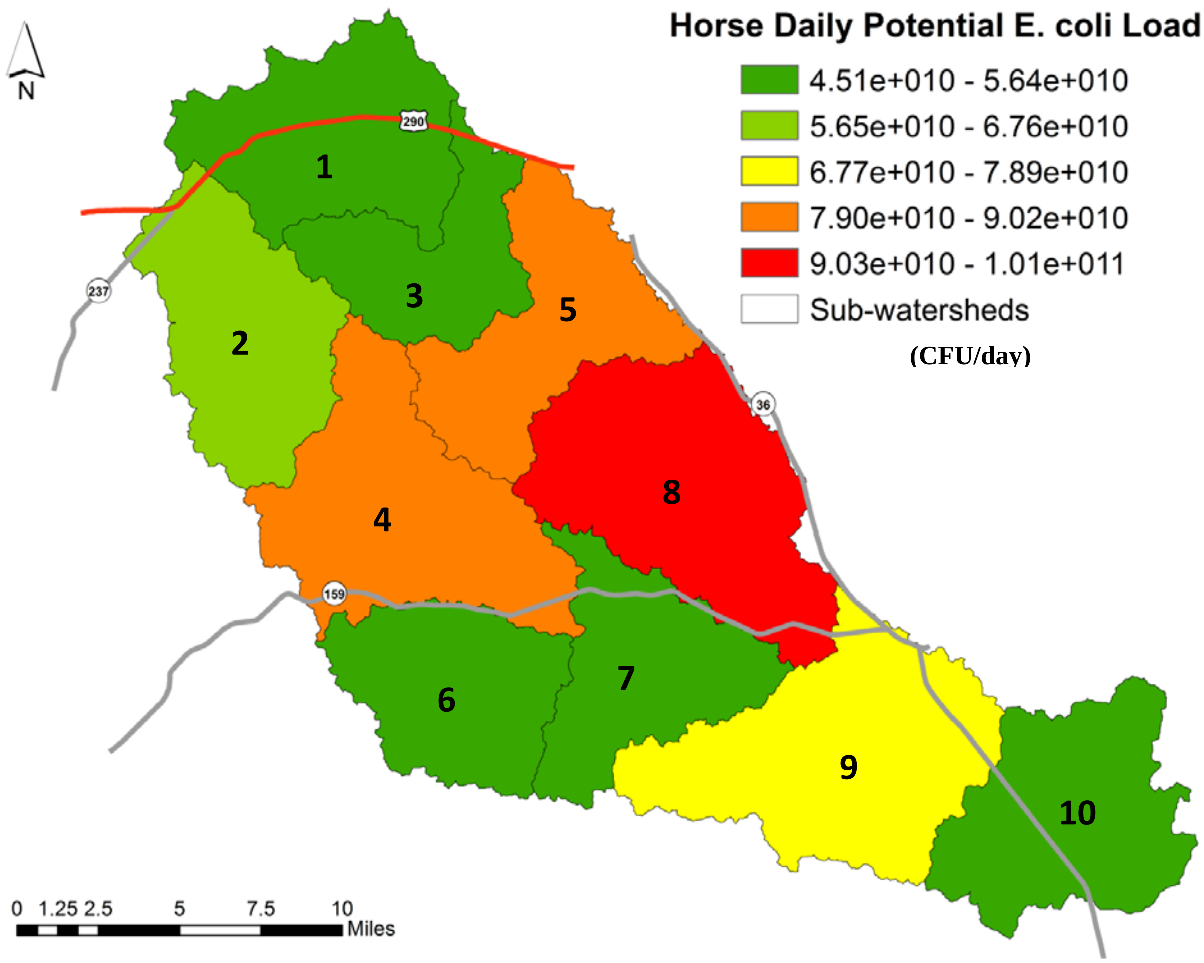

Figure 5.9. Average daily potential *E. coli* load from horses by subwatershed.

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 762 head of goats distributed on rangeland and managed pasture. SELECT analysis indicates the highest potential loading from goats is in the subwatersheds immediately north of SH-159 on the East and West forks of Mill Creek and in the far upper reaches of East Mill Creek. (Figure 5.10; subwatersheds 1, 4, and 8).

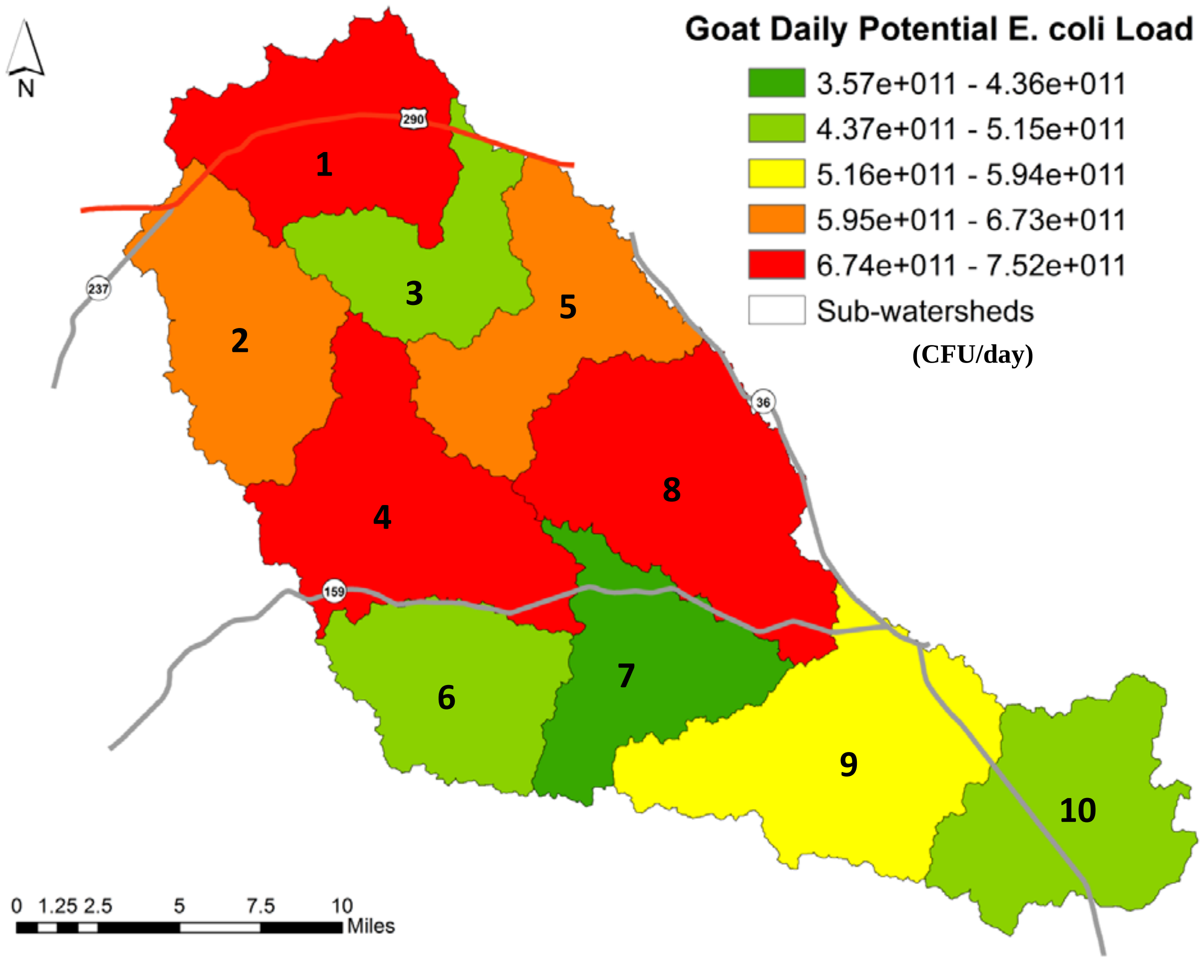

Figure 5.10. Average daily potential *E. coli* load from goats by subwatershed.

Sheep

USDA NASS data from 2012 estimates there are 322 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 uppermost subwatersheds of the East and West forks of Mill Creek, followed by the central portions of the watershed (Figure 5.11; subwatersheds 1, 2, 4, 5, and 8).

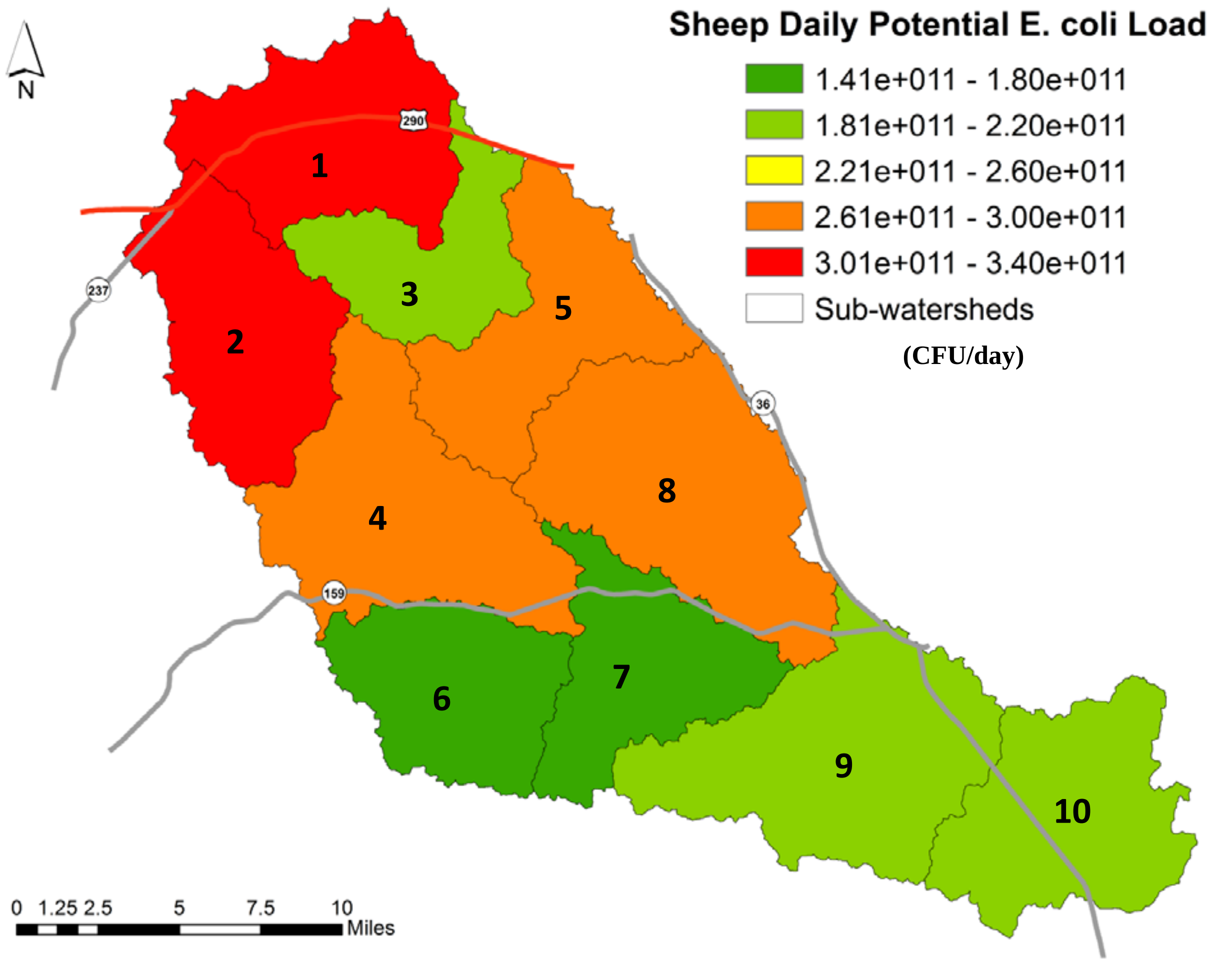

Figure 5.11. Average daily potential *E. coli* load from sheep by subwatershed.

