Upper Cibolo Creek Watershed Protection Plan

Prepared for the:

UPPER CIBOLO CREEK WATERSHED PARTNERSHIP

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- Boerne Impendent School District
- Cibolo Nature Center
- Cibolo Preserve
- City of Fair Oaks Ranch
- Cow Creek Groundwater Conservation District
- Guadalupe Blanco River Authority
- Kendall County
- Kendall Soil and Water Conservation District
- Natural Resource Conservation Service
- Texas AgriLife Extension
- Texas Parks and Wildlife Department
- Texas Stream Team with the Meadows Center for Water and the Environment at Texas State University
- San Antonio River Authority
- University of Texas at San Antonio
- Upper Cibolo Creek Land Owners Association

Without the local knowledge and subject matter expertise of stakeholders, members of the Technical Advisory Committee and Parsons Water and Infrastructure, the development of this watershed protection plan would not have been possible.

EXECUTIVE SUMMARY

The Upper Cibolo Creek (UCC) Watershed is located in southern Kendall County, Texas and lies within the headwaters of the San Antonio River Basin (Figure ES-1). Brown Spring and Champee Spring collectively form the headwaters of Cibolo Creek which flows southeast through the City of Boerne and continues across five counties before it reaches the San Antonio River almost 100 miles downstream. Due to significant groundwater recharge through fractures in the streambed, UCC downstream of Boerne is often dry during normal streamflow conditions. This feature makes the Upper Cibolo truly unique in that this vibrant perennial stream is hydraulically separated from flows further downstream near the City of San Antonio. Therefore, this Watershed Protection Plan (WPP) focuses on the 77mi^2 drainage area surrounding the upper 23 miles of Cibolo Creek, from its headwaters to the confluence with Balcones Creek near the Kendall and Comal County line.

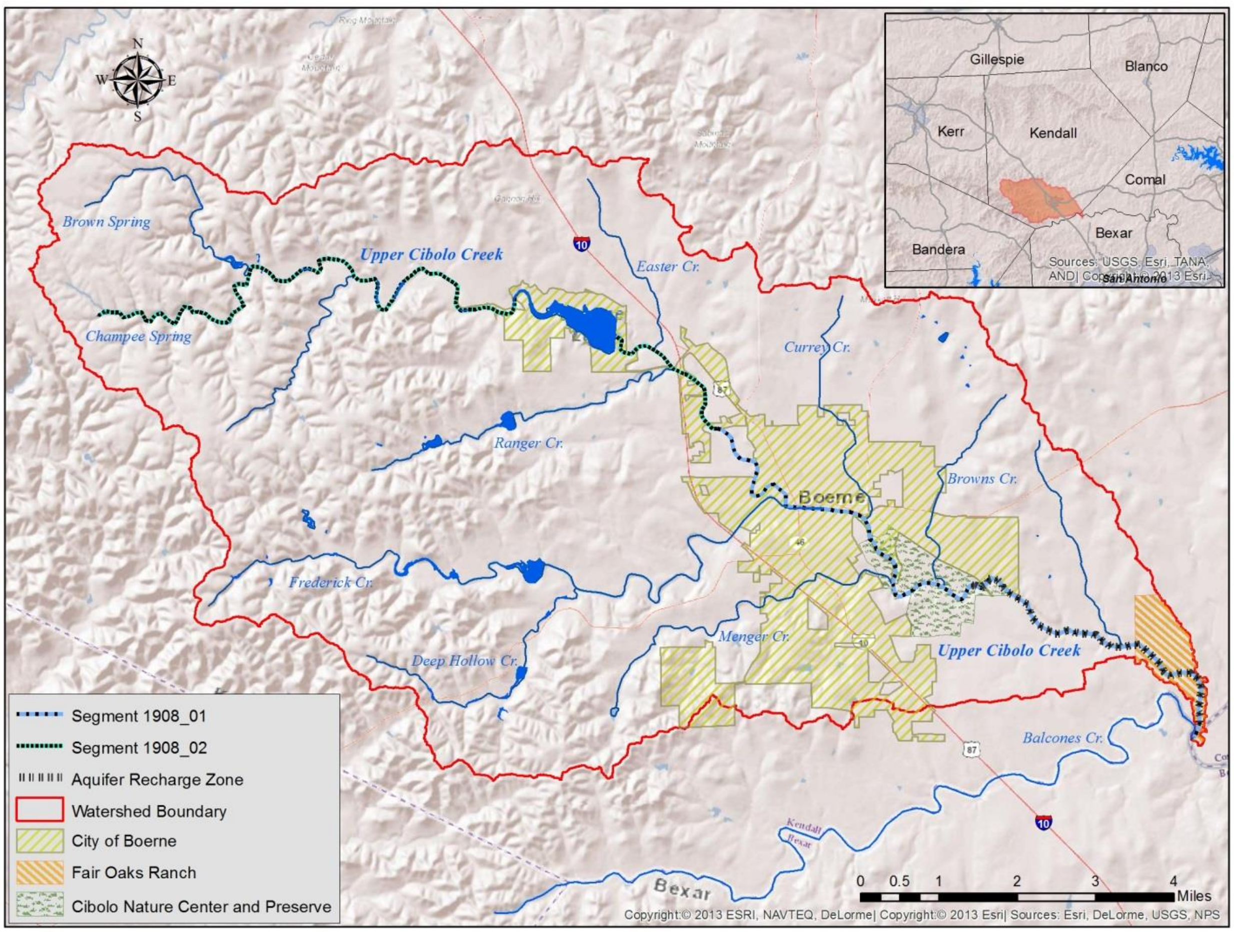


Figure ES-1. Upper Cibolo Creek Watershed located in southern Kendall County, Texas

UCC has a history of elevated bacteria levels that often exceed state standards established for safe contact recreation. Beginning in 1999, UCC (Segments 1908) was listed on the Texas Water Quality Inventory and 303(d) List of impaired waterbodies for depressed dissolved oxygen (DO) and elevated levels of fecal coliform bacteria. From 2000-2004, UCC was only listed for depressed DO and from 2006-2010 UCC was listed only for bacteria. The 2012 Draft 303(d) List once again indicates bacteria impairments in the upstream reaches of UCC. Screening level data collected during these assessments have also indicated concerns for elevated nutrient levels, primary orthophosphorus.

In 2006 and 2008, TCEQ conducted an Aquatic Life Monitoring study in the downstream reaches of the watershed and concluded that the creek contained borderline exceptional levels of aquatic life. As a result of TCEQs findings, coupled with trends in land use change and a history of water quality impairments, the City of Boerne with help and encouragement from TCEQ and the Cibolo Nature Center applied for and was awarded a Clean Water Act Section 319(h) grant to develop a WPP for the UCC Watershed.

The Upper Cibolo Creek Watershed Partnership (Partnership) was formed in 2010 to address persistent bacteria impairments within UCC and promote stakeholder participation in the watershed planning process. The Partnership framework ensures the views of local citizens, special interest groups, businesses, landowners and governing bodies are represented. Partnership stakeholders developed a primary goal for the WPP that included (at a minimum) meeting the appropriate water quality standards established for bacteria to ensure safe contact recreation. Stakeholders were also encouraged to proactively address any pollutants that might threaten or impair the physical, chemical, biological or ecological integrity and designated uses of UCC and its watershed.

By utilizing the watershed approach, stakeholders worked together in topical focus groups, stakeholder, steering committee and technical advisory committee meetings to understand why local water quality problems exist. Through these meetings, sources such as agricultural land management practices, On-Site Sewage Facilities (OSSFs), populations and impacts of feral hogs, spatial distribution of axis deer, pet waste, cliff swallow nesting sites, and seasonal and spatial variations in waterfowl abundance were identified as potential contributors to bacteria loads. As sources were identified it became evident that they could be grouped into 3 broad categories; Wildlife, Agriculture and Urban/Residential (Table ES-1).

Upon identifying sources of pollution within the watershed, stakeholders worked to understand which sources had the greatest impact on water quality conditions and what management strategies could be utilized to mitigate their effects. The Soil and Water Assessment Tool (SWAT) was used to model the impact pollutants and management strategies have on water quality throughout the watershed. Combining stakeholder input and watershed characterization data, the model was able to estimate bacteria load contributions from specific sources and causes of pollution.

This process allowed stakeholders to develop specific management strategies targeting each source in an effort to eliminate or reduce the amount of bacteria being applied to the landscape or directly to the waterbody (Table ES-2). In addition to being effective at targeting bacteria loads, these strategies were shown to have a complementary beneficial effect at reducing nutrient loads within the watershed

Table ES-1. Summary of bacteria and nutrient pollutant sources identified within the UCC Watershed

Category	Pollutant Source	Pollutant	Cause
Wildlife	Cliff Swallows (NPS)	Bacteria	Direct deposit from nesting under bridges
	Urban Waterfowl (NPS)	Bacteria	Direct deposit or stormwater wash off from adjacent land cover
	Deer (NPS)	Bacteria	Direct deposit or stormwater wash off from adjacent land cover
	Feral Hog (NPS)	Bacteria	Direct deposit or stormwater wash off from adjacent land cover
Agriculture	Livestock (NPS) cattle, horse, goats, sheep	Bacteria	Direct deposit and stormwater wash off from agricultural lands
Urban/ Residential	Urban domestic animals (dogs) (NPS)	Bacteria	Stormwater wash off from urban lands
	Urban and rural OSSFs (NPS) Failing septic tanks	Bacteria	Direct deposit and stormwater wash off from failing systems
	Residential Turfgrass (NPS)	Nutrients	Stormwater wash off of over application of fertilizer
	WWTF Treated effluent (Point Source)	Bacteria & Nutrients	Direct Discharge, sanitary sewer overflows and treatment failures

NPS = nonpoint source pollution

In addition to the SWAT model, stakeholders utilized a Decision Support System (DSS) coupled with a sensitivity analysis approach to determine the potential or maximum amount of bacteria reduction that could be achieved per management strategy. The sensitivity analysis approach is derived by evaluating the effect a management strategy has on ambient water quality when a pollutant source is nearly or completely eliminated. Using this information, stakeholders were able to more effectively set implementation levels for individual management strategies. Despite the inherent scientific uncertainty associated with predicting fate and transport of bacteria loads in creeks; using SWAT, the DSS, and sensitivity analysis it was possible to show that geographic targeting of management strategies would have a substantial benefit on water quality by reducing instream bacteria loads (Figure ES-2).

Two key management strategies quickly became apparent as most effective during the stakeholder input process; 1) Cliff swallow nest deterrents under IH-10 bridges and 2) urban waterfowl management at River Road Park in Boerne. Combined, these two strategies had the largest impact on ambient water quality. Therefore, the recommendation by stakeholders is to prioritize these projects. However, to holistically address all sources identified within the watershed, every stakeholder recommended management strategy will be implemented according to the project schedule (Table ES-2).

WPPs often recommend a variety of complex management strategies that must be implemented simultaneously on large spatial and temporal scales. Many individuals, agencies, organizations and municipalities must be involved to carry out these strategies in order to achieve water quality improvements overtime. To assist with the implementation process; local, state and federal technical and financial resources were identified to support individuals or organizations with their efforts. A local Watershed Coordinator will be the primary point of contact and liaison for any entity seeking technical or financial assistance to implement strategies outlined in the WPP.

To successfully improve conditions throughout the watershed many existing activities, practices and behaviors will need to change or be improved upon. To accomplish this; residents, tourists, land managers and local decision makers need to be made aware of activities that can both harm and protect local waterways. Stakeholders established education and outreach as a top priority early in the planning process and developed a topical Work Group to specifically address the subject. Many forms of outreach were used to enhance public understanding of this project and encourage local stakeholder participation in selecting, designing and implementing management strategies. A variety of events, workshops, trainings and literature resources were used to help create awareness for methods used to reduce bacteria loads within the watershed. The continued use of education and outreach will be an essential tool in improving current and future water quality conditions within UCC.

In summary, water quality monitoring data and SWAT modeling results used by stakeholders to evaluate existing and future water quality conditions in the UCC Watershed suggest that the spatial extent and severity of the bacteria impairment can be effectively targeted and mitigated through an adaptive watershed-based approach to implementation. A full-time Watershed Coordinator will work to sustain the Partnership, initiate implementation efforts, pursue funding sources and technical resources; oversee water quality monitoring efforts to evaluate the effectiveness of management strategies and conduct outreach and education programs throughout the watershed.

Table ES-2. Implementation schedule and associated costs for management strategies

Management Measure	Responsible Party	Unit Cost	Number Implemented			Total Cost
			Years			
			1-3	4-6	7-10	
Wildlife						
Cliff Swallow Nest Deterrents	City of Boerne TXDOT	$223,000 for design and installation	1	—	—	$223,000
Urban Waterfowl Management	COB	Year 1: $3,459 Year 2-10: $3,224/yr.	Relocate 200+	Maintain pop at 100 +/-	Maintain pop at 100 +/-	$32,475
Feral Hog Management County Trapper	USDA TWDMS	$50,000/yr.	3	2	—	$250,000
Feral Hog	TX AgriLife TWDS	$5,000/yr.	3	2		$25,000
Feral Hog Management Trapping Supplies	Landowners Texas Wildlife Services	$5,000 2014 and 2018	1	1	—	$10,000
Feral Hog Management Feeder Exclusions	Landowners	$244 per feeder	50	—	—	$12,200
Deer Management	Landowners	$55,100/year for planning, permits, hunting, trapping to Reduce pop by 4,265 over 10 yrs.	3	3	4	551,000
Agriculture						
Conservation Plans	Landowners, Ranchers	$7 per acre for planning assistance	1100 ac	1100ac	—	$15,400
Urban / Residential						
Pet Waste Management	COB	3 Installs in year 1 at $300 per unit $100 annual maintenance/ unit,	9	9	9	$5,370
OSSF Strategies: Evaluations, Documentation, Replace, Repair Failing Systems	Kendall County & COB to identify and facilitate repairs or replacement. Property owners will finance.	Goal: replace 5 failing systems in each subwatershed (150 total) Approximately $10,000 per unit	25	50	75	$1.5 million
WWTRC Construction	COB	$28 Million	1	—	—	$28 Million
WWTRC Sewer Pipeline Installations	COB	$3.5 Million	—	—	1	$3.5 Million
HHW Collection	COB, Kendall Co	$15,000	1	1	—	$30,000

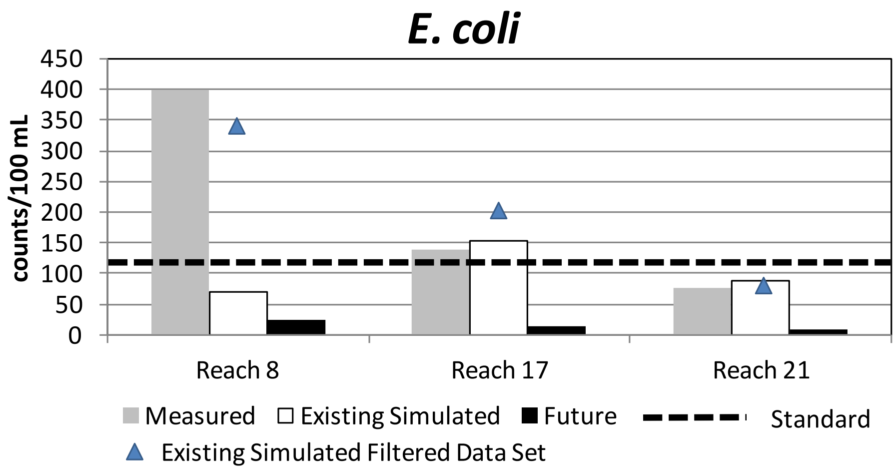


Figure ES-2. SWAT modeling results for existing and future simulated water quality conditions for *E. coli* in the upper (Reach 8), middle (Reach 17) and lower (Reach 21) portions of the UCC Watershed

Chapter 1. Introduction and Watershed Characteristics

Watershed Protection Plans (WPP) are being developed in Texas as a non-regulatory method to address local water quality impairments. The Upper Cibolo Creek (UCC) WPP provides guidance in reducing nonpoint sources of bacteria within the watershed in order to meet state water quality standards while simultaneously and proactively addressing nutrient concerns. The UCC WPP was developed by local stakeholders who have an interest in seeing waters throughout the watershed flow clean and clear.

Project History

In 2006 the Texas Commission on Environmental Quality (TCEQ) conducted a Waste Load Evaluation (WLE) on UCC in order to amend the City of Boerne's Wastewater Treatment Facility (WWTF) discharge permit. During sample site selection for the WLE, TCEQ staff was surprised to find an area with such ecological, hydrological and geological significance. The area along Cibolo Creek within the Cibolo Nature Center and the Cibolo Preserve is composed of diverse habitats where the creek contains long open runs, deep shaded pools, riffles, springs, groundwater recharge features and exposed fossil beds typically found deep within the earth's surface. TCEQ staff realized this stretch of Cibolo Creek was unique.

While conducting the WLE, TCEQ staff noticed the beginning stages of a large residential development planned for 600 homes on the property adjacent to the Cibolo Preserve. In August 2006 TCEQ conducted an Aquatic Life Monitoring (ALM) survey to determine the overall health of the creek and obtain base line data before major aspects of the construction began. Initial findings indicated borderline exceptional levels of aquatic life use. A second ALM survey was conducted in June 2008 and produced similar results**.**

In 1999, UCC (Segment 1908) upstream of the confluence with Balcones Creek near Boerne, Texas was listed on the *Texas Water Quality Inventory and 303(d) List* of impaired waterbodies for depressed dissolved oxygen (DO) and elevated levels of fecal coliform bacteria. From 2000-2004, UCC was only listed for depressed DO and in 2006-2008 UCC was listed only for bacteria. Screening level data for nutrients collected during the 2008 assessment also indicate a concern for orthophosphorus and ammonia. The *2010 Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d)* (*IR*, formerly the *Texas Water Quality Inventory*) once again indicated a bacteria impairment in the upper portion of UCC and nutrient concerns in the lower portion of the creek. As a result of TCEQs findings, coupled with trends in land use change and a history of local water quality impairments, the City of Boerne with help and encouragement from the Cibolo Nature Center, applied for and was awarded a Clean Water Act Section 319(h) grant to develop a WPP for the UCC Watershed

Purpose

The UCC has a history of elevated bacteria levels that exceed state standards set for safe contact recreation. This voluntary, non-regulatory WPP has been developed by stakeholders to holistically address local water quality concerns.

The primary goal of the plan is to recommend management strategies that can be implemented throughout the watershed to reduce *E.coli* bacteria levels within UCC and its tributaries. Management strategies aimed at reducing bacteria loads will simultaneously provide a reduction in nutrient concentrations throughout the watershed.

Nine Elements of a Watershed Plan

The U.S. Environmental Protection Agency (EPA) has identified nine key elements that are critical for achieving improvements in water quality (see Appendix C). The EPA requires that these nine elements be addressed in watershed plans funded with Clean Water Act (CWA) Section 319 funds. The UCC WPP was created using the following elements as a guide to help restore and protect local water quality:

a) Identify causes and sources of pollution that need to be controlled to achieve load reductions described in (b)
b) Estimate of load reductions expected from management strategies
c) Description of management strategies
d) Estimate of technical and financial assistance needed to implement the plan
e) Information and education component used to enhance public understanding of the plan
f) Schedule for implementation of management strategies
g) Description of interim, management milestones for determining whether management strategies are being implemented
h) Set of criteria that can be used to determine whether load reductions described in (b) are being achieved
i) Water quality monitoring component to evaluate effectiveness of implementation measured against the criteria described in (h).

The Watershed Approach

A watershed, or catchment, is a topographically defined area in which all sources of water, including lakes, rivers, streams, and wetlands, as well as ground water, drain to a common point. All land use activities that occur within a watershed have an impact on downstream water quality. Watershed management focuses on these activities and the linkages between uplands and downstream areas. In essence, WPPs address both point source and nonpoint sources of water pollution.

Point source pollution includes any pollution that may be traced back to a single source or point of origin. Point sources are often associated with industry and municipalities which are required to maintain discharge permits under the National Pollutant Discharge Elimination System (NPDES). Examples of point source pollution include pipes, drains or ditches that discharge water from factories or WWTFs. Nonpoint source pollution (NPS) consists of contaminants that are carried off the land by stormwater from many diffuse sources. NPS pollutants are often associated with land use activities such as cultivated agriculture, livestock grazing, forestry practices, small construction activities, urban areas and city streets.

Watersheds are becoming a common unit by which conservation strategies and natural resource management decisions are based. Watershed management actions and activities are employed in preventative strategies aimed at preserving existing sustainable land use practices or in restorative strategies designed to overcome identified problems or restore conditions to a desirable level where "desirable" is defined in both environmental and political terms (Brooks et al. 2003). The UCC WPP takes a holistic approach in addressing management strategies throughout the watershed and focuses on both proactive and restorative methods that will maintain and ultimately improve local water quality.

Benefits of the Watershed Approach

Watersheds are not defined by social or political boundaries. In order to improve water quality within specific waterbodies potential sources of pollution, regardless of jurisdictions, city limits or county lines must be taken into consideration. It is important to take a holistic approach in identifying these sources and ensure the views of local citizens, special interest groups, businesses and governing bodies are represented in the watershed planning process. By utilizing the watershed approach, stakeholders who represent anyone who lives works or plays within the watershed can work together to understand why water quality problems exist and develop management strategies that will improve conditions. The UCC Watershed Partnership ("Partnership") was formed to promote stakeholder cooperation even if they possess diverse backgrounds and ideals.


Photo Credit: Kari Tatro, Pamela Bransford

Stakeholders in the Upper Cibolo Creek Watershed Partnership

Stakeholder Designated Goals

Early in the planning process stakeholders developed goals for the WPP that include (at a minimum) meeting the appropriate water quality standards established for safe contact recreation. Stakeholders were also encouraged to proactively address any pollutants that might threaten or impair the physical, chemical, biological or ecological integrity and the designated uses of UCC and its watershed. Stakeholders determined that water quality goals outlined in the WPP (pg. 111) would ensure that UCC meets all state water quality standards associated with its designation for contact recreation.

Stakeholder Group Structure

Stakeholders have an opportunity to contribute ideas, opinions, and concerns regarding management strategies to address water quality conditions. All stakeholders involved in the planning process will participate as part of the Watershed Partnership structure. The Watershed Partnership includes five opportunities for participation with the following roles and responsibilities.

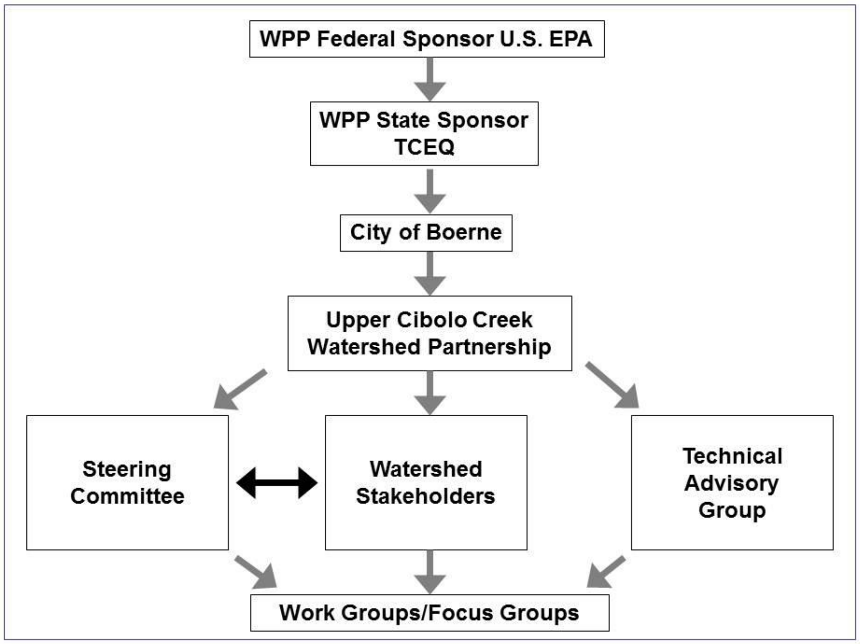


Figure 1-1. Stakeholder Group Structure for the UCC Watershed Partnership

- *Watershed Stakeholders*: Stakeholders participate in public meetings and contribute information and ideas to be considered for the plan.

- *Steering Committee*: The Steering Committee was developed to act as the decision making body within the partnership. Individuals who serve on the Steering Committee reflect the diversity of interest and viewpoints within the UCC Watershed. The overall goal of the Steering Committee is to develop and implement a WPP that will provide sustainable and cost effective results towards achieving water quality standards.

- *Work Groups*: Work groups were formed to address specific topics identified/assigned by the Steering Committee based upon information gathered during Stakeholder Meetings. Work Group discussions provided the foundation for management strategies recommended in the WPP. The following topical work groups were formed by stakeholders:

  - Education and Outreach
  - Water Quality and NPS Pollution
  - Riparian Habitat
  - Surface Water and Groundwater Interaction
  - Water Quality and Changes in Land Use

- *Focus Groups:* Focus groups were organized to provide specific information on the implementation of management strategies used to reduce bacteria loads throughout the watershed. Focus groups were composed of individuals who would likely implement management strategies recommended in the WPP. Focus groups played a key role in the water quality modeling process. The following focus groups were formed by stakeholders:

  - Urban Residents
  - Rural Residents
  - Ranching
  - Local Businesses
  - Local Government
  - Non-Profits

- *Technical Advisory Group*: A Technical Advisory Group consisting of county, state and federal natural resource agencies provided guidance to the Steering Committee and Work Groups when needed.

Watershed Characteristics

Stream Segment Description

Segment 1908 of UCC is divided into three sub-segments; sub-segment 1908_01 extends from the confluence with Balcones Creek to approximately 2 miles upstream of Hwy 87 in Boerne, sub-segment 1908_02 begins approximately 2 miles upstream of Hwy 87 and extends to just upstream of Champee Spring and sub-segment 1908_03 begins at the confluence of Balcones Creek and ends 43 miles downstream near the city of Schertz. Segments are defined by the TCEQ for the purpose of assessing waterbodies in the Integrated Report for meeting state standards. This WPP focuses on sub-segments 01 and 02 of UCC (Figure 1-2) from its confluence with Balcones Creek near the Kendall and Comal county line upstream to its source springs west of Boerne.

Watershed Characteristics

Cibolo Creek is a unique water body within the San Antonio River Basin that makes its way across 100 miles of south central Texas. Originating in the hills west of Boerne in southern Kendall County, Upper Cibolo Creek is a spring fed stream that flows for 23 miles before it returns underground to recharge the Trinity Aquifer. As the Cibolo continues along its journey to the San Antonio River, long stretches of the Middle Cibolo remain dry throughout the year. However, once the creek reaches eastern Bexar County, the Lower Cibolo once again resumes its perennial nature and is an important tributary within the river basin.

The UCC watershed, from the headwaters to its confluence with Balcones Creek has a catchment area of 76.9 mi^2 (49,209.6 acres). Champee and Brown Spring collectively form the headwaters of UCC and flows are supplemented by three spring fed tributaries (Ranger, Frederick and Menger Creeks).

On average, the City of Boerne WWTF discharges over 700,000 gallons per day into the creek which greatly supplements flows in the lower reaches of the watershed, especially during drought conditions. UCC is subject to large variations in flow due to shallow soils, groundwater recharge features and surface flows that are highly influenced by stormwater runoff.

Photo Credit: John Hallowell

Aerial views of the Resort at Tapatio Springs and downtown Boerne located within the UCC Watershed.

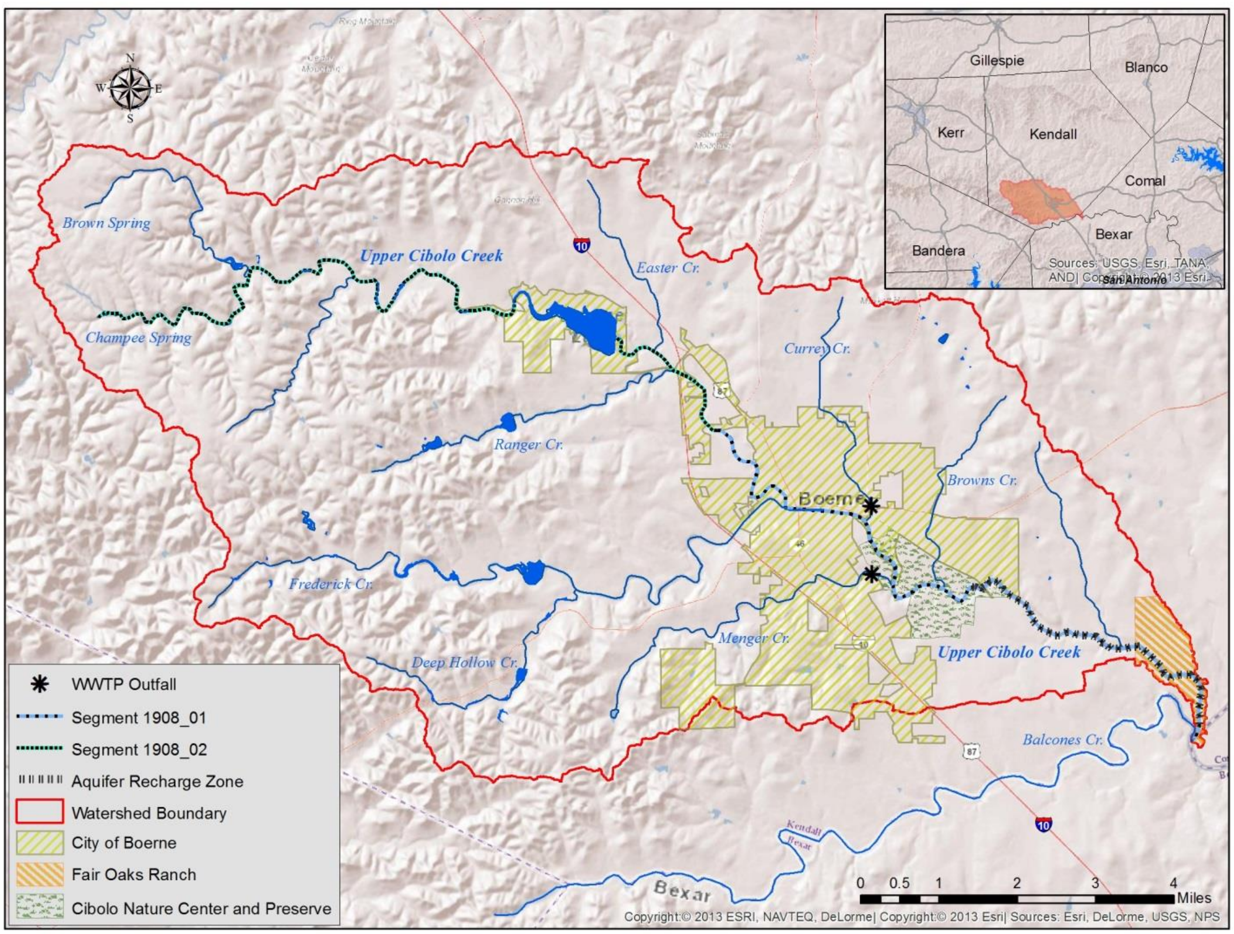


Figure 1-2. Upper Cibolo Creek Watershed located in southern Kendall County, Texas

Ecology

The UCC Watershed is located within the Balcones Canyonlands ecoregion which forms the southeastern boundary of the Edwards Plateau. The southern Edwards Plateau was shaped through uplift and subsidence along the Balcones Fault Zone, separating central Texas from the coastal plain by over 1000 feet in elevation (Spearing 1991). The Balcones Canyonlands are highly dissected through the solution of springs, streams, and rivers working both above and below ground to create canyons, sinkholes, and caverns (karst) (Griffith et al., 2007).

Flora

The Balcones Canyonlands supports a number of endemic plants and has a higher representation of deciduous woodland than elsewhere on the Edwards Plateau, with escarpment black cherry, Texas mountain-laurel, madrone, Lacey oak, bigtooth maple, and Carolina basswood (Griffith et al., 2007). Some relicts of eastern swamp communities, such as bald cypress, American sycamore, and black willow, occur along major streamcourses (Griffith et al., 2007).
Toward the west, the vegetation changes gradually as the climate becomes more arid. Plateau live oak woodland is eventually restricted to north and east facing slopes and floodplains, and dry slopes are covered with open shrublands of juniper, sumac, sotol, acacia, honey mesquite, and ceniza (Griffith et al., 2007).

This escarpment ecoregion is distinctive because its broken topography discourages intensive human development and supports diverse habitats, high species diversity and wildlife numbers, as well as refuge for endemics and endangered species (Griffith et al., 2007). One plant species located within the UCC Watershed is endangered and of special concern. Once thought extinct, Big Red Sage *Salvia pentstemonoides* was identified within the Cibolo Canyonlands southeast of Boerne, a plant only found within the Texas Hill Country. The newly discovered site contains the largest know extant population of Big Red Sage in the world (NPSOT).

Fauna

One of the more distinguishing features of the Balcones Canyonlands is the relative abundance of running water. These waterways are often picturesque and typically support high levels of aquatic life. A unique species in that it only inhabits stream and rivers within the Edwards Plateau is the Guadalupe bass *Micropterus treculii,* the official state fish of Texas. Guadalupe bass do not grow to a large size and are well adapted to the small streams of Central Texas. Pure strain Guadalupe bass populations are at risk due to impaired water quality within their range and cross-hybridization with introduced smallmouth bass *Micropterus dolomieu*. A population of Guadalupe bass exists in the downstream reaches of UCC and was recently analyzed by the Texas Parks and Wildlife Department (TPWD) for its genetic purity. Preliminary results indicate the UCC population is greater than 90% genetically pure and could be a potential source for regional restocking efforts. Guadalupe bass only exist in healthy aquatic systems and are an indicator species for environmental quality.

Sensitive Areas

The Cibolo Preserve and the Cibolo Nature Center are located on Cibolo Creek southeast of Boerne. The Cibolo Nature Center maintains a native tall grass prairie, one of the regions most threatened ecosystems, composed of species such as Big Bluestem, Indian Grass and Switchgrass. The recently created Cibolo Preserve is a 623 acre nonprofit foundation dedicated to the management of native vegetation and the preservation of unique geological and hydrological features. The Cibolo Preserve is home to Herff Falls which is an exposed Lower Cretaceous reef formed over 110 million years ago. The reef is dominated by the remains of two organisms, caprinid rudistids and massive star corals. UCC flows over the exposed reef where over time erosion formed Herff Falls, a major ground water recharge feature to the Trinity Aquifer. The Preserve also contains the entrance to Cibolo Island Cave, a recharge feature 19m deep and 21.5m in length located in UCCs flood plain. The cave is a direct conduit to a shallow aquifer where groundwater flows in the opposite direction of Cibolo Creek. The Cibolo Preserve is used a as unique outdoor laboratory for research by TPWD, The University of Texas at San Antonio and the Cibolo Nature Center.

Photo Credit: Ryan Bass

Entrance to Cibolo Island Cave located at the Cibolo Preserve

Elevation, Topography and Watershed Delineation

The UCC watershed ranges in Elevation from 1,245 ft. (380m) to 2,012 ft. (613m) above sea level (Figure 1-3). The western portion of the watershed above Champee and Brown Springs has the highest elevations while the extreme downstream reach of the watershed near the confluence with Balcones Creek is the lowest point. Topography varies throughout the watershed with the western portion characterized as steep hilly terrain with small box canyons. Topography in the eastern portion of the watershed reduces to low rolling hills interspersed with flat areas containing woodlands and small pastures.

Watershed boundaries are determined by highpoints in elevation surrounding a waterbody. Watersheds can be delineated on maps by connecting these highpoints using contours on topographic maps. Advancements in the use of Geographic Information Systems (GIS), Digital Elevation Models (DEM) and hydrologic modeling software have enhanced the ability of watershed managers to delineate and analyze watersheds. For the purpose of this project, 30 smaller watersheds (referred to as subwatersheds) were delineated inside the UCC Watershed. Additional information on watershed delineation can be found in Chapter 2.

Table 1-1. Upper Cibolo Creek Watershed Slope Categories

Slope (%)	Area (acre)	Percent of Total Watershed Area
0 – 3	12,034	24.54
3 – 9	18,433	37.59
>9	18,564	37.86

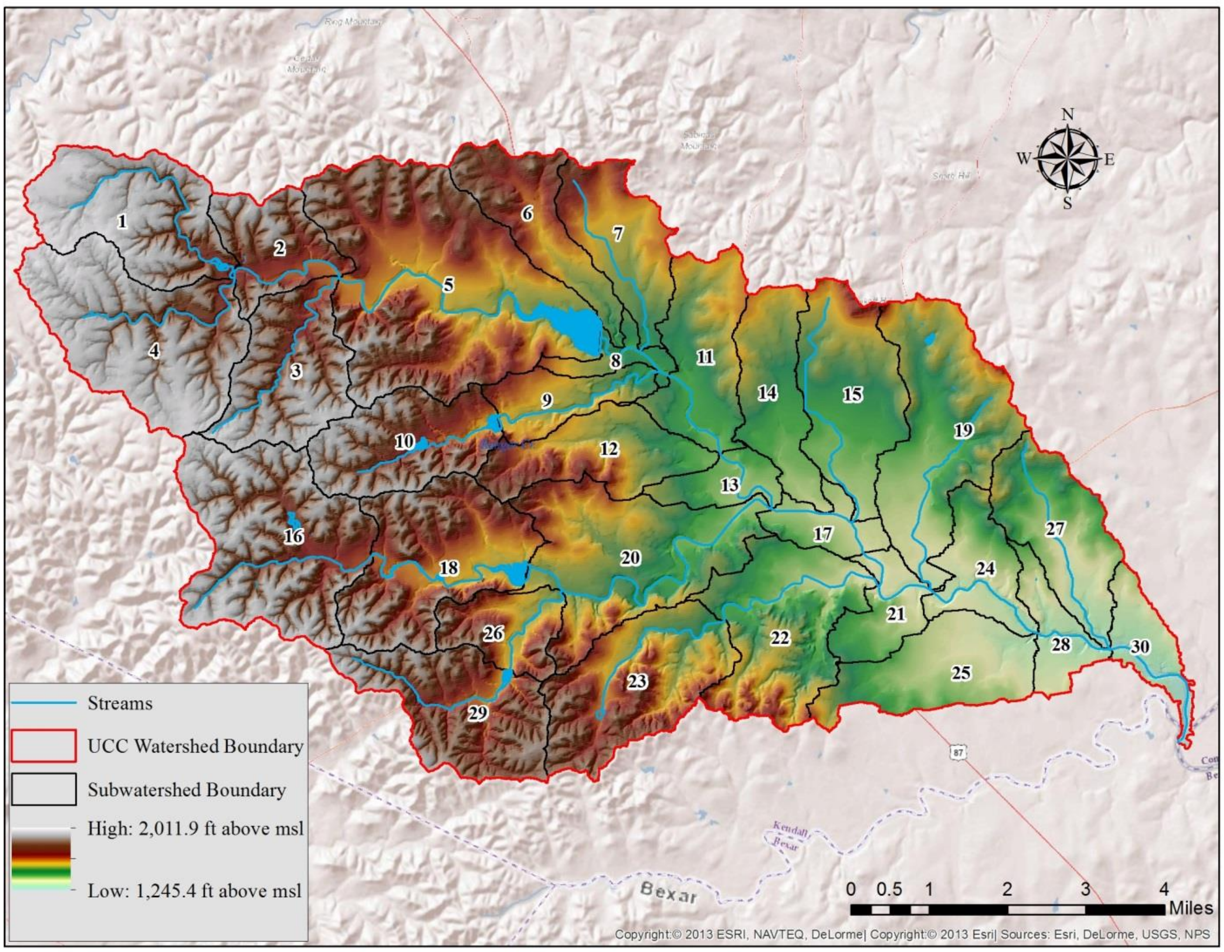


Figure 1-3. Digital elevation model for the UCC Watershed. Units expressed as feet above mean sea level (msl).

Soils

Soil is an essential part of the hydrologic cycle and plays an important role in determining the characteristics of a watershed. Detailed soil types in Kendall County were classified by the National Cooperative Soil Survey in 1972 - 1978. The soil classification is based on soil properties observed in the field or inferred from those observations or from laboratory measurements (Soil Survey 1979). In general, upland soils are very shallow to shallow, mostly stony with a loamy and clayey composition. On flood plains and stream terraces soils are deeper with a loamy and clayey composition. Soil types located within the UCC watershed can be found in Appendix A (Figure A-1, A-2).

Table 1-2. STATSGO Soil Map Units and Selected Soil Properties

STATSGO Soil Map Unit	Area (acre)	Percent of Watershed Area	Major Soil Components of Map Unit (% of Map Unit)	Hydrologic Soil Group	Available Water Capacity†	Saturated Hydraulic Conductivity† (mm/hr)	Maximum Soil Depth† (m)
TX155	28,493	58.11	Eckrant (56%)	D	0.12	1.15	0.76
			Rock Outcrop (16%)	D	0.01	450	2.03
TX105	11,482	23.42	Comfort (36%)	D	0.07	0.92	0.51
			Rumple (26%)	C	0.11	9.6	1.17
TX371	7,852	16.01	Nuvalde* (23%)	B	0.20	0.49	2.03
			Oakalla* (24%)	B	0.18	1.60	1.52
			Boerne (16%)	B	0.11	53	1.52
			Denton (10%)	D	0.20	0.38	1.78
TX071	1,204	2.46	Brackett (40%)	C	0.16	6.0	1.52
			Purves (13%)	D	0.16	0.83	0.51
			Real (10%)	D	0.13	15	0.91

† property of surface soil layer
* although the Oakalla component is more abundant in the map unit, SWAT uses the properties of the Nuvalde component

Land Use

Land owners within the watershed predominately use their property for light ranching, hunting and recreation. Many small ranchettes are scattered throughout the watershed and some large acreage ranches can be found in the headwaters region. In several locations, large tracts of ranchland are being divided into smaller holdings or developed into residential subdivisions. These changes are frequently associated with new land management strategies and oftentimes greatly increase the amount of impermeable surfaces within subwatersheds. The popularity of the Texas Hill Country as a retirement destination and the northward expansion of the greater San Antonio area will continue to influence these trends. In general, regional population growth will result in the conversion of rural properties to commercial and residential areas. The resulting change in landcover type from grasslands and forested areas to urbanized environments will likely have a negative impact on water quality and quantity. A detailed landcover map can be found in Appendix A (Figure A-2).

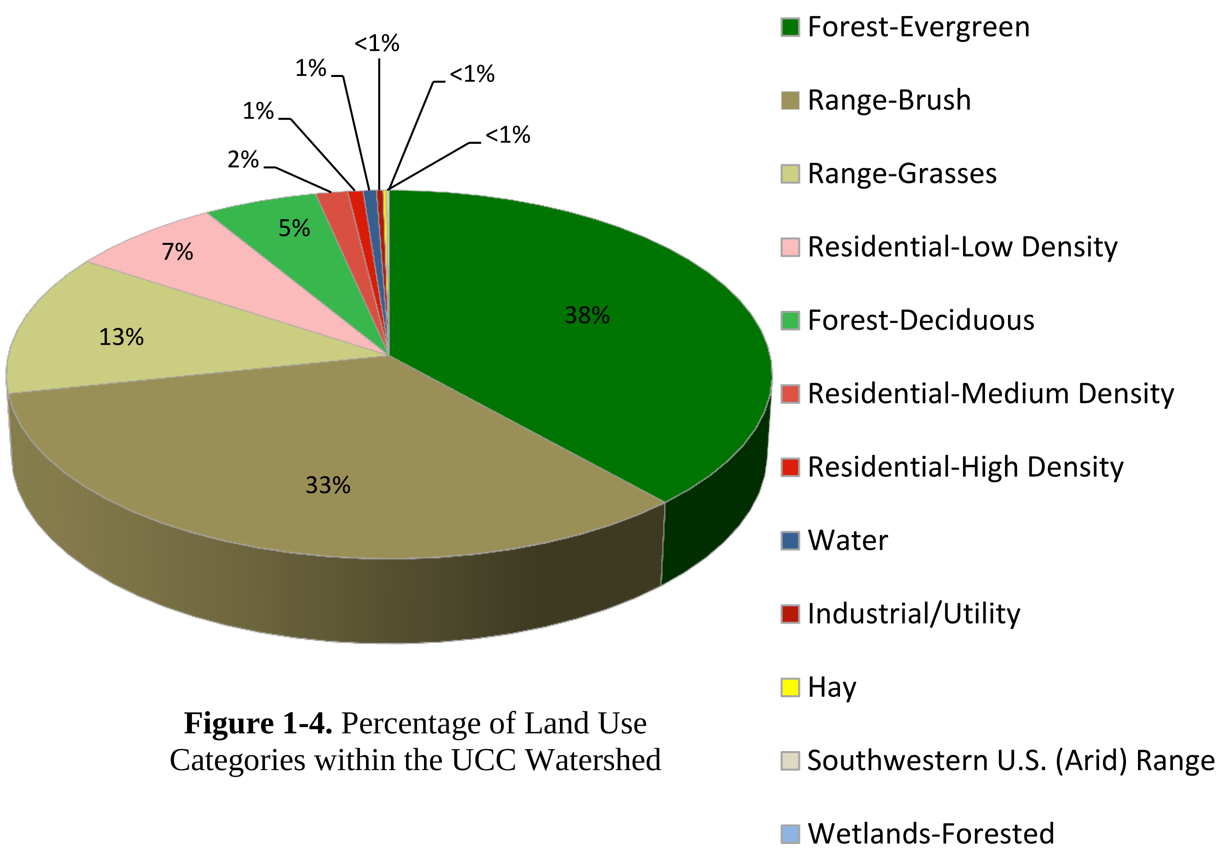


Figure 1-4. Percentage of Land Use Categories within the UCC Watershed

Climate and Precipitation

The UCC watershed is described as having a subtropical, subhumid climate characterized by hot summers and mild, dry winters (Larkin and Bomar, 1983). Boerne has an average temperature of 34ºF in January and 94ºF in July (NOAA 2009). The City of Boerne receives an annual average of 36 inches of precipitation. Although rainfall is generally distributed evenly throughout the year, higher amounts of precipitation occur in May, June, September and October (Reeves 1967). The maximum recorded precipitation for one year was 64.17 inches in 1992; the minimum was 10.29 in 1954. Historic precipitation totals for Boerne, Texas from 1912 – 2012 are found in Figure 1-5.

General Hydrology

UCC is a clear, fast flowing perennial stream characteristic of most creeks and rivers found throughout the Texas Hill Country. The hydrology of UCC is unique in that it originates as groundwater, is captured and stored by impoundments along its path downstream, utilized as a municipal water source where it is processed and returned to the stream, then finds its way underground to recharge the Trinity aquifer, all within the confines of the watershed. Base flow for the creek is primarily supplied by springs and seeps throughout the watershed. Springs typically occur at intersections of the water table and land surface where groundwater discharges into streams under the force of gravity (gravity or contact springs) (Wierman et al. 2010).

Springs are generally discrete points of discharge, often measured in cubic feet per second, while seeps are generally non-discrete zones of low flow or moist areas. (Wierman et al. 2010). Ten intermittent tributaries provide flows to the creek during wet weather conditions. Flows in the downstream reach of UCC are supported by wastewater effluent from the City of Boerne's WWTF. With an average daily discharge of greater than 700,000 gallons, the effluent maintains perennial conditions throughout this section of UCC, even during extreme drought conditions.

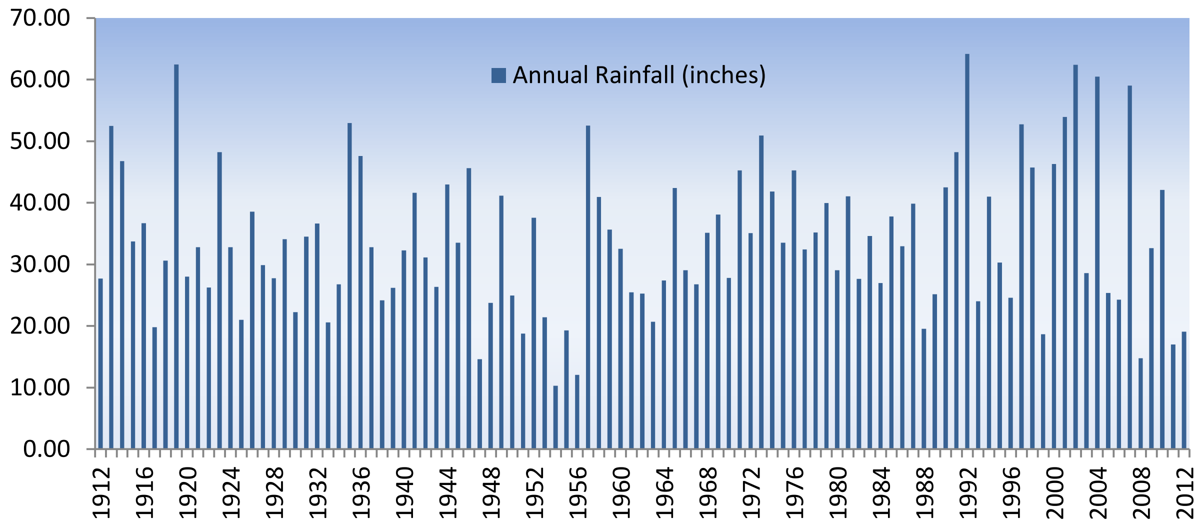


Figure 1-5. Annual precipitation measured at National Weather Service Station Index No. 41-0902-06 in Boerne, Texas from 1912 - 2012.

Surface Water Impoundments

Boerne City Lake is the primary surface water impoundment in the watershed and serves as a source of potable water for the City of Boerne. Covering approximately 188 surface acres, Boerne City Lake is located on Cibolo Creek on the northwest side of Boerne. The dam was constructed by the Natural Resource Conservation Service (NRCS) in 1978 to reduce flooding potential downstream. The conservation pool stores approximately 4,000 acre-feet of water.

Four other NRCS flood control impoundments exist in the watershed. NRCS Dams 2 and 3 are privately owned dams on Ranger Creek. The larger and more downstream of these Ranger Creek dams impounds a pool of up to 56 acres. NRCS Dam 4 impounds Lake Oz, with a pool of up to 51 acres on Frederick Creek. NRCS Dam 5 impounds a pond of up to 59 acres on Deep Hollow Creek, a tributary of Frederick Creek. The Dietert Mill Dam in Boerne creates the second impoundment on Cibolo Creek and is commonly referred to as the Duck Pond.

