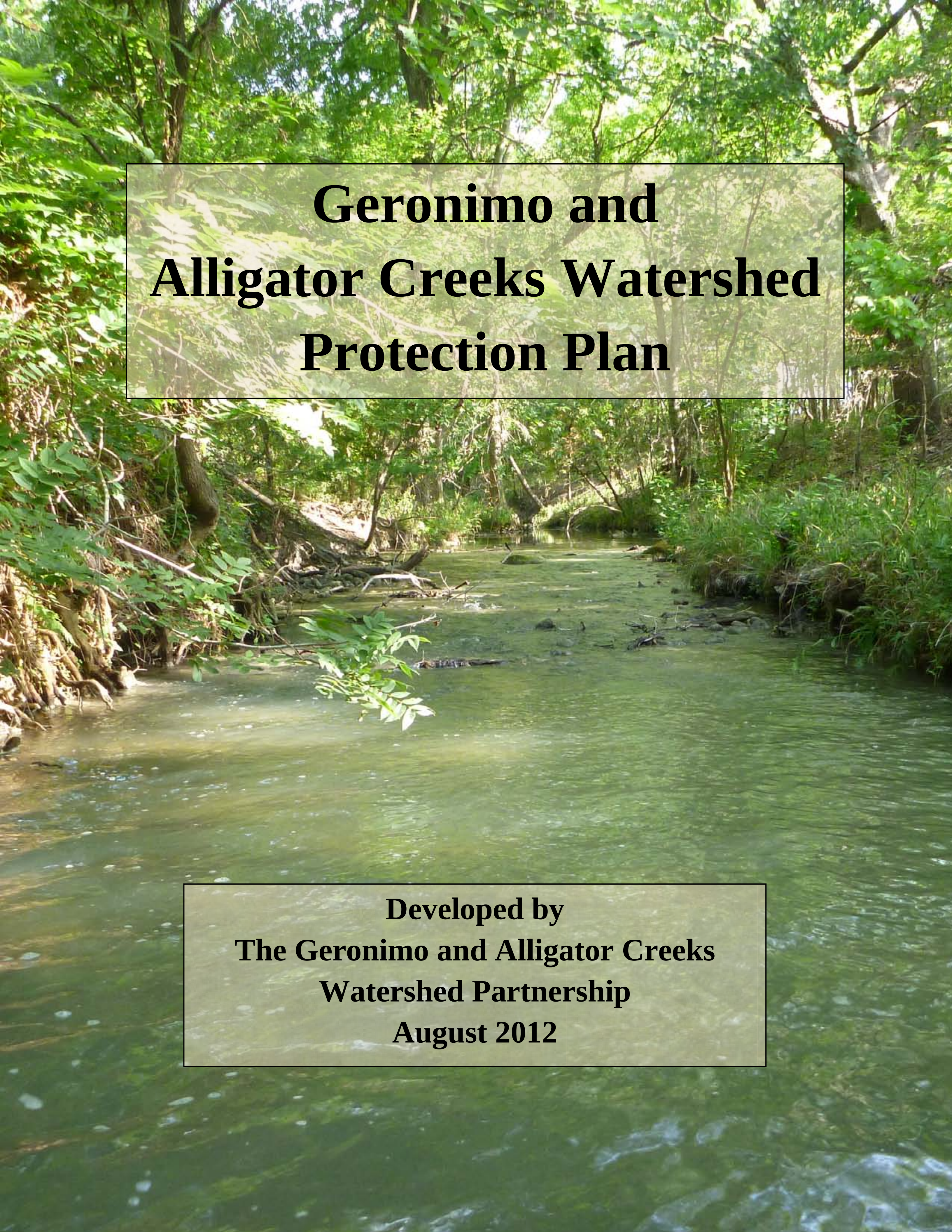

Geronimo and Alligator Creeks Watershed Protection Plan

Developed by
The Geronimo and Alligator Creeks Watershed Partnership
August 2012

Cover photo of Geronimo Creek at the Haberle Road sampling station.

Geronimo and Alligator Creeks Watershed Protection Plan

Prepared for the

Geronimo and Alligator Creeks Partnership

by

Ward Ling and Mark McFarland
Texas AgriLife Extension Service, Department of Soil and Crop Sciences

Debbie Magin
Guadalupe-Blanco River Authority

Loren Warrick and Aaron Wendt
Texas State Soil and Water Conservation Board

Funding for the development of this Watershed Protection Plan was provided through a federal Clean Water Act §319 (h) grant to the Guadalupe-Blanco River Authority, administered by the Texas State Soil and Water Conservation Board from the U.S. Environmental Protection Agency.

Acknowledgements

This document and the efforts behind its completion are the result of collaboration and cooperation between many different groups and individuals. Each has played an important role in the Geronimo and Alligator Creeks Watershed Partnership.

First and foremost, the Partnership wishes to express thanks to members of the Steering Committee for their investments of time and energy in participating throughout the process. Without their direction and support, development of this plan would not have been possible. Through the Geronimo and Alligator Creeks Watershed Protection Plan, their efforts serve as an example to all stakeholders of the importance of active stewardship of water resources.

The Geronimo and Alligator Creeks Watershed Partnership also would like to thank the members of the Urban Nonpoint Source Work Group, the Agricultural Nonpoint Source Work Group, and the Wastewater Work Group. Their specialized knowledge and expertise were key ingredients for a stakeholder developed plan. The Partnership would also like to thank members of the Technical Advisory Group for their assistance and advice:

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

The Partnership expresses thanks to Dr. R. Karthikeyan and Kyna McKee of the Texas A&M University Biological and Agricultural Engineering Department and Taesoo Lee and Dr. Raghavan Srinivasan of the Texas A&M University Spatial Sciences Laboratory for their expertise and tremendous assistance in analyzing water quality for this project.

We are especially grateful to the Texas State Soil and Water Conservation Board and the Environmental Protection Agency for funding support. Funding provided through these agencies provided for the development of this Watershed Protection Plan and established a solid foundation for watershed stewardship in Geronimo and Alligator Creeks.

Statement of Purpose

Geronimo Creek has been a vital part of growth and development in the area, due in part to its ability to maintain flow during even the most severe droughts on record. It served as a critical source of water to Native Americans and to early settlers as well. The land surrounding both Geronimo an Alligator Creeks provided excellent grazing and farming opportunities. In more recent years, the upper Alligator and lower Geronimo watersheds have undergone rapid, intense urban development. In 2008, Geronimo Creek was listed by the State of Texas as having *E. coli* bacteria levels that impaired contact recreation use of the stream, as well as having elevated nitrate-nitrogen levels. In response, the Geronimo and Alligator Creeks Watershed Protection Plan was developed using a stakeholder process driven by public participation to provide a foundation for restoring water quality in Geronimo and Alligator Creeks and their tributaries. By identifying key water quality issues in the Geronimo and Alligator Creeks 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 Geronimo and Alligator Creeks Watershed Protection Plan incorporates an analysis of existing water quality data and an investigation into potential pollutant sources based on local knowledge and experience to develop a strategy for addressing concerns related to water quality and watershed health.

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, nonprofit organizations, and state agencies. This document is a means by which stakeholders can become more familiar with the Geronimo and Alligator Creeks Watershed and actively make a difference in the quality and health of their streams through voluntary management practices. It is a starting point to focus restoration efforts and enable financial and technical assistance to facilitate improvements in Geronimo and Alligator Creeks. This Watershed Protection 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.

Table of Contents

Page

Page

List of Figures

Figure **Page**

Figure		Page

List of Tables

Table **Page**

Table **Page**

Executive Summary

Geronimo Creek is listed as impaired for contact recreation and nutrient enrichment concerns on the 2008 and 2010 303(d) List of Impaired Waters. Levels of *E. coli* bacteria exceeded water quality standards for contact recreation use, and nitrate-nitrogen concentrations exceeded screening levels resulting in a nutrient enrichment concern. Elevated levels of *E. coli* indicate the potential presence of pathogenic organisms. Elevated nitrate-nitrogen levels can cause health problems in drinking water, excessive growth of aquatic plants and algae that can lead to degradation of aquatic habitat, loss of recreation, and fish kills.

Geronimo Creek and its tributary Alligator Creek are located in Comal and Guadalupe Counties. The almost 70-square-mile Geronimo Creek watershed lies within the larger Guadalupe River Basin. Alligator Creek begins on the west side of IH-35 and flows southeast through a rapidly developing area of the Austin-San Antonio corridor before its confluence with Geronimo Creek midway through the watershed. The upper portion of the watershed lies in the extra-territorial jurisdiction (ETJ) of New Braunfels, while the lower portion is in the ETJ of Seguin. As development and population growth continue, the conversion of rural land to urban land use will increasingly impact the hydrology and water quality in the watershed.

The Texas State Soil and Water Conservation Board (TSSWCB) Regional Watershed Coordination Steering Committee (WCSC) selected Geronimo Creek for development of a watershed protection plan (WPP) based on criteria that included presence on the CWA 303(d) List, nutrient concerns, potential for success, ongoing activities, and level of stakeholder interest. Public meetings were held in New Braunfels and Seguin and shortly thereafter, the Geronimo and Alligator Creeks 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 the health of Geronimo and Alligator Creeks. The Partnership recognizes that success in improving and protecting water resources depends on the people who live and work in the watershed. The Geronimo and Alligator Creeks Watershed Protection Plan that was created through these efforts, will serve as a guidance document for restoring and protecting local water quality.

The Steering Committee, along with topical work groups created by the Partnership, dedicated significant time to the identification and locations of potential sources of pollutants in the project watershed. Potential sources identified are: urban runoff, dogs, cattle, goats, horses, deer, feral hogs, and wastewater. Most potential sources can contribute both bacteria and nutrients. While not of primary concern in this watershed, “other” pollutants such as sediment, pesticides and hydrocarbons (fuel, motor oil and grease) also may be present in runoff.

Through scientific analysis, researchers supporting the Partnership determined to what degree bacteria and nitrate-nitrogen levels in Geronimo and Alligator Creeks should be reduced to meet the water quality standard. Bacteria concentrations require a 26% reduction, while nitrate-nitrogen concentrations need to be reduced by 85%.

Based on an evaluation of existing water quality data and watershed characteristics, the Work Groups recommended management measures needed to reduce bacteria and nitrate-nitrogen levels in Geronimo and Alligator Creeks. Key recommendations adopted by the Steering Committee include the following:

The Urban Nonpoint Source Work Group focused on potential sources of bacteria and nitrate-nitrogen in existing urbanized areas of New Braunfels and Seguin, coupled with the plans for future growth and expansion. Dog waste and general urban storm water runoff were the two primary sources for which management measures were developed. City ordinances and pet waste collection facilities are proposed to address dog waste, which was identified as a significant potential pollutant source. An initial goal of the Partnership will be to support Seguin and New Braunfels in acquisition of funding to conduct detailed engineering analyses to properly locate and design storm water management practices specific to each city. In addition, New Braunfels will implement all the various required activities to manage storm water as part of their new Phase II storm water permit.

The Wastewater Work Group worked with both city and county personnel to identify management measures. Both the Seguin and New Braunfels Utilities signed Sanitary Sewer Overflow Initiative agreements with the Texas Commission on Environmental Quality to correct deficiencies in their sanitary sewer collection system. The water quality in Geronimo and Alligator Creeks will benefit directly from these upgrades. Seguin will extend sanitary sewer service to the Oak Village North Subdivision, taking homes off of failing septic systems. Both Comal and Guadalupe Counties will conduct educational programs for homeowners on septic systems.

The Agricultural Nonpoint Source Work Group recommends implementation of voluntary site-specific Water Quality Management Plan 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 grassed waterways, nutrient management, and conservation easements are highly recommended as pollution control approaches in the Geronimo and Alligator Creeks watershed. To address concerns over feral hogs, the Work Group will rely heavily upon the expertise and resources of the Texas Wildlife Services for feral hog technical assistance, education, and direct control. In addition, the goal is employ a full-time position to focus specifically on feral hog management in the Geronimo and Alligator Creeks watershed. This effort will be further supported by the use of an online feral hog reporting website, similar to the one developed for the Plum Creek watershed.

As the recommended management measures of the Geronimo and Alligator Creeks Watershed Protection Plan are put into action, it will be essential to monitor water quality and make any needed adjustments to the implementation strategy. Routine water quality monitoring at the Haberle Road station, as well as, the newly established monitoring station near the confluence with the Guadalupe River will continue throughout the implementation phase. In addition, the Guadalupe-Blanco River Authority will conduct a special study to attempt to determine the sources of the elevated nitrate-nitrogen. 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 Geronimo and Alligator Creeks were developed based on complete implementation of the watershed protection plan, with interim goals, and assume full accomplishment of pollutant load reductions by the end of the 10-year project period. The Partnership will evaluate progress towards achieving programmatic and water quality goals at years 3, 6, and 10 and make critical decisions at those year milestones. However, it can be assumed that reductions in the loadings will be tied to the 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 Geronimo and Alligator Creeks Watershed Partnership will continue to meet on a quarterly, or as needed, basis to receive updates on the progress of implementation efforts and guide the program through adaptive management actions. Ultimately, it is the goal of the Partnership and this plan to improve and protect water quality in Geronimo and Alligator Creeks so that they are restored and preserved for present and future generations.

1. Watershed Management

A watershed is an area of land that water flows across, through, or under on its way to a single 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 separated 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 with it 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 or a single point, such as a pipe 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 their effluent is permitted with specific pollutant limits to reduce their impact on the receiving stream.

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 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 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 Geronimo and Alligator Creeks 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 (Figure 1.1).

Figure1.1. Stakeholders who participated in a tour of the watershed in 2010.

2. Overview of the Watershed

GEOGRAPHY

Geronimo Creek and its tributary Alligator Creek are located in Comal and Guadalupe Counties. The almost 70-square-mile watershed lies within the larger Guadalupe River Basin. The headwaters of Alligator Creek begin in southeastern Comal County, just above IH-35 (Figure 2.1). Alligator Creek flows southeast towards Seguin until about midway in the watershed where it joins Geronimo Creek. The majority of Alligator Creek is intermittent with pools during much of the year, until just above its confluence with Geronimo Creek, where it receives spring flow. Geronimo Creek rises approximately 1 mile east of the community of Clear Springs in northwestern Guadalupe County and runs southeast for 17 miles to its confluence with the Guadalupe River, 3 miles southeast of Seguin (Figure 2.2). The majority of the Alligator Creek watershed lies within the extra-territorial jurisdiction (ETJ) of New Braunfels, while the majority of the Geronimo Creek watershed is almost entirely within the ETJ of Seguin (Figure 2.3). Geronimo Creek is perennial, receiving flows from Alligator Creek, Baer Creek, an unnamed tributary, and numerous springs along its length.

Figure 2.1. Alligator Creek flowing through a rural portion of the watershed.

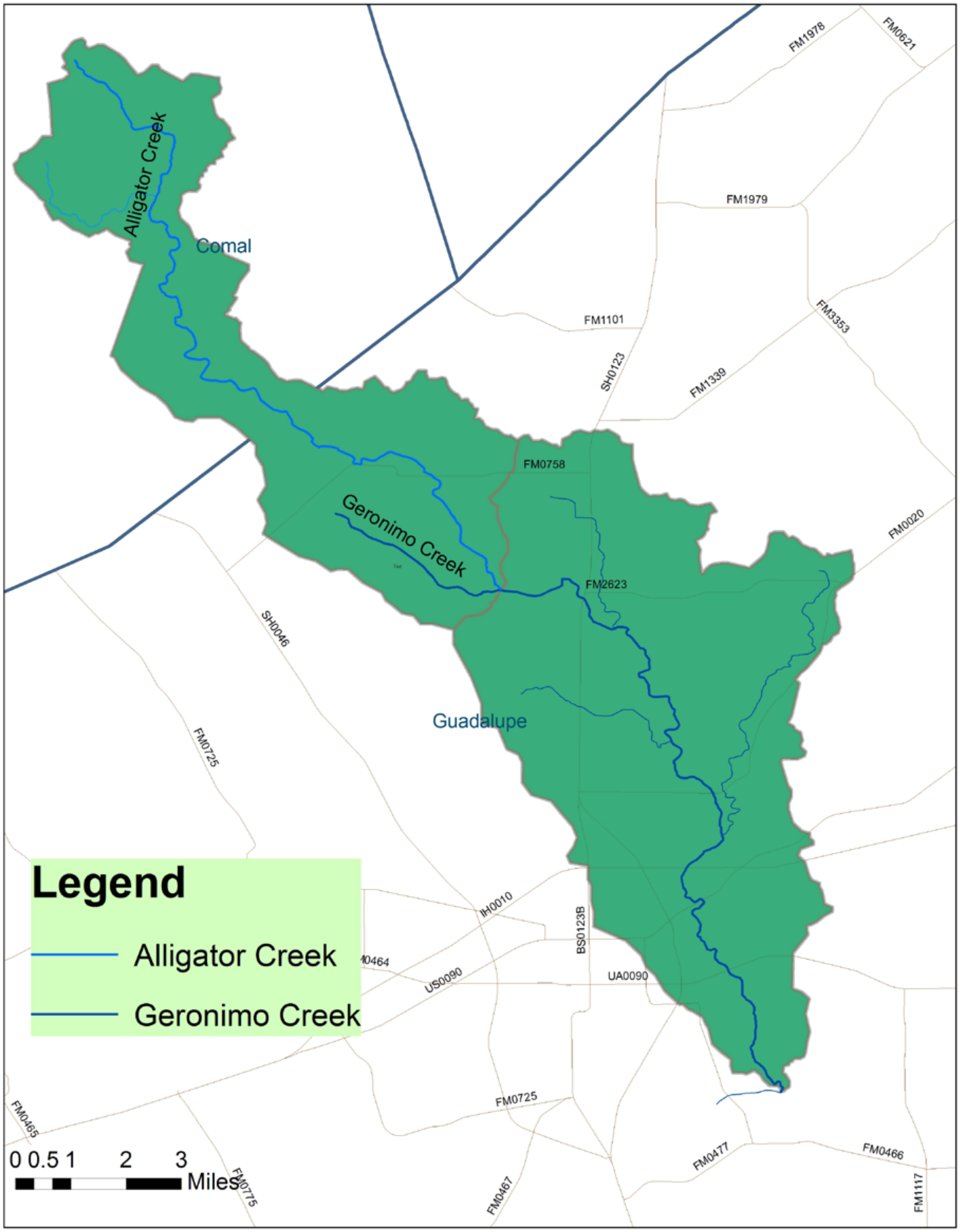

Figure 2.2. The Geronimo and Alligator Creeks Watershed.

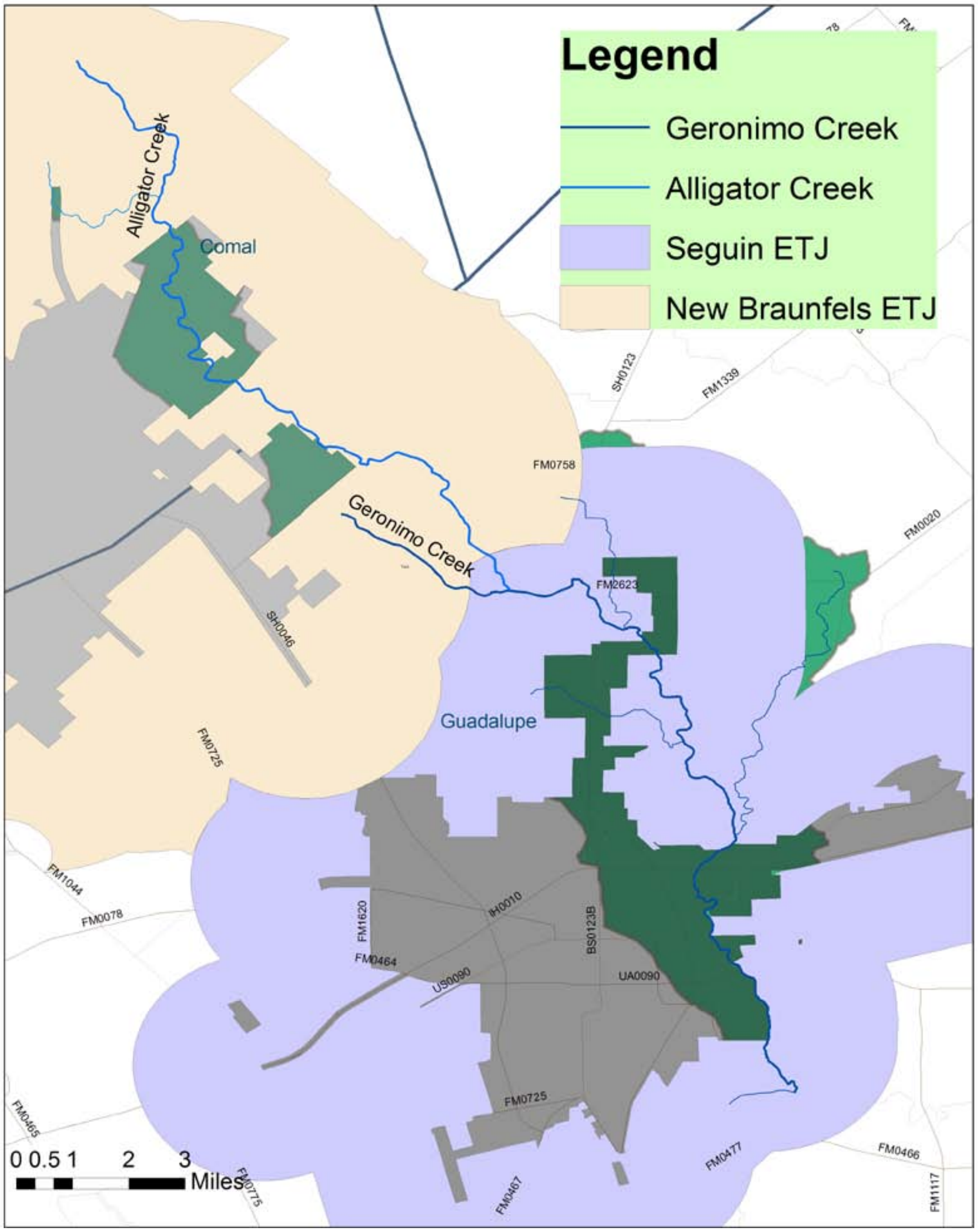

Figure 2.3. ETJs in the Geronimo and Alligator Creeks Watershed.

PHYSICAL AND NATURAL FEATURES

Ecoregions

While the headwaters of Alligator Creek begin in the Edwards Plateau/Blackland Prairies transition ecoregion zone, the majority of Alligator Creek and the entirety of Geronimo Creek flow through the Blackland Prairies ecoregion (Figure 2.4). The Edwards Plateau ecoregion is a rugged, semi-arid region of central Texas that is dominated by Ashe juniper, oaks and honey mesquite, with riparian corridors lined with bald cypress, pecan, hackberry and sycamores. The

Texas Blackland Prairies ecoregion historically was dominated by tallgrass species on uplands and by deciduous woodlands along riparian corridors (USDA, 1984). In the past, open areas in both ecoregions were maintained by natural fires and grazing by large herbivores. In more recent time, fire suppression has resulted in encroachment of woody plant species in many areas. Animals native to the area include white-tailed deer, javelina, beaver, bobcat, coyote, fox, skunk, raccoon, squirrel, turkey, 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 believed to be significant.

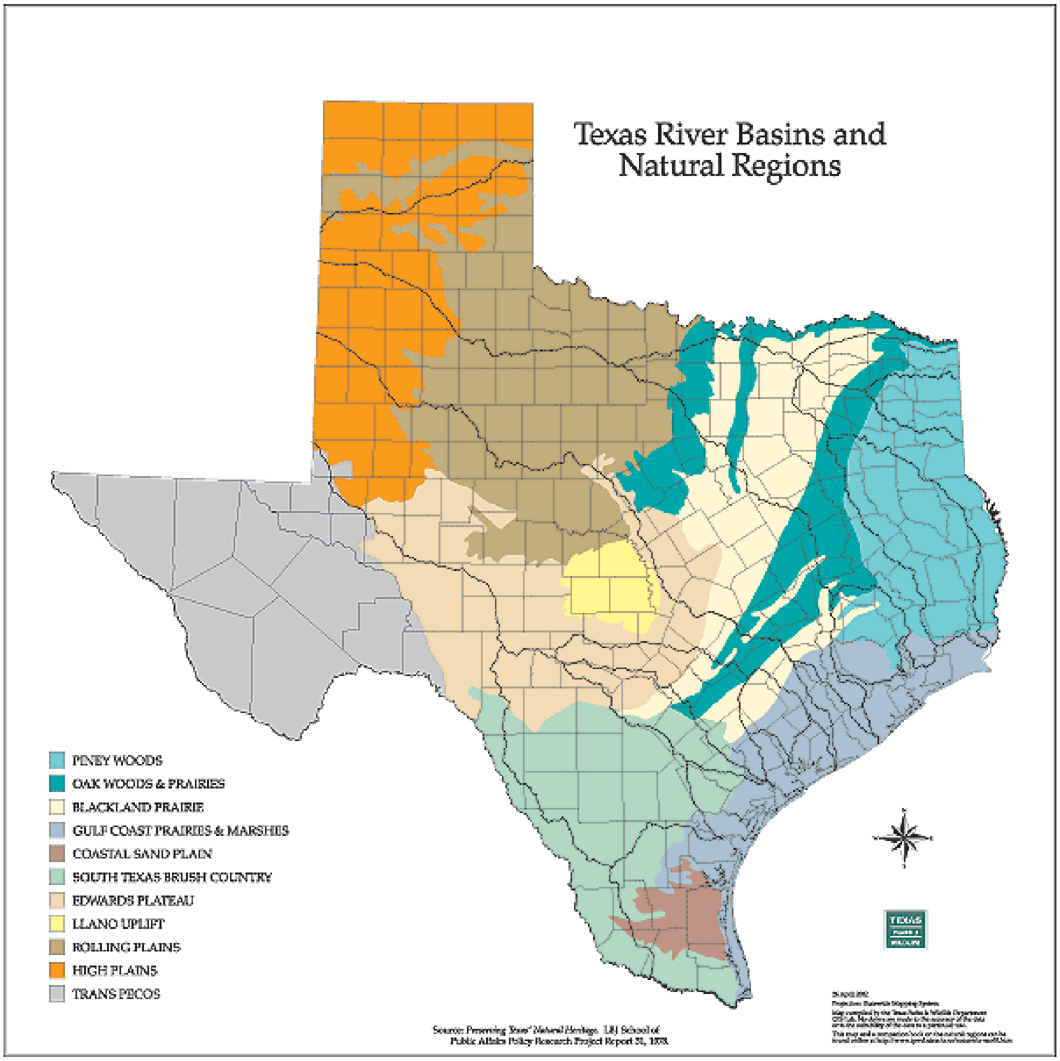

Figure 2.4. Ecoregions of Texas. Image courtesy of TPWD.

Soils

Soils in the upper end of the Alligator Creek watershed generally are shallow clayey soils with rocky outcrops (Edwards Plateau zone), transitioning to deeper clay soils on gently rolling hills farther downstream (Blackland Prairies zone) towards the confluence with Geronimo Creek. However, soils across both ecological regions are highly varied (Figure 2.5). In the upper portions of the Alligator Creek Watershed in Comal County, soils are primarily Comfort-Rock outcrop complex and Rumple-Comfort association undulating soils. Comfort-Rock outcrop complex consists of shallow, clayey soils and rock outcrops on side slopes and on hilltops and ridgetops on uplands, while the Rumple-Comfort association consists of shallow and moderately deep soils on uplands. Soils in the riparian areas of upper Alligator Creek consist primarily of Anhalt clay, a moderately deep, gently sloping dark reddish gray clay, typically overlaying fractured indurated limestone (USDA, 1984).

As Alligator Creek crosses under IH-35 and out of the Edwards Plateau/Blacklands Prairies transition zone and into the Blackland Prairies ecoregion, soils in the upland drainage area are dominated by Branyon Series clays. Branyon series consists of deep, calcareous, nearly level to gently sloping, clayey soils on ancient stream terraces. The Branyon clays are largely found in the main drainage areas of Alligator Creek, and throughout the Geronimo Creek drainage (USDA, 1977).

Water Resources

Flows in Alligator Creek are intermittent, primarily occurring only during and immediately after rainfall events. About midway through the watershed before Alligator Creek joins with Geronimo Creek, spring flows into the creek provide a more consistent supply of water. Geronimo Creek also is intermittent at its headwaters above the confluence with Alligator Creek, but receives significant spring flows below that point. Two of these springs, Timmerman Springs and an unnamed spring, provide Geronimo Creek with water even during times of intense drought. Farther downstream, Baer Creek and an unnamed tributary feed into Geronimo Creek on its way south towards the Guadalupe River.

The principle water bearing strata under the study area are the alluvium and the Leona formation. Alluvium and the Leona formation underlie the Seguin-Sunev and Branyon-Barbarosa-Lewisville associations which begin northwest of I-35 and lies to the southeast.

The chemical quality of the water from wells in the area varies greatly. Water from the alluvium and the Leona formation is generally hard and contains elevated nitrates. Nitrate concentrations vary by location within the watershed and by depth of the well. It is not uncommon to have nitrate-nitrogen concentrations at or above the primary drinking water standard of 10 mg/L.