Domestic Hogs

According to the 2012 USDA NASS county data there are approximately 44 domestic hogs in the in the Washington County portion of the watershed and 248 domestic hogs in the Austin County portion of the watershed. Stakeholders indicated that domestic hogs are most often kept in enclosures near the home or barn. For this reason, these hog populations were distributed to rural households in the Austin and Washington County portions of the watershed for SELECT analysis, respectively. Consequently, the analysis indicates the greatest potential loadings are located in the upper subwatersheds (Figure 5.12; subwatersheds 1, 2, 3 and 5).

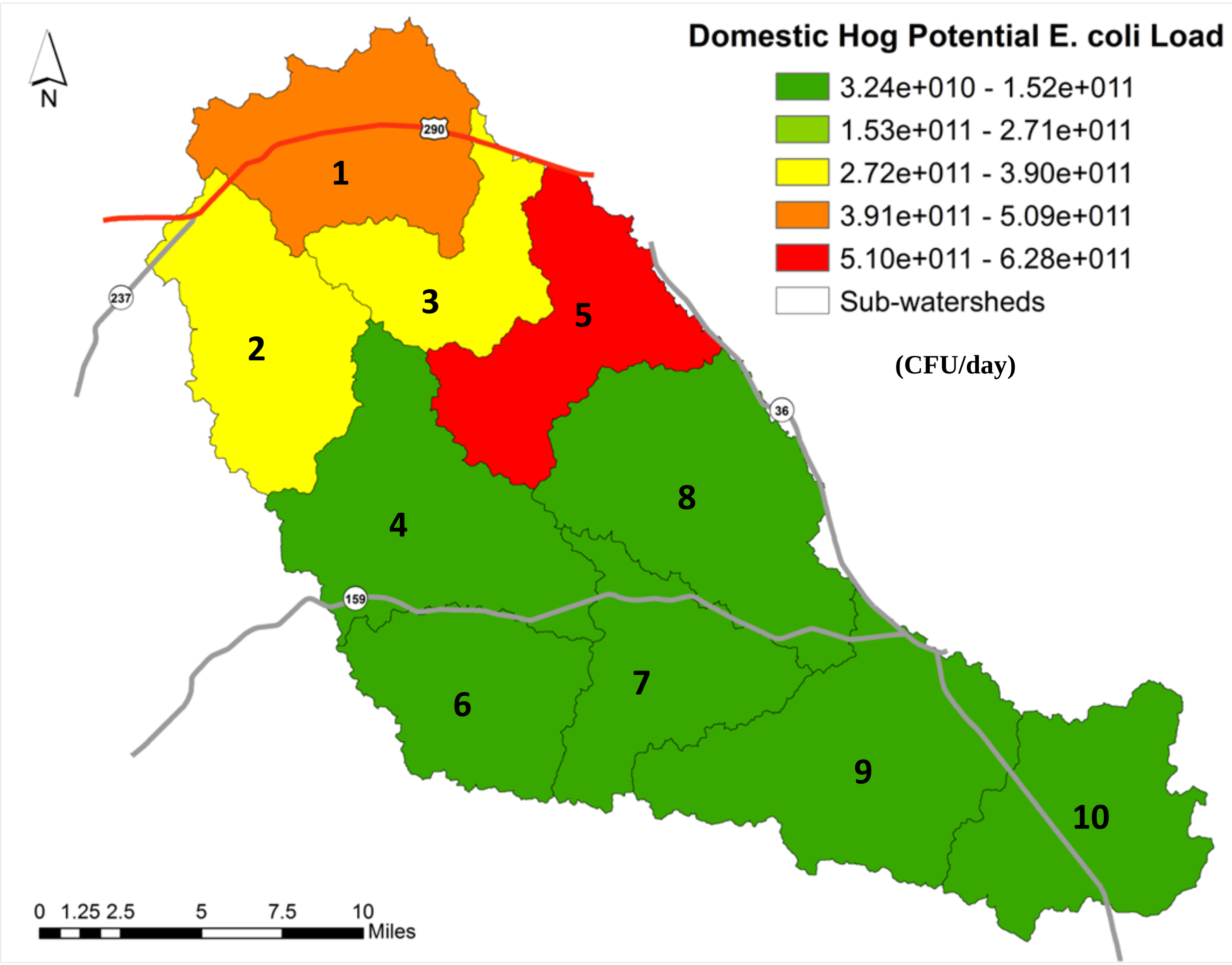

Figure 5.12. Average daily potential *E. coli* load from domestic hogs by subwatershed.

Domestic Poultry

The 2012 USDA NASS county data shows there are approximately 11,138 domestic poultry in the Austin County portion of the watershed and 46 domestic poultry in the Washington County portion of 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 Austin and Washington County portions of the watershed for SELECT analysis, respectively. As a result, the analysis indicates the greatest potential loadings are located in the lower and central portions of the watershed (Figure 5.13; subwatersheds 4, 8, 9 and 10).

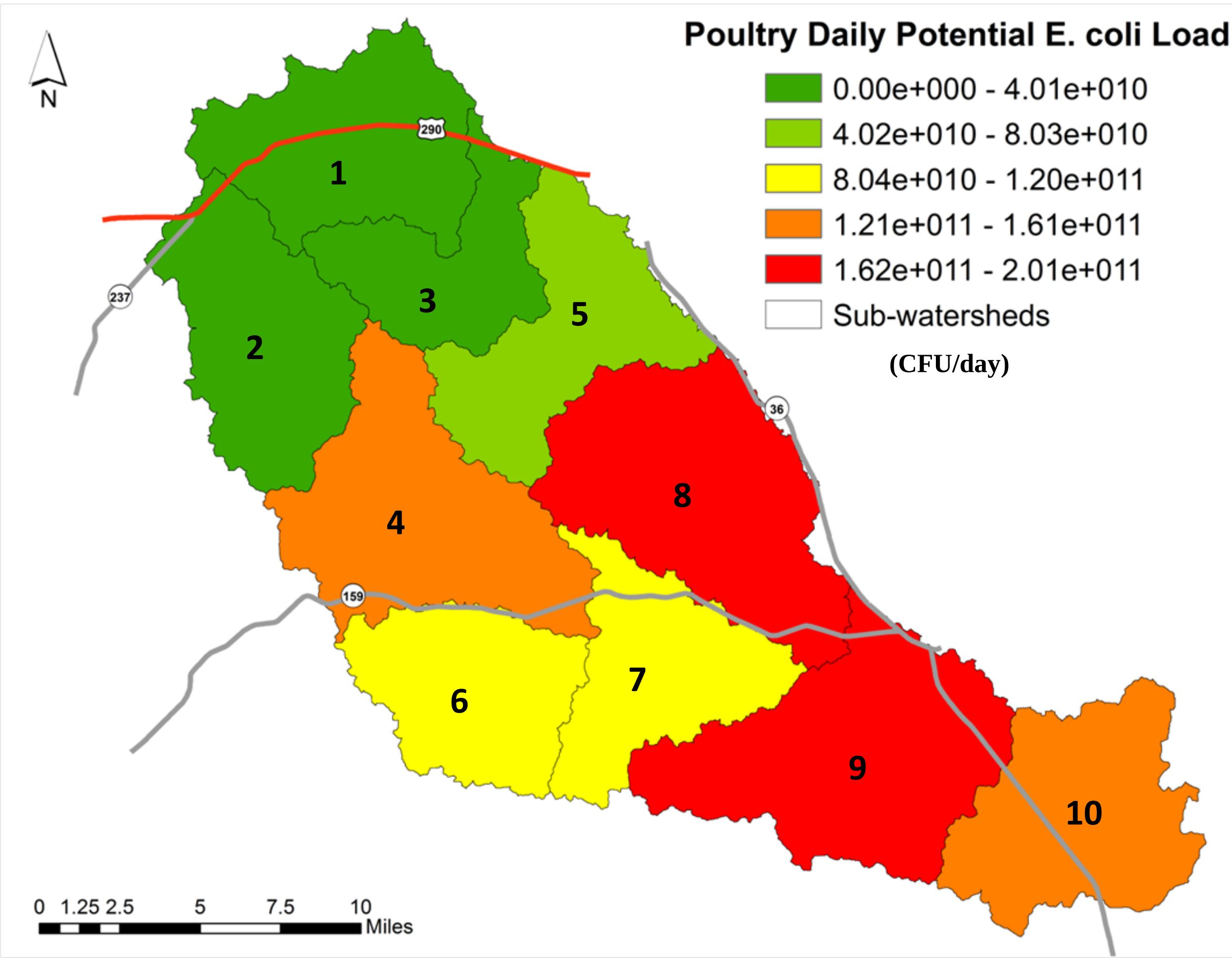

Figure 5.13. Average daily potential *E. coli* load from domestic poultry by subwatershed.

Row crops

Corn, sorghum, and cotton 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 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) only have the potential to contribute nutrients. Management measures targeting livestock will address all land uses where livestock are grazed.

WILDLIFE

In many watersheds across the country, *E. coli* input from wildlife contributes a large portion of the total stream bacteria load (MDEP, 2009). 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). Based on stakeholder knowledge, large populations of these wildlife species were not located in the Mill Creek watershed.

An assessment of watersheds within central Texas by the TCEQ included examination of bacteria sources in Peach Creek, a watershed located approximately 60 miles southwest of Mill Creek. Non-avian wildlife (wildlife other than birds) was 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 5.14). Preliminary studies have begun to investigate fecal deposition rates of riparian wildlife in Texas (Parker, 2009). The Mill Creek watershed has numerous bridge crossings, increasing the likelihood that deposition from bird bridge colonies could be a source of loading. In some watersheds, large lakes or reservoirs attract significant populations of waterfowl which can contribute to bacteria and nutrient loads. However, there are no large reservoirs to attract permanent waterfowl populations in the Mill Creek Watershed and no known large bird colonies in the area.

Figure 5.14. White-tailed deer are a potential source of bacteria in the Mill Creek 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 (TPWD, 2002).

Waste products from deer, similar to livestock, can be a potential source of nutrients and bacteria (Figure 5.14). 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). 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 Partnership and Steering Committee utilized information from local TPWD biologists in developing the deer population estimate for the watershed (Appendix F). The average density was 17.5 acres per deer in Austin County and 35 acres per deer in Washington County. Total deer population in each county was calculated by applying these densities to all land uses except urban areas, cropland, and open water. This produced watershed population estimates of 10,366 deer in Austin County and 2,344 deer in Washington County. The respective deer populations were then distributed to forestland in each county, where local TPWD biologists estimate deer spend most of their time. SELECT analysis indicates the highest potential bacteria loadings from deer occur in subwatersheds along the upper main stem of Mill Creek (Figure 5.15; subwatershed 9).