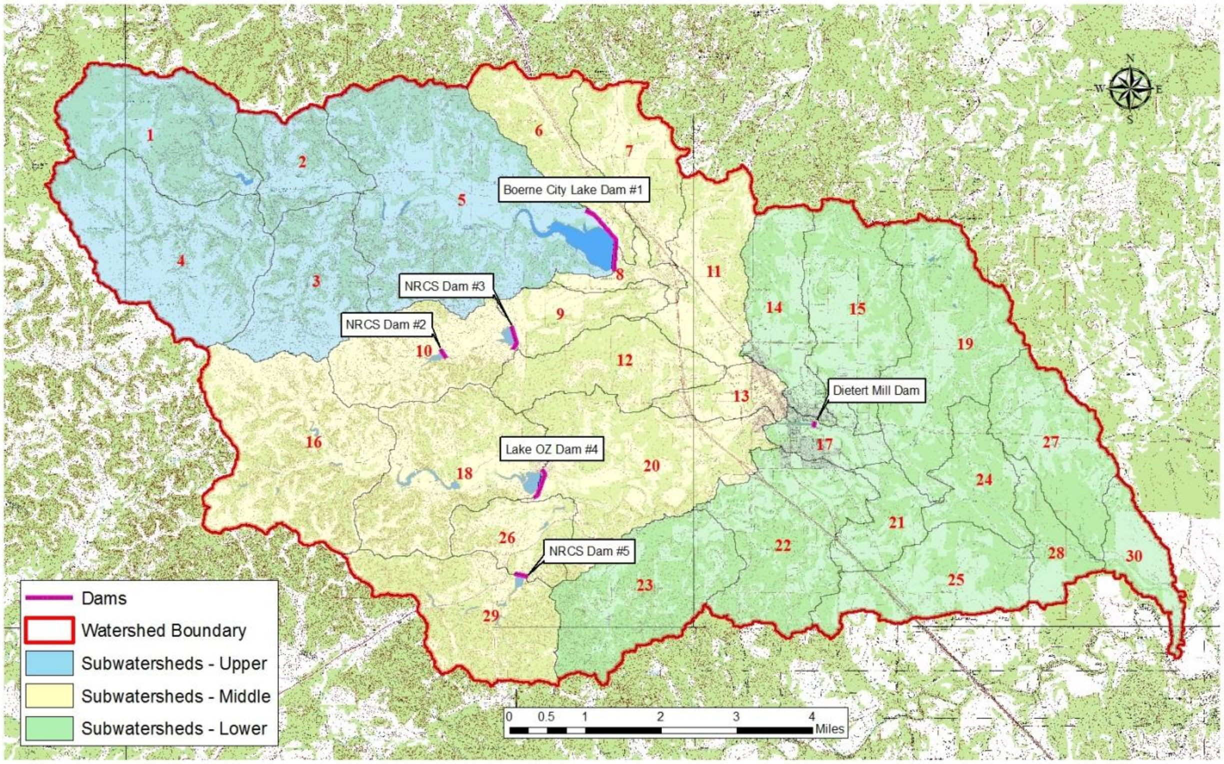


Figure 1-6. Surface Water Impoundments and Contributing Subwatersheds for Areas of UCC Influenced by Impoundments

During periods of low flow, impoundments located on UCC often leave the sections of the creek hydrologically disconnected throughout the watershed. The watershed can be divided into three areas which are highly influenced by impoundments; the headwaters to Boerne City Lake Dam (Upper), Boerne City Lake Dam to the Dietz Mill Dam (Middle) and the Dietz Mill Dam to downstream of Herff Falls (Lower). Although springs and seeps along main stem of UCC and its major tributaries support pools during summer months, it is not uncommon for portions of the creek to become dry during drought conditions.

Surface water impoundments throughout the watershed act as “sinks” for pollutants and consequently can influence downstream water quality conditions. For example, Boerne City Lake does reduce the delivery of instream bacteria loads from subwatersheds 1, 2, 3, 4 and 5 downstream to subwatershed 8. This factor suggests the major sources of bacteria loads influencing water quality conditions measured at station 12857 (Figure 1-9) originate from subwatershed 8, as well as, subwatersheds 6 (Comanche Spring), 7 (Easter Creek), and 9 and 10 (Ranger Creek) rather than from pollutant source contributions upstream of Boerne City Lake (see Chapter 4).

Groundwater Recharge

Stream flow and annual precipitation infiltrates sinkholes, fissures, and caverns of the limestone substrate to recharge the Trinity aquifer. Most groundwater recharge originates from areas outside of the region and flows through the subsurface into and through the watershed (Voulgaris, 2009). Initial studies of the Trinity Aquifer estimate a recharge coefficient of approximately 4% of annual rainfall (Mace, et al. 2000).

Localized recharge does occur by percolation of rainfall as well as in the stream bed of UCC and its tributaries, particularly if associated with a fracture zone (Figure 1-2). Cow Creek Groundwater Conservation District (CCGCD) is aware of several significant recharge features within the watershed which provide major avenues for recharge (Figure 1-7). Nowhere is this more apparent than in the lower reaches of Segment 1908 at the Cibolo Preserve where during normal flow conditions the entire volume of water returns underground through fractures in the streambed.

Picture A

Picture B

Photo credit: Bill Ward

Figure 1-7. Effects of Groundwater Recharge on the lower reach of UCC. *Picture A:* UCC at Cibolo Preserve low water crossing. *Picture B:* UCC approximately 6 miles downstream of Picture A at Hwy 3351. Both pictures were taken within the same hour on the same day in 2007.

In 2007 the U.S. Geological Survey (USGS) partnered with the U.S. Army Corps of Engineers, San Antonio River Authority (SARA), San Antonio Water System (SAWS) and the Guadalupe-Blanco River Authority (GBRA) to develop a model simulating stream flow and estimated groundwater recharge in the middle and upper reaches of the Cibolo Creek Watershed from 1992-2004 (Ockerman 2007). Results of this model provided insight to surface/groundwater interactions occurring within the region and indicated that Segment 1908 loses streamflow volume to the Trinity Aquifer outcrop through stream channel infiltration (Ockerman 2007).

Wastewater Treatment Facility Discharge

WWTFs are considered direct discharges of pollutant loads and can be a continuous source of bacteria or nutrient loading unless they are permitted as no discharge facilities. The City of Boerne operates the only permitted WWTF that discharges wastewater into Cibolo Creek or its tributaries and is currently the only point source of pollution located in the watershed.

These facilities are operated under TPDES permit WQ0010066-001 which discharges wastewater to Currey Creek, and then to Cibolo Creek. The City of Boerne has constructed a new Wastewater Treatment and Recycling Center (WWTRC) (TPDES permit WQ0010066-002) with a discharge location near the mouth of Menger Creek. The new WWTRC began operation in April 2013. Lerin Hills Municipal Utility District obtained a permit (TPDES WQ0014712-001) to discharge wastewater to a tributary of Frederick Creek, but to date the facility has not been built and no wastewater is being discharged. Another WWTF in the watershed is operated by the Kendall West Utility LLC., but this is a no-discharge facility which applies effluent as irrigation to Tapatio Springs Golf Resort.

On-Site Sewage Facilities

Bacteria and nutrient loads from an On-Site Sewage Facilities (OSSF) are considered a nonpoint source of pollution. OSSFs typically treat waste from single residences that are not connected by a sanitary sewer line to a WWTF. GIS was used to locate OSSFs throughout the watershed by identifying improved residential structures outside of known sewer service areas. The City of Boerne estimated that 2,344 OSSFs occur within the UCC Watershed, and their locations are shown in Figure 1-8**.**

Photo Credit: Ryan Bass

Bacteria "snap-shot" monitoring event conducted by stakeholders and the Texas Stream Team

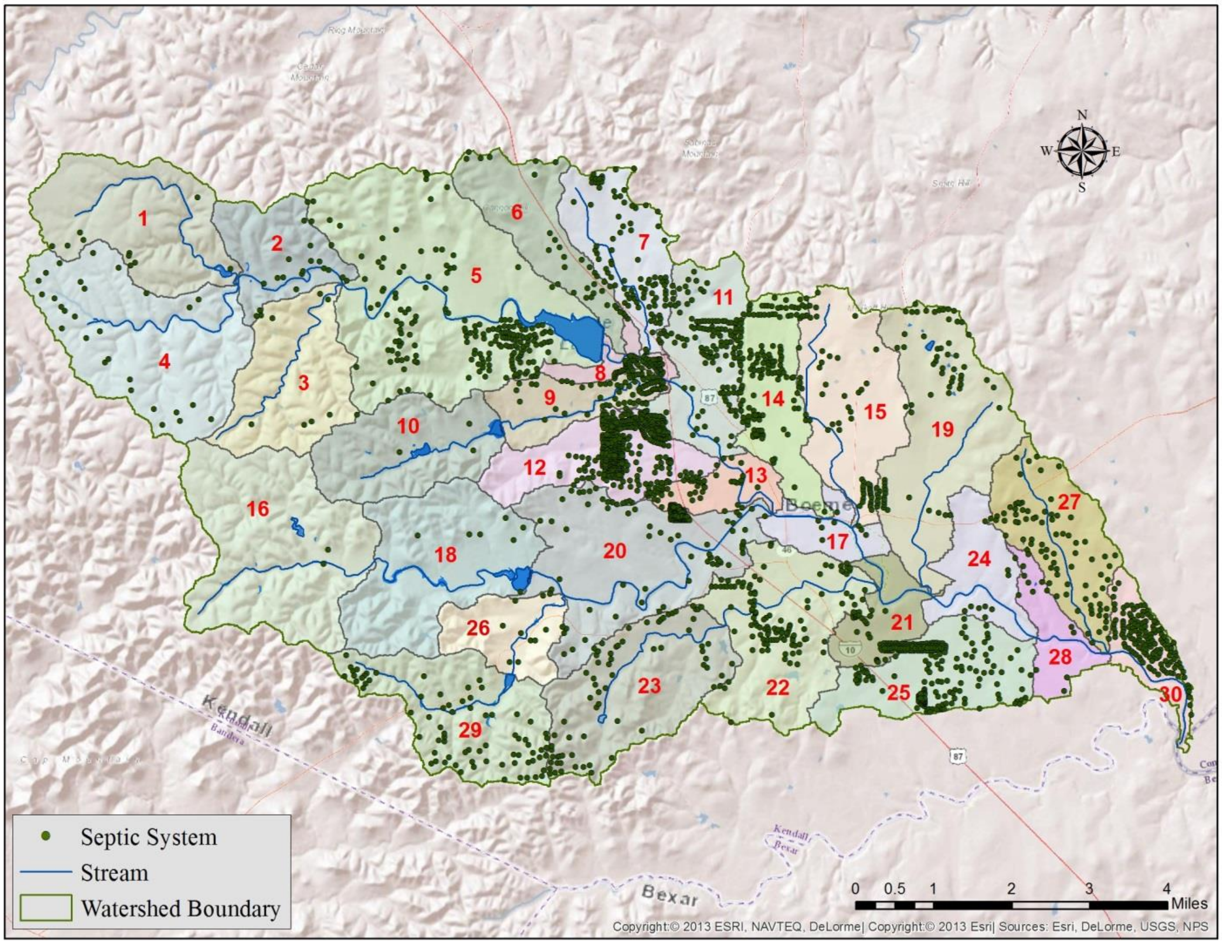


Figure 1-8. Location of OSSFs within the UCC Watershed

Water Quality Standards

The Texas Surface Water Quality Standards establish explicit goals for the quality of streams, rivers, lakes and bays throughout the state. The standards were developed to maintain the quality of surface waters in Texas so they support public health, recreational use and protect aquatic life. In short, The Texas Surface Water Quality Standards are rules that:

- Designate the uses, or purposes, for which the state's water bodies should be suitable
- Establish numerical and narrative goals for water quality throughout the state
- Provide a basis on which TCEQ regulatory programs can establish reasonable methods to implement and attain the state's goals for water quality

According to The Texas Surface Water Quality Standards (Updated November 12, 2009), Segments 1908 (01-02) are designated for the following uses:

Aquatic Life Use

The standards associated with Aquatic Life Use (ALU) are designed to protect aquatic species. The standards establish optimal conditions for the support of aquatic life and define indicators used to measure whether these conditions are met. Some pollutants or conditions that may violate this standard include low levels of dissolved oxygen, or toxics such as metals or pesticides dissolved in water. UCC is listed a maintaining a high ALU. Studies conducted on UCC by TCEQ indicate a borderline exceptional ALU.

Contact Recreation

The standard associated with this use measures the level of certain bacteria in water to estimate the relative risk of swimming or other water sports involving direct contact with the water. *E. coli* (EC), and historically fecal coliform bacteria are used to indicate the potential presence of harmful pathogens that come from the fecal matter of warm-blooded animals. It is possible to swim in water that does not meet this standard without becoming ill; however, the probability of becoming ill is higher than it would be if bacteria levels were lower. Many people utilize Boerne City Lake and Cibolo Creek at the Cibolo Nature Center for recreational purposes.

Public Water Supply

The City of Boerne utilizes water from Boerne City Lake for a portion of its public water supply. Standards associated with this use indicate whether water from a specific lake or river is suitable for use as a source for a public water supply system. Source water is treated before it is delivered to the tap. A separate set of standards governs treated drinking water. Indicators used to measure the safety or usability of surface water bodies as a source for drinking water include the presence or absence of substances such as metals, pesticides and bacteria. Concentrations of salts, such as sulfate or chloride are also measured, since treatment to remove high levels of salts from drinking water may be expensive.

Texas Surface Water Quality Standards, Numeric Criteria for Segment 1908

- *E. coli* bacteria: Geometric Mean $\leq$126 colonies /100mL
- Chloride (Cl^{-1}): 50 mg/L
- Sulfate (SO_4^{-2}): 100 mg/L
- Total Dissolved Solids: 600 mg/L
- Dissolved Oxygen: 5.0 mg/L
- Temperature: 90°F (32.2°C)
- pH Range (SU): 6.5 - 9 mg/L

Freshwater Stream Nutrient Screening Criteria:

Historically, the State of Texas does not include numerical criteria for nutrients in their surface water quality standards. To monitor nutrient levels in surface waters throughout the state the TCEQ screens phosphorus, nitrate nitrogen, and chlorophyll as a preliminary indication of areas of possible concern. The following numeric values for nutrients are used for screening purposes only. No segment specific nutrient standards exist for Segment 1908.

- Ammonia Nitrogen (NH_3-N): 0.33 milligrams per liter (mg/L)
- Nitrate Nitrogen (NO_3-N): 1.95 mg/L
- Ortho Phosphorus (PO_4-P): 0.37 mg/L
- Total Phosphorus (TP): 0.69 mg/L
- Chlorophyll-a: 14.1 micrograms per liter (µg/L)

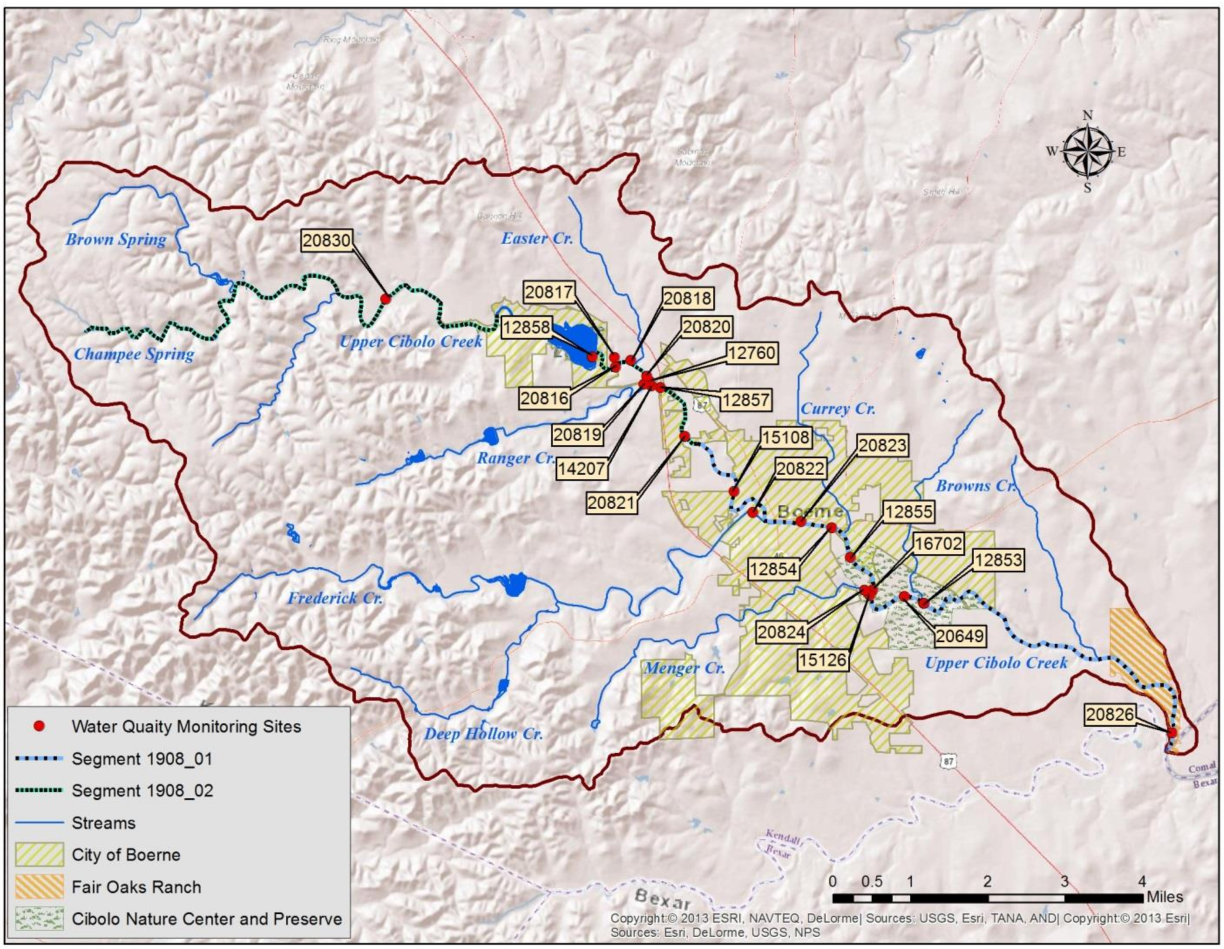


Figure 1-9. TCEQ approved water quality monitoring sites used to evaluate conditions

Texas 303d Listings for Segment 1908

Table 1-3. List of water quality impairments and concerns for Segment 1908_01 and 1908_02 from 1999-2012.

Texas 303(d) listings for Upper Cibolo Creek (Segment 1908)				
303(d) List Year	**Segment/Area**	**Impairment**	**Category/Priority**	**Concerns**
1999	1908_01	Dissolved Oxygen (DO), Bacteria	Medium	-
2000	1908_01	DO	Medium	DO
2002	1908_01	DO	5c [1]	Phosphorus
2004	1908_01	DO	5c [1]	Orthophosphorus
2006	1908_01 1908_02	Bacteria	5c [1]	-
2008	1908_01	-	5c [1]	Habitat, Orthophosphorus
	1908_02	Bacteria	-	Ammonia
2010	1908_01	-		DO, Total Phosphorus, Orthophosphorus
	1908_02	Bacteria	5c [1]	Habitat
2012 [2]	1908_01	Chloride	5c [1]	Orthophosphorus, Total Phosphorus
	1908_02	Bacteria, Chloride	5c [1]	Habitat

1 Additional data and information will be collected before a Total Maximum Daily Load is scheduled.

2 The Draft 2012 303(d) List was released at the conclusion of the UCC Watershed planning process.

Chapter 2. Water Quality Modeling

Model Selection

Water quality models are computer software tools used to simulate the movement of stormwater and pollutants from the ground surface to channels, stream networks, pipes and finally to receiving waters. These models incorporate a variety of environmental factors combined with hydrology, topography and land use practices to estimate the impact of stormwater pollution on local aquatic systems. Both single-event and continuous simulation may be performed on watersheds having storm sewers and natural drainage, for prediction of flows and pollutant concentrations. Each water quality model has its own unique purpose and simulation characteristics. Water quality models are carefully chosen to accurately estimate conditions based on specific watershed characteristics and desired outcomes.

The Soil and Water Assessment Tool (SWAT)[1] was selected to model water quality conditions throughout the watershed. SWAT is a basin-scale, continuous-time watershed model that runs on a daily time-scale. The model was selected because it is designed to predict the impact of management strategies on water, sediment, agricultural chemical, and nutrient (nitrogen and phosphorus) yields, and was expanded to simulate fecal bacteria and the in-stream processes controlling DO (Neitsch, et al. 2011). The model is also capable of continuous simulation over long time periods. Major components of the model include weather, hydrology, soil temperature and properties, plant growth, nutrients, land management, and stream routing.

SWAT is widely used by agencies such as the United States Department of Agriculture (USDA), the EPA, and the National Oceanic and Atmospheric Administration. SWAT is currently employed in a large number of water quality projects throughout the State of Texas. The USDA Agricultural Research Service and Texas A&M AgriLife Research in Temple, Texas, developed and maintained the model, and applied SWAT to numerous watersheds in Texas and around the nation (see Gassman, et al. 2007 for a full list of SWAT applications). SWAT has a long history of use for watershed assessments supporting WPPs and development of Total Maximum Daily Loads (TMDL).

Model Setup

SWAT was run for every day in the modeling period extending from 1991 through 2011. SWAT was also run for an additional four-year period from 1987 through 1990 to provide a four-year "stabilization time" for the model to develop conditions that match up with the UCC water quality conditions.

[1] revision 510 of SWAT 2009 (compile date 2/28/2012)

Model inputs, including geospatial data, climatic data time series, and other data, were processed into SWAT input files using the ArcSWAT 9.3.1 interface for SWAT2009 (Winchell, et al. 2010). The variables chosen for simulation in SWAT reflect the parameters of concern for the water quality in UCC:

- Flow
- Total suspended solids (TSS)
- Organic phosphorus (OrgP)
- Orthophosphorus (PO_4-P)
- Organic nitrogen (OrgN)
- Ammonia nitrogen (NH_3-N)
- Nitrate + nitrite nitrogen (NO_3-N)
- Carbonaceous biological oxygen demand (CBOD)
- Dissolved oxygen (DO)
- E. coli bacteria (EC)
- OrgP and PO_4-P were simulated to calculate TP.
- OrgN, NH_3-N, and NO_3-N were simulated to calculate total nitrogen (TN)
- Sediment (as TSS) was included in the model because of its close association with phosphorus and E. coli loads.

Subwatershed Delineation

In SWAT, a watershed is partitioned into a number of subwatersheds to represent unique soil, land use, and slope combinations. Figure 2-1 shows the subdivision of the UCC Watershed into 30 subwatersheds. These subwatersheds were derived from the available National Elevation Dataset (NED) along with the USGS National Hydrography Dataset (Simley and Carswell 2009) that provided the stream network information. Subwatershed outlets were created at the confluence of major streams, at dams, and at the various flow gages and water quality stations that would serve as model calibration points. Some subwatersheds were subdivided for the reasons described above or to maintain roughly equal size subwatersheds, to the extent practical. The stream flowing through a subwatershed is assigned the same number as the subwatershed, and is referred to as a stream “reach.”

Impoundments

Dams 3, 4, and Dam 5 are simulated in the SWAT model. Dieter Mill Dam and Dam 2 are not simulated in the model. Input data for impoundments consisted of the volumes required to fill the lake to the emergency and principal spillways, the surface areas at principal and emergency spillway levels, and the maximum capacities (volume) of the lake at the principal and emergency spillway levels. Water is lost from the reservoirs through evaporation, seepage through the bottom of the reservoir to groundwater, and withdrawals for use. In the model, reservoirs were allowed to spill water downstream when full, but otherwise there were no releases. Boerne City Lake serves as a water supply for the City of Boerne, providing roughly 0.5 million gallons per day, on average. Daily water withdrawals from the lake from 2000 through 2011 were provided by the City of Boerne. These withdrawals were entered into the SWAT model as a monthly average withdrawal.

Model Review by Stakeholders and Technical Advisory Committee

An initial hydrologic and water quality calibration of SWAT was presented to stakeholders and the technical advisory committee. During this presentation, preliminary modeling results, various assumptions and input parameters used were reviewed and discussed. During the meeting, stakeholders and technical advisors provided additional site specific knowledge of the watershed and pollutant sources which would prove to impact the initial calibration outcome. Following the review by stakeholders and the technical advisory committee, adjustments were made to model assumptions regarding local agricultural practices, OSSFs, recent population sightings and impacts of feral hogs, cliff swallow population estimates, the spatial distribution of axis deer, and seasonal and spatial variations in waterfowl abundance. A final model calibration was completed to incorporate these adjustments and presented to the stakeholder group. The SWAT model calibration is summarized in Chapters 2 and 3 of the UCC Watershed Modeling Report (Parsons 2013).

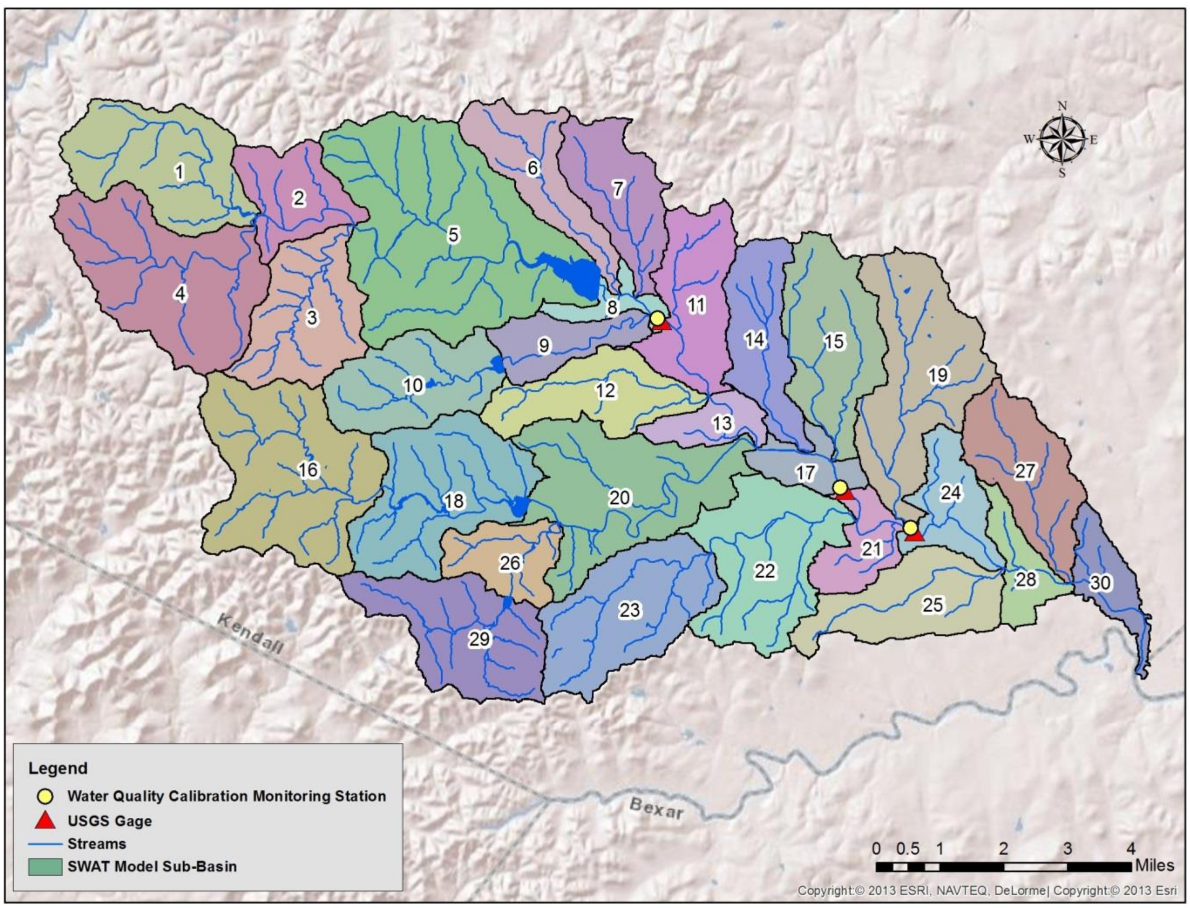


Figure 2-1. SWAT Model Subwatershed Delineations and Model Calibration Locations

Decision Support System

Most WPP projects focus primarily on quantifying the extent or severity of a pollution problem in relation to water quality standards and seek the most efficient non-regulatory methods to reduce NPS pollution. To help evaluate the impact of pollutants and the effect of targeted management strategies on water quality conditions, stakeholders utilized a Decision Support System (DSS) tool that integrated management strategy cost, stakeholder willingness to implement management strategies, and effectiveness of strategies in reducing pollution in the watershed. The DSS was developed to provide decision makers (watershed stakeholders, government agencies, and experts) greater access to and more influence over the SWAT watershed simulation model developed for this project.

The DSS is not a model, but rather an interface for the calibrated SWAT water quality model that serves as a control tool for the model that was used by the stakeholders. The DSS allows the user to track cost and environmental consequences of managerial decisions to achieve environmental goals without intimate knowledge of the underlying SWAT water quality model. The DSS is simply a display tool that uses the SWAT model outputs to support a more transparent public process where the outcome better integrates environmental benefit (pollutant load reduction), cost of management strategies, and social science (local input and support) to derive sound, legitimate decisions based on science that can be sustainably implemented.

Stakeholders provided recommendations to help guide the application of the DSS which provided further transparency to the modeling approached used to support this project. Major recommendations incorporated into the SWAT model and the application of the DSS included:

1. Feedback from the technical advisory committee on SWAT model assumptions and model inputs

2. Stakeholder approved list of management strategies that were modeled to estimate pollutant reductions (outlined in Chapters 4 and 5)

3. Estimated levels of implementation commitments were provided to guide modeling.

4. Cost estimate ranges for recommended management strategies.

The intrinsic value of the DSS is manifested in the speed at which stakeholders are able to consider multiple different implementation options and their corresponding pollutant reduction capability (benefit). For this project, the DSS and corresponding results were only applied in the consideration of reductions in *E. coli*.

Chapter 3. Causes and Sources of Pollution

A detailed watershed characterization is necessary for stakeholders to better understand the processes that impact local water quality. Stakeholder knowledge plays an important role in developing an accurate characterization and identifying causes and sources of pollution throughout the watershed. The NPS Pollution Work Group assisted the City of Boerne in developing a list of potential sources of point and nonpoint sources of pollution within the watershed.

Sources are organized into three broad categories: Wildlife, Agriculture and Urban/Residential. The following causes and sources of pollution were identified as potentially contributing to local water quality impairments. For each of the potential sources, the best available data was used as identified by the UCC Watershed Partnership for use in the SWAT model.

Wildlife

Wildlife is considered a NPS of bacteria and nutrient loading. Several species of wildlife are considered sources of pollutants to the UCC Watershed. Some species contribute loads through direct deposition; other species contribute loads to land. Fecal matter from direct discharges are deposited directly into waterways; however, land-based loads require a rain event to wash pollutants into creeks.

<u>Feral Hogs</u>

The City of Boerne estimated the feral hog population at 995 (~0.02 hogs per acre) for the Upper Cibolo Creek watershed based on published research for counties in Texas (Mellish 2011) and consultations with Texas A&M AgriLife Extension who have the most extensive information available on Texas feral hog estimates and management efforts. However, given the highly transient nature of feral hogs, stakeholders acknowledge considerable uncertainty in county population estimates. No other estimates of feral hog populations in Kendall County were found.

In the model simulation, hog manure was applied evenly across forested lands. Feral hog manure production and composition was considered the same as that of domestic hogs, and taken from the American Society of Agricultural Engineers ASAE (1998), as provided in the SWAT default manure database. Feral hogs are considered to spend substantial time in and near streams, and behavior includes land disturbance by rooting and wallowing. However, the model did not include options to simulate this behavior. Thus, the model likely underestimated their impact on water quality.

White-tailed Deer

The white-tailed deer population was estimated by the City of Boerne to be 7,030 (7 acres per deer). This estimate was derived from deer density estimates for TPWD Resource Management Unit 7 (which includes Kendall County), and the local knowledge of the TPWD wildlife biologist for the Kendall County. No other estimates of deer population density in Kendall County were found. In the model, white-tailed deer manure was applied evenly across forested lands. Deer manure production and composition was unknown; thus, values for sheep from ASAE (1998) were applied due to their similar size.

White-tailed Deer Herd in Kendall County

Axis Deer

The axis deer population was estimated by the City of Boerne to be 1,500, based on landowner observations as well as the professional judgment and local knowledge the TPWD wildlife biologist for Kendall County. No other estimates of axis deer population density in Kendall County were found.

Axis deer manure was applied evenly across forested lands only in the Cibolo Creek and Ranger Creek subwatersheds west of IH-10, where they are reported to occur. Axis deer manure production and composition was unknown; thus, values for sheep from ASAE (1998) were applied due to their similar size.

Cliff Swallows

Cliff swallows nest under the IH-10 bridges over Cibolo Creek and Frederick Creek (Subwatersheds 8 and 20). Their feces are often deposited directly into the creeks, and dense accumulations of fecal matter are visible on bridge supports over the creeks. In late February 2012 before the swallows were present, the City of Boerne counted the number of cliff swallow nest rings over water under the IH-10 and access road bridges over Cibolo Creek (893 nest rings) and Frederick Creek (403 nest rings). The nest rings were not all intact nests and it was not known how many nests had deteriorated since the previous breeding season. Cliff swallows were considered to nest beginning in March, with young birds fledging at approximately the end of April after incubation, hatching, and a fledging period for young birds (Barrett 2012; Ehrlich, et al. 1988). During nesting, both male and female swallows share foraging duties for food (Ehrlich, et al. 1988); thus, two birds were assumed per nest ring. Because the nest rings were not all intact, these calculations may overestimate the number of birds, but this number of birds is not unlike populations reported for other highly colonized bridges.

It was assumed that during March and April, one-half of the fecal matter generated by adult cliff swallows was deposited in streams. After the young birds fledge, cliff swallows are known to disperse and forage more widely, although they are still present at the nests until their migration south (assumed to occur in late September). During this post-fledging period, one–quarter of fecal matter was assumed to be directly deposited into the creeks. Indirect fecal loading from swallows to streams, via deposition to land followed by runoff, was considered insignificant relative to other sources to land and was not modeled.

Cliff Swallow Nests under IH-10 Bridge

Adult cliff swallows were assumed to weigh 25 grams (Ehrlich, et al. 1988) and their fecal production (1.6 grams/day) was estimated based on a log-log regression relationship ($r^2 = 0.986$) between manure production (dry weight) and body weight for the livestock and fowl species in ASAE (1998). As no fecal composition estimates were available for cliff swallows, the manure composition of ducks (ASAE 1998) was applied.

<u>Waterfowl</u>

Waterfowl populations were estimated as the average counts by species on three dates in October and November 2011 by a University of Texas at San Antonio student conducting an independent study. The counts were performed at four locations along Cibolo Creek (Subwatershed 17) and Ranger Creek (Subwatershed 8), but substantial populations were observed only along the portion of Cibolo Creek in central Boerne known as the Duck Pond. At this site, an average of 110 ducks, 57 geese, and five other water birds (coots, cormorants, herons, egrets) were observed. Of these waterfowl, 75 percent were considered probable permanent, domesticated species. Examples include Muscovy ducks, domestic geese, and Egyptian geese.

Some waterfowl, such as Lesser Scaup, were considered to be 100 percent associated with water. However, most of the waterfowl, including the geese, Mallards, and Black-bellied Whistling-ducks, have been observed to be present primarily on land in the vicinity of the creek. Waterfowl manure production and composition was based on reported values from ASAE (1998) for domestic ducks. It was assumed that 90 percent of duck manure was deposited on land in the vicinity of the creek, and 10 percent directly deposited to Cibolo Creek.

Livestock

Livestock in the UCC Watershed is considered a NPS of bacteria and nutrient loading. Some livestock species contribute loads through direct deposition in water bodies; other species contribute loads to land.

SWAT does not simulate individual grazing animals but accounts for a daily biomass removal (grazing) and manure application to represent their presence and associated contribution of bacteria or nutrient loading to watershed. Grazing was considered to occur year-round in the watershed.

Table 3-1. Watershed Animal Populations and Manure Deposition

Livestock	Average Total Population of Watershed	Population Density (#/acre)	Grazing Rate (dry kg/ acre/day)	Manure Deposition (dry kg/ acre/day)
Cattle	1,662	0.074	0.380	0.250
Goats	2,014	0.089	0.121	0.074
Sheep	1,261	0.056	0.024	0.017
Horses	221	0.010	0.040	0.066
Feral Hogs	995	0.040	0.040	0.032
White-tailed Deer	7,030	0.329	0.129	0.099
Axis Deer	1,500	0.185	0.072	0.055
Waterfowl	172	47	--	2.05
Cliff Swallows	2,592	modeled direct deposition to water		
Dogs	5,986	1.72	--	0.25
	2,542	3.44	--	0.50
	1,822	5.26	--	0.75

Livestock population estimates were developed based on the average reported populations of cattle, sheep, goats, and horses from the 1997, 2002, and 2007 USDA National Agricultural Statistics Survey (NASS) for Kendall County (USDA 2007). Livestock population density estimates for grazing lands in the UCC Watershed were developed for each species by dividing the average total population by the total acreage of grass and brush rangeland in the county. This density was applied to all rangeland in the watershed. Manure production rates and characteristics (*E.coli*, CBOD, and nutrient content) were taken from the (ASAE 1998), as provided in the SWAT default manure database.

Urban/Residential

Wastewater Treatment Facility Discharges

WWTFs are considered direct discharges of pollutant loads and can be a continuous source of bacteria or nutrient loading unless they are permitted as no discharge facilities (Figure 1-8). During the calibration period, the City of Boerne operated the only WWTF (Subwatershed 17) that discharged wastewater into Cibolo Creek or its tributaries. This facility operated under Texas Pollutant Discharge Elimination System (TPDES) permit WQ0010066-001, discharged wastewater to Currey Creek (subwatershed 15), and then to Cibolo Creek (Figure 1-2).

Wastewater flows and some water quality constituent loads (TSS, DO, CBOD, NH3-N, *E.coli*) in this discharge were estimated based on monthly self-reported discharge monitoring reports submitted by the City of Boerne to the TCEQ and/or EPA for the period from January 1998 through December 2011. For some other parameters (OrgN, OrgP, NO_3-N, PO_4-P), there were no self-reported discharge data, and input concentrations were estimated as the average concentrations in 15 effluent samples collected from 2007 to 2008 (HDR 2009). For periods in which data were not available, the average reported discharge and constituent loads from 1998 to 2011 were applied.

The City of Boerne constructed a new WWTRC (TPDES permit WQ0010066-002) downstream of the existing WWTF (Subwatershed 22). The new facility discharges into Menger Creek approximately 200m upstream of the confluence with UCC. The WWTRC became operational in April 2013 and utilizes advanced processes to remove nutrients, organic pollutants and bacteria.

Lerin Hills Municipal Utility District obtained a permit (TPDES WQ0014712-001) to discharge wastewater to a tributary of Frederick Creek, but to date the facility has not been built. Therefore, no wastewater effluent was included in the model for this permit. Another WWTF located in subwatershed 18 is operated by the Kendall West Utility, LLC. but this is a no-discharge facility which applies effluent as irrigation to Tapatio Springs Golf Resort. This no-discharge facility was not incorporated into the SWAT model.

On-Site Sewage Facilities

Bacteria and nutrient loads from OSSFs are considered NPS pollution. The likely locations of OSSFs were identified as those improved structures without sewer service. The City of Boerne estimated that 2,344 OSSF occur within the Upper Cibolo Creek watershed (City of Boerne 2011), and their locations are shown in Figure 1-8. The number of OSSFs were summed by subwatershed and entered into SWAT, assuming that all were conventional septic systems composed of a septic tank and drainage field. Although it is known that some advanced aerobic systems were installed in the watershed, an estimate of the number of aerobic systems was not available. Kendall County staff assumes conventional septic systems currently comprise a sizable majority of the OSSF in the UCC Watershed. Based on 2010 federal census data for Kendall County, there were approximately 2.5 residents per housing unit, on average.

City of Boerne water use data estimates an average water use of 123 gallons per person per day in the months of December, January, and February for the years 2000 through 2010. Water use for irrigation is minimal during these months; thus, consumption better reflects wastewater effluent generation.

The SWAT model incorporates complex algorithms to simulate OSSF performance (Neitsch, et al. 2011). The algorithms assume that all septic systems will fail, over time, due to clogging of soil pores in the biologically active layer (biozone) of the soil absorption system (drain field). The time to failure, which is calculated by SWAT, depends on soil properties, effluent loading rate, soil moisture, biozone thickness, and other factors. After system failure, the time until system repair was set at the SWAT default value of 70 days. All other septic system parameters were set at SWAT default values which are provided in the Modeling Report (Parsons 2013), except those for which locally derived or calibrated values were available, as noted in the previous paragraph.

Dogs

Dogs are considered a NPS of bacteria and nutrient loading. The dog population of the UCC Watershed was estimated based on the number of housing units in the watershed (from the City of Boerne [2011]), multiplied by 0.8 dogs per household, a nationwide average from the American Veterinary Medical Association (2002). The total number of dogs (10,350) was then distributed across residential land uses assuming that the dog density of the medium-density residential land was two times that of the low-density residential lands, and the dog density of the high-density residential lands was three times that of the low-density residential lands.

Dog waste was considered to be entirely deposited to pervious residential land. Dog manure production and composition were estimated from the Bacterial Indicator Tool (EPA 2000) and from Baker, et al. (2001).

Table 3-2. Estimated number of dogs within the Upper Cibolo Creek Watershed.

	Watershed Residential Units	Estimated Dogs in Watershed
City of Boerne Residential	8,430	6,744.0
City of Boerne Apartment	2,431	1,944.8
Kendall County Residential	2,077	1,661.6
Totals	**12,938**	**10,350.4**

Residential Turfgrass

Nutrient and bacteria loading to residential turfgrass can contribute to instream pollutant loads. Nutrient loading to the landscape typically occurs from the application of commercial fertilizer and bacteria loading can originate from dogs and wildlife.

Residential turfgrass was identified and quantified in each subwatershed to estimate the amount of bacteria and nutrient loading that may originate from this land cover type. Only the pervious portion of low, medium, and high-density residential land use is used to locate and calculate the area of residential turfgrass.

Urban and suburban turf grasses require periodic fertilization, irrigation, and mowing in Texas. Irrigation was simulated in SWAT using the auto-irrigation operation, which initiates irrigation when grass stress (measured as reduction in growth rate) reaches a specified threshold. For irrigation, the threshold was set at a grass stress of level of 0.5. Lawn fertilization was simulated by application of two pounds of nitrogen per 1,000 square feet of lawn per year. This matches the Texas A&M AgriLife Extension's recommendations for a "low" lawn management level (Chalmers and McAfee 2007). It is approximately equivalent to application of one 20-pound bag of a typical commercial lawn fertilizer per 5,000 square feet of lawn twice per year.

Lawn mowing was simulated in SWAT using a harvest operation twice per month from April 1 through October 15. At each mowing, 10 percent of the above-ground grass biomass was removed, but with 0 percent removal efficiency as if clippings were left on the lawn.

Table 3-3. Summary of bacteria and nutrient pollutant sources and categories

Category	Pollutant Source	Cause
Wildlife	Cliff Swallows (NPS)	Direct deposit from nesting under bridges
	Urban Waterfowl (NPS)	Direct deposit or stormwater wash off from adjacent land cover
	Deer (NPS)	Direct deposit or stormwater wash off from adjacent land cover
	Feral Hog (NPS)	Direct deposit or stormwater wash off from adjacent land cover
Agriculture	Livestock (NPS) cattle, horse, goats, sheep	Direct deposit and stormwater wash off from agricultural lands
Urban/ Residential	Urban domestic animals (dogs) (NPS)	Stormwater wash off from urban lands
	Urban and rural OSSFs (NPS) Failing septic tanks	Direct deposit and stormwater wash off from failing systems
	Residential Turfgrass (NPS)	Stormwater wash off of over application of fertilizer
	WWTF Treated effluent (Point Source)	Direct Discharge, sanitary sewer overflows and treatment failures

Chapter 4. Load Contributions and Sensitivity Analysis

This chapter describes pollutant loadings to the landscape, direct discharges to receiving waters from sources identified in Chapter 3 and their resulting effects on ambient water quality conditions within the UCC Watershed. The majority of EC and nutrient loadings are to land surfaces, where much of this load is naturally degraded, absorbed, or stored on land; only a portion of this loading is carried to surface water via surface runoff, groundwater discharge, or through the unsaturated soil zone. Instream loads are also affected by direct discharge sources which include the City of Boerne WWTF and a fraction of fecal deposition from waterfowl and cliff swallows over water. Some percentage of instream loads decay within the stream or are deposited in its sediments. This especially occurs in surface water impoundments throughout the UCC Watershed, where these impoundments act as "sinks" for instream loads and consequently can influence downstream water quality conditions. The SWAT model simulates these key processes and is helpful in quantifying the potential effectiveness of management strategies that target pollutant source within each subwatershed.

> In this chapter, the focus is on presentation of estimates for pollutant loading at the subwatershed scale from either direct discharges or directly to the landscape. Therefore the spatial unit used to present pollutant source contributions is a subwatershed.

As described in Chapter 3, pollutant loadings for specific bacteria and nutrient sources were estimated based on land use, population, agricultural census data, wildlife population estimates, local government data, literature reports, and input from stakeholders and local subject matter experts. These conditions were entered into the SWAT model, which was then calibrated to reasonably simulate existing flow and water quality conditions. A sensitivity analysis (page 53) was then performed to understand how changes in loadings from individual sources affected ambient water quality in UCC. This analysis was performed for all pollutant sources which could be addressed by specified management strategies. This analysis provided a better estimate of the available amount of pollutant loadings that could be reduced. The sensitivity analysis also gave stakeholders an understanding of the "low hanging fruit" options by identifying management strategies that had the largest reductions in pollutant loading, thereby having the most positive impact on improving instream water quality.

Pollutant Source Contributions

There are three main categories of bacteria and nutrient sources in the UCC Watershed: Wildlife, Agriculture, and Urban/Residential. Pollutant sources can be divided into those that are discharged directly to UCC or its tributaries and those originating or deposited on land surfaces within each subwatershed. Numerous land characteristics such as vegetation, slope, soil type, groundwater depth, and land cover, influence the rate and efficiency of pollutant transport from land to streams.

Some fraction of the loadings to land will eventually enter water bodies, either through rainfall runoff or through percolation into shallow groundwater followed by groundwater discharge to streams. Thus, pollutant transport from land to streams is a function of three major types of processes:

1. Loading and accumulation of pollutants on the land
2. Transformations and/or decay of pollutants on the land surface, in soil, and groundwater
3. Processes by which pollutants are washed off or percolate into streams

SWAT incorporates all three of these processes as well as instream processes that influence assimilative capacity. SWAT includes instream processes such as sedimentation, sediment re-suspension, bacteria die-off, photosynthesis, respiration, nutrient oxidation and flow which influence the loads and concentrations of pollutants in streams.

Table 3-2 provides the list of bacteria and nutrient sources identified in the UCC Watershed. Each specific pollutant source identified in Table 3-2 contributes different amounts of bacteria and nutrient loadings. Therefore, depending on the pollutant source and delivery method of loading, Unique and source specific management strategies are needed to reduce pollutants as close as possible to their respective points of origin.

During a series of Work Group meetings stakeholders evaluated potential pollutant sources and developed a list of management strategies that could be used to target water quality impairments and concerns. During these meetings stakeholders were presented with a variety of potential strategies that could be used locally, as well as techniques that have been used to reduce instream bacteria and nutrient loads in other watersheds throughout the state. After receiving stakeholder feedback, the COB project team condensed the list of strategies to those that would be most effective at targeting sources identified in the UCC Watershed. Some of these strategies can be characterized as structural and other as nonstructural BMPs. Some of the management strategies could be incorporated into the SWAT model to estimate their pollutant reduction potential, while others could not be modeled. Table 4-1 details management strategies presented to stakeholders and the subset of selected strategies that could be modeled, which they felt most directly addressed the major pollutant sources.

During the modeling process, additional Work Group meetings were facilitated with stakeholders organized into groups of individuals who would be most likely to implement the recommended strategies (Urban Residents, Local Businesses, Local Government, Nonprofits, Rural Residents and Ranching). This allowed the project team to utilize the DSS and sensitivity analysis to identify 13 primary strategies that would best target major pollutant sources in the watershed and incorporate them into the SWAT model (Table 4-1).

Table 4-1. Comprehensive list of management strategies presented to stakeholders in order to address local water quality impairments and stakeholder selected strategies to include in SWAT

Category	Management Strategies Presented to Stakeholders	Selected for SWAT Model
WWTF	Fats, Oils, Grease Education Program (Business and Residential)	
	Sanitary Sewer Overflow Program	✓
	*Routine Sewer Line Inspection / WWTP Inspections	
	*WWTP Employee Training	
	Bacteria Limits – Reduce effluent concentration	✓
	Reduced Phosphorus Limit at new WWTP to 0.5mg/L	✓
Construction Sites	Sediment and Erosion Control	
	Control stormwater runoff volume and velocity	
	Minimize soil Compaction	
	Revegetation / Soil Stabilization	
	Stormwater Training: Contractors, Developers, Managers	
OSSF	OSSF Maintenance/Inspection	
	Training for Installers and Homeowners	
	Connect OSSF within in city limits to sewer system	✓
	Replace failing OSSF outside of city limits	✓
	Create database of OSSF locations, age and type	
Agricultural	Strategies to develop site-specific Water Quality Management Plans	✓
	Focus on livestock operations and grazing practices	
Wildlife	Feral Hog Population Control	✓
	Deer Population Control (Axis and Whitetail)	✓
	Domestic Waterfowl Management (River Road Park)	✓
	Cliff Swallow Nesting Deterrents (IH-10 Bridges)	✓
Household Pets	Dogs - Pet Waste (Education Programs and Waste Stations)	✓
	Feral Cats – Discourage Feeding and Releasing	
Animal Disposal	Education on proper disposal of dead animals (livestock, wildlife, pets)	
Low Impact Development (LID)	Voluntarily adopt minimum requirements of Municipal Separate Stormwater Sewer Program (MS4)	
	Promote stormwater Infiltration, Filtration, Retention/Detention	
	Develop and Enhance Riparian Buffers	✓
Turfgrass	Education program to reduce fertilizer application in urban areas	✓

* Indicate practices already in place throughout the watershed

Tables 4-2 through 4-5 provide a summary of the estimated landscape loading of EC, TP, TN, and TSS from each source in each subwatershed. The sum of each subwatershed column provides the total potential loading of each pollutant that is applied to the landscape. Figures 4-1 through 4-3 and Figures A-4 through A-9 (Appendix A) are maps that support Tables 4-2 through 4-5 by providing a spatial display of the landscape loading estimates of EC, TP, TN and TSS by subwatershed and pollutant source categories.

Figures A-10 through A-14 (Appendix A) provide a spatial display of the yields of water, EC, phosphorus, nitrogen, and sediment to Upper Cibolo Creek from land surfaces. These yields are averages for the period 1991 through 2011, and expressed on an areal basis (e.g., kg/hectare) to facilitate comparison. These figures are generated based on SWAT model simulations of the transport of loadings from subwatersheds to streams. These figures do not account for the in-stream processes that impact the loads and concentrations of pollutants in streams.

