A WATERSHED PROTECTION PLAN FOR THE SPRING CREEK WATERSHED

Photo Credit: Jessica Casillas

SPRING CREEK WATERSHED PARTNERSHIP

Houston-Galveston Area Council

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

EPA United States Environmental Protection Agency

Spring Creek Watershed Protection Plan

Developed for Spring Creek, Segment 1008 of the San Jacinto River Basin, by the Houston-Galveston Area Council on behalf of the Spring Creek Watershed Partnership.

February 2023

Water Body	Segment	Assessment Units
Spring Creek	1008	01, 02, 03, and 04
Mill Creek	1008A	01
Upper Panther Branch	1008B	01, and 02
Lower Panther Branch	1008C	01, and 02
Bear Branch	1008E	01
Lake Woodlands	1008F	01, 02, 03, and 04
Willow Creek	1008H	01
Walnut Creek	1008I	01
Brushy Creek	1008J	01

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EPA United States Environmental Protection Agency

Texas Commission on Environmental Quality

H-GAC Houston-Galveston Area Council

SPRING CREEK WATERSHED PARTNERSHIP

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Steering Committee

The Spring Creek Watershed Partnership (Partnership) wishes to sincerely thank the members of the project's Steering Committee. These individuals and organizations provided leadership and commitment to ensure the continuity and success of the project.

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Harris County Soil and Water Conservation District

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Navasota Soil and Water Conservation District

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Texas Master Naturalists

Texas Parks and Wildlife Department

Texas State Soil and Water Conservation Board

Texas Stream Team

U.S. Army Corps of Engineers

USDA Natural Resources Conservation Service

USDA U.S. Forest Service

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Photo Credit: Rachel Windham

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Abbreviations List

AgriLife Extension	Texas A&M University AgriLife Extension
AU	Assessment Unit
BIG	Bacteria Implementation Group
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
CBOD5	Carbonaceous Biochemical Oxygen Demand, 5-day
CFU	Colony Forming Unit(s)
CRP	Clean Rivers Program
CTA	Conservation Technical Assistance
CWA	Clean Water Act
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EQIP	Environmental Quality Incentive Program
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FOG	Fats, Oils, and Grease
GBEP	Galveston Bay Estuary Program
GIS	Geographic Information System
H-GAC	Houston-Galveston Area Council
HOA	Homeowners Association
I-Plan	(TMDL) Implementation Plan
Texas Integrated Report	Texas Integrated Report of Surface Water Quality
LDC	Load Duration Curve

LID	Low Impact Development
MGD	Million Gallons per Day
mL	Milliliters
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
MUD	Municipal Utility District
NGO	Non-governmental Organization
NHD+	National Hydrography Dataset Plus
NRCS	(USDA) Natural Resources Conservation Service
OSSF	On-Site Sewage Facility
Partnership	Spring Creek Watershed Partnership
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SEP	Supplemental Environmental Project
SJRA	San Jacinto River Authority
SPCA	Society for the Prevention of Cruelty to Animals
SSO	Sanitary Sewer Overflow
SWCD	Soil and Water Conservation District
SWQS	Surface Water Quality Standards
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TPWD	Texas Parks and Wildlife Department
TPDES	Texas Pollutant Discharge Elimination System
TSS	Total Suspended Solids
TSSWCB	Texas State Soil and Water Conservation Board

TST	Texas Stream Team
TWON	Texas Well Owner Network
TWRI	Texas Water Resources Institute
USACE	United States Army Corps of Engineers (Galveston)
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WCID	Water Control and Improvement District
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility

Supporting Documents

Several supporting documents providing additional detail about the analyses and processes the Partnership undertook to develop this watershed protection plan are hosted on the project website[1]. They include:

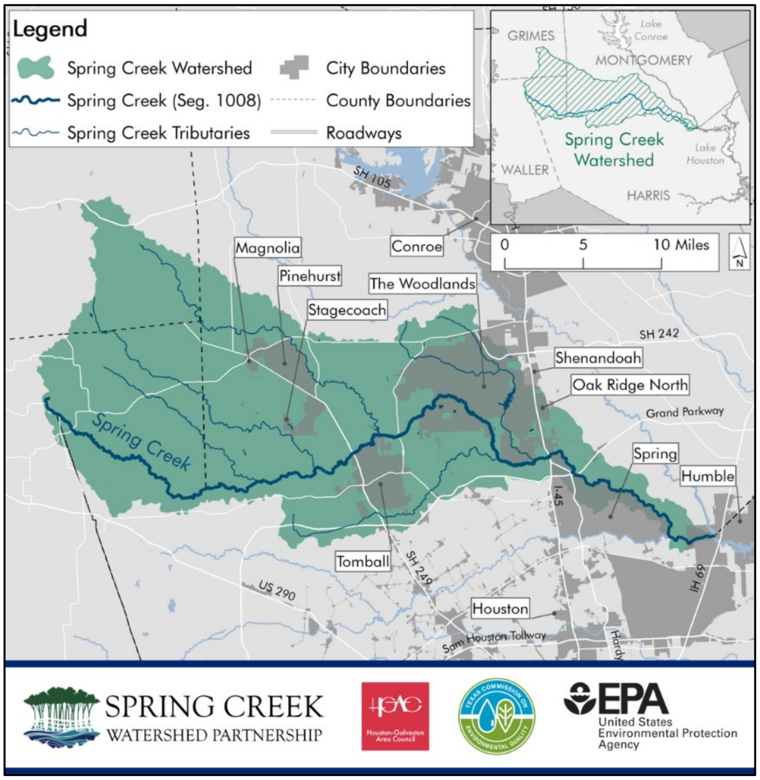
- **Quality Assurance Project Plan** – the quality assurance document indicating the manner and methods in which project modeling efforts were conducted to ensure results reflect project data quality objectives.
- **Water Quality Data Analysis Summary Report** – a detailed report on analyses of various water quality data used to characterize the conditions in the project area waterways.
- **Bacteria Modeling Report** – a detailed summary of the development, implementation, and results of the bacteria modeling efforts.
- **Public Outreach Report** – a summary of the efforts and activities conducted by the Houston-Galveston Area Council to engage and inform project stakeholders, key partners, and general watershed audiences.

[1] Visit www.springcreekpartnership.weebly.com to lean more.

Executive Summary

The Spring Creek Watershed

Spring Creek (Segment 1008) runs east from headwaters in Waller County to a confluence with the West Fork of the San Jacinto River near its confluence with Cypress Creek. Combined, these waterways contribute appreciable flows to the Lake Houston reservoir, an important drinking water source for the region. As Spring Creek forms the majority of the border between Montgomery and Harris counties, it connects a diverse landscape transitioning from natural areas such as riparian forest and grassland to the more widely developed areas near the I-45 corridor. Approximately 440 square miles of land area drain into 903 linear miles of stream network within the Spring Creek watershed. This area and its waterways represent an essential part of supporting local communities and economies, recreation, fisheries, and a diverse ecology.



Water Quality Challenges

Water quality issues, primarily high levels of fecal waste indicated by the presence of the indicator bacteria *Escherichia coli* (*E. coli*), are prevalent throughout the Spring Creek watershed and are of particular concern as flows from Spring Creek contribute to the Lake Houston reservoir. Elevated levels of fecal waste in area waterways can be a result of both human activities, such as overflow from sanitary sewers and on-site sewage facilities, as well as natural influences like waste from native wildlife and invasive species. Harmful pathogens associated with fecal waste can impact public health. In addition to water quality issues related to fecal waste, Spring Creek and its tributaries face other water quality concerns like low levels of dissolved oxygen, which can endanger aquatic life, and excess

nutrients (nitrogen and phosphorus compounds) which can exacerbate low dissolved oxygen levels. Other challenges noted by area stakeholders include increased sedimentation and trash.

Water quality is sampled in Spring Creek and its tributaries at least quarterly at 20 active monitoring stations, providing the basis for assessing the health of the system. As in past years, the 2020 Texas Integrated Report of Surface Water Quality (a summary of water quality in Texas waterways) indicates that Spring Creek has a contact recreation impairment due to levels of *E. coli* that exceed the state water quality standard. Several of Spring Creek's tributary waterways are also unable to meet the contact recreation standard, including Lower Panther Branch (1008C), Willow Creek (1008H), Walnut Creek (1008I), and Brushy Creek (1008J). The 2020 Texas Integrated Report also indicated concerns for low levels of dissolved oxygen in the Lake Woodlands Reservoir (1008F). Concerns for high nutrient concentrations were observed in the downstream portion of Spring Creek, Upper Panther Branch (1008B), Lower Panther Branch, and Willow Creek which are all located on the more developed eastern side of the watershed. Other concerns of note indicated in the 2020 Texas Integrated Report include a concern for fish community on Spring Creek and a concern for elevated levels of cadmium on Upper Panther Branch.

The sources of water quality concerns and impairments in this watershed are widespread, diffuse, and diverse in origin, making them more difficult to address through traditional approaches focusing on single entities and regulation. Primary sources of concern are pet waste, livestock, and waste from invasive feral hogs. Pollutant sources related to human activity will continue to increase as area growth drives future development in the watershed, exacerbating the existing situation. Watershed Protection Plan (WPP) project estimates indicate that necessary reductions of *E. coli* loads range from 49% to 63% currently, and without intervention, would increase to 64% to 76% by 2030.