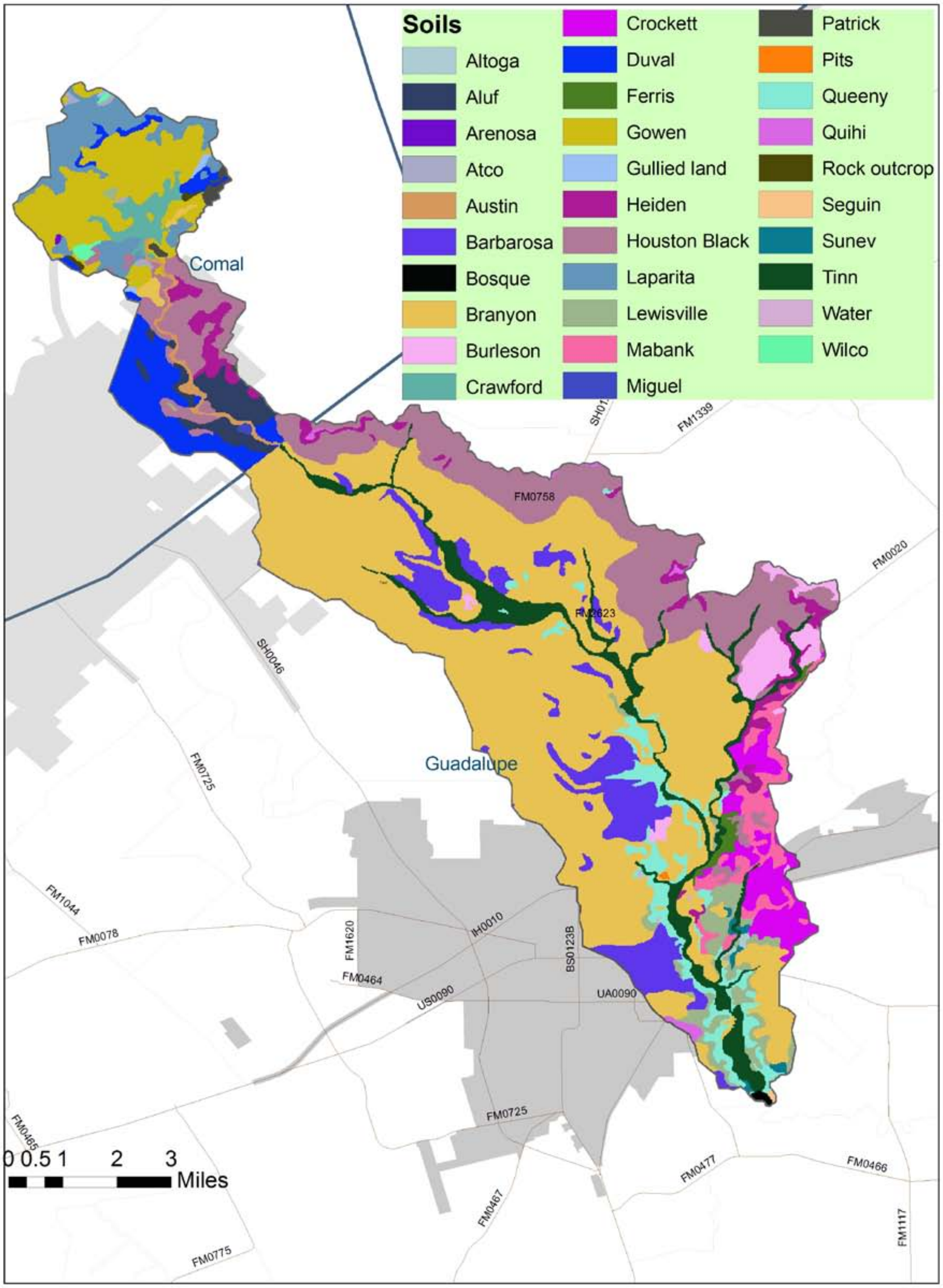

Figure 2.5. Soils of the Geronimo and Alligator Creeks Watershed.

Further exploration of the hydraulic connection between these groundwater sources and the water in the creeks may help explain the elevated nitrate-nitrogen levels in the creeks.

Fish and Benthic Macroinvertebrate Communities

Geronimo 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. The aquatic community in Geronimo Creek is representative of minimally disturbed streams of the Blackland Prairie ecoregion. Fish collected have included species such as the central stoneroller, Texas logperch, orangethroat darter, Texas shiner, largemouth and spotted bass, channel catfish, and multiple species of sunfish (Figure 2.6). Common benthic macroinvertebrates collected during sampling include mayflies, aquatic beetles, dragonflies, and dobsonflies.

Figure 2.6. Sampling fish communities in Geronimo Creek using a backpack electrofisher at the Haberle Road sampling station.

CLIMATE

The Geronimo and Alligator Creeks 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 just below 31 inches. The wettest year was 1949 with a total annual rainfall of 49.47 inches. However, in 2008 total annual rainfall for Guadalupe County was just over 10 inches. The area experienced an “exceptional drought” (Category D4) that did not break until late 2009, and experienced another extreme drought in 2011. Peak rainfall is usually the result of thundershowers in late spring. A secondary peak occurs in the fall. The prevailing winds are southeasterly March through September, and northerly October through February.

HISTORY

The earliest settlers in the Geronimo Creek watershed were Indians belonging to the Lipan Apache, Comanche and Tonkawa tribes who were drawn to the springs. These tribes were mostly nomadic, but evidence of their presence in the Geronimo Creek area is the number of arrowheads, tools and other artifacts found along the creek.

By the late 1700's, Texas was under Spanish rule. Spanish explorers had many clashes with the nomadic, native Indians in and around the area of Geronimo Creek. Archival Spanish documents from 1780 indicate that the Tio Geronimo Springs near the New Braunfels airport were owned by a Spaniard named Geronimo Flores. The area was a campsite for the Indians and visited by the Spanish scouts searching for Indians. Mr. Flores was a well-liked common man, who lived in peace with the Indians. The Spanish word *Tio* (uncle) was added to Geronimo Springs, in honor of Mr. Flores.

In the 1820's, settlers, including Stephen F. Austin and Green Dewitt began moving into the region. In a span of 50 years, Texas went from a wide open land of Indians and little civilization to a territory beginning to fill with settlers from America. Geronimo Creek and its associated springs were sought after by many settlers for the good water and excellent land for grazing and cultivation. Surveyor notes describe stands of mesquite, pecan, live oak, hackberry and elm, and shrubbery and prairie grasses found along the creek.

Texas born Jose Antonio Navarro became one of the most well-known settlers to the area. Like the Indians and soldiers, he was drawn to the area because of the springs. Navarro and his family established a ranch, where he raised cattle and horses, and he is the namesake of the Navarro Independent School District in the town of Geronimo. Other settlers that were drawn to the area were farmers and producers of German descent; cotton was the dominant crop in the area for many years.

Agriculture has always been very important in the Geronimo Creek watershed. The town of Geronimo was the center of the farming and ranching community, with cotton gins, grain storage, markets, merchandise and grocery stores and a meeting hall.

One of the most beloved families from the Geronimo Creek area is the family of William Timmermann. Timmermann had dreams of developing his property into a park for his children and the public. He bought land along the creek in 1901 that included a "waterway lane" which is an easement that allowed settlers to have access to the water in the creek. Timmermann deepened the bed of the creek and constructed two dams that provided flow for a fountain and a pond in the middle of a star formed by sidewalks. There was a fishing pond, a swimming pool with a diving board, and a bath house. Timmermann's dream of the public park came to an end with an outbreak of tuberculosis. However, it was Timmermann that noted that although there were areas in Geronimo Creek that dried up during the historic drought of the '50s, the main spring continued flowing, and the Geronimo Gin water well was able to supply area families with water.

There is a strong sense of community and history in the Geronimo Creek watershed. The Bartoskewitz family has made plans to see the history and heritage of the Geronimo Creek area preserved and passed on to future generations. The Bartoskewitzs opened the Texas Agricultural Education and Heritage Center in 2003. “The Big Red Barn” as it is known is located in the watershed off of SH-123 on Cordova Road, and has exhibits on farming and ranching.

LAND USES

Urban areas are located mainly in the upper (New Braunfels) and lower (Seguin) ends of the watershed, with rural, agricultural production lands in between. Almost the entire watershed is covered by the ETJs of the two cities.

Land use has undergone significant change since 1960. Land previously used for agricultural purposes has been converted to urban areas, both in and around the cities of New Braunfels and Seguin. In 2000, the populations of New Braunfels and Seguin were 36,494 and 22,011, respectively. In 2008, the populations of New Braunfels and Seguin were 53,547 and 26,394, reflecting 47% and 20% increases in growth, respectively. This also has been affected by proximity to cities of Austin, San Marcos, and San Antonio. Both New Braunfels and Seguin are commutable distances from these major metropolitan areas, and their increased growth is a reflection of what is occurring in the larger cities. New Braunfels is transected by the IH-35 corridor and Seguin by the IH-10 corridor, enabling easy access for commuters and commercial and industrial applications. Also, with the Guadalupe and Comal Rivers close by, tourism and water recreation activities are large contributors to the local economies.

Another significant change in land use within the agricultural realm was the conversion of cropland to pasture during the 1960s and 1970s. A portion of the cropland production was marginal due to low fertility or erosion, and was transitioned to rangeland or managed pasture resulting in a net loss of cropland. However, the area continues to be dominated by agriculture, with 92% of the land used for some kind of agricultural production. Ranch operations typically involve cattle and goat production, while corn, cotton, sorghum and oat production are the major row crops in the watershed (Figure 2.7). In the riparian areas, pecan orchards are common.

Figure 2.7. Row crop production in the Geronimo Creek Watershed.

PERMITTED DISCHARGES

The only permitted discharge in the watershed is the Geronimo Creek wastewater treatment facility (WWTF), owned and operated by Seguin. It is permitted to discharge 2.13 million gallons/day (MGD). However, the treated effluent is discharged to Geronimo Creek less than one-fourth of a mile before its confluence with the Guadalupe River. Thus, effluent from the WWTF has not contributed to the water quality impairment that has been identified in the watershed.

Neither New Braunfels Utilities or the City of Seguin have any future plans of constructing new WWTFs that would discharge to the Geronimo Creek watershed.

WATER QUALITY

Geronimo Creek has been monitored by the Guadalupe-Blanco River Authority (GBRA) as part of the Clean Rivers Program since late 1996. The creek was monitored at the SH-123 crossing (Figure 2.8) until August 2003, at which time the routine monitoring site was moved to the Haberle Road sampling location that has been monitored quarterly. The new site was a past Texas Commission on Environmental Quality (TCEQ) monitoring site and an ecoregion reference site (Figure 2.9 and Table 2.1).

Figure 2.8 Geronimo Creek just downstream of the SH-123 crossing.

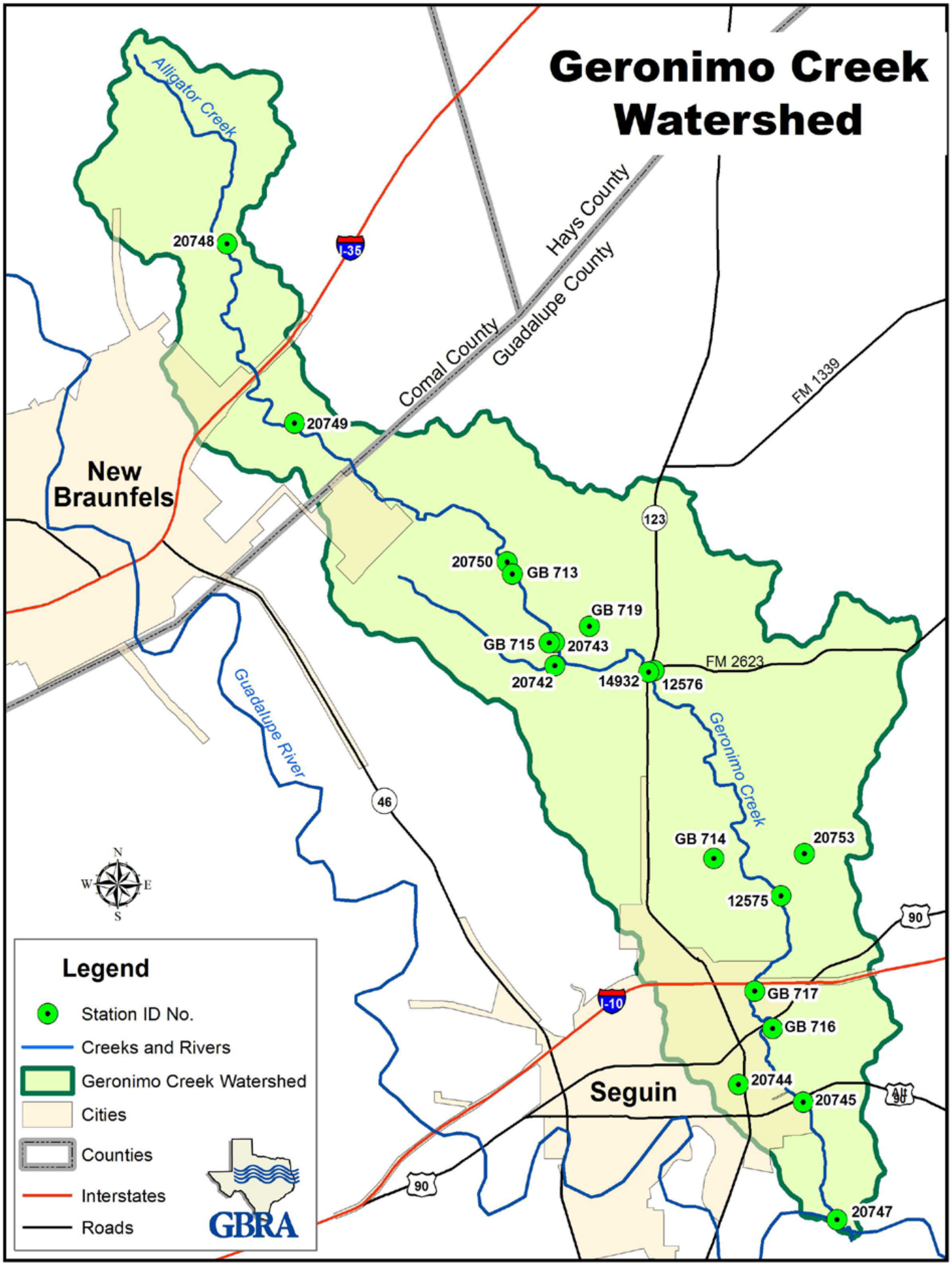

Figure 2.9. Geronimo and Alligator Creeks water sampling stations map.

Table 2.1. Sampling stations in the Geronimo and Alligator Creeks watershed.

Station ID	Description
20744	Bear Creek at East Walnut Street near Seguin, TX
20753	Unnamed tributary at Laubach Road (CR 108) near Seguin, TX
14932	Geronimo Creek at SH 123 near Geronimo, TX
GB719	Geronimo Creek headwater spring near Geronimo, TX
20742	Geronimo Creek at Huber Road near Geronimo, TX
20743	Alligator Creek at Huber Road, near Geronimo, TX
GB713	Alligator Creek Headwater Spring near Geronimo, TX
20750	Alligator Creek at Barbarosa Road (CR 107A) near Geronimo, TX
20749	Alligator Creek at FM 1101 near New Braunfels, TX
20748	Alligator Creek at FM 1102 near New Braunfels, TX
20745	Geronimo Creek at Hwy 90A in Seguin
GB717	Geronimo Creek at IH10 near Seguin
GB716	Geronimo Creek at Hwy 90 (Seguin Outdoor Learning Center)
20747	Geronimo Creek at Hollub Lane
GB715	Water well near Alligator Creek, Huber Road
GB714	Water well near Geronimo Creek at Laubach Road
12576	Geronimo Creek at Haberle Road (CRP)
12575	Geronimo Creek at FM 20

Geronimo Creek, segment 1804A, was listed on the 2000 Texas Water Quality Inventory (TWQI) with a concern for nitrate-nitrogen, and was listed again on the 2002 TWQI. The creek was not reassessed in 2004. Geronimo Creek appeared on the 2006 Texas 303(d) List with a concern for nitrate-nitrogen and an impairment of the contact recreation use, due to elevated bacteria concentrations. All waters across the state are considered to have a contact recreation designated use. All stream segments are assessed by comparing the geometric mean of the *E. coli* bacteria data available over the previous seven years to a standard. The geometric mean must be below 126 colony forming units (cfu) per 100 milliliters or the stream will be listed as impaired for bacteria. The 2008 and 2010 TWQI and Texas 303(d) List identified Geronimo Creek as impaired for contact recreation because the geometric mean for *E. coli* bacteria (162 cfu per 100 milliliters) exceeded the contact recreation stream standard established by the TCEQ. In addition, Geronimo Creek was listed as a concern due to elevated nitrate-nitrogen concentrations because all 60 measurements exceeded the screening level of 1.95 mg/L established by the TCEQ.

Since the data utilized for the Texas 303(d) List were from a limited geographic range, GBRA initiated an extensive monitoring program on Geronimo and Alligator Creeks and their tributaries as part of the development of the WPP. Data collection was conducted at 19 sites throughout the watershed. The goal was to reduce the area of influence upstream of monitoring locations in order to possibly identify “hot spots,” or areas of substantial pollutant loading. Identification of these areas would be useful for guiding implementation efforts. Some sampling of area water wells also was conducted to explore possible hydraulic connections between groundwater and surface water. Unfortunately, the exceptional drought hampered data collection at several sites due to no water or no flow. Therefore, the data collected during that period contains gaps and was not collected during “normal” conditions and is of limited use.

WATERSHED SELECTION

Selection of Geronimo and Alligator Creeks for WPP development was timely due to several factors: the City of Seguin was preparing their Master Plan to guide future development, Guadalupe County had recently received funding from the Texas Water Development Board (TWDB) for a Flood Control Study on Alligator and Geronimo Creeks, and partner support for a watershed protection planning project was high due to Geronimo Creek being listed on the Texas 303(d) List for contact recreation impairment and nutrient concerns.

The Texas State Soil and Water Conservation Board (TSSWCB) Regional Watershed Coordination Steering Committee (WCSC) prioritizes watersheds for WPP development using a set of established criteria. The WCSC is a cooperative committee of river authorities, local governments, and state and federal agencies with an interest in water quality protection, and was formed to guide the regional process of watershed protection in a 47-county area covering most of Southeast and South Central Texas. In 2008, Geronimo Creek was in the top three prioritized watersheds.

After completion of a very successful watershed protection planning project for Plum Creek in the Guadalupe River basin, GBRA partnered with and subcontracted Texas AgriLife Extension to assist with this project. GBRA obtained a Clean Water Act §319(h) grant from the TSSWCB through the United States Environmental Protection Agency (EPA) to support the planning process.

3. The Geronimo and Alligator Creeks 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. Over 350 notifications were sent by direct mail to known potential stakeholders throughout the watershed. Stakeholders were defined as those who make and implement decisions, those who are affected by the decisions made, or 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 October 2009, with one in the upper (New Braunfels) and one in the lower (Seguin) portion of the watershed. Over 100 stakeholders attended these public meetings where information was provided regarding conditions in Geronimo and Alligator Creeks and the proposed development of a WPP. Participants were invited to become members of the Geronimo and Alligator Creeks Partnership and asked to help notify other potential stakeholders that should be part of the process.

PUBLIC MEETINGS

Monthly public meetings facilitated by GBRA and Texas AgriLife Extension were held in the watershed, alternating between Partnership Meetings and various work group meetings (Figure 3.1). Technical issues were presented in detail to work groups 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 18 Work Group meetings and 6 Partnership meetings were conducted during the plan development process.

PARTNERSHIP STRUCTURE

Steering Committee Membership Formation

The Steering Committee is composed of stakeholders from the Geronimo and Alligator Creeks Watershed. Initial solicitation of members to obtain equitable geographic and topical representation was conducted using three methods: 1) consultation with Texas AgriLife Extension Service County Agents, GBRA, Comal-Guadalupe Soil and Water Conservation

District and local and regional governments, 2) meetings with various stakeholder interest groups and individuals, and 3) self-nomination or requests by various stakeholder groups or individuals.

Figure 3.1. Stakeholders participated in numerous Work Group and Steering Committee meetings.

The Steering Committee was designed to reflect the diversity of interests within the Geronimo and Alligator Creeks 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 24 members solely for reasons of practicality. The public was encouraged to attend all meetings and provide input throughout the planning process.

The Steering Committee provided the method for public participation in the planning process and was instrumental in obtaining local support for actions aimed at restoring surface water quality in Geronimo and Alligator Creeks.

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
- Subdivision developments

Ground Rules

The Steering Committee is the decision-making body for the Partnership. 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. 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 (Seguin Master Plan and the TWDB Flood Study); and
- Regional cooperation.

Development of the Geronimo and Alligator Creeks WPP required a 3 year period. However, achieving water quality improvements will likely require significantly more time, since implementation is an iterative process of executing programs and practices with evaluation of 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 (geomean of 126/cfu *E. coli* and 1.95 mg/L nitrate-nitrogen), 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 the successful implementation of the plan, Steering Committee members signed the final WPP.

Work Groups

Three topical work groups were formed by the Steering Committee: Agricultural Nonpoint Source, Urban Nonpoint Source, and Wastewater Infrastructure. Each Work Group was composed of Steering Committee members and any other members of the Partnership, including the Technical Advisory Group, with expertise and/or a vested interest in that topic. There was no limit to the number of members on a work group, and approximately 18 Partnership members participated in each work group meeting. Functions of the Work Groups were as follows:

- <u>Agricultural Nonpoint Source Work Group</u> – The purpose of this Work Group was to identify potential sources of nonpoint source pollution stemming from agricultural land uses. This included cropland, pastureland, rangeland, and forestland. Sources discussed included runoff from cropland, livestock, wildlife and feral hogs (invasive species). This Work Group recommended strategies and practices to reduce and prevent pollution from these sources. In addition, outreach and education programs for targeted audiences associated with these sources were identified.

- <u>Urban Nonpoint Source Work Group</u> – The purpose of this Work Group was to identify potential sources of nonpoint source pollution stemming from urban land use. This included residential, commercial, and industrial areas. Sources discussed included runoff from "paved" surfaces, pets, and other non-livestock domestic species. Urban growth and development were key issues. This Work Group recommended strategies to reduce and prevent pollution from these sources, as well as outreach and education programs for urban audiences.

- <u>Wastewater Infrastructure Work Group</u> – The purpose of this Work Group was to discuss potential sources of pollution stemming from on-site sewage facilities (OSSFs or septic systems) and WWTFs. Regionalization of wastewater treatment, the conversion of OSSFs to a centralized WWTF, and repair/replacement of OSSFs were among the key issues discussed. This Work Group recommended strategies to reduce and prevent pollution from these sources, and outreach and education programs for related audiences.

Technical Advisory Work Group

A Technical Advisory Group (TAG) consisting of state and federal agencies with water quality responsibilities provided guidance to the Steering Committee and participated in each Work Group. 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
- Texas AgriLife Extension Service
- Texas AgriLife Research
- Texas Department of Agriculture (TDA)
- Texas Parks and Wildlife Department (TPWD)
- Texas State Soil and Water Conservation Board
- Texas Water Development Board
- 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 Geronimo and Alligator Creeks 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 classifications was conducted (Figure 4.1).

The first step in development of the land use dataset was to select appropriately dated imagery for the Geronimo and Alligator Creeks watershed. This was accomplished using aerial imagery with 1-meter resolution available through the National Agriculture Imagery Program. Imagery taken during 2008 was 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 B for complete descriptions and a full explanation of land use data).

Figure 4.1 This example of the forest land use classification is along Geronimo Creek near the Haberle Road sampling station.

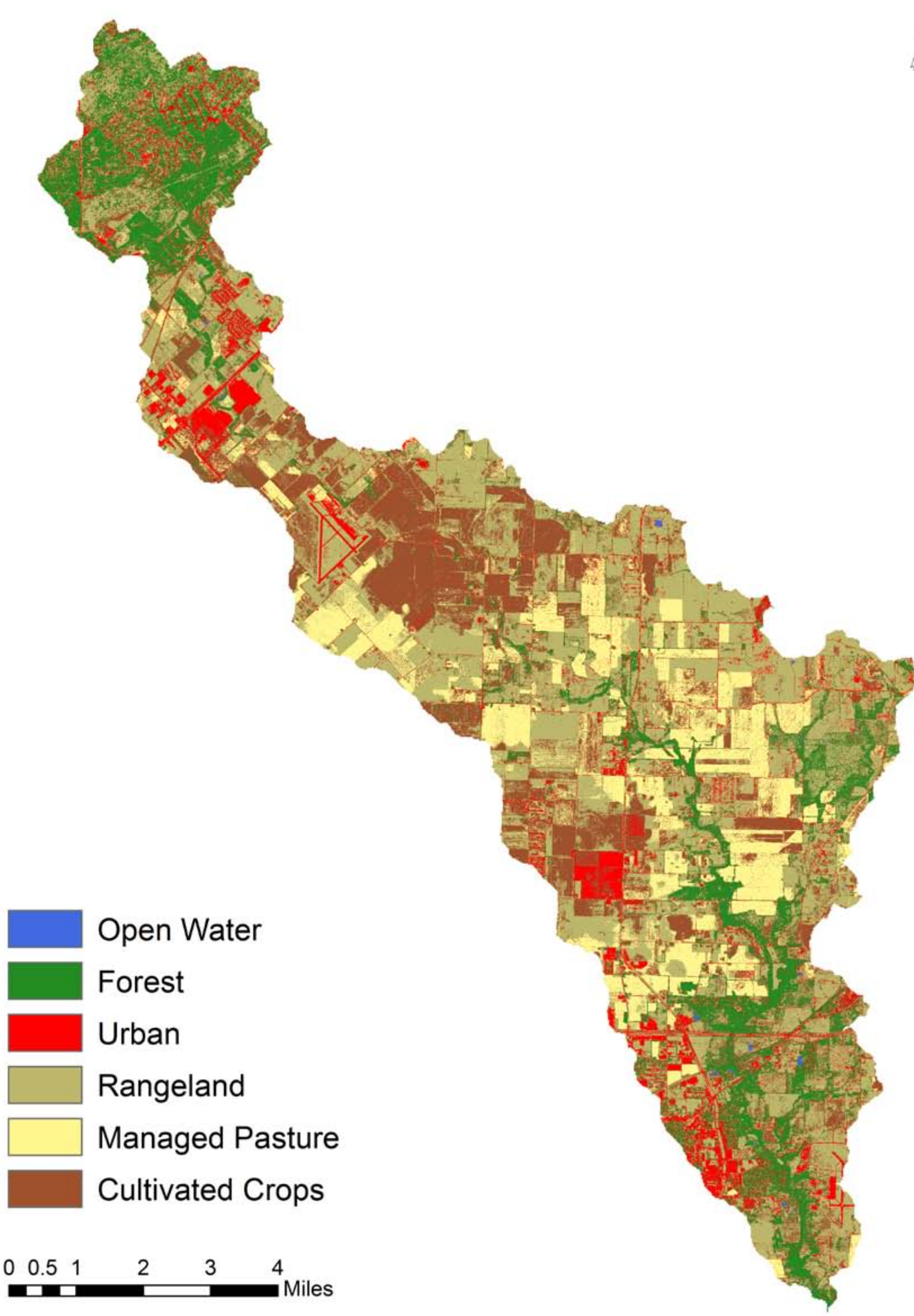

Figure 4.2. Geronimo and Alligator Creeks Watershed land use map.

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 39% rangeland, 23% cropland, 15% managed pasture, 15% forest, and 8% urban areas.

Table 4.1. Summary of land uses in the Geronimo and Alligator Creeks Watershed.

Land Use	Percentage of Total	Acres
Rangeland	39.4	16,397
Cultivated Crops	22.5	9,381
Managed pasture	15.4	6,406
Forest	14.6	6,088
Urban	7.9	3,282
Open water	0.2	72
Total	100.0	41,626

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

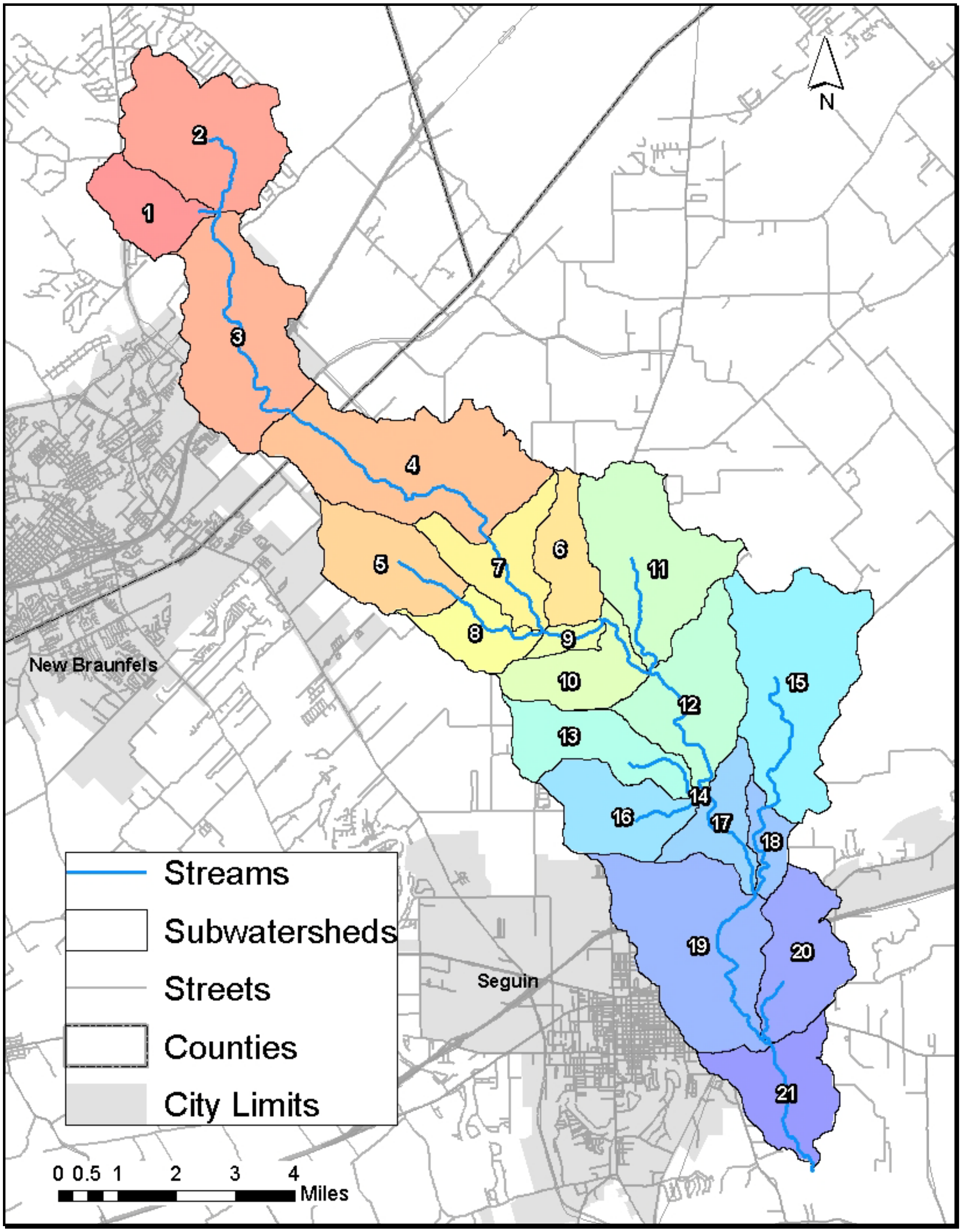

Figure 4.3. Subwatersheds of the Geronimo and Alligator Creeks Watershed.

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). An LDC allows for a visual determination of pollutant loadings under different flow conditions. The first step in developing an 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 Flow Estimates

There are no stream flow gages on Geronimo or Alligator Creeks. As a result, the Soil and Water Assessment Tool (SWAT) was utilized to develop flow estimates for the watershed by modeling flow in a larger portion of the Guadalupe River Basin (including Geronimo and Alligator Creeks). Model outputs were compared to historic flow data from USGS stream gages above and below the confluence of Geronimo Creek. These data along with data from a stage height gage on Geronimo Creek at SH-123, flow data from the USGS flow stations, and instantaneous flow data from Geronimo Creek (at the SH-123 and Haberle Road sites) were used for model calibration (see Appendix E for a more complete explanation of SWAT).