Stakeholders work to develop management strategies to target bacteria loads

Table 4-2. Estimated Landscape Loadings from EC Sources (billions of colonies per day)

	Agriculture				Wildlife					Urban/Residential					Total
Subwatershed	Cattle	Goats	Sheep	Horses	Feral hogs	White-tailed deer	Axis deer	Waterfowl	Cliff swallows	Dogs	Turfgrass Fertilization	Atmospheric Deposition	WWTF	OSSFs	
1	5940	244	514	3.51	671	5000	2920	0	0	0	0	0	0	1170	16500
2	3250	134	281	1.92	343	2560	1490	0	0	0	0	0	0	1980	10000
3	4890	201	423	2.89	561	4180	2440	0	0	0	0	0	0	1050	13700
4	13200	542	1140	7.79	598	4460	2600	0	0	0	0	0	0	3260	25800
5	19500	801	1680	11.5	1070	7940	4630	0.00104	0	191	0	0	0	22000	57800
6	5760	236	498	3.4	180	1340	782	0	0	1040	0	0	0	3610	13400
7	2960	122	256	1.75	397	2960	1730	0	0	1020	0	0	0	11000	20400
8	1630	67	141	0.962	36.7	274	160	0.00064	32.4	445	0	0	0	8850	11600
9	2320	95.4	201	1.37	158	1180	686	0	0	160	0	0	0	8040	12800
10	9530	391	824	5.62	185	1380	803	0	0	0	0	0	0	350	13500
11	5790	238	500	3.42	228	1700	0	0	0	2330	0	0	0	17500	28300
12	3010	124	260	1.78	371	2770	0	0	0	2030	0	0	0	45900	54500
13	815	33.5	70.4	0.481	63.2	471	0	0	0	2700	0	0	0	8160	12300
14	4000	164	346	2.36	197	1470	0	0	0	2860	0	0	0	15800	24800
15	5990	246	518	3.54	362	2700	0	0	0	3330	0	0	0.25	6410	19600
16	12400	508	1070	7.3	724	5400	0	0	0	159	0	0	0	233	20500
17	1180	48.3	102	0.695	57.9	432	0	44.5	0	2360	0	0	0	932	5160
18	7160	294	619	4.23	589	4390	0	0	0	1870	0	0	0	816	15700
19	9480	389	819	5.59	619	4620	0	0	0	1010	0	0	0	7690	24600
20	7380	303	638	4.35	762	5680	0	0	13	2190	0	0	0	16100	33100
21	2180	89.6	188	1.29	151	1130	0	0	0	1260	0	0	0	5710	10700
22	5200	214	450	3.07	494	3680	0	0	0	4310	0	0	0	14300	28700
23	5230	215	452	3.09	691	5150	0	0	0	242	0	0	0	8160	20100
24	2890	119	249	1.7	288	2150	0	0	0	137	0	0	0	1280	7110
25	6090	250	526	3.59	250	1870	0	0	0	2350	0	0	0	22400	33700
26	3630	149	314	2.14	179	1330	0	0	0	401	0	0	0	1280	7290
27	6740	277	583	3.98	278	2070	0	0	0	820	0	0	0	9320	20100
28	2460	101	213	1.45	160	1190	0	0	0	53.5	0	0	0	1630	5810
29	5050	208	437	2.98	613	4570	0	0	0	616	0	0	0	8740	20200
30	3130	129	270	1.85	80.6	600	0	0	0	678	0	0	0	15500	20400
Total	169000	6930	14600	99.6	11400	84600	18200	44.5	45.4	34500	0	0	0.25	269000	608000

All data expressed in colonies per day

Table 4-3. Estimated Landscape Loadings of Total Phosphorus

	Agriculture				Wildlife					Urban/Residential					Total
Subwatershed	**Cattle**	**Goats**	**Sheep**	**Horses**	**Feral hogs**	**White-tailed deer**	**Axis deer**	**Waterfowl**	**Cliff swallows**	**Dogs**	**Turfgrass Fertilization**	**Atmospheric Deposition**	**WWTF**	**OSSFs**	
1	2.136	0.451	0.103	0.2	0.667	1	0.583	0	0	0	0	0	0	0.082	5.22
2	1.168	0.247	0.056	0.11	0.341	0.512	0.298	0	0	0	0	0	0	0.139	2.87
3	1.758	0.371	0.085	0.165	0.557	0.836	0.487	0	0	0	0	0	0	0.073	4.33
4	4.743	1.002	0.228	0.445	0.594	0.892	0.52	0	0	0	0	0	0	0.228	8.65
5	7.006	1.479	0.337	0.657	1.059	1.589	0.927	0.002†	0	0.166	0.341	0	0	1.541	15.10†
6	2.069	0.437	0.1	0.194	0.179	0.268	0.156	0	0	0.904	1.732	0	0	0.253	6.29
7	1.064	0.225	0.051	0.1	0.394	0.592	0.345	0	0	0.887	1.643	0	0	0.767	6.07
8	0.586	0.124	0.028	0.055	0.036	0.055	0.032	0.001†	0.009†	0.387	0.719	0	0	0.62	2.65†
9	0.835	0.176	0.04	0.078	0.157	0.235	0.137	0	0	0.139	0.299	0	0	0.563	2.66
10	3.425	0.723	0.165	0.321	0.184	0.275	0.161	0	0	0	0	0	0	0.024	5.28
11	2.081	0.439	0.1	0.195	0.227	0.341	0	0	0	2.027	2.993	0	0	1.223	9.63
12	1.083	0.229	0.052	0.102	0.369	0.553	0	0	0	1.763	2.905	0	0	3.213	10.27
13	0.293	0.062	0.014	0.027	0.063	0.094	0	0	0	2.344	2.623	0	0	0.571	6.09
14	1.437	0.303	0.069	0.135	0.196	0.293	0	0	0	2.488	3.404	0	0	1.109	9.43
15	2.154	0.455	0.104	0.202	0.36	0.54	0	0	0	2.892	3.618	0	6.7†	0.449	17.47
16	4.447	0.939	0.214	0.417	0.72	1.08	0	0	0	0.138	0.294	0	0	0.016	8.27
17	0.423	0.089	0.02	0.04	0.058	0.086	0	0.126†	0	2.05	2.598	0	0	0.065	5.56†
18	2.573	0.543	0.124	0.241	0.586	0.878	0	0	0	1.624	2.556	0	0	0.057	9.18
19	3.406	0.719	0.164	0.32	0.615	0.923	0	0	0	0.874	1.445	0	0	0.538	9.00
20	2.652	0.56	0.128	0.249	0.757	1.135	0	0	0.004†	1.908	2.966	0	0	1.125	11.48†
21	0.784	0.165	0.038	0.074	0.15	0.226	0	0	0	1.094	1.1	0	0	0.4	4.03
22	1.87	0.395	0.09	0.176	0.491	0.736	0	0	0	3.746	4.442	0	0	1.003	12.95
23	1.879	0.397	0.09	0.176	0.687	1.03	0	0	0	0.211	0.432	0	0	0.571	5.47
24	1.037	0.219	0.05	0.097	0.286	0.429	0	0	0	0.119	0.211	0	0	0.09	2.54
25	2.188	0.462	0.105	0.205	0.249	0.373	0	0	0	2.044	2.539	0	0	1.566	9.73
26	1.305	0.276	0.063	0.122	0.178	0.266	0	0	0	0.349	0.561	0	0	0.09	3.21
27	2.423	0.512	0.117	0.227	0.276	0.414	0	0	0	0.713	1.377	0	0	0.652	6.71
28	0.884	0.187	0.043	0.083	0.159	0.239	0	0	0	0.047	0.096	0	0	0.114	1.85
29	1.817	0.384	0.087	0.17	0.61	0.914	0	0	0	0.536	0.943	0	0	0.612	6.07
30	1.125	0.237	0.054	0.106	0.08	0.12	0	0	0	0.589	1.094	0	0	1.085	4.49
Total	60.65	12.81	2.92	5.69	11.28	16.92	3.65	0.13†	0.01†	30.04	42.93	0	6.7†	18.84	212.57†

All data expressed in kg of total phosphorus per day
† includes direct deposition to Cibolo Creek and its tributaries; other sources are to land and only a portion reaches the creek
no measurements of atmospheric deposition of phosphorus are available – atmospheric sources of phosphorus are likely minor but not zero

Table 4-4. Estimated Landscape Loadings of Total Nitrogen

	Agriculture				Wildlife					Urban/Residential					Total
Subwatershed	Cattle	Goats	Sheep	Horses	Feral hogs	White-tailed deer	Axis deer	Waterfowl	Cliff swallows	Dogs	Turfgrass Fertilization	Atmospheric Deposition	WWTF	OSSFs	
1	7.77	1.97	0.49	1	1.96	4.75	2.77	0	0	0	0	12.63	0	0.61	33.95
2	4.25	1.08	0.27	0.55	1	2.43	1.42	0	0	0	0	6.61	0	1.04	18.65
3	6.39	1.62	0.4	0.82	1.64	3.97	2.32	0	0	0	0	10.46	0	0.55	28.17
4	17.25	4.38	1.08	2.23	1.75	4.23	2.47	0	0	0	0	17.5	0	1.71	52.60
5	25.48	6.47	1.6	3.29	3.11	7.55	4.4	0.01†	0	0.81	3.1	29.33	0	11.54	96.69†
6	7.52	1.91	0.47	0.97	0.52	1.27	0.74	0	0	4.43	15.72	7.72	0	1.89	43.16
7	3.87	0.98	0.24	0.5	1.16	2.81	1.64	0	0	4.35	14.91	8	0	5.74	44.20
8	2.13	0.54	0.13	0.27	0.11	0.26	0.15	0.00†	0.026†	1.9	6.52	2.18	0	4.64	18.86†
9	3.04	0.77	0.19	0.39	0.46	1.12	0.65	0	0	0.68	2.72	4.93	0	4.21	19.16
10	12.46	3.16	0.78	1.61	0.54	1.31	0.76	0	0	0	0	9.9	0	0.18	30.70
11	7.57	1.92	0.48	0.98	0.67	1.62	0	0	0	9.93	27.16	9.23	0	9.16	68.72
12	3.94	1	0.25	0.51	1.08	2.63	0	0	0	8.64	26.37	8.56	0	24.05	77.03
13	1.07	0.27	0.07	0.14	0.18	0.45	0	0	0	11.48	23.8	3.34	0	4.27	45.07
14	5.23	1.33	0.33	0.67	0.57	1.39	0	0	0	12.19	30.89	7.83	0	8.3	68.73
15	7.83	1.99	0.49	1.01	1.06	2.56	0	0	0	14.17	32.84	11.53	4.80†	3.36	81.64†
16	16.17	4.11	1.02	2.09	2.11	5.13	0	0	0	0.68	2.67	18.49	0	0.12	52.59
17	1.54	0.39	0.1	0.2	0.17	0.41	0	0.36†	0	10.04	23.58	3.43	0	0.49	40.71†
18	9.36	2.38	0.59	1.21	1.72	4.17	0	0	0	7.96	23.2	14.54	0	0.43	65.56
19	12.39	3.15	0.78	1.6	1.81	4.38	0	0	0	4.28	13.12	15.7	0	4.03	61.24
20	9.64	2.45	0.61	1.24	2.22	5.39	0	0	0.011†	9.35	26.92	16.74	0	8.42	82.99†
21	2.85	0.72	0.18	0.37	0.44	1.07	0	0	0	5.36	9.98	4.46	0	2.99	28.42
22	6.8	1.73	0.43	0.88	1.44	3.5	0	0	0	18.35	40.31	13.39	0	7.51	94.34
23	6.83	1.74	0.43	0.88	2.02	4.89	0	0	0	1.03	3.93	12.97	0	4.27	38.99
24	3.77	0.96	0.24	0.49	0.84	2.04	0	0	0	0.59	1.91	5.8	0	0.67	17.31
25	7.96	2.02	0.5	1.03	0.73	1.77	0	0	0	10.02	23.04	9.55	0	11.72	68.34
26	4.75	1.21	0.3	0.61	0.52	1.26	0	0	0	1.71	5.09	5.34	0	0.67	21.46
27	8.81	2.24	0.55	1.14	0.81	1.97	0	0	0	3.49	12.5	9.44	0	4.88	45.83
28	3.21	0.82	0.2	0.41	0.47	1.13	0	0	0	0.23	0.87	3.89	0	0.85	12.08
29	6.61	1.68	0.42	0.85	1.79	4.34	0	0	0	2.62	8.55	11.85	0	4.58	43.29
30	4.09	1.04	0.26	0.53	0.24	0.57	0	0	0	2.89	9.93	4.09	0	8.12	31.76
Total	220.55	56.03	13.86	28.46	33.14	80.39	17.32	0.37†	0.04†	147.18	389.64	299.42	4.80†	141.02	1432.22†

All data expressed in kg of total nitrogen per day

† includes direct deposition to Cibolo Creek and its tributaries; other sources are to land and only a portion reaches the creek

Table 4-5. Estimated Landscape Loadings of Sediment

	Agriculture				Wildlife					Urban/Residential					Total
Subwatershed	**Cattle**	**Goats**	**Sheep**	**Horses**	**Feral hogs**	**White-tailed deer**	**Axis deer**	**Waterfowl**	**Cliff swallows**	**Dogs**	**Turfgrass Fertilization**	**Atmospheric Deposition**	**WWTF**	**OSSFs**	
1	0.194	0.056	0.013	0.05	0.042	0.125	0.073	0	0	0	0	0	0	0.001	0.55
2	0.106	0.031	0.007	0.027	0.021	0.064	0.037	0	0	0	0	0	0	0.001	0.29
3	0.16	0.046	0.011	0.041	0.035	0.104	0.061	0	0	0	0	0	0	0.001	0.46
4	0.431	0.125	0.029	0.111	0.037	0.111	0.065	0	0	0	0	0	0	0.002	0.91
5	0.637	0.185	0.042	0.164	0.066	0.199	0.116	0	0	0.008	0	0	0	0.017	1.43
6	0.188	0.055	0.012	0.049	0.011	0.033	0.02	0	0	0.045	0	0	0	0.003	0.42
7	0.097	0.028	0.006	0.025	0.025	0.074	0.043	0	0	0.044	0	0	0	0.008	0.35
8	0.053	0.015	0.004	0.014	0.002	0.007	0.004	0	0	0.019	0	0	0	0.007	0.13
9	0.076	0.022	0.005	0.02	0.01	0.029	0.017	0	0	0.007	0	0	0	0.006	0.19
10	0.311	0.09	0.021	0.08	0.011	0.034	0.02	0	0	0	0	0	0	0	0.57
11	0.189	0.055	0.013	0.049	0.014	0.043	0	0	0	0.101	0	0	0	0.013	0.48
12	0.098	0.029	0.007	0.025	0.023	0.069	0	0	0	0.088	0	0	0	0.034	0.37
13	0.027	0.008	0.002	0.007	0.004	0.012	0	0	0	0.117	0	0	0	0.006	0.18
14	0.131	0.038	0.009	0.034	0.012	0.037	0	0	0	0.124	0	0	0	0.012	0.40
15	0.196	0.057	0.013	0.051	0.022	0.067	0	0	0	0.145	0	0	0.008†	0.005	0.56†
16	0.404	0.117	0.027	0.104	0.045	0.135	0	0	0	0.007	0	0	0	0	0.84
17	0.038	0.011	0.003	0.01	0.004	0.011	0	0.007†	0	0.102	0	0	0	0.001	0.19†
18	0.234	0.068	0.015	0.06	0.037	0.11	0	0	0	0.081	0	0	0	0.001	0.61
19	0.31	0.09	0.02	0.08	0.038	0.115	0	0	0	0.044	0	0	0	0.006	0.70
20	0.241	0.07	0.016	0.062	0.047	0.142	0	0	0	0.095	0	0	0	0.012	0.69
21	0.071	0.021	0.005	0.018	0.009	0.028	0	0	0	0.055	0	0	0	0.004	0.21
22	0.17	0.049	0.011	0.044	0.031	0.092	0	0	0	0.187	0	0	0	0.011	0.60
23	0.171	0.05	0.011	0.044	0.043	0.129	0	0	0	0.011	0	0	0	0.006	0.47
24	0.094	0.027	0.006	0.024	0.018	0.054	0	0	0	0.006	0	0	0	0.001	0.23
25	0.199	0.058	0.013	0.051	0.016	0.047	0	0	0	0.102	0	0	0	0.017	0.50
26	0.119	0.034	0.008	0.031	0.011	0.033	0	0	0	0.017	0	0	0	0.001	0.25
27	0.22	0.064	0.015	0.057	0.017	0.052	0	0	0	0.036	0	0	0	0.007	0.47
28	0.08	0.023	0.005	0.021	0.01	0.03	0	0	0	0.002	0	0	0	0.001	0.17
29	0.165	0.048	0.011	0.043	0.038	0.114	0	0	0	0.027	0	0	0	0.007	0.45
30	0.102	0.03	0.007	0.026	0.005	0.015	0	0	0	0.029	0	0	0	0.012	0.23
Total	5.514	1.601	0.365	1.423	0.705	2.115	0.456	0.007†	0	1.502	0	0	0.008†	0.202	13.90†

All data expressed in metric tons per day
† includes direct deposition to Cibolo Creek and its tributaries; other sources are to land and only a portion reaches the creek
no measurements of atmospheric deposition of solids are available – atmospheric sources of solids are likely minor but not zero

Figure 4-1. *E.coli* Loads Deposited on Land from Wildlife Sources

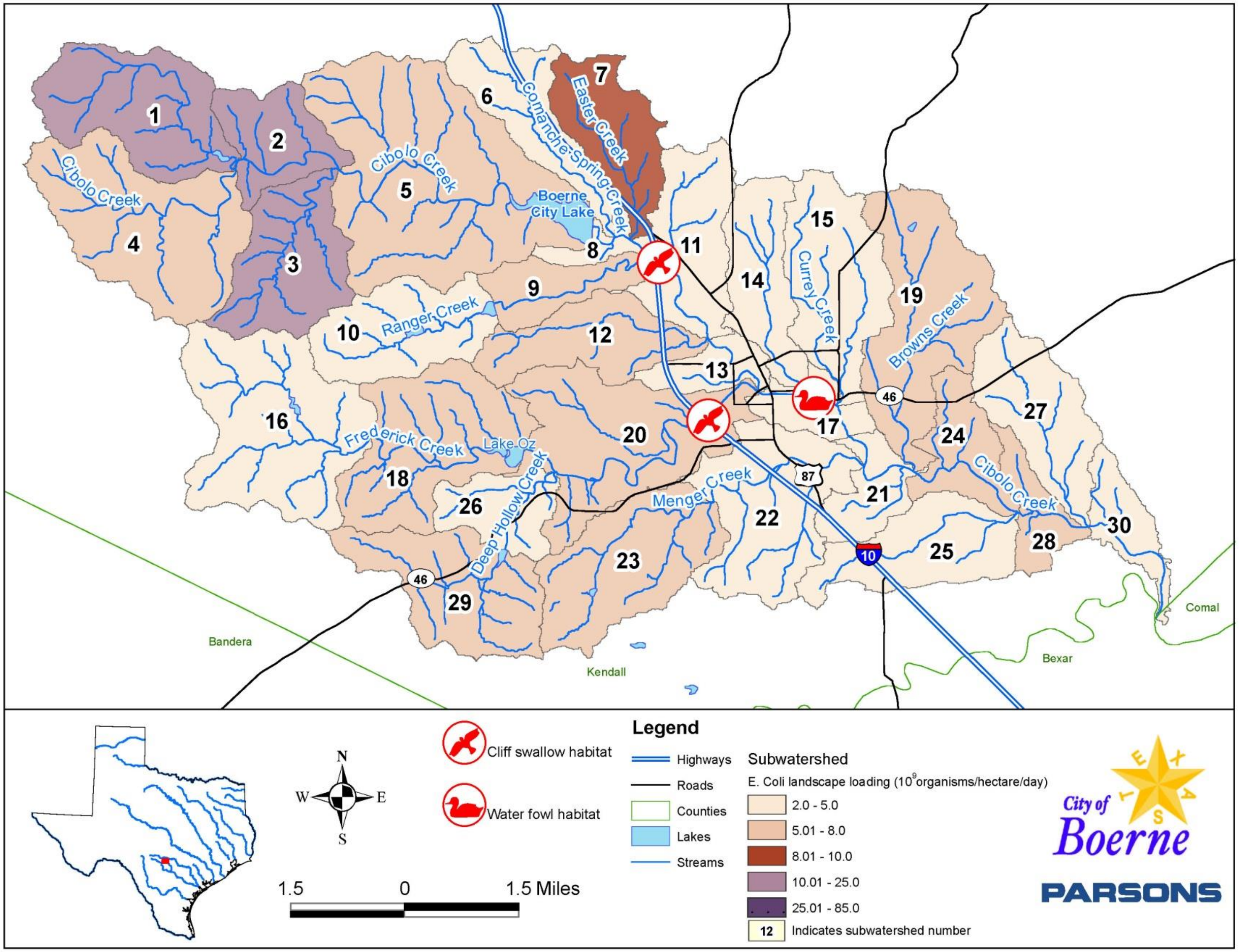


Figure 4-2. *E.coli* Loads Deposited on Land from Agricultural Sources

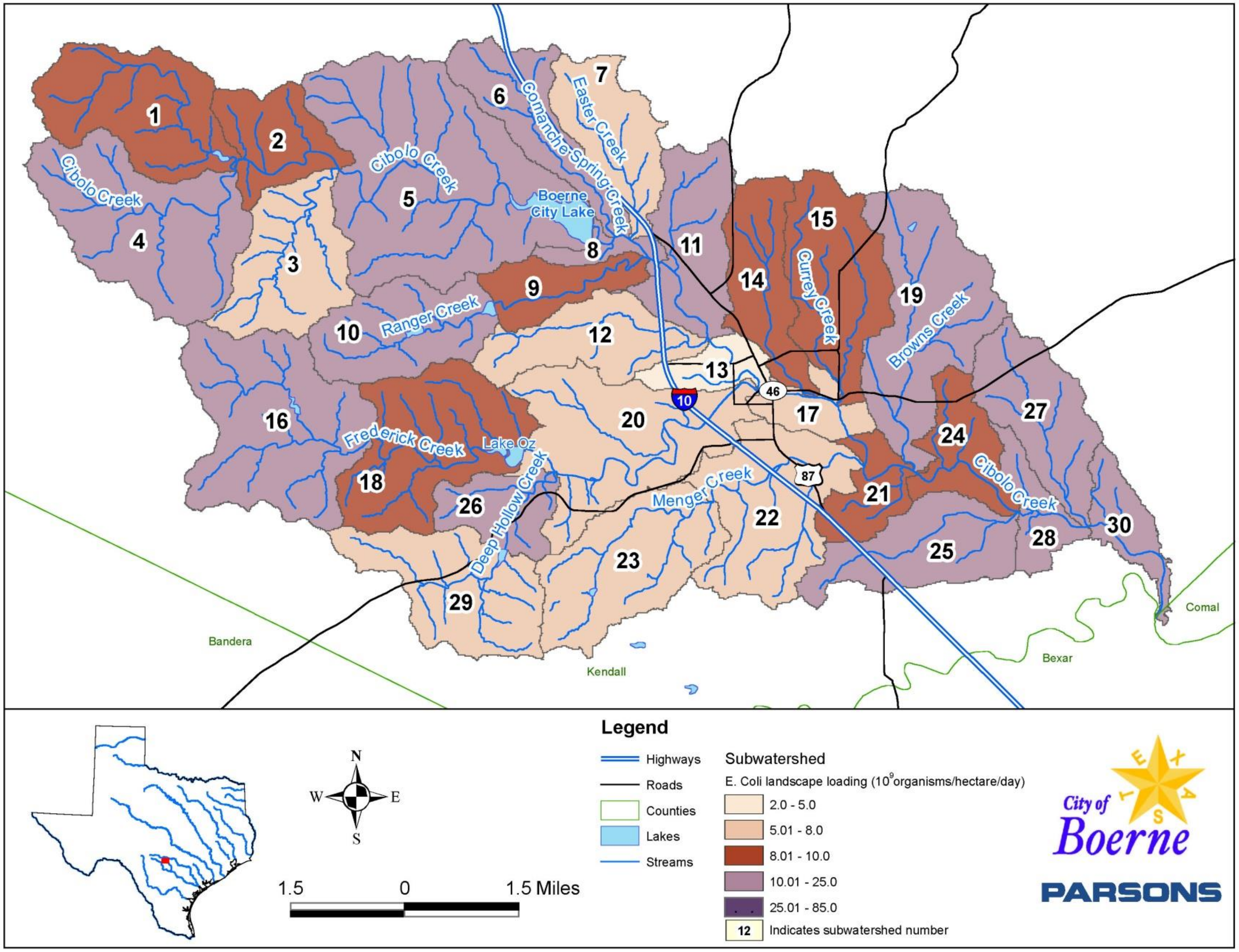
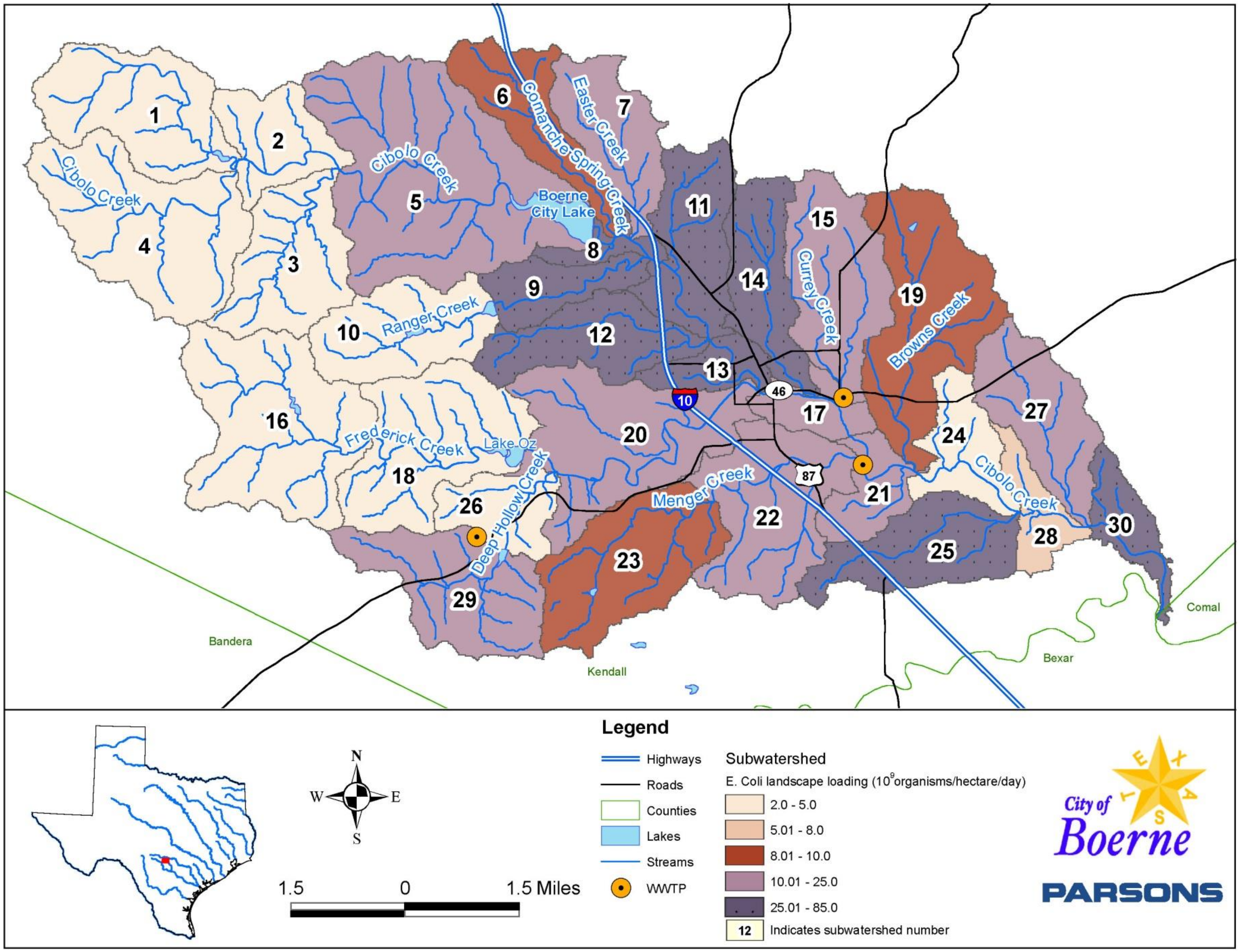


Figure 4-3. *E.coli* Loads Deposited on Land from Urban/Residential Sources



The calibrated SWAT model was used to simulate a wide array of factors and natural processes that influence instream concentrations of bacteria and nutrients. SWAT was also used to estimate reductions of instream loads that can be achieved by implementing management measures targeted at different pollutant sources.

Stakeholders acknowledged at the outset of the project that it was not possible or practical to reduce all pollutant sources identified in Tables 4-1 through 4-5 to zero. The subset of management strategies proposed by stakeholders was not intended to address all pollutant sources, and therefore, the total effect by all strategies cannot remove all pollutant sources. In some cases (i.e., some livestock and wildlife, atmospheric deposition) stakeholders recognized that it would not be possible to address a specific source or portion of a source. Simulated instream loads were compared to the "base line scenario," which represents the modeled average condition over the past 21 years to identify the percentage of the loads that can be reduced. Table 4-6 presents the *E.coli* load available for reduction in each stream reach along the main stem of UCC that could be addressed by the implementation of stakeholder suggested management strategies.

Table 4-6. *E. coli* source loads available for reduction in UCC

Subwatershed (UCC main stem)	Base Line (10^9 org/day)	Available for Reduction (10^9 org/day)	Percent Available for Reduction (%)
5	0.44	0.07	16.4%
8	0.34	0.31	91.3%
11	0.16	0.15	91.6%
13	0.08	0.07	91.8%
15	0.28	0.28	100.0%
17	37.20	37.10	99.8%
21	18.30	18.30	99.8%
24	6.98	6.97	99.8%
28	3.38	3.38	99.8%
30	1.01	1.01	99.8%

Sensitivity Analysis

The SWAT model was used to estimate how much a particular pollutant source contributes to the total instream load. This was augmented with a sensitivity analysis by running the model, iteratively decreasing an individual bacteria source and holding all other sources constant. This exercise was not completed to characterize specific nutrient sources.

It was determined that conducting a sensitivity analysis for bacteria sources would serve as an adequate surrogate for estimating and prioritizing the relative contributions of nutrient sources. For EC, the percent reduction is based on the geometric mean of the calibrated model for the base condition. The percent reduction calculation was conducted using the following standard formula:

$$R = \frac{C_0 - C_s}{C_0} \cdot 100$$

Where R = Reduction, percent

C_0 = Base condition geometric mean, orgs/100mL

C_S = Management strategy geometric mean, orgs/100mL

Through the combination of the sensitivity analysis and presenting results using the DSS stakeholders were able to quickly understand which bacteria sources had the most significant impact on instream water quality. Estimated instream loads from pollutant sources targeted by stakeholders are presented in Table 4-7. Values less than $1x10^6$ were not included in Table 4-7. The first column in Table 4-7 is the allowable load based on the water quality goal of 126 orgs/100mL (determined by multiplying the flow times the standard). Based on long-term model simulations, this suggests that Reach 17 is the only reach not expected to attain water quality standards under current conditions (i.e., base line load in Table 4-7 is greater than Water Quality Goal). Although Reach 8 is identified on the 2010 §303(d) list as impaired by EC, the model predicts that it should meet water quality standards. This is due to the fact that the water quality sampling data from Station 12857 used for beneficial use assessment has been biased towards low flow conditions in months when EC concentrations are expected to be high from the seasonal swallow population present under the I-10 bridge. The last column represents the total instream load that could be targeted for future reductions. Bacteria loadings may remain in a watershed given that stakeholders deemed it unnecessary to implement management strategies beyond the level necessary to achieve the water quality goal and because not all sources of EC are targeted by implementation strategies.

Table 4-7. Estimated Instream *E. coli* Load Contribution (10^6 orgs/day) [1]

Sensitivity Analysis of Source Categories - Adjusted Source Contribution (10^6 orgs/day)	**WQ Goal at 126 cfu/100 mL**	**Base Line**	**Cliff Swallow Nests**	**Urban Waterfowl**	**Pet (Dog) Waste**	**Feral Hog**	**Deer**	**Agricultural Runoff (Conservation Plans)**	**Failing OSSFs outside of city limits[2]**	**Failing OSSFs within city limits[2]**	**Fertilizer Application on Urban Landscapes[3]**	**Urban Runoff (Filter Strips)**	**TPDES WWTP**	**Reduction achieved from all BMPs**	**Not Addressed**
Reach 1	1,218	<1				<1	<1	<1						<1	<1
Reach 2	3,301	<1				<1	<1	<1						<1	<1
Reach 3	1,534	<1				<1	<1	<1						<1	<1
Reach 4	1,720	<1				<1	<1	<1						<1	<1
Reach 5	9,193	479			7	1	15	23						46	433
Reach 6	1,656	<1			<1	<1	<1	<1						<1	<1
Reach 7	1,324	<1			<1	<1	<1	<1						<1	<1
Reach 8	5,274	533	440		82	<1	1	<1						523	10
Reach 9	417	<1			<1	<1	<1	<1						<1	<1
Reach 10	6,252	<1				<1	<1	<1						<1	<1
Reach 11	6,841	232	180		48	<1	<1	<1						228	4
Reach 12	3,048	<1			<1	<1	<1	<1						<1	<1
Reach 13	9,721	106	77		27	<1	<1	<1						104	2
Reach 14	1,798	<1			<1	<1	<1	<1						<1	<1

Table 4-7. Estimated Instream *E. coli* Load Contribution (10^6 orgs/day) [1]

Sensitivity Analysis of Source Categories - Adjusted Source Contribution (10^6 orgs/day)	WQ Goal at 126 cfu/100 mL	Base Line	Cliff Swallow Nests	Urban Waterfowl	Pet (Dog) Waste	Feral Hog	Deer	Agricultural Runoff (Conservation Plans)	Failing OSSFs outside of city limits[2]	Failing OSSFs within city limits[2]	Fertilizer Application on Urban Landscapes[3]	Urban Runoff (Filter Strips)	TPDES WWTP	Reduction achieved from all BMPs	Not Addressed
Reach 15	7,783	238			17	<1	2	11					208	238	<1
Reach 16	4,651	<1			<1	<1	<1	<1						<1	<1
Reach 17	27,467	33,520	3,738	25,249	3,322	72	272	737					126	33,516	4
Reach 18	659	<1			<1	<1	<1	<1						<1	<1
Reach 19	213	<1			<1	<1	<1	<1						<1	<1
Reach 20	9,643	<1	<1		<1	<1	<1	<1						<1	<1
Reach 21	22,949	15,926	1,686	11,362	2,288	52	176	303					56	15,924	2
Reach 22	682	<1			<1	<1	<1	<1						<1	<1
Reach 23	325	<1			<1	<1	<1							<1	<1
Reach 24	18,495	5,787	613	4,112	805	26	94	116					20	5,786	1
Reach 25	106	<1			<1	<1	<1							<1	<1
Reach 26	2,256	<1			<1	<1	<1	<1						<1	<1
Reach 27	228	<1			<1	<1	<1	<1						<1	<1
Reach 28	15,061	2,649	268	1,788	472	14	48	50					9	2,648	<1
Reach 29	8,299	<1			<1	<1	<1	<1						<1	<1
Reach 30	13,136	754	76	505	134	5	15	17					3	754	<1

1 = Values presented in Table 4-7 represent geometric means of simulation period excluding zero flows. Table cells with no values indicate that bacteria concentrations were below detection limits.

2 = Instream loads from OSSFs across any given subwatershed on average are considered negligible because for the small number of estimated failing systems it was predicted that they would be repaired or mitigated within 70 days.

3 = Fertilizer Application to residential and commercial lawns does not generate bacteria loading to the landscape or the receiving water.

Prioritization of Sources through Sensitivity Analysis

The combination of SWAT model outputs, a DSS and sensitivity analysis allowed stakeholders to evaluate modeling results in Table 4-6 that geographically summarize the impact of major contributing pollutant sources. Results of the sensitivity analysis suggest avian fecal matter is a significant contributor of bacteria and nutrient loading to the main stem of UCC. Two specific areas were identified as the likely reasons for avian loads to UCC: the concentration of cliff swallows nesting under I-10 bridges and urban waterfowl on Cibolo Creek at River Road Park in Boerne. The park has experienced a significant increase in the population of non-native domestic waterfowl. Stakeholders and the Technical Advisory Committee agree that this is due to easy access to food (a result of humans feeding waterfowl), protected nesting sites and few predators. This combination of factors give some species of birds an unnatural advantage over other species (protected nesting and secure food sources) that may be causing bird populations to increase, resulting in bacteria levels that exceed natural assimilative capacity of creeks. Table 4-6 shows that cliff swallows and urban waterfowl comprise the majority of load contributions for the select group of subwatersheds along the main stem of UCC.

Photo Credit: Ryan Bass

Effects of the 2011 drought on UCC at Sparkling Springs upstream of Boerne City Lake

Chapter 5. Management Strategies and Load Reduction Potential

Management strategies are needed to address the array of bacteria sources throughout the Watershed. This chapter demonstrates that the implementation of select management strategies can achieve instream bacteria concentrations that meet UCCs designation for contact recreation. Stakeholders in the Upper Cibolo Creek Watershed Partnership worked together to identify realistic management strategies that will reduce instream pollutant loads to achieve and maintain surface water quality standards. This chapter focuses on both modeled and non-modeled management strategies recommended by stakeholders that will be most effective in meeting overall WPP goals.

In this chapter, because results of instream pollutant load reductions and concentrations are provided, the spatial unit used to present results is a stream reach. Results for any given stream reach represent the modeled cumulative loading from upstream subwatersheds that have an impact on the instream water quality.

The public process that supported the watershed modeling effort included focus group and steering committee meetings where individuals were able to contribute their knowledge of potential bacteria and nutrient sources as well as propose management strategies. Management strategies that address both point and nonpoint sources of bacteria and nutrient loads were considered. Management strategies that could be modeled were incorporated into the SWAT model and integrated into the DSS.

As described in Chapter 4, the DSS, coupled with the sensitivity analysis approach, provided stakeholders with the potential amount of bacteria reduction that could be achieved per management strategy. The sensitivity analysis approach is derived by evaluating the effect a management strategy has on ambient water quality when a pollutant source is nearly or completely eliminated. Using this information and the DSS, stakeholders were able to more effectively recommend and ultimately set implementation levels for individual management strategies based on their effectiveness, cost and likelihood of being implemented in their community. The description of these strategies and their estimated reduction levels are described in this chapter.

Management Strategies

The goal of management strategies outlined in this chapter are to treat, reduce, or adsorb bacteria loading discharged directly into a creek or transported by polluted stormwater as it flows from the landscape. Table 5-1 presents the EC load (million organisms per day) reduction potential for each proposed management strategy. Table 5-2 details percent reductions of EC loads achieved through the implementation of management strategies.

Figures 5-1, 5-2 and 5-3 present reduction estimates expressed as percentages at Reach 8,17 and 21 respectively.. Load reduction estimates are not provided for every strategy in every stream reach because some had either very low bacteria counts or proposed management strategies had no discernible impact due to the distribution of sources throughout the watershed.

Although the final model results suggest that a strategy may not be effective at reducing pollutant loads, it is possible upon further investigation that a source could be identified which, if removed, could have a significant beneficial impact on load reduction. For example, if more than five OSSFs per subwatershed are failing and are close to streams in the UCC watershed, this could be a substantial source of bacteria and nutrient loading. This type of source is of particular concern because human waste carries the most harmful pathogens. Therefore, all of the following management strategies should be considered as practical approaches for reducing bacteria and nutrient loads.

Photo Credit: Ryan Bass

Streamside Management Workshop hosted by the Cibolo Nature Center

Table 5-1. Management Strategies Reductions for *E. coli* (million orgs/day)[1]

Sensitivity Analysis of Source Categories - Source Contribution (million orgs/day)	WQ Goal at 126 cfu/100 mL	Base Line	1:Cliff Swallow Nest Deterrents	2:Urban Waterfowl Management	3: Pet (Dog) Waste Reduction	4:Feral Hog Reduction	5:Deer Management	6:Conservation Plan	7:Replace failing OSSFs outside of city limits[2]	8:Connect OSSFs within city limits to sewer system	9:Reduce Commercial Fertilizer Application to Urban Landscapes[3]	10:Filter Strips	11:TPDES WWTP Improvements	Load reduction achieved from all BMPs	Not Addressed
Reach 1	1,218	<1				<1	<1	<1						<1	<1
Reach 2	3,301	<1				<1	<1	<1						<1	<1
Reach 3	1,534	<1				<1	<1	<1						<1	<1
Reach 4	1,720	<1				<1	<1	<1						<1	<1
Reach 5	9,193	479			1	1	6	1						9	470
Reach 6	1,656	<1			<1	<1	<1	<1						<1	<1
Reach 7	1,324	<1			<1	<1	<1	<1						<1	<1
Reach 8	5,274	533	346		6	<1	7	<1						359	174
Reach 9	417	<1			<1	<1	<1	<1						<1	<1
Reach 10	6,252	<1				<1	<1	<1						<1	<1
Reach 11	6,841	232	148		4	<1	3	<1						155	77
Reach 12	3,048	<1			<1	<1	<1	<1						<1	<1
Reach 13	9,721	106	66		2	<1	1	<1						70	36
Reach 14	1,798	<1			<1	<1	<1	<1						<1	<1
Reach 15	7,783	238			2	<1	<1	<1					14	17	222
Reach 16	4,651	<1			<1	<1	<1	<1						<1	<1

Table 5-1. Management Strategies Reductions for E. coli (million orgs/day) (Continued*)*

Sensitivity Analysis of Source Categories - Source Contribution (million orgs/day)	WQ Goal at 126 cfu/100 mL	Base Line	1:Cliff Swallow Nest Deterrents	2:Urban Waterfowl Management	3: Pet (Dog) Waste Reduction	4:Feral Hog Reduction	5:Deer Management	6:Conservation Plan	7:Replace failing OSSFs outside of city limits[2]	8:Connect OSSFs within city limits to sewer system	9:Reduce Commercial Fertilizer Application to Urban Landscapes[3]	10:Filter Strips	11:TPDES WWTP Improvements	Load reduction achieved from all BMPs	Not Addressed
Reach 17	27,467	33,520	3,282	18,937	371	28	97	19					15	22,749	10,771
Reach 18	659	<1			<1	<1	<1	<1						<1	<1
Reach 19	213	<1			<1	<1	<1	<1						<1	<1
Reach 20	9,643	<1	<1		<1	<1	<1	<1						<1	<1
Reach 21	22,949	15,926	1,523	8,522	234	24	64	6					7	10,379	5,547
Reach 22	682	<1			<1	<1	<1	<1						<1	<1
Reach 23	325	<1			<1	<1	<1							<1	<1
Reach 24	18,495	5,787	553	3,084	84	11	34	3					3	3,773	2,015
Reach 25	106	<1			<1	<1	<1							<1	<1
Reach 26	2,256	<1			<1	<1	<1	<1						<1	<1
Reach 27	228	<1			<1	<1	<1	<1						<1	<1
Reach 28	15,061	2,649	250	1,341	47	7	19	1					1	1,666	983
Reach 29	8,299	<1			<1	<1	<1	<1						<1	<1
Reach 30	13,136	754	71	379	14	3	7	<1					<1	473	281

1 = Values presented in Table 4-7 represent geometric means of simulation period excluding zero flows. Table cells with no values indicate that bacteria concentrations were below detection limits.

2 = Instream loads from OSSFs across any given subwatershed on average are considered negligible because for the small number of estimated failing systems it was predicted that they would be repaired or mitigated within 70 days.

3 = Fertilizer Application to residential and commercial lawns does not generate bacteria loading to the landscape or the receiving water.

Table 5-2. Percent Reductions of EC Loads from Implementation of Management Measures

Source Reduction (%)	WQ Goal at 126 cfu/100 mL	Base Line	1:Cliff Swallow Nest Deterrents	2:Urban Waterfowl Management	3: Pet (Dog) Waste Reduction	4:Feral Hog Reduction	5:Deer Management	6:Conservation Plan	7:Replace failing OSSFs outside of city limits	8:Connect OSSFs within city limits to sewer system	9:Reduce Commercial Fertilizer Application to Urban Landscapes	10:Filter Strips	11:TPDES WWTP Improvements	Simulated Source load reduction achieved from all BMPs
Reach 1	1,218	0				0.4%	1.9%	0.3%						2.6%
Reach 2	3,301	0				0.4%	1.8%	0.3%						2.5%
Reach 3	1,534	0				0.4%	0.4%	0.2%						1.0%
Reach 4	1,720	0				1.2%	1.0%	0.0%						2.2%
Reach 5	9,193	479			0.3%	0.2%	1.3%	0.2%						1.9%
Reach 6	1,656	0			2.1%	0.0%	0.2%	0.0%						2.3%
Reach 7	1,324	0			2.3%	0.0%	0.1%	0.1%						2.4%
Reach 8	5,274	533	65.0%		1.1%	0.1%	1.2%	0.0%						67.4%
Reach 9	417	0			1.4%	0.0%	0.5%	0.1%						2.1%
Reach 10	6,252	0				0.0%	1.8%	0.4%						2.2%
Reach 11	6,841	232	63.8%		1.6%	0.1%	1.2%	0.0%						66.7%
Reach 12	3,048	0			2.5%	0.0%	0.2%	0.0%						2.7%
Reach 13	9,721	106	62.8%		2.0%	0.1%	1.2%	0.0%						66.2%
Reach 14	1,798	0			2.8%	0.0%	0.1%	0.0%						2.8%
Reach 15	7,783	238			0.7%	0.1%	0.2%	0.1%					5.9%	7.0%
Reach 16	4,651	0			1.2%	0.4%	0.9%	0.2%						2.6%
Reach 17	27,467	33,520	9.8%	56.5%	1.1%	0.1%	0.3%	0.1%					0.0%	67.9%
Reach 18	659	0			2.9%	0.1%	0.1%	0.1%						3.3%

Table 5-2. Percent Reductions of EC Loads from Implementation of Management Measures (continued)

Source Reduction (%)	WQ Goal at 126 cfu/100 mL	Base Line	1:Cliff Swallow Nest Deterrents	2:Urban Waterfowl Management	3: Pet (Dog) Waste Reduction	4:Feral Hog Reduction	5:Deer Management	6:Conservation Plan	7:Replace failing OSSFs outside of city limits	8:Connect OSSFs within city limits to sewer system	9:Reduce Commercial Fertilizer Application to Urban Landscapes	10:Filter Strips	11:TPDES WWTP Improvements	Simulated Source load reduction achieved from all BMPs
Reach 19	213	0			0.5%	0.0%	2.4%	0.1%						3.0%
Reach 20	9,643	0	64.0%		2.3%	0.0%	0.0%	0.0%						66.2%
Reach 21	22,949	15,926	9.6%	53.5%	1.5%	0.2%	0.4%	0.0%					0.0%	65.2%
Reach 22	682	0			2.8%	0.0%	0.1%	0.0%						3.0%
Reach 23	325	0			1.8%	0.5%	0.8%							3.0%
Reach 24	18,495	5,787	9.6%	53.3%	1.5%	0.2%	0.6%	0.1%					0.0%	65.2%
Reach 25	106	0			3.0%	0.0%	0.0%							3.1%
Reach 26	2,256	0			2.5%	0.1%	0.4%	0.0%						3.0%
Reach 27	228	0			1.3%	0.1%	0.1%	0.2%						1.7%
Reach 28	15,061	2,649	9.4%	50.6%	1.8%	0.3%	0.7%	0.0%					0.0%	62.9%
Reach 29	8,299	0			2.4%	0.2%	0.2%	0.1%						2.8%
Reach 30	13,136	754	9.4%	50.2%	1.8%	0.4%	0.9%	0.1%					0.0%	62.8%

Figures 5-1 through 5-3 provide summary pie charts for Reaches 8, 17 and 21, respectively, to display the EC reductions achieved through the implementation of management strategies presented in Table 5-2. Rounding of numbers in pie charts may not total 100%.

Figure 5-1. EC Pollutant Reductions for Reach 8

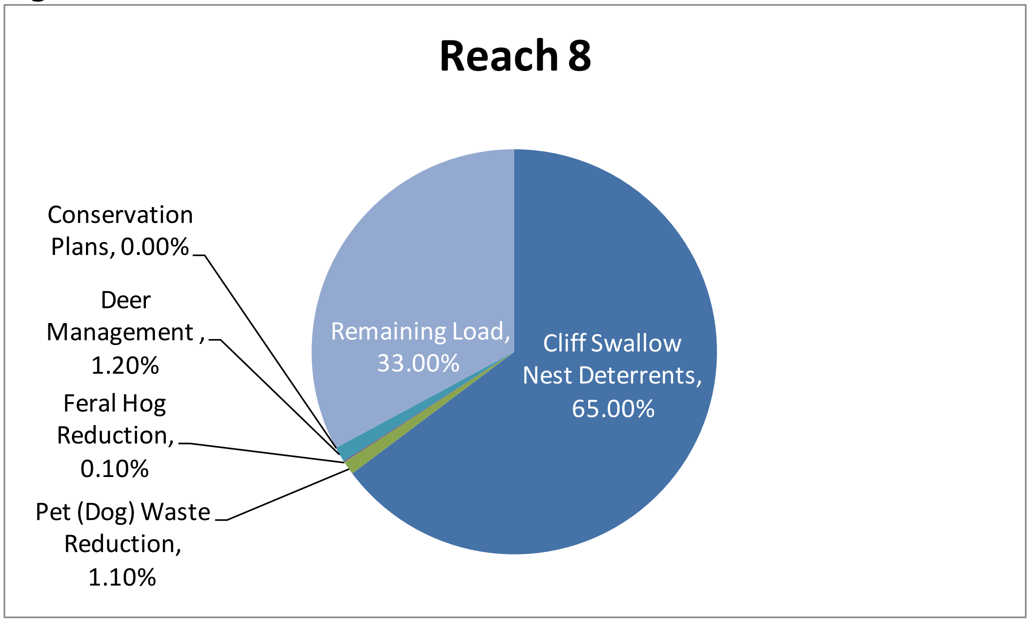


Figure 5-2. EC Pollutant Reduction for Reach 17

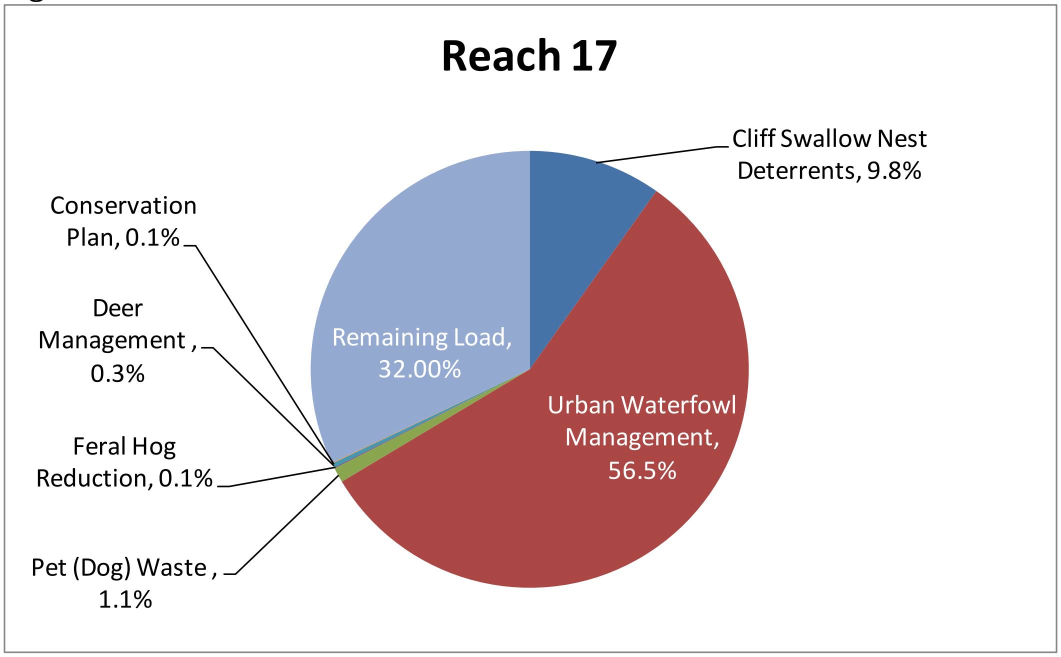


Figure 5-3. EC Pollutant Reduction for Reach 21

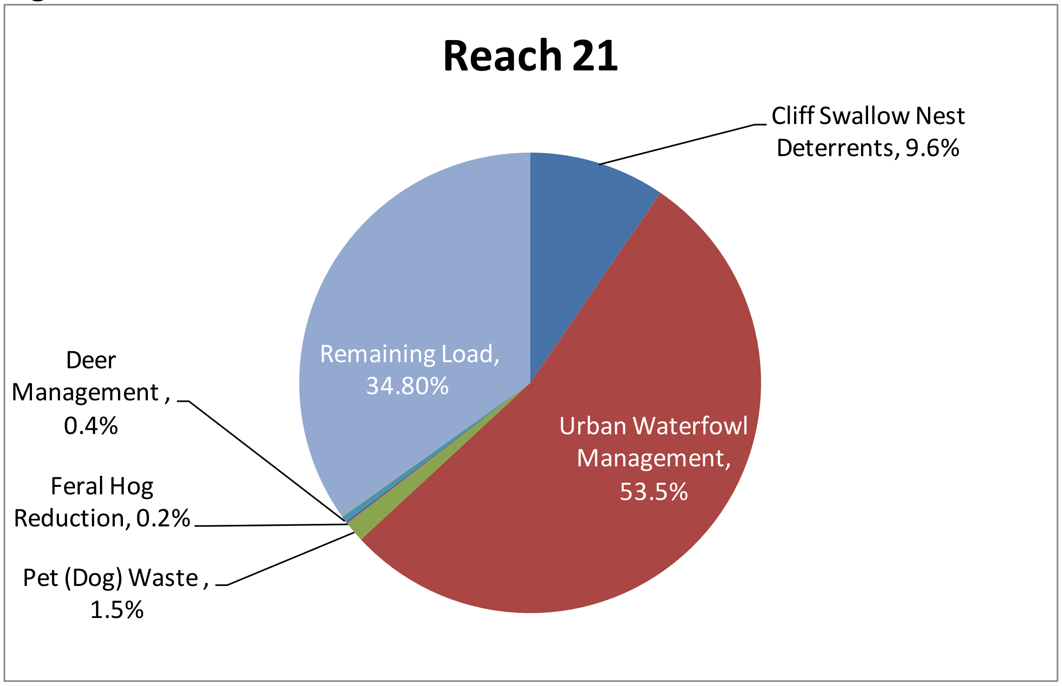


Photo Credit: Paul Barwick

Stormwater Runoff into Upper Cibolo Creek at River Road Park in Boerne

Cliff Swallow Nest Deterrents

Water quality monitoring and modeling demonstrate that isolated areas under bridges that cross UCC where there are high densities of nesting cliff swallows have a direct impact on instream water quality. As a seasonal direct discharge to the creek, cliff swallows are considered a significant contributor of bacteria and nutrient loading. Using the sensitivity analysis, stakeholders acknowledged that cliff swallows nesting under the IH-10 and feeder road bridges that cross UCC and Frederick Creek in subwatersheds 8 and 20 are a prominent pollutant-loading source that should be targeted. Implementation of this management strategy will require a significant financial and operations and maintenance commitment from the Texas Department of Transportation (TxDOT) and potential subcontractors. Elimination of the cliff swallow population nesting above UCC at the IH-10 locations could translate to an estimated 65 percent reduction in bacteria loads.