Local concerns over the future of Spring Creek led to the development of this WPP as a voluntary, locally-led approach to improving water quality for this area. The Houston-Galveston Area Council (H-GAC) and the Texas Commission on Environmental Quality (TCEQ) facilitated the formation and efforts of the Spring Creek Watershed Partnership, a group of local stakeholders representing residents, government, industry, agricultural producers, community groups, and other local partners. The purpose of the WPP is to use sound science and local knowledge to identify sources of pollution and support community-led decision-making about potential solutions.

Finding Solutions

The Partnership used a variety of methods to evaluate the causes and sources of water quality issues. Interpretation of water quality monitoring data and computer modeling efforts were shaped by local knowledge. Local stakeholders reviewed and revised these results and used them to inform decisions about potential solutions. Specific focus was given to reducing fecal waste, which can directly impact human health, and precursors for low dissolved oxygen, which impacts aquatic life and recreational fishing. Activities to address fecal waste sources and other concerns were identified and discussed by members of the Partnership who worked diligently to balance local interests and ensure that solutions reflected community priorities. Because pollutant sources are diverse, the Partnership's recommendations represent a flexible range of solutions designed to adapt to changing conditions. The result of these efforts is a set of voluntary solutions that will guide efforts to improve water quality through 2030.

Implementing the Plan

Implementation of the WPP will require the continued coordination, cooperation, and commitment of the local partners. The general guidelines for implementation established by the stakeholders are that solutions should be voluntary, solutions should be cost-effective, decisions should continue to be made by local stakeholders, education should be a primary tool, due diligence should be given to avoiding unintended consequences, and that established programs or resources should be used whenever possible in place of new efforts. A crucial aspect of supporting these efforts will be an ongoing education and outreach campaign focused on increasing public awareness and participation. Successful implementation will rely on an active, engaged stakeholder group.

Ensuring Success

As the WPP is implemented, the stakeholders will review efforts periodically to ensure that progress is being made. The stakeholders established a series of milestones and measures of success to aid in determining whether progress is being made. The ultimate test of the WPP's success will be the ability of the waterways to meet state water quality standards based on water quality monitoring data. However, incremental progress will also be measured by achieving programmatic goals. The WPP will utilize adaptive management to modify approaches to meet new challenges and changing conditions. The following table is a guide to the contents of the WPP. Additional information on specific items can be found in Appendix A.

Watershed Protection Plan Content Guide

WPP Section	Description	EPA Element	Location
Section 1 – Project Background	An introduction to the watershed planning process for Spring Creek	NA	pp. 1-7, Appendix A
Section 2 – Watershed Characterization	A summary of the physical (geography, climate, *etc.*), human (land use, political geography), and water quality characteristics of the watershed	NA	pp. 9-36, Appendix B
Section 3 – Identifying Pollutant Sources	An evaluation of water quality data, stakeholder knowledge and modeling results to identify and characterize causes and sources of pollution	• Element A – Identify the causes and sources of pollution	pp. 38-93, Appendix B
Section 4 – Improving Water Quality	Establishing the amount of reduction in pollutant source loads needed to achieve water quality goals	• Element B – Estimate of load reductions	pp. 95-110
Section 5 – Recommended Solutions	A description of the solutions recommended by the Partnership, including information about the selection process, and the cost and technical expertise needed to implement them	• Element C – Description of management measures • Element D - Estimate of technical and financial resources needed	pp. 112-151, Appendices C and D
Section 6 – Education and Outreach	An outline of the education and outreach efforts that will increase public awareness of the WPP and support its implementation	• Element E – Information and Public Education Component	pp. 153-164
Section 7 – Implementation	The schedules for implementation, and measurable milestones for tracking progress	• Element F – Schedule for implementation • Element G – Interim measurable milestones	pp. 166-183
Section 8 – Evaluating Success	An overview of the criteria and data that will be used to evaluate the success of implementation efforts	• Element H – Criteria for successful implementation • Element I – Monitoring component to evaluate effectiveness	pp. 185-190

Section 1

Project Background

Photo Credit: Jessica Casillas

Section 1. Project Background

Background

The Spring Creek Watershed Partnership (Partnership) developed this watershed protection plan (WPP) to address water quality issues in Spring Creek and its tributaries. The purpose of this planning effort is to use a watershed approach to identify and reduce sources of contamination in the watershed through effective, voluntary solutions.

A Watershed Approach

A watershed is generally defined as all the area of land that drains to a common body of water. Watersheds can range in size from the drainage basins of large rivers to small catchments that may cover a few square miles of a local neighborhood. Regardless of the scale, they are more than just drainage boundaries. Watersheds are dynamic systems and represent the sum of everything that happens on that land. The way we use the land, the natural processes that take place on it, the way these things change over time; everything that takes place within a watershed influences the quality of the water that flows over it and into its water bodies (**Figure 1**[2]).

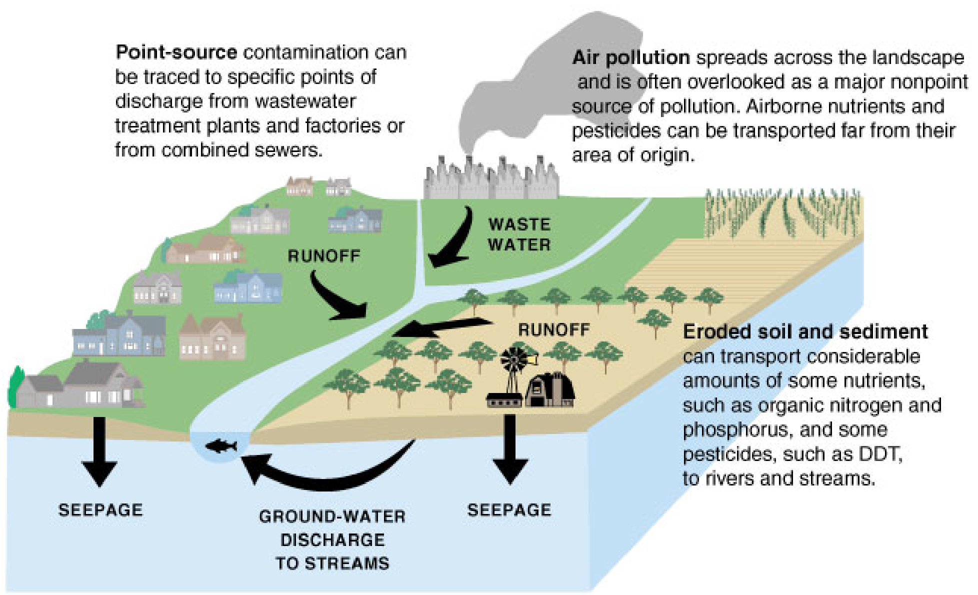


Figure 1. Pollution sources in a watershed

Because watersheds are determined by the topography of the land rather than political boundaries, they often cross multiple political jurisdictions. Water is not bound by political geography; contaminants in the water can travel freely across borders. Pollution entering

[2] Image courtesy of United States Geological Survey (USGS)

the waterway in one part of the watershed can impact other areas downstream. This fundamental aspect of watersheds limits the ability of individual political entities to wholly address sources of contamination in their waterways.

A **watershed approach** addresses water quality issues by focusing on both the waterways and their watershed as a linked system in which the drainage area's mix of land uses and potential sources of pollution are considered. Benefits of a watershed approach include:

- Reflecting the connection between land and water,
- Coordinating multi-jurisdictional efforts to focus on shared priorities, and
- Helping stakeholders understand potential future impacts to waterways based on the changing character of their watershed.

In Texas, the watershed approach to address water quality issues is often employed through the development of a WPP.

Watershed Protection Plans

WPPs are planning documents that serve as a road map for local communities to take active stewardship of their surface water resources. In Texas, most WPPs follow the United States Environmental Protection Agency's (EPA) nine element model[3], which outlines several key steps to characterizing a watershed, understanding its water quality challenges, and devising appropriate solutions. Developed through locally led planning projects, WPPs use scientific analysis and stakeholder knowledge to identify and characterize water quality priorities and identify voluntary solutions to meet specific goals. Unlike regulatory actions to restore water quality, the WPP process is a non-regulatory approach based on the use of voluntary management measures employed by local communities who have a stake in their waterways[4]. At the heart of the WPP process is a recognition of the value of natural benefits ("ecosystem services") provided by the watersheds.

Public participation is a core component of the WPP process because the successful implementation of a WPP relies on an engaged and committed stakeholder group. **Stakeholders** are defined as any person or group in the watershed who has a defined interest in the waterway or who may be impacted by the water quality issues or the WPP recommendations. Stakeholders can include residents, elected officials, local governments, landowners, agricultural producers, recreation enthusiasts, businesses, and community groups. WPPs are best served by a diverse group of stakeholders who can represent the

[3] More information on EPA's guidance for developing watershed-based plans can be found at: https://www.epa.gov/nps/handbook-developing-watershed-plans-restore-and-protect-our-waters

[4] While there are no mandatory elements recommended by this WPP, local partners currently engage in regulatory activities that are supplemental to this project as part of their normal operations (*e.g.*, enforcement of municipal pet waste ordinances).

different interests in the watershed. The stakeholder group is often facilitated by state or regional organizations like the Texas Commission on Environmental Quality (TCEQ) and Texas State Soil and Water Conservation Board (TSSWCB) who use their expertise in watershed management to guide the stakeholders' efforts. Funding for WPPs is often provided through federal Clean Water Act (CWA) grants, some of which require matching funds or in-kind time from local stakeholders.