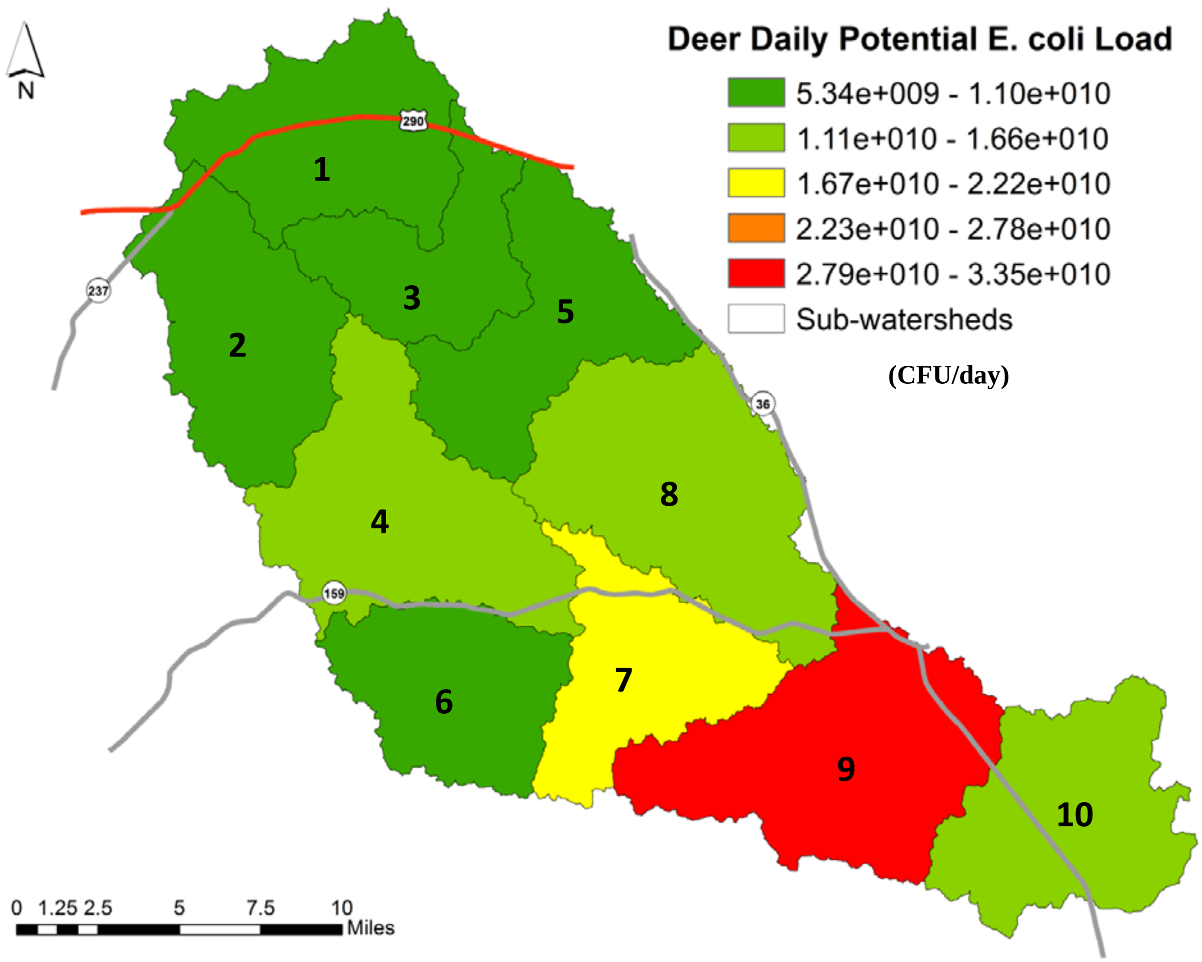

Figure 5.15. Average daily potential *E. coli* load from deer by subwatershed.

Feral Hogs

In many watersheds across the state and much of the southern United States, feral hogs are a concern (Figure 5.16). By definition, feral hogs are not wildlife, but are either domesticated hogs that have become feral, Russian boars, and/or hybrids of the two (TCE, 2004). 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 5.16. 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 (Figure 5.17). 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. 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 in comparable bottomland habitats indicate hogs typically occur at densities of 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 of 2008-2009 and 2011 likely impacted the feral hog population in the watershed, but due to their prolific nature these animals have the capacity to “bounce back” and 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 5.17. Property damage due to feral hogs.

The Partnership and Steering Committee utilized published population estimates for feral hogs combined with local information sources including farmers, ranchers, veterinarians, AgriLife Extension County Agents, and USDA NRCS personnel. SELECT analysis for the Plum Creek WPP used 12 feral hogs/mile^2, while the Geronimo and Alligator Creeks WPP used 25 feral hogs/mile^2 and the Buck Creek WPP used 26 feral hogs/mile^2. Due to concerns over a growing feral hog population, the Steering Committee elected to use a density of 26 feral hogs/mile^2 (1 hog/25 acres), applying this to all land use categories except urban and open water to determine the population estimate for the watershed. At the direction of the Steering Committee, these feral hogs were then distributed to the riparian corridors (within 500 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). This resulted in a total population estimate of 10,702 feral hogs in the watershed. SELECT analysis indicates that the majority of the potential bacteria impact due to feral hogs is located in the lower and central portions of the watershed (Figure 5.18; subwatersheds 4, 8, and 9).

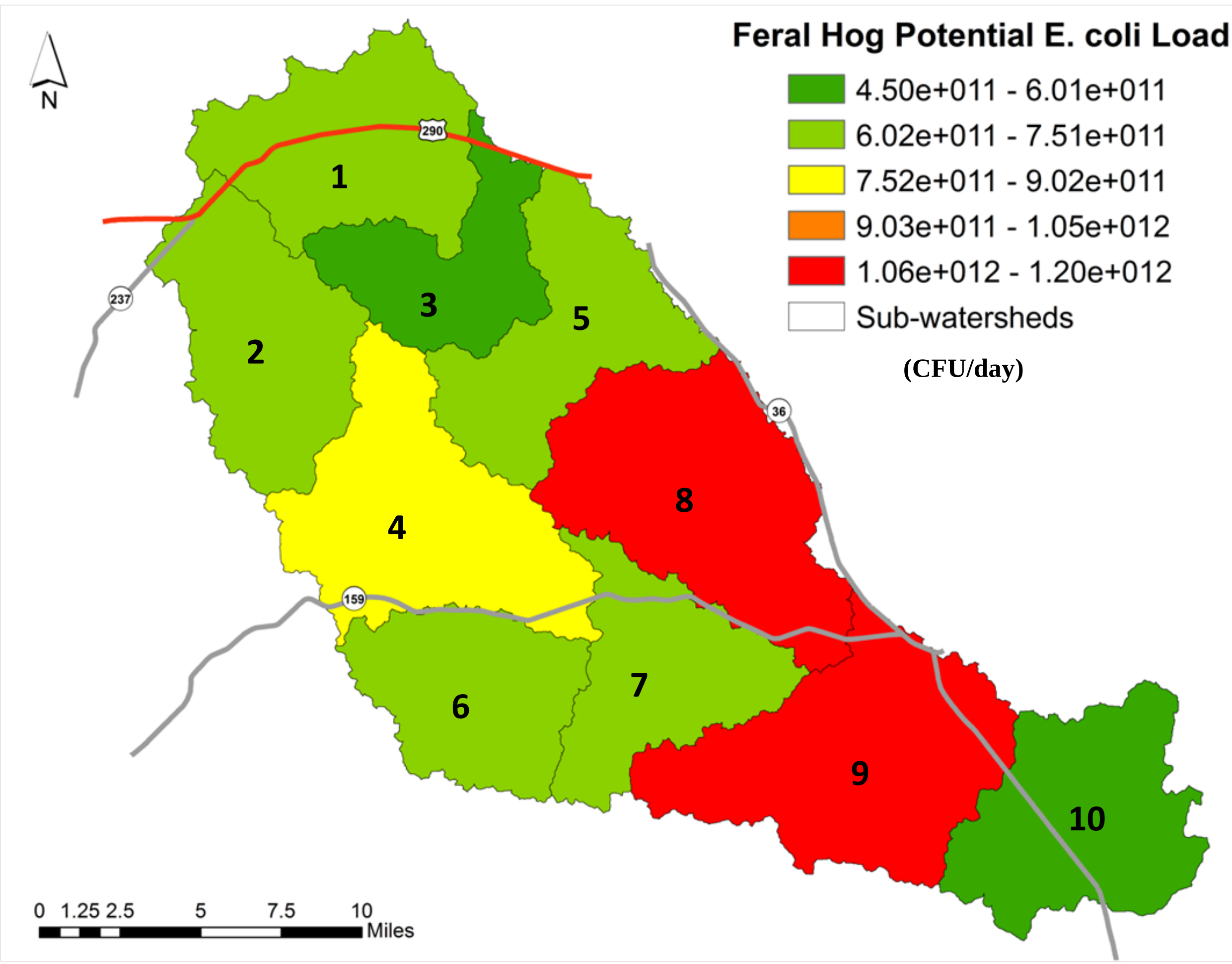

Figure 5.18. Average daily potential *E. coli* load from feral hogs by subwatershed.

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 5.19.

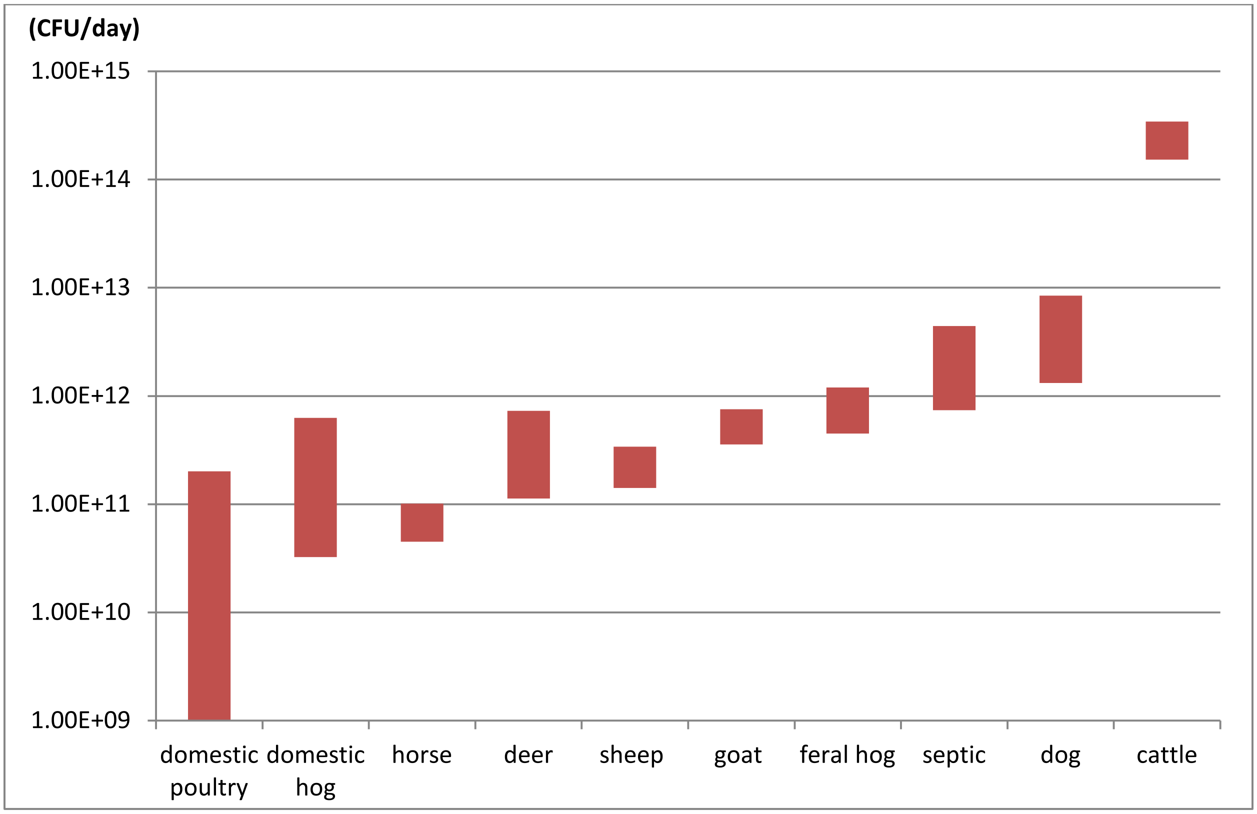

Figure 5.19. Relative ranges in loading by potential source across subwatersheds for Mill Creek (cfu/day).

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 Mill Creek. 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 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). Due to the limited existence of volunteer and nonprofit organizations in the watershed, much of the recommended management measures focused on the activities of individuals and local, state, and federal government entities.

URBAN NONPOINT SOURCE MANAGEMENT MEASURES

Management of potential sources of bacteria in existing urbanized areas of Bellville, Brenham, Burton, and Industry, coupled with the potential for future growth and expansion, was the focus of urban nonpoint source management. Dog waste and general urban storm water 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 city-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 storm water engineering assessments of Bellville and Brenham to determine the most effective types, design, and placement of structural control measures.
• Implement non-structural storm water BMPs, where possible.
• Implement or expand pet and feral animal waste management activities.
• Provide guidelines and training for effective nutrient management on city property.
 	
Brenham
• Initiate storm water management activities.
    o Public education and outreach.
    o Public involvement or participation.
    o Establish an illicit discharge detection and elimination program.
    o Manage construction site storm water runoff.
    o Manage post-construction runoff.
    o Establish pollution prevention and good housekeeping practices for municipal operations.
• Seek funding for implementation of targeted control measures.
• Initiate a pet spay/neuter program.
• Install pet waste stations in neighborhoods and parks, where needed.
• Provide training to watershed ISDs, city and county maintenance and parks departments, and other interested parties.
 	