<table>
<tr><th colspan="2">Cliff Swallow Management</th><td colspan="2" rowspan="4"></td></tr>
<tr><td colspan="2">Scope: Reduce bacteria loads by cliff swallows nesting under IH-10 bridges over UCC by installing nest deterrent structure under bridges at UCC.</td></tr>
<tr><td colspan="2">Location: UCC at Interstate Highway 10 bridges (Reaches 8 and 20)</td></tr>
<tr><td colspan="2">Critical Areas: UCC, Frederick Creek</td></tr>
<tr><td colspan="4">Goal: Pursue a 65% reduction in direct deposition of bacteria loads in reach 8 and reach 20 by discouraging cliff swallows from nesting under Interstate Highway 10 bridges over UCC.</td></tr>
<tr><td colspan="4">Description: Water quality monitoring in UCC at IH-10 identified the site (12857) as containing persistently elevated levels of bacteria. Routine monitoring at the site has kept Segment 1908 on the Texas 303(d) List for bacteria since 2006. Additional water quality monitoring by the City of Boerne upstream of IH-10 has pointed to a localized bacteria source. Cliff swallows nesting under the bridge were identified as the likely source. The city will work with TxDOT to develop a strategy to discourage swallows from nesting at the site.</td></tr>
<tr><th colspan="4">Implementation</th></tr>
<tr><th>Participation</th><th>Projects</th><th>Period</th><th>Costs</th></tr>
<tr><td>TxDOT, City of Boerne, CWA Section 319 Grant Program</td><td>Work with TxDOT staff to determine the most effective and cost efficient strategy to discourage and prevent birds from nesting at the site.</td><td>2014-2018, 5 years</td><td>$223,000</td></tr>
<tr><th colspan="4">Load Reduction</th></tr>
<tr><td colspan="4">Reductions will be high because the strategy will prevent a large population of the cliff swallows from nesting directly over the creek at IH-10.</td></tr>
<tr><th>Effectiveness:</th><td colspan="3">Very High: Elimination of a direct discharge source can have an immediate beneficial effect on reducing instream bacteria and nutrient loads.</td></tr>
<tr><th>Difficulty:</th><td colspan="3">High: The planning, design, and installation of nest deterrent structures will be difficult. All aspects of the process will be costly and involve an extensive amount of construction, site disturbance, and traffic control issues.</td></tr>
</table>

Urban Waterfowl Management

Domestic waterfowl populations on UCC within Boerne city limits have reached an all-time high. Both water quality monitoring and modeling indicate that areas with domestic waterfowl populations contain elevated levels of bacteria that often exceed state standards set for contact recreation. In addition to bacteria concerns, the large number of ducks and geese are a direct deposition source of nutrient loading to UCC, and create a sanitation issue along sidewalks and around picnic tables adjacent to the creek. Because domestic waterfowl spend a majority of their time on land, large amounts of fecal matter can accumulate which is unsightly, causes foul odors, and is easily washed into the creek during rainfall events.

To establish a manageable waterfowl population, improve water quality, and maintain sanitary conditions around picnic areas within River Road Park, stakeholders recommended trapping and removing 75-100 ducks and geese from the area. In 2012, the City of Boerne proactively initiated a relocation program and successfully moved 80 birds to locations outside of the watershed. To support the initial relocation efforts, long-term management strategies should be implemented to keep the population at a reasonable level. Modeling has shown that diligent annual management of the waterfowl population on UCC along River Road Park could translate to an 80 percent reduction in bacteria loads.

Short-term Management Strategies

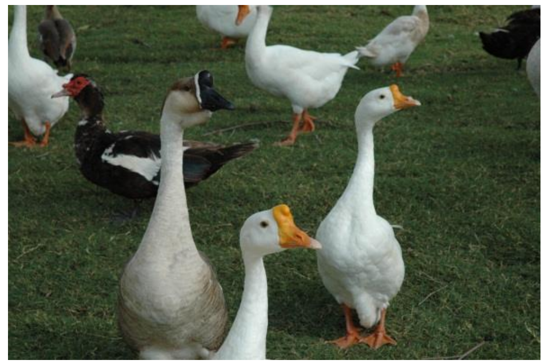
Capturing and removing waterfowl will be the most immediate and successful management strategy used to reduce populations. The difficult aspect of this strategy is finding an appropriate location where birds can be permanently relocated without compounding the same problem on other waterways. Once captured, birds will be relocated to properties outside the watershed that contain suitable habitat for domestic waterfowl. Efforts will be made to keep mated pairs together during the relocation process. Birds will be captured using a walk in trap and transported in pet carriers.

Long-term Management Strategies

An education program should be established to inform the public about the harmful effects caused by feeding waterfowl, both on the environment and the overall health of the waterfowl population. The goal of the program would be to discourage feeding of waterfowl by residents and tourists. To achieve this goal, print literature and permanent signs should be used at the park. An egg oiling program conducted by the City of Boerne will be used to limit the number of eggs that hatch annually. A long-term commitment to this program would greatly reduce the number of new birds at the site. Egg oiling will occur annually two to three times during spring and early summer months.

Migratory waterfowl and resident populations of native Black-bellied whistling ducks reside along the creek throughout the year. _No egg oiling would occur for these native species_. An initial target population of approximately 100 domestic ducks and geese will be maintained at the park. However, if bacteria levels remain above standards, additional captures and relocations should be scheduled to further reduce the population.

Urban Waterfowl Management



Scope:

- Reduce population through relocation and egg oiling to meet bacteria reduction goals
- Establish long-term management program
- Conduct annual census to track population
- Establish outreach and education program to discourage feeding and releasing birds

Location: Upper Cibolo Creek at Reach 17

Critical Areas: River Road Park

Goal: Reduce domestic waterfowl populations on UCC to accomplish at least a 50% reduction in EC loading which will meet water quality objectives, improve sanitary conditions at the park, and improve the health of resident waterfowl.

Description: To establish a manageable domestic waterfowl population, improve water quality, and maintain sanitary conditions around picnic areas within River Road Park, initial implementation efforts will focus on trapping and removing 75-100 ducks and geese from the area. Long-term management strategies will be utilized to prevent population growth, including annual egg oiling and development of outreach materials to discourage feeding and releasing ducks.

Implementation

Participation	Projects	Period	Costs
City of Boerne Staff, Urban Residents and Tourists	Initial relocation program to reduce waterfowl population, annual nest searches and egg oiling, outreach materials.	2013-2022, 10 years	$32,478

Load Reduction

Reductions will be high because the strategy will remove a large portion of the domestic waterfowl population that directly deposits fecal matter into the creek or directly on the bank. Diligent annual management of the waterfowl population on UCC along River Road Park could translate to an 80% reduction in bacteria loads.

Effectiveness:	High: Reduction of a direct deposition source can have an immediate beneficial effect on water quality.
Difficulty:	High: domestic waterfowl management strategies are somewhat easy to implement and are very cost effective compared to the load reduction potential. The difficulty arises in identifying relocation sites outside the watershed and transferring the birds. Also, there is a public perception aspect to this strategy that can potentially complicate the process. The City of Boerne's initial relocations efforts were successful and was accomplished through cooperation and support of the general public.

Pet (Dog) Waste Management

Water quality modeling identified pet waste as the third leading contributor of *E. coli* bacteria within the watershed. Pet waste loads are highest within urban areas of the watershed and management strategies primarily target urban residential pet waste. The City of Boerne Parks and Recreation Department manages 8 miles of walking and biking trails as well as 550 acres of park land, most of which is situated along Cibolo Creek or Boerne City Lake. These public areas are popular locations for people to exercise their pets, which results in the deposit of fecal matter. The city currently maintains six pet waste stations throughout the city and has plans to install three additional collection stations along city trails. Pet owners can reduce their pet's contribution to local bacteria levels by simply picking up and properly disposing of their pet's waste. Ideally, pet waste should be placed into plastic bags and added to household garbage, or buried and covered with approximately 8 inches of soil. Pet waste should never be buried near vegetable gardens or used as a component of garden compost.

Most rural residents within the watershed live on larger acreage properties. Stakeholders realize that in rural areas, most pets have large areas to roam and locating pet waste can be challenging and time consuming. Due to the high concentration of dogs within urban areas, stakeholders recommend that outreach efforts focus on pet waste removal in urban areas, including public spaces and urban residential units.

Photo Credit: Danny Zincke

Pet Waste Station on Curry Trail in the City of Boerne

Pet (Dog) Waste Management

Scope:

- Establish outreach and education program to encourage pet owners to pick up after their pets and properly dispose of the waste.
- Educate pet owners on how pet waste effects water quality
- Install additional pet waste stations at public areas within the watershed

Location: Within Boerne City Limits

Critical Areas: City Parks, Trails, Urban Residents

Goal: Reduce the amount of pet waste within the City of Boerne and reduce the potential for bacteria from pet waste to wash into local waterways.

Description: There are an estimated 8,689 dogs that live within Boerne city limits. Stakeholders feel that reductions in pet waste will be best achieved through targeted outreach and education programs within urban areas. The City of Boerne will develop educational material to inform residents of the effect pet waste can have on local water quality and encourage proper disposal of pet waste. The City will also maintain nine pet waste stations throughout city parks and trails. The city will potentially install more stations in the future if appropriate sites are identified.

Implementation

Participation	Projects	Period	Costs
Urban Residents and Tourists	Develop education materials encouraging the removal of pet waste from the landscape. Maintain pet waste stations throughout the city.	2014-2023, 10 years	$10,400

Load Reduction

Reductions in bacteria loading could range from 1% to 2% if this management strategy is continuously implemented to minimize daily contributions of fecal matter deposited on the landscape from the large number of dogs within the city limits.

Effectiveness:	Medium: Given the size of urban dog populations and their use of urban parks, reduction of pet waste in urban watersheds can have beneficial effect on water quality.
Difficulty:	Low: Developing and distributing educational materials will be an easy task. Pet waste stations are already in place and routine maintenance of these stations already occurs.

Feral Hog Reduction

Invasive species such as feral hogs have become a major concern in Texas. This is evident from efforts in other Texas watersheds, such as the Plum Creek watershed where stakeholders and watershed managers "identified feral hogs as a significant potential source of water pollution in their watershed" (Lewis *et. al.* 2012). Feral hogs are located in all parts of the UCC watershed where they have caused damage to property and negatively impacted riparian habitat. Despite limited data to actually quantify the percentage of bacteria contributions from feral hogs, stakeholders believe they are a serious concern and are actively working to eradicate this invasive species from their lands. Stakeholders are committed to working with agencies to make gains in quantifying and reducing the feral hog population. Most stakeholders believe feral hogs will continue to be a problem unless there is a more comprehensive, integrated eradication plan initiated by private, local, state and federal entities.

Feral hog control will be a challenge. Efforts by the USDA's Texas Wildlife Services (TXWS) show there are many factors related to feral hog management (Muir and McEwen 2007). TXWS reports that feral hog populations will continue to be detrimental to the environment unless management measures are put in place and efforts are made to keep feral hogs from moving to other sites. Hunting has long been in practice, but it is most effective at night, around water sites, after crop harvests, and in areas with low cover. Various types of baited traps are often used as a primary method of control. TXWS concludes that these efforts are effective in reducing damage to crops by reducing feral hog numbers and causing changes in behavior. To date, specific correlations between reductions in hog populations and reductions in instream bacteria concentrations have not been quantified. Stakeholders are certain that if the feral hog population is reduced it would contribute to bacteria load reductions. However, stakeholders acknowledge that implementation of a comprehensive program will be difficult and costly. Issues such as quantifying population reductions, absentee land owners, cost of setting up county-wide management strategies and issues with disposal may result in a low number of landowners who aggressively manage feral hogs.

Accurate watershed or county based feral hog population estimates do not exist. Despite little data on the number of hogs within the UCC Watershed or the number of hogs currently being removed from the population annually, stakeholders initially suggested a 25% reduction in the feral hog population within Kendall County. With no reliable method(s) available to quantify the percentage of hogs being removed from the county or watershed, stakeholders decided to promote a 25% increase in ongoing efforts to remove as many hogs as possible from the watershed. The goal of completely eradicating feral hogs may not be likely, but it is possible to reduce their numbers over time. Stakeholders believe that with a concerted effort it is conceivable that the population can be reduced within the next five years. To accomplish this, landowners must benefit from financial support and training to better trap and dispose of hogs.

Feral Hog Management

Scope:

- Advance a comprehensive county-wide approach to reduce feral hog population
- Identify incentives for reducing feral hog population
- Integrate technical assistance, education and outreach into approach
- Quantify benefits of population reduction

Location: All subwatersheds

Critical Areas: All subwatersheds

Goal: Decrease feral hog populations in Kendall County and the UCC Watershed. Promote a 25% increase in efforts to remove hogs from the watershed and quantify efforts/benefits.

Description: County government officials collaborating with select state agencies would implement a variety of existing and new programs aimed at culling and trapping feral hogs to reduce the population.

Implementation

Participation	Recommendations	Period	Capital Costs
Kendall County and Texas AgriLife Extension Service	Hire one county trapper to assist Kendall County @ $50,000	2014-2018	$250,000
	Purchase hog control supplies	2014, 2018	$10,000
	Investigate feasibility of establishing a trial bounty program (3,000 per year)	2014-2015	$6,000
	Formulate and implement use of online tracking tools to improve data management and demonstrate progress at reducing feral hog population	2014	Cost included in County Trapper costs
Texas Wildlife Services	Reduce feral hog population through hunting and trapping	2014-2018	$25,000
Landowners	Construct fencing around deer feeding stations to deny hog access at $244 per deer feeder (fencing for 50 deer feeders in watershed was estimated)	2014-2016	$12,200
		Total	$297,200

Load Reduction

Will reduce bacteria loading to rangeland, forestland, and direct deposition to waterbodies. This program will be most effective in addressing direct deposition as these animals spend a large portion of their time in riparian corridors. An instream load reduction of approximately 2% or less is estimated from implementation of a feral hog management program across the watershed.

Effectiveness:	High: Will result in a direct decrease in bacteria and nutrient loading to streams.
Difficulty:	High: Proliferation and transient nature of hogs, coordination of multiple activities to achieve success is difficult and the number of willing players must be high to achieve success.

Deer Management

Stakeholders commented during public meetings that white-tailed and axis deer along with small mammal populations throughout the UCC Watershed have increased over the past several years. Annual TPWD white-tailed deer population estimates show an increase in the deer population since 2005. Although deer do not produce as much fecal matter as cattle and hogs, the ease with which they can access the riparian corridor makes them a known pollutant source that will be difficult to manage. Stakeholders agree it is important to address both white-tailed and axis deer in all parts of the watershed. Stakeholders suggested that a practical approach would be to try to increase the acreage of forest and rangeland operating as wildlife management associations (WMA) for white-tailed deer and pursue options for reducing the axis deer population. WMAs provide an opportunity for neighboring landowners to work together in order to better manage free-ranging wildlife populations and improve habitat conditions. Landowners can develop a wildlife management plan where they work with a TPWD biologist to determine the recommended deer density goal, sex ratio, and fawn production. The promotion of WMAs would help to control deer populations within the watershed and likely translate to decreases in bacteria. Costs associated with establishing WMAs are low, but there are continuing cost landowners incur to meet the goals of wildlife management. TWPD provides resources to support establishing WMAs and wildlife biologists to assist with management decisions.

Stakeholders recommended implementation of specific management strategies to reduce the overall deer population by 50 percent. The two main options considered for reducing the axis deer population include capturing or hunting, both of which will require significant resources, skill, and time. Stakeholders acknowledge that implementation of this management strategy will be difficult and the certainty of participation by landowners is unknown. However, stakeholders agree that every effort should be made to implement this management strategy. The pollutant reduction effectiveness of this strategy suggests approximately three percent of the load can be removed if the 50 percent reduction target in the deer population can be achieved.

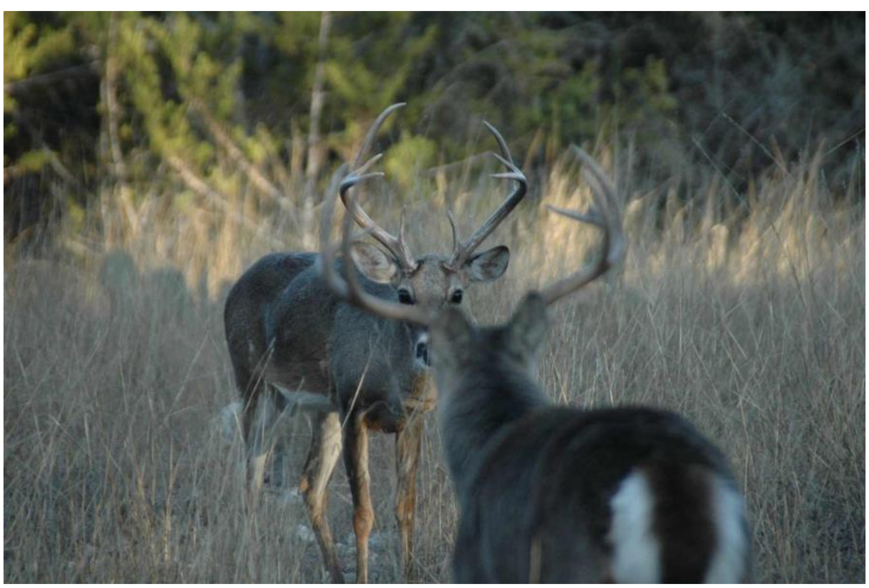


Photo Credit: Ryan Bass

White-tailed deer in the Upper Cibolo Creek Watershed

Deer Management

Scope:

- Work with TPWD to reduce white-tailed and Axis deer overpopulation
- Establish WMAs
- Conduct census and research
- Support landowners in executing WMAs and population control methods

Location: All subwatersheds

Critical Areas: Forest and range land, particularly upstream of subwatershed 13

Goal: Manage deer populations in the watershed through promotion of WMAs and reducing number of white-tailed and axis deer.

Description: Deer populations can be addressed in all parts of the watershed by increasing the acreage of forest and rangeland operating in association with a WMA. TPWD works with landowners to establish WMAs to perform research on wildlife populations and habitat, conduct education on sound resource management, and provide outdoor recreational opportunities. Landowners can develop a wildlife management plan where they work with TPWD biologist to determine the recommended deer density goal, sex ratio, and fawn production. This would help in controlling the deer population that would likely translate to decreases in bacteria. Axis deer population should be targeted for reduction by using approved capture and release methods and hunting where appropriate. Special emphasis for removing deer from urban watersheds was recommended.

Implementation

Participation	Projects	Period	Costs
Landowners	Control deer population through Wildlife Management Plans in association with WMAs, Deer Management Permits, and trapping	2014-2023, 10 years	$551,000

Load Reduction

Pollutant load reduction potential is low because deer utilize a wide variety of habitat types and have a low production rate of bacteria as compared to other sources in the watershed. An instream load reduction of approximately 2% or less is estimated from implementation of a deer management program across the watershed.

Effectiveness:	Medium: The greater the reduction in deer population the more bacteria reductions on land and through direct deposition can be achieved. An instream load reduction of approximately 2% or less is estimated from implementation of a deer management program across the watershed.
Difficulty:	High: Reducing the deer population over the entire watershed requires substantial coordination and commitment and may also create concerns among the hunting community; mobility of deer population from adjacent counties can impede localized progress.

Conservation Plans

Currently, there are no row crop agricultural activities occurring within the UCC Watershed and recent changes in land use do not indicate these practices will increase in the future. However, ranching and small livestock operations do exist. Ranching is not a dominate economic activity in the UCC Watershed, but creeks and small impoundments are substantial resources to these operations and maintaining that water supply is vital to profitability. Ranchers and landowners can develop comprehensive plans specific to their property with the goal of enhancing range conditions while protecting water quality and riparian habitat. Referred to as Conservation Plans, these plans allow landowners to implement a customized suite of strategies, making their operations profitable and sustainable while protecting the environment.

A conservation plan is a site-specific plan for agricultural lands to achieve a level of pollution prevention or abatement consistent with state water quality standards (Texas State Soil and Water Conservation Board [TSSWCB] 2012). A few examples of site-specific management strategies include: alternative watering sources, riparian buffers, modification of production practices, and rotational grazing. A plan covers an entire ranch, and includes examination of appropriate grazing systems, water facility considerations, livestock carrying capacity, nutrient management strategies, cross fencing, brush control and beneficial use of agricultural waste. These plans may also have subcomponents for irrigation waters, erosion control, and are flexible enough to cater to a wide range of operating systems. Based on discussions with the TSSWCB and the Kendall Soil and Water Conservation District there are currently no conservation management plans being implemented in the UCC Watershed. Local Soil and Water Conservation District and NRCS offices are available to provide technical and financial assistance for developing and implementing plans.

Stakeholders understand challenges associated with the expense, time and difficulty for landowners to develop and implement conservation plans. This, coupled with minimal contributions of pollutant loadings estimated to originate from ranching activities; stakeholders recommend targeting 10% of rangeland (2,200 acres) with this implementation strategy. Stakeholders feel that 2,200 acres under conservation management is an optimistic starting point for which this program can grow. Efforts will be made to recognize landowners who establish conservation plans in hopes of encouraging additional support for this management strategy throughout the watershed.

Conservation Plans

Scope:

- Work with ranchers to encourage good grazing management
- Provide incentives
- Provide education
- Establish conservation plans and stream buffers
- Use in conjunction with other management strategies

Location: Rangeland and pasture land in subwatersheds (approximately 10% of the 22,000 acres of rangeland in the UCC Watershed)

Critical Areas: subwatersheds 1, 2, 3, 4, 5, 6, 7, 10, 16, 18, 20, 23, 26, 29

Goal: Encourage the use of grazing management to maintain and enhance range conditions throughout the watershed and reduce bacteria loads washing off properties during rainfall events.

Description: A conservation plan is a site-specific plan for agricultural lands to achieve a level of pollution prevention or abatement consistent with state water quality standards (Texas State Soil and Water Conservation Board [TSSWCB] 2012). A few examples of site-specific management strategies include: alternative watering sources, riparian buffers, modification of production practices, and rotational grazing. A plan covers an entire ranch, and includes examination of appropriate grazing systems, water facility considerations, livestock carrying capacity, nutrient management strategies, cross fencing, brush control and beneficial use of agricultural waste.

Implementation

Participation	Projects	Period	Costs
Rancher	Grazing management	2015-2023, 9 Years	$15,400

Load Reduction

Reductions may be low because livestock density in the watershed is low and the land already naturally treats bacteria.

Effectiveness:	Medium: Ongoing stewardship of range land and pasture land reduces sediment, bacteria, and nutrient loading to receiving waters.
Difficulty:	Very high, most ranchers may be aware of the practice but will need substantial assistance in developing a plan

On-Site Sewage Facilities Strategies

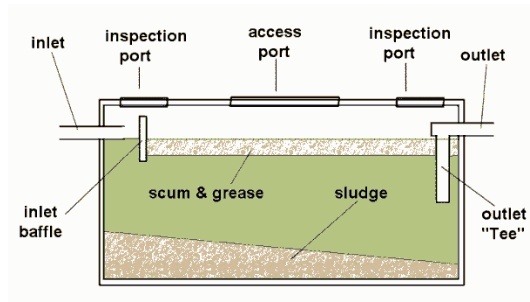
The State of Texas has a permitting program for the management of OSSFs with minimum requirements for the establishment, repair, operation, maintenance, permitting, and inspection of OSSFs. Permitting and inspection responsibilities are delegated to counties or their authorized agents. An owner of an OSSF is not required to comply with these requirements if their OSSF is not creating a nuisance and the OSSF was installed before September 1, 1989, provided the system has not been altered, and is not in need of repair. However, unauthorized discharges of effluent into or adjacent to waters of the state are prohibited. Homes that can reasonably connect to a centralized sewer system may be required to connect even if their system is functioning to avoid the potential for surface discharges. Discharges from OSSFs are a threat to public health and the environment as they cause bacterial contamination of groundwater and surface water as well as promote algae growth and other problems in lakes, rivers, streams, and wetlands. Human waste is associated with a variety of bacterial, protozoan, and viral pathogens, which represent the greatest concern to human health.

The Kendall County authorized agent indicated that failing OSSFs in the UCC Watershed would be easy to identify and there would be incentive for homeowners to fix a failing system on their own if they can afford the costs. Kendall County lacks the resources to undertake a watershed-wide investigation for OSSFs that need to be replaced or repaired. Owners of OSSFs are ultimately responsible for maintaining, repairing or replacing an improperly functioning system. To implement an effective management strategy for decreasing pollutant loads from failing or improperly functioning OSSFs will require a new and expanded collaborative effort between the county and citizens or business with OSSFs. The focus of OSSF management strategies will begin with three major efforts:

1. Obtain funding to investigate, locate, document and map failing or noncompliant OSSFs
2. Identify and acquire funding sources to connect OSSFs to a centralized wastewater collection system where possible or provide cost share for replacement of OSSFs
3. Work with Kendall County to improve the database that tracks system type, installation date, maintenance records, and documentation of seepage or failure

Modeling results suggest that the effects of failing septic tanks are minimal. However, completion of the first step of this strategy is necessary to effectively prioritize this BMP within the watershed.

OSSF Strategies



Scope:

- Guidance document and training for inspections and database development
- Determine hot spots of human bacteria sources through geo-location and bacteria source tracking
- Prioritize areas for inspection
- Conduct inspections
- Report OSSF failures & prioritize repairs
- Acquire funding and prioritize projects
- Replace failing OSSFs or connect to sewer system
- Public awareness of OSSF failures and prevention activities

Location: all subwatersheds

Critical Areas: households within 150' of creeks and close to central sanitary collection systems.

Goal: Identify and replace or repair failing OSSF annually from 2014 through 2023 to protect and restore water quality. System repair or replacement will be based on individual evaluations and proximity to waterways or sanitary sewer collection system infrastructure.

Description: This strategy seeks to develop criteria to determine the inspection frequency rate necessary to ascertain if OSSFs are failing, conducting reconnaissance to identify areas of chronic OSSF failure, train OSSF inspectors/investigators on how to conduct visual inspections of OSSF, through public outreach notify homeowners in areas of chronic OSSF failure of assistance provided to address failing OSSF, and conduct visual inspections of OSSF. Based on a prioritized list of failing OSSFs, financial assistance should be provided to pump solids from primary septic tanks, replace failing OSSF, or connect a select subset of OSSF to the City of Boerne centralized system.

Implementation

Participation	Projects	Period	Costs
Kendall County and COB will help identify problems, facilitate repair, seek financial assistance programs, property owner financed	1) Investigate, locate, document and map failing or noncompliant OSSFs 2) Connect OSSFs to a centralized wastewater collection system where possible or provide cost share for replacement 3) Work to improve the database that tracks system type, installation date, maintenance records, and documentation of seepage or failure	2014-2023, 10 Years	$1.5 Million

Load Reduction

Reductions are low because OSSFs only contribute a small portion to the total bacteria load. However, as this wastewater is untreated it is important to eliminate the potential for discharges as it is dangerous to human health and any discharge is unauthorized.

Effectiveness:	High: Targeting replacement or removal of failing systems near riparian corridors can significantly reduce bacteria and nutrient loading to receiving waters.
Difficulty:	High: Costs may add value to household, but finding households could be difficult

Wastewater Treatment Facility Strategies

Each WWTF has an operating permit issued by TCEQ that establishes effluent limits. Under most operating conditions, the City of Boerne WWTF meets its permit requirements. There are cases, such as periods of heavy rainfall, where it is possible for permits to be violated as influent flow can exceed treatment capacity. Under heavy rain conditions a WWTF may be overwhelmed with inflow and infiltration in the wastewater stream making it difficult to treat wastewater properly. Despite this, the City of Boerne has rarely exceeded permitted water quality parameters. The consequence is that it is possible for the effluent stream to contain elevated levels of bacteria. The City of Boerne WWTF monitors bacteria levels daily and has never violated its permitted bacteria limits, even under high flows.

The City of Boerne recently completed construction on a new WWTF which will add treatment capacity for Boerne's growing population. The new facility is called the Wastewater Treatment and Recycling Center (WWTRC) because it will also produce recycled water for irrigation and other non-potable uses. The new plant became operational in April 2013. The WWTRC collects flows from the southeast and southwest side of Boerne, reducing flows to the existing WWTF. The new WWTRC includes advanced wastewater treatment processes that remove nutrients in addition to organic pollutants. The plant will discharge water that is lower in nutrients reducing its impact on the quality of receiving waters. It will also produce water that is very low in bacteria and high in dissolved oxygen. The new WWTRC will have a new discharge point on Menger Creek (Reach 15) before flowing to Cibolo Creek. The new discharge location will be farther downstream on UCC that the existing WWTF discharge.

Photo Credit: Don Burger

City of Boerne WWTRC - Biological Nutrient Removal Aeration Basin

WWTF Improvements

Scope:

- Add additional capacity
- Add enhanced nutrient treatment
- Move effluent location

Location: City of Boerne WWTF 350 S. Esser Road
City of Boerne WWTRC, 41 Old San Antonio Road

Critical Areas: City of Boerne service area, Boerne city limits.

Goal: Increase the capacity to handle more flow, treat more efficiently, and to have higher quality effluent for discharge and reuse.

Description: Design, construction, operation, and management of a new 1.4 MGD WWTF to meet future growth of the City of Boerne. Treatment efficiency and capacity will be improved; the new WWTRC will be capable of removing suspended and floatable material, remove biodegradable organics, and eliminate pathogenic organisms; additional capacity to better handle peak flows.

Implementation

Participant	Projects	Period	Costs
City of Boerne	Construct new WWTRC that will discharge 1.4 MGD	2012-2013	$28 Million
City of Boerne	Construction interceptor sewers and other pipelines to redirect flows to the new WWTRC	2013-2023	$3.5 Million

Load Reductions

During low flow conditions, the new discharge location from the City of Boerne WWTRC maybe one of the few sources of bacteria loading to Menger Creek. While the Menger discharge site results in a new loading source, modeling demonstrates that this new direct discharge will not contribute additional bacteria loading to UCC because of very low bacteria levels contained in the effluent discharge.

Effectiveness:	Medium: Reducing bacteria loads from the WWTF will provide minimal instream improvement because the treatment plants typically discharge insignificant bacteria loads on a daily basis.
Difficulty:	Low: Construction of the new WWTRC is already underway

Complementary Nutrient Reduction Potential

This chapter summarizes how management strategies were identified, modeled, and evaluated primarily for their effectiveness at reducing instream bacteria loading and concentrations. As previously stated, all management strategies considered by stakeholders are effective at reducing bacteria and will have a complementary beneficial effect at reducing nutrient loads within the UCC Watershed. UCC has been identified as having concerns for TP in the downstream reaches of the watershed. While a separate sensitivity analysis for TP loading was not prepared, the SWAT water quality model and DSS were used to estimate potential reduction of TP loads from the management strategies recommended by stakeholders. In addition to those management strategies, two additional strategies were incorporated into the SWAT model at the request of the stakeholders based on their ability to specifically reduce nutrient loading to receiving waters, 1) riparian buffers in urban watersheds and 2) reduction of fertilizer application on residential/commercial lawns. These strategies were recommended as a proactive measure to holistically address potential future sources of water quality impairments within the UCC Watershed.

Riparian Buffers in Urban Areas

Land uses within urban watersheds have numerous sources that contribute bacteria and nutrient loads to the landscape, such as pets, faulty residential sewer connections, small livestock, and a wide array of wildlife (e.g., deer, raccoons, opossums, birds, coyote, rodents, etc.) that have adapted to urbanized areas. Therefore, municipal leaders are willing to consider the use of setbacks as buffers/filters along creeks and streams in urbanized watersheds. The goal is to increase the amount of riparian buffer acreage adjacent to drainage ways and creeks so that wash off from properties is treated to some degree before it reaches creeks.

Mechanisms to implement this management strategy lie within the city's jurisdiction and willingness to adopt ordinances that establish rights-of-way, setbacks, or buffers along existing drainages and creeks that would be acceptable and aesthetically pleasing to existing and future property owners. As new neighborhoods are developed, an ordinance requiring buffers or low impact development could also be established. Riparian buffers could be highly effective when implemented, but if the land adjacent to creeks is privately owned it will be particularly difficult for cities to establish continuous, adequate buffers. There may also be ways to create incentives for property owners to establish riparian buffers on their own. Stakeholders acknowledged that ordinance development and compliance, long-term maintenance of riparian buffers, and quantification of effectiveness of this management strategy are all significant challenges. It will take several years to establish rights-of-way, develop vegetative buffers, and demonstrate benefits to landowners.

Riparian Buffer – Urban Areas

Scope:

- Develop and enhance urban riparian zones
- Promote the removal of contaminants from stormwater runoff

Location: City of Boerne

Critical Areas: UCC and tributaries

Goal: Increase the amount of riparian buffer acreage adjacent to drainage ways and creeks so stormwater from urban areas will be treated to some degree before it reaches creeks.

Description: Mechanisms to implement this management strategy lie within a city's jurisdiction and willingness to adopt ordinances that establish rights-of-way, setbacks, or buffers along existing swales and creeks that would be acceptable and aesthetically pleasing to existing and future property owners.

Implementation

Participant	Projects	Period	Costs
Urban Property Owners	Establish and Manage Riparian Buffers, promote native vegetation, remove exotic vegetation	2016-2023	Not Estimated
City of Boerne	Establish and manage riparian buffers on city owned property, explore the development of a riparian buffer ordinance	2016-2023	Not Estimated
Fair Oaks Ranch	Establish and manage riparian buffers on city owned property, explore the development of a riparian buffer ordinance	2016-2023	Not Estimated

Load Reductions

Many variables contribute to a riparian areas ability to filter pollutants from surface water. However, it is well documented that well established riparian buffers are effective at filtering contaminants from stormwater runoff and promote healthy aquatic systems.

Effectiveness:	High, Riparian buffers could be highly effective if implemented within the watershed.
Difficulty:	High. Major hurdles are public perception regarding aesthetic values. The establishment and maintenance riparian buffers is moderately labor intensive.

Reduction of Fertilizer Application on Residential/Commercial Lawns

Most commercial fertilizers contain both nitrogen and phosphorus. Municipalities around the nation have taken steps to ban or curtail the use of phosphorus-containing lawn fertilizers that can be transported by rainfall runoff to streams and lakes and affect water quality. In the September 2009 edition of the journal, *Lake and Reservoir Management*, a study on the Huron River was published demonstrating that phosphorus levels dropped by an average of 28 percent after Ann Arbor, Michigan adopted an ordinance in 2006 curtailing the use of phosphorus on lawns (Lehman, et al. 2009). This study, along with other research, guided stakeholders to recommend that the reduction of fertilizer applications on residential/commercial lawns be investigated as a management strategy.

Stakeholders suggested exploring the establishment of a city ordinance preventing or curtailing the land based application of products containing phosphorus. Key stakeholders (City of Boerne, businesses, homeowners) recommended that implementation of this management strategy be guided by an adaptive management approach. Future water quality monitoring and additional detailed analysis using SWAT at the subwatershed level could further refine the TP load reduction potential in this watershed associated with curtailed or banned use of fertilizer applications to residential/commercial lawns.

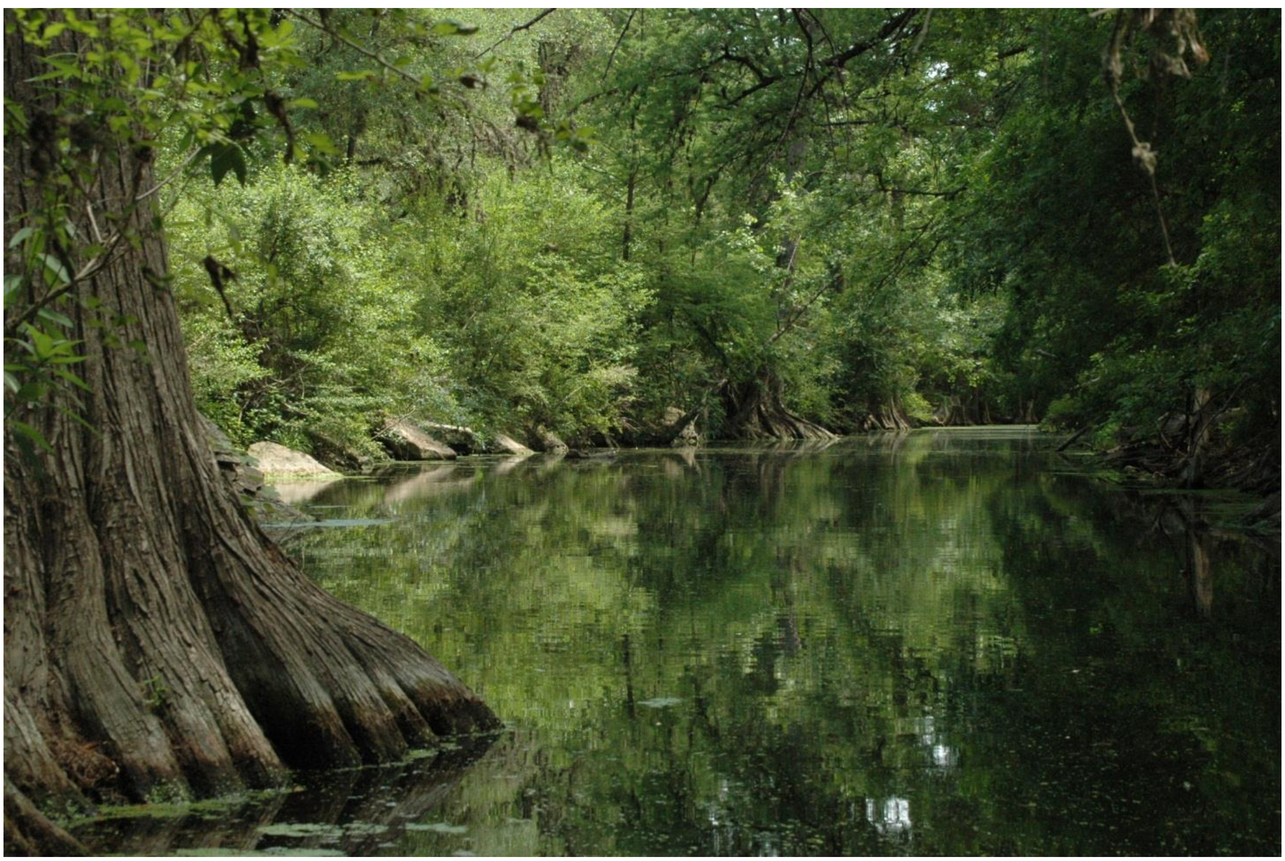


Photo Credit: Ryan Bass

Upper Cibolo Creek at the Cibolo Nature Center

Reduce Urban Fertilizer Application

Scope: Develop an education program targeting urban fertilization reduction, specifically working to reduce phosphorus applications to landscape.

Explore the development of a city ordinance to curtail the use of phosphorus for lawn fertilizer applications, Utilize watershed Work Group(s)

Location: City of Boerne

Critical Areas: Urban areas of the UCC Watershed

Goal: Reduce the use of phosphorus-containing lawn fertilizers that can be transported by rainfall runoff to streams and lakes and affect water quality.

Description: Stakeholders wish to curtail the application of phosphorus-containing lawn fertilizers that can be transported by rainfall runoff to streams and lakes and affect water quality

Implementation

Participant	Projects	Period	Costs
City of Boerne	Develop targeted education program to promote well-timed fertilizer applications at the appropriate application rate. Continue use of watershed work group(s) to evaluate process	2014-2020	$10,000
Urban Property Owners	Fertilize urban lawns at appropriate times and at recommended application rates. Utilize organic or low phosphorus fertilizers	2014-2020	Not Estimated
City of Boerne	Continue to fertilize city owned athletic fields and city parks with organic fertilizers at appropriate intervals and at recommended application rates	2014-2020	Not Estimated
Fair Oaks Ranch	Fertilize city owned athletic fields at appropriate intervals and at recommended application rates. Utilize organic or low phosphorus fertilizers	2014-2020	Not Estimated
BISD	Fertilize school district owned athletic fields at appropriate intervals and at recommended application rates. Utilize organic or low phosphorus fertilizers	2014-2020	Not Estimated

Load Reductions

The reduction of fertilizer applications on residential/commercial lawns can reduce TP loads throughout the watershed.

Effectiveness:	High: Reducing the amount of phosphorus directly applied to the landscape will have a beneficial effect in reducing nutrient levels in UCC.
Difficulty:	High: Difficult to change residential lawn fertilization practices on a large scale.

Hazardous Household Waste

Hazardous Household Waste (HHW) can consist of a wide variety of products. Anything from paint, fertilizer, cleaning chemicals, petroleum products, insecticides, pesticides and herbicides can be considered HHW. HHW can inflict serious problems on local water quality and aquatic life when improperly disposed. Most all products include disposal instructions on their labels and should be followed as closely as possible. Unfortunately, a "just pour it out" mentality exists because it is often the easiest and cheapest method of disposal, especially when a product has either expired or additional product remains after its intended use. To prevent HHW from entering local waterways stakeholders recommend creating and distributing targeted education materials informing residents and businesses of the potential impacts HHW can have on aquatic systems. Two free HHW collection events will be organized and facilitated by the City of Boerne. The disposal of HHW is very expensive and collection events can easily cost tens of thousands of dollars. Each proposed collection event in Boerne will be operated with a financial cap. Items will be collected until a predetermined maximum processing fee (financial limit) is reached.

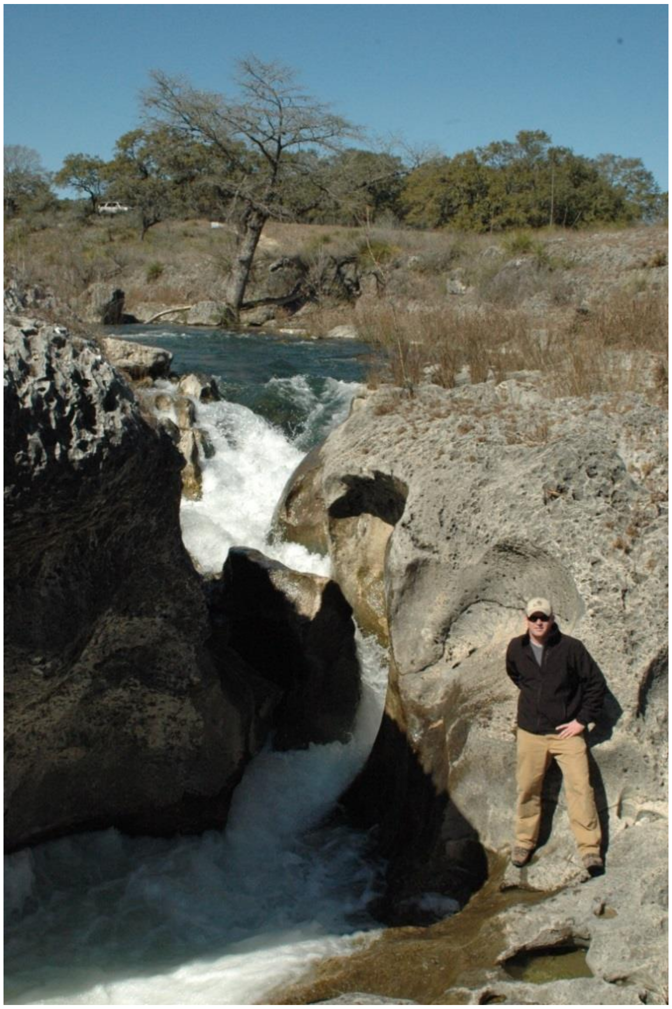


Photo Credit: Bill Lende

Herff Falls at the Cibolo Preserve

Hazardous Household Waste (HHW)

Scope:

- Develop an education program promoting proper disposal of HHW
- Work to facilitate HHW collection events to provide opportunities for the proper disposal of products that pose a threat to water quality

Location: All Subwatersheds

Critical Areas: All Subwatersheds

Goal: Provide opportunities for individuals to properly dispose of HHW. The primary goal will be to prevent fertilizers, herbicides, insecticides, pesticides and petroleum products from reaching waterways. Two collection events will be coordinated within the UCC Watershed

Description: Currently there are no easy or opportunities for individuals within Kendall County and the UCC Watershed to dispose of HHW. This strategy will develop education materials to inform residents and businesses of the impacts chemicals have on aquatic systems if improperly disposed. Free collection events will be organized to allow for the drop off and disposal of HHW.

Implementation

Participant	Projects	Period	Costs
City of Boerne Kendall County	Develop targeted education program to inform residents and businesses of the impacts chemicals have on aquatic systems if improperly disposed.	2014-2020	$5,000
City of Boerne Kendall County	Organize and facilitate two free HHW collection events in Boerne.	2015, 2020	$30,000

Load Reductions

HHW collection events can potentially reduce nutrient loads throughout the watershed by providing opportunities for proper disposal of old fertilizers and other potentially harmful products.

Effectiveness:	High: The improper or illegal disposal of HHW could have detrimental impacts on local water quality conditions and aquatic life.
Difficulty:	High: HHW collection events are very expensive and will require additional funding or in-kind contributions to facilitate.

Summary of Pollutant Load Reductions

Water quality monitoring data and modeling used by stakeholders to evaluate existing and future water quality conditions in the UCC Watershed suggest that the spatial extent and severity of the bacteria impairment can be effectively targeted and mitigated through an adaptive watershed-based approach to implementation. The primary focus of the WPP is to reduce bacteria loads throughout the watershed, ensure UCC meets state surface water quality standards, and ultimately be removed from the 303(d) List. The focus of modeling efforts was to provide loads and associated reductions that need to be achieved in order to meet stakeholder recommended water quality goals. To further characterize nutrients and the associated effects on dissolved oxygen, a greater level of effort would be necessary to determine baseline conditions and establish an acceptable weight-of-evidence approach between estimated TP reductions and long-term water quality conditions in UCC.

Despite the inherent scientific uncertainty associated with predicting fate and transport of bacteria and nutrient loads in creeks, the SWAT model, DSS, and sensitivity analysis determined that geographic targeting of management strategies would have a substantial benefit on water quality by reducing both instream bacteria and nutrient concentrations. Furthermore, the DSS tools were able to assist stakeholders with prioritizing management strategies such as cliff swallow nest deterrents and urban waterfowl management based on their pollutant load reduction effectiveness and associated costs. Model results suggest that implementation of these two management strategies, along with the additional stakeholder recommended strategies, can achieve the water quality goal established for *E.coli*.

Load duration curves are useful graphic tools for demonstrating potential for attainment of water quality standards under all flow conditions. Figures 5-1 through 5-3 provide load duration curves for Reaches 8, 17 and 21 and display the expected pollutant reductions at each site. These reaches were chosen because of 1) their location to the upper, middle, and lower portions of the watershed, 2) the proximity to current and historic USGS stream flow gage locations at reaches 8 and 21 and 3) their association with impairments or localized sources of bacteria loads. The solid line on each figure is the water quality standard represented as the allowable count of bacteria per day where attainment is achieved by being below the line. Using Reach 17 as an example, the gray dashes represent the simulated load based on the calibrated SWAT model. The dashes are above the standard at the 40th flow exceedance percentile. This means that bacteria levels are typically higher during mid-range to low flows. The dark dashes represent the simulated load once all management strategies are implemented to the degree stakeholders recommended and shows values are lowered by one magnitude overall where nearly all dashes are below the standard. Using Reach 17 as an example, at the 50th flow exceedance percentile, the geometric mean of the load dropped from 3.63×10^{10} orgs/day to 3.6×10^{9} orgs/day. The load duration curves for Reaches 8 and 21 have simulated loads lower than the water quality goal. Comparison of all three load duration curves demonstrates that the bacteria water quality goal can be met from the implementation of various management strategies over time.