A Watershed Protection Plan for Spring Creek

Water quality issues in the Spring Creek system (Segment 1008) and local concern over the impact of future changes in the watershed were the impetus for undertaking a watershed-based plan. Previous projects in the greater Lake Houston Watershed area, including the Lake Conroe WPP[5], the East and West Forks of the San Jacinto River Total Maximum Daily Load (TMDL)[6], the West Fork San Jacinto River and Lake Creek WPP[7], the Cypress Creek WPP[8] and various other TMDLs in the area established widespread local interest and commitment to address water quality. The desire to evaluate these areas on a local level for Spring Creek, and to consider other local concerns, led to the formation of the Partnership in 2020. The WPP model was chosen for its ability to address other local concerns in addition to surface water quality standard (SWQS) impairments and for its voluntary nature. Additionally, the intent to coordinate water quality issues with community concerns about hydrologic issues and sedimentation were at the forefront of local considerations.

The Spring Creek Watershed Partnership

The Partnership is a group of local stakeholders from various interests and partner agencies committed to protecting the public health, economy, and environment of their communities. Local facilitation of the Partnership was supported by the Houston-Galveston Area Council (H-GAC) as part of a joint project with TCEQ, funded through a CWA §319(h) grant from EPA. The Partnership is a voluntary association of stakeholders, holding no regulatory power. This WPP is a summary of the multi-year planning effort conducted by the Partnership and serves as guidance for future implementation activities. Using the watershed planning model, this plan is based on local decision-making supported by local knowledge, robust public participation, and technical and scientific analysis. The Partnership held six full Partnership meetings and two sets of topical Work Group meetings between July

[5] More information on this project can be found at: https://www.sjra.net/wp-content/uploads/2014/12/Lake-Conroe-Watershed-Protection-Plan.pdf

[6] More information on this project can be found at: https://www.h-gac.com/watershed-based-plans/east-and-west-forks-of-the-san-jacinto-river-tmdl-and-implementation-plan

[7] More information on this project can be found at: http://www.westfork.weebly.com

[8] More information on this project can be found at http://www.cypresspartnership.weebly.com/

2020 and August 2021 to discuss and provide feedback on a variety of water quality issues[9] (**Table 1**). Representation from a diverse range of local stakeholders ensured that recommendations of the group were vetted from multiple viewpoints and interests. All meetings were open to the public, and materials were disseminated on the project website and via email. A core group of stakeholders served as a Steering Committee, and the meetings operated under a set of ground rules spelled out in the project's public participation plan[10]. Topical Work Group meetings were held as needed throughout the project to allow for detailed conversation on specific topics. Work Groups made recommendations to the full Partnership for items that required more detailed knowledge or deeper deliberation.

Table 1. Meetings of the Spring Creek Watershed Partnership

Date	Meeting Type	Topics
Jul. 29, 2020	Partnership (virtual)	Project introduction, water quality data review, and invitation to nominate Steering Committee
Oct. 8, 2020	Partnership (virtual)	Steering Committee formation, water quality analysis, and pollution source model review and discussion
Dec. 10, 2020	Partnership (virtual)	Discussion of model revisions, and invitation to join Work Groups
Feb. 8 & 9, 2021	Work Groups (virtual) • Human Sources & Pet Waste • Agriculture, Wildlife & Invasives	Review of water quality improvement strategies commonly implemented throughout the region, and call for suggestions of new implementation measures/ opportunities for collaboration
Mar. 1 & 2, 2021	Work Groups (virtual) • Human Sources & Pet Waste • Agriculture, Wildlife & Invasives	Discussion of project timeline, reduction targets, and water quality improvement solution logistics to recommend to Partnership
Apr. 4, 2021	Partnership (virtual)	Discussion of Work Group recommendations, approval of project timeline, tentative approval of reduction targets and water quality improvement solutions to include in first draft of WPP
Jun. 3, 2021	Partnership (virtual)	Discussion of WPP draft and suggestions for revision
Aug. 3, 2021	Partnership (virtual)	Overview of WPP edits before final agency review

In addition, project staff held meetings with local stakeholders and groups to gather more local knowledge and seek additional feedback. Local agencies and other organizations (*e.g.*, local Soil and Water Conservation Districts) served as non-voting technical advisors who helped provide expert knowledge and guidance to support the Partnership and coordinate its efforts with other local projects. Project

[9] More information on the individual meetings and process can be found in Stakeholder Outreach Report available on the project website at: http://www.springcreekpartnership.weebly.com/

[10] See: https://springcreekpartnership.weebly.com/uploads/1/3/0/7/130710643/10159_5.1_ppp.pdf

staff further supported the efforts of the Partnership by engaging the public at local outreach events throughout the project.

Water Quality Goals

As part of developing the WPP, the Partnership developed a set of water quality goals that shaped their approach. Subsequent sections of this WPP expand on the details of how the Partnership established recommendations to meet these aims, and how they will be implemented, but the broad water quality goals for the Partnership are:

- *Plan for 2030* — The stakeholders balanced the need to account for future growth in this developing watershed with the potential uncertainty of future projections past a 10-year window. Based on the level of water quality issues, the likely path of development in the watershed, and the need to phase implementation over time to reduce local burden, 2030 was selected as the end of the planning horizon. The stakeholders and project staff consider this a viable timeframe based on WPPs approved for similar developing areas.

- *Reduce fecal waste* — Potential fecal pathogens, as measured by the bacteria species *Escherichia coli* (*E. coli*)[11] as an indicator of fecal waste, are the primary focus of the Partnership due to their potential impact on human health, presence as an impairment for many of the segments of the watershed, and relationship to causes and sources within the scope of the voluntary WPP effort. The focus of this WPP is to reduce excess levels of human and animal waste in the water for the sake of public health, recreational economy, and regulatory compliance with the *E. coli* geomean SWQS criterion for primary contact recreation 1 (126 colony forming units (cfu) per every 100 milliliters (mL)). This goal involves identifying and quantifying causes and sources of fecal waste and developing recommended best practices sufficient to meet modeled reduction goals. **The priority goal of the WPP is to improve and maintain *E. coli* levels at or below the contact recreation standard (primary contact recreation 1).**

- *Improve dissolved oxygen* — Adequate dissolved oxygen (DO) levels are important for maintaining aquatic communities. The goal is to recommend solutions to improve DO levels.

[11] Throughout this WPP, "bacteria" or "*E. coli*" should be taken to mean *E. coli* in its role as an indicator of fecal waste and its associated pathogens in water rather than specifically attributing potential health impacts to *E. coli*.

- *Reduce excessive nutrients* — Nutrients (phosphorus and nitrogen compounds) are potential sources of depressed DO due to their role in algal blooms. Nutrients do not have water quality standard numeric criteria associated with them though they may lead to a DO impairment. Because no DO impairment exists for the assessed water bodies of this system, the stakeholders elected to make nutrients a secondary concern. Efforts to reduce nutrients are not modeled or quantified, but instead expected as a secondary benefit from many fecal waste reduction solutions.

- *Address other stakeholder concerns* — The WPP model allows for the consideration of other local water quality issues outside SWQS impairments and concerns. No modeling or specific quantification was conducted for stakeholder concerns, but the goal of the project remains to support or selectively implement related best practices to reduce issues as appropriate. Specific concerns include trash and illegal dumping, sediment, and impacts from hydrologic issues in the watershed.

Guiding Principles

In addition to the water quality goals, the Partnership detailed some guiding principles throughout the development of the WPP. Those principles include an emphasis on:

- *Distinct areas* — While the various elements of the Spring Creek Watershed are part of a single system, areas within the system are unique in character and challenges. The consideration of the differing needs of these watershed areas is built into this WPP process and recommendations.

- *Locally-led decisions* — While project staff and other parties may provide information and guidance to the stakeholders, the ultimate decisions for the WPP, within the bounds of the WPP model, will be made by local stakeholders.

- *Voluntary solutions* — The WPP will only include recommendations that are voluntary. Neither the Partnership nor H-GAC will exercise any regulatory mandate through this WPP.

- *Use what works* — Where existing programs with proven success are available, they should be used. The Partnership will seek to coordinate efforts with similar projects to ensure a limitation to redundant efforts. The Partnership recognizes and respects the efforts of local agencies, organizations and individuals and seeks to support rather than supplant them.

- *Coordination is key* — an extensive amount of activity is occurring in the watershed, both in terms of development and mitigation activities for hydrologic and environmental factors. Because of the density of actions and actors, this WPP seeks to the highest degree practicable to coordinate its aims and recommendations with related or adjacent efforts.

- *Education and outreach are vital* — Education and outreach are an important part of fostering the implementation of the WPP, and an essential element in its future success. The Partnership will seek to be transparent and build relationships with the community at every feasible opportunity.