Bellville
• Initiate storm water management activities.
    o Public education and outreach.
    o Public involvement or participation.
    o Establish an illicit discharge detection and elimination program.
    o Manage construction site storm water runoff.
    o Manage post-construction runoff.
    o Establish pollution prevention and good housekeeping practices for municipal operations.
• Seek funding for implementation of targeted control measures.
• Initiate a pet spay/neuter program.
• Install pet waste stations in neighborhoods and parks, where needed.
• Provide training to watershed ISDs, city and county maintenance and parks departments, and other interested parties.

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

Urban Nonpoint Source Management Measures
Burton • Seek funding for implementation of targeted control measures. • Initiate a pet spay/neuter program. • Install pet waste stations in neighborhoods and parks, where needed. • Provide training to watershed ISDs, city and county maintenance and parks departments, and other interested parties. Industry • Seek funding for implementation of targeted control measures. • Initiate a pet spay/neuter program. • Install pet waste stations in neighborhoods and parks, where needed. • Provide training to watershed ISDs, city and county maintenance and parks departments, and other interested parties.

Dog Waste Management Measures

SELECT analysis was used to estimate the total number of dogs in each subwatershed. These numbers were then multiplied by the necessary bacteria load reduction (43%) to estimate the minimum number of dogs that should be managed within each area. Results for the 10 subwatersheds are presented in Table 6.2. Based on these estimates, emphasis and resources will be directed primarily into the urbanized subwatersheds associated with Bellville and Brenham. Management strategies will include spay/neuter programs, waste bag dispenser and collection stations, code enforcement, and intensive public outreach.

Table 6.2. Recommended number of dogs under pet waste management practices.

County	Subwatershed	Total Dogs	Dogs Managed
Washington	1	932	401
	2	616	265
	3	519	223
	5	755	325
	County Total	2822	1213
Austin	4	1233	530
	6	775	333
	7	419	180
	8	589	253
	9	2637	1134
	10	637	274
	County Total	6290	2705
Total		9112	3918

Spay/Neuter Program

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.

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

Pet Waste Ordinances

The City of Bellville currently has a leash law for dogs in the city limits. The Chesley baseball fields and the Sens Activity Center are the only public recreational areas in Bellville that lie within the Mill Creek watershed. Neither location is well suited for dog-related recreation. However, the city plans to install pet waste stations and proper signage should a notable increase in dog traffic at these locations be observed. The City also plans to install pet waste stations and proper signage at any new parks constructed within the Mill Creek watershed, and launch an education and outreach program to raise awareness about pollution from pet waste. The city will consider implementing an ordinance requiring pet owners to remove any waste deposits from public and private areas.

The City of Brenham requires all pets to be confined to their owner's property, and on a leash when off of their property. City ordinance also restricts the number of pets (dogs or cats) per household. Enforcement of these ordinances is conducted by City Police and the Brenham Animal Control Department. Public education and notification of these ordinances are made available at locations offering pet vaccinations and adoptions. Also, the city will explore implementing a pet waste ordinance requiring pet owners to remove waste deposits from public areas.

Several residential neighborhoods in the watershed currently do not have pet waste stations. The Partnership will work to secure funding to purchase and install pet waste stations and develop an outreach campaign to educate local citizens on the importance of pet waste management.

Animal Friends Shelter

The Animal Friends Shelter is a 501c(3) nonprofit that provides care and temporary refuge for homeless and unwanted animals in Austin County and the surrounding area. The shelter houses an average of 50 animals at any given time and is located immediately adjacent to Mill Creek, approximately 3 miles southwest of Bellville. The shelter has expressed interest in relocating to an upland site, further away from natural waterways. The Partnership will assist the shelter in identifying a suitable location. In addition, the Partnership will work with the shelter to establish a spay/neuter program in the watershed, as previously noted.

Urban Storm Water Management

An initial goal of the Partnership will be to support Bellville and Brenham in acquisition of funding to conduct detailed engineering analyses to properly locate and design storm water management practices specific to each city. In the scope of work for the engineering analysis, it will be required that the goal of the study be consistent with the goals of the Mill Creek WPP to reduce bacteria loading. Results of the analysis will be used by the cities to ensure selection and proper installation of the most effective structural control measures.

Additional funding will be sought to design and construct modified storm water conveyance systems for cities in the watershed. Currently, storm water does not receive any treatment before entering Mill Creek or one of its tributaries. Enhancements to storm water systems would have direct benefits to the water quality of the receiving stream.

Phase I and II Storm Water Permitting

In Texas, regulation of storm water 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 Phase I MS4 Permit is required.

Stormwater from smaller urbanized areas is regulated by Phase II MS4 Storm Water permits. These smaller 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.

The City of Brenham does not currently fall under regulation of a Phase II MS4 storm water permit. However, the city is considering implementing the following six control measures in advance of future growth which may lead to permitting requirements.

- Public education and outreach.
- Public involvement or participation.
- Detection and elimination of illicit discharges.
- Controls for storm water runoff from construction sites.

- Post-construction storm water management in areas of new development and redevelopment.
- Pollution prevention and "good housekeeping" measures for municipal operations.

Bellville has not passed the population threshold that would trigger a Phase II Storm Water Permit; however, there is potential for future growth. Because of this, the Partnership will work with the City of Bellville to assist in the development of storm water management strategies and seek funding when possible to facilitate implementation. Bellville has a strong commitment to environmental stewardship. City ordinance prohibits discharge to public waters any wastewater that contains strong acids, fertilizer, fats, grease, oil, and toxic and poisonous substances. The City will develop storm water management strategies that incorporate the following six control measures, when funding is available:

- Public education and outreach.
- Public involvement or participation.
- Detection and elimination of illicit discharges.
- Controls for storm water runoff from construction sites.
- Post-construction storm water management in areas of new development and redevelopment.
- Pollution prevention and "good housekeeping" measures for municipal operations.

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

- Storm water drain stenciling.
- Installation of storm water detention facilities.
- Storm water detention pond retrofits to enhance reduction of bacteria.
- Provide public education on proper disposal of fats, oils, and grease.
- Design a recognition program for voluntary bacteria reduction measures incorporated in new developments.
- Encourage the use of green infrastructure in street and sidewalk design.

Nutrient Management

Bellville ISD operates three school campuses that lie in the watershed, Bellville High and Junior High, O'Bryant Primary and Intermediate, and West End Elementary. The High School and Junior High School maintain football and baseball fields located on their shared campus. Additionally, there are two soccer fields, a football practice field, and a track and field practice area located onsite. Storm water runoff from the campus flows directly into an unnamed tributary of Boggy Creek. In addition, Boggy Creek also receives direct storm water runoff from two parks managed by the City of Bellville.

West End Elementary School is operated by Bellville ISD and located in Industry, TX. The campus area includes a softball field and grass covered playground area approximately two acres in size. Storm water from this location drains directly into a tributary of West Mill Creek.

Burton ISD maintains a baseball field, softball field, and football field at their lone campus in the upper reaches of East Mill Creek. Storm water from this location drains directly into Indian Creek.

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.

WASTEWATER MANAGEMENT MEASURES

The Partnership and Steering Committee worked with both city and county personnel to identify management measures that should be included in the WPP. Table 6.3 includes a summary of key measures and actions recommended by the Partnership.

Wastewater Treatment Facilities

As previously noted, three wastewater treatment facilities discharge to Mill Creek. While all WWTFs must comply with site-specific regulations contained in a TPDES permit issued by the TCEQ, the Partnership recommends any new wastewater treatment facilities permitted to discharge in the watershed be designed as 5-5-2-1 systems (refers to WWTF permit limits to treat BOD/TSS/NH_3/TP), at a minimum, and include bacteria monitoring. The Partnership also recommends any planned upgrades to the three existing WWTFs in the watershed incorporate the same design considerations, where possible.

Table 6.3. Summary of wastewater management measures for the Mill Creek Watershed.

Wastewater Management Measures
• The cities of Brenham and Bellville will explore the possibility of participating in the SSO Initiative with TCEQ. • All cities in the watershed will work to extend sanitary sewer service to residents in marginal areas utilizing septic systems. • Both counties will continue current inspection and enforcement programs for septic systems. • Both 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.

Sanitary Sewer Collection Systems and Overflow Initiative

Municipalities manage the means of wastewater conveyance to WWTFs 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, maintenance, operations, and management (CMOM) are four important elements to consider when designing a collection system.

The TCEQ has developed a program called the Sanitary Sewer Overflow Initiative (SSO Initiative) to help collection system owners follow the 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 CMOM into regular municipal operations and developing an SSO Plan. Since responsibility for violations such as SSOs rests with the TPDES permitted facility, it is in the best interests of both the facility and the facility manager. 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 Partnership will support the Cities of Bellville, Burton, and Industry in development of an SSO plan under this initiative. An SSO plan may include activities such as the establishment of maintenance schedules for all lift stations; inspection of high risk infrastructure; procedures for involving operations personnel in engineering design review; establishing a fats, oils and grease program; rehabilitation of defective pipes as they are identified; and, implementation of corrective actions to protect facilities when evidence of vandalism is found.

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 Mill Creek 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 6.4).

Table 6.4. 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	745	93	521
2	493	71	375
3	415	53	272
4	954	134	801
5	604	58	524
6	620	62	442
7	335	31	279
8	421	37	313
9	1014	85	834
10	510	44	311
Total	6111	669	4672

Based on estimated failure rate and proximity to a waterway, the greatest concentration of systems in need of management is in the upper reaches of East Mill Creek (subwatersheds 1 and 5) in Washington County. Additional target areas will include subwatersheds 4, 6, 8, and 9 in Austin 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 both Austin and Washington 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.

Austin and Washington 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, this central database 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. Both counties have aggressive septic system enforcement procedures, and processes are in place with local court systems for fast resolution of septic system violations. In Austin and Washington Counties, septic system owners must maintain a maintenance contract with a licensed provider at all times. However, both counties allow homeowners to forego this requirement and maintain their own system provided the homeowner has attended a county-approved training course. Both counties also have adopted more stringent requirements including the need for a permit for all systems, floodplain determination, and 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.

The City of Bellville has an ordinance requiring every home within city limits to be connected to the city's sanitary sewer system. Although other cities in the watershed have similar requirements, 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).

Household Hazardous Waste

In the lower portion of the watershed both Austin County and the City of Bellville have programs to deal with household hazardous waste products and debris. The City of Bellville is currently offering a week-long collection event to city residents in the spring and fall. As soon as funding can be secured, the city plans to establish a permanent drop center where residents can dispose of household hazardous waste and make the center known to the public through education and outreach efforts. The Partnership will assist Bellville in obtaining funding for expanding the frequency and types of materials currently accepted at the week-long events, as well as outreach and education efforts to encourage participation.

Washington County and the City of Brenham offer a spring household hazardous waste collection event for residents each March. Citizens are encouraged to dispose of items such as furniture, mattresses, household and yard debris, auto batteries, and scrap metal. The City of Brenham and Washington County would like to expand the program to accept household hazardous waste products and offer collection events more frequently, pending acquisition of funding with assistance from the Partnership.

AGRICULTURAL 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. 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 Mill Creek Watershed Partnership will pursue funding to support a financial incentives program for the Austin and Washington County 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.

Livestock Operations

Based on 2012 USDA-NASS data, the average farm size was estimated to be 176 acres in Austin County and 137 acres in Washington County. 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, domestic hogs, and horses). 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.

Table 6.5. Recommended number of management plans for livestock operations by subwatershed.

County	Subwatershed	Animal Units	Number of Farms	Recommended # of WQMPs
Washington	1	4233	85	37
	2	2710	54	23
	3	4182	84	36
	5	5978	120	52
Austin	4	4037	81	35
	6	5442	109	47
	7	2995	60	26
	8	3493	70	30
	9	4620	92	40
	10	3993	80	34
	Total	41682	835	359

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 (43%) was applied to the total number of livestock operations within each subwatershed to determine the number of operations that should undergo plan development (Table 6.5). Based on these estimates, the number of livestock operation management plans required for individual subwatersheds ranges from 23 to 52. A total of 359 management plans are necessary for the entire Mill Creek 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.

Cropland Operations

Although there are only a small number of cropland acres 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. Initial efforts will focus on subwatersheds 9 and 10, where the majority of cropland acres are found, and priority will be given to operations immediately adjacent to waterways.

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.