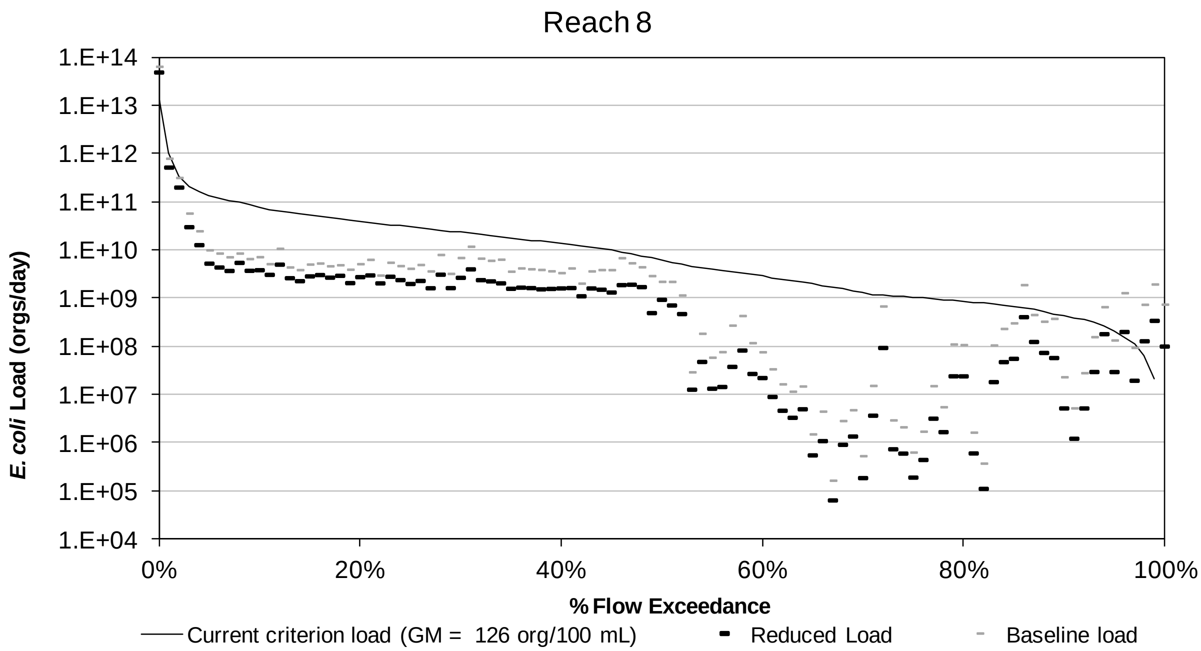


Figure 5-4. Expected Reductions for Reach 8

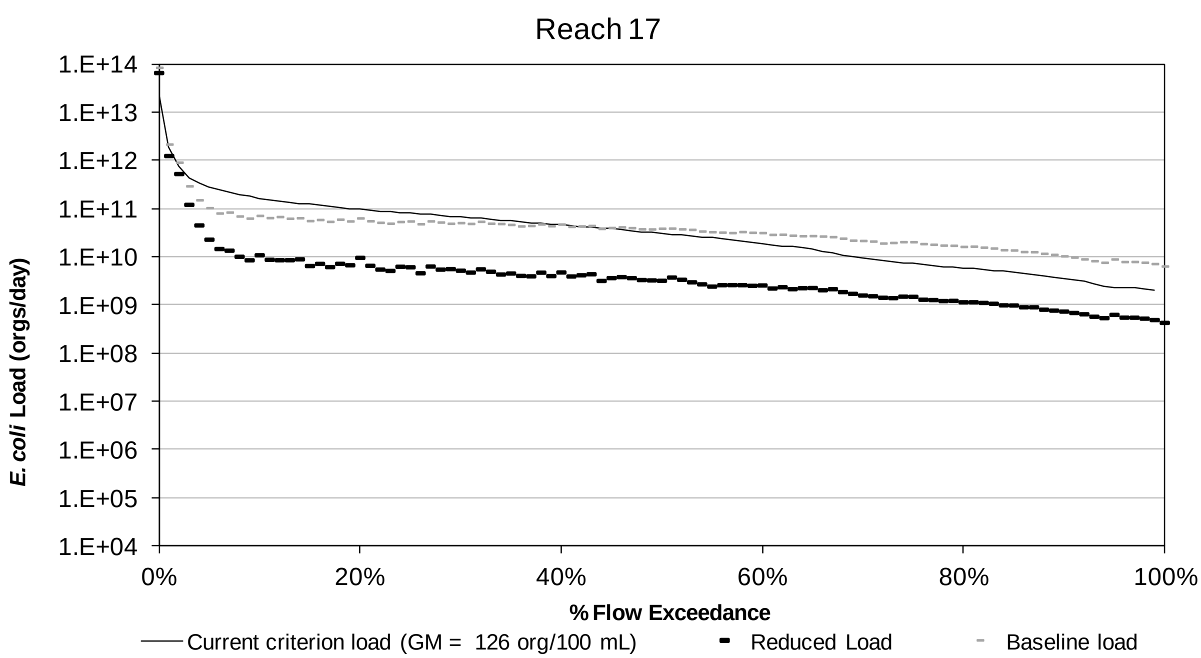


Figure 5-5. Expected Reductions for Reach 17

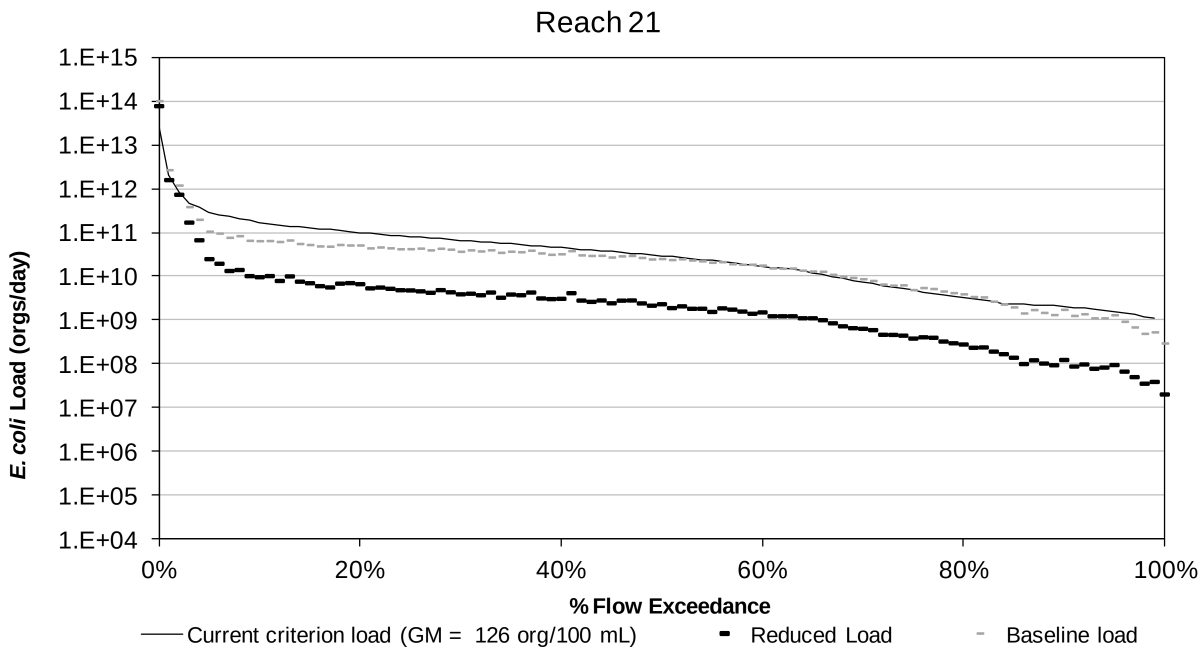


Figure 5-6. Expected Reductions for Reach 21

Using the sensitivity analysis, stakeholders quickly identified the two most prominent bacteria loading sources as direct discharges from cliff swallows and waterfowl. To target these sources, stakeholders recommended evaluating the effectiveness of two different management strategies, structural barriers to deter birds nesting underneath Interstate Highway (IH-10) bridges and decreasing domestic waterfowl populations on UCC at River Road Park. Aided by the DSS, stakeholders were able evaluate pollutant load reductions from the additional management strategies listed in Table 8-1.

The public process documented feedback from stakeholders on key factors such as perceived reduction effectiveness, project difficulty, and proposed timelines. Certain management strategies have a finite implementation period; some will require continuous implementation and still others warrant a mid-course review to determine what level of additional implementation is necessary.

Chapter 6. Estimate of Technical and Financial Assistance Needed for Implementation

To holistically address water quality impairments, WPPs often recommend a variety of complex management strategies that must be implemented simultaneously on large spatial and temporal scales. Many individuals, agencies, organizations and municipalities must be involved to carry out these strategies in order to achieve water quality improvements overtime. This chapter provides information regarding the potential sources of technical and financial assistance that could be utilized to implement strategies within the UCC Watershed.

Watershed Coordinator

Management strategies can sometimes be technical in nature and require a great deal of assistance to fully achieve implementation. As a result, a full time Watershed Coordinator should be employed within the watershed to promote implementation of the WPP. A watershed coordinator will pursue funding sources for implementation projects; oversee water quality monitoring efforts to evaluate the effectiveness of management strategies and conduct outreach and education programs. A local Watershed Coordinator will be the primary point of contact and liaison for any individual(s), organization, nonprofit or local government seeking technical or financial assistance to implement strategies outlined in the WPP.

Technical Assistance

Most management strategies suggested by stakeholders will require substantial assistance and technical expertise to execute. Individuals wishing to implement strategies should work with the local Watershed Coordinator and local agency personnel as needed to ensure all available resources are utilized. The local Watershed Coordinator will facilitate assistance through the following agencies and local government organizations when implementing strategies in the associated pollutant source category. Table 6-1 details available resources for technical assistance which could be utilized to support implementation efforts.

Wildlife

- Texas Parks and Wildlife Department (TPWD)
  - All wildlife related management strategies
- Texas Department of Transportation (TXDOT)
  - Assist with cliff swallow nest deterrents at bridges on IH-10
- City of Boerne (COB)
  - A technical resource and liaison for all management strategies outlined in the WPP
- Kendall County
  - OSSF strategies: inspection, permitting, data collection, system evaluation

Agriculture

- Natural Resource Conservation Service (NRCS)
  - Assistance with Conservation Plans, Riparian Buffer
- Texas State Soil and Water Conservation Board (TSSWCB)
  - Assistance with Conservation Plans, Riparian Buffers
- Texas A&M AgriLife Extension (TX AgriLife)
  - Assistance with Conservation Plans, Riparian Buffers, Feral Hogs
- Texas Department of Agriculture (TDA)
  - Assistance with Conservation Plans, Riparian Buffers
- Kendall Soil and Water Conservation District (KSWCD)
  - Assistance with Conservation Plans, Riparian Buffers

Urban/Residential

- City of Boerne
  - A technical resource and liaison for all management strategies outlined in the WPP
- Kendall County
  - OSSF strategies: inspection, permitting, data collection, system evaluation

General

- TCEQ Clean Water Act (CWA) Section 319 Grant/Nonpoint Source Program
  - Provides technical assistance and guidance for planning and implementation related strategies. Acts as liaison between the City of Boerne and the U.S. EPA
- Environmental Protection Agency CWA Section 319 Grant/Nonpoint Source Program
  - Serves at technical resource for WPP project related planning and implementation activities funded with CWA 319 monies.

Financial Assistance

Financial assistance will be required to implement many of the management strategies recommended in the WPP. Strategies such as the new City of Boerne WWTRC and pet waste removal stations have already been funded or will not require large amounts of additional financing to accomplish their intended goals. However, some individuals or groups working to implement strategies may be unable to entirely fund a project and will need to seek additional financial assistance. Table 6-1 provides examples of funding sources and is not meant to be a comprehensive list. Funding sources come and go over time. The Watershed Coordinator will track funding sources relevant to the implementation of specific strategies and act as a liaison to assist individuals or organizations in obtaining financial assistance for approved projects. The following programs and funding sources could potentially be utilized to implement strategies identified in the WPP.

Clean Water Act State Revolving Fund

The Clean Water Act State Revolving Fund is a loan assistance program for water quality improvement projects. The program is funded by the EPA through the TWDB.

Section 319(h) Federal Clean Water Act

CWA Section 319 funds support a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, demonstration projects and monitoring to assess the success of specific nonpoint source implementation projects. Funding is provided by the U.S. EPA through TCEQ and TSSWCB and could be used to support implementation projects within the watershed.

Section 604(b) Federal Clean Water Act

Grant funds are used to determine the nature and extent of point and non-point source water pollution and to develop water quality management plans. States are encouraged to give priority to watershed restoration planning. This program complements the EPA's overall watershed protection efforts as stated in the Agency's Strategic Plan.

Section 106 State Water Pollution Control Grants

Section 106 grants are federally funded and support state water quality programs, including water quality assessment, monitoring, water quality planning and standard setting, TMDL development, point source permitting, training, and public information.

NRCS Financial Assistance Programs

The NRCS offers voluntary programs to eligible landowners and agricultural producers to provide financial and technical assistance to help manage natural resources in a sustainable manner. These programs provide financial assistance to help plan and implement conservation practices that address natural resource concerns or opportunities to help save energy, improve soil, water, plant, air, animal and related resources on agricultural lands and non-industrial private forest land. Of the many programs offered by the NRCS, the Environmental Quality Incentives Program (EQIP) and the Wildlife Habitat Incentive Program (WHIP) would be most helpful for landowners within the watershed.

<u>Environmental Quality Incentives Program</u>

EQIP is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of ten years in length. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and non-industrial private forestland.

Wildlife Habitat 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. The NRCS administers WHIP to provide both technical assistance and up to 75 percent cost-share assistance to establish and improve fish and wildlife habitat.

WHIP cost-share agreements between NRCS and the participant generally last from one year after the last conservation practice is implemented but not more than 10 years from the date the agreement is signed.

USDA Rural Development Program (USDA-RD)

The USDA Rural Development Program offers financial support program through grants and low-interest loans to support such essential public facilities and services such as water and sewer systems. The program offers technical assistance and information to help agricultural producers and cooperatives get started and improve the effectiveness of their operations. The program works to help rural individuals, communities and businesses obtain the financial and technical assistance needed to address their diverse and unique needs.

Texas Farm & Ranch Lands Conservation Program

The Texas Farm and Ranch Lands Conservation Program was developed to assist private landowners in protecting their land from development, to keep it under private ownership and in agricultural production. The program allows the Texas General Land Office to work with landowners in facilitating the purchase of development rights through "voluntary landowner agreements." These agreements allow landowners to receive substantial payments while maintaining ownership of their property.

Feral Hog Abatement Grant Program

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. This program provides assistance to landowner through direct control measures and community based education and outreach.

Water Supply Enhancement Program

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. A cost-share program was created for brush control and limits the cost share rate to 80% of the total cost of a practice. If the demand for funds under the cost-sharing program is greater than funds available, the board shall establish priorities favoring areas with the most critical water conservation needs and projects that will be most likely to produce substantial water conservation. The board shall give more favorable consideration to a particular project if the applicants individually or collectively agree to increase the percentage share of costs under the cost-share arrangement. The quantity of stream flows or groundwater or water conservation from the eradication of brush is a consideration in assigning priority.

Landowner Incentive Program

The Texas Landowner Incentive Program (LIP) is a collaborative effort between TPWD Wildlife and Inland Fisheries Divisions to meet the needs of private, non-federal landowners wishing to enact good conservation practices on their lands for the benefit of healthy terrestrial and aquatic ecosystems. LIP focuses on projects aimed at creating, restoring, protecting and enhancing habitat for migratory birds and species of greatest conservation need 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.

Regional Water Supply and Wastewater Facility Planning Program

The Texas Water Development Board offers grants to political subdivisions of the State of Texas to evaluate and determine the most feasible alternatives to meet regional water supply and wastewater facility needs, estimate the costs associated with implementing feasible regional water supply and wastewater facility alternatives, and identify institutional arrangements to provide regional water supply and wastewater services for areas in Texas.

Texas Department of Transportation Enhancement Program

TxDOT administers the federally funded Transportation Enhancement Program, which provides opportunities for non-traditional transportation related activities. Projects should go above and beyond standard transportation activities and be integrated into the surrounding environment in a sensitive and creative manner that contributes to the livelihood of communities, promotes stewardship of the environment. Projects undertaken with enhancement funds are eligible for reimbursement of up to 80 percent of allowable costs. The program includes projects for environmental mitigation to address water pollution due to highway runoff. Activities in this category include programs designed to minimize pollution associated with storm-water runoff from transportation facilities. Eligible mitigation projects include those that incorporate aesthetic and ecological considerations and promote groundwater recharge.

Table 6-1. Management strategies, available resources for technical assistance and examples of potential financial assistance providers for project implementation.

Management Strategy	Resources for Technical Assistance	Potential Financial Assistance Provider(s)
Cliff Swallow Nest Deterrents	TXDOT, COB	EPA/TCEQ CWA Section 319, CWA State Revolving Fund,
Urban Waterfowl Management	COB, TPWD	City of Boerne Parks and Recreations
Deer Management	TPWD	TPWD Wildlife Management Associations and Co-op Programs, LIP
Feral Hog Reduction	TX AgriLife, TPWD, Kendall County	Texas AgriLife Extension Service – Wildlife Services, TPWD, LIP
Conservation Plans	TSSWCB, USDA-RD, NRCS, KSWCD, TX AgriLife	(TSSWCB) Water Supply Enhancement Texas Brush Control Program, TX AgriLife, NRCS, USDA-RD, LIP
Pet (Dog) Waste	COB	City of Boerne Parks and Recreations, EPA/TCEQ CWA Section 319, TPWD National Recreational Trails Fund, TxDOT Transportation Enhancement Program
Evaluation and documentation of OSSF statistics. Replace or repair failing OSSFs outside of COB	Kendall County, COB	EPA/TCEQ CWA Section 319, CWA State Revolving Fund, Section 106 Grant, Regional Water Supply & WWF Planning Program
Connect OSSFs within Boerne City Limits to Sewer System	COB	TX Dept. of Agriculture Texas Capital Fund Main Street Improvements Program, CWA State Revolving Fund, USDA-RD, Regional Water Supply & WWF Planning Program
Reduced Application of Urban Fertilizer	COB	EPA/TCEQ CWA Section 319, Section 106 Grant
Riparian Buffers	COB	Landowner, Developer, EPA/TCEQ CWA Section 319 , TX F&R Conservation Program, LIP
Green Infrastructure, LID	COB	Landowner, Developer, EPA/TCEQ CWA Section 319, CWA State Revolving Fund
City of Boerne New WWTF	COB	COB - Funded

Figure 6-1 displays a preliminary estimate of the financial investment in the watershed associated with modeled management strategies. In order to achieve water quality goals, investments will have to be made consistently over time for the first five years with some additional investment carried beyond 2018 as necessary.

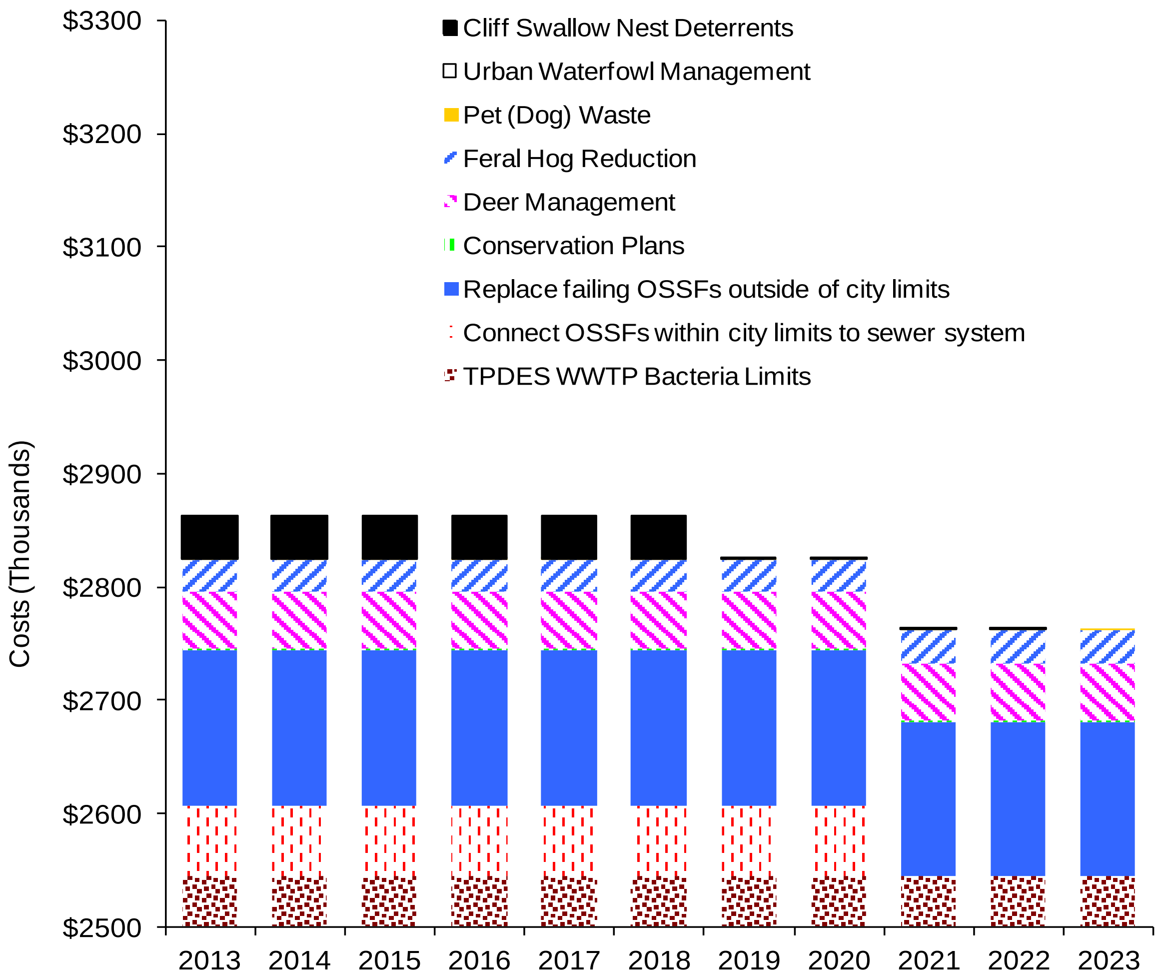


Figure 6-1. Investments over-time by management strategy

A comprehensive benefit cost analysis for the project was not necessary as two key management strategies quickly became apparent as the most effective during the stakeholder input process. Cliff swallows nest deterrents under IH-10 bridges and urban waterfowl management were recognized as viable, practical, and not as costly and difficult to implement as other projects. Combined, these two strategies also had the largest impact on ambient water quality. Therefore, the recommendation by stakeholders is to proceed with these projects as a priority along with implementation of other projects as funding becomes available and bacteria sources can be pinpointed. The City of Boerne also made a major commitment toward improving water quality in UCC by initiating construction of the new WWTRC. This significant infrastructure investment is a valuable step toward reducing bacteria and nutrient levels in UCC for decades to come.

Chapter 7. Information and Education Component

To successfully improve water quality conditions throughout the watershed many existing activities, practices and behaviors will need to change or be improved upon. To accomplish this task; residents, tourists, land managers and local decision makers need to be made aware of activities that can both harm and protect local waterways. This chapter focuses on education and outreach activities conducted during the watershed planning process, as well as new and continued activities that are needed for an informed community and achievement of water quality goals.

Watershed Planning Phase Education and Outreach Efforts

Throughout the watershed planning process many forms of outreach and education were used to enhance public understanding of the project and encourage local stakeholder's early and continued participation in selecting, designing and implementing the NPS management strategies that will be implemented throughout the watershed. Stakeholders recognized the importance of education and outreach in the effort to achieve water quality standards and formed a topical Work Group to specifically address the subject. The following events, workshops, trainings and literature resources were used to help create awareness for methods used to reduce NPS pollution within the watershed.

Print Media/ Outreach Literature

Print and electronic media were used to inform the public of local water quality conditions and the WPP process. Local newspapers, newsletters and magazines were routinely used throughout the planning process to distribute information and encourage stakeholder participation. Additional public information articles will be published in the above mentioned media outlets to promote the implementation of management strategies recommended in the UCC WPP.

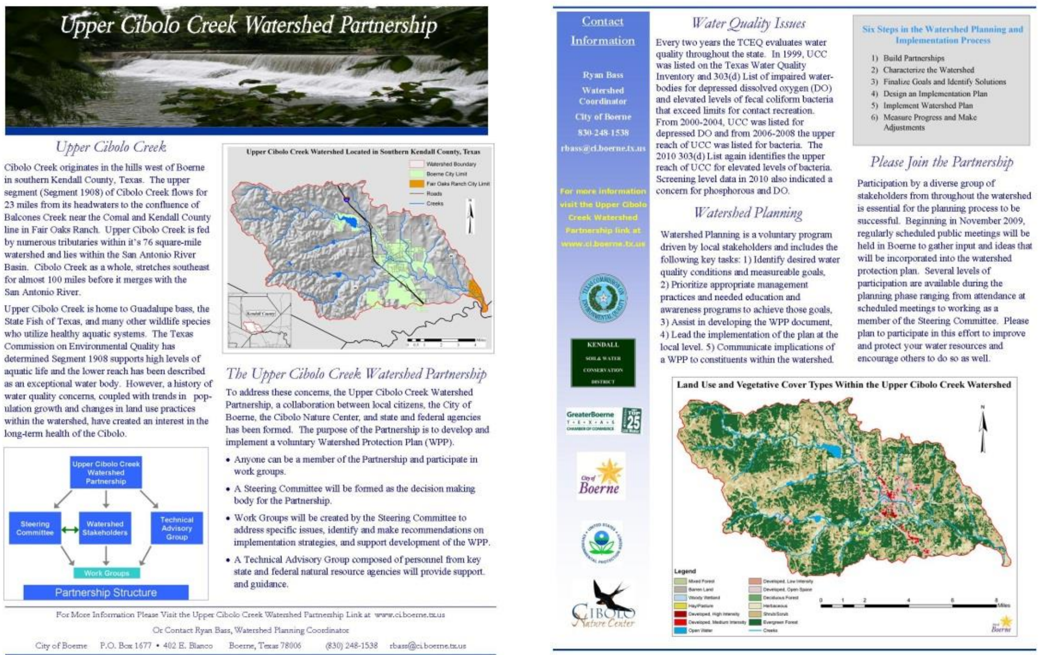
<u>Public Participation Plan</u>

A Public Participation Plan (PPP) (Appendix D) was developed to detail the Partnerships organizational structure and establish ground rules for the group's decision making process. The PPP also outlined the Partnerships protocol for media relations and methods of outreach and education. The PPP can be referenced at the project website found at www.ci.boerne.tx.us.

<u>Factsheets</u>

As a tool to ensure stakeholders were both engaged and knowledgeable on local water quality conditions a project factsheet was widely distributed throughout the watershed. The factsheets purpose was to familiarize citizens with the watersheds boundaries, the history of water quality impairments and to recruitment stakeholders for the Partnership. The factsheet explains how stakeholders can assist in developing management strategies aimed at improving water quality conditions throughout the watershed.

The project factsheet has been and will continue to be updated as the WPP is implemented and water quality conditions change over time. The City of Boerne also created a Riparian Function factsheet to inform citizens on the importance of riparian areas and the benefits healthy riparian areas provide to aquatic systems.



Upper Cibolo Creek Watershed Partnership Project Factsheet

<u>Project Website</u>

A project webpage is supported and maintained on the City of Boerne website (www.ci.boerne.tx.us). The UCC WPP link contains project related information including maps, factsheets, the PPP and contact information for citizens interested in getting involved with the Partnership. The Partnership will work to develop a stand-alone website dedicated to promoting the implementation of the UCC WPP as well as local and regional conservation efforts. Additionally, project staff will develop and maintain social media outlets in an effort to reach a broader audience regarding news, programs, event and activities occurring within the watershed related the WPP.

Workshops and Events

The City of Boerne sponsored and co-sponsored several workshops, trainings and events to promote land stewardship within the UCC Watershed. Workshops will continue to be utilized throughout the watershed as an education tool to promote health land stewardship practices in an attempt to improve water quality conditions in UCC.

Texas Watershed Steward

The Texas Watershed Steward (TWS) program is a one-day educational workshop designed to improve the quality of Texas' water resources by educating and informing local stakeholders about their watersheds characteristics, potential impairments, and steps that can be taken to help improve and protect water quality in their watershed. The program is sponsored by the Texas AgriLife Extension Service and the Texas State Soil and Water Conservation Board (TSSWCB) and made possible through a Clean Water Act §319(h) grant from the TSSWCB and the U.S. Environmental Protection Agency (EPA). A Texas Watershed Steward program was held at the Boerne Convention and Community Center on March 25, 2010. The training was attended by 48 participants and focused specifically on water quality concerns of the Upper Cibolo Creek Watershed.

Homeowner Maintenance of Aerobic Systems Workshops

In cooperation with the Guadalupe Blanco River Authority (GBRA) and Texas AgriLife Extension, a workshop was held on September 17, 2010 at the Boerne Convention and Community Center on homeowner maintenance of aerobic septic systems. The workshop covered county regulations regarding maintenance schedules, system troubleshooting, system operation and general maintenance techniques to keep the systems operating properly. The workshop quickly reached its 50 person capacity and over 100 individuals were on a waiting list to attend the workshop. Due to its popularity efforts will be made to hold additional Homeowner Maintenance workshops for Kendall County residents.

Local Residents attend a Homeowner Maintenance of Aerobic Septic Systems Workshop in Boerne

Watershed Tour

A watershed tour was provided for stakeholders on June 12, 2010 to improve their understanding of the ecological and hydrological features that make UCC and its watershed unique. The 5 hour tour included presentations by guest speakers on the importance of healthy riparian habitat, local geology, groundwater/surface water interactions, the function of Boerne City Lake as a flood control structure and a visual explanation of sub-watershed boundaries in the headwater reaches of the watershed. The tour was attended by 24 stakeholders. The Partnership plans to hold an additional watershed tour for local decision makers in Kendall County, City of Boerne and Fair Oaks Ranch.

Photo Credits: Kari Tatro

TPWD wildlife biologist Rufus Stephens, geologist Bill Ward and KSWCD board member Dusty Bruns conduct presentations on healthy riparian systems and geologic features of Herff Falls during the UCC Watershed tour

Texas Stream Team Training and Bacteria Snapshot Survey

The Texas Stream Team is a network of trained volunteers and supportive partners who work together to gather information about the natural resources of Texas. Volunteers are trained to collect quality-assured information that can be used to make environmentally sound decisions. The Texas Stream Team is a program of the Meadows Center for Water and the Environment at Texas State University-San Marcos and is administered through a cooperative partnership with the Texas Commission on Environmental Quality (TCEQ) and the Environmental Protection Agency (EPA). On November 10, 2010 thirty-four participants completed a training event held at the Cibolo Nature Center to become volunteer monitors and start collecting water quality data on waterways throughout central Texas.

During December 2010 and January 2011 several newly trained Stream Team volunteer monitors participated in a bacteria snapshot event to identify areas throughout the watershed that contained elevated levels of bacteria.

The snapshot team started on the downstream reach of UCC and worked upstream collecting samples at every accessible location on the Cibolo and its tributaries. The goal of the snapshot was to determine bacteria levels throughout the watershed within a few hours on a specific day.

On three sampling days the team collected and analyzed over 100 samples for *E.coli*. Results of the snapshot identified urban reaches of the Cibolo, specifically areas with abundant numbers of domestic waterfowl as containing elevated levels of bacteria that exceeded state standards for contact recreation. Results of the bacteria snapshot aided in identifying locations for water quality monitoring sites during the watershed planning process.

Photo Credits: Ben Eldredge, Ryan Bass

Participants at the Texas Stream Team Training and the Bacteria Snapshot Project

Storm Drain Labeling

The City of Boerne installed storm drain markers on stormwater drains and sidewalks throughout Boerne city limits. The aluminum makers serve as reminders to the public that stormwater runoff drains to Cibolo Creek and its tributaries. The goal of the labeling program is to prevent individuals from disposing of materials or liquids into storm drains.

Upper Cibolo Watershed Festival and Green Living Fair

In cooperation with TCEQ, the CNC and other private sponsors, the City of Boerne coordinated and hosted a watershed festival to raise awareness for local water quality concerns and regional environmental stewardship. The festival was held at Main Plaza in Boerne on September 17, 2012 at drew an estimated crowd of over 800 people. The event provided booth space for businesses, nonprofit groups and natural resource agencies to showcase their products and information. Guest speakers conducted 30 minute workshops during the event on topics that included organic gardening, rainwater harvesting, watershed protection and local water quality, xeriscaping with native plants and low impact development techniques.

Photo Credit: Ryan Bass

UCC Watershed Festival and Green Living Fair Poster and Festival Vendors

Boerne Independent School District Education Program

The Education and Outreach Work Group identified middle school age children as an important age group to target because erosion and pollution related topics are introduced in science curriculum during these grades. The City of Boerne partnered with the Cow Creek Ground Water Conservation District (CCGCD) and the Boerne Independent School District (BISD) to develop a classroom based education program for 7th grade students. During the 2010 and 2011 school year the program was presented to over 1200 students in Boerne. During the program students watched a short educational film created by CCGCD on the groundwater resources of Kendall County followed by a presentation on water conservation techniques. Students were next led through a discussion on how watersheds function, local water quality impairments and sources of bacteria within the watershed. To further explain the watershed concept and how point source and NPS pollution can impact surface waters the students worked through a series of pollution scenarios using an EnviroScape Watershed Model.

To promote the use of local information on watersheds and water quality concerns in the classroom, BISD science teachers were presented watershed related education materials during the 2011 in-service training. Teachers were updated on existing watershed conditions, information on the watershed planning process and how material covered in the BISD science curriculum can be enhanced using local watersheds as real world examples.

Natural Resource Interpretative Signs

During the watershed planning process the City of Boerne initiated construction on the Patrick Heath Public Library. The Library achieved a Leadership in Energy Efficient Design (LEED) Gold Certification for its construction and uses several low impact development techniques in managing stormwater on the property.

Using grant funds and technical support from the GBRA, an outdoor natural resource interpretative area was created that prominently displays signs on the topics of local watersheds and river basins, groundwater, the water cycle, cultural heritage and local wildlife. The library also has a large rainwater catchment system that demonstrates how rainwater can be used for landscape irrigation. The GBRA also funded a digital kiosk where users can navigate with a touch screen through surface and groundwater related material as well as information on the topics listed above. Each screen on the kiosk contains links to agency websites and Wikipedia pages on relevant pre-programed subject matter.

Photo Credit: Pamela Bransford

City of Boerne Mayor Mike Schultz and Bill West General Manager of the, GBRA Participate in a Ribbon Cutting Event for the GBRA Interpretative Displays at the Patrick Heath Public Library

Implementation Phase Targeted Education and Outreach Efforts

Field Guide to the Upper Cibolo Creek Watershed

A "Field Guide to the Upper Cibolo Creek Watershed" has been developed as an outreach tool for local residents. The field guide includes a wide variety of information on the natural resources found within the watershed and best management practices (BMP) that can be used to have a positive impact on the environment. Specifically, the document promotes both urban and rural stewardship practices that have a beneficial impact on the ecology and water quality of UCC and its watershed. The document will be made available to local real estate agents with the intent of distribution to new homeowners within the watershed.

The guide will also be available digitally in portable document format and will be distributed through electronic mail, on partner websites and compact disk. The City of Boerne will seek funding to provide additional print copies for distribution throughout the watershed.

Low Impact Development Guidance Document

Stakeholders were presented with Low Impact Development (LID) techniques as a potential management strategy that could be used to improve overall stormwater quality. Stakeholders realize that LID is a technique that when/where possible can and should be utilized within the watershed. However, it became apparent that LID would be difficult to use when trying to target specific pollutant sources identified in the WPP and SWAT model. Major challenges to LID being included as a targeted strategy include: 1) difficulty predicting future development sites 2) unknown size, scope and initiation of potential projects and 3) landowner's, developers and engineers ability/willingness to finance and incorporate LID into new designs or retrofit existing stormwater management systems. These reasons coupled with the unpredictable nature of residential and commercial development trends resulted in stakeholders omitting LID as a strategy to target identified sources of pollution in the SWAT model. However, Stakeholders do recommend LID practices be utilized whenever possible on new construction and retrofit projects. To accomplish this, stakeholders suggest promoting LID techniques through outreach and education activities.

The CCGCD has partnered with the Greater Edwards Aquifer Alliance (GEAA), TCEQ, EPA, and the City of Boerne to develop a LID manual and educational video series for Kendall County. The UCC Watershed will be featured in the project because of its ongoing watershed planning efforts. The LID manual and videos will primarily focus on best practices for managing stormwater on new and existing commercial and residential developments as well as general water conservation practices and aquifer protection. The project will serve as reference material for anyone involved with the construction or maintenance of stormwater management features in an effort to improve the quality of runoff before it reenters an aquifer system. Future stormwater management workshops will utilize the manual as supporting material and be made available to local contractors, developers and engineers. The manual will be available digitally in portable document format and will be distributed through electronic mail, on partner websites and compact disk

Green Living Fair

The Partnership will continue to support the City of Boerne in the Annual Green Living Fair held during September at the Main Plaza in Boerne. The fair promotes energy and water conservation efforts throughout the region and allows businesses specializing in "green" products to set up booths as vendors at the event. The fair also features local natural resource conservation agencies providing a venue to promote their services.

Boerne Independent School District Education Program

The City of Boerne will continue its collaboration with the CCGCD to conduct an annual in-class education program to Boerne 7th graders. The program will focus on local water quality and quantity issues within the watershed and ways the students can protect and conserve water.

Domestic Waterfowl Management Program

A targeted outreach and education program will be used to support the City of Boerne's efforts to implement a domestic waterfowl management program. Information will be included on signs located at River Road Park that will describe the negative impacts of releasing and feeding waterfowl at the park. A public information program will be initiated throughout Boerne discouraging the feeding of waterfowl. Literature will be included in city utility bills and articles will be provided to local newspapers.

Pet Waste Management

The City of Boerne will develop educational material to inform residents of the effect pet waste can have on local water quality and encourage proper disposal of pet waste. The City will also maintain nine pet waste stations throughout city parks and trails. Due to the high concentration of dogs within urban areas, stakeholders have recommended that outreach efforts focus on pet waste removal in urban areas, including public spaces and urban residential units.

Creek Cleanup Events

Keep Boerne Beautiful is a local chapter of the Keep Texas Beautiful, a nonprofit organization dedicated to reducing litter in the state of Texas. Keep Boerne Beautiful holds annual litter clean-up events in Boerne where volunteers form into groups and are assigned specific locations to collect litter.

The Partnership will form a group to collect litter from creeks within the watershed during this event. All trash collected from UCC and its tributaries will be placed in a visible area at the event along with outreach material to generate awareness for watershed protection and the effects of litter on water quality.

Household Hazardous Waste Collection

Hazardous Household Waste (HHW) collection events provide residents with an opportunity to properly dispose of hazardous chemicals. It is common for HHW, including fertilizers, to be improperly disposed of and potentially enter local waterways through stormwater runoff. In addition to items that could impact existing nutrient and bacteria concerns, collection events provide an easy and safe method for the proper disposal of more harmful products such as pesticides, herbicides and insecticides. The City of Boerne will seek funding to operate or supplement the cost associated with a HHW collection event.

Homeowner Maintenance of Aerobic Septic Systems

Workshops on the maintenance of aerobic septic systems are important for rural residents within Kendall County. The workshops provide residents who utilize septic systems the basic knowledge of system operations and proper maintenance techniques. The workshops are especially useful for first time septic system owners. Participants who attend the workshops reduce the chances for system malfunctions and surface water contamination within the watershed. The City of Boerne will seek funding to host additional septic system maintenance workshops.

Promotion of GBRA Online Training Modules

Texas AgriLife Extension, Texas State Soil and Water Conservation Board and the GBRA partnered to develop and promote online modules that include information on Septic Systems, Fats, Oils, and Grease, and Stormwater Management. The City of Boerne will promote the use of these online training tools through links on the project website and social media outlets.

Homeowner Yard Care Workshops

Fertilizer is often applied to residential lawns according to recommendations on the product label. Oftentimes the application occurs without individuals knowing the nutrient content of the soil and this can lead to an over application of the product. Excess nutrients not utilized by vegetation are typically washed off during rainfall events and carried to local waterways in stormwater runoff.

Elevated levels of nutrients in local waterways can have harmful effects on water quality. The City of Boerne will seek funding to host a homeowner yard care workshop that will guide homeowners through the soil testing process, how to interpret soil test results, and proper timing and application of fertilizer. The workshop will also promote composting, rain water harvesting, and xeriscaping.

Turf Grass Management Workshops

A refresher course will be offered for turf grass managers within the watershed on proper fertilization techniques and water requirements. The course will target individuals who manage athletic fields, golf courses as well as professional lawn care maintenance personnel. The City of Boerne will seek funds to offer the course for free of for a reduced rate.

Soil Testing Events for Watershed Residents

The City of Boerne will seek funding to conduct a free of charge or reduced cost soil testing event for watershed residents. The Partnership website will promote the use of Texas AgriLife Extensions soil testing services and the use of their online fertilizer calculator to assist in the proper application rates for fertilizer on residential lawns. The online calculator assists individuals in interpreting soil test results and determining the proper type and application rate for fertilizers.

Livestock Grazing Management Workshops

The City of Boerne will work with Texas AgriLife Extension, the NRCS and the Kendall Soil and Water Conservation District to organize and host a Livestock Grazing Management Workshop for watershed landowners. The workshop will focus on both large and small acreage grazing management techniques.

Streamside Management Workshops

The City of Boerne will work with the NRCS and the CNC to organize and host a Streamside Management Workshop for anyone interested in the benefits of healthy riparian areas. The workshop will focus on both urban and rural streamside management with a focus on maintaining healthy riparian buffers.

Feral Hog Management Workshops

Stakeholders indicated throughout the planning process that feral hogs were a problem within the watershed and requested assistance with controlling hog populations within the watershed. The City of Boerne will seek funding to organize and host a feral hog management workshop that will provide landowners with the knowledge, skills and ability to help remove hogs from the watershed.

Photo Credit: Ryan Bass

City of Boerne sponsored invasive species removal and creek clean-up project on Cibolo Creek

Chapter 8. Project Implementation

Schedule for Implementation and Measureable Milestones

Table 8-1 details the schedule and estimated costs associated with the implementation of management strategies recommended in this plan. Figures 8-2 through 8-4 display the incremental reduction in bacteria loads that could be realized over time from the coordinated, cumulative implementation of modeled management strategies discussed in Chapter 5. These graphs do not include management strategies targeted for TP reductions: filter strips in urban watersheds and reduction of fertilizer applications on residential/commercial lawns.

As previously discussed, the figures show that urban water fowl and cliff swallows have the greatest potential for bacteria load reductions and improvement of instream EC concentrations. These graphs assume there is a commitment to implement all management strategies modeled across all subwatersheds. Additional pollutant load reductions can be expected from implementation of recommended practices/activities that were not modeled (e.g., LID, outreach and education events, workshops, trainings, local and social media) which focus on stewardship of surface water resources across the UCC Watershed.

The incremental reduction in bacteria loads is compared each year to the instream loading goal (orange bar) that is targeted at each index station on reaches 8, 17 and 21 (Figure 9-1). These graphs also display the importance of developing performance measures to evaluate water quality improvements over time, which are necessary to guide decision making under an adaptive management approach.

Photo Credit: Ryan Bass

Cliff swallows nesting over UCC at IH-10 bridges

Table 8-1. Implementation schedule and associated costs for management strategies, education and outreach and long-term water quality monitoring program

Management Measure	Responsible Party	Unit Cost	Number Implemented			Total Cost
			Years			
			1-3	4-6	7-10	
Wildlife						
Cliff Swallow Nest Deterrents	City of Boerne TXDOT	$223,000 for design and installation	1	—	—	$223,000
Urban Waterfowl Management	COB	Year 1: $3,459 Year 2-10: $3,224/yr.	Relocate 200+	Maintain pop at 100 +/-	Maintain pop at 100 +/-	$32,475
Feral Hog Management County Trapper	USDA TWDMS	$50,000/yr.	3	2	—	$250,000
Feral Hog	TX AgriLife TWDS	$5,000/yr.	3	2		$25,000
Feral Hog Management Trapping Supplies	Landowners Texas Wildlife Services	$5,000 2014 and 2018	1	1	—	$10,000
Feral Hog Management Feeder Exclusions	Landowners	$244 per feeder	50	—	—	$12,200
Deer Management	Landowners	$55,100/year for planning, permits, hunting, trapping to Reduce pop by 4,265 over 10 yrs.	3	3	4	551,000
Agriculture						
Conservation Plans	Landowners, Ranchers	$7 per acre for planning assistance	1100 ac	1100ac	—	$15,400
Urban / Residential						
Pet Waste Management	COB	3 Installs in year 1 at $300 per unit $100 annual maintenance/ unit,	9	9	9	$5,370
OSSF Strategies: Evaluations, Documentation, Replace, Repair Failing Systems	Kendall County & COB to identify and facilitate repairs or replacement. Property owners will finance.	Goal: replace 5 failing systems in each subwatershed (150 total) Approximately $10,000 per unit	25	50	75	$1.5 million
WWTRC Construction	COB	$28 Million	1	—	—	$28 Million
WWTRC Sewer Pipeline Installations	COB	$3.5 Million	—	—	1	$3.5 Million
HHW Collection	COB, Kendall Co	$15,000	1	1	—	$30,000

Table 8-1. Implementation schedule and associated costs for management strategies, education and outreach and long-term water quality monitoring program (continued)

Management Measure	Responsible Party	Unit Cost	Number Implemented			Total Cost
			Years			
			1-3	4-6	7-10	
Outreach and Education						
Trainings, Festival Workshops, Media, Newsletter, BISD Education Program, Literature Creation and Distribution, Website	COB	$59,500	1	-	-	59,500
Water Quality Monitoring						
Sampling and Analysis	COB	$72,957	1	-	-	$72,957

Criteria used to determine if load reductions are being achieved

Water quality conditions within UCC have historically been measured against Surface Water Quality Standards established by TCEQ. Stakeholders recommended that these same standards be used as criteria to determine if implemented management strategies improve water quality conditions over time. With a primary focus on reducing bacteria loads, the WPP will use state standards for *E.coli* as a benchmark to monitor changes and evaluate the success of local watershed planning efforts. However, stakeholders are acutely aware that Segment 1908 has been identified as a concern for nutrients. Until standards are developed for instream nutrient concentrations, stakeholders have agreed to use the numeric values associated with screening criteria as a pro-active goal for nutrients. These criteria will determine if further planning actions are needed over time should management strategies not perform as expected. Specifically, stakeholders wish to see water quality goals meet the following criteria:

<u>Standards</u>

- E. coli bacteria: Geometric Mean: 126 colonies #/100ml
- Dissolved Oxygen: 5.0 mg/L
- Temperature: 90°F (32.2°C)
- pH Range (SU): 6.5 - 9 mg/L

<u>Screening Levels</u>

- Ammonia Nitrogen: 0.33 milligrams per liter (mg/L)
- Nitrate Nitrogen: 1.95 mg/L
- Ortho Phosphorus: 0.37 mg/L
- Total Phosphorus: 0.69 mg/L

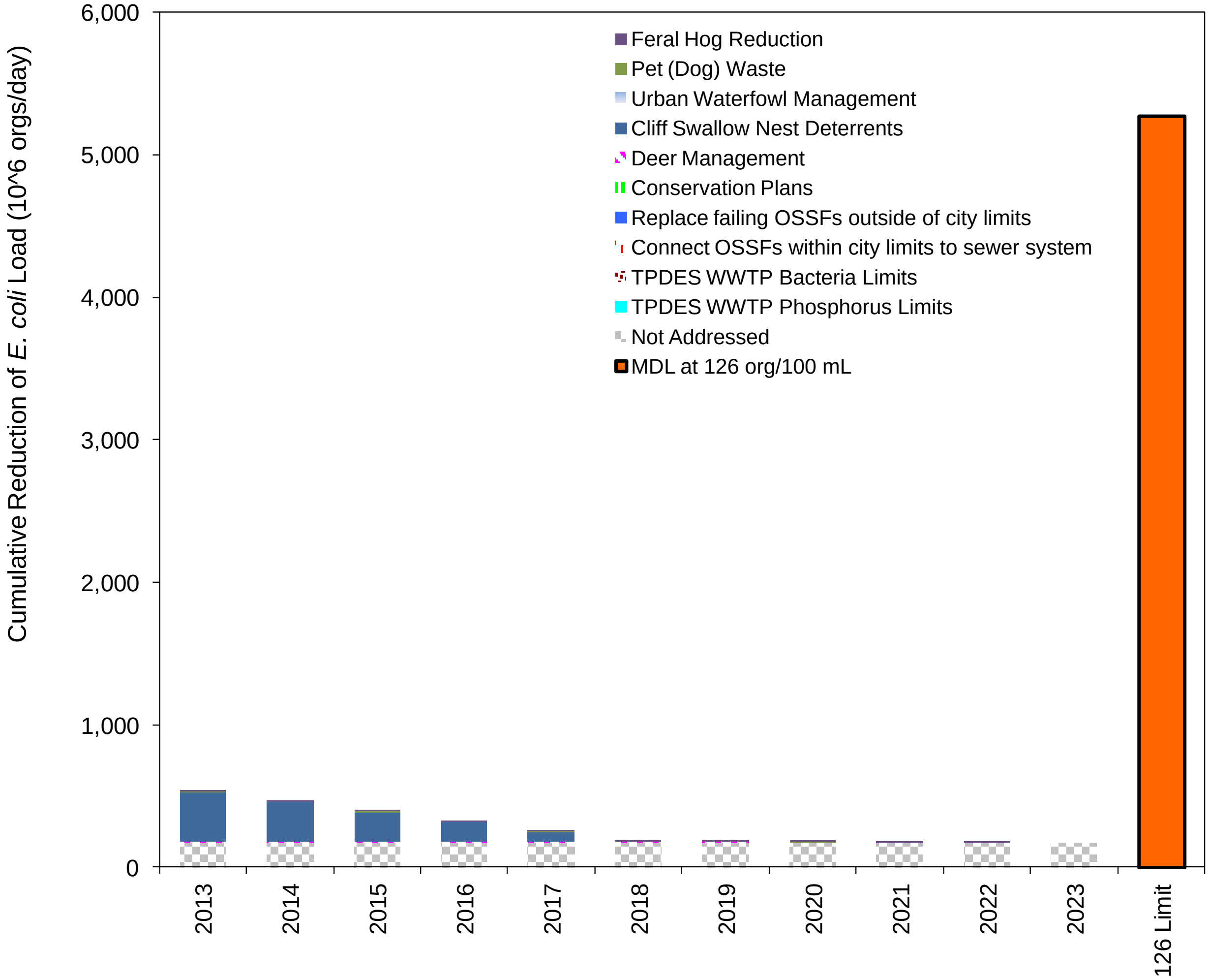


Figure 8-1. Cumulative reductions of *E.coli* loads over time for Reach 8 by management strategy