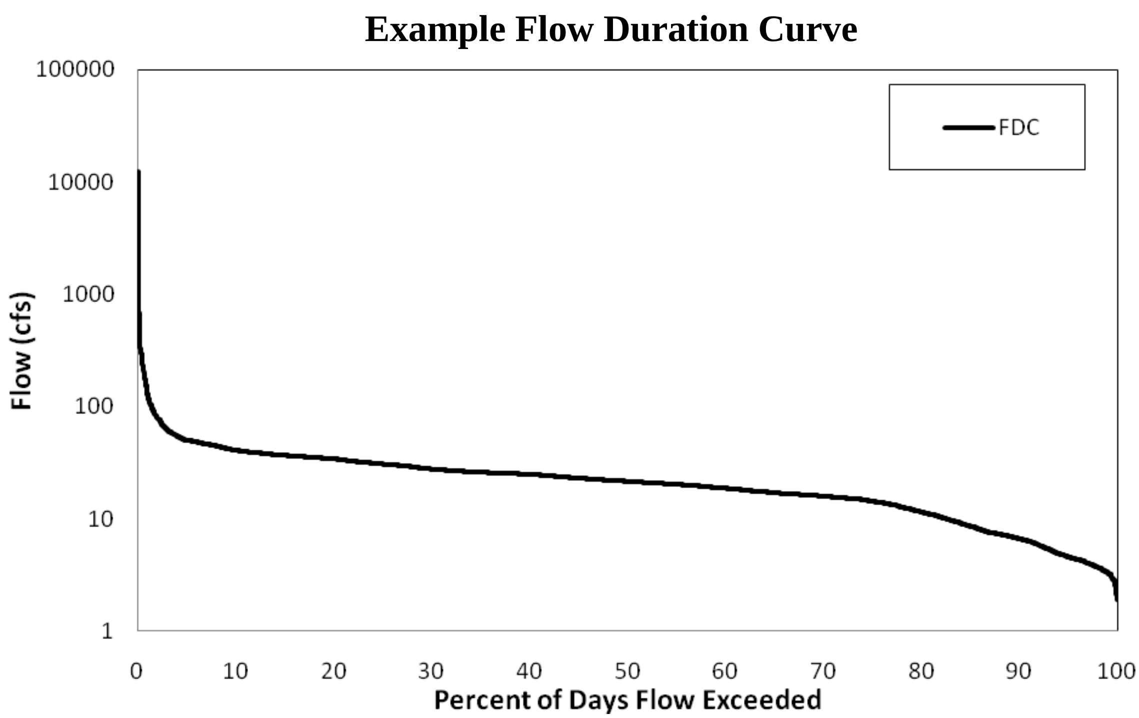

Figure 4.4. Example flow duration curve. Historical stream flow data are used to determine how frequently stream conditions exceed different flows.

Next, data from the flow duration curve are multiplied by the concentration of the water quality criterion 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 standard. 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 both bacteria and nitrate-nitrogen in this plan. As previously discussed in Chapter 1, the geometric mean of *E. coli* must be below 126 cfu/100 mL and nitrate-nitrogen concentrations must be below the screening level of 1.95 mg/L to avoid being listed as a water quality concern. Thus, threshold concentrations used in the LDC analysis were 113 cfu/100 mL [126 – (126 x 0.1)] for bacteria and 1.76 mg/L [1.95 – (1.95 x 0.1)] for nitrate-nitrogen, as approved by the Steering Committee.

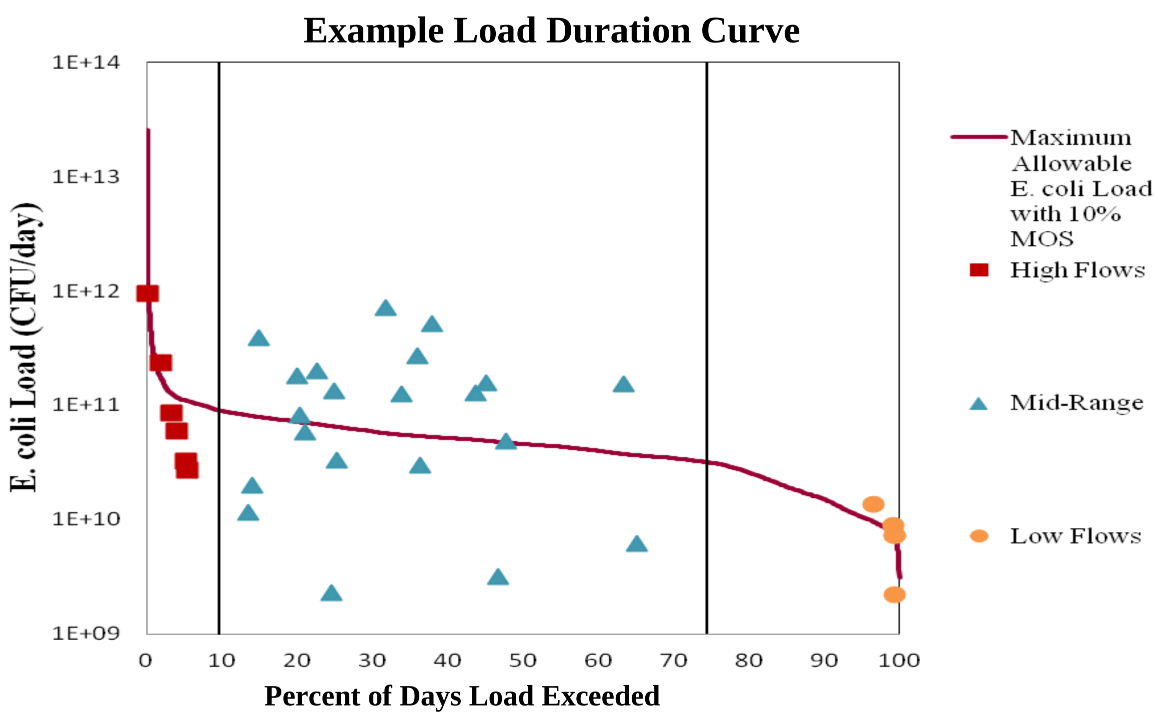

Figure 4.5. Example load duration curve. Multiplying stream flow by pollutant concentration produces an estimate of pollutant load.

Stream monitoring data for a pollutant can be plotted on the curve to show the frequency and magnitude of exceedances. In the example in Figure 4.4, 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. Typically, flow regimes are identified as areas of the LDC where the slope of the curve changes. In this example, as in the actual LDCs for Geronimo and Alligator Creeks, there are three flow regimes: high (0-10), mid range (11-74), and low flows (75-100). 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 3, 24, and 18% are needed at high, mid-range and low flows, respectively.

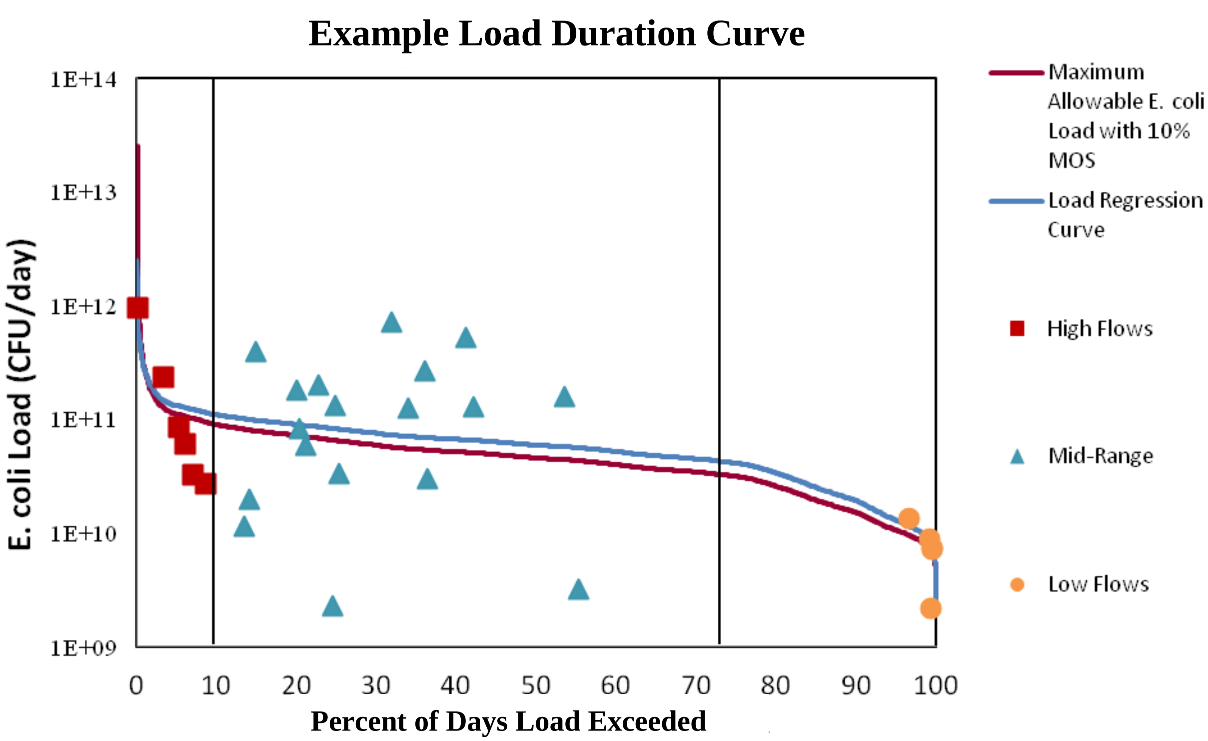

Figure 4.6. Example load duration curve with monitored samples and calculated "line of best fit."

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 considered to be the primary causes of impairment. This is because high flows are typically associated with higher rainfall events that generate surface runoff which can carry pollutants to the stream. In contrast, exceedances at low flows are generally attributed to point sources since no runoff is entering the stream and only direct discharges or deposition into the stream are contributing (see Appendix D for a more detailed explanation of 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 Geronimo and Alligator Creeks 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 21 subwatersheds based on the best available data and information regarding its presence in a given subwatershed. Geographical distributions and 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 G.

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 determining 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 Geronimo and Alligator Creeks 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 Geronimo and Alligator Creeks 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 distributions, or other factors, the Geronimo and Alligator Creeks 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

LDC analysis for the Geronimo and Alligator Creeks watershed was conducted for the only two locations with sufficient data, Geronimo Creek at SH-123 and Geronimo Creek at Haberle Road. As discussed earlier, routine sampling at the SH-123 site began in 1996 and continued through spring of 2003. In fall of 2003, the SH-123 site was relocated downstream to the end of Haberle Road due to safety concerns, and that site has since served as the only routine monitoring station in the watershed (Geronimo Creek has only one assessment unit). As a result, the Haberle Road location is the site with the most current data, represents a larger area of the watershed (the SH-123 sampling station and the Haberle Road sampling station have drainage areas of 19,423 and 26,731 acres, respectively), and has greater flow due to contributions from several springs and a small tributary. Data from the Haberle Road sampling station is utilized by TCEQ for the 305(b) assessment of Geronimo Creek and is a TCEQ ecoregion reference site. For these reasons, the Haberle Road sampling station was used to determine load reduction goals for the watershed and for assessing future changes. The Steering Committee opted to use the load reduction goal of 26% calculated for the Haberle Road sampling station since it is more conservative, considers changes in pressures in the watershed with population growth, and is thus, more protective of the watershed for the long term. This load reduction has been applied across the watershed for all sources and all flow regimes. Most BMPs have impact across all flow regimes, with highest efficiencies at their design flows. Analysis of data from the Haberle Road sampling site reveals no load reduction is necessary at low flows, but there exists individual sample results above the geomean standard (126 cfu/100mL) for contact recreation. It is anticipated that application of the 26% load reduction across all flow regimes will reduce or eliminate these occasional exceedances. The 1996-2003 data for the SH-123 sampling location also were analyzed to provide supplemental information.

In 2008, monitoring was initiated at the SH-123 site, as well as 18 other sites, to collect additional data. The purpose of the monitoring was to support planning efforts by identifying areas of concern and potential locations where management measures should be focused, as well as to assist in the selection of a second routine monitoring site. The additional data from the 18 sites were not used for LDC development due to the limited number of data points collected. Although the majority of the data for the SH-123 site are pre-2003, data from the more recent targeted monitoring effort also were included in the analysis for that site. Stakeholders wanted a sampling location near the lowest point of the watershed. In response, a new sampling location (20747) was added to the monitoring schedule, and will be used to assist with monitoring implementation activities.

BACTERIA LOADS

SH-123 Monitoring Station

Results of the LDC analysis for the SH-123 site indicate that the bacteria water quality standard for contact recreation is not supported at any flow level (Fig 4.7). Based on the regression analysis, reductions in *E. coli* loads of 8, 22, and 21% will be required at high, medium and low flows, respectively, to achieve the water quality criterion for primary contact recreation.

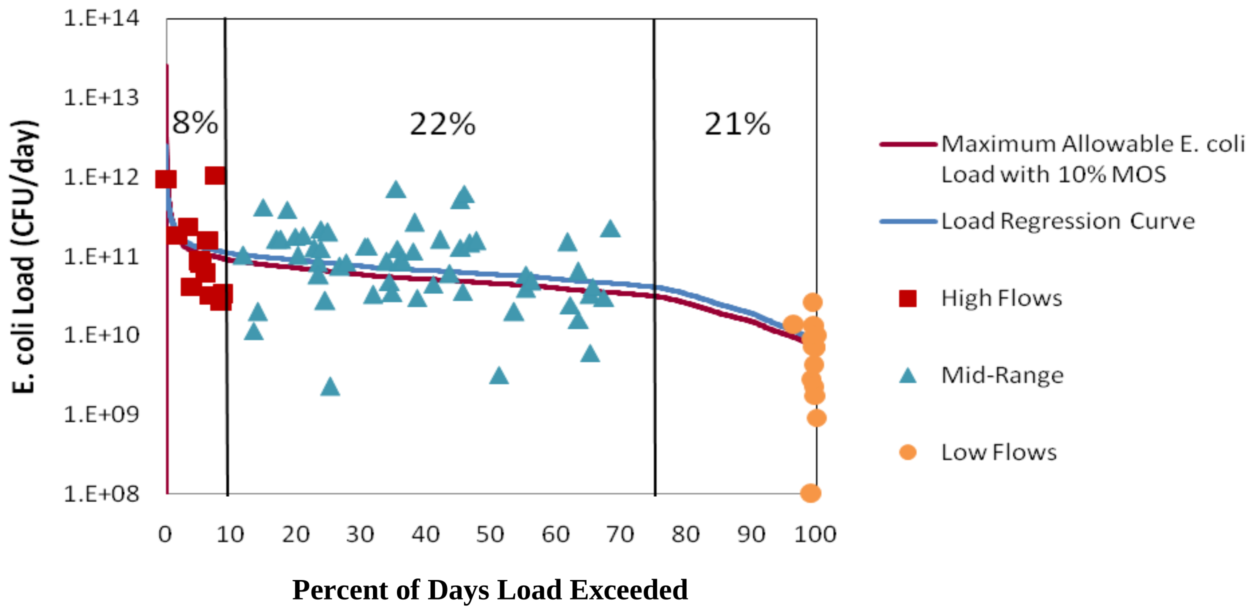

Figure 4.7. Load duration curve for *E. coli* at the SH-123 monitoring station.

Haberle Road Monitoring Station

LDC analysis for the Haberle Road site indicates that bacteria loads exceed the water quality standard for contact recreation at medium flows, while contact recreation use is supported at low flows (Figure 4.8). Average flow at this site is generally double the flow measured at the SH-123 site due to contributions from a number of springs and a small tributary. In order to meet water quality standards at the Haberle Road site, 26 and 0% reductions in the *E. coli* load are necessary at medium flows and low flows, respectively. Due to the lack of sufficient data at high flows, load reduction estimates were not calculated. As noted earlier, this is the location that reflects the reduction goals for the watershed.

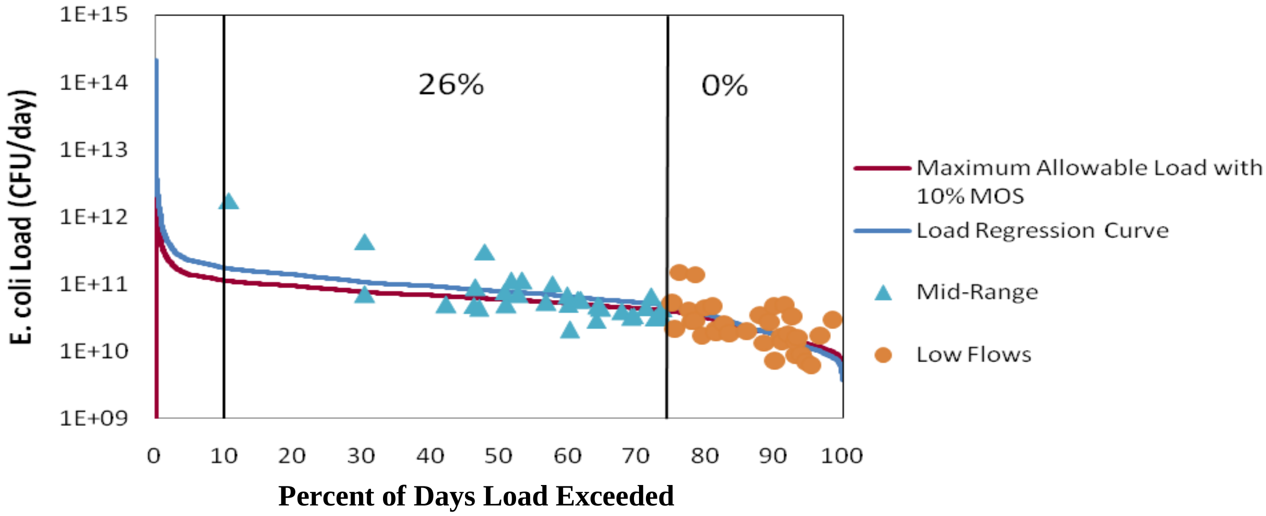

Figure 4.8. Load duration curve for *E. coli* at the Haberle Road monitoring station.

NITRATE-NITROGEN LOADS

Nitrate-nitrogen concentrations are elevated at both monitoring stations. Nitrate-nitrogen load reductions necessary to meet the screening criteria at SH-123 are 82% at high and medium flow, and 81% at low flow (Figure 4.9). Similarly, load reductions at the Haberle Road station to meet the nitrate-nitrogen screening criteria are 85 and 86% at medium and low flows, respectively (Figure 4.10). Due to the lack of sufficient data at high flow, load reduction estimates were not calculated.

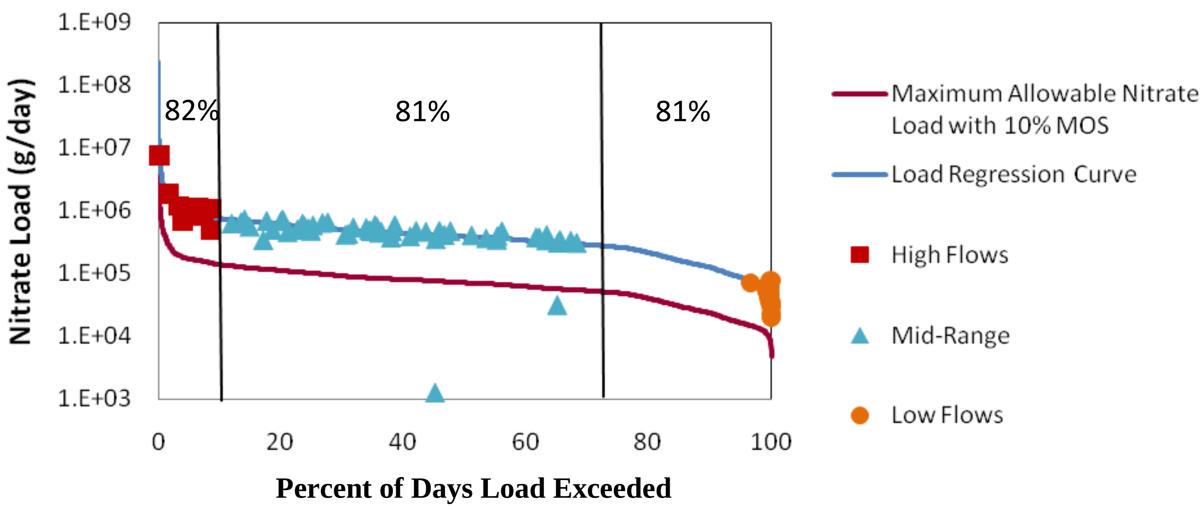

Figure 4.9. Load duration curve for nitrate-nitrogen at the SH-123 monitoring station.

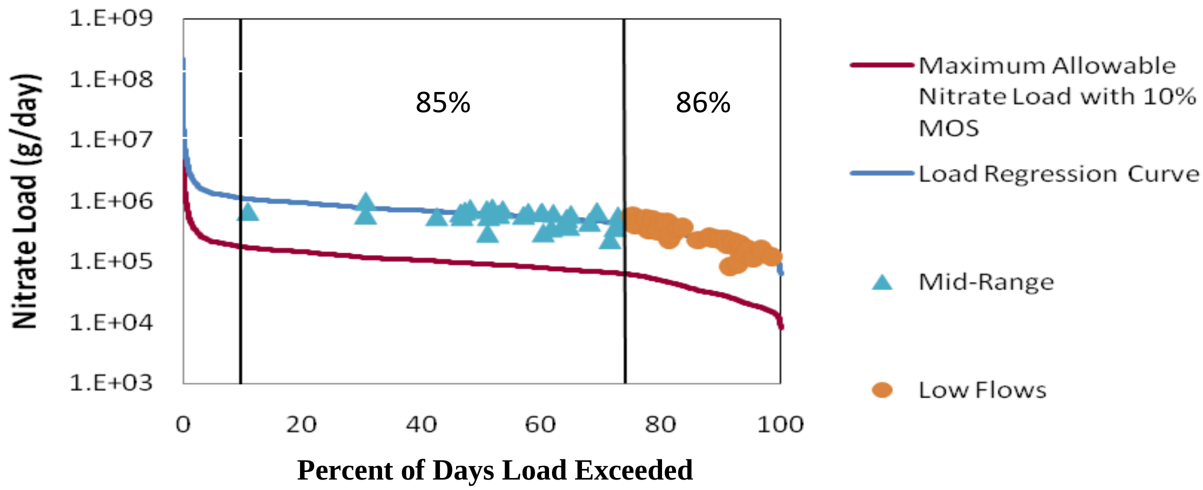

Figure 4.10. Load duration curve for nitrate-nitrogen at the Haberle Road monitoring station.

RECOMMENDED PERCENT LOAD REDUCTION

Based on results of the LDC analysis, the Steering Committee determined to utilize the estimated 26% percent reduction in bacteria loads calculated for the Haberle Road site for mid-range flows, which is the critical period for contact recreation to occur, as the target load reduction applied to all potential load sources of bacteria in the Geronimo and Alligator Creek watershed. This represents a conservative approach designed to achieve water quality standards for bacteria.

While LDC analysis indicated that nitrate-nitrogen levels exceed the screening criterion across all flow ranges, a review of area water well data in the Texas Water Development Board Groundwater Database revealed evidence of historically elevated nitrate-nitrogen concentrations (2 mg/L to over 40 mg/L) which pre-date the first use of inorganic fertilizers in the late 1940s (See Appendix F for more information). For example, one well drilled in the Alligator Creek watershed in 1943 yielded a nitrate concentration of 21.6 mg/L. Water testing data from the same time period for several other wells located in the Leona Formation and in immediately adjacent watersheds showed nitrate-nitrogen concentrations ranging from 10.8 to 21.7 mg/L. These data suggest that “natural,” non-anthropogenic sources of nitrate-nitrogen are impacting instream levels of this pollutant.

Testing of three drinking water wells in the watershed by GBRA in 2009 provided further evidence of natural nitrogen sources. Water well testing was performed to identify potential groundwater sources that are in close enough proximity to potentially contribute to stream flows and influence instream nitrate-nitrogen concentrations. Average nitrate-nitrogen concentrations in the wells were 21.8, 16.8, and 0.1 mg/L nitrate-nitrogen, with well depths being 20, 25, and 100 feet, respectively. Concentrations of nitrate-nitrogen in shallow groundwater sources in the area are similar to those measured in the creeks. More intensive sampling and study would be required to accurately allocate the contribution of nitrates from groundwater. Another important observation is that the loading which might be expected from fertilizer and waste products during runoff conditions is not demonstrated by a noticeable increase in nitrate-nitrogen concentrations in the stream when compared to levels measured during ambient flows. The Steering Committee determined that together, these factors suggest that activities in the watershed are having little impact on instream nitrate-nitrogen concentrations.

Nevertheless, target load reductions are presented in the plan for reference, and it is anticipated that implementation of management measures recommended to achieve target reductions in bacteria loads will concomitantly reduce potential nitrate-nitrogen loading. Other management measures, in addition to those that remove both bacteria and nitrate-nitrogen, also are recommended in the plan to minimize nitrate-nitrogen loading from anthropogenic sources.

ANNUAL LOADS AND LOAD REDUCTIONS

Based on the LDC analysis, mean annual loads, load reductions, and target loads for bacteria (cfu/year) and nitrate-nitrogen (g/year) were calculated utilizing data from the Haberle Road monitoring station (Table 4.2). Calculations for bacteria were based on loading occurring between the 11^{th} and 74^{th} percentile flows, which is the range of flows for which the effective implementation of management measures is considered to be feasible. Calculations for nitrate-nitrogen were based on loading occurring between the 11^{th} and 100^{th} 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 Haberle Road monitoring station.

Pollutant	Mean Annual Load	Mean Annual Load Reduction	Mean Annual Target Load	Reduction Goal (%)
E. coli (cfu/year)	3.47×10^{13}	9.66×10^{12}	2.51×10^{13}	26
Nitrate-nitrogen (g/year)	6.99×10^{5}	5.92×10^{5}	1.07×10^{5}	85

HOW VARIABLE FLOWS INFLUENCE TRENDS IN BACTERIA LOADS

Table 4.3 is a summary of the estimated annual average bacteria load categorized by flow condition for the Haberle Road monitoring station. Nonsupport of the primary contact recreation use during high and medium 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 medium range stream flows are more common and considered more manageable using available BMPs. On that basis, the focus of implementation will be on management of loading that occurs during the medium flow range (11-74th percentile flows). Bacteria loading at low flows is not of sufficient magnitude to cause nonattainment of the water quality standard for primary contact recreation (Figure 4.11).

Table 4.3. Estimated average annual *E. coli* loads under different flow conditions in Geronimo Creek based on water quality data at the Harbele Road monitoring station.

Monitoring Station	Loading by Streamflow Condition (cfu/yr)	
	Medium Flow	Low Flow
Geronimo Creek at Haberle Road	3.47×10^{13}	8.51×10^{12}

Figure 4.11. Contact recreation in Geronimo Creek. Photo courtesy of Bill Evans.

5. Pollutant Source Assessment

As noted previously, the only permitted point source in the watershed (the Seguin WWTF) is located on Geronimo Creek near the confluence with the Guadalupe River. As a result, implementation efforts will focus on nonpoint sources of pollution. The Topical Work Groups dedicated significant time to identification of potential nonpoint sources of pollutants in the watershed. Local information and statistics were gathered from stakeholders. Based on this information, the likely potential sources of pollutants were identified and are presented in Table 5.1.

Table 5.1. Potential pollutant sources in the Geronimo and Alligator Creeks Watershed identified by the Steering Committee.

Source Categories	Potential Sources	Bacteria	Nitrate-Nitrogen
Urban	Urban Runoff	X	X
	Dogs	X	X
Wastewater	Septic Systems	X	X
Agriculture	Cropland		X
	Cattle	X	X
	Horses	X	X
	Goats	X	X
Wildlife and Nondomestic Animals	Deer	X	X
	Feral Hogs	X	X

Many pollutant sources can contribute both *E. coli* and nitrate-nitrogen. In most cases, identification and management of bacteria sources also will reduce nitrogen contributions, particularly when sources include human and animal waste. However, some land use and management practices, such as crop production and lawn and landscape fertilization, only impact nitrogen loading and will be included to supplement control measures intended to reduce bacteria pollution.

SELECT ANALYSIS RESULTS

Total estimated daily *E. coli* loads summed for all potential sources in each of the 21 subwatersheds in Geronimo and Alligator Creeks 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. This information will be useful in the targeting and planning of implementation efforts to achieve water quality goals.

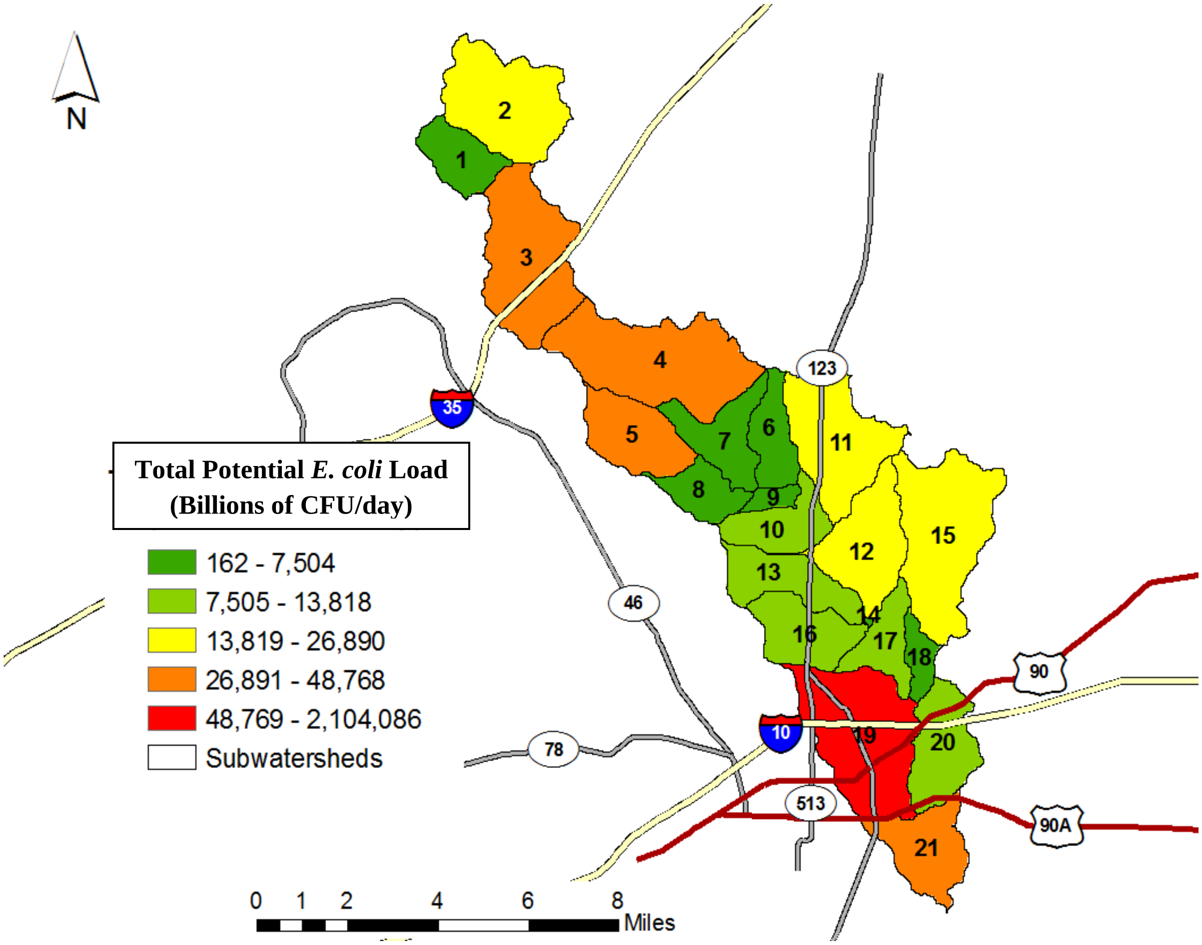

Figure 5.1. Average total daily potential *E. coli* contribution from all sources by subwatershed.