WILDLIFE AND NON-DOMESTIC ANIMAL MANAGEMENT MEASURES

Based on SELECT analysis, non-domestic animals are a significant potential contributor of pollutants to Mill Creek. 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 Mill Creek Watershed Protection Plan.

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 (43%); results are presented in Table 6.6. 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.

Table 6.6. Recommended number of feral hogs to be removed by subwatershed.

County	Subwatershed	Total Hogs	Hogs To Be Removed
Washington	1	877	377
	2	649	279
	3	889	382
	5	1737	747
	County Total	4152	1785
Austin	4	1030	443
	6	1206	519
	7	1022	439
	8	869	374
	9	1596	686
	10	826	355
	County Total	6549	2816
	Watershed Total	10701	4601

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 Texas A&M AgriLife Extension Wildlife and Fisheries Department will seek funding to employ a full-time position to focus specifically on feral hog management in the region. This position will work directly with landowners in the Mill Creek watershed to provide technical assistance in managing feral hog populations (Figure 6.1).

Figure 6.1. Hunting and trapping are effective techniques for managing feral hog populations.

To further enhance program targeting and success, a feral hog reporting website developed by Extension as part of the Plum Creek project will enable reporting of the date, time, location, and approximate number of feral hogs observed in the Mill Creek 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 feral hog management workshop conducted by AgriLife Extension to educate landowners regarding feral hog control strategies.

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.

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.

MILL CREEK DRAINAGE DISTRICT

The Mill Creek Drainage District was formed in 1935 with the purpose of mitigating the frequency and severity of damaging flood events in the lower portion of the Mill Creek Watershed. Initially the district levied taxes to support implementation of flood control measures. However, with the onset of WWII and the subsequent financial strain on local citizens, the district ceased taxation and scaled back its efforts. The district has remained in place to serve the needs of local citizens should the need arise. The Partnership will work with the Mill Creek Drainage District to ensure that future efforts to minimize flood damage incorporate aspects to improve water quality, whenever possible. The Partnership also will support the drainage district in the acquisition of funding to incorporate water quality BMPs into its flood control management strategy and identify methods to further reduce flooding in Mill Creek.

EDUCATIONAL INITIATIVES

The Washington County Wildlife Society is a non-profit organization consisting of local stakeholders aimed at improving wildlife habitat and associated wildlife populations in the county. One component of the wildlife society's mission is to enhance conservation through education. Through the L.A.N.D.S. (Learning Across New Dimensions in Science) program, the wildlife society has helped introduce natural resource education into seventh and eighth grade classrooms in Washington County. Extension and the Texas Wildlife Association are currently revising the L.A.N.D.S. program curriculum to include a water quality component. Once complete, the Washington County Wildlife Society would like to make the curriculum available to ISDs throughout the Mill Creek Watershed. The Partnership will work with the wildlife society to introduce the L.A.N.D.S. program to classrooms throughout the watershed.

The Washington County Fairgrounds provide a location for outdoor and classroom educational programs. The facility hosts the annual Lone Star Water Forum, an education program focused on addressing local and regional water issues. In addition, Extension utilizes the fairgrounds complex to deliver educational programming throughout the year. Washington County would like to expand the water education programs offered at the fairgrounds to include classes that educate participants about water quality in Mill Creek. Pending funding, the county plans to upgrade its facilities to incorporate new educational opportunities about the impact of BMPs on water quality for ISDs, municipal employees, and other interested groups and citizens.

VOLUNTEER PROGRAMS

The only known active volunteer groups in the watershed, with a significant focus on water quality and environmental protection, are the Bluebonnet Master Gardener Association, the Gideon Lincecum Master Naturalist Chapter, and the Washington County Wildlife Society. Efforts will be made to establish new volunteer groups and to bolster the activities of existing volunteers in the Mill Creek watershed. Soliciting volunteers to participate in stream cleanup events and engage in water quality data collection through the Texas Stream Team program will be initial priorities.

LOCALLY BASED WATERSHED COORDINATOR

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 Mill Creek Watershed. As a result, the Steering Committee recommends that a local Watershed Coordinator position be established 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, H-GAC, and other watershed interest groups to keep them informed and involved in implementation activities being carried out in the watershed.

Initial funding for the Watershed Coordinator will be incorporated into a CWA 319(h) implementation grant proposal. Subsequently, and with assistance from the Partnership, the Watershed Coordinator will work to identify and build support for local funding to provide salary and operating costs for continuation of the position.

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 (newspaper, newsletter, factsheets) 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

ADAPTIVE IMPLEMENTATION

Due to the dynamic nature of watersheds and the countless variables governing landscape processes across scales of time and space, some uncertainty is to be expected when a watershed protection plan is developed and implemented. As the recommended restoration measures of the Mill Creek Watershed Protection Plan are put into action, it will be necessary to track the water quality response over time and make any needed adjustments to the implementation strategy. In order to provide flexibility and enable such adjustments, adaptive implementation will be utilized throughout the process.

Adaptive implementation (AI) is often referred to as "learning by doing" (USDA, 2007). It is the on-going process of accumulating knowledge about the causes of impairment as implementation efforts progress, which results in reduced uncertainty associated with modeled loads. As implementation activities are instituted, water quality is tracked to assess impacts and guide adjustments, if necessary, 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 Mill Creek, are good candidates for AI.

Adaptive implementation relies on constant input of watershed information and the establishment of intermediate and final water quality targets. Pollutant concentration targets for Mill Creek were developed based on complete implementation 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 early in the process, implementation of other measures will require more time, energy, and funding. For this reason, reductions in pollutant loads and associated concentrations initially may be gradual. However, it can be assumed that reductions in the loadings will be tied to the implementation of management measures throughout the watershed. Thus, these 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 here, these estimates serve as a tool to facilitate stakeholder evaluation and decision-making based on AI.

Table 7.1. *E. coli* bacteria target concentrations for the SH-36 sampling location during the 10-year implementation schedule.

Year	*E. coli* Concentration (cfu/100mL)
2016	192
2019	166
2022	139
2026	113

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 Mill Creek. These values will be compared to the incremental reductions outlined in Table 7.1 to determine if any 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 management. 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 Mill Creek watershed rely on the existing monthly routine monitoring station at SH-36 (CRP Station #11576). This location has been the main sampling location since 1974, is used by TCEQ to conduct the assessment for the Texas Integrated Report of Surface Water Quality, and will be an important part of continued efforts to track the success of implementation.

Ambient in-stream data collected at this site 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 detect the development of additional water quality problems, as well as measure progress toward the goals established in this plan.

Targeted Water Quality Monitoring

To support WPP development, a special project funded by the TSSWCB and conducted by Extension and H-GAC 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 *Phase 1: Data Collection and Development of Essential Components for the Mill Creek Watershed Protection Plan*, utilized a combination of nine routine sampling stations and four targeted locations (Figure 7.1).

Prior to the onset of this project, no subwatershed level water quality data had been collected in the Mill Creek watershed. The Clean Rivers Program monitoring station located at SH-36 was the sole sampling location used to assess water quality in Mill Creek. Thus, 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 data at these sites. If possible, and adequate resources are available, samples will be analyzed for the full suite of water quality parameters.

Extension and H-GAC will continue to collect water quality data in Mill Creek in order to assess trends and fill information gaps identified during development of the WPP. This intensive monitoring effort will refine the focus of management efforts as well as track performance of on-going implementation activities. Funding will be required to continue monitoring throughout the 10-year period of implementation.

A summary of these water quality monitoring efforts are as follows:

- Continue routine sampling at 9 sites bi-monthly (every other month) for the duration of the proposed 10-year project implementation.
- Wet and dry weather sampling twice per season at all 9 routine locations and 4 additional targeted monitoring sites for the duration of proposed 10-year project implementation.

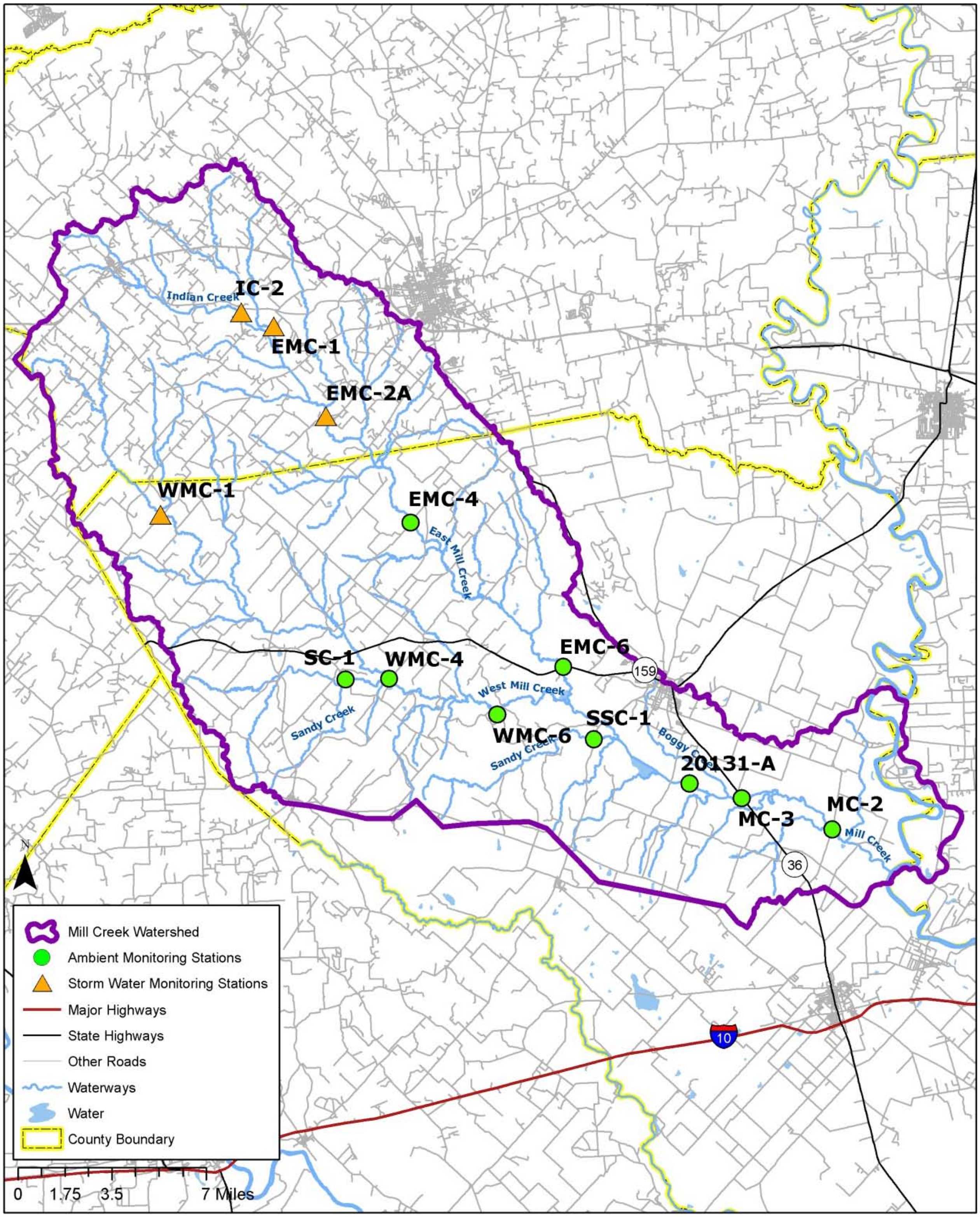

Figure7.1. Water quality monitoring locations in the Mill Creek Watershed.

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 implementation has occurred to assess change. The most appropriate location likely would be the SH-36 monitoring station (Figure 7.2). Surveys of the fish and macroinvertebrate communities in the stream as well as the plant communities and physical characteristics of the environment adjacent to the stream 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 Mill Creek.

Figure 7.2. SH-36 sampling location on Mill Creek. Image courtesy of H-GAC.

SELECT

SELECT was utilized to identify potential pollutant sources in the watershed and 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 need to be employed 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 a recommendation. 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 targeting of efforts may be adjusted to most effectively achieve overall project goals.

BACTERIAL SOURCE TRACKING

The Mill Creek 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, an estimate of the associated costs, potential sources of funding, and an estimate of load reductions expected as a result of program implementation. Some management measures are part of ongoing budgeted operations of counties and municipalities. All management measures identified in the Mill Creek Watershed Protection Plan are voluntary. The schedule for implementation is based on a combination of factors, such as available resources, financial ability, and political will.