Based on these water quality goals, and guided by the principles, the Partnership developed the recommendations and considerations contained in this WPP.

Figure 2. Spring Creek running through the George Mitchell Preserve

Section 2

Watershed Characterization

Photo Credit: Jessica Casillas

Section 2. Watershed Characterization

Watershed characterization considers the natural features of the land, the human elements that interact with them, and the relationship these factors have with water quality. This represents the first step in understanding the causes and sources of pollution in the watershed to identify effective means to address them. Evaluating all elements and factors that shape the connection between land and water is part of a watershed approach to improving water quality.

Geography

The watershed area of Spring Creek includes portions of Grimes, Harris, Montgomery, and Waller counties (**Figure 3**). On the northwest side of the Houston-Galveston region, this drainage area is connected to the Houston metropolitan area by State Highway (SH) 249, and Interstate 45 (I-45) transportation corridors (**Figure 4**).

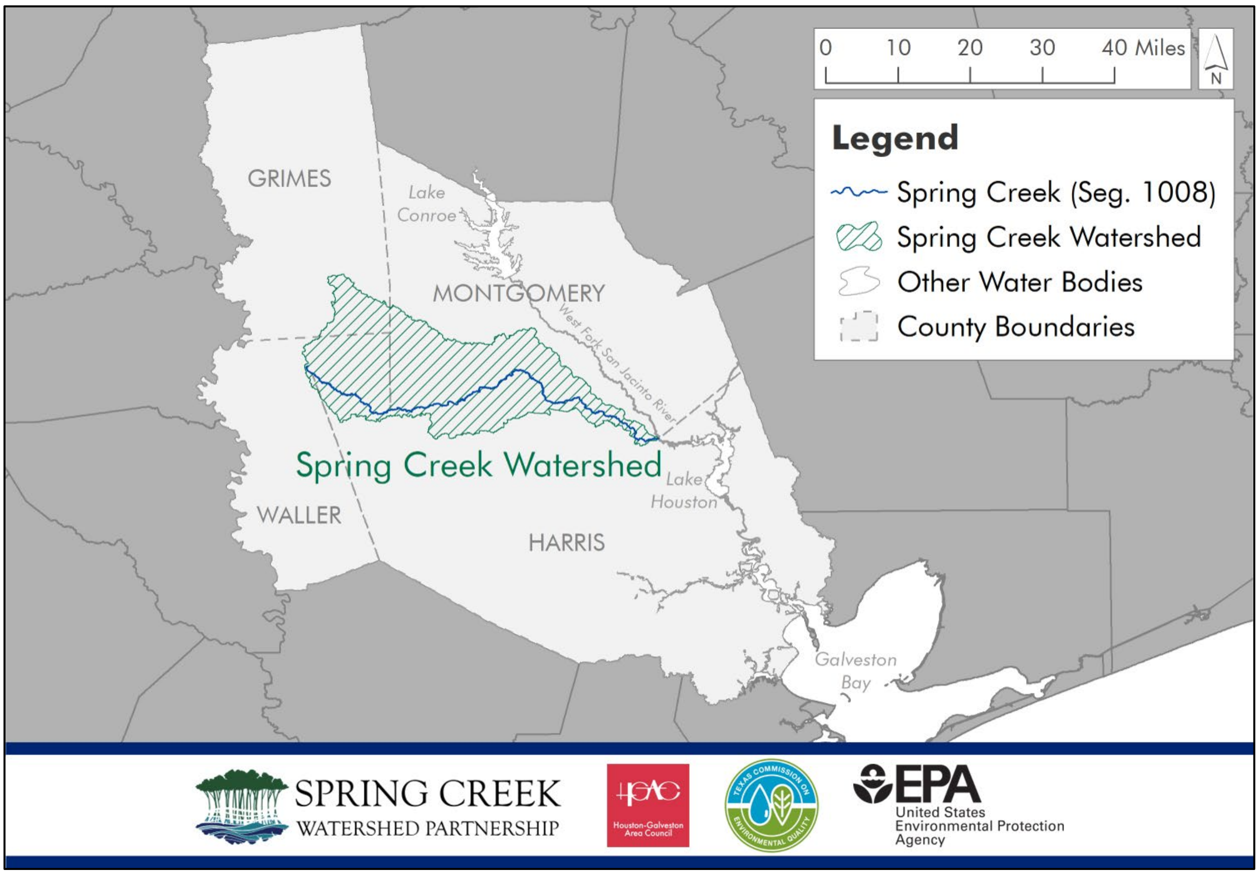


Figure 3. Regional context for the Spring Creek watershed

Regional Context

Spring Creek and its network of tributaries are part of the broader West Fork San Jacinto River Basin (Segment 1004) between Lake Conroe to the north, and Lake Houston to the southeast. Spring Creek flows into the West Fork of the San Jacinto River directly upstream of that waterway's confluence with Lake Houston. Lake Houston's prominence as a drinking water source, recreational venue, and as an integral part of the complicated hydrology of the San Jacinto River Basin make the contributions from Spring Creek and other tributaries especially important in a regional context.

Watershed Delineation

The Spring Creek watershed was delineated using a combination of existing data, map review, and field observations (**Figure 4**). The primary watershed and subwatershed delineations were developed from National Hydrography Dataset Plus (NHD+) watershed layers, with minor adjustments to reflect conditions on the ground, segregate tributaries, and normalize subwatershed size. NHD+ data was compared with United States Geological Survey (USGS) Hydrologic Unit Code 12 and 10 data, and other local sources. Compared to aerials and known hydrologic boundaries, the NHD+ data was closest to expected actual drainage patterns in this system. Staff conducted map surveys using online mapping and limited field reconnaissance to confirm assumptions.

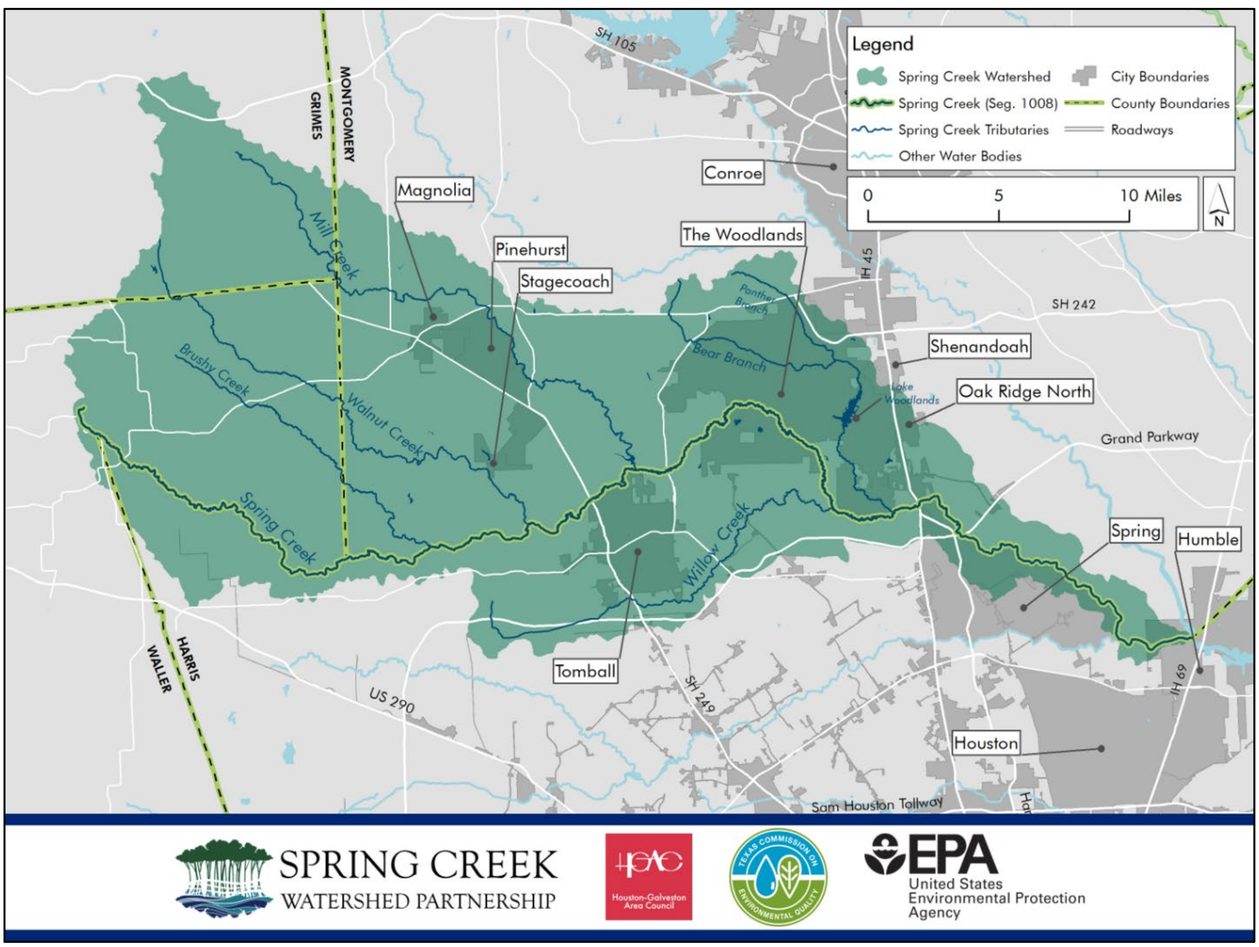


Figure 4. Spring Creek watershed

Subwatersheds were further delineated from a selection of existing and continuing water quality monitoring stations to ensure the ability to evaluate these areas during the implementation of the WPP (**Figure 5**). Considerations for the selection of the stations were their ability to represent different areas of the watershed, the natural hydrologic elements of the watershed (*e.g.*, major tributaries), appreciable areas of developmental or land cover type, and general comparability in size. The resulting subwatersheds balance these interests, with the highest priority given to representation by ongoing monitoring stations at their terminal ends.