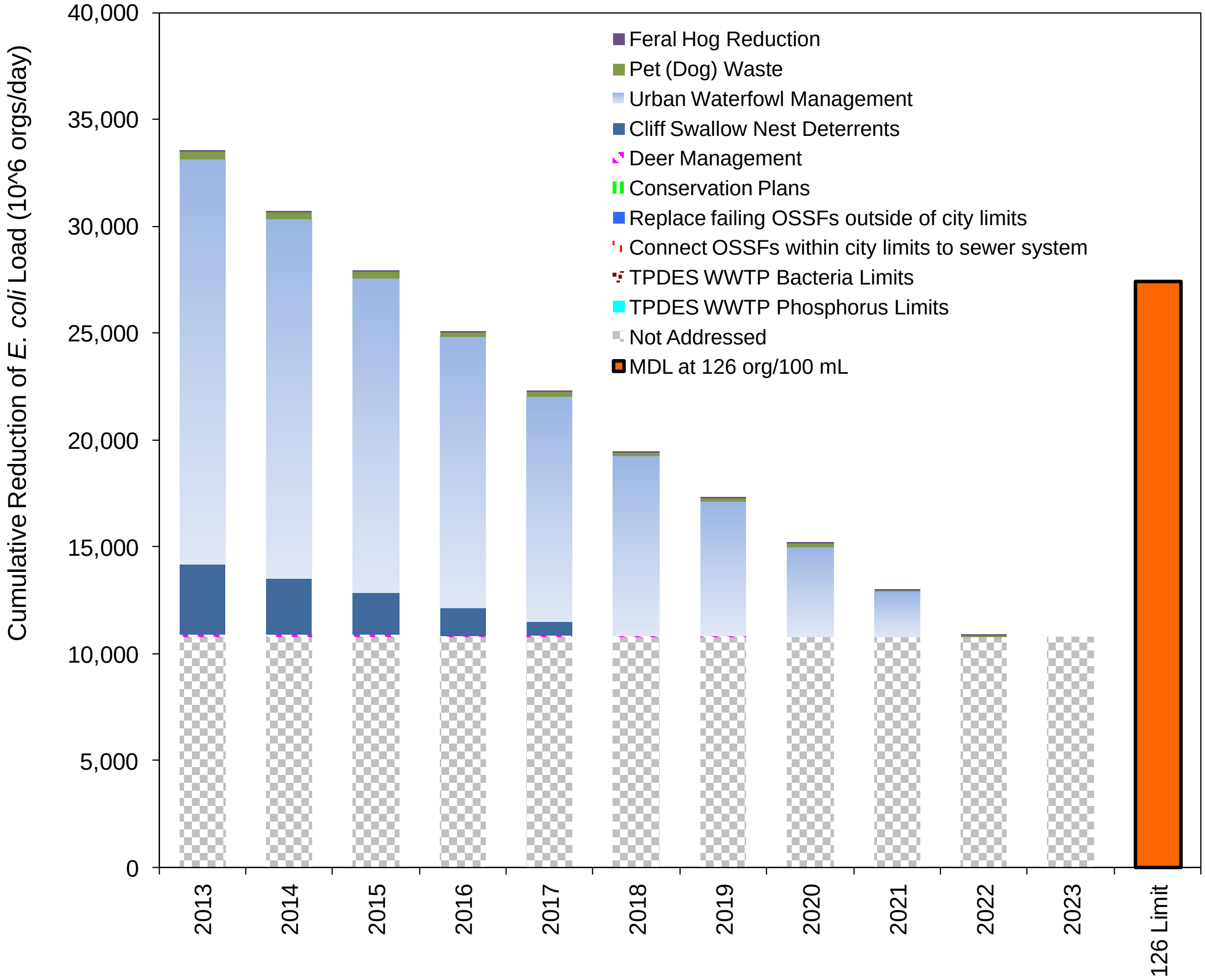


Figure 8-2. Cumulative reductions of *E.coli* loads over time for Reach 17 by management strategy

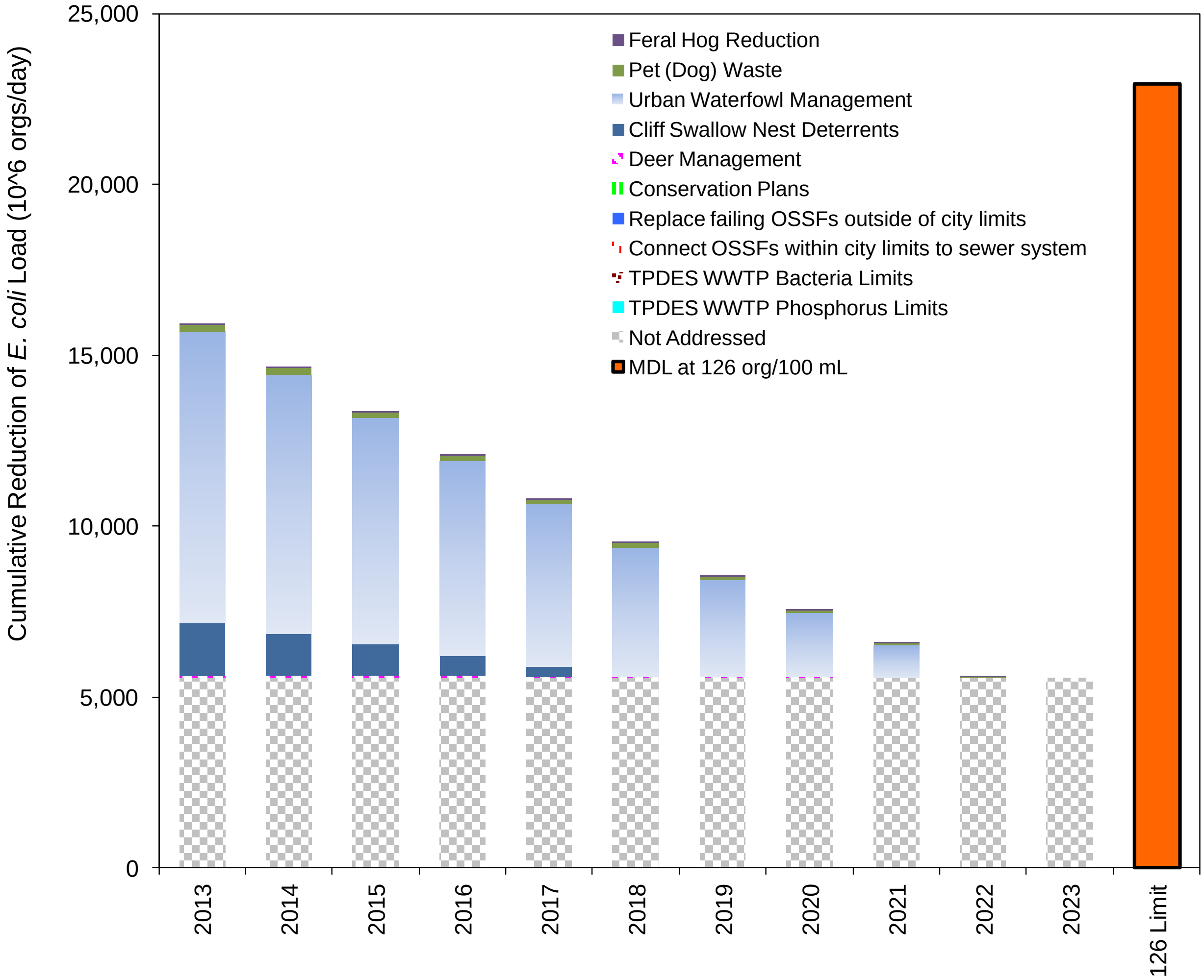


Figure 8-3. Cumulative reductions of *E.coli* loads over time for Reach 21 by management strategy

Adaptive Management

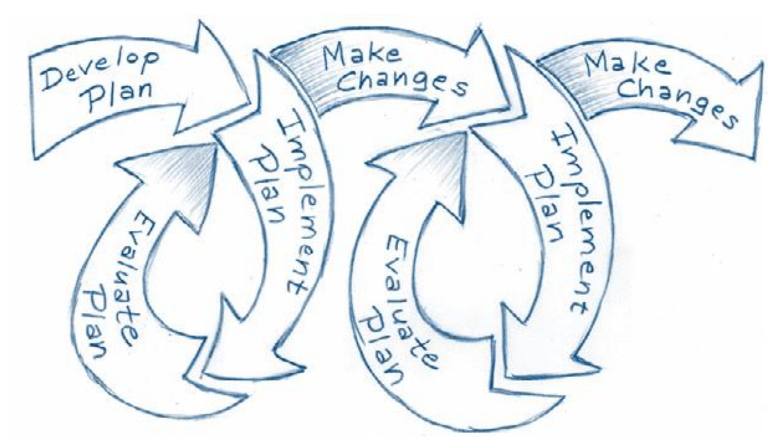
Watershed protection plans are most effective when the outcomes of implementation efforts are evaluated over time. The restoration of impaired waterbodies revolves around a system of planning, implementation, evaluation and adaptation to changes within the watershed. This system drives an adaptive management approach by providing a mechanism to reevaluate implementation plans should substantial progress toward meeting watershed goals not occur.

Specific emphasis should be placed on collecting more data and periodically using the SWAT modeling tools to evaluate progress of pollutant load reductions. Data will be used to look at water quality trends over time to evaluate conditions pre and post implementation of management strategies. Reevaluations should occur at key periods over the estimated 10-year implementation period. This will allow the Partnership to adjust implementation strategies should water quality impairments persist throughout the watershed.

To summarize the temporal relationship between the investment of financial resources and the cumulative effect of implementing BMPs concurrently, Table 8-5 presents the potential progression of water quality improvements by displaying reductions in EC concentrations at the three water quality index stations (Figures 9-1) and will be used as interim goals for the WPP. Table 8-5 provides interim milestones that can be tracked over time to demonstrate the effectiveness of implementation efforts occurring throughout the watershed. Water quality standards can ultimately be attained and Table 8-5 provides an estimated year for realizing this goal at the

Table 8-2. Interim *E. coli* geometric mean concentration (cfu/ml) targets for evaluating pollutant load reductions over time and guiding the adaptive management approach.

Year	Reach 8	Reach 17	Reach 21	Standard
2013	71	**154**	87	126
2014	62	**136**	78	126
2015	52	**119**	68	126
2016	43	102	58	126
2017	34	84	48	126
2018	25	67	38	126
2019	25	54	31	126
2020	25	41	24	126
2021	24	28	16	126
2022	24	15	9	126
2023	24	15	8	126



Two different data analysis methods were needed to assess the performance of the SWAT model to predict outcomes and to estimate or predict the level of reduction achieved from proposed management strategies. The first method was to compare actual field data collected to simulation data, known as a calibration. Because the model simulation can provide thousands of data points (concentration and flow) for a single location, as compared to a few dozen samples (concentration only) taken in the field, a filtering process was used to match the simulation data to the days of actual sample data. Once the filtering was complete, the geometric mean for both the measured sample data and filtered simulated data can be compared. This comparison is useful to determine how well the model is performing. In theory, if the model is perfect there would be no difference between the two numbers.

After the model is calibrated, it is ready to make predictions on what-if scenarios. Again, a comparison of geometric means is made (before and after inclusion of each strategy), to determine if there is a pollutant load reduction effect from a given project. However, to make use of the entire simulation dataset, no filtering was applied to allow the inclusion of low flow conditions which the SWAT model can provide. The inclusion of the entire data set from the model represents more typical average conditions because a much broader range of flow can be considered that was not characterized with field sampling. Thus, it is possible for model simulation outcomes to result in different concentrations than that measured in the field. This difference is possible because a simulation can account for flow conditions that are difficult to sample in the field: low flow because there is insufficient amount of water to collect samples and high flows because of the danger of collecting a sample. For this project, the reliance on measured data may be biased towards higher flow conditions since few low flow conditions were captured in the limited sample set available. This selection of flow conditions skews the measured data set towards higher flow conditions, which coincide with higher concentrations of bacteria. These characteristics are manifested in EC concentration values provided in Table 8-6 and Figure 8-5.

To provide the greatest amount of information for decision making, this project used a filtering process to allow an apples-to-apples comparison of calibration data to simulation outcomes and no filtering of low flow conditions to asses future BMP so as to:

1) Maximize the use of the data

2) Improve statistical strength derived from longer period of record

3) Account for a broad range of flow conditions.

It is possible to have measureable difference between filtered and non-filtered data. This is particularly so in Reach 8, as it had few water quality samples, a wide range of concentrations, and very low flows.

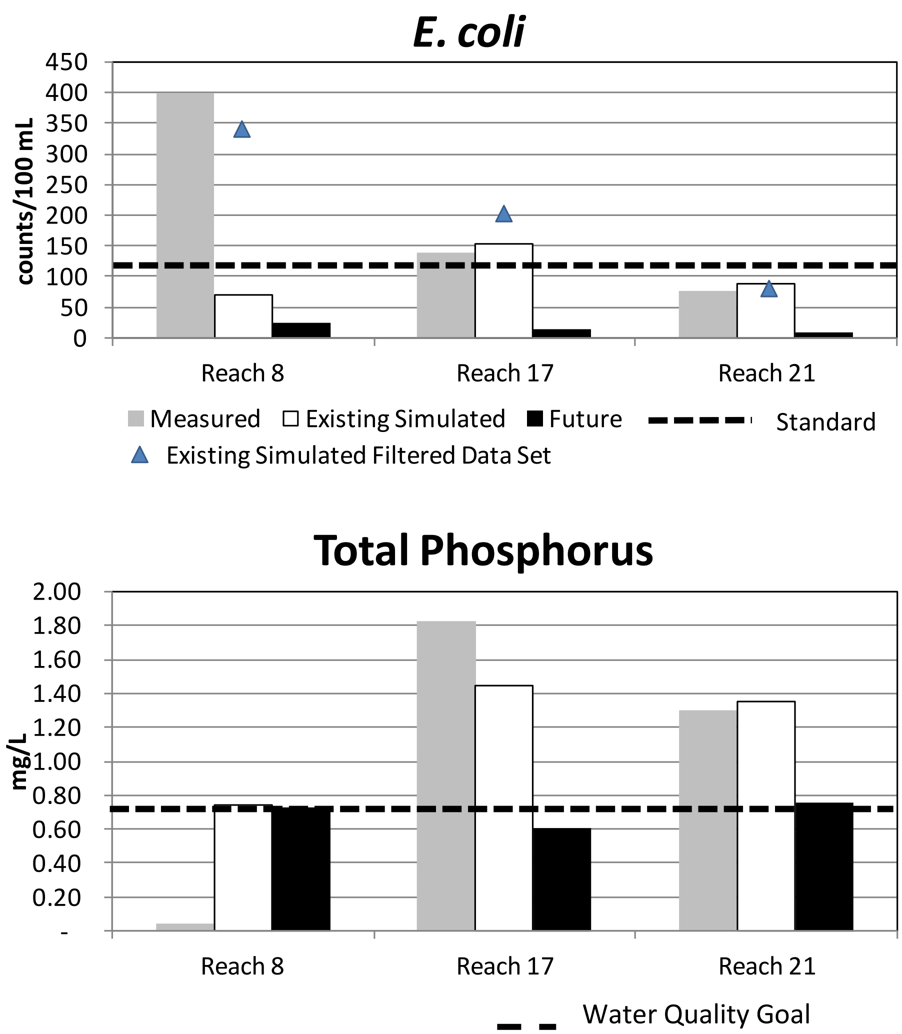


Figure 8-4. Potential Future Water Quality Conditions for *E.coli* and Total Phosphorus

Table 8-3. Potential future water quality conditions for *E.coli* and Total Phosphorus

Concentration		**Reach 8**	**Reach 17**	**Reach 21**
Total Phosphorus (mg/L)	**Measured**	0.04	1.83	1.30
	Existing Simulated	0.74	1.44	1.35
	Future	0.73	0.61	0.76
	WQ Goal	0.69	0.69	0.69
***E. coli* (counts/100 mL)**	**Measured**	399	140	76
	Existing Simulated	71	154	87
	Future	24	15	8
	WQ Standard	126	126	126
Loads[1]				
Total Phosphorus (kg/d)	**Measured**	na	na	na
	Existing Simulated	9.21	31.85	22.76
	Future	9.07	27.40	19.68
	Maximum Daily Load	6.30	25.91	15.60
***E. coli* (10^6 counts/day)**	**Measured**	na	na	na
	Existing Simulated	480	33,520	15,926
	Future	34	3,260	1,657
	Maximum Daily Load	5,274	27,467	22,949

1 = A loading estimate (counts/day) is a product of flow (cubic meters per second [cms]) and concentration (counts/100 mL). Because field samples are taken when flow exists, the load calculation only considers instances when there was measurable flow (flow > 0 cms).

Chapter 9. Water Quality Monitoring to Evaluate Effectiveness

Stakeholder objectives for the WPP are to reduce *E.coli* loads throughout the watershed and work to ensure UCC is compliant with Texas Surface Water Quality Standards. To examine changes in water quality conditions throughout the watershed, a long-term monitoring program has been developed to evaluate the effectiveness of management strategy implementation efforts. Monitoring sites were strategically located to determine if targeted strategies have beneficial impacts on water quality conditions and to further investigate nutrient concerns that have been identified within the watershed (Figure 9-1). The spatial distribution of monitoring sites will allow the City of Boerne to gather data that accurately represents watershed conditions over time. The City of Boerne will lead the long-term monitoring program and collect data under a TCEQ approved Quality Assurance Project Plan (QAPP). The monitoring program will include routine sampling of Field Parameters, Priority Parameters and Stormwater Parameters (Table 9.1, 9.2) The City of Boerne will collect samples quarterly at 6 sites on UCC and 3 sites on Frederick Creek. An automated ISCO sampler will be maintained at the USGS gage 08183890 (station 12855) located at the Cibolo Nature Center. The automated sampler will be utilized in an attempt to sample a minimum of 3 stormwater events per year. Samples will be analyzed at the San Antonio River Authority's Environmental Laboratory and results will be submitted quarterly to TCEQ's Surface Water Quality Monitoring Information System. The combination of routine and stormwater sampling will fill data gaps regarding water quality at varied hydrologic flow conditions.

Monitoring sites located in subwatersheds 8, 17 and 21 will be used to determine if the WPP is effective at reducing NPS pollution and if water quality conditions are improving throughout the watershed (Figure 9.1). Referred to as index sites, these locations were chosen based on their proximity to identified pollutant sources and location of targeted management strategies. Bacteria "benchmarks" determined by SWAT model outputs will be used as milestones to evaluate implementation efforts (Table 9.3). These benchmarks represent the geomean of EC concentrations. The overall geomean for each site will be used for evaluation purposes. However, data will be evaluated temporally to better understand season impacts on water quality conditions

As part of an Adaptive Management approach to the WPP, the City of Boerne will facilitate annual monitoring reviews to ensure efforts to improve water quality conditions are being realized over time. During these reviews, stakeholders will be presented with implementation updates and sampling results. The overall WPP, recommended management strategies and long-term monitoring plan will be re-evaluated every 3 years (2014, 2017, 2020 and 2023). The monitoring plan is adaptive and adjustment may be necessary in response to changes in land use. Management strategies outlined in the WPP will be adjusted should stakeholders feel that progress is not being made towards achieving water quality goals (page 109).

Table 9-1. Long-term water quality monitoring parameters for routine sampling and automated stormwater data collection.

Field Parameters		***Priority Parameters***		***Stormwater Parameters***	
Parameter	**Units**	**Parameter**	**Units**	**Parameter**	**Units**
pH	S.U.	Residue, Total Non-Filterable (TSS)	mg/L	Residue, Total Non-Filterable (TSS)	mg/L
DO	mg/L	E. coli, IDEXX Colilert	MPN/100 mL	E. coli, IDEXX Colilert	MPN/100 mL
Specific Conductance	µS/cm	holding time, E. coli, IDEXX Colilert[8]	hours	holding time, E. coli, IDEXX Colilert	hours
Temperature	° C	Ammonia-N, total (non distilled)	mg/L	Ammonia-N, total (non distilled)	mg/L
Transparency Secchi Disk	meters	Total Kjeldahl N	mg/L	Total Kjeldahl N	mg/L
Days since precipitation event	days	Total Phosphorus - P	mg/L	Total Phosphorus - P	mg/L
Estimated Flow	cfs	O-phosphate-P, field filter <15 min.	mg/L	O-phosphate-P, field filter <15 min.	mg/L
Flow measurement method	1. Gage 2. Electric 3. Mechanical 4. Weir/Flume 5. Doppler	Chlorophyll a	µg/L		
Flow severity	1. No Flow 2. Low 3. Normal 4. Flood 5. High 6. Dry	Pheophytin-a	µg/L		
Water Color	1. Brown 2. Reddish 3. Green 4. Black 5. Clear 6. Other				
Water Odor	1. Sewage 2. Oily/chemical 3. H2S 4. Musky 5. Fishy 6. None 7. Other				
Present Weather	1. Clear 2. Partly Cloudy 3. Cloudy 4. Rain 5. Other				

Table 9-2. Long-term monitoring sites used to determine effectiveness of management strategies

Waterbody	SWQMIS Site Number	Location	Subwatershed (Figure 9-1)	Parameters (Table 9-1)	Frequency
UCC	12853	Cibolo Preserve	24	Field, Priority	Quarterly
UCC	12855	CNC	21*	Field, Priority, Storm	Quarterly, Storm Events
UCC	20823	Duck Pond	17*	Field, Priority	Quarterly
Frederick Cr.	20822	Graham Street	13	Field, Priority	Quarterly
Frederick Cr.	New Site: FC1	Below IH-10	20	Field, Priority	Quarterly
Frederick Cr.	New Site: FC2	Above IH-10	20	Field, Priority	Quarterly
UCC	12857	Below IH-10	8*	Field, Priority	Quarterly
UCC	New Site: UC1	Above IH-10	8	Field, Priority	Quarterly
UCC	20830	Sparkling Springs	5	Field, Priority	Quarterly

** Index site used to evaluate the effectiveness of the implementation strategies described in the WPP*

Table 9-3. Bacteria targets (concentration geomean) at index sites to evaluate the effectiveness of implementation efforts. Evaluations will occur every 3 years throughout the 10 year implementation period.

Year	*Reach 8 (Station 12857)*	*Reach 17 (Station 20823)*	*Reach 21 (Station 12853)*
2014	62	136	78
2017	34	84	48
2020	25	41	24
2023	24	15	8

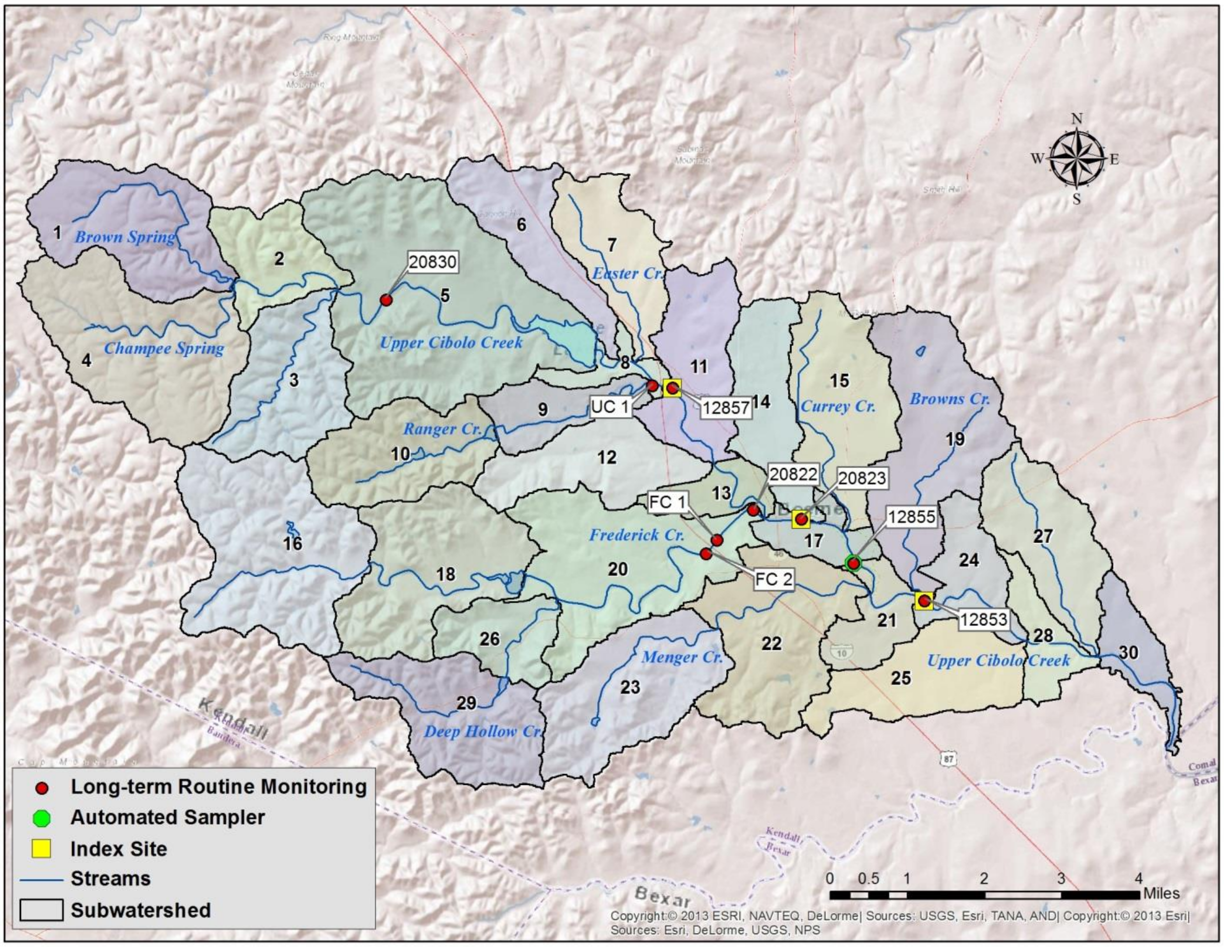


Figure 9-1. Long-term water quality monitoring sites within the UCC Watershed.

Photo Credit: Ryan Bass

City of Boerne Automated stormwater sampler and USGS flow gage located at the Cibolo Nature Center

LIST OF ACCRONYMS

ALM	Aquatic Life Monitoring
ALU	Aquatic Life Use
BISD	Boerne Independent School District
BMP	Best Management Practice
CBOD	Carbonaceous Biological Oxygen Demand
CCGCD	Cow Creek Groundwater Conservation District
Cl	Chloride
CNC	Cibolo Nature Center
C^{o}	Degrees Centigrade
COB	City of Boerne
DO	Dissolved Oxygen
DSS	Decision Support System
EC	Escherichia *coli* bacteria
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FOG	Fats, Oils, Grease
GBRA	Guadalupe Blanco River Authority
HHW	Hazardous Household Waste
HRU	Hydrologic Response Unit
IH-10	Interstate Highway 10
Kg	Kilogram
LEED	Leadership in Energy Efficient Design
LID	Low Impact Development
LIP	Landowner Incentive Program
m	meter

mg/L	Milligrams per Liter
ml	Milliliters
MSL	Mean Sea Level
NASS	National Agricultural Statistics Survey
NED	National Elevation Dataset
NH_3-N	Ammonia Nitrogen
NOAA	National Oceanic and Atmospheric Administration
NO_3-N	Nitrate + Nitrite Nitrogen
NPS	Nonpoint Source
NPSOT	Native Plant Society of Texas
NRCS	Natural Resource Conservation Service
NSE	Nash Sutcliff Efficiency
OrgN	Organic Nitrogen
OrgP	Organic Phosphorus
OSSF	On-Site Sewer System
PPP	Public Participation Plan
r^2	Coefficient of Determination
S.U.	pH Range
SARA	San Antonio River Authority
SAWS	San Antonio Water System
SO	Sulfate
SWAT	Soil and Water Assessment Tool
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPDES	Texas Pollutant Discharge Elimination System

TPWD	Texas Parks and Wildlife Department
TSS	Total Suspended Solids
TSSWCB	Texas State Soil and Water Conservation Board
TWS	Texas Watershed Steward
TXDOT	Texas department of Transportation
UCC	Upper Cibolo Creek
UCCW	Upper Cibolo Creek Watershed
USDA	United States Department of Agriculture
USDA-RD	United States Department of Agriculture – Rural Development
USGS	United States Geological Survey
WHIP	Wildlife Habitat Incentive Program
WLE	Waste Load Evaluation
WMA	Wildlife Management Association
WPP	Watershed Protection Plan
WS	Wildlife Services
WWTF	Wastewater Treatment Facility
WWTRC	Wastewater Treatment and Recycling Center
µg/L	Micrograms per Liter

LITERATURE CITED

American Veterinary Medical Association. 2002. U.S. Pet Ownership and Demographics Sourcebook (2002 Edition). Schaumberg, IL.

ASAE (American Society of Agricultural Engineers). 1998. ASAE Standards, 45th Edition: Standards, Engineering Practices, Data. St. Joseph, MI.

Baker, LA, D Hope, Y Xu, J Edmonds, and L. Lauver. 2001. Nitrogen Balance for the Central Arizona – Phoenix (CAP) Ecosystem. *Ecosystems* 4: 582-602.

Barrett, M. 2011. Sources and Persistence of *E. coli* in Inland Texas Streams. Presentation to the Texas Watershed Coordinator's Roundtable, July 27, 2011. Online available http://watershedplanning.tamu.edu/developing/roundtable/ [Accessed June 27, 2012].

Brooks, K.N., P.F. Ffolliott, H.M. Gregersen, and J.L. Thames. 2003. *Hydrology and the Management of Watersheds.* Iowa State Press, Ames, IA.

Chalmers and McAfee. 2007. Lawn Fertilization for Texas Warm-Season Grasses. Publication E-437. Texas Agrilife Extension. Texas A&M University System. College Station, TX. Online available http://Agrilifebookstore.org/ [Accessed August 21, 2012].

City of Boerne. 2011. Upper Cibolo Creek Watershed Characterization. January 31, 2011.

Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1988. The Birder's Handbook: A Field Guide to the Natural History of North American Birds. Simon & Schuster, New York, NY.

EPA. 2000. Bacterial Indicator Tool; User Guide. EPA-823-B-01-003. Office of Water. Washington, DC. March 2000.

Gassman, P.W., M.R. Reyes, C.H. Green, and J.G. Arnold. 2007. The Soil and Water Assessment Tool: Historical Development, Applications, and Future Research Directions. *Trans. ASABE* 50(4):1211-1250.

Griffith, G.E., S.B. Bryce, J.M. Omernik, and A. Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality. Austin, TX. 125p.

HDR. 2009. Cibolo Creek Water Quality Monitoring and Modeling. Prepared for City of Boerne, February 2009.

Larkin, T.J., and Bomar, G.W., 1983. Climatic Atlas of Texas: Texas Department of Water Resources, Limited Printing Report LP-192, 151 p.

Lehman, John T., Bell, Douglas W. and McDonald, Kahli E. 2009. *Reduced river phosphorus following implementation of a lawn fertilizer ordinance*. Lake and Reservoir Management, 25: 3, 307 — 312. Published on: 01 September 2009. Accessed via Internet, August2012:

Lewis, Chancey, Berg, Matt, Cathey, James, Gallagher, Jim, Dictson, Nikki and McFarland, Mark. 2012. *Recognizing Feral Hog Sign*. Texas AgriLife Extension Service. Accessed via Internet, August, 24, 2012; http://feralhogs-tamu-edu.wpengine.netdna-cdn.com/files/2010/05/RecognizingFeralHogSign.pdf

Mace, R., Chowdhury, A.H., Anaya, R., Way, S.C., 2000. Groundwater Availability of the Trinity Aquifer, Hill Country Area, Texas: Numerical Simulations through 2050. Report 353, Texas Water Development Board Austin, Texas.

Mellish, J.M. 2001. Estimating State-wide Feral Hog Growth Rates in Texas. M.S. Thesis.

Muir, T.J., and G.WcEwen. 2007. Methods and Strategies for Managing Feral Hog Damage in Grain Production Areas in Central Texas. In *Managing Vertebrate Invasive Species*: *Proceedings of an International Symposium* (G.W. Witmer, W.C. Pitt, K.A. Fagerstone, eds) USDA/APHIS/WS, National Wildlife Research Center, Fort Collins, CO.

Nash, J.E., and J.V. Sutcliffe. 1970. River flow forecasting through conceptual models part I - A discussion of principles. *J. of Hydrology* 10(3):282-290.

Neitsch, S.L., J.G. Arnold, J.R. Kiniry, and J.R. Williams. 2011. *Soil and Water Assessment Tool Theoretical Documentation: Version 2009*. Texas Water Resources Institute Technical Report No. 46. Texas A&M University System. College Station, TX 77843-2118.

NOAA, 2009. National Climatic Data Center. Temperature and Precipitation. National Oceanic and Atmospheric Administration.

Ockerman, D.J. 2007. Simulation of Stream Flow and Estimation of Ground-water Recharge in the Upper Cibolo Creek Watershed, South-Central Texas 1992-2004. U.S. Geological Survey Scientific Investigations Report 2007-2502.

Reeves, R. D., 1967. Ground Water Resources of Kendall County, Texas, Texas Water Development Board, Austin, Texas, Report 60.

Simley, J.D., W.J. Carswell, Jr. 2009. *The National Map*—Hydrography: U.S. Geological Survey Fact Sheet 2009-3054, 4 p.

Soil Survey of Kendall County Texas, 1979. United States Department of Agriculture, Soil Conservation Service in cooperation with the Texas Agricultural Experiment Station.

Spearing, D., 1991, Roadside geology of Texas: Mountain Press Publishing Company, Missoula, Montana, 418 p.

Texas A&M University, College Station, Texas.

TSSWCB. 2012. Water Quality Management Plan Program. Internet accessed: July 6, 2012. http://www.tsswcb.state.tx.us/wqmp

USDA. 2007. Census of Agriculture, National Agricultural Statistics Service, United States Department of Agriculture. www.nass.usda.gov/Statistics_by_State/Texas/index.asp

Voulgaris, M., 2009. Cow Creek Groundwater Management Plan, Cow Creek Groundwater Conservation District. Boerne, Texas.

Wierman, D.A., A.S. Broun, and B.B. Hunt, 2010. Hydrogeologic Atlas of the Hill Country Trinity Aquifer, Blanco, Hays, and Travis Counties, Central Texas: Prepared by the Hays-Trinity, Barton Springs/Edwards Aquifer, and Blanco Pedernales Groundwater Conservation Districts, July 2010.

Winchell, M., R. Srinivasan, M. Di Luzio, and J. Arnold. 2010. ArcSWAT Interface for SWAT 2009 – User's Guide. Texas Agrilife Research and USDA Agricultural Research Service.

Appendix A. Maps

Figure A-1. Detailed Soil types found in the Upper Cibolo Creek Watershed

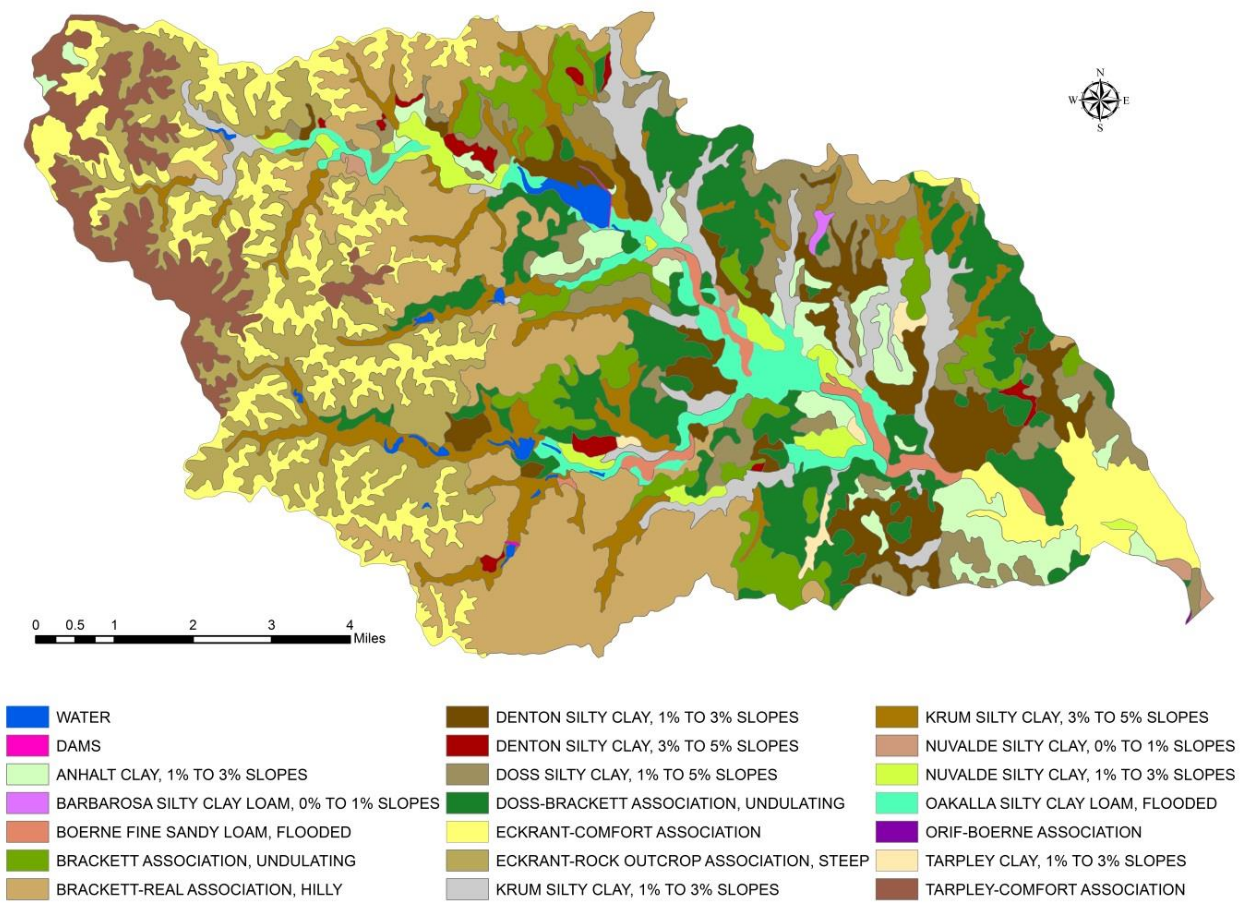


Figure A-2. General STATSGO Soil Map of the Upper Cibolo Creek Watershed

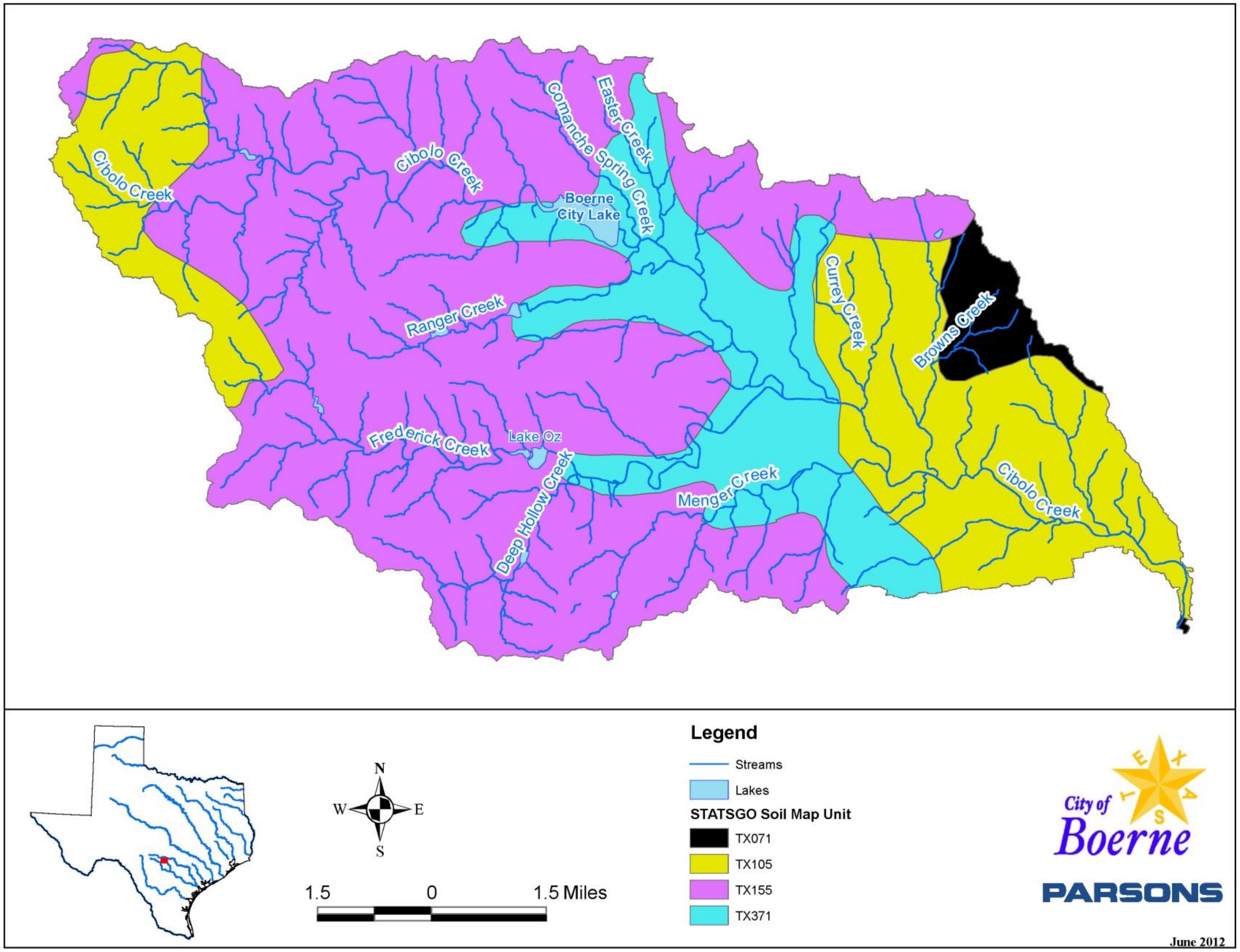


Figure A-3. Landcover types identified in the updated 2006 NLCD for the UCC Watershed