TECHNICAL ASSISTANCE

Successful implementation of the Mill Creek 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 manpower 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 to achieve water quality goals in the watershed. Focused and continued implementation of key restoration measures will require the creation of multiple full-time equivalent positions in the watershed to coordinate and provide technical assistance to stakeholders.

URBAN STORMWATER MANAGEMENT MEASURES

Structural and programmatic urban storm water controls are the responsibility of the individual municipalities in the watershed. However, identification and design of specific improvements to storm water conveyances are beyond the scope of these entities. Thus, funding will be sought to support professional engineering analysis to assess the need for construction of new structural controls and upgrades to existing components of storm water facilities. Funding also will be sought to assist the cities 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.

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 both Austin and Washington 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.

AGRICULTURAL MANAGEMENT MEASURES

Technical support from the TSSWCB, Austin and Washington County 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 will be necessary. The position will 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 will be relied upon to identify and engage key potential agricultural producers. The duration of the position will be dictated by demand for enhanced technical assistance, assuming water quality monitoring results indicate the need for continued improvement.

NON-DOMESTIC ANIMAL AND WILDLIFE MANAGEMENT MEASURES

Management of the feral hog control program will be coordinated through Texas A&M AgriLife Extension, 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 direct control efforts.

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 constructed for implementation of the Mill Creek 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 acquisition of funding, hiring of staff, and the implementation of new programs, all of which will have initial time demands. In addition, substantive changes in water quality often are delayed 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. Image courtesy of Beth Luedeker.

Table 8.1. Jurisdiction, implementation milestones, and estimated financial cost for recommended management measures.

Management Measure	Jurisdiction	Unit Cost	Number Implemented			Total Cost
			Year			
			1-3	4-6	7-10	
Urban Stormwater Management Measures						
Pet Waste Collection Stations	Bellville, Burton, Brenham, Industry	$620/station $85 annual/station	6	3	3	$17,640
Initiate Spay/Neuter Program	Bellville, Burton, Brenham, Industry	$35,000	3	---	---	$105,000
Comprehensive Urban Stormwater Assessment	Cities of Bellville, Burton, and Industry	$35,000/survey	3	---	---	$105,000
Enhance Stormwater Management Practices	Cities of Bellville, Burton, Brenham, Industry					$105,000
Modify Stormwater Conveyance Systems	Cities of Bellville and Brenham					$1,200,000

Management Measure	Jurisdiction	Unit Cost	Number Implemented Year			Unit Cost
			1-3	4-6	7-10	
Wastewater Management Measures						
Wastewater Collection System Line Testing / Replacement (SSO Initiative)	Cities of Bellville, Burton, and Industry					$14,500,000[1]
Modifications to Lift Stations (SSO Initiative)	Cities of Bellville, Burton, and Industry	$86,000/lift station				$14,500,000[1]
Expand County OSSF Education Programs	Extension	$2,500 event	2	2	2	$15,000
Septic System Repair	Homeowner	$5,000/system	121	235	313	$3,345,000
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	Austin and Washington Counties	$12,500/event	2	3	4	$112,500

Management Measure	Jurisdiction	Unit Cost	Number Implemented			Unit Cost
			Year			
			1-3	4-6	7-10	
Agricultural Management Measures						
WQMP Technician (New Position)	SWCDs	$75,000/year[2]	1			$750,000
Water Quality Management Plans	SWCDs	$15,000/plan	15	147	197	$5,385,000
Non-Domestic Animal and Wildlife Management Measures						
Feral Hog Control (Existing Position)	Extension	$75,000/year[2]	1			$750,000
Feral Hog Control (Equipment)	Extension	$500/trap	10	---	---	$5,000
Monitoring Component						
Targeted Water Quality Monitoring	Extension & H-GAC	---	1	1	1	$650,000
Comprehensive Stream Assessment	TAMU	$1,500/ assessment	3	3	3	$13,500
Bacterial Source Tracking and Wildlife Surveys	TAMU	---	---	---	1	$200,000

[1] Currently underway using City of Bellville funds. Total includes lift station modifications, WWTF expansion, sewer line testing/replacement/extension, construction of new water towers, and other infrastructure-related projects.
[2] Total includes salary and benefits (health insurance, annual/sick leave, etc.).

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 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 Mill Creek 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. Jurisdiction, implementation milestones, and estimated financial costs for outreach and education efforts.

<table>
<tr><th rowspan="3">Outreach Activity</th><th rowspan="3">Jurisdiction</th><th colspan="3">Number Implemented</th><th rowspan="3">Total Cost</th></tr>
<tr><th colspan="3">Year</th></tr>
<tr><th>1-3</th><th>4-6</th><th>7-10</th></tr>
<tr><td colspan="6">Broad-Based Programs</td></tr>
<tr><td>Texas Watershed Steward Training Sessions</td><td>Extension</td><td>1</td><td>1</td><td>---</td><td>n/a[1]</td></tr>
<tr><td>Public School Education Program</td><td>Extension & Washington County Wildlife Society</td><td>1</td><td>1</td><td>1</td><td>$25,000</td></tr>
<tr><td>Mill Creek Watershed Protection Brochure and Newsletters</td><td>Extension</td><td>5</td><td>5</td><td>5</td><td>$10,000</td></tr>
<tr><td>Displays at Local Events</td><td>Extension/TSSWCB</td><td>6</td><td>6</td><td>6</td><td>$3,600</td></tr>
<tr><td>Nonpoint Source Pollution Educational Programs</td><td>Extension</td><td>3</td><td>3</td><td>4</td><td>$100,000</td></tr>
<tr><td colspan="6">Urban Programs</td></tr>
<tr><td>Urban Sector Nutrient Education</td><td>Extension</td><td>3</td><td>3</td><td>4</td><td>$45,000</td></tr>
<tr><td>Pet Waste Programs</td><td>Cities, TCEQ, Extension</td><td>3</td><td>3</td><td>4</td><td>$35,000</td></tr>
<tr><td>Urban Smart Growth Workshops</td><td rowspan="3">TCEQ & Extension</td><td>2</td><td>---</td><td>---</td><td rowspan="3">$20,000</td></tr>
<tr><td>Fats, Oil, Grease Workshops</td><td>2</td><td>---</td><td>---</td></tr>
<tr><td>Master Gardner and Master Naturalist Programs</td><td>2</td><td>2</td><td>2</td></tr>
<tr><td>Sports and Athletic Field Education (SAFE)</td><td>Extension</td><td>3</td><td>3</td><td>4</td><td>$45,000</td></tr>
</table>

Outreach Activity	Jurisdiction	Number Implemented Year			Total Cost
		1-3	4-6	7-10	
Wastewater Programs					
Advertise Septic System Online Training Modules	Extension	3	3	4	$10,000
Septic System Workshops and Assistance	Extension, Austin & Washington Counties	3	3	4	$25,000
Agricultural Programs					
Soil and Water Testing Campaigns	Extension	3	3	3	$40,000
Agriculture Nutrient Management Education	Extension	3	3	3	$1,100
Crop Management Seminars	Extension	3	3	3	$1,100
Agricultural Waste Pesticide Collection Days	TCEQ	2	3	4	$125,000
Livestock Grazing Management Education	Extension	3	3	3	$1,100
Non-Domestic Animal and Wildlife Programs					
Feral Hog Management Workshop	Extension	2	1	2	$40,000
Additional Programs					
Community Stream Cleanup Events	Extension	2	3	3	$40,000
Rainwater Harvesting Education/ Demonstration	Extension	2	1	2	$25,000
Post "Don't Mess With Texas Water" Signage (H.B. 451, 82nd Legislative Session)	Extension	4			$4,000
Watershed Coordinator	Extension				$950,000[2]

[1] Funded through the TSSWCB through an existing CWA section 319(h) grant.
[2] Total includes salary and benefits (health insurance, annual/sick leave, etc.) and travel.

PROGRAM COORDINATION

In addition to technical and financial assistance required for implementation of management measures and outreach programs, it is recommended that a full-time Watershed Coordinator be employed to facilitate continued progress. This position will oversee project activities, seek additional funding, organize and coordinate regular updates for the Partnership, maintain the website, and coordinate outreach and education efforts in the watershed. An estimated $95,000 per year including salary, benefits, and travel expenses will be necessary for this position.

SOURCES OF FUNDING

Acquisition of funding from multiple sources to support implementation of management measures will be critical for the success of the Mill Creek 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.

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.

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.

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.

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).

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.

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.

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.

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.

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.

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.

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.

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 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.

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 Mill Creek Watershed Partnership. Funding also will be sought from TCEQ through this program to support urban storm water assessments for municipalities in the watershed and related programs.

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 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.

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 in the watershed.

EXPECTED LOAD REDUCTIONS

Expected load reductions of *E. coli* bacteria at the SH-36 monitoring station as a result of full implementation of the Mill Creek 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 Mill Creek Watershed.

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

Management Measure	Expected *E. coli* Load Reduction[1]
Urban Stormwater Management Measures	
Pet Waste Collection Stations	1.24×10^{13}
Pet Waste Ordinance and Outreach and Education Program	
Pet Spay/Neuter Programs	
Comprehensive Urban Stormwater Assessments and Stormwater Conveyance Modifications	
Enhance Stormwater Management Practices	
Wastewater Management Measures	
Wastewater Collection System Line Testing/Replacement	1.95×10^{9}
Modifications to Lift Stations	
Septic System Workshops	8.05×10^{12}
Septic System Repair	
Septic System Replacement	
Septic System Connection to Sewer	
Expand the Existing Household Hazardous Waste Programs	
Agricultural Management Measures	
WQMP Technician (New Position)	1.04×10^{15}
Water Quality Management Plans	
Non-Domestic Animal Measures	
Feral Hog Control (Regional Position)	3.19×10^{12}
Feral Hog Control (Equipment)	

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

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Appendix A: List of Acronyms

7Q2	Minimum 7-Day, 2-Year Discharge
AI	Adaptive Implementation
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
BRA	Brazos River Authority
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
EDAP	Economically Distressed Area Program
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESRI	Environmental Systems Research Institute
ETJ	Extraterritorial Jurisdiction
GBRA	Guadalupe-Blanco River Authority
GIS	Geographic Information System
H-GAC	Houston-Galveston Area Council
LDC	Load Duration Curve
MGD	Million Gallons per Day
MS4	Municipal Separate Storm Sewer System
NAIP	National Agriculture Imagery Program
NASS	National Agricultural Statistics Service
NEMO	Nonpoint Source Education for Municipal Officials
NOAA	National Oceanic and Atmospheric Administration

NPS	Nonpoint Source Pollution
NRCS	National Resources Conservation Service
OSSF	On-Site Sewage Facility
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
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSS	Total Suspended Solids
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
WWTF	Wastewater Treatment Facility

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 *(Section 8 & 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 *(Section 6 & 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 *(Section 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 & 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 & 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 6 & 7 and Executive Summary)*

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 Mill Creek Watershed Partnership (hereafter referred to as the Partnership) agreed to and signed by the members of the Mill Creek 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 Mill Creek (Segment 1202K). According to the 2014 Texas Water Quality Inventory and 303(d) List, Mill Creek does not support the contact recreation use 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 Mill Creek 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 Mill Creek.

TIME FRAME

Development of a Mill Creek WPP will require at least a 6-month period. The Steering Committee will function under a July 2015 target date to complete the initial development of the WPP. Achieving water quality improvement in Mill Creek 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 from the Mill Creek Watershed. Initial selection of members for equitable geographic and topical representation was conducted using three methods: 1) consultation with the Texas AgriLife Extension Service County Agents, Austin and Washington County Soil and Water Conservation Districts 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 Mill Creek 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 may elect a chair if deemed appropriate at any time by a majority of members; otherwise, it will remain a facilitated group. AgriLife Extension will serve as the facilitator through a contract with the 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 one 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.

Work groups and individual 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:

- 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)
- USDA Natural Resources Conservation Service (USDA-NRCS)
- USDA Farm Service Agency (USDA-FSA)

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 unable to attend a Steering Committee meeting (an absentee) may send an alternate. An absentee should provide advance notification to the facilitator of the desire to send an alternate.