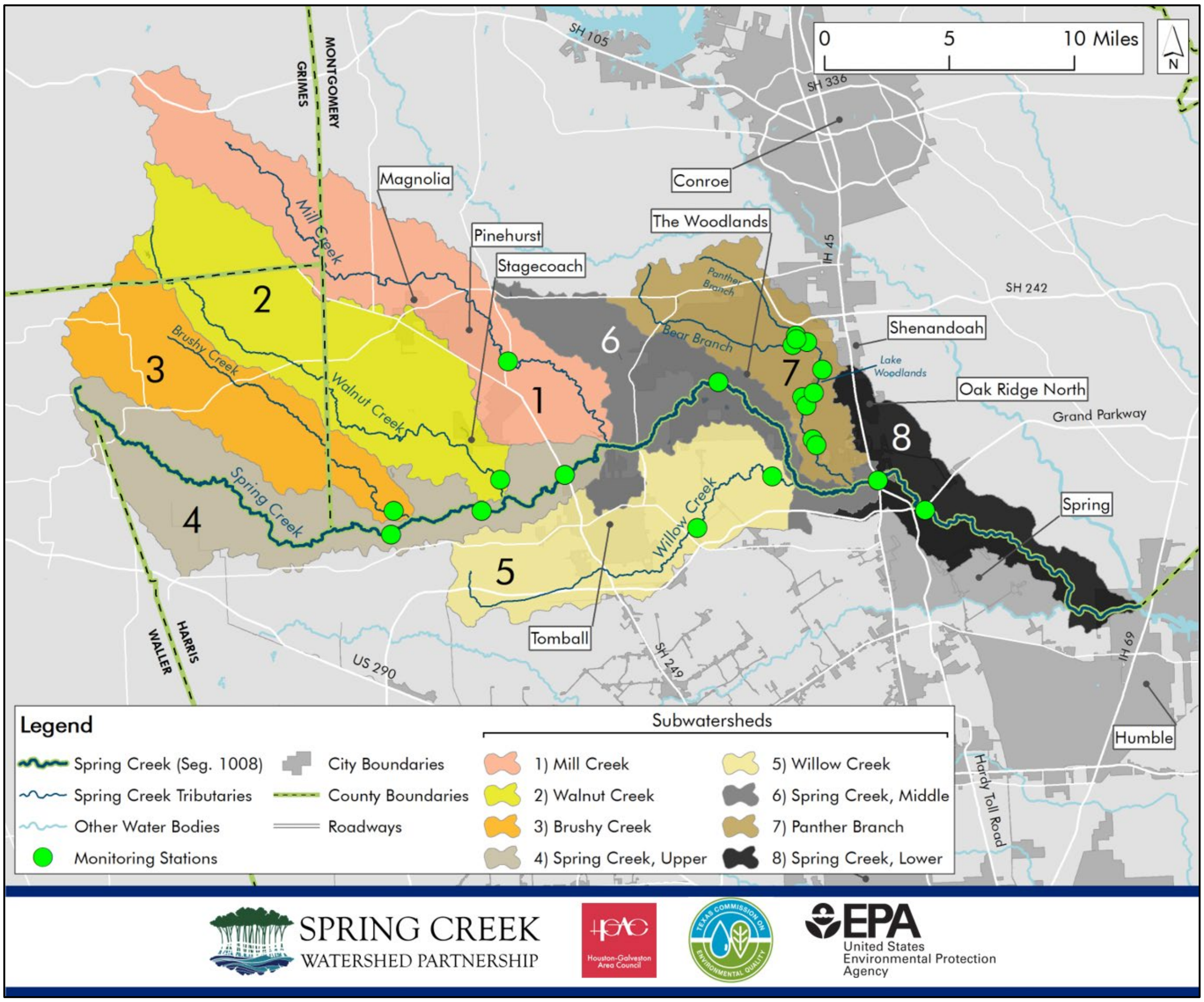


Figure 5. Spring Creek subwatersheds and monitoring station locations

Drainage Area and Stream Network

The full drainage area of the Spring Creek watershed covers over 440 square miles and the stream network that makes up its drainage system includes 903 linear miles of waterways (**Figure 6**). The drainage network includes both natural streams, modified waterways, and manmade drainage (channels and storm sewer systems) of varying size.

Each of Spring Creek's primary tributaries (Mill Creek, Upper and Lower Panther Branch, Bear Branch, Lake Woodlands, Willow Creek, Walnut Creek, and Brushy Creek) are themselves networks of smaller tributaries and drainage conveyances.

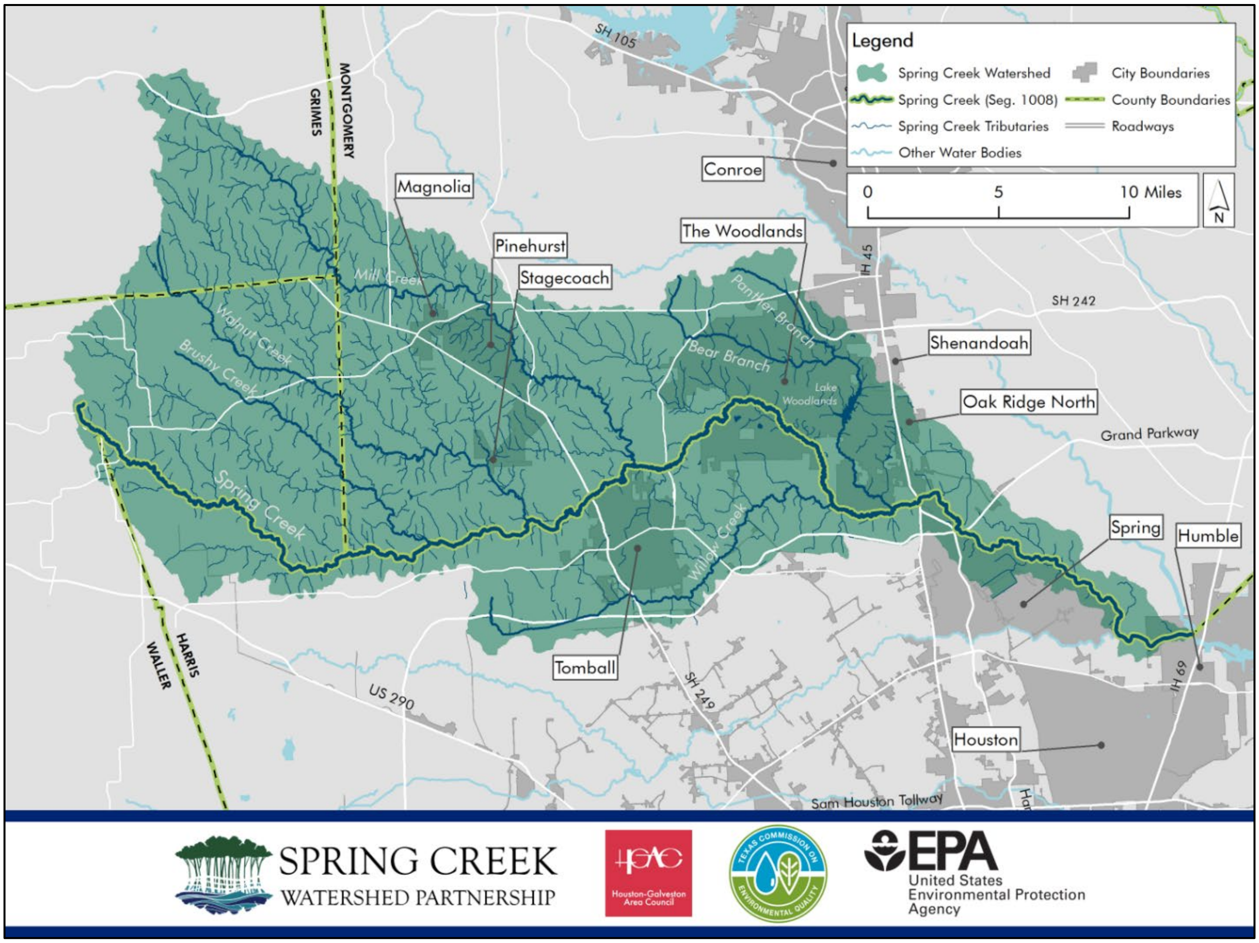


Figure 6. Hydrology in the Spring Creek watershed

The main channel of Spring Creek starts in the undeveloped areas of eastern Waller County and northwestern Harris County. As it progresses east, the waterway grows in size. Once the main channel passes into more developed area east of SH 249, the waterway is a moderately sized creek in normal flow conditions, though the dimensions of the inundated area expand considerably following high rainfall events. Throughout the rest of its meandering path Spring Creek retains this character, although the area it traverses is primarily denser subdivision and commercial development. The stream network of the Spring Creek watershed contains many primary tributaries[12] (**Figure 7**). These include[13]:

- **Mill Creek (1008A)** — Mill Creek represents a portion of the headwaters for Spring Creek, forming a confluence with Spring Creek just north of Tomball. It is primarily characterized by more natural land types, excepting some developed areas including the cities of Magnolia, Pinehurst, and Stagecoach.
- **Upper Panther Branch (Segment 1008B)** — Upper Panther Branch is a heavily modified waterway primarily serving as a drainage conveyance amidst dense suburban development.
- **Lower Panther Branch (Segment 1008C)** — Lower Panther Branch is also a heavily modified waterway primarily serving as a drainage conveyance amidst dense suburban development for The Woodlands Township. It forms a confluence with Spring Creek just west of its crossing at I-45.
- *Metzler Creek (Segment 1008D) — Metzler Creek is a tributary to Willow Creek.*
- **Bear Branch (Segment 1008E)** — Bear Branch is also a heavily modified waterway primarily serving as a drainage conveyance amidst dense suburban development. It forms a confluence with Upper Panther Branch just above Lake Woodlands.
- **Lake Woodlands (Segment 1008F)** — Lake Woodlands is a reservoir separating the upper and lower portions of Panther Branch located centrally in The Woodlands Township.
- **Willow Creek (Segment 1008H)** — Willow Creek serves as drainage conveyance for the Tomball area. It forms a confluence with Spring Creek upstream of the confluence between Lower Panther Branch and Spring Creek.
- **Walnut Creek (Segment 1008I)** — Walnut Creek represents a portion of the headwaters for Spring Creek, forming a confluence with Spring Creek just west of SH 249. It is primarily characterized by more natural land types.
- **Brushy Creek (Segment 1008J)** — Brushy Creek also represents a portion of the headwaters for Spring Creek, forming a confluence with Spring Creek upstream of the confluence between Walnut Creek and Spring Creek. It is primarily characterized by more natural land types.
- *Arnold Branch (Segment 1008K) — Arnold Branch is a tributary to Walnut Creek via Mink Branch.*
- *Mink Branch (Segment 1008L) — Mink Branch is a tributary to Walnut Creek.*

[12] The primary tributaries discussed here are the unclassified segments which are assessed by TCEQ and are the more prominent tributary systems in the watershed. Additional named tributaries exist in the watershed but are considered part of the general drainage network for the purpose of this WPP.
[13] Italics represent unclassified segments not assessed in the 2020 Texas Integrated Report of Surface Water Quality.

- *Sulphur Branch (Segment 1008M) — Sulphur Branch is a tributary to Walnut Creek.*

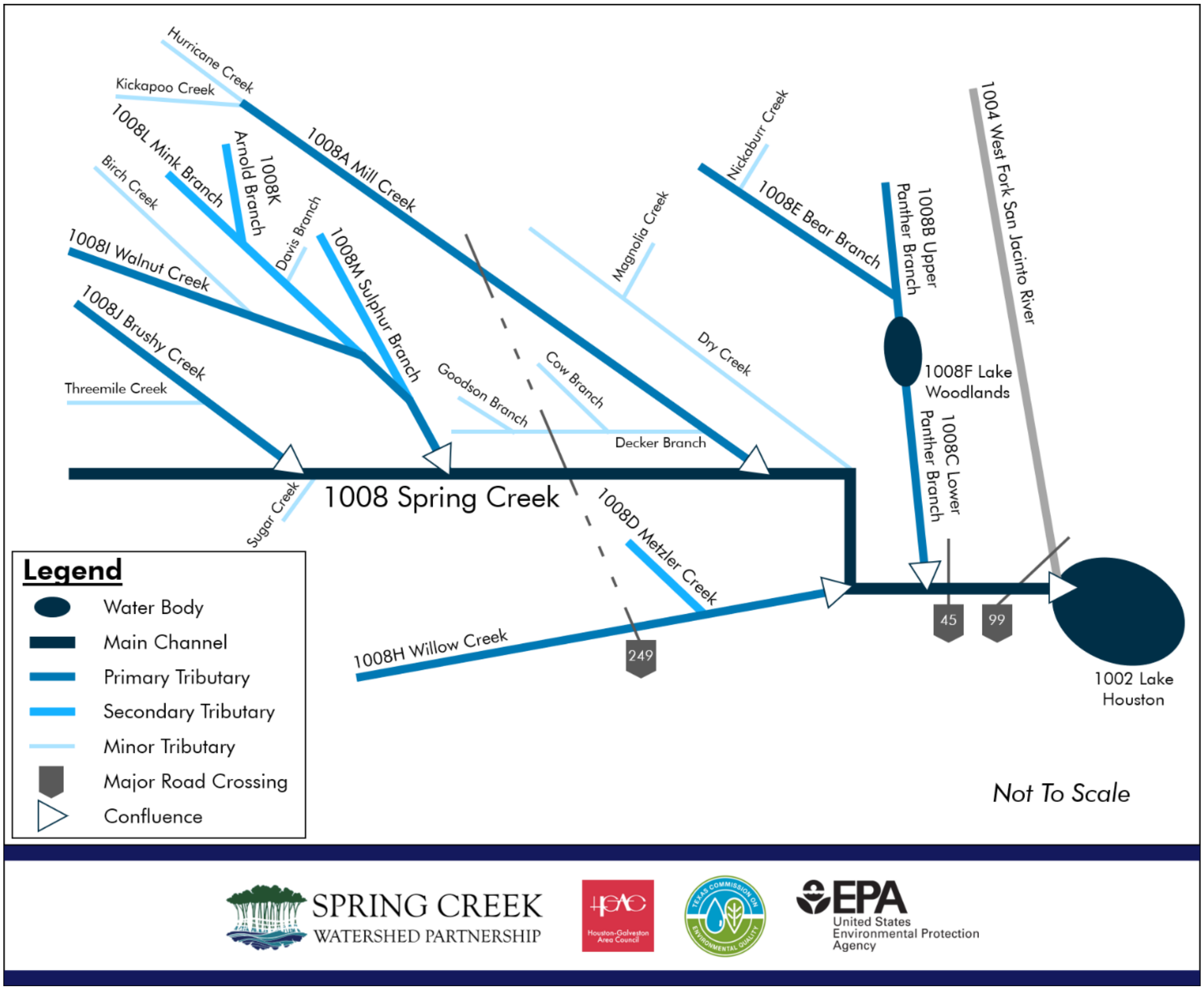


Figure 7. Stream network diagram

Recreational paddling and fishing are common on the main stem, and recreational trails are widespread and increasing in its riparian corridors. The system in general supports a high-quality aquatic ecosystem. Despite the rapid and expansive development along the transportation corridors, much of the waterway maintains a wooded riparian buffer.

Political Geography

The Spring Creek watershed includes a mix of land uses, with a primarily rural western third, a transitional middle third, and a densely suburban/urban eastern third. While the watershed encompasses or overlaps with portions of some cities or census-designated place communities (Magnolia, Pinehurst, Stagecoach, The Woodlands Township, Shenandoah, Oak Ridge North, Tomball, Spring, Houston, and Humble; **Figure 8**) some of the developed areas are communities represented by special districts (municipal utility districts, water control and improvement districts, utility districts, *etc.*) or private utilities within unincorporated areas. There are 103 of these districts or communities that provide water or sewer service within the watershed, ranging from small municipal utility districts (MUDs) representing single neighborhoods, to large master-planned communities. These areas are a common form of residential development in the watershed by area.