The following sections present and discuss results of the SELECT analysis for each of the potential nonpoint sources 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 G.

URBAN RUNOFF

The Urban Nonpoint Source Work Group utilized estimates of impervious surface cover from the land use analysis (see Appendix H) and bacteria loading estimates from a study conducted by the City of Austin (1997) to complete SELECT analysis for urban runoff (Figure 5.2). As would be expected, the five subwatersheds containing the majority of urban development, including the cities of New Braunfels and Seguin, show the greatest potential for urban-related pollution (Figure 5.3).

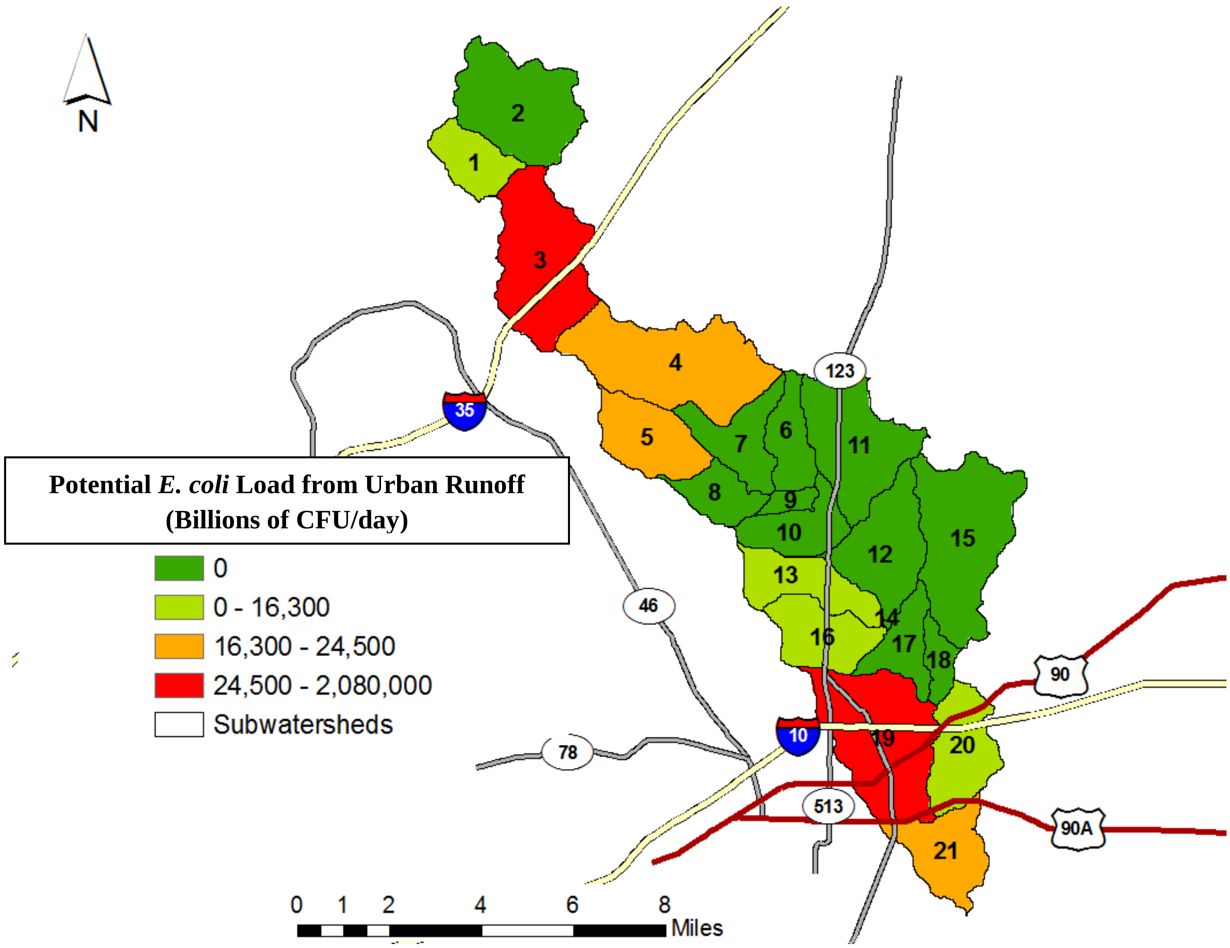

Figure 5.2. Average daily potential *E. coli* load from urban runoff by subwatershed.

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 Geronimo and Alligator Creeks watershed. New Braunfels, located along the IH-35 corridor in the far northern portion of the watershed will soon be under municipal separate storm sewer system (MS4) regulations as a part of the federal Clean Water Act due to exceedance of the population threshold set by EPA (residential population of at least 50,000 and an overall population density of at least 1,000 people per square mile). The city of Seguin most likely will fall under the same regulations following the next census due to its rapid population growth. Phase II stormwater regulations are intended to preserve, protect, and improve the Nation's water resources from polluted stormwater runoff (EPA, 2000). Important aspects of the MS4 regulations and future changes in population and potential for pollutant contributions from these urbanizing areas are discussed in more detail in the Management Measures chapter.

Figure 5.3. Town Center at Creekside on IH-35 in New Braunfels is an example of expanding urbanization in the Alligator Creek Watershed.

DOMESTIC DOGS

Management of pet waste can have a substantial impact on the quality of stormwater runoff from areas of high pet populations. Pet waste management primarily deals with dog and cat waste in these urban areas. 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 that are 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). All four local veterinarians suggested that the watershed dog population was slightly higher than either of these averages, and recommended a dog ownership of 1.0 dog/household. This conservative estimate was accepted by the Urban Nonpoint Source work group and used for planning purposes.

According to 2000 US Census population data for the watershed and using an average of 1.0 dog/household, there are an estimated 6,362 dogs in the watershed. These animals are concentrated in urban areas, particularly in Seguin and New Braunfels, which have more households and a greater human population. Growth in both cities has been significant since 2000, with the population of New Braunfels increasing 47% from 2000 to 2008, and Seguin experiencing 20% population growth during that same time period. These population growth estimates are based upon 2000 Census data (2010 Census was not yet available) and city population data from stakeholders. Based on this information, the SELECT analysis indicates the greatest potential for pollutant loads from pets occurs in these urbanized subwatersheds (Figure 5.4).

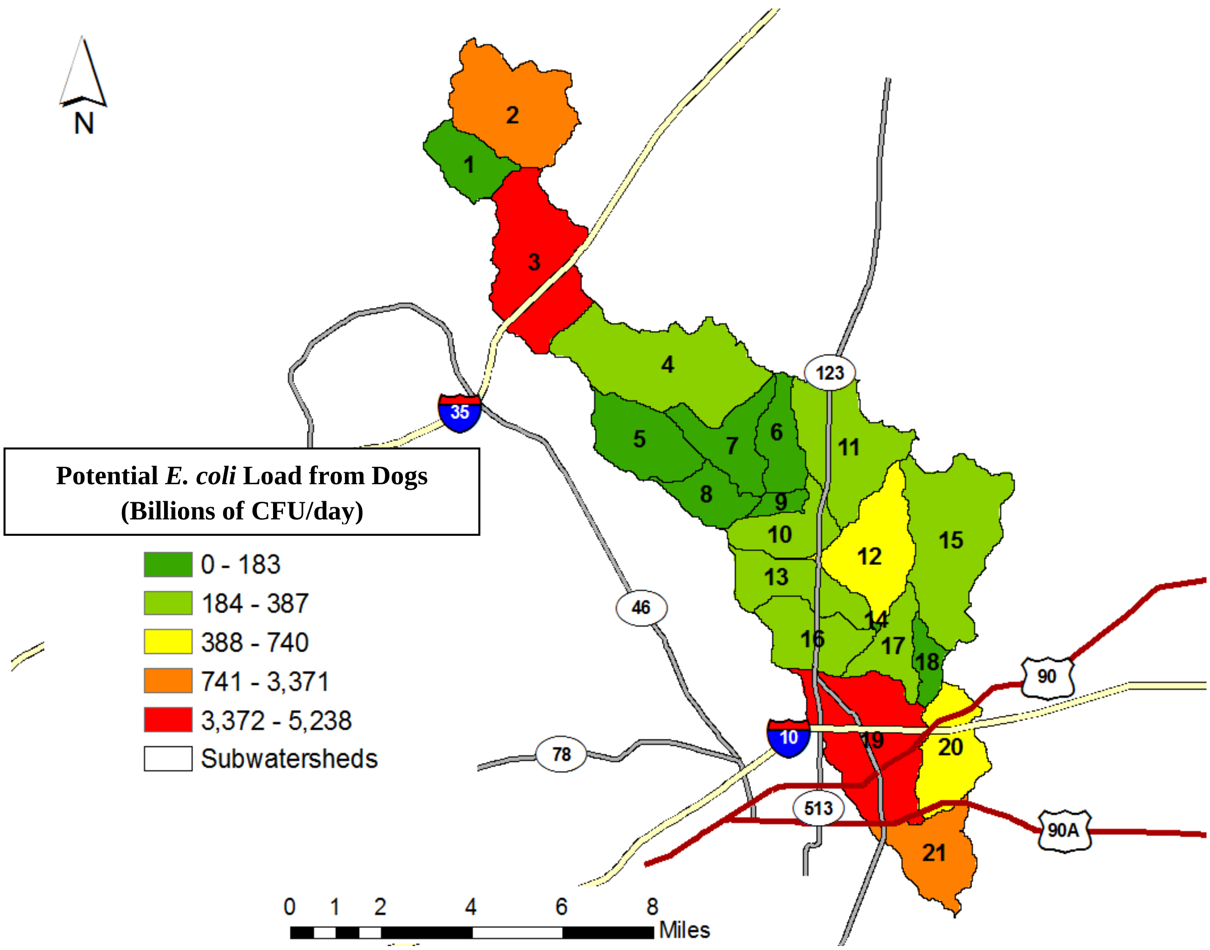

Figure 5.4. Average daily potential *E. coli* load from domestic dogs by subwatershed.

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 Geronimo and Alligator Creeks 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 5.5). Failure also can result from hydraulic overload of the system by adding additional homes to an existing system that was not designed to accept the increased load. Other factors that can contribute to system failure are improper installation and improper system design.

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

In Texas, installation of a septic system requires a permit that is obtained through a relatively new permit process mandated by the State beginning 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. Furthermore, a septic system is exempt from the permitting requirement if: 1) it serves a single family residence on a tract of land that is 10 acres or larger, 2) the septic system is not causing a nuisance or polluting groundwater, 3) all parts of the system are at least 100 feet from a property line, 4) all effluent is disposed of on the property, and 5) the single family dwelling is the only dwelling on the tract of land.

The Wastewater Infrastructure Work Group utilized soil type and age of system as the two key variables for predicting septic system failure rates. System age was based on date of platting, while soil type was obtained from NRCS soil surveys. Estimated failure rate categories were 5, 10, or 15%, based on the calculated index (see Appendix G for a complete explanation of the calculated index). This index of possible 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. Based on SELECT analysis, the greatest potential loading from septic systems is located in subdivisions just west of the IH-35 corridor in Comal County and in subdivisions located in or near the lower one-third of the watershed in Guadalupe County (Figure 5.6).

AGRICULTURE

The Agriculture Nonpoint Source Work Group identified several agricultural and wildlife sources of bacteria and nitrate-nitrogen, and helped develop animal population estimates used in SELECT analysis.

Livestock

Cattle, goats, and horses 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.

<u>Cattle</u>

Based on USDA National Agricultural Statistics Service (USDA NASS) census data, cattle are the dominant livestock species in the watershed (Fig. 5.7). Like most 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.

Development of the cattle population estimates was conducted as this area of the state was recovering from almost two years of extreme drought, during which time most cattle operations were markedly reduced. Many operations were in the early stages of restocking, and so estimates were based on historical averages prior to the recent drought. There are no concentrated animal feeding operations in the watershed, such as feedlots or dairies.

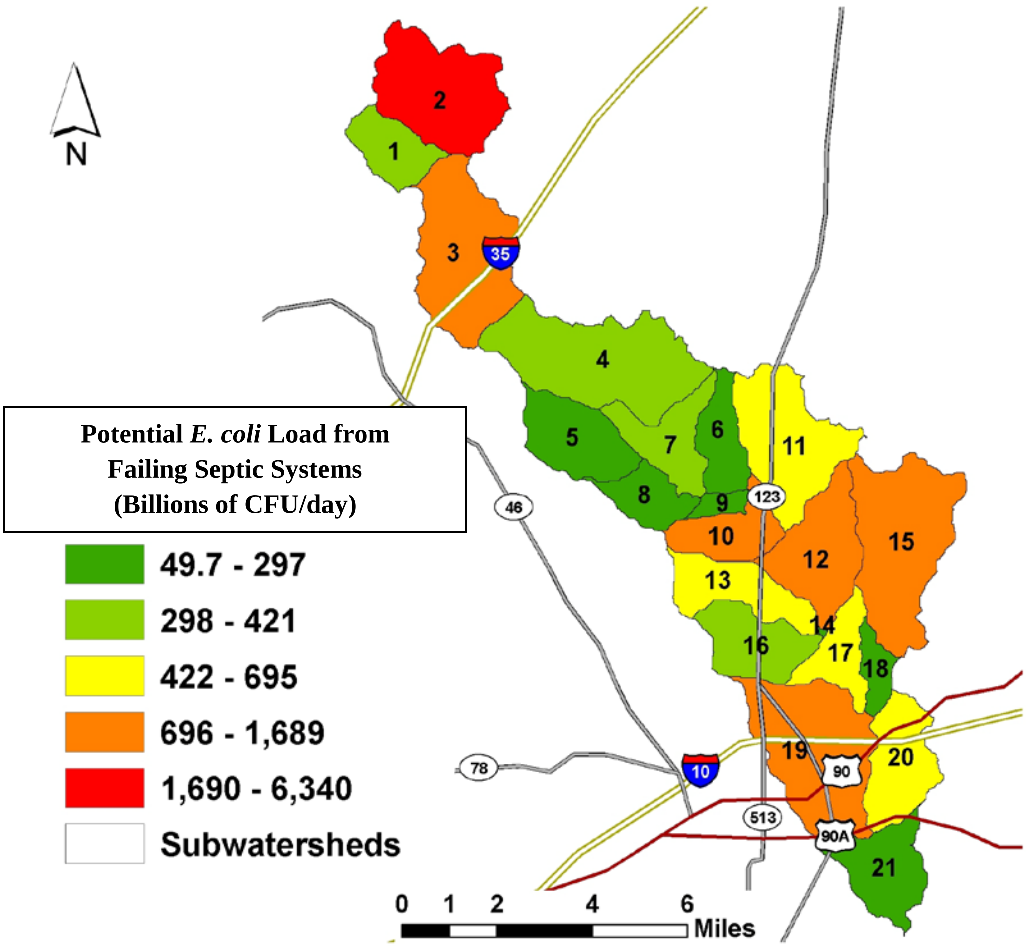

Figure 5.6. Average daily potential *E. coli* load from failing septic systems by subwatershed.

Figure 5.7. Cattle in the Geronimo Creek Watershed.

In lieu of using NASS census data and to be more conservative, the Agricultural Nonpoint Source Work Group chose to utilize local knowledge of area stocking densities. Different stocking densities were used for the two counties and applied to selected land uses to determine cattle populations and distribution for SELECT analysis. Stocking densities were 1 head of cattle per 20 acres in Comal County and 1 head of cattle per 10 acres in Guadalupe County. The different stocking densities were based on differences in land cover and terrain between the Edwards Plateau and the Blacklands Prairie. Cattle were distributed across land covers used for grazing in each county, which include rangeland, forest, 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 local stakeholder-derived information, the total cattle population in the watershed was estimated at 2,629 head (NASS data estimate was 1,785 head). The SELECT analysis indicated that the largest potential source of loading from cattle is found approximately midway down the watershed in the eastern portion (Figure 5.8). The subwatershed which includes the urban areas around Seguin also has potential for a significant cattle population due to the land use types in that area.

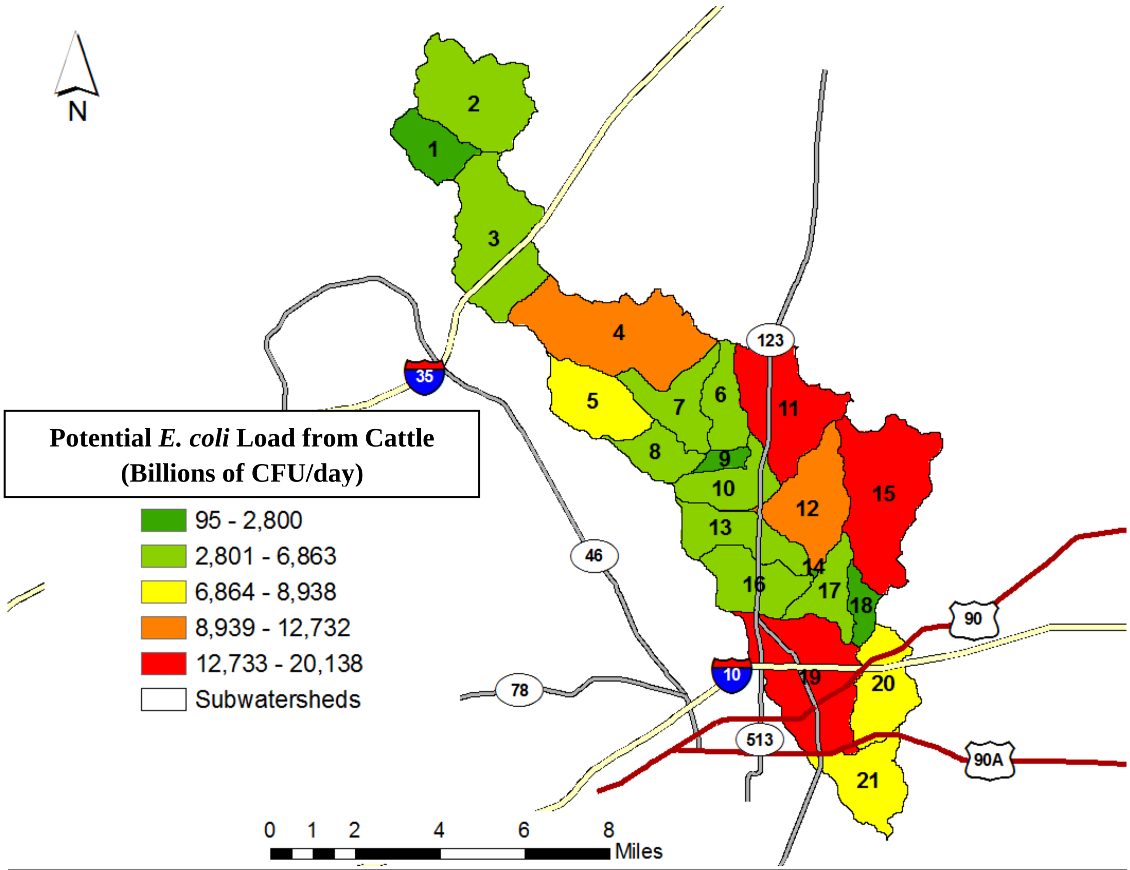

Figure 5.8. Average daily potential *E. coli* load from cattle by subwatershed.

<u>Goats</u>

USDA NASS data from 2002 and 2007 were utilized to create a baseline estimate of the goat population. The Agricultural Nonpoint Source Work Group then used local knowledge to provide population estimates of known operations, which were inserted into specific subwatersheds. The total watershed population was estimated to be 750 head of goats distributed on rangeland, forest, and managed pasture. To accurately characterize the watershed, portions of the total population were allocated to individual subwatersheds where specific larger operations were known to exist. SELECT analysis indicates the highest potential loading from goats is located central to the watershed, followed by lesser populations in the northern end just east of the IH 35 corridor (Figure 5.9).

Figure 5.9. Goats on a farm in the Geronimo Creek Watershed.

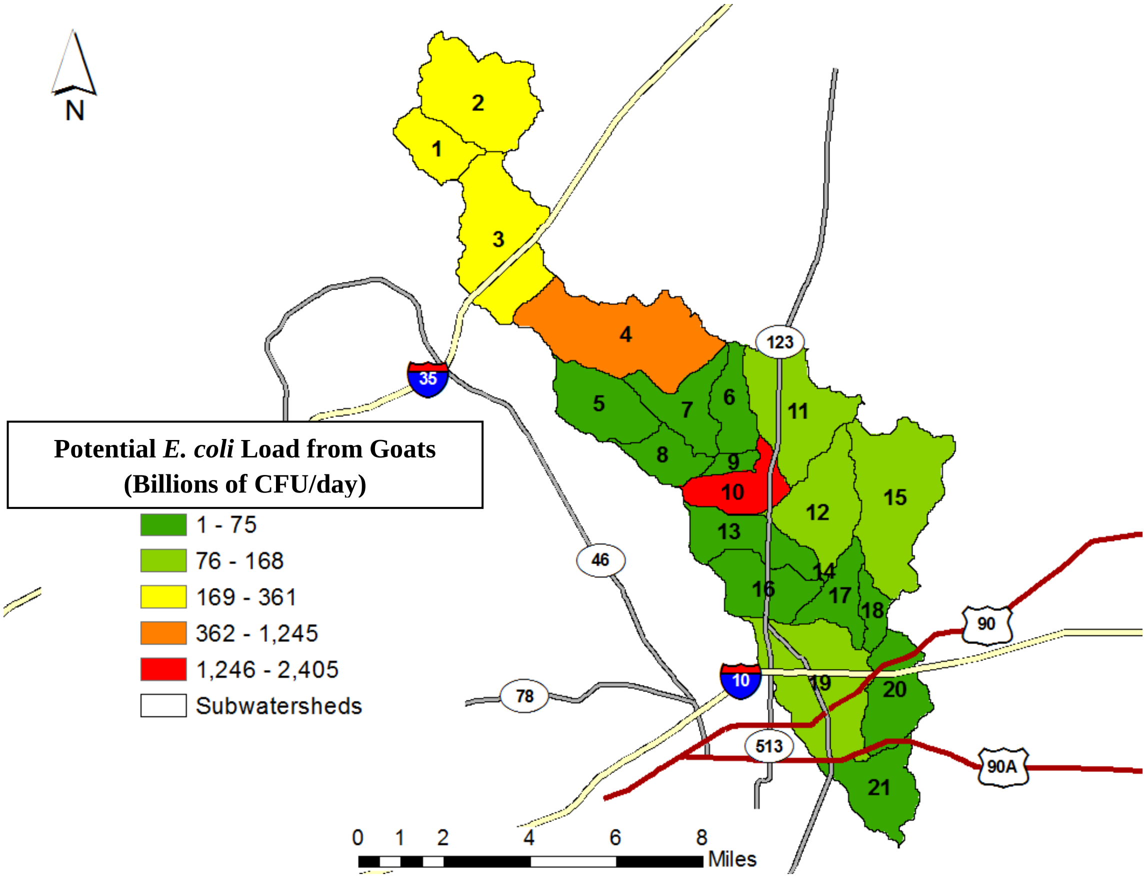

Figure 5.10. Average daily potential *E. coli* load from goats by subwatershed.

Horses

The Agricultural Nonpoint Source Work Group based the horse population on 2002 and 2007 USDA NASS county data which estimates there are approximately 124 horses in the watershed (Figure 5.11). This approach was used since stakeholders felt that it accurately estimated the horse population in the watershed. In addition, the Work Group recommended distributing these animals on rangeland where most of the animals are grazed, and which is a widely distributed land use across the watershed. While the total population of horses in the watershed is low compared to other livestock, management practices directly affect the potential for these animals to be contributors of bacteria and nitrogen. Stakeholders indicated that horses in the watershed are often kept on undersized acreages which results in overgrazing, and potentially increased runoff of fecal material. SELECT analysis indicates the greatest potential loadings are located in the upper watershed, and following southward along the easternmost edge of the watershed (Figure 5.12).

Figure 5.11. A horse grazing in the Geronimo Creek Watershed.

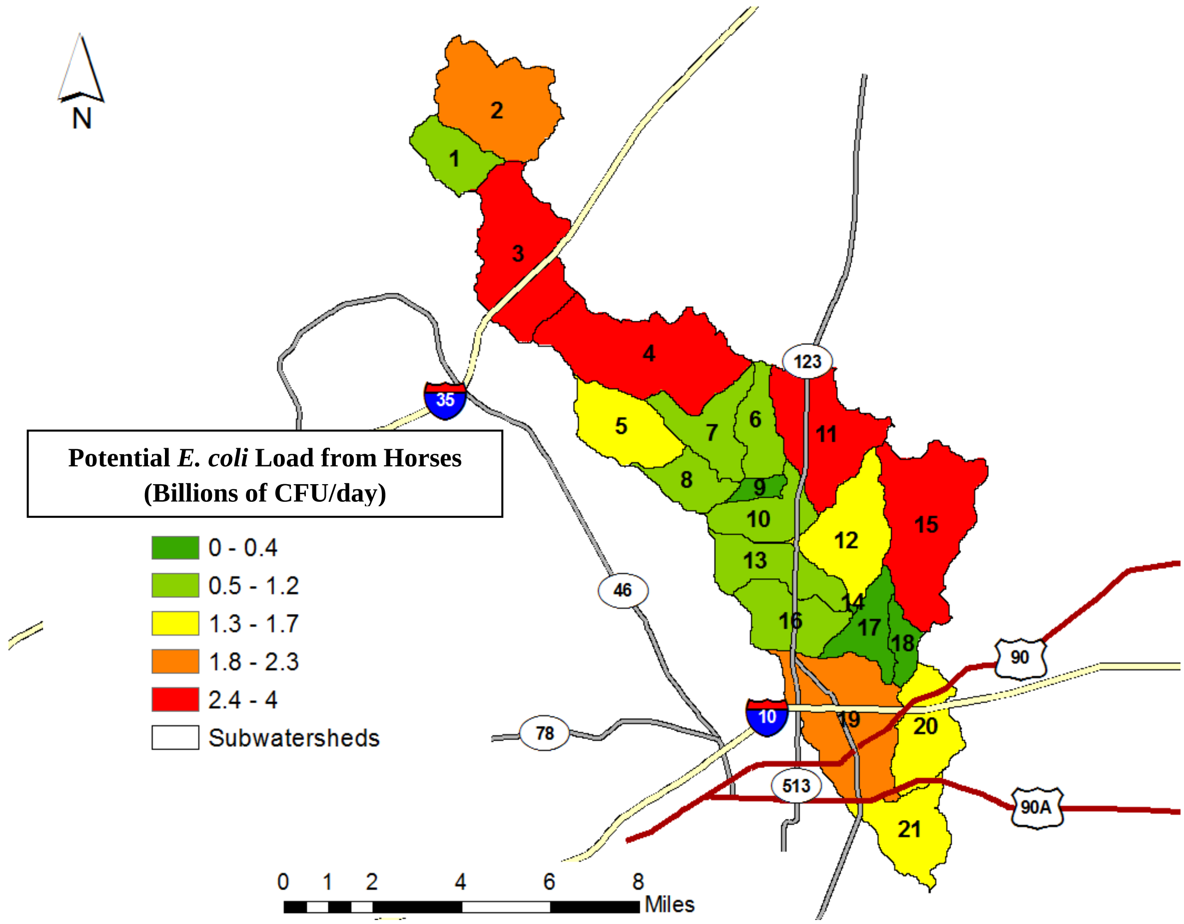

Figure 5.12. Average daily potential *E. coli* load from horses by subwatershed.

Row crops

Corn, sorghum, cotton and wheat are the main crops grown in the watershed, while managed pasture serves to produce hay and forage crops for livestock. Fields that are grazed by livestock, including corn and sorghum stubble, wheat and managed pasture can be 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, 2009). Based on stakeholder knowledge, large populations of these wildlife species were not located in the Geronimo and Alligator Creeks watershed.

An assessment of watersheds within central Texas by the TCEQ included examination of bacteria sources in Peach Creek, a watershed located approximately 40 miles to the east of Seguin. 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 the method of determining the sources of fecal bacteria in water samples by identifying the genetic material of the bacteria found in the water sample and matching it to its source. The non-avian wildlife component includes animals such as raccoons, coyotes, deer, and other mammals. However, information on the abundance and contributions of most wildlife species is very limited. In Texas, the only wildlife species with routinely measured population estimates is the white-tailed deer (Figure 5.13). Preliminary studies have begun to investigate fecal deposition rates of riparian wildlife in Texas (Parker, 2009). The Geronimo and Alligator Creeks watershed has only 3 bridge crossings, reducing the likelihood that deposition from bird bridge colonies is a large 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 Geronimo and Alligator Creeks Watershed and no known large bird colonies in the area.

Figure 5.13 White-tailed deer are a potential source of nitrate-nitrogen and bacteria in the Geronimo and Alligator Creeks 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.