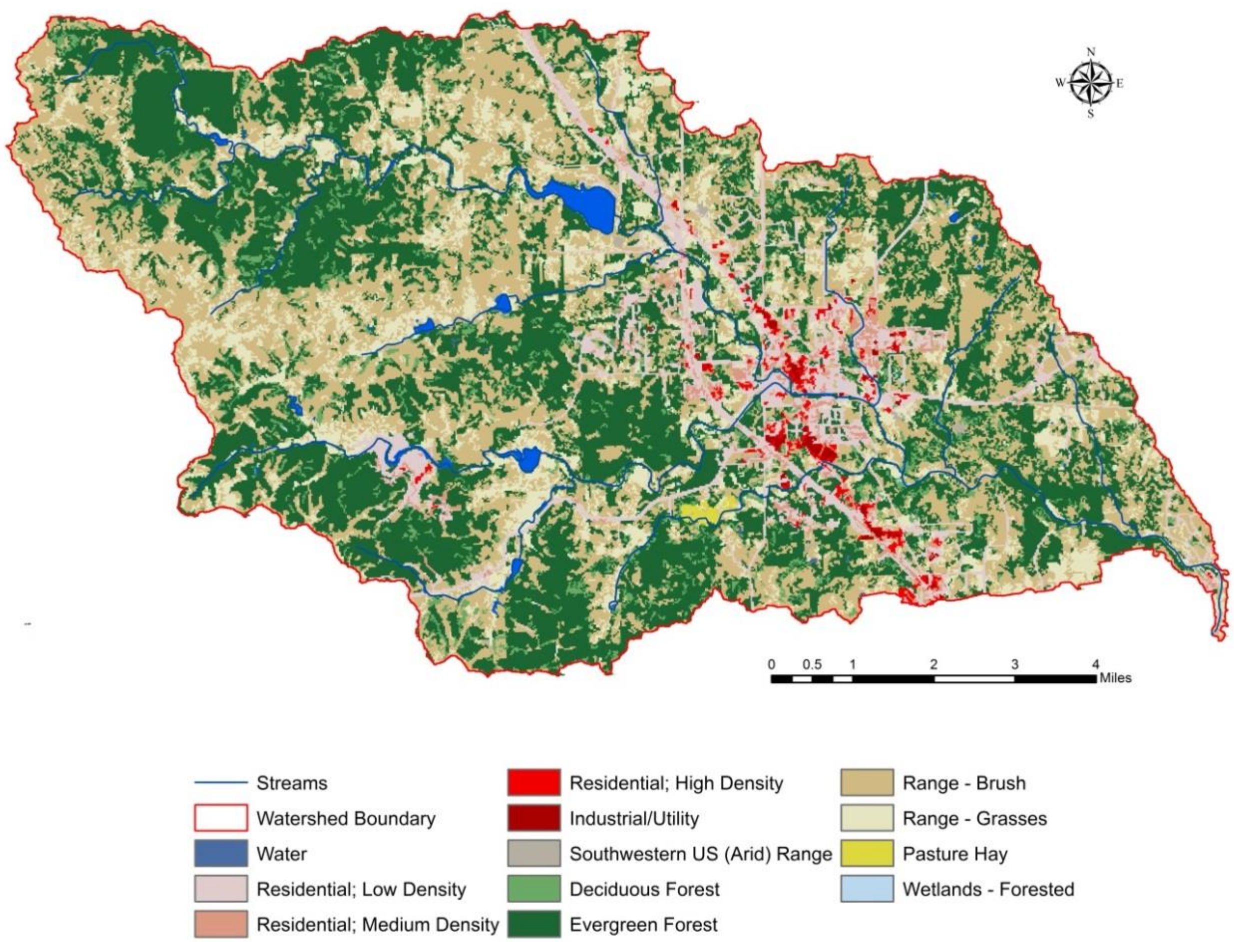


Figure A-4. Upper Cibolo Creek Permitted Wastewater Treatment Facilities

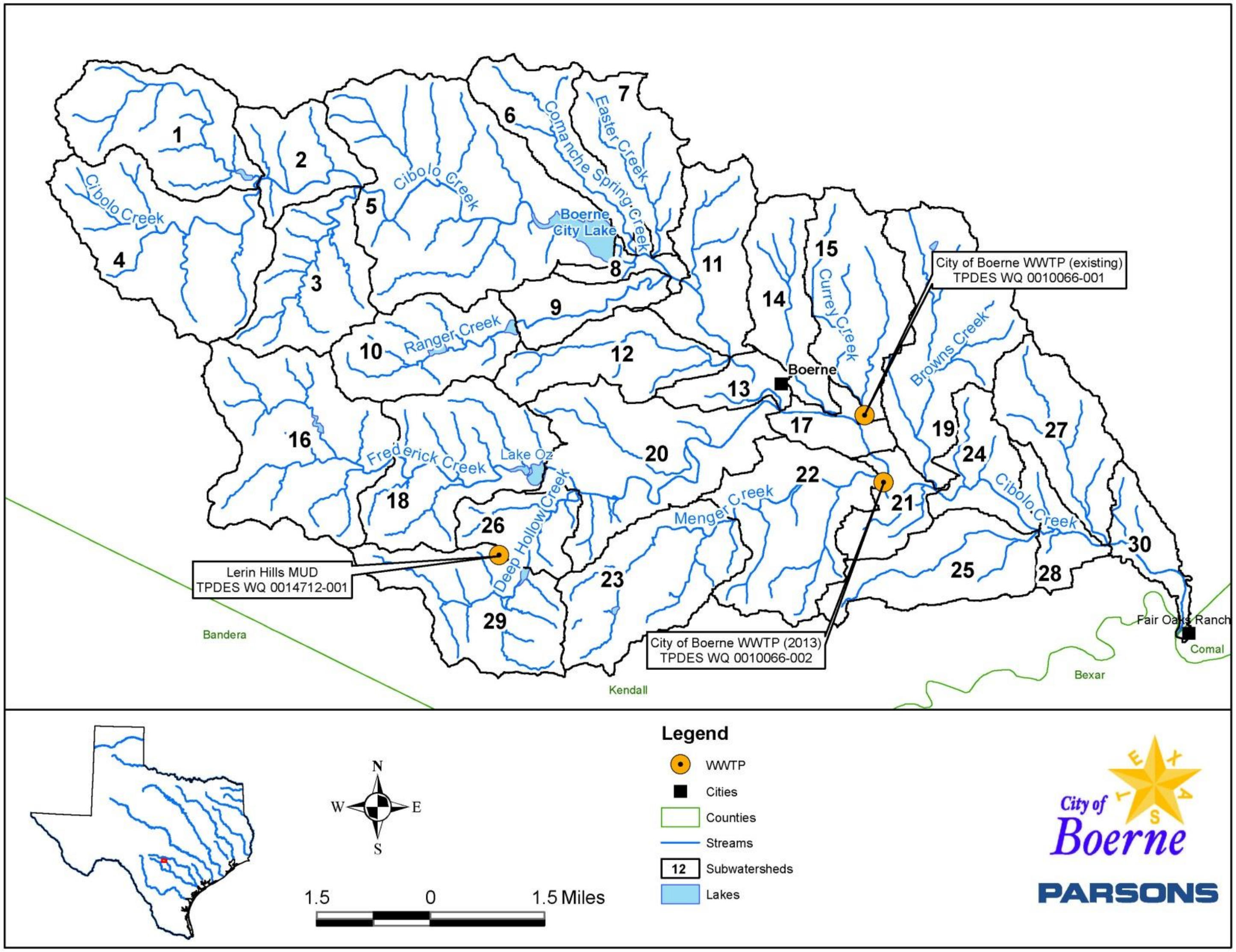


Figure A-5. Phosphorus Loads to Land from Wildlife Sources

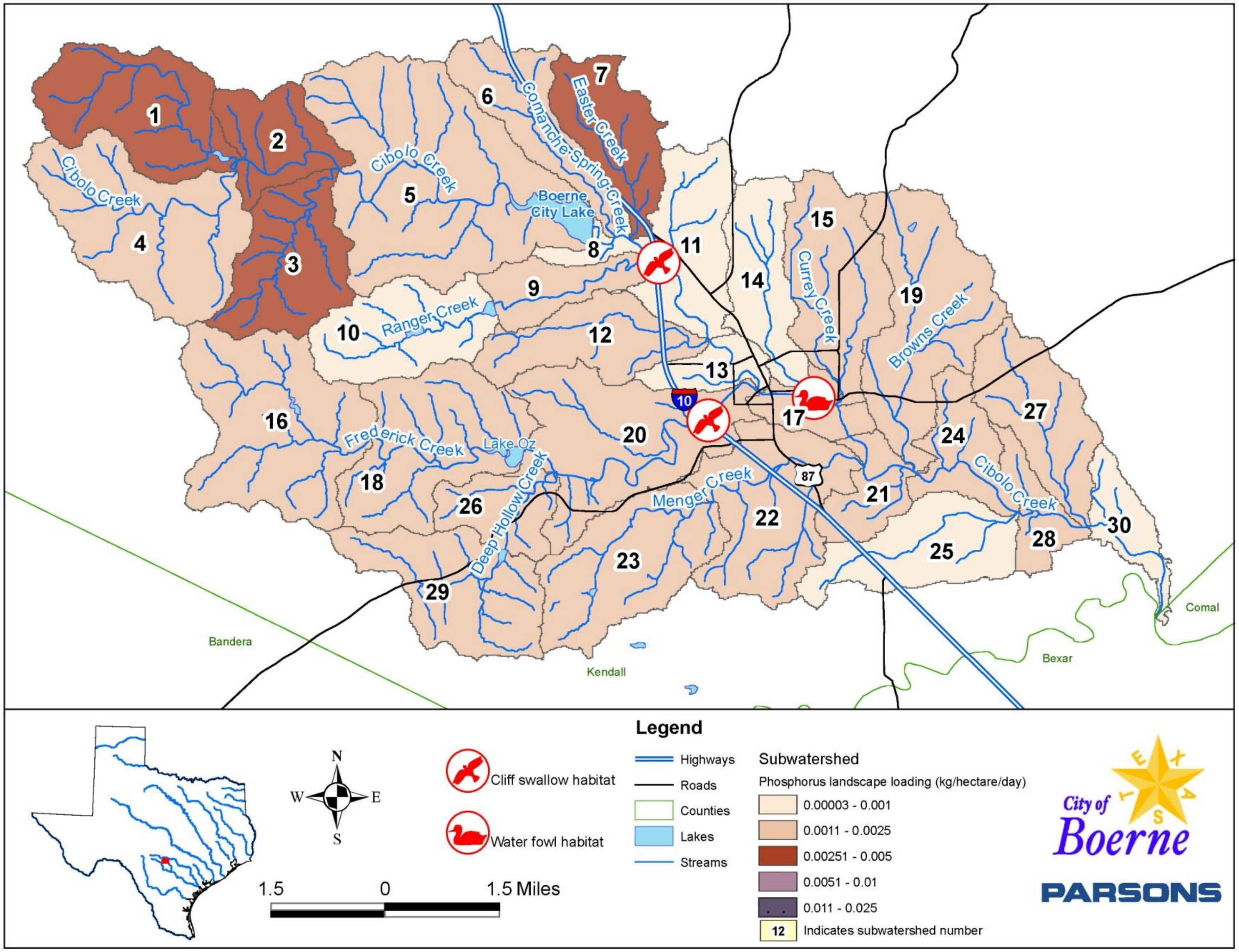


Figure A-6. Phosphorus Loads to Land from Agricultural Sources

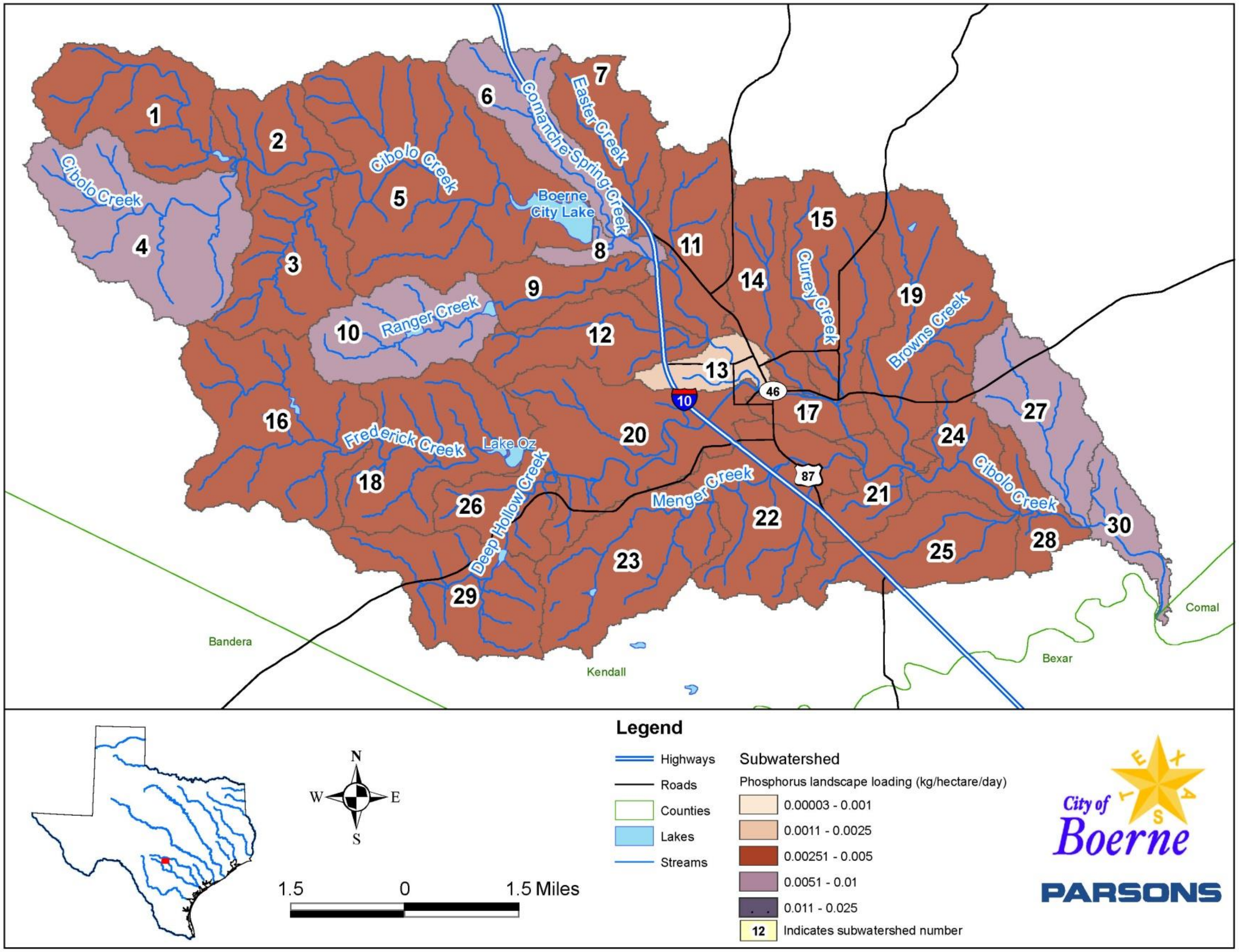


Figure A-7. Phosphorus Loads to Land from Urban/Residential Sources

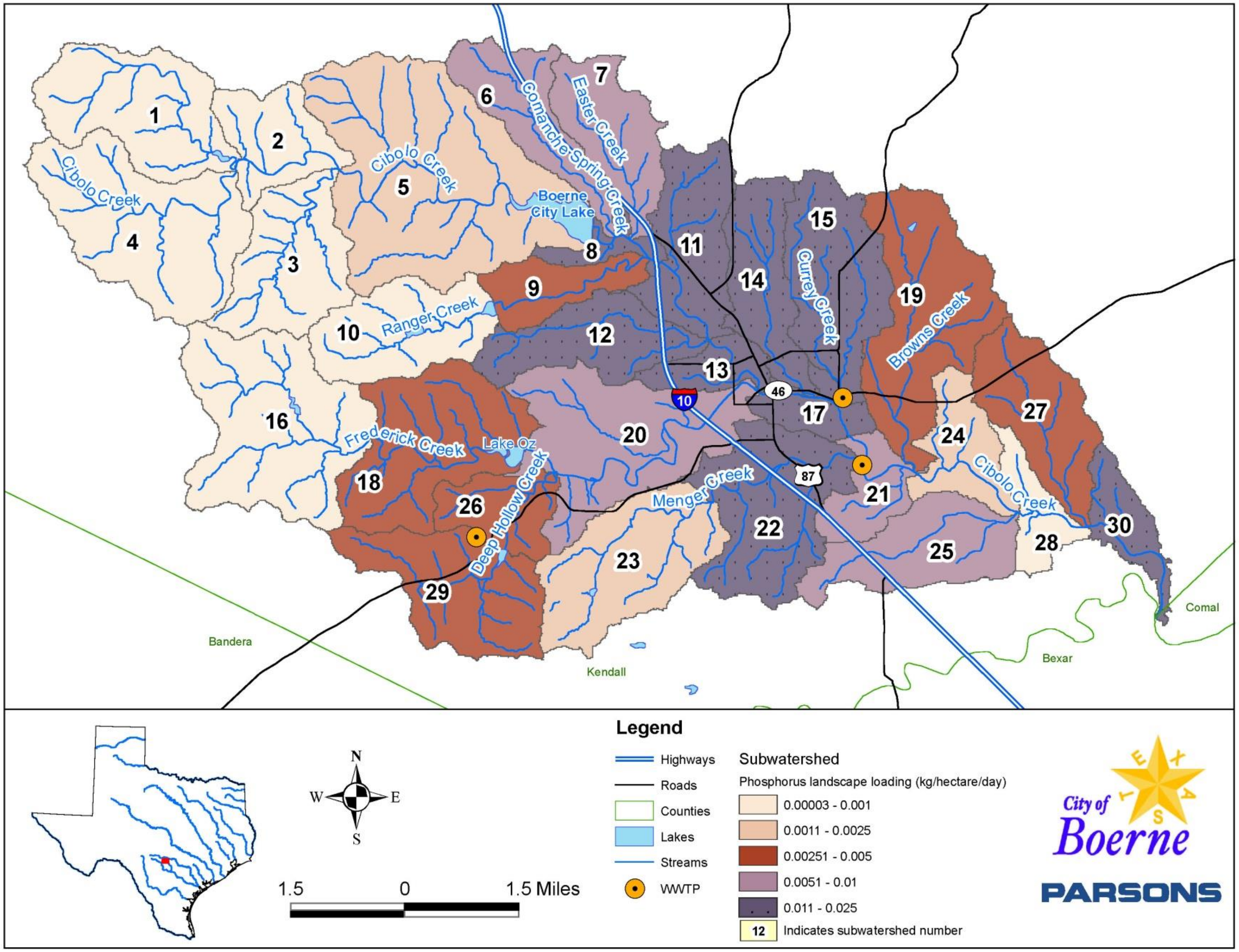


Figure A-8. Nitrogen Loads to Land from Wildlife Sources

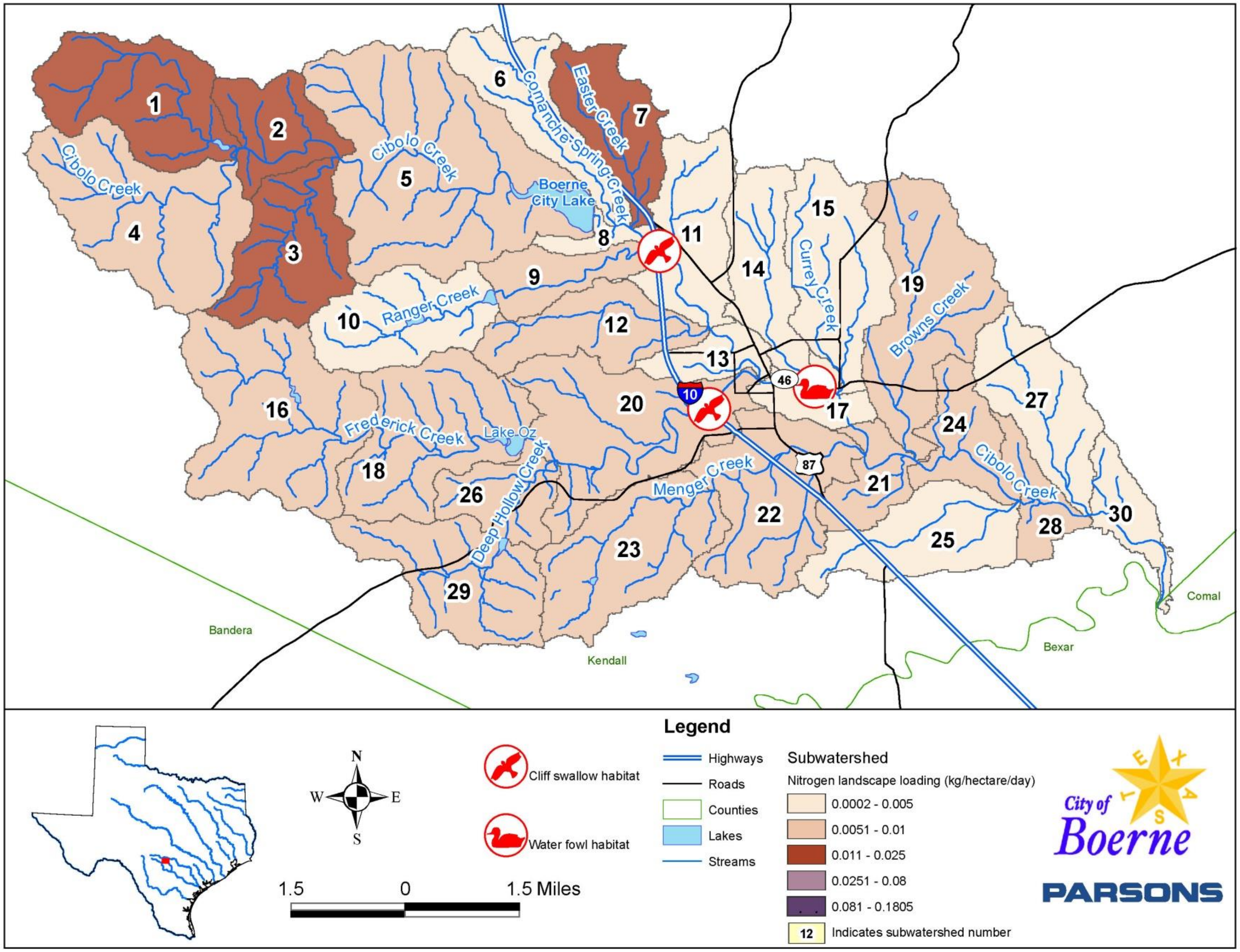


Figure A-9. Nitrogen Loads to Land from Agricultural Sources

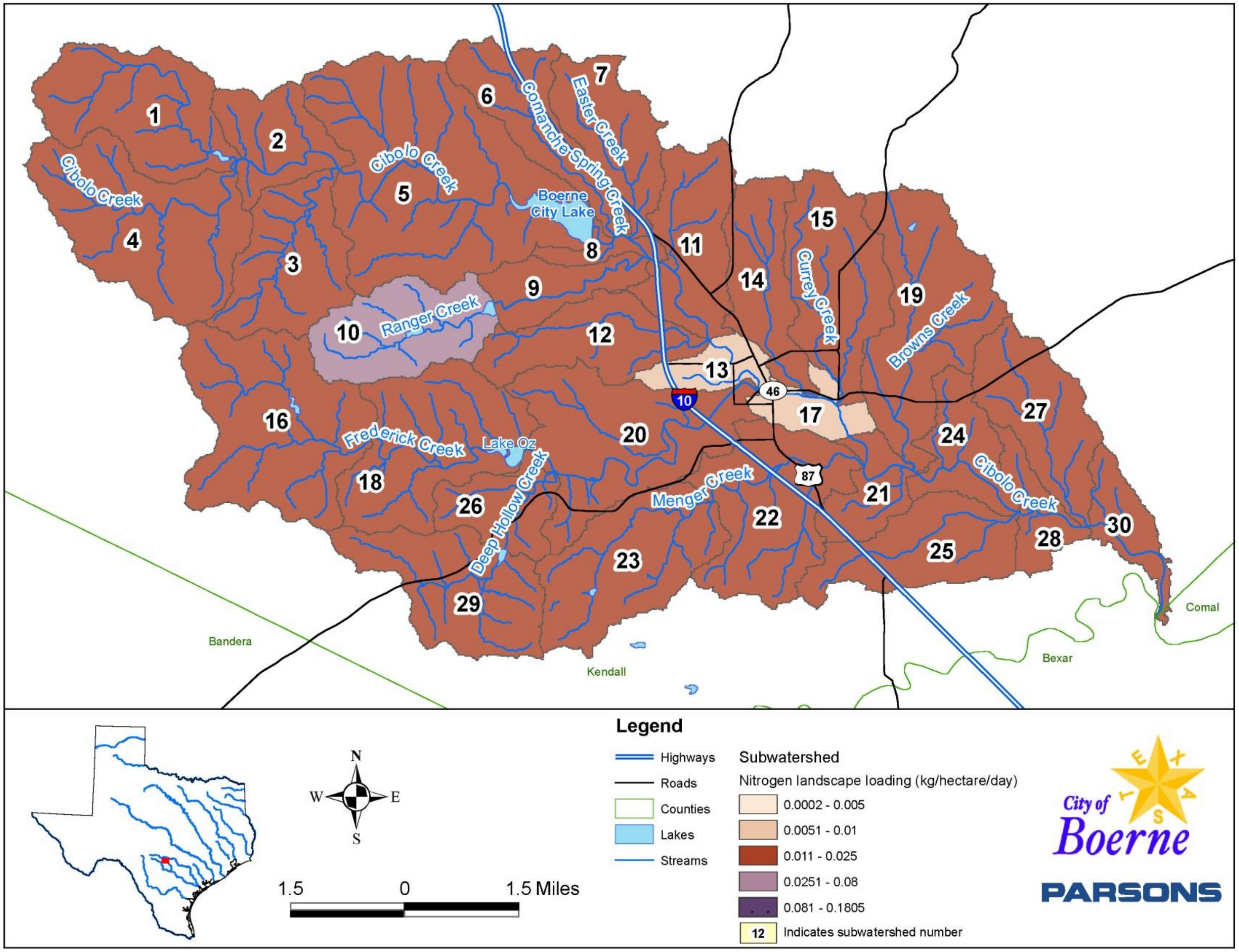


Figure A-10. Nitrogen Loads to Land from Urban/Residential Sources

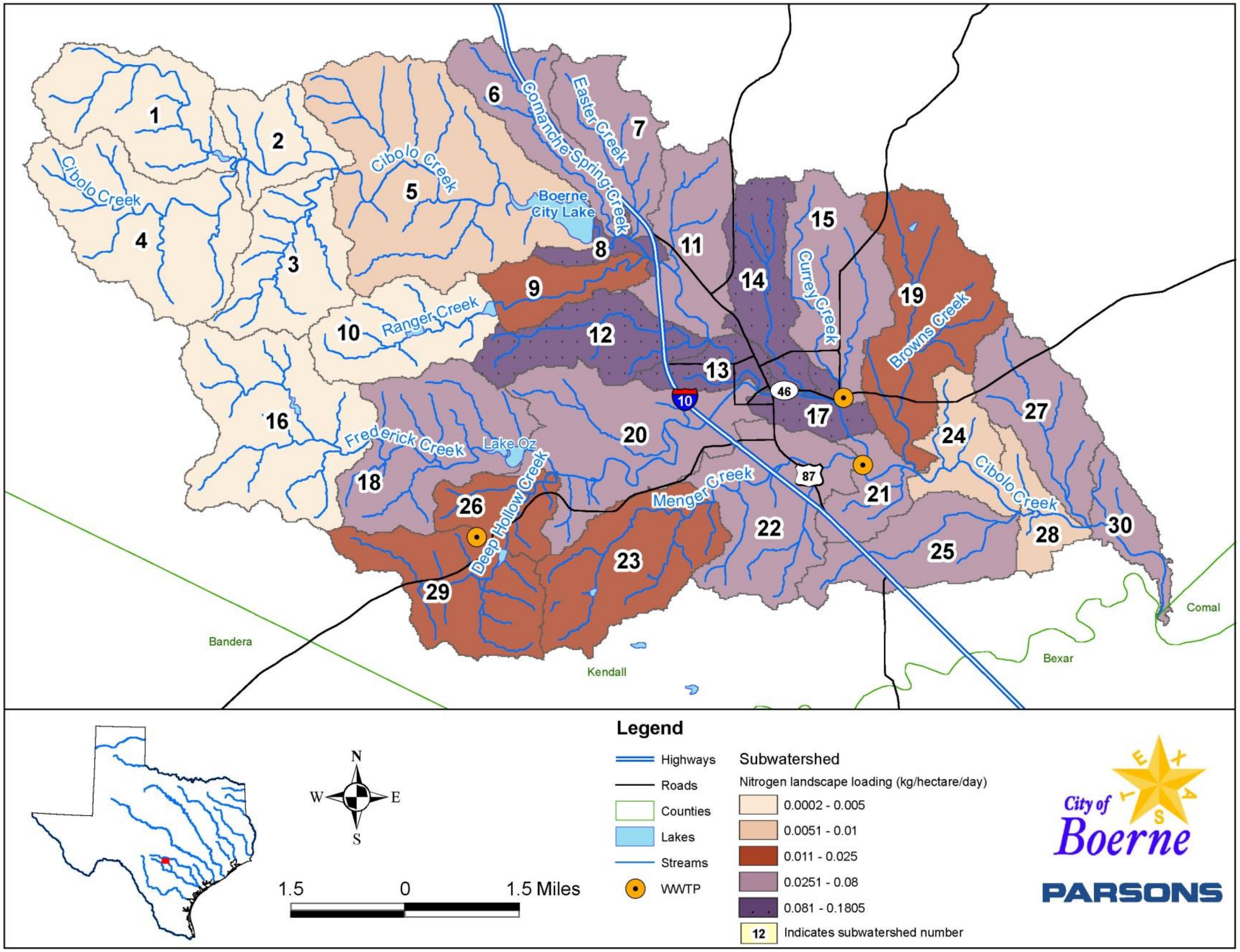
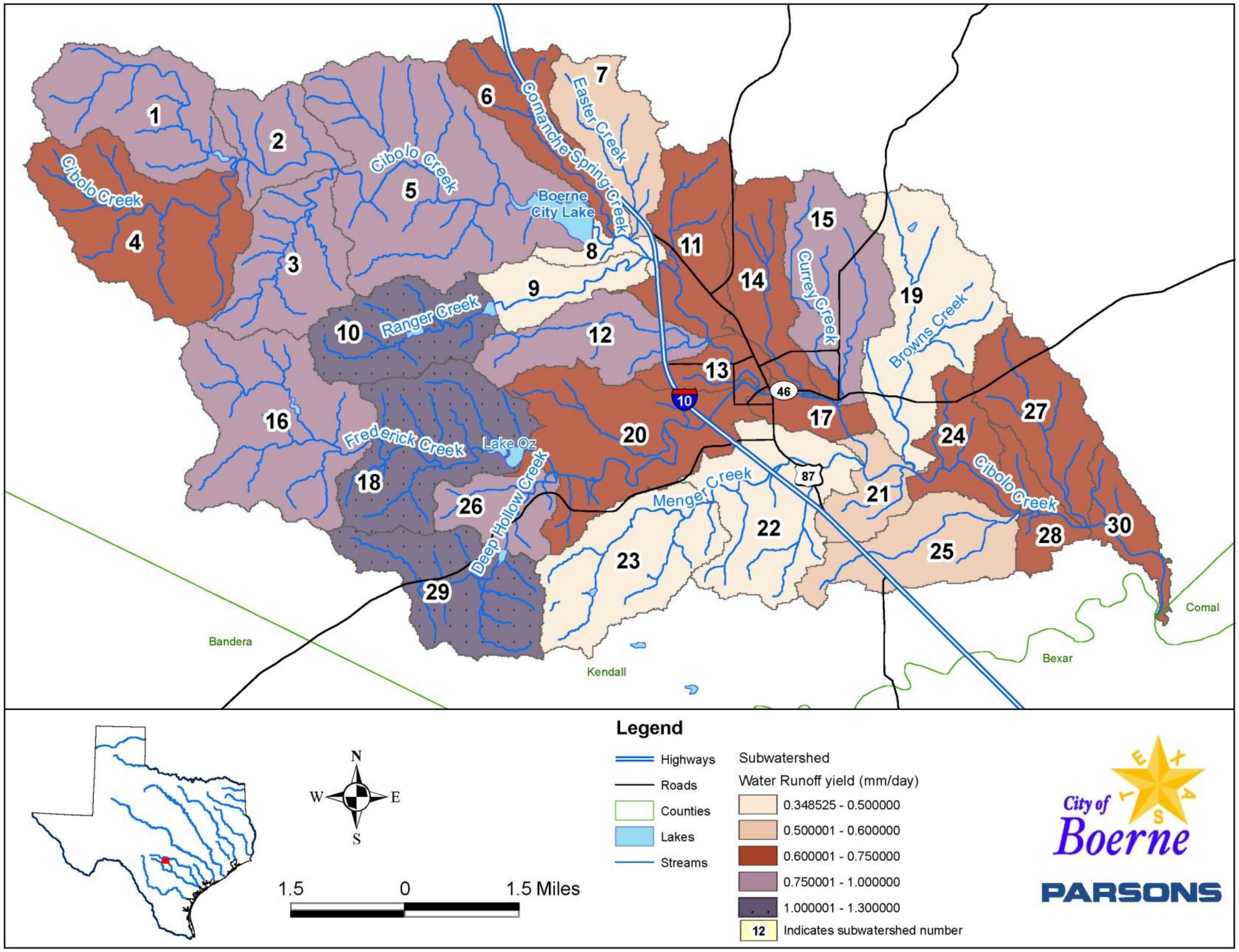


Figure A-11. Water Yield* from Subwatersheds to Upper Cibolo Creek and its Tributaries



***Water yield** is runoff from a drainage basin, including ground-water outflow that appears in a stream. Water yield is precipitation minus evapotranspiration.

Figure A-12. *E.coli* Yields from Subwatersheds to Upper Cibolo Creek and its Tributaries

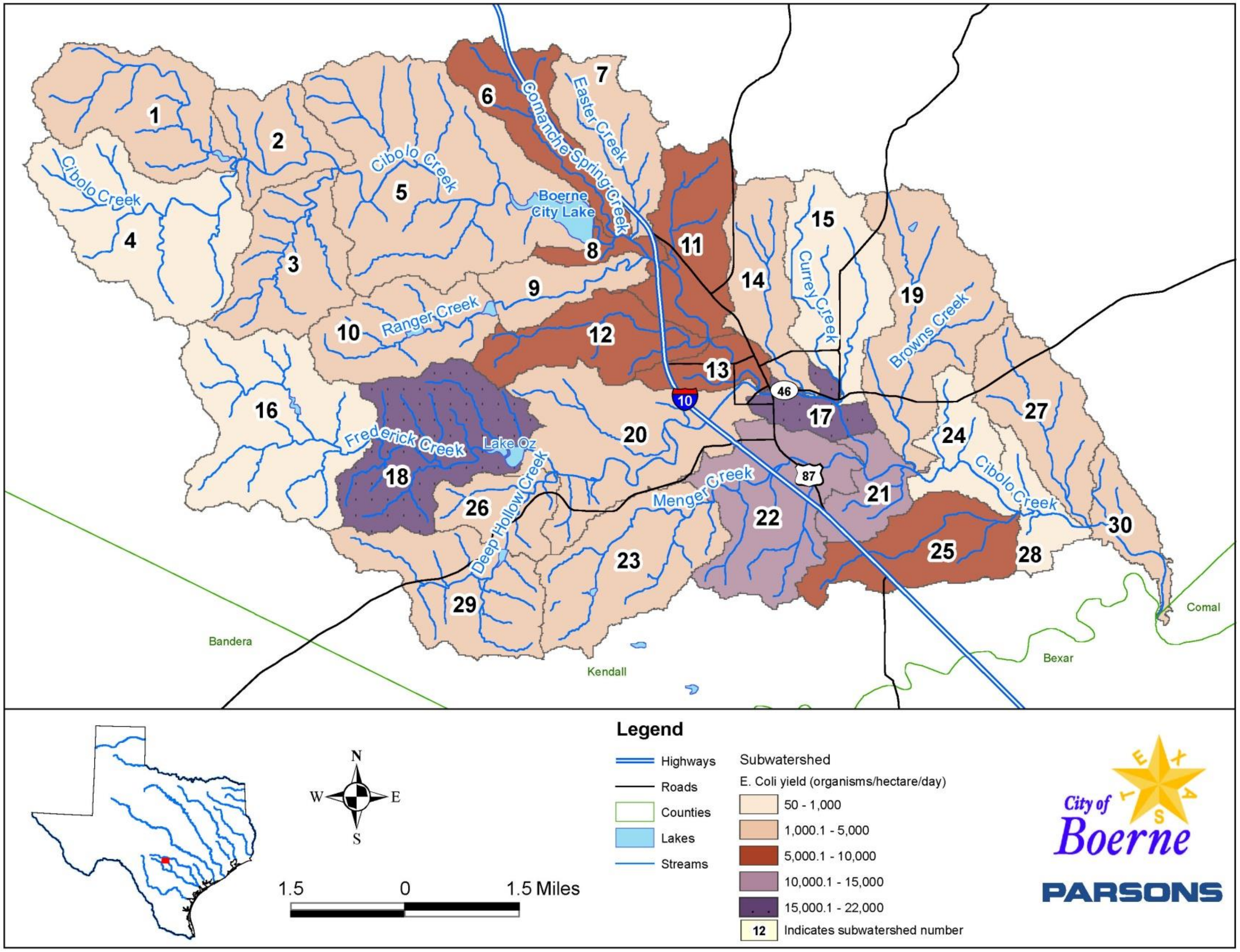


Figure A-13. Phosphorus Yields from Subwatersheds to Upper Cibolo Creek and its Tributaries

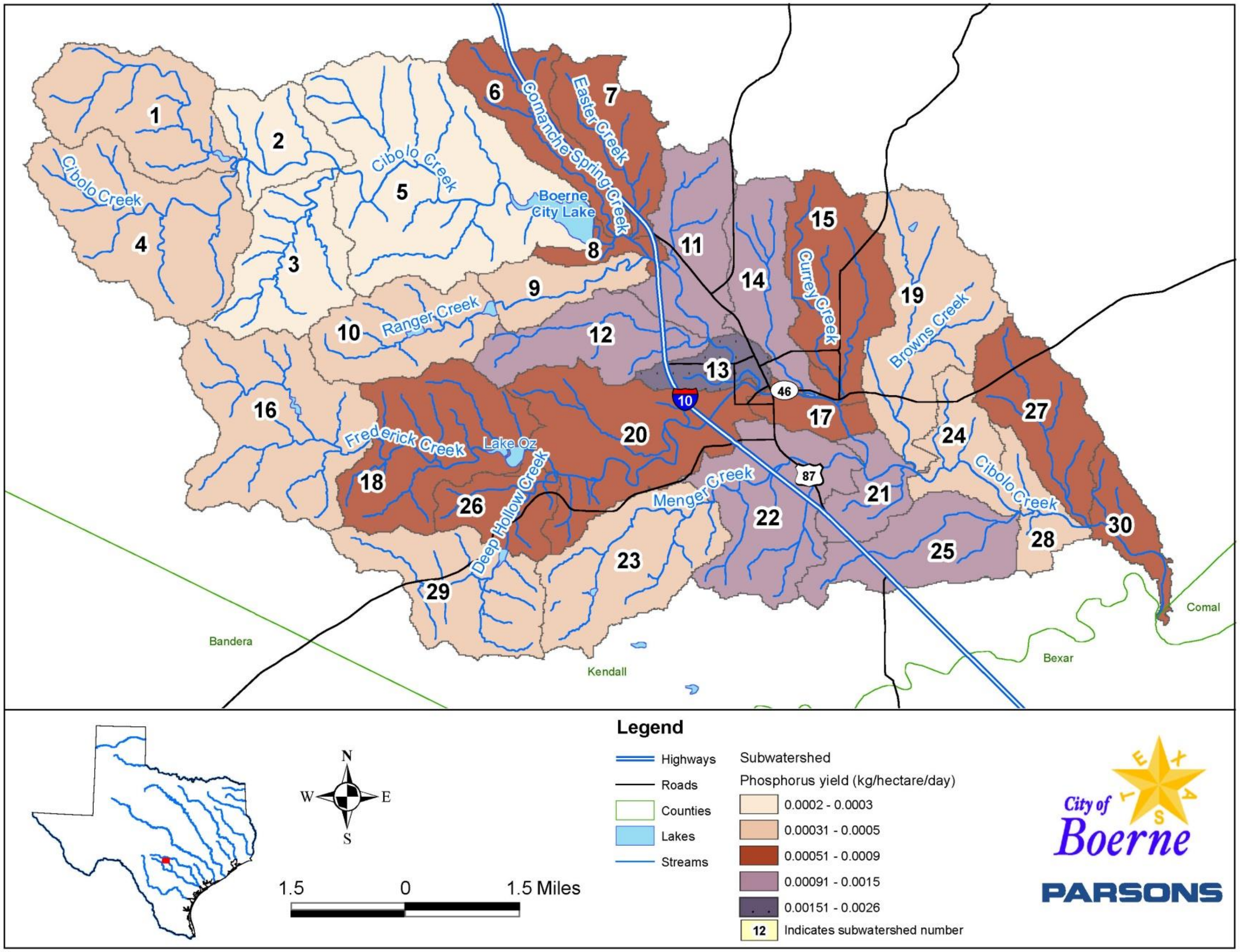


Figure A-14. Nitrogen Yields from Subwatersheds to Upper Cibolo Creek and its Tributaries

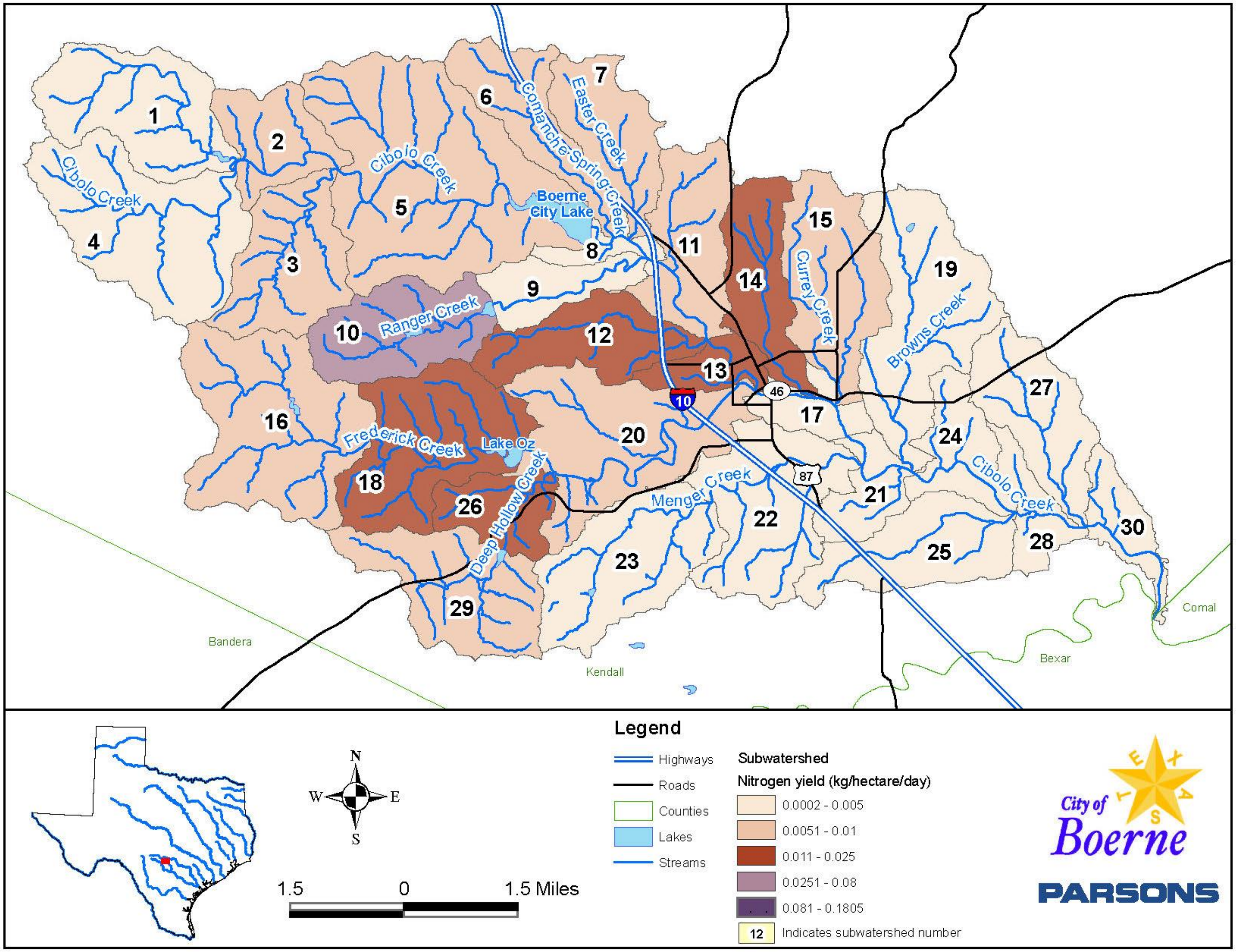
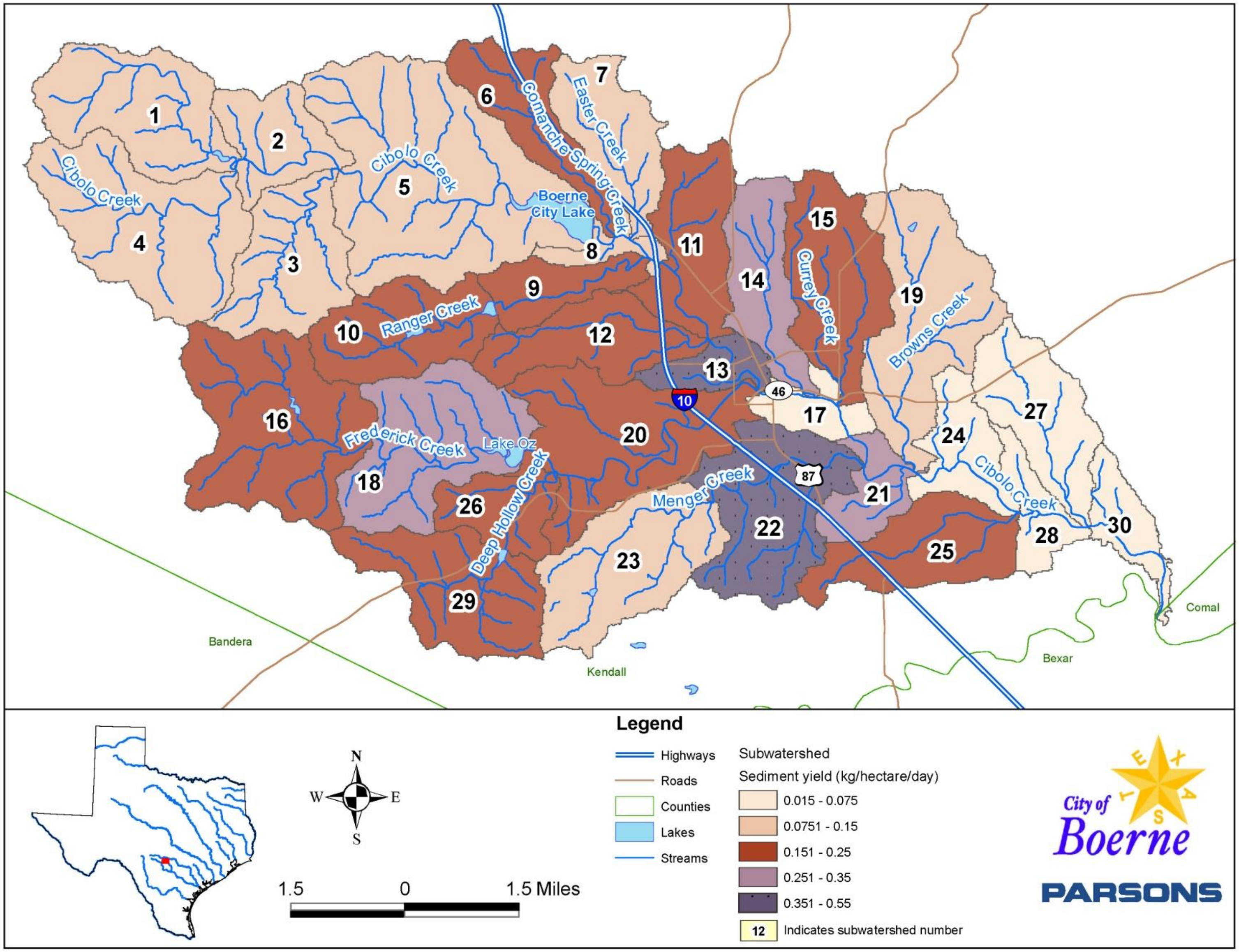


Figure A-15. Sediment Yield from Subwatersheds to Upper Cibolo Creek and its Tributaries



Appendix B. SWAT Model Calibration

General Notes on Model Calibration

Calibration is the process where the model input parameters are adjusted until simulated data from the model match with observed data. Model calibration, in this setting, is defined as how well the models are able to reproduce measured values.

Calibration was performed for the period from January 1, 1991 to December 31, 2011. Initial calibrations were performed for the period exclusive of 2007 and 2011, which were utilized to validate the model. For many parameters, few water quality measurements remained in the calibration data set after excluding the 2011 data points. Therefore, final calibration statistics and figures include the complete data period from 1991 to 2011.

In the SWAT calibration, model parameters related to watershed/landscape processes were adjusted to match the measured and simulated flow, TSS, nutrients, *E.coli*, and DO at key locations in the watersheds. During the calibration process, the model parameters to which the model was most sensitive were adjusted within literature-recommended ranges or as indicated from watershed-specific data. As a general rule, the most sensitive parameter was adjusted first, followed by the next most sensitive, and so on.

Calibration was done systematically, in the following order:

1. Stream flow and water balance
2. TSS
3. TN and TP
4. OrgN, OrgP, NH_3-N, NOx-N, and PO4-P
5. DO
6. *E.coli*

There were multiple iterations of the model calibration process, as model parameter changes affected more than one of the modeled parameters.

Time series and flow duration plots (between simulated and observed data) and observed vs. modeled averages were used to evaluate the prediction (performance) of the model during calibration. Model calibration statistics, including the overall mass balance, the coefficient of determination (r^2), and Nash-Sutcliffe modeling efficiency (NSE) (Nash and Sutcliffe 1970) were used as quantitative measures of model fit to supplement the visual evaluation of fit. The formulas for model fit statistics are provided below, where y_i is the measured value, $\hat{y}_i$ is the model predicted value, an overscore indicates a mean value, and n is the number of measurements. Values of r^2 can range from 0 to 1, with 1 indicating a perfect relationship. Values of NSE can range from $-\infty$ to 1, with 1 indicating a perfect relationship and 0 indicating that the relationship is as strong as the average measured value.

Coefficient of Determination

$$r^2 = \left\{ \frac{\sum_{i=1}^{n}(y_i - \bar{y})(\hat{y}_i - \bar{\hat{y}})}{\left[\sum_{i=1}^{n}(y_i - \bar{y})^2\right]^{0.5} * \left[\sum_{i=1}^{n}(\hat{y}_i - \bar{\hat{y}})^2\right]^{0.5}} \right\}^2$$

Nash-Sutcliffe Efficiency

$$NSE = 1 - \sum_{i=1}^{n}(y_i - \hat{y}_i)^2 / \sum_{i=1}^{n}(y_i - \bar{y})^2$$

The following goodness-of-fit criteria were established for this project as acceptable model calibration targets: In practice the best reasonable calibration fit was attempted.

- Total annual averages of daily flows will be calibrated so predicted values agree with measured values within 20%, the r^2 of daily flows is greater than 0.5, and the NSE for daily flows is greater than 0.4. These criteria are consistent with those for more than 100 SWAT calibration studies from the United States reported in the literature (Gassman, et al. 2007).

- Concentrations of TN, TP, OrgN, NH_3-N, NO_x-N, dissolved PO4-P, fecal bacteria (as *E.coli*), and DO were calibrated so the mean of the predicted values falls within two standard deviations of the mean of observed concentrations within the calibration period.

Hydrologic Calibration

Hydrologic calibration was performed based on measured flow data available at three USGS gages on Upper Cibolo Creek (Table 3-1 and Figure 2-7). The monitoring period of record for these three gages differed, with little temporal overlap. Thus, hydrologic calibration of the SWAT model was made more difficult by spatial and temporal disparities in flow monitoring records.

Table B-1. Hydrologic Calibration Gages

USGS Gage	Gage Description	Drainage Area (square miles)	Period of Record	Model Reach
08183850	Cibolo Creek at IH-10 above Boerne	29.0	May 23, 1996 – May 9, 2007	8
08183890	Cibolo Creek at Cibolo Nature Center near Boerne	56.3	Nov. 10, 2005 - current	17
08183900	Cibolo Creek near Boerne	68.4	Jan. 1, 1991 - Dec. 31, 1995 May 11, 2011 - current†	21

† 2011 data from gage 08183900 were not used in calibration

SWAT is a distributed hydrological model with more than 100 parameters that can be adjusted to achieve the best calibration (fit) of the model to measured flow and water quality data. There is no unique combination of parameter adjustments to achieve calibration. Based on past experience and an initial sensitivity analysis (sequentially varying one calibration parameter at a time), the modeling team identified a smaller set of model parameters to adjust to best achieve the calibration to observed data. Table B-2 summarizes these model parameters along with their calibrated values.

Table B-2. SWAT Parameters Adjusted for Hydrologic Calibration

Parameter	Units	Description	Subwatershed	Calibrated Value	Typical Range (Default Value)
ESCO	--	Soil evaporation compensation factor	1-10	0.75	0 – 1 (0.95)
			11-30	0.95	
GW_DELAY	day	time groundwater spends in the vadose zone	All	360	0 – 500 (31)
GW_REVAP	--	Groundwater revap coefficient	All	0.07	0.02 – 0.20 (0.02)
GWQMN	mm	Threshold storage in shallow aquifer for return flow	All	20	0 - 5000 (0)
RCHRG_DP	--	Fraction of infiltrated shallow groundwater lost to deep aquifer	1-18,20,26,29	0.2	0 – 1 (0.05)
			19,21-25,27-28,30	0.8	
TRNSRCH	--	Fraction of losses from the main channel lost to deep aquifer	All	0.5	0 – 1 (0)
CH_K2, CH_K1	mm/hr	Hydraulic conductivity of the main and tributary channels	All	2.5	0 – 500 (0)
EVRCH	--	Reach evaporation adjustment factor	All	0.9	0 – 1 (0)
EVRSV	--	Reservoir evaporation adjustment factor	All	1	0 – 1 (0.6)
RES_K	mm/hr	Hydraulic conductivity of the reservoir bottom	All	1	0 – 1 (0)
SOL_AWC	--	Soil available water capacity	1 - 10	0.01 increase	0 – 1 (varies)
			11-30	default	
SOL_K	mm/hr	Soil saturated hydraulic conductivity	All	50% reduction	0 – 2000 (varies)
CN2	--	SCS curve number - moisture condition 2	All	27% reduction	30 – 100 (varies)

All parameter adjustments were within typical SWAT ranges for the parameters, as reported in the database accompanying the SWAT model. Most parameters were adjusted on a watershed level, i.e., the same value or adjustment was applied in each of the 30 subwatersheds. To address spatial variability from gage to gage, some parameters were adjusted by subwatershed groups, depending on whether they occurred in the upper (subwatersheds 1-10), middle (subwatersheds 11-18, 20, 26, and 29), or lower watershed (subwatersheds 19, 21-25, 27-28, 30). Adjusting parameters by sub-watershed, or by land use, slope, or soil type, is common practice in SWAT application (Neitsch, et al. 2011). Spatial variations are expected due to variations in elevation, climate, bedrock geology, and aquifer recharge zones. In particular, spatial parameter adjustments accounted for the fact that:

- Flow in Cibolo Creek is influenced by groundwater levels in the Trinity Aquifer (City of Boerne 2011);
- Springs support baseflow in several of the upper and middle subwatersheds;
- Karst terrain is present in the watershed; and
- Percolation from Cibolo Creek and its tributaries serves to recharge the Trinity Aquifer over the aquifer's outcrop zone (Ockerman 2007).

Primary calibration targets included the overall flow balance for the modeled period, annual water balances, and monthly flow balances. Some differences are expected due to the spatial and temporal heterogeneity of rainfall, and the distance from the rain gage to various points in the watershed. Model-generated flow duration curves were also compared to measured values.

Figures B-1 through B-2 display time series of observed vs. predicted monthly and annual flows in Cibolo Creek at IH-10 (reach 8), along with model fit statistics. The model's prediction of the total amount of flow generated from the watershed, as well as its annual and monthly distribution, is in agreement with the measured data, as reflected by NSEs of greater than 0.8. Figure B-3 provides a flow duration curve in logarithmic scale. A flow duration curve depicts the percentage of time that stream flow exceeds various thresholds. Figure B-3 also illustrates that the model matches observed flows over the full spectrum of flow conditions.

Figures B-4 through B-5 display time series of observed vs. predicted monthly and annual flows in Cibolo Creek at the Cibolo Nature Center (reach 17), along with model fit statistics. The model's prediction of the total amount of flow generated from the watershed, as well as its annual distribution, is in agreement with the measured data, as reflected by NSEs of greater than 0.8. The monthly flow calibration was satisfactory, with an NSE of 0.677, even though flow predictions of some large rainfall events in August 2007 and September 2007 were not well predicted. With only a single rain gage in the watershed, SWAT is extremely sensitive to measured rainfall, which can vary a large amount over a short distance. Figure B-6 provides a flow duration curve, which illustrates that the model matches observed flows over the full spectrum of flow conditions.