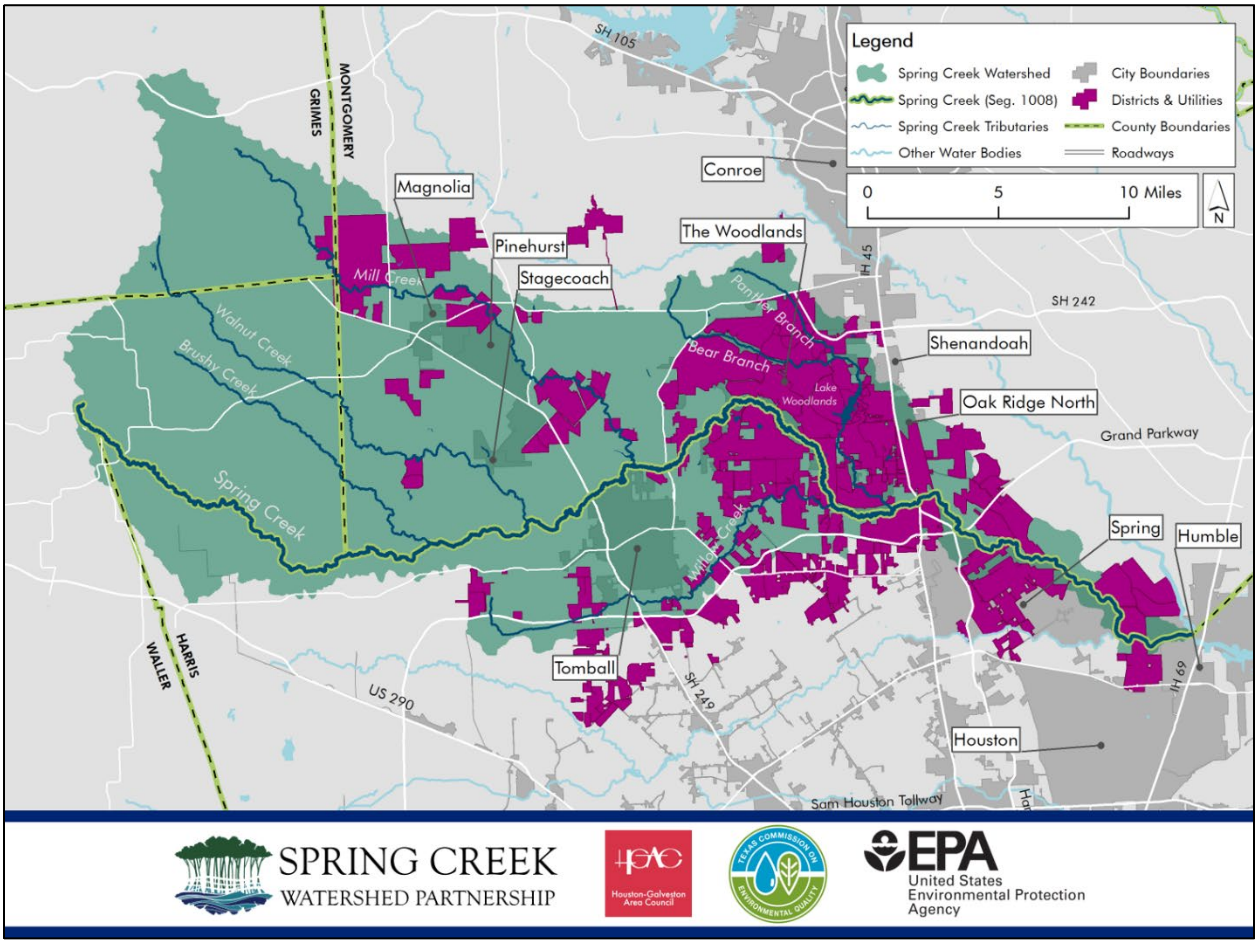


Figure 8. Districts and utilities in the Spring Creek watershed

The watershed includes portions of Grimes County Commissioner Precinct 2, Harris County Commissioner Precincts 3, and 4, Montgomery County Commissioner Precincts 2, 3, and 4, and Waller County Commissioner Precinct 2. Representation at the national level includes United States House of Representatives Districts 2, 8, 10, and 18 (in addition to the United States Senate general representation). Representation at the state level includes Texas House of Representatives Districts 3, 13, 15, 126, 127, 130, and 150; and Texas State Senate Districts 4, 5, 7, 15, and 18. In addition, the watershed overlaps the service area of a variety of other districts and authorities, including the North Harris County Regional Water Authorities, the San Jacinto River Authority, the Gulf Coast Waste Disposal Authority, the Coastal Water Authority, the Harris County Flood Control District, and Port of Houston Authority. Soil and Water Conservation Districts include those for Montgomery

County, Harris County and Navasota. Additionally, several independent school districts, and several other special purpose districts overlap with the watershed area.

Much of the population growth in the watershed has followed the major transportation corridors of I-45, SH 249, and SH 99. The focus of new development is westward, as growth continues to push out of the urban core of Houston. Development in the eastern portion of the watershed, especially east of SH 249, is primarily densely suburban in character, with some smaller industrial areas. While the primary development upstream of SH 249 is still light rural residential, agricultural, or undeveloped areas, development is pushing rapidly into this area and its eastern edges are in transition.

Water Rights

Water quality is the focus of this WPP, rather than issues involving water supply. However, the Spring Creek watershed is a conduit for water augmenting public water supplies in Lake Houston (via the West Fork San Jacinto River) and includes developed areas with pollutant sources in or adjacent to floodplains. Therefore, water supply in this watershed can potentially impact the quality of source water that must be treated for use as drinking water. Considerations for matters of water supply can also provide context for understanding the waterways.

Texas grants the right to use state water (including waterways like Spring Creek) through water rights permits. There are 18 water rights permits in the Spring Creek watershed, representing a mix of on-channel reservoirs (impoundments) and diversion rights (**Table 2**). The majority of the impoundments are used for recreational purposes. The maintenance of the 5,324 acre-feet of existing impoundments are not likely to have an impact on average flows in Spring Creek except potentially in extreme drought conditions. Permits for diversions are chiefly oriented toward irrigation for development, particularly for the establishment of The Woodlands. The San Jacinto River Authority (SJRA) holds a substantial permit at Lake Houston for the diversion of up to 14,644 acre-feet of groundwater based effluent return flows, which SJRA can contract to users upstream in the watershed. However, the full amount is not likely to be diverted to the Spring Creek watershed. Finally, Harris County Flood Control District No. 18 and Palmetto Transoceanic, LLC hold rights to a combined 260 acre-feet for the purposes of flood management. Excluding groundwater and flood control, only 557 acre-feet of diversions from the watershed are permitted annually.

Table 2. Water rights in the Spring Creek watershed

Water Right	Water Right Holder	Impoundment Area (acre-feet)	Diversion (acre-feet)	Priority Date
Certificate of Adjudication 10-3959	The Woodlands Development Company, L.P. The Woodlands Township, Woodlands Commercial Properties Company, L.P., CC Panther Oaks, LLC, CC Woodlands LLC	1,460 (recreational use; groundwater and/or contracted return flows to replenish water loss and diversion from reservoir)	750 (agriculture and recreational use)	Sept. 5, 1972 (February 18, 2016 time priority is related to a diversion rate)
Certificate of Adjudication 10-3960	Sequoia Golf Woodlands LLC, BL R Owner LLC	20 (recreational use; water loss from reservoir to be replenished with groundwater or by treated effluent)	NA	Jan. 21, 1974
		90 (recreational use; water loss from reservoir to be replenished with groundwater or by treated effluent)	310 (agriculture use)	
Certificate of Adjudication 10-3961	PPE WC Investment, LLC, PPE Woodmill Creek, LLC, Camden Woodmill Creek, LLC	NA	25 (agriculture use)	Nov. 4, 1974
Certificate of Adjudication 10-3957	C. R. Hocott, Trustee, Frances Goss, Mary G. Vosteen	36 (recreational use)	NA	Feb. 17, 1975
		4.5 (recreational use)	NA	
		3.8 (recreational use)	NA	
		3.2 (recreational use)	NA	
Certificate of Adjudication 10-3958	Lester Neidigk	246 (recreational use)	NA	Mar. 14, 1986
Certificate of Adjudication 10-3952	Koll Northstar Houston Oaks LP	39	32 (agriculture use)	June 23, 1975

Water Right	Water Right Holder	Impoundment Area (acre-feet)	Diversion (acre-feet)	Priority Date
Certificate of Adjudication 10-3955	Stagecoach Farms Civic Club, Inc.	101 (recreational use)	NA	July 21, 1975
		14 (recreational use)	NA	Jan. 24, 1983
Certificate of Adjudication 10-3953	Lake Winona Property Owners Association	85 (recreational use)	NA	Oct. 27, 1975
Certificate of Adjudication 10-3956	Lake Hollyhill Owners Association, Inc.	52 (recreational use)	NA	Nov. 10, 1975
Certificate of Adjudication 10-3954	Woodlands Lakes Civic Club, Inc.	45 (recreational use)	NA	Dec. 22, 1975
Water Use Permit 3882	San Jacinto River Authority, CW Operating Company, Inc	600 (recreational use)	500 (agriculture use)	February 17, 1982
Water Use Permit 5408	Richfield Investment Corporation, Wood Trace Municipal Utility District 1	92 (recreational use)	NA	Mar. 10,1992
		177 (recreational use)		Mar. 18, 1993
		82.5 (recreational use)		Mar. 18, 1993
Water Use Permit 5471	Indigo Lakes Property Owners Association	563 (recreational use)	NA	Oct. 18, 1993
		Increase capacity to 1,164 (recreational use)		July 26, 1994 (for the additional 601 acre-feet of water)
Water Use Permit 5572	Properties of the Southwest One, Inc.	11 (recreational use)	NA	Jan. 17, 1997
Water Use Permit 5576	Lake Windcrest Property Owners Association	345 (Unnamed reservoir; recreational use)	NA	Feb. 20, 1997
		Increase capacity to 707 (Unnamed reservoir; recreational use)		May 10, 2004 (for the additional 362 acre-feet of water)
		150 (Azure Lake; recreational use)		Nov. 24, 2009
		58.7 (Upper Serenity Lake;		Nov. 24, 2009

Water Right	Water Right Holder	Impoundment Area (acre-feet)	Diversion (acre-feet)	Priority Date
		recreational use)		
		40.7 (Lower Serenity Lake; recreational use)		Nov. 24, 2009
Water Use Permit 5809	San Jacinto River Authority	NA	14,944 (return flows for municipal and industrial purposes)	Aug. 28, 2003
Water Use Permit 12678	Harris County Improvement District No. 18	32 (flood control)	Flood control diversion, all water returned to the stream	May 6, 2011
Water Use Permit 12708	Palmetto Transoceanic, LLC	9.6 (flood control)	Flood control diversion, all water returned to the stream	Sept. 19, 2012

Flood Mitigation

Approximately 17% of the watershed is in the 100- or 500-year floodplains (**Figure 9**). However, recent events like the floods of 2015 and 2016, and Hurricane Harvey have shown that the floodplains do not always accurately account for flooding potential in the watershed, which can exacerbate the release of pollutants into waterways. Areas in which flooding is unexpected may be especially vulnerable to erosion, flood damage, and pollution from sources not designed for flooding situations.