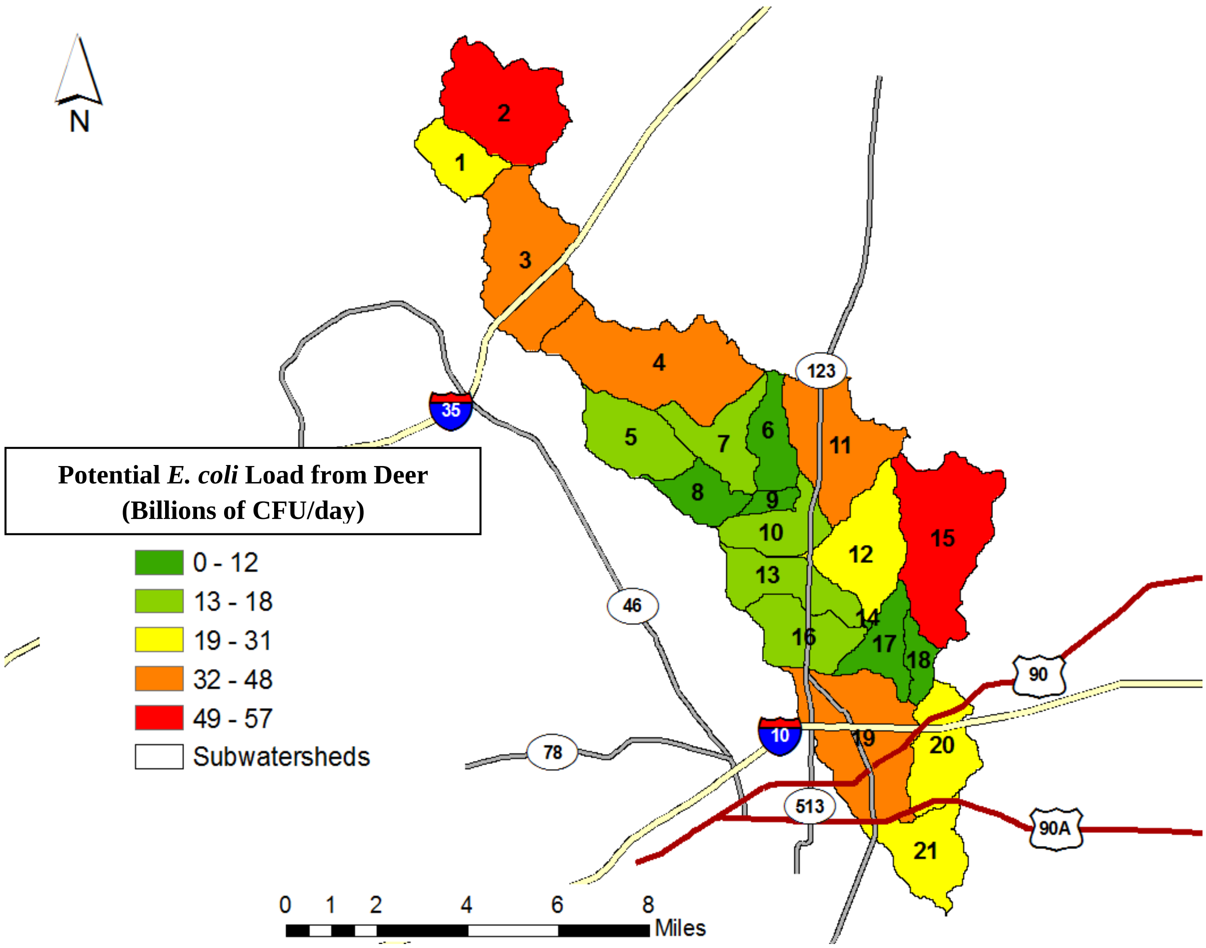

Figure 5.14. Average daily potential *E. coli* load from deer by subwatershed.

The Agricultural Nonpoint Source Work Group utilized the most recent four years of TPWD deer census data in developing the deer population estimate for the watershed (Lockwood, 2008). The four–year average density was 96.6 deer per 1000 acres, which was applied to rangeland and forestland and produced a watershed population estimate of 2,172 deer. SELECT analysis indicates the highest potential bacteria loadings from deer occur in 6 (red and orange) subwatersheds.

Feral Hogs

In many watersheds across the state and much of the southern United States, feral hogs are a concern (Figure 5.15). By definition, feral hogs are not wildlife, but are either domesticated hogs that have become feral, Russian boars, and/or hybrids of the two (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 limitations such as bag limits or closed seasons. Little data exist on their abundance and distribution. This is compounded by their high rate of reproduction and tendency to move in groups along waterways over large areas of a watershed in search of food.

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

According to 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. 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 and soil loss. 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 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).

The Agricultural Nonpoint Source Work Group 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 Buck Creek WPP used 26 feral hogs/mile^2. Due to concerns over a growing feral hog population, the Work Group elected to use the more conservative density of 25 feral hogs/mile^2 (1 hog/25.6 acres), applying this to all land use categories except urban and open water to determine the population estimate for the watershed. This resulted in a total population estimate of 1,626 feral hogs in the watershed. At the direction of the Work Group, these feral hogs were then distributed to the perennial riparian corridors (within 300 feet of a perennial stream), areas they are most likely to frequent and where known sightings have occurred (see Appendix G for a more complete explanation of feral hog distribution). SELECT analysis indicates that the majority of the potential bacteria impact due to feral hogs is located in the east-central portion of the watershed (Figure 5.16).

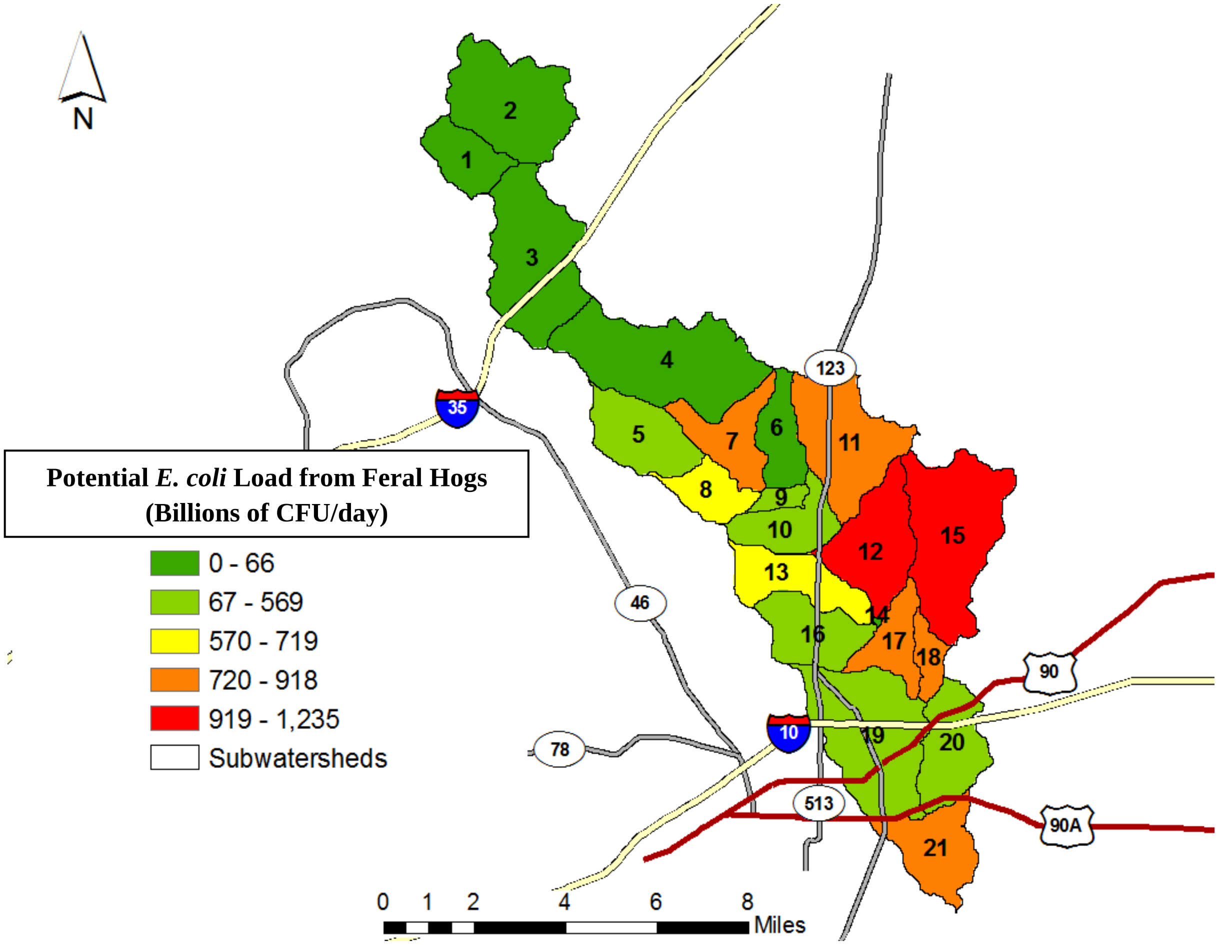

Figure 5.16. Average daily potential *E. coli* load from feral hogs by subwatershed.

Relative Ranges of Bacteria Loading

Due to the differences found in each of the potential sources, there is a range of the average daily potential load from each source category. Factors that impact these differences are 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 5.17.

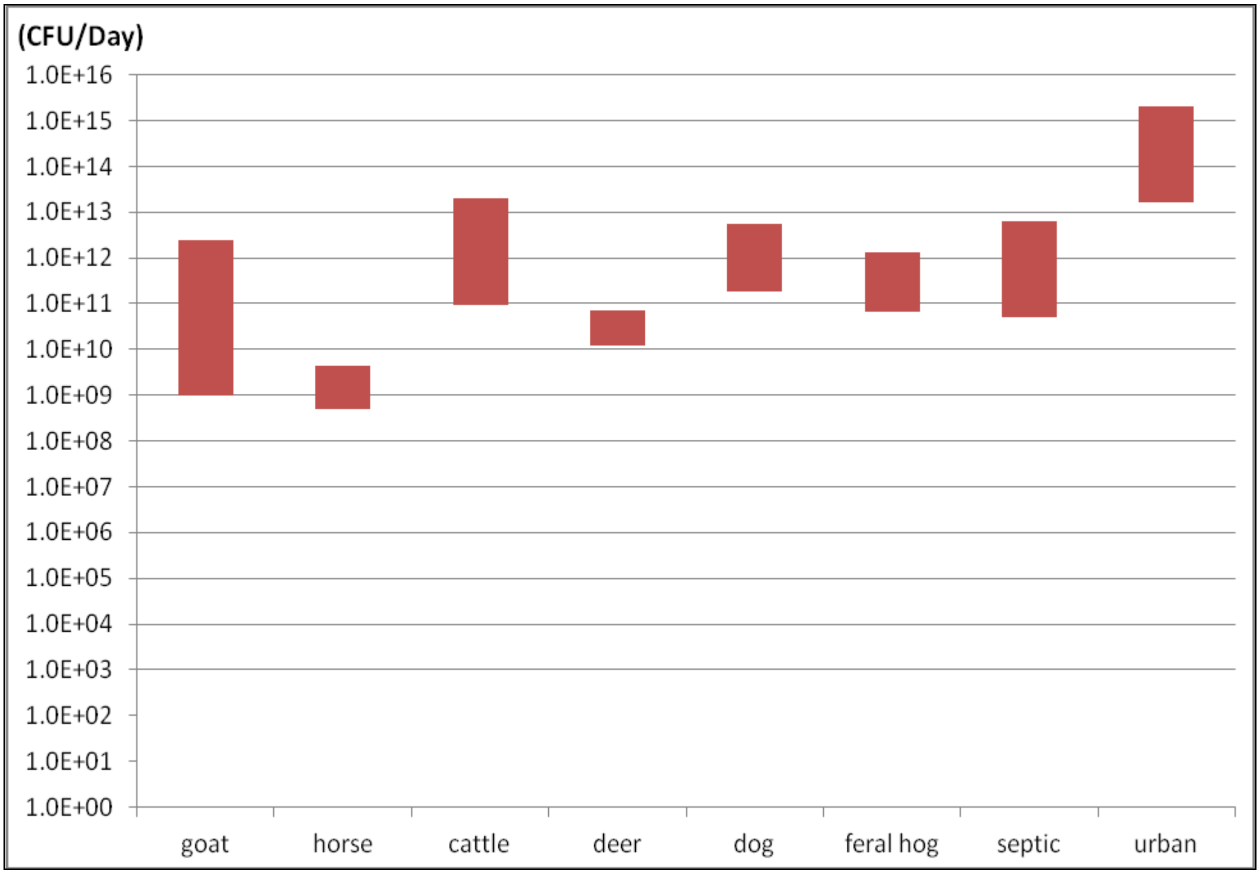

Figure 5.17. Relative ranges in loading by potential source across subwatersheds for Geronimo and Alligator Creeks (cfu/day).

6. Management Measures

Based on a thorough evaluation of water quality data and supporting information characterizing the watershed, the Work Groups identified management measures that will be necessary to reduce pollutants entering Geronimo and Alligator Creeks. 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 in nitrate-nitrogen loading, and some practices specifically target nutrients to further limit potential nitrogen contributions.

The management measures discussed in this chapter represent the stakeholders recommendations and plan to reduce and control the major potential sources of loading within the watershed. Management measures were established under three general categories: Urban Nonpoint Source, Wastewater, and Agricultural Nonpoint Source (see Appendix J for Management Practice Efficiencies).

URBAN NONPOINT SOURCE MANAGEMENT MEASURES

Management of potential sources of bacteria in existing urbanized areas of New Braunfels and Seguin, coupled with the plans for future growth and expansion, was the focus of the Urban Nonpoint Source Work Group. Dog waste and general urban storm water runoff were the two primary sources for which management measures were developed. A summary of recommended urban nonpoint source management measures common to both 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 New Braunfels and Seguin to determine the most effective types, design and placement of structural control measures.
• Implement non-structural components of Phase II MS4 permits on a voluntary basis in advance of program requirements, where possible.
• Implement or expand pet and feral animal waste management activities.
• Provide guidelines and training for effective nutrient management on city property.
 	
New Braunfels
• Increase the frequency and coverage of Phase II storm water permit activities.
    o Initiate a public education and outreach program focusing on stormwater.
    o Create opportunities for public involvement and participation in the Phase II stormwater program.
    o Establish an illicit discharge detection and elimination program.
    o Manage construction site stormwater runoff.
    o Manage post-construction runoff.
    o Establish pollution prevention and good housekeeping practices for municipal operations.
• Utilize results of the storm water engineering analysis to seek funding for implementation of targeted control measures.
• Implement a spay/neuter program.
• Install additional pet waste stations in neighborhoods and parks, where needed.
• Provide nutrient management training to watershed ISDs, city and county maintenance and parks departments, and other interested parties.
 	
Seguin
• Utilize results of the storm water engineering analysis to seek funding for implementation of targeted control measures.
• Continue/expand the existing spay/neuter program.
• Install additional pet waste stations in neighborhoods and parks, where needed.
• Provide nutrient management 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 (26%) to estimate the minimum number of dogs that should be managed within that area. Results for each of the 21 subwatersheds are presented in Table 6.2. Based on these estimates, emphasis and resources will be directed primarily into the urbanized subwatersheds associated with New Braunfels and Seguin. 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
Comal	1	47	12
	2	1070	278
	3	1346	350
	County Total	2463	640
Guadalupe	4	89	23
	5	40	10
	6	20	5
	7	58	15
	8	37	10
	9	11	3
	10	119	31
	11	108	28
	12	166	43
	13	89	23
	15	105	27
	16	91	24
	17	124	32
	18	13	3
	19	1645	428
	20	236	61
	21	636	165
	County Total	3587	933
Total		6050	1573

Spay/Neuter Program

The City of Seguin has participated in the Animal Friendly Grant Program offered by the Zoonosis Control Branch of the Texas Department of State Health Services (DSHS). This program 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 that is 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 that has an established program for sterilizing animals owned by the general public at minimal or no cost.

The 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 City of Seguin Animal Control Department received its first grant award in 2007 and obtained a continuation grant in 2008. Due to the high demand for these services in the first two years, the City of Seguin applied again in 2009. A new grant allowed the City to continue the program into 2010. In the past four years, more than 1,200 pets have been spayed or neutered in Seguin through the program.

The success of the program is due largely to it being a community effort in cooperation with local veterinary clinics, local media, and residents. One hundred percent of the funds awarded go directly to pay for services provided by the veterinary clinics in the area. All four veterinary clinics accept program vouchers, which allow qualifying low and moderate-income families in the community to spay and neuter their cats and dogs for free. However, the program is limited to city residents of Seguin. There is a need to expand this program to the City of New Braunfels and to residents who live outside the city limits in the unincorporated areas of Guadalupe and Comal counties. An entity that can serve a larger jurisdiction will need to be identified to apply for grant funding to reach residents in these areas.

Pet Waste Ordinances

The City of Seguin currently has a leash law for dogs in the city limits. The city also plans to install pet waste stations and proper signage, and launch an education and outreach program to raise awareness about pollution from pet waste A new “dog park” was opened in a section of Starke Park. Proper management of pet waste is required in the park which may reduce loadings in other areas of the city.

The City of New Braunfels identified pet waste as an issue, and has a pet waste ordinance that requires pet owners to remove any deposits from public walks, recreation areas, or private property including the property of the pet owner. In addition, city code requires that all pets, including cats, be confined to their owner's property, and on a leash when off of their property. New Braunfels city code restricts pet ownership to no more than 4 cats or 4 dogs/household. Enforcement of these ordinances is conducted by City of New Braunfels Park Rangers, in addition to City Police, and the New Braunfels Animal Control Department. Public education and notification of these ordinances is made available at locations where pet vaccinations and adoptions are carried out, as well as through signage in the high traffic areas of the major park in New Braunfels.

New Braunfels also plans to establish a "dog park" which will require proper management of pet waste. The park will not be located in the Geronimo or Alligator Creeks watershed, but may reduce potential loading by attracting watershed pet owners to this well managed area. The Partnership will assist New Braunfels with a comprehensive public outreach and education effort, which may include brochures, press releases, utility inserts, and public service announcements to inform the public about ordinances, the new dog park facility, and the importance of proper pet waste management.

There are several residential neighborhoods near the headwaters of Alligator Creek that 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 of existing pet waste ordinances and the importance of pet waste management.

Urban Storm Water Management

An initial goal of the Partnership will be to support Seguin and New Braunfels 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 Geronimo and Alligator Creek WPP to reduce loading of bacteria and nitrogen. Results of these analyses will be used by the cities to ensure selection and proper installation of the most effective structural control measures.

<u>Phase II Storm Water Permitting</u>

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 (Figure 6.1).

Figure 6.1. Urbanized area in the Alligator Creek Watershed in Comal County.

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. Based on the 2010 census, the City of New Braunfels will fall under regulation of a Phase II MS4 storm water permit. As a result, the city will be required to develop a storm water management plan (SWMP) that includes at least the following six control measures (see Appendix K for MS4 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

New Braunfels will apply these Phase II permit requirements to the entire city limits, which will impact the upper Alligator Creek watershed. The City is currently in the process of initiating practices that are consistent with a Phase II permit such as monthly sweeping of all city streets, development of an illicit discharge detection program, public outreach and education, construction storm water runoff controls, and other good housekeeping activities. Also, New Braunfels is committed to increasing the frequency and coverage of these activities as they make ready for Phase II regulation requirements.

In addition to the requirements of their Phase II permit, and to further reduce potential pollutant loading to Alligator Creek, it is recommended that New Braunfels 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, and the storm water management program
- Strive to incorporate bacteria reduction elements into flood control features

Seguin has not passed the population threshold that would trigger a Phase II Storm Water Permit, but is expected to if growth continues at the present rate. Because of this, the Partnership will work with the City of Seguin to assist with preparations for Phase II requirements and to seek funding when possible to facilitate the transition. Seguin has a strong commitment to environmental stewardship. 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

Seguin has recently begun to implement some new “good housekeeping” measures. Street sweeper trucks sweep all streets in the city that are not State highways once per month. Brush placed at the curb for weekly pickup is taken to a central facility where it is turned into mulch and given away for free to citizens.

Nutrient Management

Seguin ISD operates only one school in the watershed, the Seguin High School. The main football field is covered in Astroturf, so nutrient management on that facility is limited. However, within the High School complex, there is natural turf on two soccer fields, a football practice field, a band practice field, a softball field, and one baseball field, all covering approximately 20 acres. Storm water runoff is directed to a detention facility before traveling to Geronimo Creek. In addition, the city manages 3 parks, 5 sports fields, a golf course, and a wave pool. Maintenance and Operations staff from the ISD, 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 nitrogen, and to take advantage of potential fertilizer cost savings.

New Braunfels is committed to reducing nutrient runoff from urban areas that are managed by city operations. For this reason, maintenance and operations staff from New Braunfels ISD, New Braunfels Public Works Department, and Comal County will be offered SAFE Program training in nutrient management to reduce potential runoff losses of nitrogen, and to take advantage of potential fertilizer cost savings.

Guadalupe County does not have a mulching program and does not apply fertilizer or compost to county road right-of-ways. Comal County does have a chipping program where they create wood chips from citizen supplied brush and offer it back to the public for free. However, they do not apply compost, mulch, or fertilizer to county road right-of-ways.

Town Center At Creekside is a 400 plus acre development in the Alligator Creek watershed located in New Braunfels. When fully developed, it will be a combination of retail businesses, hotels, single and multi-family residential living, medical center, 29 acres of parks, a playground, and nature trail. The landscape management company that services the property has agreed to participate in nutrient and integrated pest management workshops and trainings, and to implement the knowledge gained into the management of this substantial development.

WASTEWATER MANAGEMENT MEASURES

The Wastewater Work Group 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 Work Group.

Wastewater Treatment Facilities

No centralized wastewater treatment facilities discharge in the upper watershed. However, with future growth this is likely to change. While all WWTFs must comply with site-specific regulations contained in a TPDES permit issued by the TCEQ, the Partnership also will recommend that 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.

Table 6.3. Summary of wastewater management measures for the Geronimo and Alligator Creeks Watershed.

Wastewater Management Measures
• The City of Seguin and New Braunfels Utilities (NBU) will fully implement actions and programs consistent with existing SSO Initiative agreements. • The City of Seguin will extend sanitary sewer service to residents in the Oak Village North Subdivision, and whenever possible will work to provide sewer service to other marginal areas utilizing septic systems. • NBU will work to provide sewer service to other marginal areas utilizing septic systems according to prevailing extension policies and as development warrants. • 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 expanded 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 at the state level to assist collection system owners in Texas that follows the EPA guidance called the Sanitary Sewer Overflow Initiative (SSO Initiative). 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 SSO Initiative is to reduce the number of SSOs that occur in Texas and to address them before they harm human health, safety, or the environment and before they become enforcement issues (TCEQ, 2008), by incorporating CMOM into regular municipal operations. Since responsibility for violations such as SSOs rests with the TPDES permitted facility, it is in the facility manager's best interest to reduce SSOs to prevent enforcement actions, as well as health and safety risks to the public. An SSO Plan identifies all high risk areas and documented problems in a collection system, and establishes a step by step plan to address these problem areas and proactively address future issues.

New Braunfels Utilities, which is a separate entity from the City of New Braunfels, signed their agreement with TCEQ in 2010 to participate in the SSO Initiative program. The initial focus of their SSO Initiative Agreement will be for activities in their jurisdiction that fall within the traditional Edwards Aquifer region. Activities will include: establishment of maintenance schedules for all lift stations, inspection of high risk infrastructure, procedures for involving operations personnel in engineering design review, expansion of the 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. By July 2011, NBU will enlarge their efforts to cover areas within their jurisdiction but outside of the Edwards Aquifer region. NBU will inspect at a rate of 150,000 feet of pipe, or 10% of the non-Edwards system each year, and 20% of the system located over the Edwards Aquifer annually. Beginning in October 2011, and on an annual basis, NBU will submit an annual report to the TCEQ regarding the status and progress of their corrective actions. The report will include specific corrective actions completed, as well as any proposed actions that were delayed or not completed, with explanations as to why they were not completed. This will occur annually until 2020. The final report summarizing all corrective actions is due to the TCEQ in October 2020.

Seguin also signed an agreement with TCEQ in 2010 to participate in the SSO Initiative program. Flooding of a lift station at the Geronimo Creek WWTF has been a recurring issue for the facility. As a result, modifications to the lift station are the main component of the Seguin SSO Agreement that impact the Geronimo Creek watershed. Historically, when Geronimo Creek would rise during flood events, flood waters would enter the lift station causing a shutdown of the WWTF since all the sewer comes through the lift station that is flooded. Pending available funding sources, Seguin plans to seal the wet well of the lift station to stop infiltration of flood waters, raise all electric components including a generator above the 100 year flood plain in order for the lift station to continue to operate when Geronimo Creek leaves its banks, and add an additional submersible pump as back up. Seguin also will be submitting annual status reports to the TCEQ.

Septic Systems

SELECT analysis was utilized to estimate the number of potentially failing septic systems in the watershed, and identified those systems in close proximity (within 1,000 ft) to Alligator and Geronimo Creeks and their tributaries. These systems will be targeted for repair or replacement 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	45	6	1
2	1071	126	126
3	226	33	72
4	51	7	20
5	14	2	5
6	12	2	0
7	44	6	16
8	28	4	18
9	10	1	8
10	108	16	32
11	90	13	34
12	151	20	7
13	67	9	10
14	0	0	0
15	97	14	30
16	59	7	12
17	92	11	65
18	13	2	8
19	151	20	11
20	90	12	8
21	32	5	10
Total	2303	296	484

Based on estimated failure rate and proximity to a waterway, the greatest concentration of systems in need of management is in the upper portion of the watershed (subwatersheds 2 and 3, Fig. 5.6) in Comal County. Additional target areas will include subwatersheds 10 and 12 in the midsection and subwatersheds 15, 17 and 20 in the lower zone. Inspection programs will initially focus on these areas, but over time will work to address all subwatersheds.

To assist in the 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 Comal and Guadalupe Counties. In cooperation with the counties, 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 will then be targeted to these residents.

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, and 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 Guadalupe County, aerobic septic system homeowners must maintain a maintenance contract with a licensed maintenance provider at all times. Comal County does not require homeowners with aerobic systems to have a maintenance contract with a service company, and allows homeowners to maintain their system. However, Comal County did adopt more stringent requirements including a larger lot size, a permit for all systems, flood plain determination, sewer line sizing, and restrictions on items (such as picnic tables, play equipment, and barbeque pits) that can be placed within the surface application spray area.

There also are some septic systems still present within the city limits or extraterritorial jurisdictions of the two cities. One example is Oak Village North, a subdivision of approximately 148 homes that was originally built outside the Seguin city limits in 1985. The neighborhood is located just north of IH-10 and east of SH-123. Drainage from the neighborhood enters Geronimo Creek, and several of the homes are within 1,000 feet of the waterbody. As Seguin grew, Oak Village North was annexed by the city in 2007. Since the subdivision was originally constructed outside of the city limits, all the homes have individual septic tank systems. System age combined with a seasonally high water table has made system failure a growing concern. In late 2010, the City of Seguin made plans to extend sanitary sewer to the neighborhood. The project is scheduled to begin in 2012, and may take up to 2 years to complete. Once complete, the potential load from this area will be eliminated. Funding will be sought to assist homeowners with decommissioning the old septic systems, in order to remove the potential sources of bacteria and nitrates. Also, additional funding will be sought to design and construct a modified stormwater conveyance system for the neighborhood. Currently, stormwater does not receive any treatment before directly entering Geronimo Creek. Enhancements to the stormwater system would have a direct benefit to the water quality of the receiving stream.

Another goal of the WPP is to assist with identifying funding sources to support extending sanitary sewer services to areas not served by a collection system. This is a multi-phase, expensive 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 G).

Household Hazardous Waste

New Braunfels currently has a program to deal with household hazardous waste products, but plans to expand the program as part of their upcoming MS4 compliance. The City is currently operating a bulk cleanup day once per quarter, and a household hazardous waste and pharmaceutical waste day once per year. The city plans to establish a drop center where residents can dispose of household hazardous waste, and to make the center known to the public through education and outreach efforts. The Partnership will assist New Braunfels in obtaining funding for expanding the frequency and types of materials accepted at these events, as well as outreach and education efforts.

Seguin has a Community Clean Up Day twice per year at which citizens are encouraged to dispose of items such as: furniture, mattresses, household items, appliances without Freon (such as dishwashers and dryers), refrigerators without a compressor, and dried up paint cans. Seguin would like to expand the items receivable to include household hazardous waste products such as chemicals (including fertilizers and pesticides), petroleum products, wet paint cans, and pharmaceutical drugs, pending acquisition of funding with assistance from the Partnership.

AGRICULTURAL NONPOINT SOURCE MANAGEMENT MEASURES

The Agricultural Nonpoint Source Work Group recommended that multiple agricultural BMPs be integrated, where appropriate, into local operations in order to address all potential agricultural-related sources of bacteria. They further recommend that 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 "on-the-ground" implementation. 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 Geronimo and Alligator Creeks Watershed Partnership will pursue funding to support a financial incentives program for the Comal-Guadalupe SWCD and the creation of a new technician position to provide assistance in the watershed. This new employee will serve the watershed by working one-on-one with local agricultural producers to develop and implement WQMPs.

Based on 2007 USDA-NASS data, the average farm size was estimated to be 205 acres in Comal county and 156 acres in Guadalupe county. Local knowledge from NRCS, Extension, and agricultural producers indicates that livestock operations in the watershed maintain an average of approximately 33 animal units (cumulative cattle, sheep, goats, and horses). Utilizing this information, along with results from the SELECT and LDC analyses, the number of comprehensive management plans necessary for livestock and cropland operations within each subwatershed was estimated and is presented in Tables 6.5 and 6.6, respectively.

LIVESTOCK OPERATIONS

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 (26%) 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 0 to 3. A total of 23 management plans are necessary for the entire Geronimo and Alligator Creeks watershed.

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

County	Subwatershed	Animal Units	Number of Farms	Recommended # of WQMPs
Comal	1	54	2	1
	2	126	4	1
	3	128	4	1
Guadalupe	4	249	8	2
	5	149	5	1
	6	98	3	1
	7	79	2	1
	8	83	3	1
	9	30	1	0
	10	173	5	1
	11	279	8	2
	12	207	6	2
	13	96	3	1
	14	2	na	na
	15	340	10	3
	16	105	3	1
	17	96	3	1
	18	46	1	0
	19	293	9	2
	20	152	5	1
	21	140	4	1
	Total	2925	89	23

Financial incentives and technical assistance programs will be directed to subwatersheds with the greatest number of operations. However, recognizing that livestock numbers within individual subwatersheds 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, and particularly those located closest to streams and drainage areas.

CROPLAND OPERATIONS

A target number of cropland management plans needed to support the estimated nutrient load reduction (85%) also was determined (Table 6.6) as a management tool, although natural sources

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

County	Subwatershed	Cropland Acres	Number of Farms	Recommended Number of Management Plans
Comal	1	122	1	1
	2	337	2	2
	3	716	3	3
Guadalupe	4	2137	14	12
	5	495	3	3
	6	241	2	2
	7	829	5	4
	8	242	2	2
	9	25	n/a	0
	10	248	2	2
	11	417	3	3
	12	384	2	2
	13	741	5	4
	14	1	n/a	0
	15	635	4	3
	16	546	4	3
	17	175	1	1
	18	109	1	1
	19	522	3	3
	20	370	2	2
	21	270	2	2
	Total	9563	61	55

are believed to be the dominant cause of elevated nitrogen levels. Total cropland acreage in each subwatershed was divided by average watershed farm size to estimate the number of cropland operations. Required nitrate-nitrogen reduction for the watershed was then used to determine the number of cropland operations within each subwatershed needing plan development.