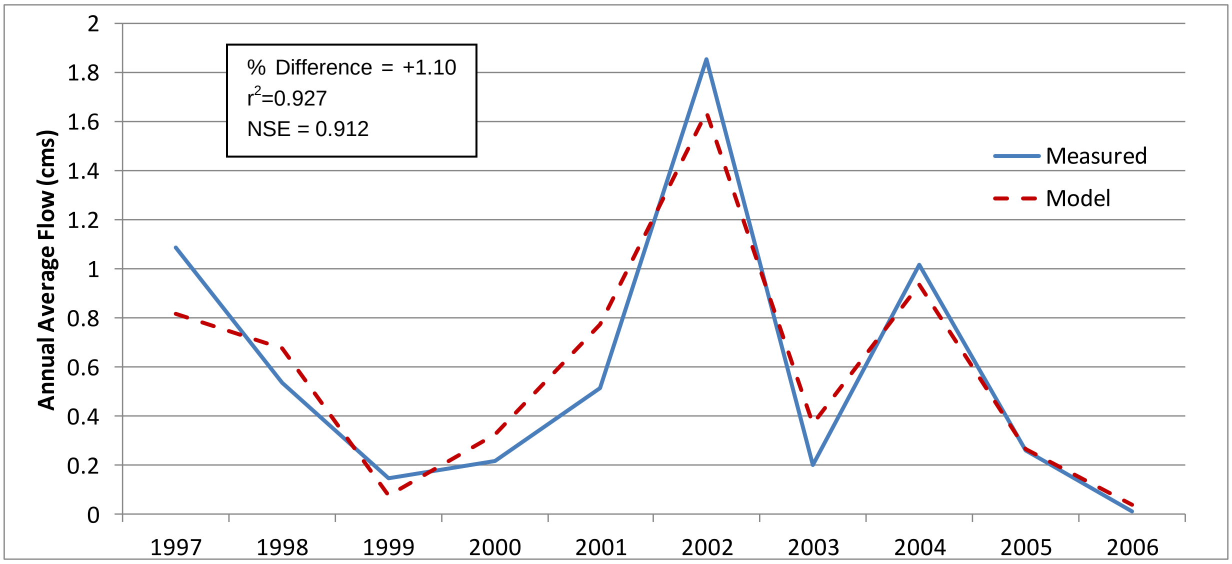


Figure B-1. Observed and Modeled Average Annual Flow at USGS Gage 08183850

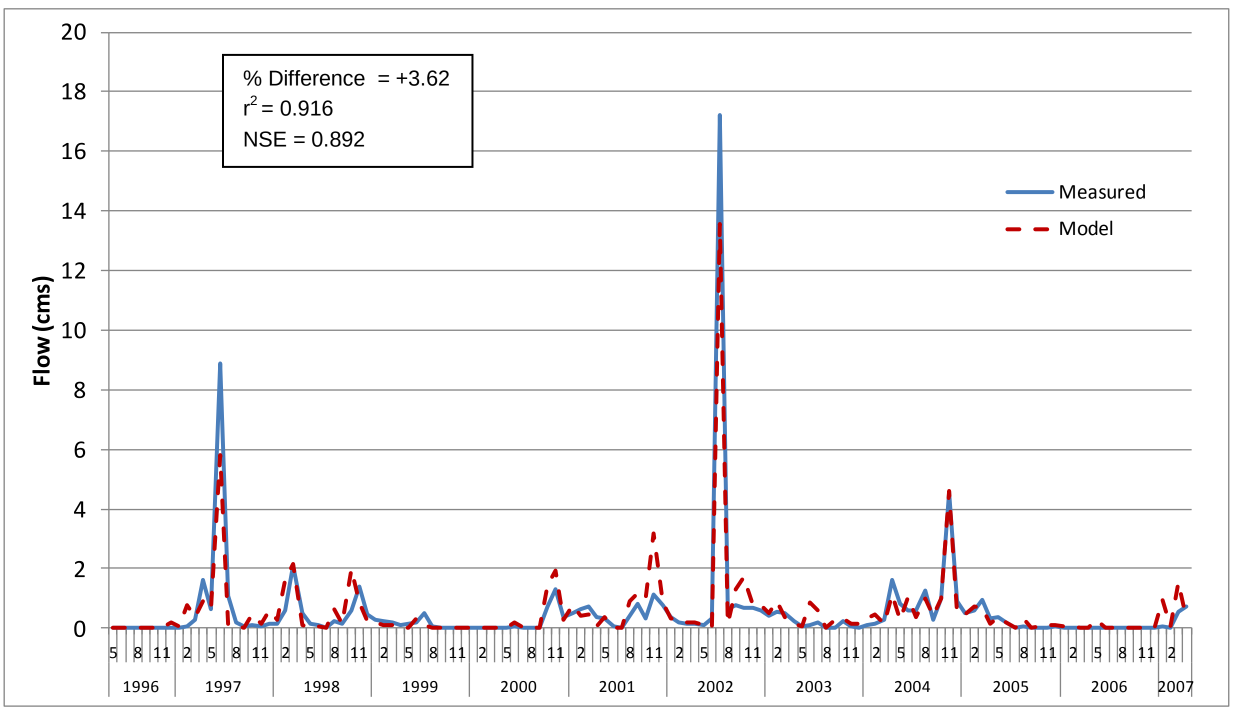


Figure B-2. Observed and Modeled Monthly Flow at USGS Gage 08183850

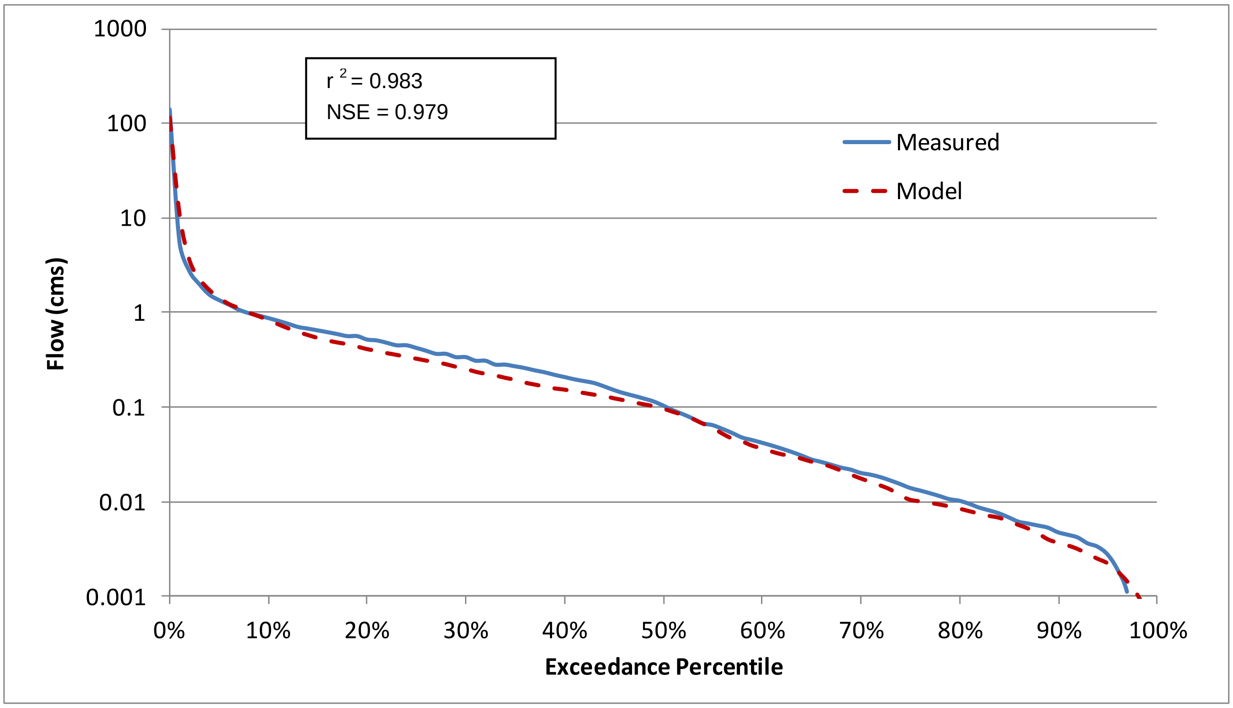


Figure B-3. Observed and Modeled Daily Flow Duration Curve at USGS Gage 08183850

The above figure illustrates the percentage of days (x-axis) that flow in the stream was greater than the flow value on the y-axis. The figure shows that the peak daily observed flow (at the upper left) was a bit greater than 100 cms, and essentially no flow (<0.001 cms) is observed on approximately 3-4 percent of days.

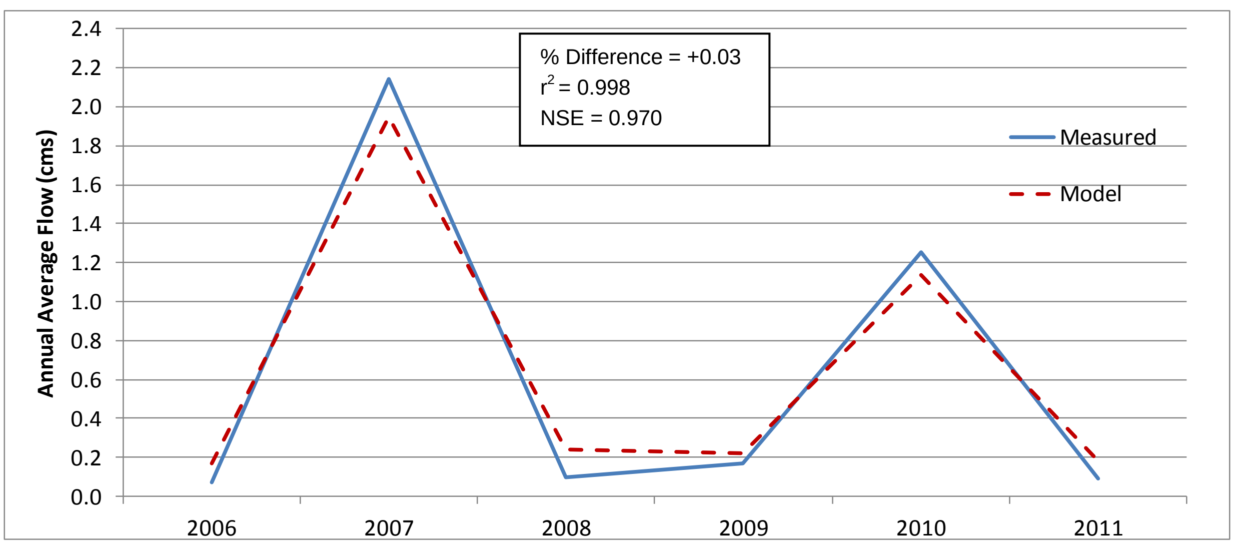


Figure B-4. Observed and Modeled Average Annual Flow at USGS Gage 08183890

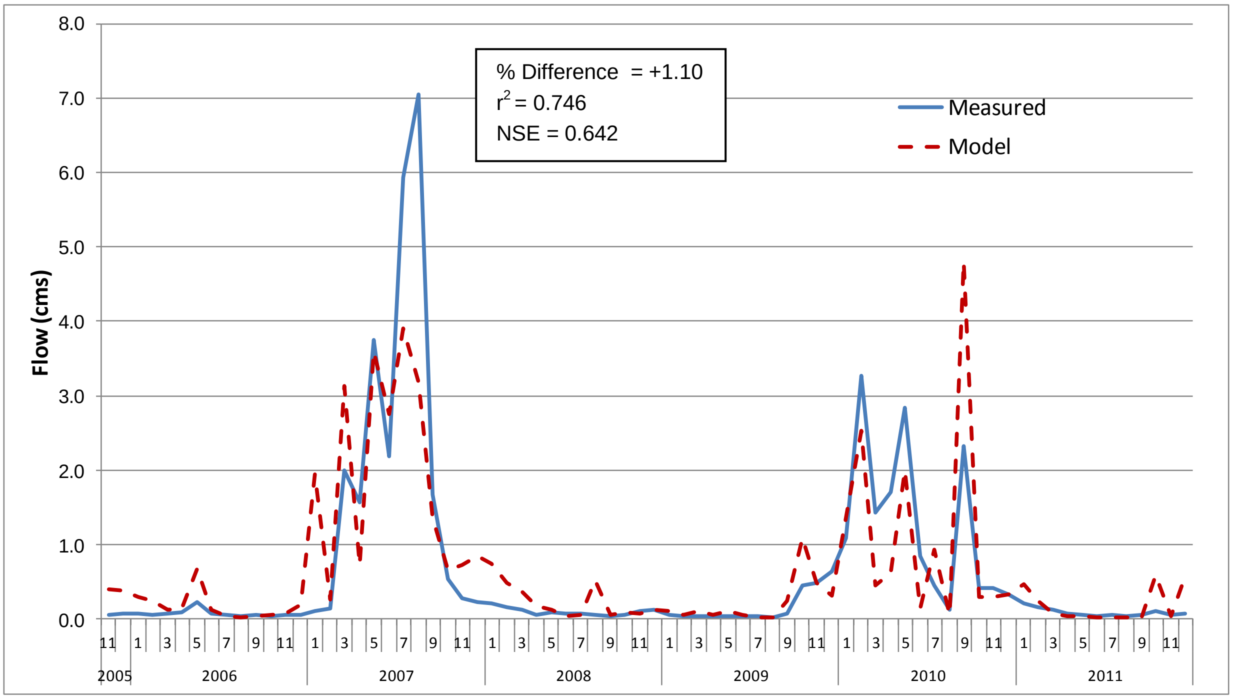


Figure B-5. Observed and Modeled Monthly Flow at USGS Gage 08183890

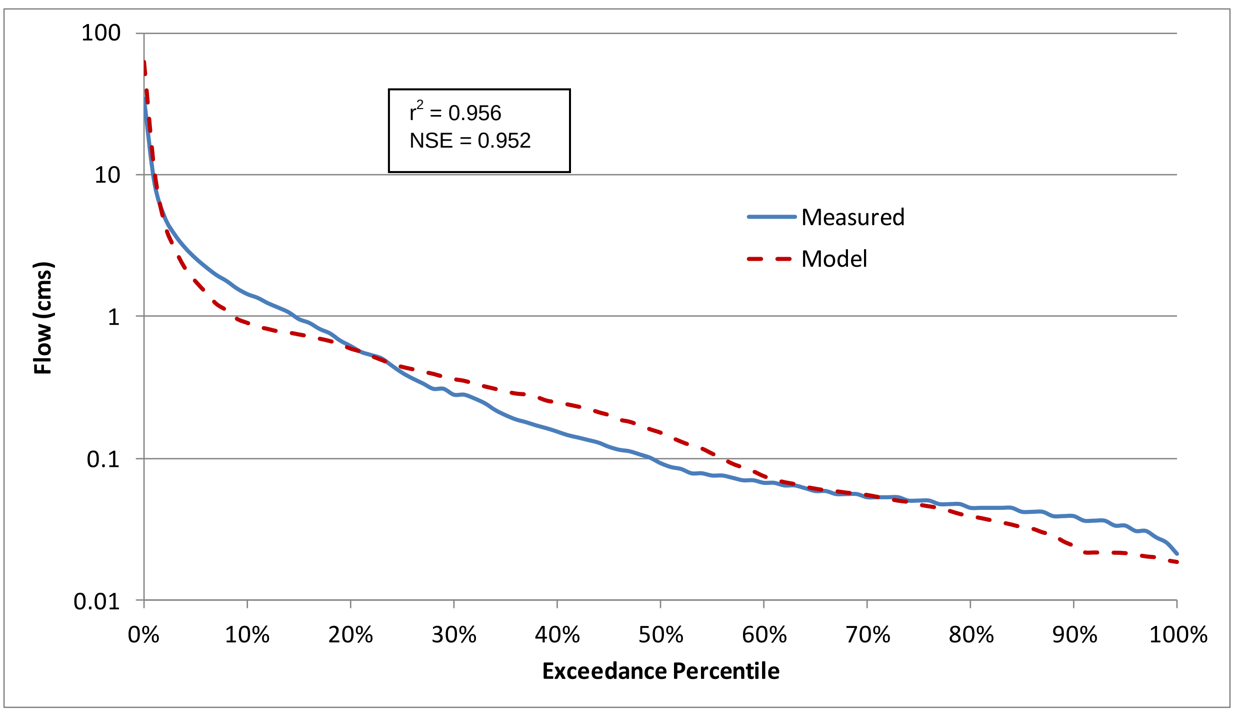


Figure B-6. Observed and Modeled Daily Flow Duration Curve at USGS Gage 08183890

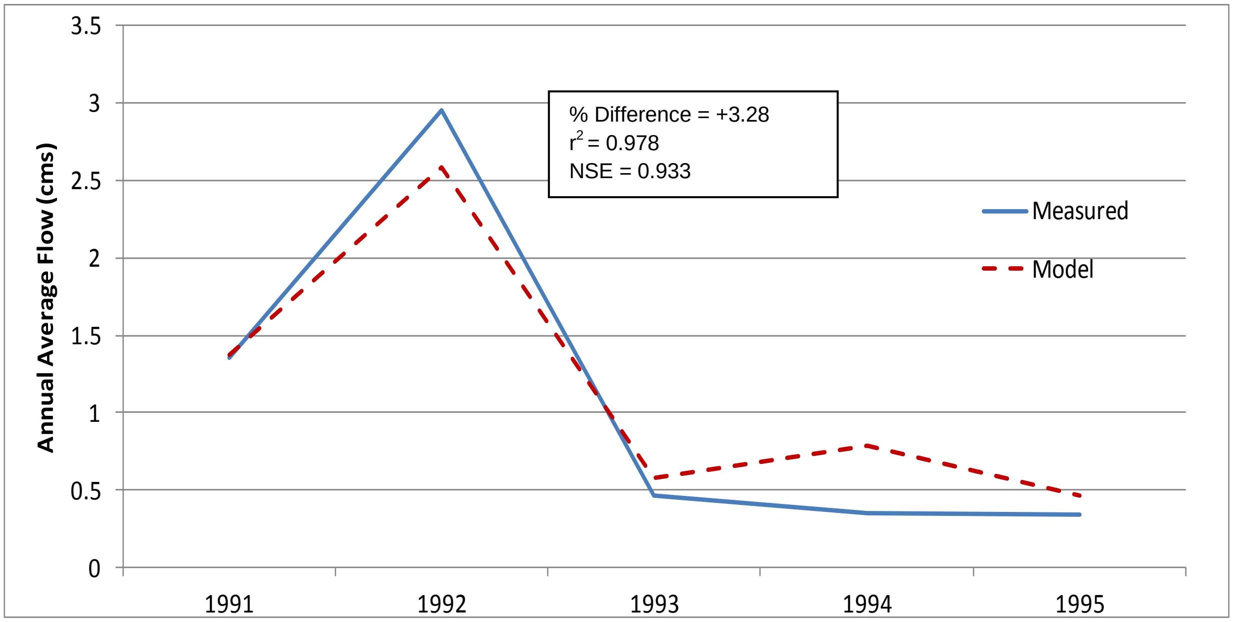


Figure B-7. Observed and Modeled Average Annual Flow at USGS Gage 08183900

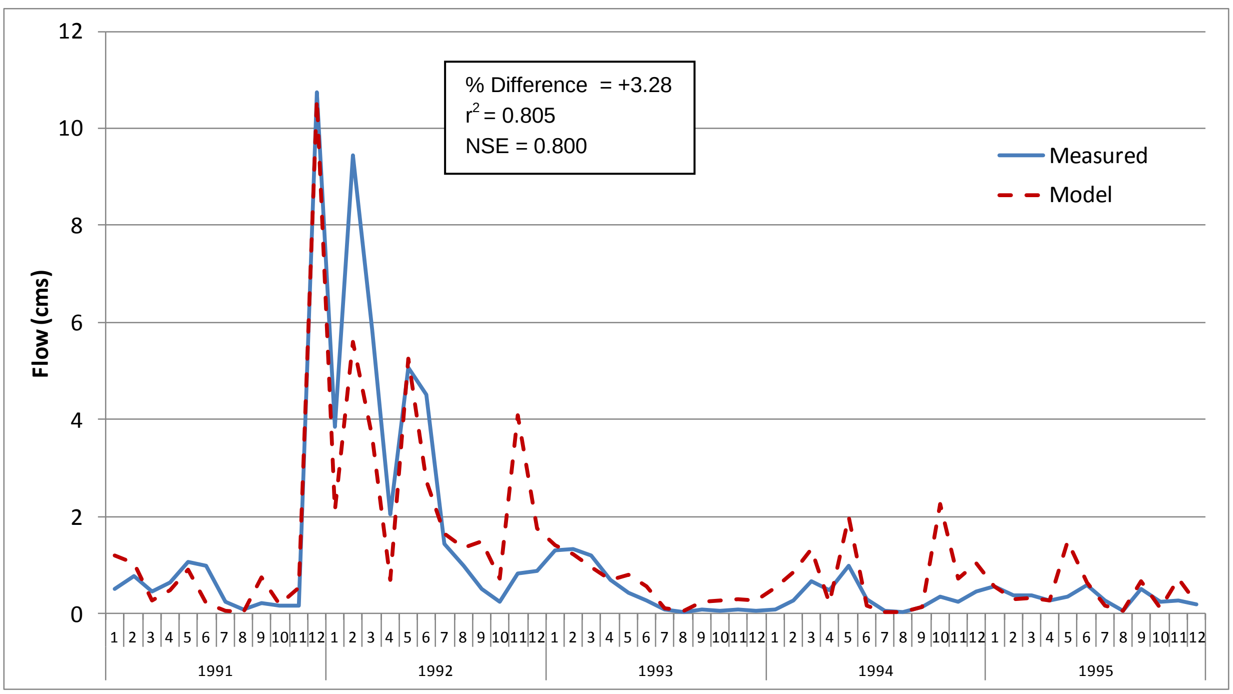


Figure B-8. Observed and Modeled Monthly Flow at USGS Gage 08183900

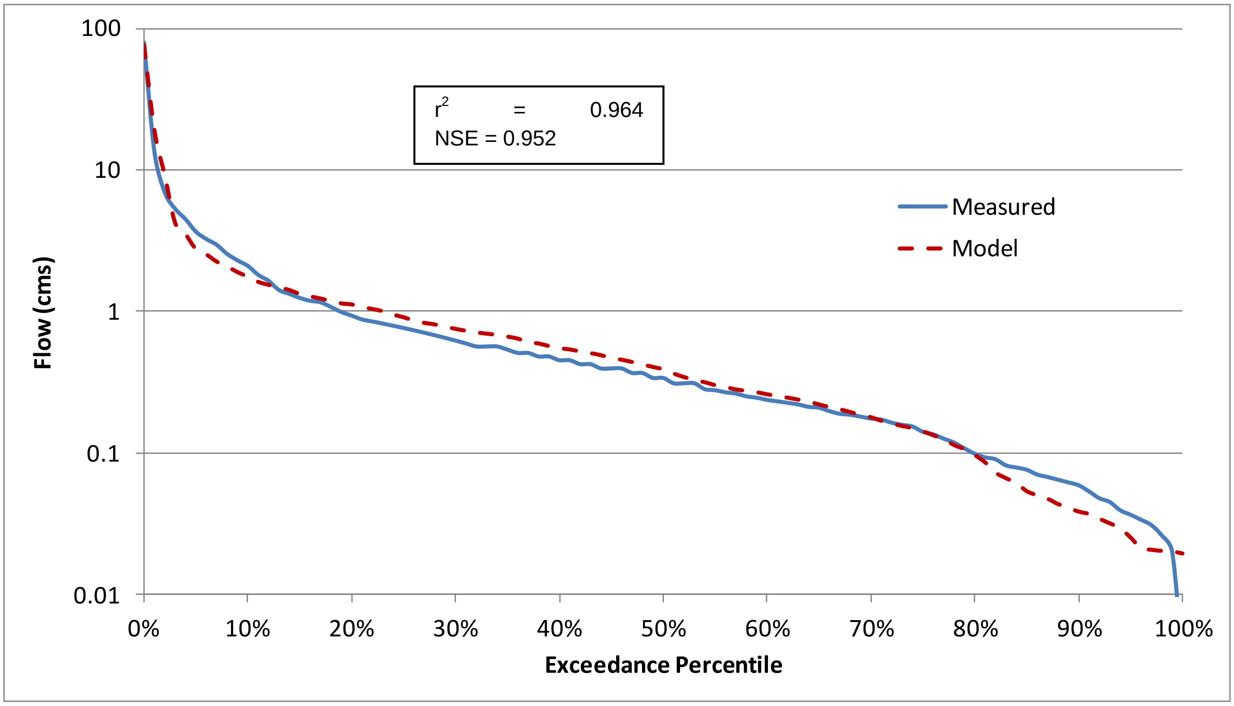


Figure B-9. Observed and Modeled Daily Flow Duration Curve at USGS Gage 08183900

Water Quality Calibration

Water quality data collected from 1990 to 2011 from stations co-located with the flow calibration gages were used for water quality calibration (Figure 2-7). These stations, along with the nearby flow stations, are listed in Table B-3. Table B-3 summarizes the available water quality data for those stations, as retrieved from the TCEQ surface water quality monitoring information system (for data collected prior to mid-2011), or provided by the City of Boerne (for data collected in 2011). This monitoring dataset includes ambient quality-assured data collected by the City of Boerne, TCEQ, San Antonio River Authority, Texas A&M University–Kingsville, and the Conrad Blucher Institute for Surveying and Science.

The calibration dataset was biased toward low flow conditions, and in some cases a majority of the data was collected during 2011 in the midst of a drought. The average model-predicted flow at Upper Cibolo Creek at IH-10 (reach 8) on the 34 days when *E.coli* samples were collected was 3.2 cfs, less than 20% of the 17.1 cfs average flow for the full calibration period. Similarly, the average flow at the same site on 25 days when total phosphorus was collected was 3.7 cfs. Further downstream at reach 17, the average model-predicted flow was 13.0 cfs on the 27 days when *E.coli* samples were collected, and 15.2 cfs on the 33 days when TP samples were collected, while the average flow for the calibration period was 36.7 cfs.

The ambient water quality dataset used for water quality calibration was also somewhat biased toward the warmer months, particularly from March to August when cliff swallows were expected to be present. Of the 34 *E.coli* samples collected, 23 were collected during the six months when swallows are typically present.

This sampling bias is believed to have contributed to the evaluation by the model of Reach 8 as not meeting water quality standards for contact recreation, despite inclusion of that site on the 303(d) List of impaired waterbodies.

Most of the samples were collected when *E.coli* conditions are expected to be high due to the presence of swallows, and less flow in Cibolo Creek to dilute their *E.coli* contributions. Relatively fewer samples were collected under conditions when *E.coli* concentrations are expected to be low (September through February).

SWAT was calibrated by comparing the averages of the measured concentrations to the average model-predicted concentrations on the same dates. Table B-4 summarizes the array of parameters that were adjusted to calibrate SWAT for sediment, phosphorus, nitrogen, DO and *E.coli*.

Table B-3. Summary of Available Water Quality Data

Station ID	Description	Model Reach	Period	Number of Samples								
				TSS	PO4-P	TP	TKN	NH3-N	NOx-N	*E.coli*	cBOD	DO
12857	Cibolo Creek at IH-10 (08183850)	8	1990-2000	2	3	3	0	3	3	0	0	3
			2001-2010	4	15	12	5	7	14	14	4	14
			2011	10	10	10	10	10	4	20	4	10
12855	Cibolo Creek at Boerne City Park (08183890)	17	1990-2000	4	6	7	1	6	7	1	0	12
			2001-2010	5	5	5	4	5	5	5	0	7
			2011	21	21	21	21	21	6	21	6	20
12853	Cibolo Creek southeast of Boerne (08183900)	21	1990-2000	27	27	27	23	27	27	0	0	24
			2001-2010	0	11	11	13	13	12	0	13	13
			2011	20	20	20	20	20	5	20	5	20

Table B-4. List of Adjusted Parameters for Water Quality Calibration of the SWAT Model

Calibration Type	Parameter	Units	Description	Subwatershed or Reach	Calibrated Value	Normal Range (Default Value)
E.coli	BACTMIX	10 m^3/Mg	*E.coli* percolation coefficient	All	7	7 – 20 (10)
	BACT_SWF	--	Fraction of applied manure that has live *E.coli*	All	1	0 – 1 (0)
	BACTKDQ	m^3/Mg	*E.coli* partition coefficient	All	10	0 – 500 (175)
	WDLPRCH, WDLPRES	day^{-1}	die-off factor for *E.coli* in streams and reservoirs	All	2	(0)
Phosphorus	GWSOLP	mg/L	PO4-P concentration in groundwater	All	2	0-1000 (0)
	LAT_ORGP	mg/L	OrgP concentration in base flow	All	20	0 – 200 (0)
	PSETLR	m/yr	Phosphorus settling rate in reservoir	All	20	2 – 20 (10)
	BC4	day^{-1}	Rate for mineralization of ORGP to PO4-P	All	0.01	0.01 – 0.7 (0.35)
Nitrogen	BC1	day^{-1}	Rate of conversion of NH3-N to nitrite	All	0.1	0.1-1.0 (0.55)
	BC2	day^{-1}	Rate of conversion of nitrite to nitrate	All	0.2	0.2-2.0 (1.1)
	BC3	day^{-1}	Rate of conversion of ORGN to NH4-N	All	0.02	0.02-0.4 (0.35)

Calibration Type	Parameter	Units	Description	Subwatershed or Reach	Calibrated Value	Normal Range (Default Value)
	SDNCO	--	Denitrification threshold soil water content	All	1	0 - 1.2 (1.1)
	HLIFE_NGW	days	Half-life of nitrogen in groundwater	All	5	0 – 500 (0)
DO	RK1	day^{-1}	cBOD deoxygenation rate	All	0.02	.02 - 3.4 (1.71)
	RK2	day^{-1}	Oxygen reaeration rate	6-9	50	0 – 100 (50)
				17	0.05	
				Other reaches	1.0	
	RK3	day^{-1}	cBOD settling rate	All	-0.36	-0.36 – 0.36 (0.36)
Sediment	RESNSED	mg/l	reservoir normal sediment concentration	All	1	1-5000 (10)
	SPCON	--	Sediment re-entrainment linear parameter	All	0.0002	0.0001-.01 (0.0001)
	SPEXP	--	Sediment re-entrainment exponent	All	1.5	1 – 1.5 (1)

Figure B-10 compares observed and measured *E.coli* concentrations. Due to the broad range of measured concentrations spanning multiple orders of magnitude, logarithmic-transformed concentrations are shown. The height of the blue bar illustrates the average of the measured concentrations. The narrow black "whiskers" illustrate the variability in the measured concentrations, showing one standard deviation above and below the average concentration. The average concentration predicted by the model at each site is illustrated by the vertical red bars. Model-predicted concentrations agree well with the observed data, especially at model Reach 8 (Cibolo Creek at IH-10), where a water quality impairment has been identified. The water quality criterion for *E.coli* is 126 organisms per 100 ml, approximately 2.1 in base 10 log-transformed units.

Figure B-11 compares observed and modeled TP concentrations for the three calibration stations. The model predicts the average of the measured TP concentrations except at model Reach 8. Reach 8 is an extremely shallow monitoring site (typically only 6 inches deep) often with very low flow. SWAT and most other water quality models have some difficulty simulating water quality under stagnant conditions. There are also large populations of attached algae and macrophytes, which are not simulated in SWAT, but may take up the available phosphorus.

Figure B-12 compares observed and measured TN concentrations for the three calibration stations. The model predicts the average of the measured TN concentrations at the various locations within 0.5 mg/L at each of the three stations.

Figure B-13 compares observed and measured DO concentrations. The model predictions are in fair agreement with measured values at all three stations.

Figure B-14 compares observed and modeled TSS concentrations for the three calibration stations. The model predicts the average of the measured TSS concentrations at the various locations within 2 mg/L at each of the three stations.

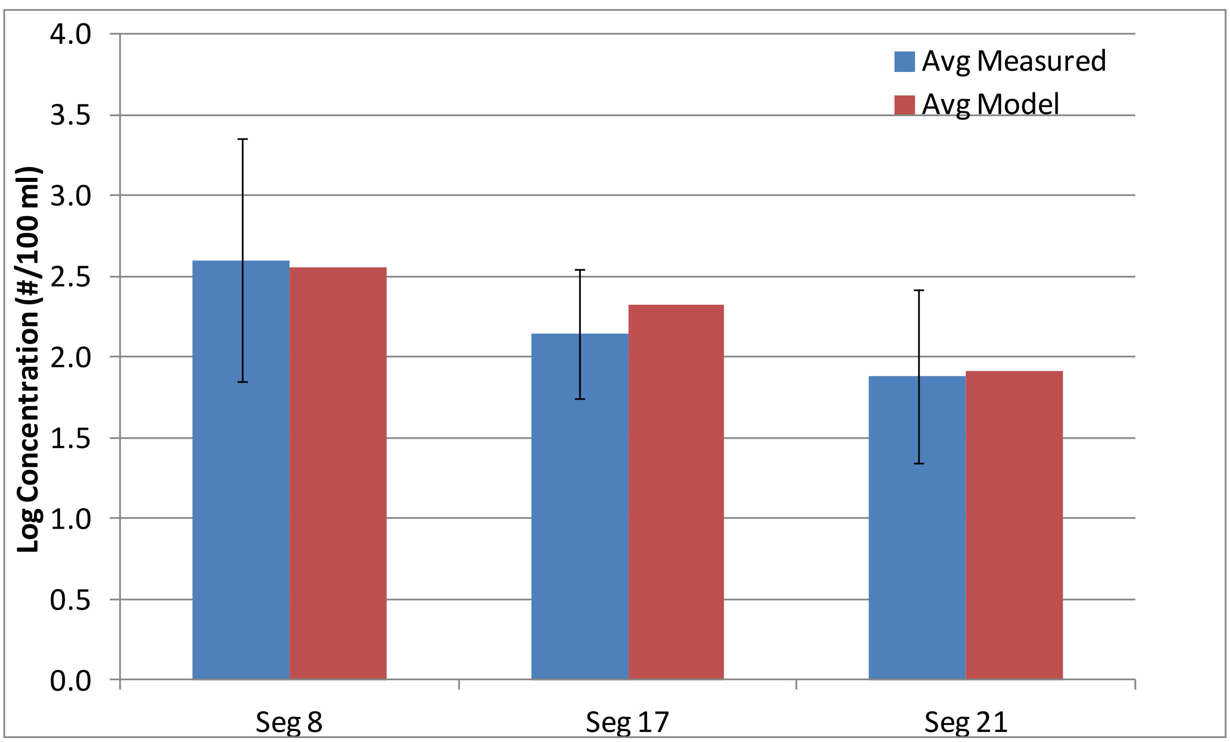


Figure B-10. Observed and Modeled Average *E.coli* Concentrations

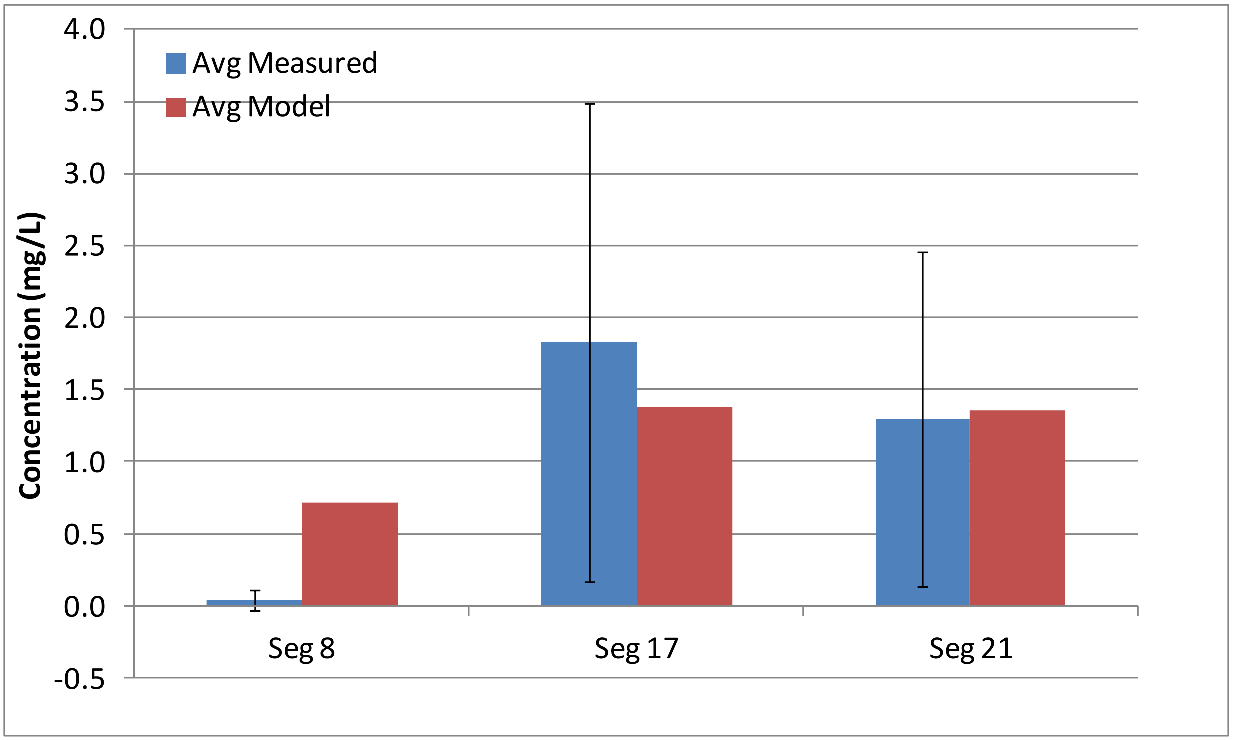


Figure B-11. Observed and Modeled Average TP Concentrations

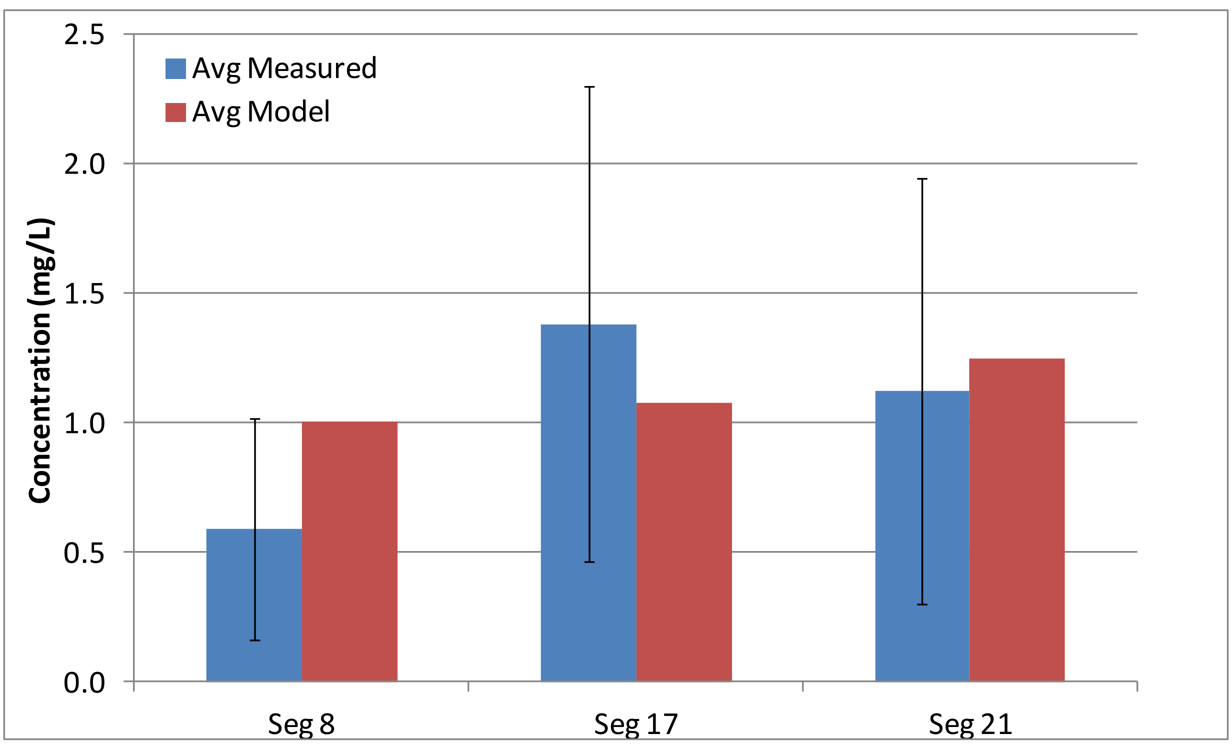


Figure B-12. Observed and Modeled Average TN Concentrations

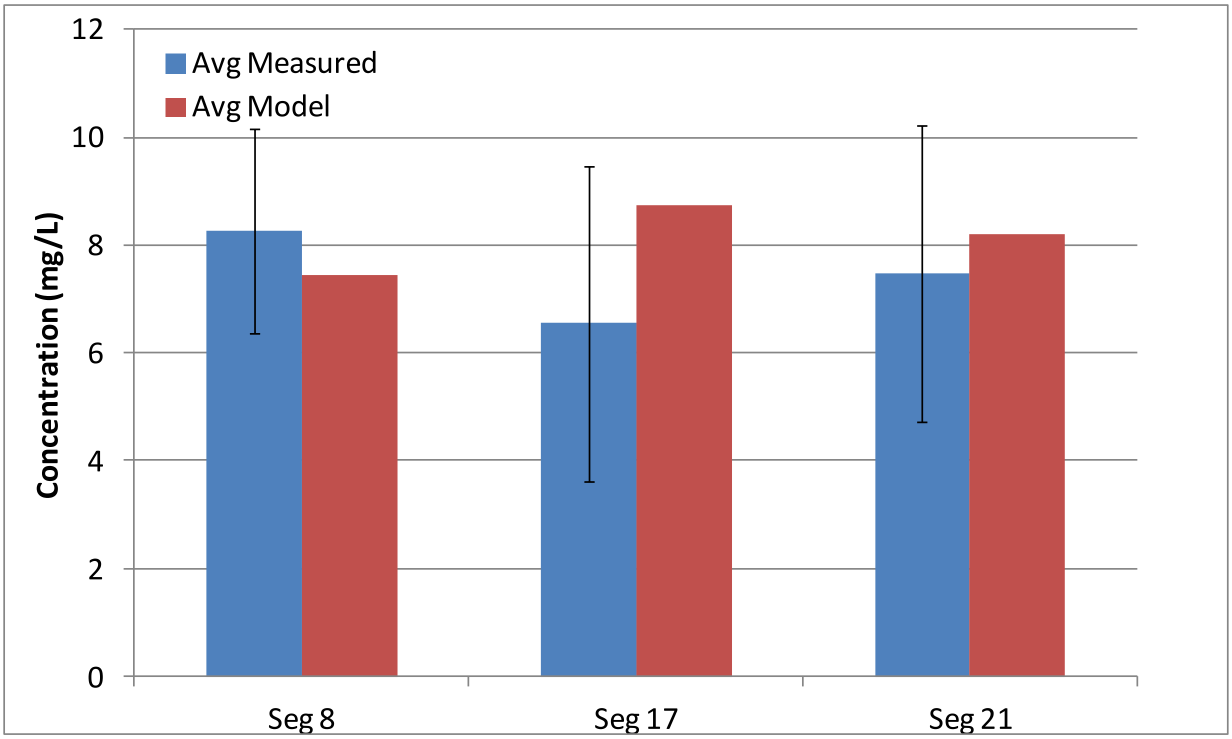


Figure B-13. Observed and Modeled Average DO Concentrations

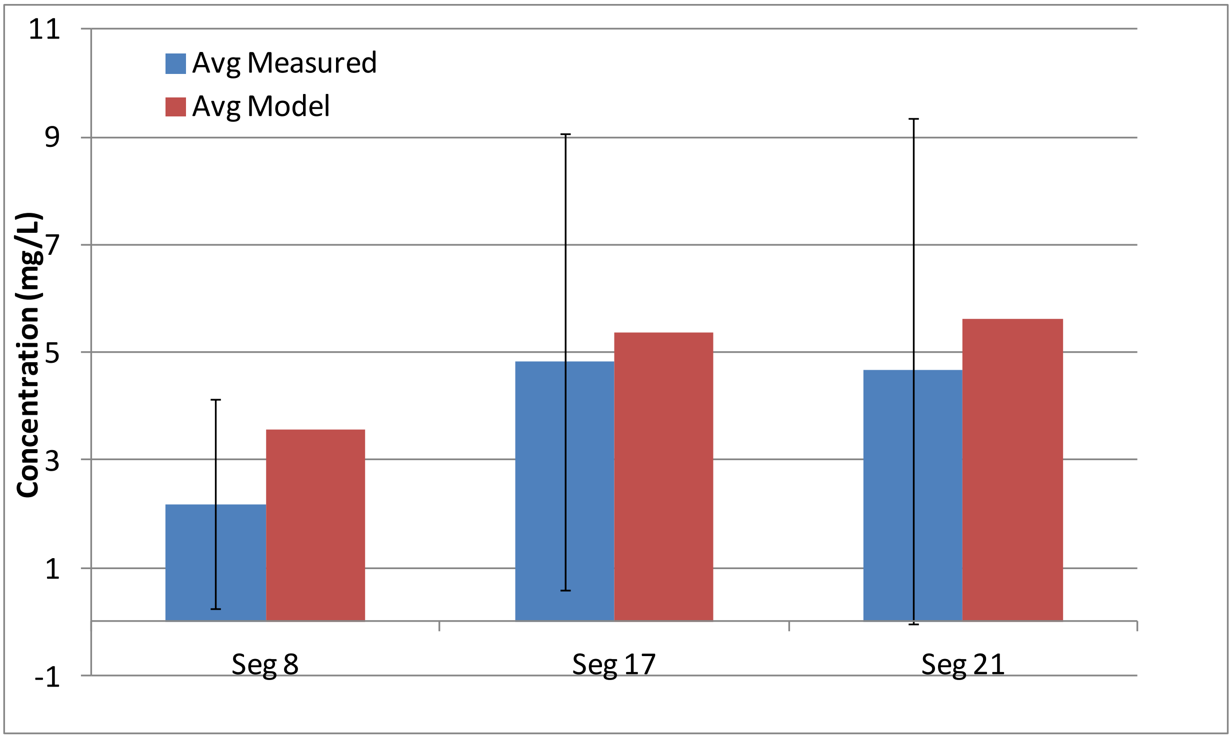


Figure B-14. Observed and Modeled Average TSS Concentrations

Table B-5 summarizes the model fit for the various water quality parameters. As can be seen, in most cases the model reproduces total nutrient concentrations within calibration targets. In some instances, the model does not replicate speciation of the nutrients (e.g., the relative abundance of nitrate, ammonia, and organic nitrogen), but nevertheless TP and TN predicted averages are within targets.

Table B-5. Summary of Model Fit for Water Quality Average Concentrations

Parameter	Rch 8		Rch 17		Rch 21	
	Mean (±SD)	Model	Mean (±SD)	Model	Mean (±SD)	Model
TSS	2.19±1.94	3.56	4.82±4.24	5.35	4.66±4.68	5.63
log *E.coli*	2.60±0.75	2.55	2.14±0.40	2.32	1.88±0.54	1.91
PO_4-P	0.02±0.04	0.79	1.62±1.28	1.35	1.18±1.01	1.27
TP	0.04±0.07	0.71	1.83±1.66	1.38	1.30±1.17	1.35
OrgN	0.19±0.15	0.01	0.60±0.28	0.04	0.59±0.25	0.08
NH_4-N	0.06±0.05	0.00	0.06±0.03	0.02	0.06±0.06	0.08
NO_x-N	0.34±0.43	1.11	0.73±0.92	0.94	0.47±0.82	1.11
TN	0.59±0.43	1.00	1.38±0.92	1.08	1.12±0.82	1.25
cBOD	1.00±0.00	0.01	1.33±0.82	1.47	1.72±1.13	1.24
DO	8.25±1.90	7.46	6.55±2.92	8.74	7.48±2.76	8.19

Reach 8 was often the most difficult to simulate. This may be due to:

- Extreme shallowness of the monitoring station, which enhances the influence of sediments relative to water column processes simulated in the model;
- Abundance of attached algae and macrophytes, which are not simulated by SWAT;
- Flow is often minimal and stagnant conditions typically prevail; and
- Much of the total flow volume is from the occasional wet weather spillage from Boerne City Lake, for which no monitoring data exist to provide a boundary condition.

Surface water impoundments in the Upper Cibolo Creek watershed act as “sinks” for pollutants and consequently can influence downstream water quality conditions. Boerne City Lake does reduce the delivery of instream bacteria loads from subwatersheds 1, 2, 3, 4 and 5 downstream to subwatershed 8. This is another factor that suggests the major sources of bacteria loads influencing water quality conditions measured at station 12857 originate from subwatershed 8, as well as, subwatersheds 6 (Comanche Spring Creek), 7 (Easter Creek), and 9 and 10 (Ranger Creek) rather than from pollutant source contributions upstream of Boerne City Lake.

Model Validation

Model validation proves the capability of the model to predict future conditions by testing the model with relatively extreme conditions. The model was validated by comparing the model output to measured data collected during the years 2007 and 2011, as specified in the project Quality Assurance Project Plan. These are the most recent exceptionally wet and dry years. In 2007 more than 58 inches of rain fell in the watershed, while 2011 was one of the driest years on record. Except for four TSS and *E.coli* measurements at Station 12853, there were no water quality measurements during 2007 at any of the calibration sites.

Model validation criteria were identical to calibration criteria. The model met validation criteria for flow, TSS, *E.coli*, DO, TP, and TN at all sites except as noted in the following paragraphs.

The calibrated model did not meet validation criteria for TP (or PO4-P) at Station 12857 (Reach 8) where in 2011 the measured average TP level was 0.02 mg/L and the average modeled concentration on these dates was 0.12 mg/L. However, with the levels of a similar and low magnitude, and the standard deviation of measured data artificially lowered by detection limits, it was found that substantial improvement could not be obtained by re-calibration.

The calibrated model did not meet validation criteria in 2011 for DO at Station 12855 (Reach 17) or Station 12857 (Reach 8). The average measured DO concentration at Station 12857 in 2011 was 8.5 mg/L and the average model-predicted concentration was 4.0 mg/L. At Station 12855 in 2011, the average measured DO concentration was 4.6 mg/L while the average model-predicted concentration was 8.8 mg/L. Re-calibration did not improve model predictions. In SWAT, re-aeration is strongly controlled by water velocity. Under low flow conditions such as those prevalent in 2011, the model did not perform well. Thus, model predictions of DO concentrations should be used with caution, especially for low flow conditions.

The model did not meet validation criteria for OrgN or NH_3-N at any of the three stations, often under-predicting measured levels of OrgN and over-predicting NH_3-N. To some extent these results for ammonia were affected by artificially low variation in reported concentrations due to censored values at a constant laboratory reporting limit. Model parameters governing rates of conversion among nitrogen species were adjusted within normal ranges, but validation targets could not be achieved while maintaining TN within calibration.

Appendix C. EPAs Nine Elements of Watershed Plans

Element A. *Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed (e.g., X number of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded streambank needing remediation.*

What does this mean?
Your watershed plan should include a map of the watershed that locates the major causes and sources of impairment. To address these impairments, you will set goals that will include (at a minimum) meeting the appropriate water quality standards for pollutants that threaten or impair the physical, chemical, or biological integrity of the watershed covered in the plan. This element will usually include an accounting of the significant point and nonpoint sources in addition to the natural background levels that make up the pollutant loads causing problems in the watershed. If a TMDL exists, this element may be adequately addressed. If not, you will need to conduct a similar analysis to do this. The analytical methods may include mapping, modeling, monitoring, and field assessments to make the link between the sources of pollution and the extent to which they cause the water to exceed relevant water quality standards.

Element B*. An estimate of the load reductions expected from management measures.*

What does this mean?
On the basis of the existing source loads estimated for element *a*, you will similarly determine the reductions needed to meet the water quality standards. You will then identify various management measures (see element *c* below) that will help to reduce the pollutant loads and estimate the load reductions expected as a result of these management measures to be implemented, recognizing the difficulty in precisely predicting the performance of management measures over time. Estimates should be provided at the same level as that required in the scale and scope component in paragraph *a* (e.g., the total load reduction expected for dairy cattle feedlots, row crops, or eroded streambanks).

Element C. *A description of the nonpoint source management measures that will need to be implemented to achieve load reductions in paragraph 2, and a description of the critical areas in which those measures will be needed to implement this plan.*

What does this mean?
The plan should describe the management measures that need to be implemented to achieve the load reductions estimated under element *b*, as well as to achieve any additional pollution prevention goals called out in the watershed plan (e.g., habitat conservation and protection). Pollutant loads will vary even within land use types, so the plan should also identify the critical areas in which those measures will be needed to implement the plan. This description should be detailed enough to guide implementation activities and can be greatly enhanced by identifying on a map priority areas and practices.

Element D. *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.*

What does this mean?
You should estimate the financial and technical assistance needed to implement the entire plan. This includes implementation and long-term operation and maintenance of management measures, I/E activities, monitoring, and evaluation activities. You should also document which relevant authorities might play a role in implementing the plan. Plan sponsors should consider the use of federal, state, local, and private funds or resources that might be available to assist in implementing the plan. Shortfalls between needs and available resources should be identified and addressed in the plan.

Element E. *An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.*

What does this mean?
The plan should include an I/E component that identifies the education and outreach activities or actions that will be used to implement the plan. These I/E activities may support the adoption and long-term operation and maintenance of management practices and support stakeholder involvement efforts.

Element *f. Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.*

What does this mean?
You should include a schedule for implementing the management measures outlined in your watershed plan. The schedule should reflect the milestones being developed.

Element G. *A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.*

What does this mean?
You'll develop interim, measurable milestones to measure progress in implementing the management measures for your watershed plan. These milestones will measure the implementation of the management measures, such as whether they are being implemented on schedule, whereas element *h* (see below) will measure the effectiveness of the management measures, for example, by documenting improvements in water quality.

Element H. *A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.*

What does this mean?
As projects are implemented in the watershed, you will need water quality benchmarks to track progress. The *criteria* in element *h* (not to be confused with *water quality criteria* in state regulations) are the benchmarks or waypoints to measure against through monitoring. These interim targets can be direct measurements (e.g., fecal coliform concentrations) or indirect indicators of load reduction (e.g., number of beach closings). You should also indicate how you'll determine whether the watershed plan needs to be revised if interim targets are not met. These revisions could involve changing management practices, updating the loading analyses, and reassessing the time it takes for pollution concentrations to respond to treatment.

Element I. *A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item* h *immediately above.*

What does this mean?
The watershed plan should include a monitoring component to determine whether progress is being made toward attaining or maintaining the applicable water quality standards. The monitoring program should be fully integrated with the established schedule and interim milestone criteria identified above. The monitoring component should be designed to determine whether loading reductions are being achieved over time and substantial progress in meeting water quality standards is being made. Watershed-scale monitoring can be used to measure the effects of multiple programs, projects, and trends over time. Instream monitoring does not have to be conducted for individual management strategies unless that type of monitoring is particularly relevant to the project.