An alternate attending with prior notification from an absentee will serve as a proxy for that absent Steering Committee member and will have voting privileges.

Absentees also may 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 a representative of either Extension or TSSWCB present.

FACILITATORS

AgriLife Extension will serve as the lead facilitator for the Partnership, Steering Committee, and Work Groups. The facilitator is an independent position, financed through a State nonpoint source grant from the TSSWCB. Both the TSSWCB and Extension have specific roles in the planning process.

TSSWCB: The TSSWCB provides technical assistance to the stakeholders in developing the Mill Creek WPP. The TSSWCB will ensure the planning process culminates in a WPP for Mill Creek that satisfies the nine elements essential for acceptance by the U.S. Environmental Protection Agency.

AgriLife Extension: Extension will serve as an educator and facilitator to help the Steering Committee organize its work, conduct meetings, coordinate educational trainings and draft notes and other materials if requested, and work with the TSSWCB to facilitate plan development. Extension will co-lead the meetings and work with all members to ensure the process runs smoothly. Extension will work with the Steering Committee to prepare meeting summaries, assist in the location and/or preparation of background materials, distribute documents the Steering Committee develops, conduct public outreach, moderating public workshops, provide assistance to Steering Committee members regarding committee business between meetings, guide the work of any standing or ad hoc Work Groups, 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 all meetings.

OPEN DISCUSSION

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

AGENDA

AgriLife Extension 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 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

Extension will take notes during the meetings and may conduct audio recording (for the sole purpose of note taking). If requested, Extension will draft meeting notes and distribute them to the Steering Committee or Work Group for their review and approval. All meeting summaries will be posted on the project website.

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 AgriLife Extension or TSSWCB. If Committee spokespersons are needed, they will be selected by the Steering Committee.

DEVELOPMENT AND REVISION OF GROUNDRULES

These ground rules were drafted by AgriLife Extension 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

Two primary resources were utilized to conduct the land use classification analysis. The National Agriculture Imagery Program (NAIP) and Landsat-8 databases provided imagery for Austin County and Washington County. NAIP and Landsat-8 images have a spatial resolution of 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), Cropland Data Layer (CDL), Gridded Soil Survey Geographic Database (gSSURGO), and National Elevation Dataset (NED).

Methods

Austin and Washington County 2012 NAIP was mosaicked and clipped to the watershed boundary in order to create complete coverage. 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 decision tree classification method. The decision tree method assigns pixels to each class by applying a series of thresholds to each input. The See5 software package was used to produce the decision tree based on a variety of inputs derived from satellite images and ancillary data. The decision tree was then applied to the datasets using ENVI geospatial imagery processing and analysis software.

Landsat 8 scenes which have been radio metrically calibrated to top-of-atmosphere reflectance in ENVI are extracted for the study area using the Mill Creek 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 as well as ancillary data are used as inputs in the decision tree classification. Input values are identified by selecting 50% of ground control points from each desired output class and extracting values from selected input rasters at each point. See5's algorithm evaluates all of the values and produces a decision tree output that base classifies the input values. The decision tree constructed by See5 is then reconstructed in ENVI and evaluated for preliminary accuracy. The final output pixel-based classification is filtered to reduce speckling in the output. Finally, 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. Due to a lack of sample point volume in some classes and in order to improve the classification, 50% of ground control points were only set aside for the grassland and pasture/hay classes. Accuracy was assessed by selecting 30 additional random points from each class and evaluating them against the 2012 NAIP as well as the newly released 2014 NAIP. The accuracy assessment yielded a result of 68% overall accuracy when all classes were evaluated individually. Overall accuracy increased to 77% when the four developed land classes as well as barren land were evaluated as one class.

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 graminoid 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.

Barren Land - (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of the total cover and includes transitional areas.

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

Near Riparian Forested Land - Areas dominated by trees generally greater than 16 feet tall, and greater than 50% of the total vegetation cover. These areas are found in close proximity to streams, creeks and/or rivers.

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 for the SH-36 sampling station from 1982 to 2014 was utilized to develop the FDC for that location. These results are used to create a graph of flow volume versus frequency, which produces the flow duration curve.

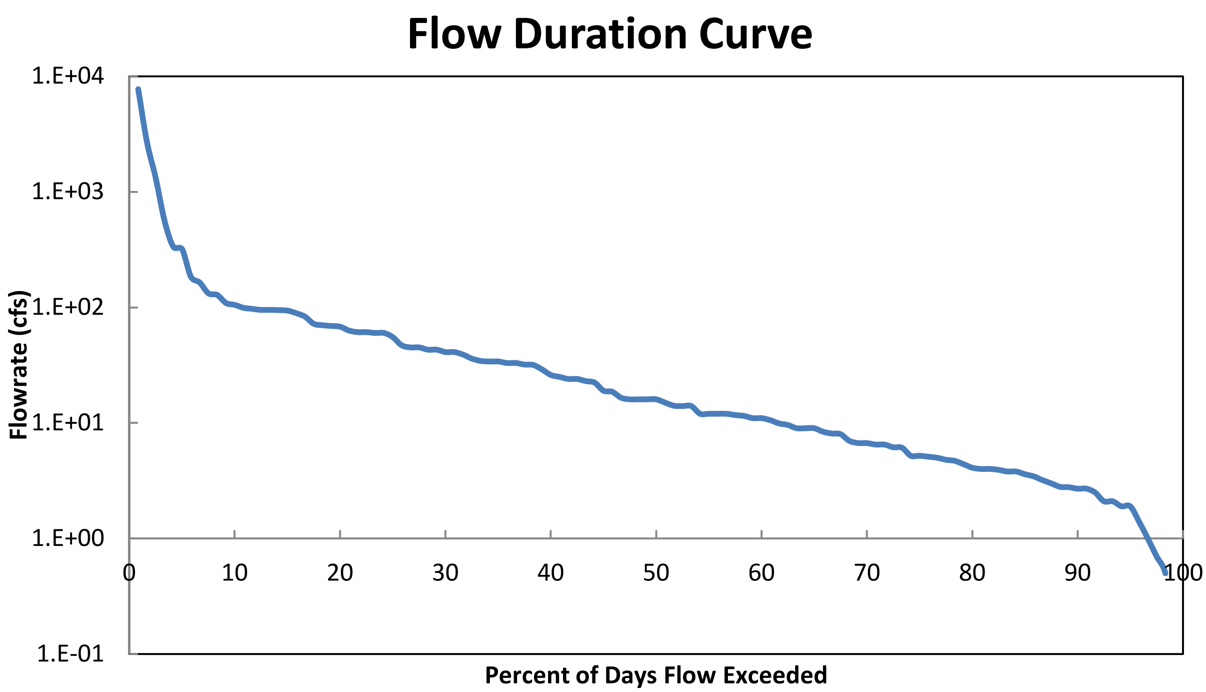

Figure E.1. Mill Creek flow duration curve.

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 Mill Creek, there are three flow regimes: high (0-10^{th} percentile flow, 105.1 cfs to 7,710 cfs), mid-range (11^{th} – 84^{th} percentile flow, 11.1 cfs to 105 cfs) , and low flows (85^{th} -100^{th} percentile flow, 0.174 cfs to 11 cfs). These regimes reflect where a change in the slope of the LDC line is detected. Bacteria data plotted on the LDCs for Mill Creek in this report covered data collected from 1982 to 2014 for the SH-36 sampling station. 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.

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.

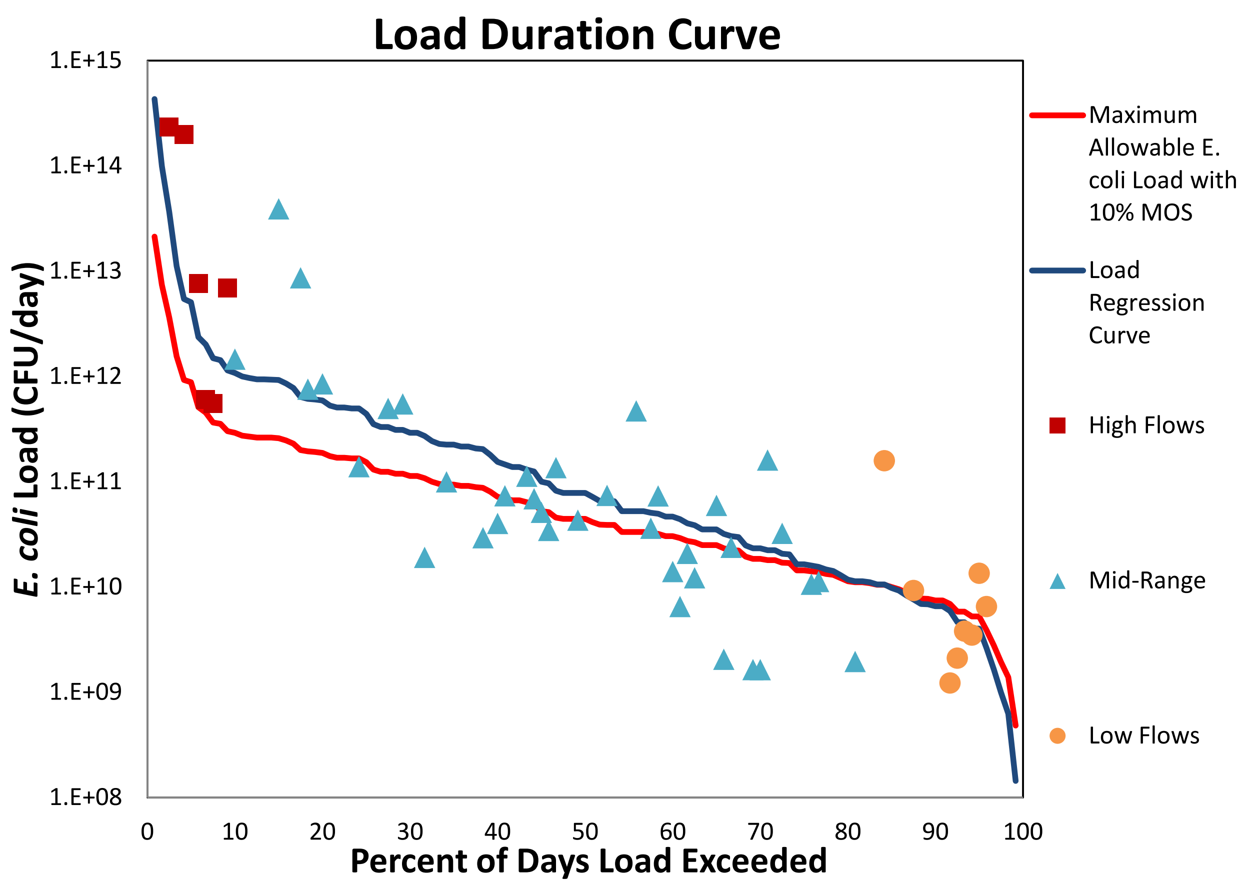

Figure E.2. Mill Creek load duration curve for *E. coli* at the SH-36 monitoring station.

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 2012 National Agriculture Imagery Program (NAIP) and 2013-2014 Landsat-8 imagery, and a pixel-based decision tree classification system. The watershed was divided into 10 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.