To optimize the water quality benefits of plan development and implementation, management practices which most effectively control bacteria and nutrient losses 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: Although not currently an approved financial incentive practice, creation of shade reduces time spent loafing in streams and riparian areas, thus reducing pollutant loading. Efforts will be made to include this practice as a component of livestock management plans.

WILDLIFE AND NON-DOMESTIC ANIMAL MANAGEMENT MEASURES

Based on SELECT analysis, non-domestic animals are a significant potential contributor of pollutants to Geronimo and Alligator Creeks. Feral hogs are a largely unmanaged, non-native species with growing numbers in the watershed. The Agricultural Nonpoint Source Work Group 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 Geronimo and Alligator Creeks 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 (26%), and is displayed in Table 6.7. Because the SELECT analysis used to determine total hog numbers also identified the most likely habitat zones based on land cover, initial management efforts will focus in those areas of highest concentration. These hog numbers represent initial goals over the course of the project, and as more information is gathered or if populations increase rapidly, these targets will be adjusted accordingly.

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

County	Subwatershed	Total Hogs	Hogs To Be Removed
Comal	1	0	0
	2	0	0
	3	0	0
	County Total	0	0
Guadalupe	4	0	0
	5	79	21
	6	2	1
	7	114	30
	8	104	27
	9	69	18
	10	82	21
	11	133	35
	12	177	46
	13	91	24
	14	10	3
	15	170	44
	16	75	19
	17	130	34
	18	118	31
	19	73	19
	20	73	19
	21	124	32
	County Total	1625	422
	Watershed Total	1625	422

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 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, pursuant to funding the Texas AgriLife Extension Wildlife and Fisheries Department will employ a full-time position to focus specifically on feral hog management in the Geronimo and Alligator Creeks watershed. The position will work directly with landowners to remove animals from the watershed by trapping and hunting.

To further enhance program targeting and success, the feral hog reporting website developed for the Plum Creek WPP project will be expanded for Geronimo and Alligator Creeks to enable reporting of the date, time, location, and approximate number of feral hogs observed. 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 land owners 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. Bacterial Source Tracking may be utilized to determine which types of animals have the greatest *E. coli* contribution. 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.

FLOOD MITIGATION STUDY

Officials from Guadalupe County received funding from the Texas Water Development Board (TWDB) for assistance with the Flood Protection Planning Program in January 2009 resulting in the development of the Geronimo Creek Flood Protection Plan (TWDB, 2011). Local governments and agencies supporting the study were: Guadalupe County, Comal County, City of New Braunfels, City of Seguin, and GBRA. The primary goal of the study was to identify potential methods that would reduce flooding in the Geronimo Creek watershed (including Alligator Creek). To achieve this goal, detailed hydrologic and hydraulic models were developed to evaluate existing watershed conditions and identify impacts due to development that has occurred since the Effective FEMA Flood Insurance Study of 1976. Secondly, the hydrologic and hydraulic data were used to evaluate structural and nonstructural mitigation alternatives, the benefits and costs of the options, and their effectiveness for reducing the risk and frequency of flooding.

While the study was independent of the Geronimo WPP, members of the Partnership and Steering Committee participated in the process to ensure mutually relevant issues, concerns, and solutions were discussed in both processes. Representatives from the consulting firm conducting the flood study also presented their findings to the Partnership, which offered recommendations on how best to blend the goals of improved water quality (in regards to bacteria and nitrogen) and flood protection. Seven possible types of projects were considered by the flood study planning committee. Four types were structural modifications: channel modifications, brush removal, bridge and low water crossing improvements, and regional storm water detention ponds. The three remaining non-structural options were regional detention regulations, a flood early warning system, and buyouts for repetitive loss structures in one area of the watershed. The non-structural solutions were difficult to assess relative to inherent benefits, construction costs, or implementation costs.

Channel modifications, brush clearing, and stream crossing improvements were found to have negligible impacts on the water surface elevations of the floodplain. Although making improvements to roads and bridges could reduce the risk of loss of life for motorists, it had a limited impact on flooding and proved to be non-beneficial based on construction costs. The analysis determined that use of detention ponds to reduce flooding resulted in minor beneficial impacts to the floodplain. The overall costs associated with building detention structures far exceed the benefits to the community.

As the ultimate goal of minimizing flood damage could not be achieved through peak flow reduction in a cost-effective manner, a flood planning and regulatory approach shows the most promise. Options for this approach include the creation of regional detention regulations to minimize future development in the floodplain, increasing restrictions to construction within the 1% annual floodplain, and the installation of physical measures such as flood warning systems and automatic gates at crossings in order to increase public safety during flood events. Buyouts and relocation of repetitive loss structures were shown to be cost-beneficial alternatives to reduce flood damage in the Elmwood subdivision in Seguin. Further study and specific design criteria will be needed to most effectively and efficiently combine the function of storm water control with water quality enhancement from the same structure or management practice.

SEGUIN OUTDOOR LEARNING CENTER

The Seguin Outdoor Learning Center (SOLC) is a non-profit organization that provides outdoor and classroom educational and recreational programs with a facility located on the banks of Geronimo Creek in Seguin. The 115 acre facility has a history center, conference room, outdoor pavilion and education building, outdoor stage, and pond. Started in 1995, the SOLC hosts school field trips, summer science camps, Boy Scout merit badge courses, hunter education courses, and many other programs and activities. Due to the impact it has had on local students, the Texas Outdoor Education Association named the SOLC the Outstanding Outdoor Education Program in the State of Texas in 1997. The SOLC would like to expand their educational programs to include classes that will educate participants about water quality issues in Geronimo and Alligator Creeks. Pending funding, the SOLC would offer new educational opportunities for ISDs, municipal employees, and other interested groups and citizens about the impact of bacterial nonpoint source pollution on area waterbodies.

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 Geronimo and Alligator Creeks Watershed. As a result, the Steering Committee recommends that a local Project Coordinator position be established in the watershed. A locally based Watershed Coordinator can best facilitate local 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, GBRA, and other watershed interest groups to keep them informed and involved in implementation activities being carried out in the watershed. The Watershed Coordinator also will work to secure external funding to facilitate implementation activities and to support salary and operating costs for continuation of the position.

Initial funding for the Watershed Coordinator will be incorporated into a CWA 319(h) grant proposal. Subsequently, with assistance from the Partnership the position will work to identify and build support for local funding of the Watershed Coordinator 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 federal, state, and local grants, loans, etc (salary and operating).
- Track and document implementation efforts to assess progress toward established goals.
- Evaluate water quality data to monitor progress and determine the need for new approaches.
- Coordinate and conduct water resources 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 Geronimo and Alligator Creeks 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 ongoing process of accumulating knowledge of the cause 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 Geronimo and Alligator Creeks, 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 Geronimo and Alligator Creeks 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 Haberle Road sampling location during the 10-year implementation schedule.

Year	***E. coli* Concentration (cfu/100mL)**
2013	162
2016	146
2019	130
2022	113

MONITORING AND WATER QUALITY CRITERIA

Water quality data will be analyzed using a 3-year geometric mean for *E. coli* bacteria to examine trends in Geronimo and Alligator 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 to compare against the water quality criteria.

Current water quality monitoring efforts in the Geronimo and Alligator Creeks watershed rely on the existing monthly routine monitoring station at Haberle Road (Station #12576). This location has been the main sampling location since 2003, it is used by TCEQ to conduct the assessment for the Texas Water Quality Integrated Report, and will be an important part of continued efforts to track the success of implementation. An additional routine monitoring site will be added on Geronimo Creek just above the confluence with the Guadalupe River. This new site will be utilized to monitor changes in water quality at the lower end of the watershed as implementation progresses.

Ambient in-stream data collected at these sites will include: flow, *E. coli*, nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, total dissolved solids, total suspended solids, pH, chlorophyll-a, pheophytin, sulfate, orthophosphorus, total phosphorus, total hardness, 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 measuring progress toward goals to address the current issues.

Continued routine monthly sampling at the Haberle Road site is considered essential. In addition, the Steering Committee recommends continued and more frequent sampling be conducted at Alligator Creek at Barbarosa Road, Geronimo Creek at Haberle Road, and lower Geronimo Creek monitoring stations.

Targeted Water Quality Monitoring

To supplement routine sampling, a special Surface Water Quality Monitoring project funded by the TSSWCB and conducted by the GBRA will increase the temporal and spatial resolution of sampling efforts to more effectively pinpoint the timing and sources of high pollutant loads. A combination of additional routine stations, multiple targeted locations, urban stormflow monitoring, wastewater effluent sampling, and springflow sampling will be utilized (Figure 7.1). A summary of the water quality monitoring components of this project are as follows:

- Increase routine sampling sites from 1 monthly to 8 sites monthly (duration of 18 months).
- Targeted wet and dry weather sampling twice per season at all 8 routine locations and 6 additional targeted monitoring sites (18 months).
- Springflow sampling once per season at 1 spring in central portion of watershed (18 months).
- Quarterly monitoring of 1 spring and 2 wells.

The monitoring program will collect additional data, look for trends and fill data gaps identified during the development of the WPP. Two new sites on Geronimo Creek will replace two routine/targeted sites included in earlier targeted monitoring that were determined to be ineffective due to lack of flow or proximity to other sites. One of the sites will be located at Geronimo Creek at IH-10 in order to collect routine and targeted monitoring downstream of the Oak Village North Subdivision that has had known failing septic systems and where Seguin is expanding the city’s wastewater collection system. The second site will be on SH-90 near the SOLC.

This intensive monitoring effort will refine the focus of management efforts as well as track the performance of ongoing implementation activities during the study. For this reason, funding will be required to continue monitoring throughout the 10 year period of implementation.

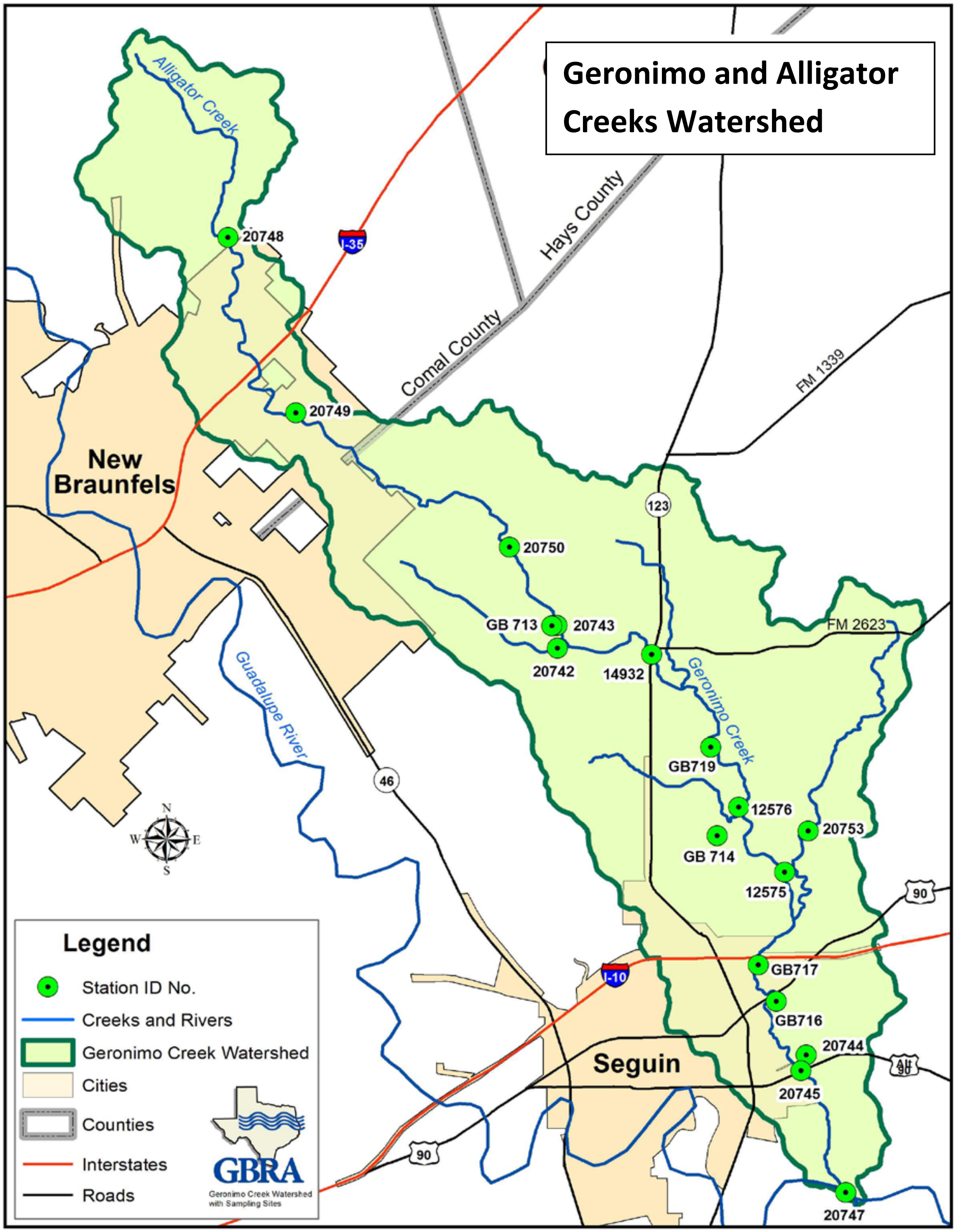

Figure7.1. Sampling locations in the Geronimo and Alligator Creeks Watershed.

Stream Biological Assessments

In addition to these water quality analyses, GBRA will conduct a biological and habitat assessments at the Haberle road monitoring station (Figure 7.2) once in 2012, and will conduct two biological monitoring events in 2013. 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 to changes in stream conditions. These surveys will be intensified in the summer of 2013 in order to determine if the stream is meeting current aquatic life use standards. These surveys may be continued after 2013 to determine if water quality trends result in measurable changes in the biological communities in Geronimo Creek. Reports will be developed after each survey and compared with results from previous surveys to determine differences over time.

Figure 7.2. Haberle Road sampling location on Geronimo Creek.

SELECT

SELECT was utilized to identify potential pollutant sources in the watershed and to estimate their distribution and the degree of contribution by each. As implementation moves forward, SELECT may again be employed to model changes within the watershed. At years 3, 6, and 10, based upon progress made towards implementation of tables 8.1 and 8.2, combined with an analysis of the latest water quality data, critical decisions will be made. It will be decided by the stakeholders at those year markers to determine whether SELECT will be utilized to analyze any significantly modified land uses. Information on animal numbers and distribution, changes in population and urban development, and other key inputs will enable current strategies to be evaluated. 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 Geronimo and Alligator Creeks Watershed Partnership Steering Committee and Work Groups also recommended employing Bacterial Source Tracking (BST) techniques as an additional management tool, if 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 will 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 tables 8.1 and 8.2, combined with an analysis of the latest water quality data, critical decisions will be made. It will be decided by the stakeholders at those year markers to determine whether BST will be utilized to attempt to further identify bacteria sources in selected areas. BST may be employed if initial efforts aimed 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 identified are part of ongoing budgeted operations of counties and municipalities. All management measures identified in the Geronimo and Alligator Creeks 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 Geronimo and Alligator Creeks 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 entities 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 individual entities in the watershed. However, identification and design of specific improvements to storm water conveyances are beyond the scope of most municipal operations and Phase II stormwater permit requirements. Professional engineering analysis will be essential to assess construction of new structural controls and upgrades to existing components of storm water facilities. Funding will be sought to support these engineering evaluations for Seguin and New Braunfels. Funding will be sought to assist Seguin with modifications to urban stormwater conveyance systems in areas to enhance stormwater treatment before entering impaired waterways. Subsequent implementation of recommended and targeted stormwater management controls, along with enhanced monitoring and management procedures and installation of pet waste collection stations will enable the achievement of target urban pollutant load reductions. Throughout this process, the continued assistance and commitment of city officials and staff will be critically important to the implementation of recommended management measures.

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 Comal and Guadalupe 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 Comal-Guadalupe SWCD and USDA-NRCS personnel is critical to proper selection and placement of appropriate management measures on individual agricultural properties. However, due to the number of management plans that will be 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 livestock and cropland 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 AgriLife Extension, with a new staff position housed in the watershed. Animal number targets will be used as an initial measure of program effectiveness. In addition, feral hog surveys 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 Steering Committee and work groups, 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 Geronimo and Alligator Creeks Watershed Protection Plan. Increments of years 1-3, 4-6, and 7-10 post-approval and implementation of the plan have been defined. In addition, estimated quantitative targets have been established for most management measures. This allows key milestones to be tracked over time so that 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, changes in water quality often are delayed following initial implementation of management measures, and substantive changes generally require several years to be discernible.

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

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

Management Measure	Jurisdiction	Unit Cost	Number Implemented Year			Total Cost
			1-3	4-6	7-10	
Urban Stormwater Management Measures						
Pet Waste Collection Stations	City of New Braunfels	$620/station $85 annual/station	6	3	3	$14,325
Pet Waste Collection Stations	City of Seguin	$620/station $85 annual/station	5	2	2	$10,935
Initiate Spay/Neuter Program	City of New Braunfels	$35,000	1	---	---	$35,000
Enhance existing Spay/Neuter Program	City of Seguin	$35,000	1	1	1	$35,000[1]
Comprehensive Urban Stormwater Assessment	Cities of Seguin and New Braunfels	$35,000/survey	2	---	---	$70,000
Increase frequency and coverage of Phase II Permit Activities	City of New Braunfels					$743,000[2]
Street Sweeping Program	Cities of Seguin and New Braunfels		12	12	16	$240,000[1,2]
Enhance Stormwater Management Practices	City of Seguin					$75,000
Modify stormwater conveyance systems	City of Seguin					$1,200,000

Management Measure	Jurisdiction	Unit Cost	Number Implemented			Unit Cost
			Year			
			1-3	4-6	7-10	
Wastewater Management Measures						
Wastewater Collection System line testing/replacement (SSO Initiative)	New Braunfels Utilities					$331,800[2]
Modifications to the Geronimo Creek Lift Station (SSO Initiative)	City of Seguin	$1,680,000/lift station	1			$1,680,000[1]
Expand County OSSF Education Programs	Extension	$2,500 event	2	2	2	$15,000
Septic System Repair	Homeowner	$5,000/system	10	15	15	$200,000
Septic System Replacement	Homeowner	$10,000/ system	15	15	15	$450,000
Septic System Decommissioning	Homeowner	$2,000/system	148	74	74	$592,000
Expand the Existing Household Hazardous Waste Programs	Cities of Seguin and New Braunfels	$12,500/event	2	2	2	$75,000

Management Measure	Jurisdiction	Unit Cost	Number Implemented			Unit Cost
			Year			
			1-3	4-6	7-10	
Agricultural Management Measures						
WQMP Technician (New Position)	SWCD	$75,000/year	1			$750,000
Water Quality Management Plans	SWCD	$15,000/plan	15	31	32	$1,170,000
Non-Domestic Animal and Wildlife Management Measures						
Feral Hog Control (New Position)	Extension	$90,000/year[4]	1			$900,000
Feral Hog Control (Equipment)	Extension	$500/trap	10	---	---	$5,000
Monitoring Component						
Targeted Water Quality Monitoring	GBRA	---	1	1	1	$TBD
Comprehensive Stream Assessment	GBRA	$1,500/ assessment	3	3	3	$4,500
Bacterial Source Tracking and wildlife surveys	TAMU	---	---	---	1	$200,000

[1] Currently underway using City of Seguin funds.
[2] Currently underway using City of New Braunfels funds.
[3] Currently underway using New Braunfels Utilities funds.
[4] Total includes salary, benefits (health insurance, annual/sick leave, etc.) office rental, communications (fax, phone), travel/vehicle expenses, and computer cost.

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 GBRA 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 Geronimo and Alligator Creeks 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.

Outreach Activity	Jurisdiction	Total Cost			Total Cost
		1-3	4-6	7-10	
Broad-Based Programs					
Texas Watershed Steward Training Sessions	Extension	1	---	---	n/a
Public School Education Program	GBRA	1	1	1	$25,000
Alligator and Geronimo Creek Watershed Protection Brochure and Newsletters	GBRA	5	5	5	$10,000
Displays at Local Events	Extension/TSSWCB	6	6	6	$3,600
Nonpoint Source Pollution Educational Programs	Seguin Outdoor Learning Center		3	3	$100,000
Urban Programs					
Urban Sector Nutrient Education	Extension	3	3	4	$45,000
Pet Waste Programs	Cities, TCEQ, Extension	3	3	4	$35,000
NEMO Workshops	GBRA, TCEQ, Extension	2	---	---	$20,000
Fats, Oil, Grease Workshops		2	---	---	
Master Gardner and Master Naturalist Programs		2	2	2	
Sports and Athletic Field Education (SAFE)	Extension	3	3	4	$45,000

Outreach Activity	Jurisdiction	Total Cost			Total Cost
		1-3	4-6	7-10	
Wastewater Programs					
Advertise Septic System Online Training Modules	GBRA	3	3	4	$10,000
Septic System Workshops and Assistance	Extension /GBRA	4	3	3	$25,000
Agricultural Programs					
Soil and Water Testing Campaigns	Extension	3	3	3	$36,000
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	1	1	1	$75,000
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	GBRA	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

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 Program 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 $85,000 per year including travel expenses will be necessary for this position.

SOURCES OF FUNDING

Successful acquisition of funding to support implementation of management measures will be critical for the success of the Geronimo and Alligator Creeks 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 Steering Committee and Work Groups, city officials, agency representatives, and other professionals were used to estimate financial needs. In some cases, funding for some activities 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 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 in the planning, design, and construction of facilities, collection systems, storm water pollution control projects, and nonpoint source pollution control projects.

USDA Rural Development Program (USDA-RD)

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 is a voluntary program for agricultural landowners. Through the Conservation you 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, Conservation Reserve Program protects groundwater and helps improve the condition of lakes, rivers, ponds, and streams.

Wildlife Habitat Incentive Program

The Wildlife Incentive Program (WHIP) is a voluntary program for conservation-minded landowners who want to develop and improve wildlife habitat on agricultural land, nonindustrial private forestland, and Indian land. The Natural Resources Conservation Service andministers WHIP to provide both technical assistance and up to 75 percent cost-share assistance to establish and improve fish and wildlife habitat. Key WHIP objectives include restoration of declining or important native fish and wildlife habitats; reduction of the impacts of invasive species on fish and wildlife habitats; and restore, develop or enhance declining or important aquatic wildlife species' habitats.

Agricultural Water Enhancement Program

The Agricultural Water Enhancement Program (AWEP) is a voluntary conservation initiative 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). This project can provide funding for agricultural producers to develop natural resource conservation plans and implement best management practices that will assist in improving water quality.

Texas Capital Fund

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

Agricultural Water Conservation Program

Provides grants and low-interest loans to political subdivision 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. 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 AgriLife Extension Service - Wildlife Services and the Texas Parks and Wildlife Department receive funding under this grant program.

Outdoor Recreation Grants

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 will be 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 will be in the $15,000 to $25,000 range.

Water Supply Enhancement Program

In Chapter 203 of the Texas Agriculture Code, the TSSWCB is designated as the agency responsible for administering the Texas Brush Control Program to enhance water supplies through the selective control of water-depleting brush. Chapter 203 created a cost share program for brush control, created the Brush Control Fund, limits the cost share rate to 80% of the total cost of a practice, and limits the cost share program to critical areas designated by the TSSWCB and to methods of brush control approved by the TSSWCB. It also establishes criteria for approving applications, setting priorities and contracting for cost sharing.

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. As a program, LIP efforts are focused on 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 (EDAP)

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 present facilities are inadequate to meet residents' minimal needs. While the majority of the watershed does not meet these requirements, small pockets within the area may qualify based on economic requirements of the program. Groups representing these areas may pursue funds to improve wastewater infrastructure.

Environmental Quality Incentives Program (EQIP)

The Environmental Quality Incentives Program is administered by the USDA-NRCS. This voluntary conservation program promotes agricultural production and environmental quality as compatible national goals. Through financial incentives, 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 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 feasible 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, federal funds are allocated to be 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, 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. Section 319(h) funds from the TSSWCB supported the development of the Geronimo and Alligator Creeks Watershed Protection Plan. Additional funding will be sought through TSSWCB to support WQMP implementation efforts. Funding also will be sought from TCEQ through this program to support urban storm water assessments for both cities and related programs.

Supplemental Environmental Project Program (SEP)

The Supplemental Environmental Projects 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 (CRP)

The 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 source to support and enhance surface water quality monitoring in the watershed.

Water Quality Management Plan Program

The WQMP program is administered by the TSSWCB. Also known as the Senate Bill 503 program, the WQMP program is 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 503 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 Haberle Road monitoring station as a result of full implementation of the Geronimo and Alligator Creeks 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 Geronimo and Alligator Creeks Watershed.

Table 8.3. Estimated pollutant load reductions expected upon full implementation of the Geronimo and Alligator Creeks Watershed Protection Plan.

Management Measure	Expected *E. coli* Load Reduction[1]
Urban Stormwater Management Measures	
Pet Waste Collection Stations	6.38×10^{11}
Pet Waste Ordinance and Outreach and Education Program	
Pet Spay/Neuter Programs	
Comprehensive Urban Stormwater Assessments and stormwater conveyance modifications	1.87×10^{12}
Street Sweeping	
Phase II Permit Activities	
Wastewater Management Measures	
Wastewater Collection System Line Testing/Replacement	1.31×10^{9}
Modifications to the Geronimo Creek Lift Station	
Septic System Workshops	5.02×10^{11}
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)	6.24×10^{12}
Water Quality Management Plans	
Deer	2.90×10^{10}
Non-Domestic Animal Measures	
Feral Hog Control (New Position)	3.77×10^{11}
Feral Hog Control (Equipment)	

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

References

American Veterinary Medical Association. 2002. U.S. Pet Ownership and Demographics Source Book. Schaumberg, Ill. Center for Information Management, American Veterinary Medical Association.

American Veterinary Medical Association. 2007. U.S. Pet Ownership and Demographics Source Book. Schaumberg, Ill. Center for Information Management, American Veterinary Medical Association.

City of Austin. 1997. Evaluation of Non-point Source Controls, Volumes 1-2. COA-ERM/WQM & WRE. 1997-04.

EPA. 2001. Protocol for Developing Pathogen TMDLs. Office of Water, United States Environmental Protection Agency.

EPA. 2006. An Approach for Using Load Duration Curves in Developing TMDLs. Office of Wetlands, Oceans, and Watersheds, United States Environmental Protection Agency.

Lockwood, M. 2005. White-Tailed Deer Population Trends. Federal Aid in Fish and Wildlife Restoration. Project W-127-R-14. Texas Parks and Wildlife Department.

Reed, Stowe, and Yanke. 2001. Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-Site Sewage Facility Systems in Texas, Prepared in Cooperation with the Texas On-Site Wastewater Treatment Council.

Taylor, R. 2003. The Feral Hog in Texas. Texas Parks & Wildlife Department.

Texas Water Development Board. 2011. Final Geronimo Creek Flood Protection Plan, Guadalupe County. http://www.twdb.state.tx.us/RWPG/rpgm_rpts/0904830951_Geronimo.pdf

United States Deparment of Agriculture Soil Conservation Service. 1984. Soil Survey of Comal and Hays Counties Texas.

United States Deparment of Agriculture Soil Conservation Service. 1977. Soil Survey of Guadalupe County, Texas.

USDA. 2002. Census of Agriculture – County Data. National Agricultural Statistics Service: 560-634, 716-718, 719-729, 730-732, 733-734.

Appendix A: List of Acronyms

7Q2	Minimum 7-Day, 2-Year Discharge
AI	Adaptive Implementation
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
cfu	Colony Forming Units
CRP	Clean Rivers Program
CWA	Clean Water Act
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
LDC	Load Duration Curve
MGD	Million Gallons per Day
MS4	Municipal Separate Storm Sewer System
NAIP	National Agriculture Imagery Program
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
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
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility

Appendix B: Partnership Ground Rules

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

The signatories to these Ground Rules agree as follows:

GOALS

The goal of the Partnership is to develop and implement a Watershed Protection Plan (WPP) to improve and protect the water quality of Geronimo (Segment 1804A) and Alligator Creeks; Alligator Creek is a tributary to Geronimo Creek. According to the *2008 and 2010 Texas Water Quality Inventory and 303(d) List*, Geronimo Creek exhibits elevated nutrient levels and 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 Geronimo 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 Geronimo Creek.

TIME FRAME

Development of a Geronimo Creek WPP will require at least a 15-month period. The Steering Committee will function under a March 2011 target date to complete the initial development of the WPP. Achieving water quality improvement in Geronimo 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

Selection

The Steering Committee is composed of stakeholders from the Geronimo Creek Watershed. Initial solicitation of members for equitable geographic and topical representation was conducted using three methods: 1) consultation with the Texas AgriLife Extension Service County Agents, Guadalupe-Blanco River Authority (GBRA), Comal-Guadalupe Soil and Water Conservation District 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.

Membership

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 Geronimo 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;
- Prioritization of programs and practices to achieve water quality and programmatic goals;
- Help develop a WPP document;
- Lead the effort to implement this plan 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 and/or GBRA 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 will serve on at least one work group and represent that work group at Steering Committee meetings to bring forth information and recommendations.

WORK GROUPS

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

Work Groups will include, but will not be limited to, the following:

- <u>Agricultural Nonpoint Source Work Group</u> – The purpose of this Work Group is to discuss the specific causes and sources of nonpoint source pollution stemming from general agricultural and silvicultural (forestry) sources. This includes cropland, pastureland, rangeland, and forestland. Sources to be discussed include runoff from cropland, livestock, wildlife and feral hogs (invasive species). This Work Group will also identify and recommend strategies to reduce and abate pollution from these sources. Outreach and education programs for targeted audiences associated with these sources will be handled by this Work Group.

- <u>Urban Nonpoint Source Work Group</u> – The purpose of this Work Group is to discuss the specific causes and sources of nonpoint source pollution stemming from general urban sources. This includes residential, commercial, and industrial land uses. Sources to be discussed include runoff from "paved" sources, pets and other non-livestock domestic species. Urban growth and development is a topic within the realm of this Work Group. This Work Group will also identify and recommend strategies to reduce and abate pollution from these sources. Outreach and education programs for targeted audiences associated with these sources will be handled by this Work Group.

- Wastewater Infrastructure Work Group – The purpose of this Work Group is to discuss the specific causes and sources of pollution stemming from on-site sewage facilities (OSSFs or septic systems) and wastewater treatment facilities (WWTFs). Regionalization of wastewater treatment, the conversion of OSSFs to a centralized WWTF, and repair/replacement of OSSFs are topics within the realm of this Work Group. This Work Group will also identify and recommend strategies to reduce and abate pollution from these sources. Outreach and education programs for targeted audiences associated with these sources will be handled by this Work Group.

Flood Mitigation Study– Guadalupe County is conducting a flood planning study on Geronimo and Alligator Creeks with funding from the Texas Water Development Board. While the flood planning study is wholly independent from the development of this WPP, it is anticipated that outcomes and recommendations from the flood planning study may be mutually beneficial to water quality restoration and protection, as well as flood mitigation. The holistic nature of watershed planning emphasizes the need to integrate these two processes. Members of the Partnership and Steering Committee, including the Facilitators, will participate, as appropriate, in the Guadalupe County flood planning study to ensure mutually relevant issues, concerns, and solutions are discussed in both processes.

Tasks such as research or plan drafting will be better performed by these topical work groups. Work Group members will discuss specific issues and assist in developing that portion of the WPP, including implementation recommendations.

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

TECHNICAL ADVISORY GROUP

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

- Texas Commission on Environmental Quality
- Texas AgriLife Extension Service

- Texas AgriLife Research
- Texas Department of Agriculture
- Texas Parks and Wildlife Department
- Texas State Soil and Water Conservation Board (TSSWCB)
- Texas Water Development Board
- U.S. Environmental Protection Agency
- U.S. Geological Survey
- USDA Natural Resources Conservation Service
- USDA Farm Service Agency

Replacements and Additions

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

Alternates

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

Absences

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

DECISION MAKING PROCESS

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

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

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

Quorum

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

FACILITATORS

AgriLife Extension and GBRA serve as the Facilitators for the Partnership, Steering Committee, and Work Groups. The Facilitators are independent positions, financed through a federal Clean Water Act §319(h) nonpoint source grant from the TSSWCB and the U.S. Environmental Protection Agency. Each has specific roles to perform in facilitating the Partnership and Steering Committee.

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

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

MEETINGS

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

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

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

OPEN DISCUSSION

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

AGENDA

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

MEETING SUMMARIES

The Facilitators will take notes during the meetings and may conduct audio recording (for the sole purpose of note taking). Meeting summaries will be based on notes and/or the recording. The Facilitators will draft meeting notes and distribute them to the Steering Committee or Work Group 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, GBRA 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, GBRA 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 C: Nine Key Elements of Watershed Protection Plans

A. Identification of Causes and Sources of Impairment

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

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

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

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

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

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

G. Milestones

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

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

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 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) provided image data for Comal County and Guadalupe County. These images had a spatial resolution of 1 meter. Secondly, TPWD provided a system that was used to aid in classification of NAIP images. This is a highly accurate classification system that consists of polygons representing numerous classes.

Methods

The Comal and Guadalupe county 2008 NAIP imagery was mosaicked and clipped to the watershed boundary in order to create complete coverage. The watershed was then classified using two supervised, pixel-based classification algorithms: Mahalanobis Distance and Maximum Likelihood. Mahalanobis Distance is based on correlations between variables by which different patterns can be identified and analyzed. It is a useful way of determining similarity of an unknown sample set to a known one. Maximum Likelihood is a method of estimating the parameters of a statistical model. These two classification methods were performed using ENVI geospatial imagery processing and analysis software.

Six land use classes were identified using regions of interest (a region of interest is an area selected that has a specific homogeneous land use cover type). Regions of interest help classify unknown pixels by using a classification algorithm which results in the following land use groups: Open Water, Barren, Urban, Forest, Pasture, and Cultivated Crops. Regions of interest were selected in the watershed in the form of points. The larger portion of the image was classified using Maximum Likelihood. Due to the similarity between barren land and urban, two subsets were made for areas with large amounts of barren land to accurately classify each region without overestimating barren land. Each subset was classified individually using Mahalanobis Distance. The subsets were then reclassified to remove everything but barren land. In other areas, pastures and crops were difficult to differentiate so a class called pasture/crops was created to account for this. Also, the crops class was split into red and green classes due to variability throughout the image. Active cropland appeared red in a false color composite image, while fallow land that had been tilled appeared green. The TPWD classifications were compared to NAIP images to determine land uses but the classification was 2-4 years older than the images and some areas had changed. The most accurate classifications for the two subsets and the main image were selected and converted to an Erdas Imagine file. The barren subsets and the complete classification were then merged together using ArcMap spatial analyst.

The classification naming code is as follows: 1. Open Water, 2. Forest, 3. Urban, 4. Rangeland, 5. Managed Pasture, and 6. Cultivated Crops.

Results

Overall the classification resulted in a complete coverage of the study area with good accuracy based on visual assessment. Maximum Likelihood was chosen for the larger portion of the image, although it overestimated urban areas. Mahalanobis Distance was used for classification of the subsets, although it overestimated forest. Both overestimations interfered with the classification of crops and pastures, due to the inability to differentiate between some vegetation classes, which resulted in overlap or overestimation of one class or the other.

Land Use Categories

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

Rangeland - Areas of unmanaged shrubs, grasses, or shrub-grass mixtures.

Managed Pasture - 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: Developing Flow Estimations

Geronimo and Alligator Creeks have no long-term flow data available for use in LDC and SELECT analyses. As a result, the Spatial Sciences Laboratory at Texas A&M University utilized the Soil and Water Assessment Tool (SWAT) model to develop flow estimates for the Geronimo and Alligator Creeks watershed by modeling flow in a larger portion of the Guadalupe River watershed (including Geronimo and Alligator Creeks) and comparing model outputs to historic flow data from U.S. Geological Survey (USGS) gages 08169500 and 08169792 for the most recent 80 year period.

WWTF flows were accounted for in modeled flows of Geronimo Creek. The same spatial data sets utilized in the SELECT model were used as inputs or initial conditions for the SWAT model simulations. Annual flow for the modeled watershed was calibrated to be within 15% of recorded annual flow at the downstream USGS gage. Partitioning of stream flow between surface and baseflow also was calibrated according to the base flow filter to be within 15% of measured values. There were a total of 21 subwatersheds delineated using the SWAT model. Subwatershed 14 is substantially smaller in size compared to the other subwatersheds. Due to its unique hydrology, though, it must remain its own separate subwatershed in order to maintain the calibration of the overall model. Outputs from the calibrated SWAT model predicted incremental flow at designated points in Geronimo and Alligator Creeks. These predicted flow data were incorporated into SELECT and LDC analyses.

Appendix F: Load Duration Curve Explanation

A widely accepted approach for analyzing water quality is the use of a Load Duration Curve (LDC). An 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. 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 Haberle Road sampling station from 1998 to 2009 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.

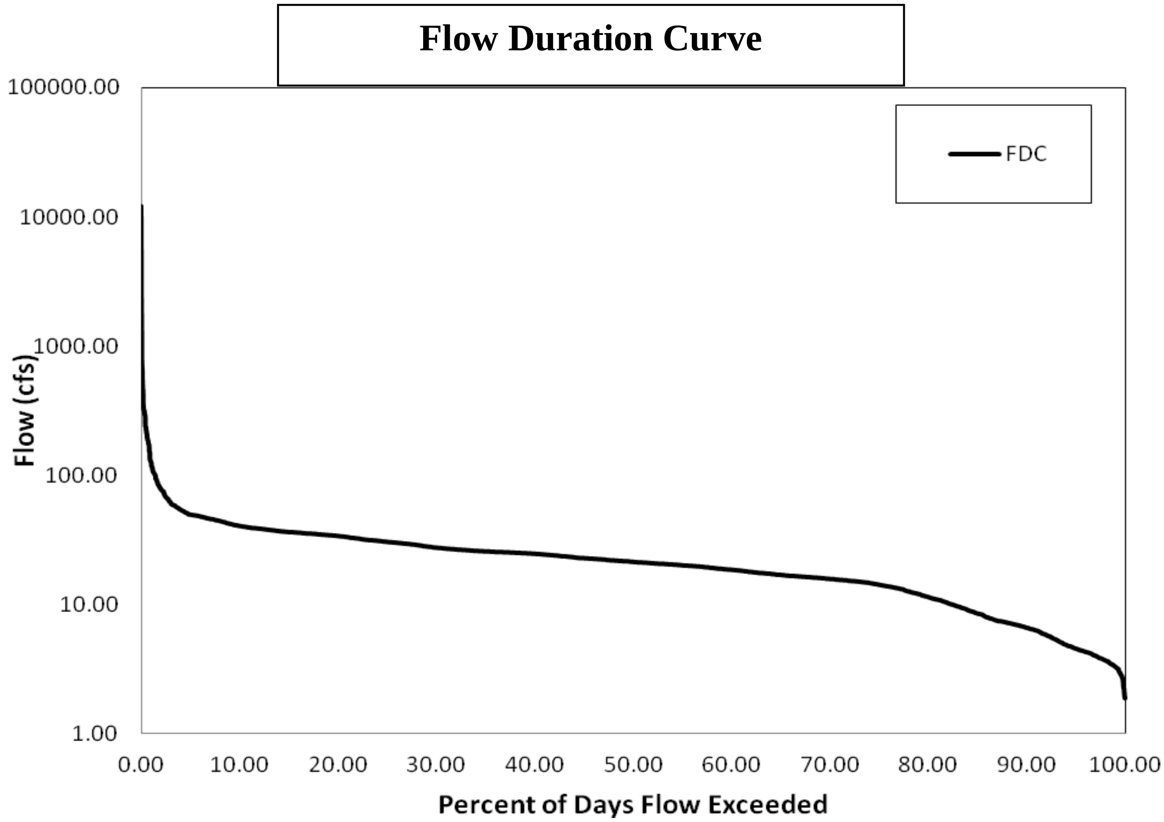

Figure F.1. Example flow duration curve.

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 both bacteria and nitrate-nitrogen in this plan. For contact recreation in Texas, the geomean of *E. coli* must be below 126 cfu/100 mL. Currently there are no numeric standards for nitrate-nitrogen; however, there is a screening level of 1.95 mg/L for nitrate-nitrogen. Thus, threshold concentrations used in the LDC analysis were 113 cfu/100mL for bacteria and 1.76 mg/L for nitrate-nitrogen.

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 Geronimo Creek, there are three flow regimes: high (0-10th percentile flow, 4.1 cfs to 12,205 cfs), mid range (11th – 74th percentile flow or 14.3 cfs to 41 cfs) , and low flows (75th -100th percentile flow or 1.89 cfs to 14.3 cfs). These regimes reflect where a change in the slope of the LDC line is detected. Bacteria data plotted on the LDCs for Geronimo Creek in this report covered data collected from 2003 to 2009 for the Haberle Road 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 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. 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.

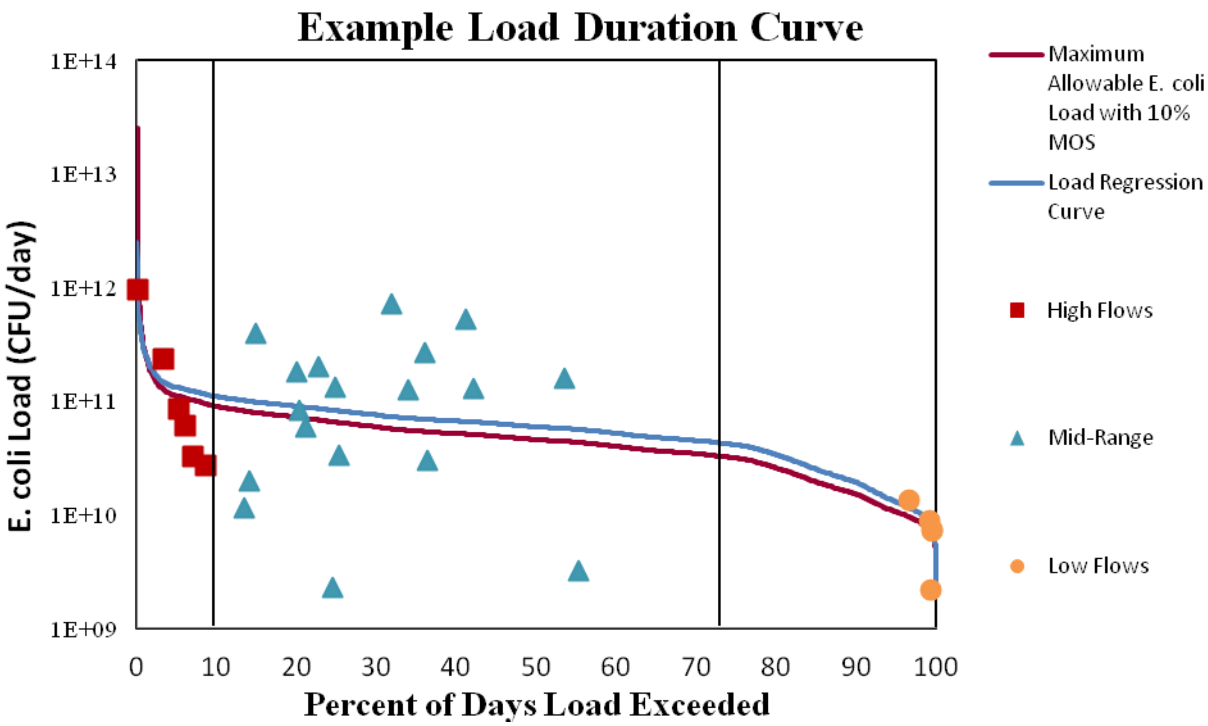

Figure F.2. Example load duration curve.

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.

Appendix G: 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 2008 National Agriculture Imagery Program (NAIP) imagery and a 2008 Texas Parks and Wildlife (TPWD) Classification. The watershed was divided into 21 subwatersheds based on elevation changes along tributaries and the main segment of the water body. Since SELECT divides the watershed into a raster grid with a 30-meter cell size, the potential load is calculated over the entire watershed at a 30-meter cell size. The individual raster files for each source are then added together spatially to create a total load raster for the watershed that is divided into 30-meter grid cells.

Urban Runoff

Bacteria losses were based on a runoff curve number approach to estimate runoff (PBS&J, 2009). Data were generated on a subwatershed basis and then aggregated. *E. coli* bacteria numbers in runoff were calculated for each subwatershed separately. The spatial aspects of the model for each subwatershed were determined in ArcGIS and then exported into Microsoft Excel.

Mathematical Model

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

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

Where:

Impervious Cover = Percent impervious area in subwatershed (%)

Urban Area = Urban area in subwatershed (acres)

Subwatershed Area= Subwatershed area (acres)

The percentage of impervious cover was found for each subwatershed for the PBS&J study to be utilized to find the amount of *E. coli* per subwatershed. The graph below (Figure G.1) shows the relation of impervious cover and fecal coliform for City of Austin stormwater runoff.

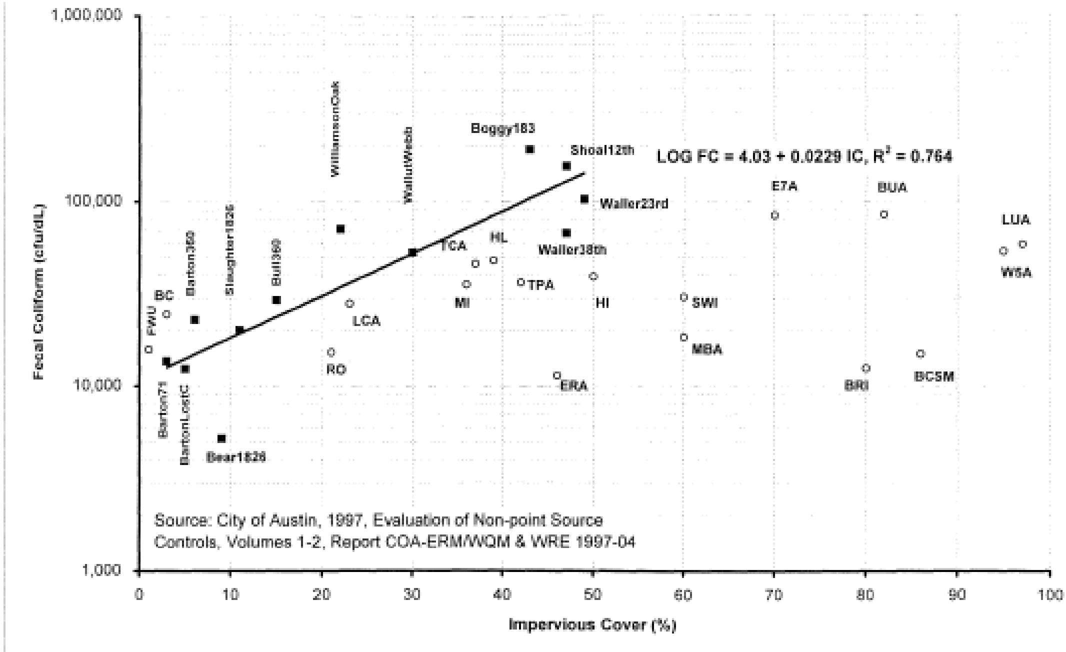

Figure G.1. Fecal coliform mean EMCs for City of Austin stormwater runoff (PBS&J, 2009)

The percentage of impervious cover was then inputted into the equation below (PBS&J, 2009):

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

Where:

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

IC = Impervious Cover (%)

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

Curve Number Approach

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

Two assumptions made for this project in determining appropriate curve numbers were use of antecedent moisture condition II and a hydrologic soil group of D. Antecedent condition II assumes normal soil moisture before the rainfall event as compared to dry or wet soil moisture. Soils in hydrologic soil group D have high runoff potential and very low infiltration rates when thoroughly wetted. They consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material (Haan, Barfield, & Hayes, 1994). Group D soils were chosen for the entire watershed as a conservative measure, and because many of the soil series in the watershed are shallow clayey soils over limestone bedrock. The curve numbers chosen for the specific land uses are presented in Table G.1 below.

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

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

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

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

Where:

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

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

A_i = the amount of area for the appropriate curve number

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

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

Where:

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

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

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

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

Where:

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

P= the accumulated precipitation (inches)

S= maximum soil water retention parameter (inches)

An accumulated precipitation of 4 inches per day was based on Soil Conservation Service rainfall data for a two-year, 24-hr rainfall event in the area. This rainfall event was chosen because it is a small rainfall event that would regularly cause runoff in this region without causing flooding. The total runoff volume for each subwatershed was then calculated by multiplying the accumulated runoff by the amount of urban area. The volume of runoff was then converted to a daily potential *E. coli* load using the formula below:

E. coli load = *E. coli* * V * (102790 L/1 acre-inches) * (1000 mL/1 L)

Where:

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

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

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

Domestic Dogs

By multiplying the average number of dogs/household by the number of households in each subwatershed, dog density was estimated and total potential daily bacterial load was approximated using:

$$DogLoad = \# Households * (1.0 \text{ dog/household}) * (5*10^9 \text{ cfu/day}) * 0.63$$

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 2000 census block data from the U.S. Census Bureau along with 911 address information for Guadalupe County, the number and location of households in the Geronimo and Alligator Creeks Watershed were determined. Census data were used to determine the average number of people per home. The 911 address data were used to identify locations of households in the watershed. Homes within city limits (CCN) were determined to be on city sewer facilities, except in instances such as the Oak Village North Subdivision (inside city limits but not on a sanitary sewer collection system), and those outside city limits were assumed to rely on septic systems. Using home and subdivision records obtained from the counties, the age of homes, and thus septic systems, were determined. Data on age and location of systems, were combined with the soils data to assign a potential malfunction rate (OSSF Index, Table G.2, G.3, G.4, and Figure G.2). Potential malfunction rate classifications were 5, 10, and 15%. Of the 2,356 systems, 980 were assigned a 10% malfunction rate, and 1,376 were assigned a 15% malfunction rate (Table G.5).

OSSF Index Calculations

OSSF Index = 0.7 * Soil Rate + 0.3 * Age Rate

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

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 G.2. Soil limitations classes.

Limitations Class	Soils Rate
Slightly	1
Somewhat	2
Very	3
Not Rated	-99

Table G.3. Septic system age classes.

Age (years) Class	Age Rate
0 - 15	1
16 - 30	2
>30	3
No Data	-99

Table G.4. OSSF indexes and associated malfunction rates.

Index	Percent Malfunction
<0 (Age or soil unknown)	15
0.0 – 1.5	5
1.5 – 2.5	10
2.5 – 3.0	15

Table G.5. Results of classification by index.

Index	Percent Malfunction	Ratio (#homes in each index category/total #homes)
<0	15	822/2356
0 – 1.5	N/A	0/2356
1.5 – 2.5	10	980/2356
2.5 – 3.0	15	554/2356

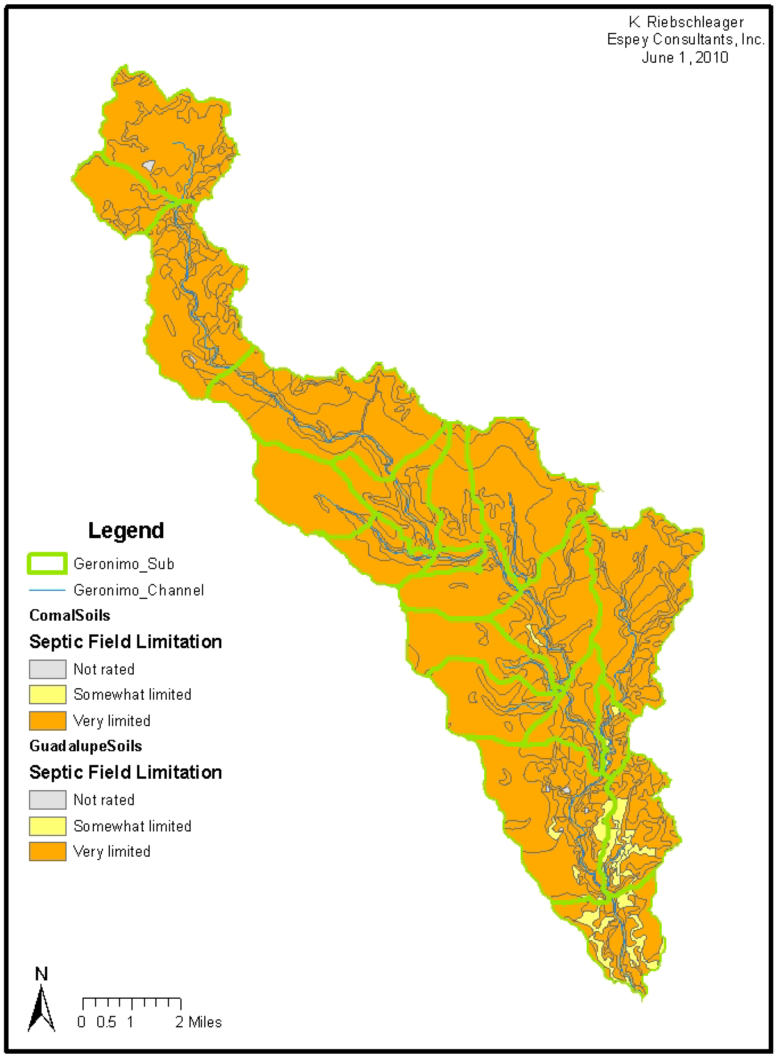

Figure G.2. Soil suitability for onsite sewage facilities in the Geronimo and Alligator Creeks Watershed.

Cattle

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

$$\text{Cattle Load} = \#\ \text{Cattle}*5.4*10^{9}\ \text{cfu/day}*0.63$$

Where $5.4*10^{9}$ cfu/day *0.63 is the average daily *E. coli* production per head of cattle (EPA 2001).

Goats

The estimated population was based upon a combination of population statistics from the USDA NASS data and stakeholder knowledge and observation. NASS data resulted in a watershed population estimate of 364 goats. However, stakeholder knowledge identified particular subwatersheds that had higher than average populations. Specifically, 150 goats were distributed in subwatershed 4, 300 goats were distributed in subwatershed 10, 100 were distributed across subwatersheds 1, 2, and 3, and 200 were distributed on the remaining subwatersheds. The total watershed population was estimated to be 750 head of goats distributed on rangeland, forest, and managed pasture. Portions of the total population were allocated to individual subwatersheds where populations were known to exist, in order to more accurately characterize the watershed. Based on these population estimates, the total potential daily *E. coli* load for goats was estimated using:

$$\text{Goat Load} = \text{\# goats}*18*10^{9}\ \text{cfu/day}*0.63$$

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

Wildlife

The potential bacteria concentration of white-tailed deer in the Geronimo and Alligator Creek Watershed was estimated using deer census estimates from TPWD (Lockwood 2008). Average densities of the white-tailed deer within resource management units for 2005 through 2008 were obtained for the SELECT analysis. Based on the average number of deer per 1000 acres, deer were distributed on forest and rangeland and the total number of deer in each subwatershed was calculated. The total potential daily bacteria load for each subwatershed was then estimated using the *E. coli* production rate of Zeckoksi et al. (2005). The Alligator and Geronimo Creeks watershed is located in parts of TPWD Resource Management Units (RMU) 7 and 11, with RMU 7 covering more of the watershed than RMU11 (Figure G.3). For this reason, white-tail deer population density estimates for RMU 7 were used. An average of the most recent 4 years of white-tail deer census data was used (Figure G.4).

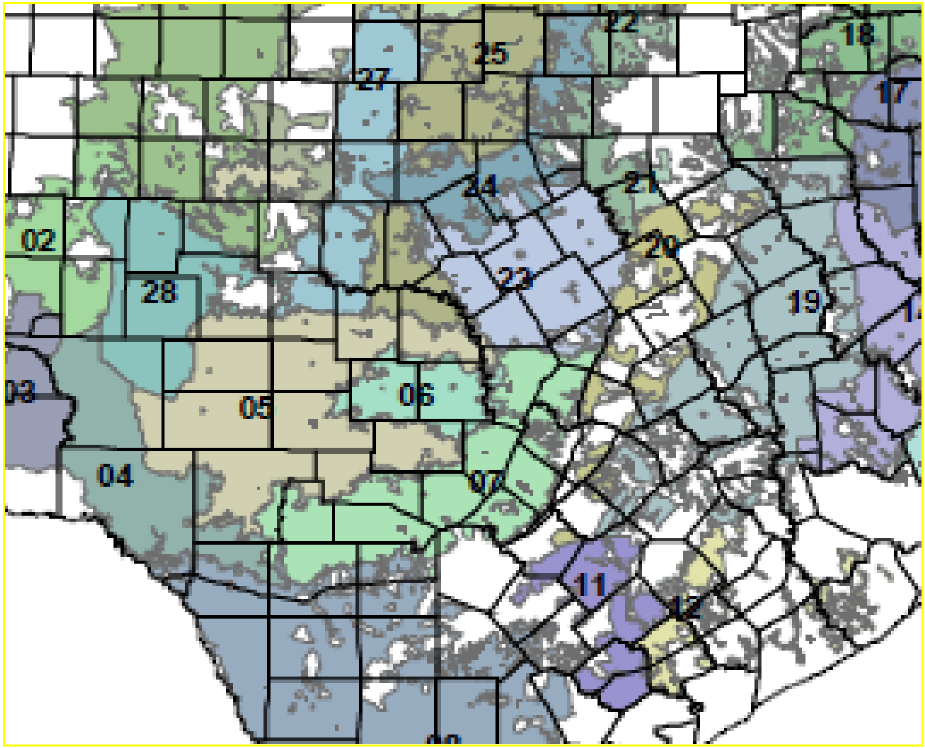

Figure G.3. TPWD RMU boundaries.

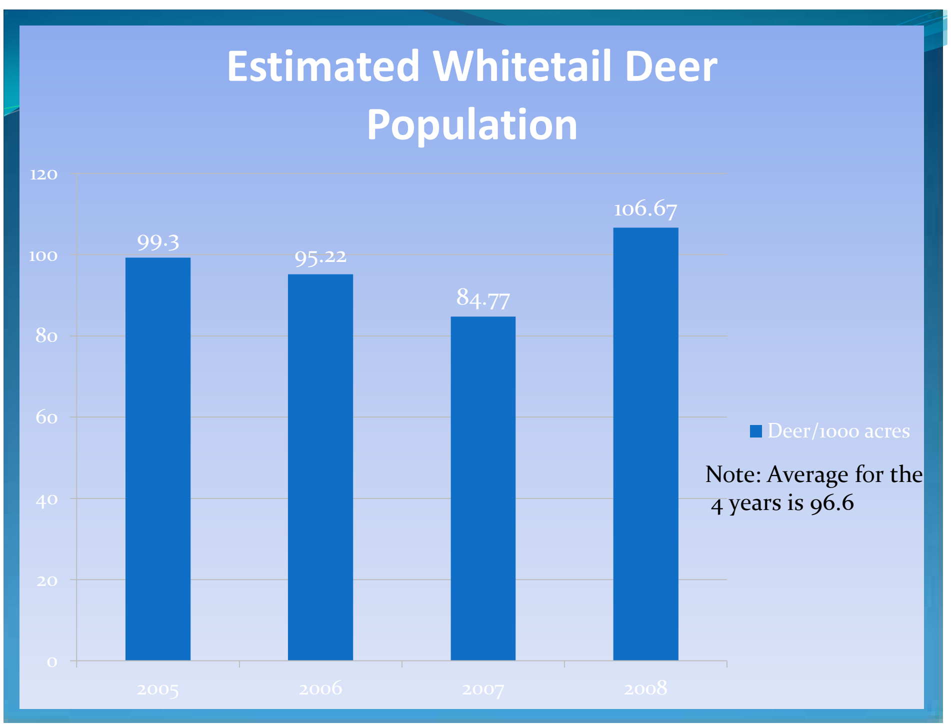

Figure G.4. The last four years of whitetail deer census data for the area from TPWD.

Feral Hog

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

$$\text{Feral Hog Load} = \text{\# hogs} * 8.9 * 10^9 \text{ cfu/day} * 0.63$$

Where $8.9*10^9$ 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 300 foot area surrounding perennial streams in the watershed, but does not include urban areas that are located in the buffer (Figure G.5). It is understood that feral hogs are located outside of these areas.