Domestic Dogs

By multiplying the average number of dogs/household by the number of households in each subwatershed, dog density was estimated and total potential daily bacterial load 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 Mill Creek Watershed were determined. Census data and OSSF permit data for Austin County were used to determine the average number of people per home and locations of households in the watershed. Homes within the city limits (CCN) of Bellville, Burton, and Industry were determined to be on city sewer facilities, and those outside city limits were assumed to rely on septic systems. The septic drain field 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 6,131 systems, 3,529 were assigned an 8% malfunction rate, 20 were assigned a 10% malfunction rate, and 2,582 were assigned a 15% malfunction rate (Table F.2).

$$SepticLoad = SepticSystems * MalfunctionRate * \frac{10x10^{6} cfu}{100 mL} * \frac{210 gal}{household / day} * \frac{3758.4 mL}{gal} * 0.63$$

Factors in the equation that determined potential loads from septic systems were: 10^6 cfu/100 mL is the fecal coliform concentration in effluent, 210 gallons per household per day is assumed to be daily discharge, and 0.63 is to convert from 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	3,529/6131
10	20/6131
15	2,582/6131

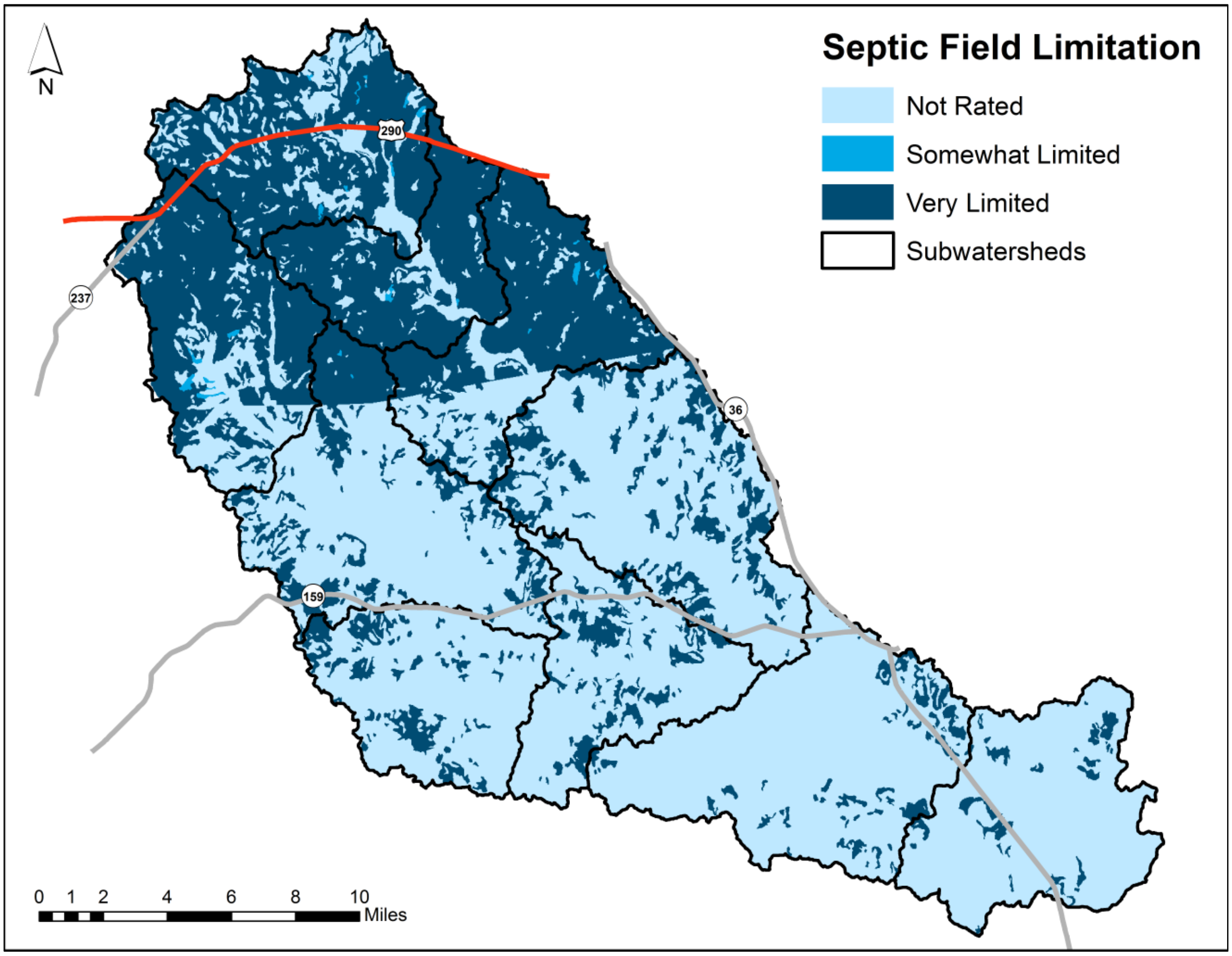

Figure F.1. Soil suitability for onsite sewage facilities in the Mill Creek Watershed.

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 for Austin and Washington Counties was the most recent version available and was utilized by stakeholders as a baseline estimate of livestock populations in the Mill Creek 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 Hogs

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

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

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

Wildlife

The potential bacteria concentration of white-tailed deer in the Mill Creek Watershed was estimated using deer census estimates from TPWD. The Mill Creek watershed is located in TPWD Resource Management Unit (RMU) 19 (Figure F.2). Average densities of the white-tailed deer population within RMU 19, along with estimates from local TWPD biologists, were obtained for the SELECT analysis. Based on the estimated number of deer per acre, a total deer population was calculated for the watershed and distributed on forestlands. The total potential daily bacteria load for each subwatershed was then estimated using the *E. coli* production rate of Zeckoksi et al. (2005).

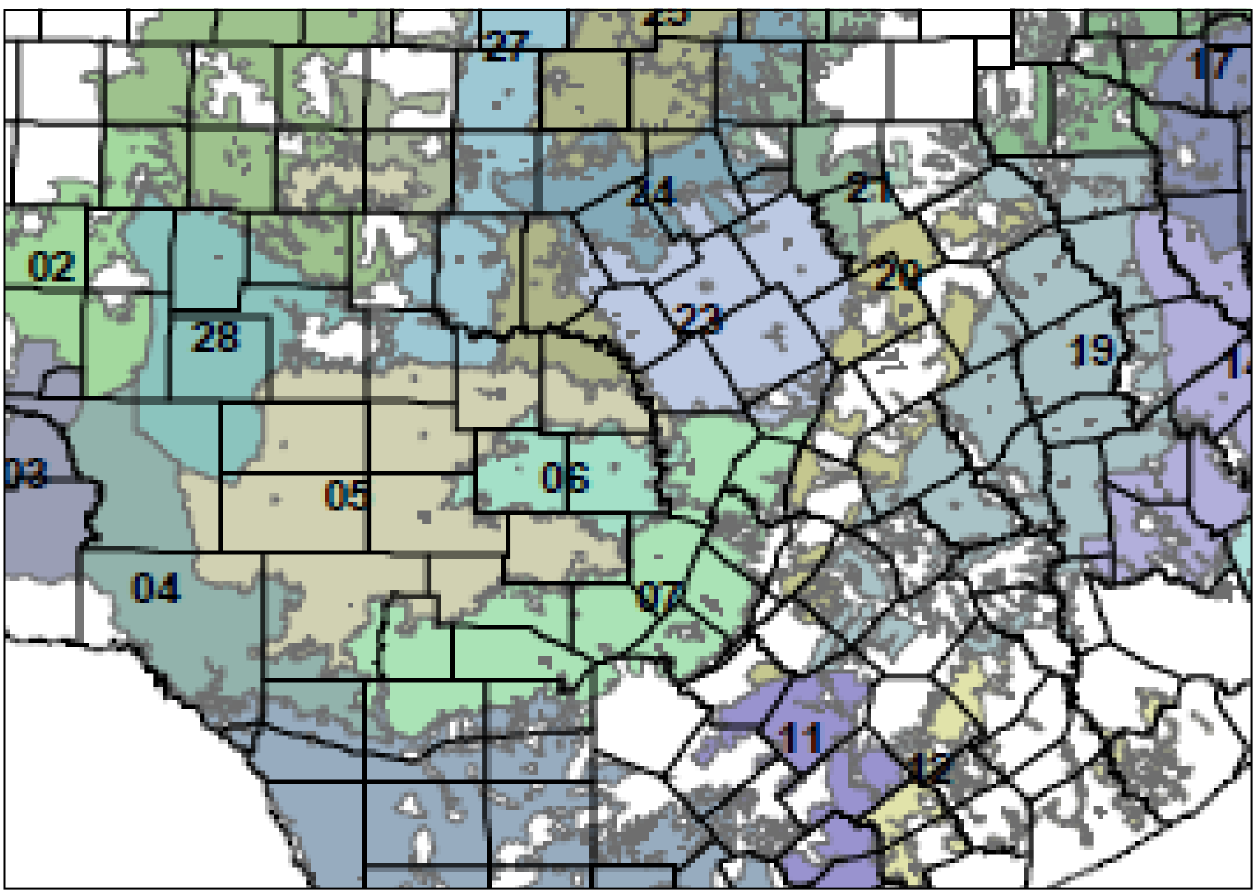

Figure F.2. TPWD RMU boundaries.

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 500 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.

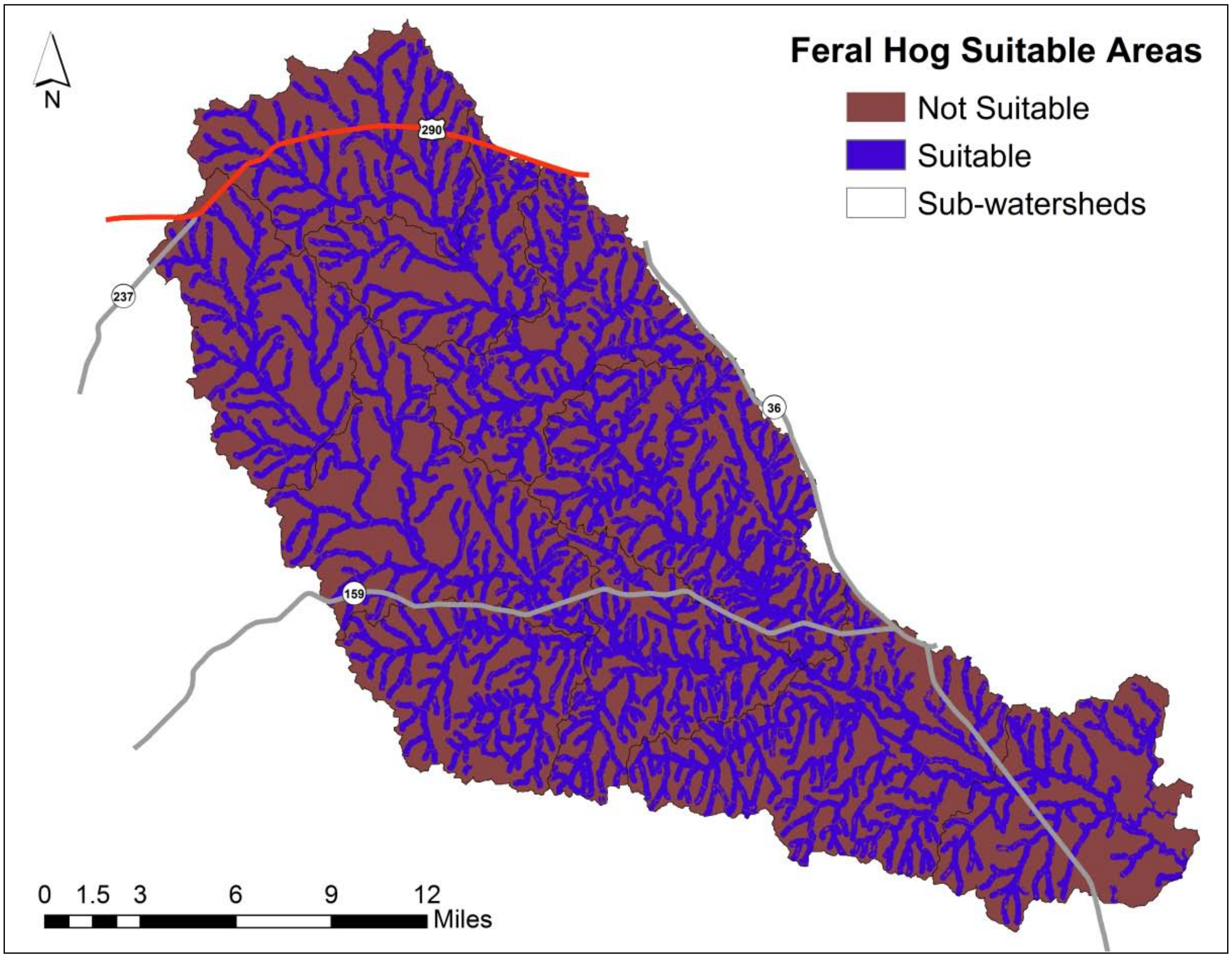

Figure F.3. The most suitable habitat for feral hogs.

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.

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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.
*** Reductions 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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AGRICULTURAL MANAGEMENT PRACTICES

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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