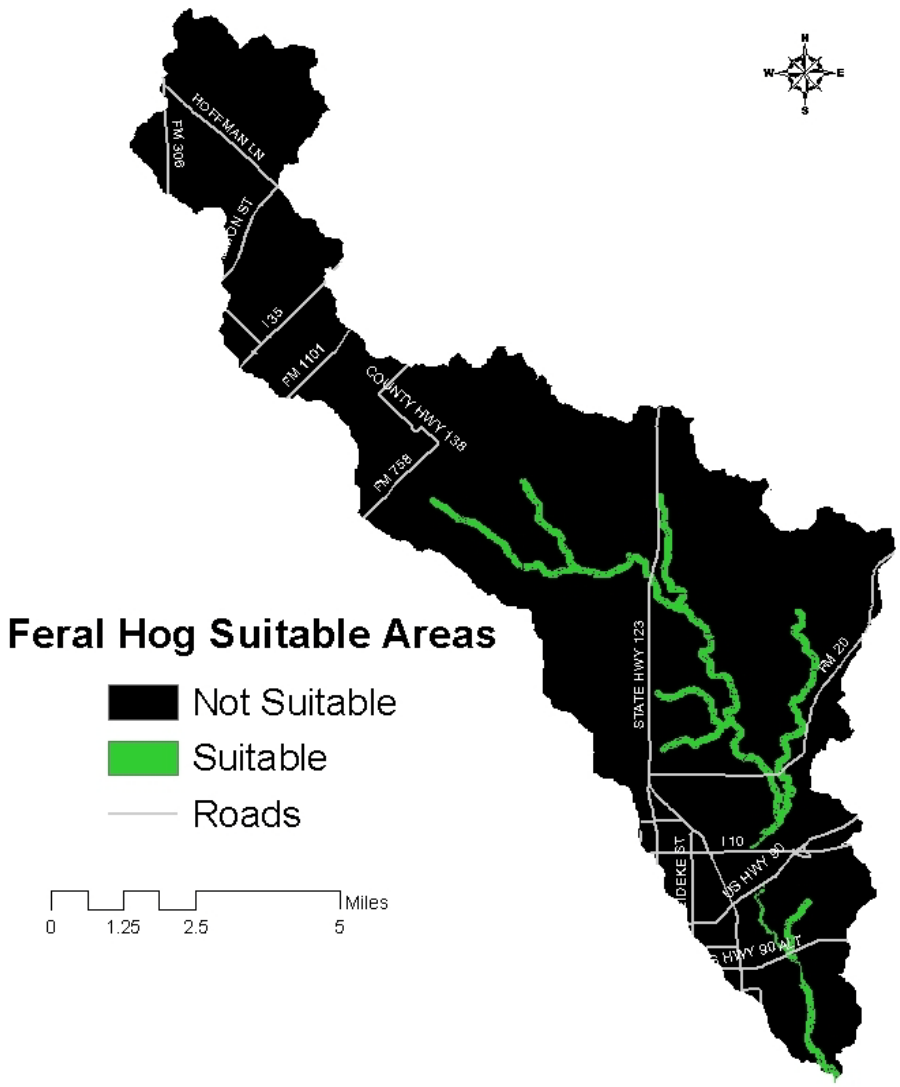

Figure G.5. The most suitable habitat for feral hogs.

Appendix H: 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, 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, or 113 cfu/100mL (standard is a geomean of 126 cfu/100mL), and a 10% reduction in the nitrate-nitrogen screening level, or 1.76 mg/mL (screening level is a geomean of 1.95 mg/mL). An implicit margin of safety was employed during development of several numeric SELECT inputs. For example, when estimating dog populations, the American Veterinary Medical Association estimates that in Texas average dog ownership is 0.63 dogs/household and the national average is 0.8 dogs/household. Based upon stakeholder input and in an effort to be conservative, the dog population in the watershed was estimated to be 1.0 dog/household.

Appendix I: TWDB Groundwater Database Data

The Texas Water Development Board Groundwater Database contains data for one water well located in the Alligator Creek watershed that was drilled in 1943, prior to widespread use of inorganic nitrogen fertilizers by agriculture. The well is listed as State Well Number 6824101, and the information provided for the well is presented below.

Table I.1. Water quality data from State Well Number 6824101.

Date	12/03/1943
Balanced/Unbalanced	Balanced
Calcium (mg/L)	112
Magnesium (mg/L)	10
Sodium (mg/L)	40
Carbonate (mg/L)	0
Bicarbonate (mg/L)	302
Sulfate (mg/L)	18
Chloride (mg/L)	52
Total Nitrate (mg/L)	96
Total Dissolved Solids (mg/L)	476
Phenolphthalein alkalinity (ppm)	0
Total alkalinity (ppm)	247
Total hardness (ppm)	320
Percent sodium	21
SAR	0.97
RSC	0

Appendix J: Management Practice Efficiencies

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

URBAN MANAGEMENT PRACTICES

Table J1. 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 J2. 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 J3. Load reductions for bioretention.

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 J4. Load reductions for infiltration trench/basin.

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 J5. 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 J6. 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 J7. 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 J8. 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 J9. 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.

Urban Management Practices References

Bell, W., L. Stoke, L.J. Gavan, and T.N. Nguyen. 1995. Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filter BMPs City of Alexandria, Department of Transportation and Environmental Services, Alexandria, VA.

Bicki, T.J. and R.B. Brown. 1990. On-Site Sewage Disposal – The importance of the wet season water table. J. Env. Health, Vol. 52, Num. 5, pp. 277-279.

Birch, G.F., M.S. Fazeli, and C. Matthai. 2005, Efficiency of an Infiltration Basin in Removing Contaminants From Urban Stormwater Environmental Monitoring and Assessment. Vol. 101 pp 23-38.

California Stormwater Quality Association. 2002. California Stormwater BMP Handbook New Development and Redevelopment. Vegetated Swale Low Impact Best Management Practice (BMP) Information Sheet www.charlesriver.org.

Center for Watershed Protection. Stormwater Manager's Resource Center. Pollution Prevention Fact Sheet: Animal Waste Collection. <http://www.stormwatercenter.net/Pollution_Prevention_Factsheets.

Charles River Watershed Association. 2008. Vegetated Swale Low Impact Best Management Practice (BMP) Information Sheet www.charlesriver.org.

City of Austin. 1990. Removal Efficiencies of Stormwater Pollution for the Austin, Texas Area. Environmental Resources Management Division, Environmental and Conservation Services Department, City of Austin, Austin, TX.

City of Austin. 1995. Characterization of Stormwater Pollution for the Austin, Texas Area. Environmental Resources Management Division, City of Austin, Austin, TX.

Claytor, R.A., and T.R. Schueler. 1996. Design of Stormwater Filtering Systems, The Center for Watershed Protection, Silver Spring, MD

Cogger, C.G. and B.L. Carlile. 1984. Field Performance of Conventional and Alternative Septic Systems in Wet Soils. J. Env. Qual. 13:137-142.

Davis, A., Shokouhian, M., Sharma, H., Henderson, C. 1997. Bioretention Monitoring-Preliminary Data Analysis Environmental Engineering Program of the University of Maryland, College Park, MD.

Dayton Avenue Project. 1993. "Dayton Biofilter-Grass Swale" Accessed October 18, 2011. Mississippi Department of Marine Resources - http://www.dmr.state.ms.us/CMP/Storm/APPENDIX-C/Dayton%20Biofilter%20Grass%20Swale.pdf.

De J. Quinonez-Diaz, M., M.M. Karpiscak, D.D. Ellman, and CP. Gerba. 2001. Removal of Pathogenic and Indicator Microorganisms by a Constructed Wetland Receiving Untreated Domestic Wastewater. Journal of Environmental Science and Health. Vol. A36(7) pp 1311-1320.

EPA National Pollutant Discharge Elimination System National Menu of Stormwater Best Management Practices. Pet Waste Management. Accessed: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=4.

EPA. 1993. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. EPA-840-B-92-002. U.S. Environmental Protection Agency (USEPA), Office of Water, Washington, D.C.

EPA. 2002. Onsite Wastewater Treatment Systems Manual (EPA/625/R-00/008).

EPA. 2004. The Use of Best Management Practices in Urban Watersheds. National Risk Management Research Laboratory Office of Research and Development. U.S. Environmental Protection Agency. Cincinnati, OH. Pg 5-25.

EPA National Pollutant Discharge Elimination System (NPDES). 2006. Bioretention. Accessed: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm.

EPA National Pollutant Discharge Elimination System (NPDES). 2006. Dry Detention Ponds. Accessed: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm.

EPA National Pollutant Discharge Elimination System (NPDES). 2006. Stormwater Wetland. Accessed:http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm.

EPA National Pollutant Discharge Elimination System (NPDES). 2006. Wet Detention Ponds. Accessed:http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm.

EPA Storm Water Technology Fact Sheet: Infiltration Trench. 1999. U.S. EPA, Office of Water, Washington, D.C.

EPA Storm Water Technology Fact Sheet: Sand Filters. 1999. U.S. EPA, Office of Water, Washington, D.C.

EPA Storm Water Technology Fact Sheet: Vegetated Swales. 1999. U.S. EPA, Office of Water, Washington, D.C.

EPA. 2005. National Management Measures to Protect and Restore Wetlands and Riparian Areas for the Abatement of Nonpoint Source Pollution, U.S. EPA Office of Water. Nonpoint Source Control Branch.

Galli, J. 1990. Peat Sand Filters: A Proposed Storm Water Management Practice for Urbanized Areas. Metropolitan Washington Council of Governments.

Gerba, C. P., J. A. Thurston, J. A. Falabi, P. M. Watt, and M. M. Karpiscak. 1999. Optimization of Artificial Wetland Design for Removal of Indicator Microorganisms and Pathogenic Protozoa. Water Science and Technology. 40(4-5): 363-368.

Glick, R., G.C. Chang, and M.E. Barrett. 1998. Monitoring and evaluation of stormwater quality control basins. Watershed Management: Moving from Theory to Implementation, Denver, CO. pp 369-376.

Greb, S., S. Corsi, and R. Waschbush. 1998. Evaluation of Stormceptor and Multi-Chamber Treatment Train as Urban Retrofit Strategies. Presented at Retrofit Opportunities for Water Resource Protection in Urban Environments, Chicago, IL.

Hatt, B.E., T.D. Fletcher, and A. Deletic. 2008. Hydraulic and Pollutant Removal Performance of Fine Media Stormwater Filtration Systems. Environmental Science and Technology. Vol. 42(7) pp 2535-2541.

Hogland, W., J. Niemczynowice, and T. Wahalan. 1987. The Unit Superstructure during the Construction Period. The Science of the Total Environment. Vol 59 pp 411-424.

Horner, R.R., and C.R. Horner. 1995. Design, Construction, and Evaluation of a Sand Filter Stormwater Treatment System, Part II, Performance Monitoring. Report to Alaska Marine Lines, Seattle, WA.

Huddleston, G.M., W.B. Gillespie, and J.H. Rodgers. 2000. Using Constructed Wetlands to Treat Biochemical Oxygen Demand and Ammonia Associated with a Refinery Effluent. Ecotoxicology and Environmental Safety. Vol 45 pp 188-193.

Hunt, W.F., A.R. Jarrett, J.T. Smith, and L.J. Sharkey. 2006. Evaluating Bioretention Hydrology and Nutrient Removal at Three Field Sites in North Carolina. Journal of Irrigation and Drainage Engineering (ASCE). Vol 132(6) pp 600-608.

Hunt, W.F., J.T. Smith, S.J. Jadlocki, J.M. Hathaway, and P.R. Eubanks. 2008. Pollutant Removal and Peak Flow Mitigation by a Bioretention Cell in Urban Charlotte, N.C. Journal of Environmental Engineering (ASCE). Vol 134(5) pp 403-408.

Khan, Z., C. Thursh, P. Cohen, L. Kulzer, R. Franklin, D. Field, J. Koon, and R. Horner. 1992. Biofiltration Swale Performance, Recommendations, and Design Considerations. Municipality of Metropolitan Seattle, Water Pollution Control Department, Seattle, WA.

Khatiwada, N.R. and C. Polprasert. 1999. Kinetics of Fecal Coliform Removal in Constructed Wetlands. Water Science and Technology. Vol. 40(3) pp 109-116.

Kovacic, D.A., M.B. David, L.E. Gentry, K.M. Starks, and R.A. Cooke. 2000. Wetlands and Aquatic Processes: Effectiveness of Constructed Wetlands in Reducing Nitrogen and Phosphorus Export from Agricultural Tile Drainage. Journal of Environmental Quality. Vol 29 pp 1262-1274.

Leif, T. 1999. Compost Stormwater Filter Evaluation. Snohomish County, Washington, Department of Publick Works, Everett, WA.

Mallin, M.A., S.H. Ensign, T.L. Wheeler, and D.B. Mayes. 2002. Surface Water Quality Pollutant Removal Efficacy of Three Wet Detention Ponds. Journal of Environmental Quality. Vol 31 pp 654-660.

Maryland Environmental Services Division. 2007. Bioretention Manual. Department of Environmental Resources, The Prince George's County, Maryland.

Metropolitan Washington Council of Governments. 1983. Urban Runoff in the Washington Metropolitan Area: Final Report. Urban Runoff Project, EPA Nationwide Urban Runoff Program. Metropolitan Washington Council of Governments, Washington, DC.

N.P.R.D. 2007. National Pollutant Removal Performance Database. Version 3. Center For Watershed Protection. Ellicott City, Maryland.

NCDENR. 2007. Stormwater BMP Manual. Chapter 11. Sand Filter.

Neralla, S., R.W. Weaver, B.J. Lesikar, R.A. Persyn. 2000. Improvement of domestic wastewater quality by subsurface flow constructed wetlands. Bioresource Technology. Bol 75 pp 19-25.

Newman, J.M. and J.C. Clausen. 1997. Seasonal Effectiveness of a Constructed Wetland for Processing Milkhouse Wastewater. Wetlands, Vol 17(3), pp. 375-382.

NVPDC. 1992. Northern Virginia BMP Handbook: A Guide to Planning and Designing Best Management Practices in Northern Virginia. Northern Virginia Planning District Commission and Engineers Surveyors Institute.

Passeport, E., W.F. Hunt, D.E. Line, R.A. Smith, and R.A. Brown. 2009. Field Study of the Ability of Two Grassed Bioretention Cells to Reduce Storm-Water Runoff Pollution. Journal of Irrigation and Drainage Engineering (ASCE). Vol 135(4) pp 505-510.

Pennsylvania Stormwater Best Management Practices Manual. 2006. Chapter 6. Infiltration Basin. pp 27-32.

Peterson, J., L. Redmon, and M. McFarland. 2011. Reducing Bacteria With Best Management Practices for Livestock- Waste Storage Facility. *http://agrilifebookstore.org*.

Pitt, R. 1996. The Control of Toxicants at Critical Source Areas. Presented at the ASCE/Engineering Foundation Conference, Snowbird, UT.

Pitt, R., M. Lilburn, and S. Burian. 1997. Storm Drainage Design for the Future: Summary of Current U.S. EPA Research. American Society of Civil Engineers Technical Conference, Gulf Shores, AL.

Prince George's County. 1993. Design Manual for Use of Bioretention in Stormwater Management. Department of Environmental Resources. Prince George's County, Landover, MD.

Raisin, G.W., D.S. Mitchell, and R.L Croome. 1997. The effectiveness of a small constructed wetland in ameliorating diffuse nutrient loadings from an Australian rural catchment. Journal of Ecological Engineering. Vol 9 pp 19-35.

Rifai, H. 2006. Study on the Effectiveness of BMPs to Control Bacteria Loads. Prepared by University of Houston for TCEQ as Final Quarterly Report No. 1.

Schueler, T. 1997. Influence of Ground Water on Performance of Stormwater Ponds in Florida. Watershed Protection Techniques. Vol. 2(4) pp 525-528.

Schueler, T.R. 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments.

Schueler, T.R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMP's. Metropolitan Washington Council of Governments. Washington D.C.

Sharkey, L.J. 2006. The Performance of Bioretention Areas in North Carolina: A Study of Water Quality, Water Quantity, and Soil Media. Thesis for Master of Science Degree. North Carolina State University, Biological and Agricultural Engineering.

Smith, D.R., K.A. Collins, and W.F. III. Hunt. 2006. North Carolina State University Evaluates Permeable Pavements. Interlocking Concrete Pavement Magazine. pp 18-23.

Smith, R.A. and W.F. Hunt. 2007. Pollutant Removal in Bioretention Cells with Grass Cover. Proceedings of the World Environmental and Water Resources Congress 2007, pp 1-11.

Southwest Florida Water Management District. Reducing Pet Waste. Accessed: http://www.swfwmd.state.fl.us/download/social_research/Pet_Waste_Final_Report.pdf.

Stanley, D.W. 1996. Pollutant Removal by a Stormwater Dry Detention Pond. Water Environment Research. Vol. 68(6) pp 1076-1083.

Stenstrom, T. A. and A. Carlander. 2001. Occurrence and Die-off of Indicator Organisms in the Sediment in Two Constructed Wetlands. Water Science and Technology 44(11-12): 223-230.

Stewart, W. 1992. Compost Stormwater Treatment System. W&H Pacific Consultants. Portland, OR. Also in Innovative Leaf Compost System Used to Filter Runoff at Small Sites in the Northwest Watershed Protection Techniques. Center for Watershed Protection. 1994. Vol. 1(1) pp 13-14.

Stormwater Management. 1994. Three Year Performance Summary of Stormwater Pollution and Treatment – 185th Avenue, Hillsboro, Oregon. Technical Memorandum. Stormwater Management, Portland, OR.

Washington Department of Ecology. Focus on Pet Waste Management – Considerations for the Selection and Use of Pet Waste Collection Systems in Public Areas. Accessed: http://www.ecy.wa.gov/pubs/0310053.pdf.

Welborn, C., and J. Veenhuis. 1987. Effects of Runoff Control on the Quality and Quantity of Urban Runoff in Two Locations in Austin, TX. USGS Water Resources Investigations Report 87-4004.

Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. EPA Office of Science and Technology. TetraTech Inc.

Wisconsin Stormwater Manual: Infiltration Basins and Trenches. 2000. University of Wisconsin Extension. Wisconsin Department of Natural Resources. http://www.uwex.edu/ces/pubs.

Young, G.K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. FHWA-PD-96-032, Federal Highway Administration.

Yousef, Y.A., T. Hvitved-Jacobsen, M.P. Wanielista, and H.H. Harper. 1987. Removal of Contaminants in Highway Runoff Flowing Through Swales. The Science of the Total Environment. Vol. 59 pp 391-399.

Yousef, Y.A., M.P. Wanielista, and H.H. Harper. 1985. Removal of Highway Constituents by Roadside Swales. Transportation Research Record 1017 pp 62-68.

Yu, S.L. and R.J. Kaighn. 1994. Testing of Best Management Practices for Controlling Highway Runoff, Phase II. Virginia Department of Transportation, Report No. FHWA/VA-94-R21, Richmond, VA.

Yu, S.L. and R.J. Kaighn. 1995. The Control of Pollution in Highway Runoff Through Biofiltration. Volume II: Testing of Roadside Vegetation. Virginia Department of Transportation, Report No. FHWA/VA-95-R29.

Yu, S.L., S.L. Barnes, and V.W. Gerde. 1993. Testing of Best Management Practices for Controlling Highway Runoff. Virginia Department of Transportation, Report No. FHWA/VA-93-R16, Richmond, VA.

AGRICULTURAL MANAGEMENT PRACTICES

Table J10. 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 J11. 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 J12. 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 J13. 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 J14. 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 J15. 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.

Nutrient Management

Table J16. 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 J17. 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 J18. 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 J19. 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 J20. 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 J21. 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.

Agricultural Management Practices References

Arabi, M. 2005. A modeling framework for evaluation of watershed management practices for sediment and nutrient control, Thesis for PhD. Purdue University.

Arabi, M., R.S. Govindaraju, H.M. Mohamed, and Engel, B.A. 2006. Role of Watershed Subdivision on Modeling the Effectiveness of Best Management Practices With SWAT. Journal of the American Water Resources Association; Vol 42(2) pp 513.

Chaubey, L., D.R. Edwards, T.C. Daniel, and P.A. Moore. 1994. Nichols D.J., Effectiveness of Vegetative Filter Strips in Retaining Surface-Applied Swine Manure Constituents. Transactions of the ASAE. 37(3): pp 837-843.

Chow, T.L., H.W. Rees, and J.L. Daigle. 1999. Effectiveness of terraces/grassed waterway systems for soil and water conservation: A field evaluation. Journal of Soil and Water Conservation. Vol. 54, 3. pp 577.

Clawson, J.E. 1993. The use of off-stream water developments and various water gap configurations to modify the behavior of grazing cattle. M.S. Thesis, Oregon State University, Department of Rangeland Resources, Corvallis, OR.

Coyne, M.S., R.A. Gilfillen, R.W. Rhodes, and R.L. Blevins. 1995. Soil and fecal coliform trapping by grass filter strips during simulated rain. *Journal of Soil and Water Conservation* 50(4)405-408.

Delgado, J.A. and W.C. Bausch. 2005. Potential use of precision conservation techniques to reduce nitrate leaching in irrigated crops. Journal of Soil and Water Conservation. Vol. 60(6) pp 379.

Di, H.J. and K.C. Cameron. 2002. The use of a nitrification inhibitor, dicyandiamide (DCD), to decrease nitrate leaching and nitrous oxide emissions in a simulated grazed and irrigated grassland. Journal of Soil Use and Management. Vol. 18, pp 395-403.

Dickey, E.C. and D.H. Vanderholm. 1981. Vegetative Filter Treatment of Livestock Feedlot Runoff. *Journal of Environmental Quality* 10(3):279-284.

Dillaha, T.A., D.L. Sherrard, S. Mostachimi, and V.O. Shanholtz. 1988. Evaluation of Vegetative Filter Strips as a BMP for Feed Lots. Journal of Water Pollution Control Federation. Vol. 60, No. 7, July 1988, 1231-1238.

Dosskey, M.G., M.J. Helmers, T.G. Eisenhauer, T.G. Franti, and K.D. Hoagland. 2002. Assessment of concentrated flow though riparian buffers. Journal of Soil and Water Conservation. Vol. 57(6) pp 336.

Fiener, P. and K. Auerswald. 2003. Effectiveness of Grassed Waterways in Reducing Runoff and Sediment Delivery from Agricultural Watersheds. Journal of Environmental Quality. Vol. 32(3): 927.

Godwin, D.C. and J.R. Miner. 1996. The potential of off-stream livestock watering to reduce water quality impacts. *Bioresource Technology* 58:285-290.

Goel, P.K., R.P. Rudra, B. Gharbaghi, S. Das, and N. Gupta. 2004. Pollutants Removal by Vegetative Filter Strips Planted with Different Grasses. ASAE/CSAI Annual International Meeting. Ottowa, Ontaria, Canada.

Grace, J.M. III. 2000. Forest road sideslopes and soil conservation techniques. Journal of Soil and Water Conservation. Vol 55(1) pp 96.

Hartley, M.J., G.C. Atkinson, K.H. Bimler, T.K. James, and A.I. Popay. 1978. Control of barley grass by grazing management. Proceedings of New Zealand Weed Pest Control Society Conference. 31: pp 198-202.

Helgeson, E.A. 1942. Control of leafy spurge by sheep. North Dakota Agricultural Experiment Station, Bimonthly Bull. Vol. 4(5) pp 10-12.

Johnston, A. and R.W. Peake. 1960. Effect of Selective Grazing by Sheep on the Control of Leafy Spurge. Journal of Range Management, Vol 13(4) pp 192-195.

Larsen, R.E., R.J. Miner, J.C. Buckhouse, and J.A. Moore. 1994. Water Quality Benefits of Having Cattle Manure Deposited Away From Streams. Biosource Technology Vol. 48 pp 113-118.

Lee, K-H., T.M. Isenhart, R.C. Schultz, and S.K. Michelson. 1999. Nutrient and Sediment Removal by Switchgrass and Cool-Season Grass Filter Strips in Central Iowa, USA. Journal of Agroforestry Systems. Vol. 44(2-3) pp 121-132.

Lim, T.T., D.R. Edwards, S.R. Workman, B.T. Larson, and L. Dunn. 1998. Vegetated Filter Strip Removal of Cattle Manure Constituents in Runoff. Transactions of the ASABE. Vol 41(5) pp 1375-1381.

Lym, R.G., K.K. Sedivec, and D.R. Kirby. 1997. Leafy spurge control with angora goats and herbicides. Journal of Range Management. Vol 50(2) pp 123-128.

Magette, W.L., R.B. Brinsfield, R.E. Palmer, and J.D. Wood. 1989. Nutrient and Sediment Removal by vegetated filter strips. Trans ASAE 32: pp 663–667.

Miner, J. R., J. C. Buckhouse, and J.A. Moore. 1992. Will a Water Trough Reduce the Amount of Time Hay-Fed Livestock Spend in the Stream (and therefore improve water quality). *Rangelands* 14(1):35-38.

Olson, B.E. and J.R. Lacey. 1994. Sheep: A Method for Controlling Rangeland Weeds. Sheep Research Journal: Special Issue.

Parsons, J.E., R.D. Daniels, J.W. Gilliam, and T.A. Dillaha. 1991. The effect of vegetation filter strips on sediment and nutrient removal from agricultural runoff. In: Proceedings, Environmentally Sound Agriculture Conference, April, Orlando, FL.

Peter, J., T. William, and D.L. Correll. 1984. Nutrient Dynamics in an Agricultural Watershed: Observations on the Role of a Riparian Forest. Journal of Ecology. Vol 65, No. 5, pp 1466-1475.

Peterson, J., L. Redmon, and M. McFarland. 2011. Reducing Bacteria With Best Management Practices for Livestock- Waste Storage facility. *http://agrilifebookstore.org*. AgriLife Bookstore.

Peterson, J., L. Redmon, and M. McFarland. 2011. Reducing Bacteria With Best Management Practices for Livestock- Watering Facility. *http://agrilifebookstore.org*. AgriLife Bookstore.

Peterson, J., L. Redmon, and M. McFarland. 2011. Reducing Bacteria With Best Management Practices for Livestock- Prescribed Grazing. *http://agrilifebookstore.org*. AgriLife Bookstore.

Peterson, J., L. Redmon, and M. McFarland. 2011. Reducing Bacteria With Best Management Practices for Livestock- Stream Crossing. *http://agrilifebookstore.org*. AgriLife Bookstore.

Peterson, J., L. Redmon, and M. McFarland. 2011. Reducing Bacteria With Best Management Practices for Livestock- Watering Facility. *http://agrilifebookstore.org*. AgriLife Bookstore.

Popay, I. and R. Field. 1996. Grazing Animals as Weed Control Agents. Weed Technology, Vol 10(1) pp 217-231.

Raphs, M.H., J.E. Bowns, and G.D. Manners. 1991. Utilization of larkspur by sheep. Journal of Range Management. Vol 44 pp 619-622.

Rifai, H. 2006. Study on the Effectiveness of BMPs to Control Bacteria Loads. Prepared by University of Houston for TCEQ as Final Quarterly Report No. 1.

Robichaud, P.R., T.R. Lillybridge, and J.W. Wagenbrenner. 2006. Effects of postfire seeding and fertilization on hillslope erosion in north-central Washington, USA. Catena Vol. 67, pp 56-67.

Rolston, M.P., M.G. Lambert, D.A. Clark, and B.P. Devantier. 1981. Control of rushes and thistles in pasture by goat and sheep grazing. Proceedings of New Zealand Weed Pest Control Conference. 34: pp 117-121.

Schoonover, J.E., W.J. Willard, J.J. Zaczek, J.C. Mangun, and A.D. Carver. 2006. Agricultural Sediment Reduction by Giant Cane and Forest Riparian Buffers. Journal of Water, Air, and Soil Pollution. Vol. 169 pp 303-315.

Sheffield, R.E., S. Mostaghimi, D.H. Vaughn, E.R. Collins Jr., and V.G. Allen. 1997. Off-Stream Water Sources for Grazing Cattle as a Stream Bank Stabilization and Water Quality BMP. Transactions of the ASABE, Vol 40(3): 595-604.

Tate, K.W., G.A. Nader, D.J. Lewis, E.R. Atwill, and J.M. Connor. 2000. Evaluation of Buffers to Improve the Quality of Runoff from Irrigated Pastures. Journal of Soil and Water Conservation. Vol 55(4) pp 473.

Wittry, D.J. and A.P. Mallarino. 2004. Comparison of Uniform and Variable-Rate Phosphorus Fertilization for Corn-Soybean Rotations. Agronomy Journal, Vol 96, pp 26-33.

Young, R.A., T. Huntrods, and W. Anderson. 1980. Effectiveness of vegetated buffer strips in controlling pollution from feedlot runoff. *Journal of Environmental Quality* 9:483-487.

Also see Lone Star Healthy Streams Program *Research Bibliography* at http://lshs.tamu.edu/research/.

Appendix K: Phase II MS4 Storm Water Program Overview

Minimum Control Measures and Compliance Strategies

Control Measures	What is Required	Best Management Practices
Public Education and Outreach	Implement a public education program to distribute educational materials to the community about the impacts of stormwater discharges on local water bodies and the steps that can be taken to reduce stormwater pollution.	Brochures or fact sheets
		Recreational guides
		Alternative information sources
		A library of educational materials
		Volunteer citizen educators
		Event participation
		Educational programs
		Storm drain stenciling
		Storm water hotlines
		Economic incentives
		Public Service Announcements
		Tributary signage
Public Participation and Involvement	Provide opportunities for citizens to participate in program development and implementation.	Public meetings/citizen panels
		Volunteer water quality monitoring
		Volunteer educators/speakers
		Storm drain stenciling
		Community clean-ups
		Citizen watch groups
		"Adopt A Storm Drain" programs
		Legally prohibit non-storm water discharges into the MS4.
		Implement a plan to detect and address non-storm water discharges into the MS4.
		Educate public employees, businesses, and the general public about the hazards of illegal discharges and improper disposal of waste.

Control Measures	What is Required	Best Management Practices
Construction Site Runoff Control	Develop, implement, and enforce an erosion and sediment control program for construction activities that disturb 1 or more acres of land.	Have procedures for site plan review of construction plans that include requirements for the implementation of BMPs to control erosion and sediment and other waste at the site.
		Have procedures for site inspection and enforcement of control measures.
		Have sanctions to ensure compliance (established in the ordinance or other regulatory mechanism).
		Establish procedures for the receipt and consideration of information submitted by the public.
Post-Construction Runoff Control	Develop, implement, and enforce a program to reduce pollutants in post-construction runoff to their MS4 from new development and redevelopment projects that result in the land disturbance of greater than or equal to 1 acre.	Planning procedures
		Site-based BMPs
		Stormwater Retention/Detention BMPs
		Infiltration BMPs
		Vegetative BMPs
Pollution Prevention/Good Housekeeping	Develop and implement an operation and maintenance program with the ultimate goal of preventing or reducing pollutant runoff from municipal operations into the storm sewer system.	Employee training on how to incorporate pollution prevention/good housekeeping techniques into municipal operations.
		Maintenance procedures for structural and non-structural controls.
		Controls for reducing or eliminating the discharge of pollutants from areas such as roads and parking lots, maintenance and storage yards.
		Procedures for the proper disposal of waste removed from separate storm sewer systems.
		Ensure that new flood management projects assess the impacts on water quality and examine existing projects for incorporation of additional water quality protection devices or practices.

The information given herein is for educational purposes only. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by Texas AgriLife Extension Service is implied.

Educational programs conducted by Texas AgriLife Extension Service serve people of all ages regardless of socioeconomic level, race, color, sex, religion, handicap or national origin.

Issued in furtherance of Cooperative Extension Work in Agriculture and Home Economics, Acts of Congress of May 8, 1914, as amended, and June 30, 1914, in cooperation with the United States Department of Agriculture. Edward G. Smith, Director, Texas AgriLife Extension Service, The Texas A&M University System.