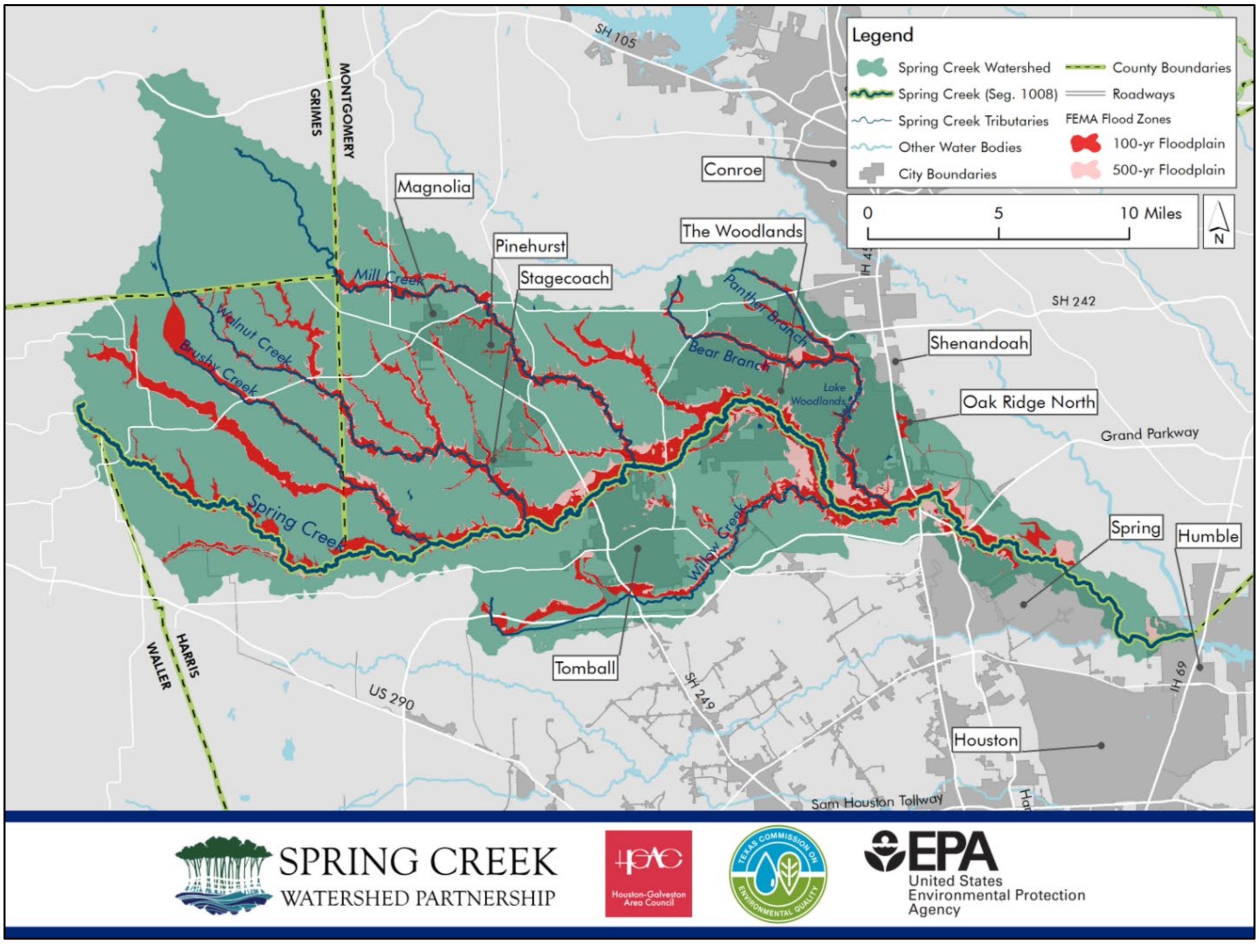


Figure 9. Floodplains in the Spring Creek watershed

Physical and Natural Characteristics

The physical aspects of watershed areas can impact how natural processes and effects of human development affect water quality.

Topography

The watershed area is along the transitional area between the Southern Central Plains and the Gulf Coast Plains. As such, it experiences more topographical variation than areas closer to the coast in the Houston-Galveston region (**Figure 10**).

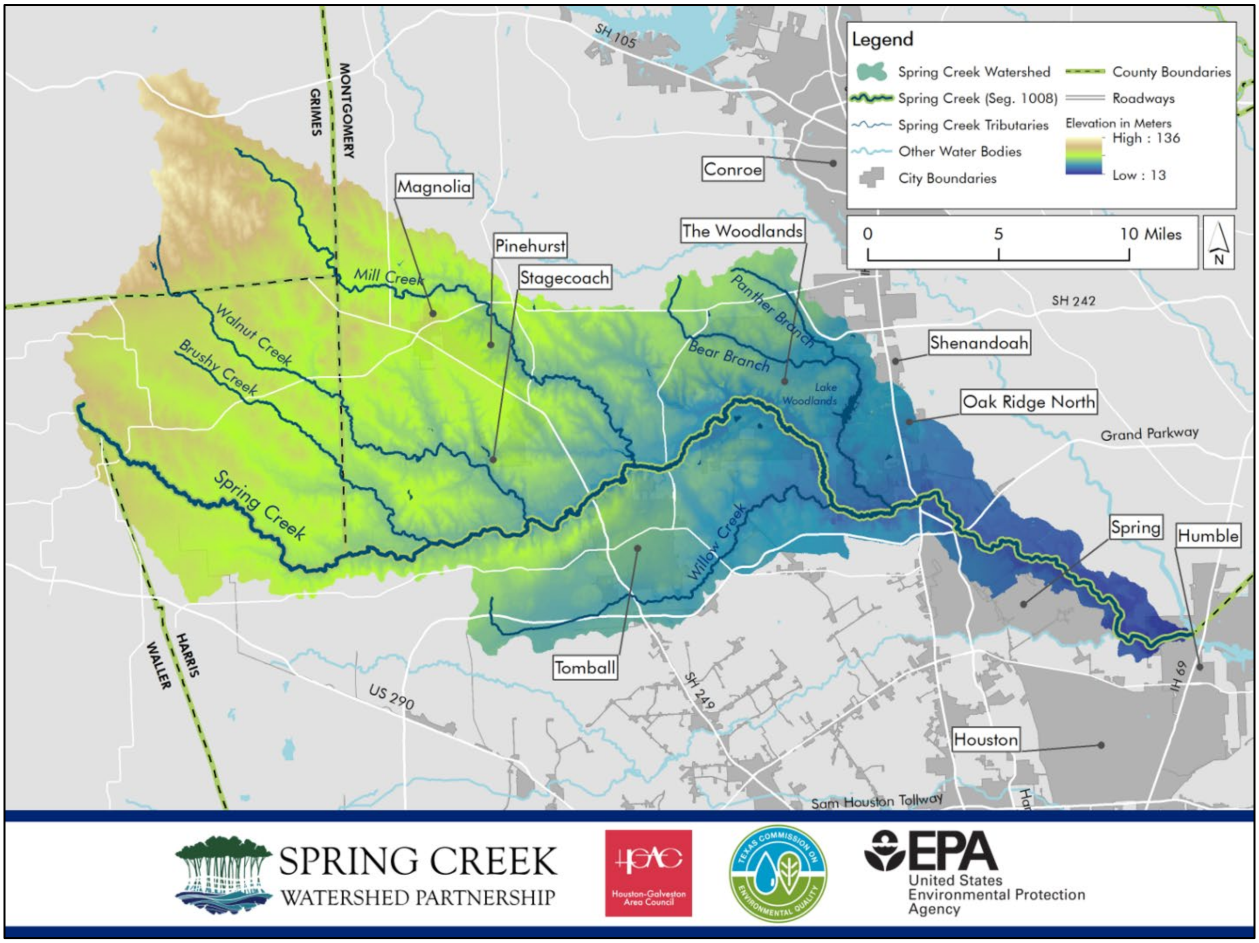


Figure 10. Elevation in the Spring Creek watershed

Elevation generally decreases from northwest to southeast, and from headwaters toward the drainage pathways. There is a 123-meter difference between the highest and lowest points[14] of the watershed.

[14] Based on USGS Digital Elevation Model 10-meter resolution spatial data.

Climate

The climate of the area is categorized as humid subtropical, indicating it has winters cold enough to generate occasional freezing conditions. Average rainfall for the area is between 42-50 inches of rain, with western areas being drier on the average than eastern areas of the watershed. However, drought events can have appreciable effect on the area, as evidenced in the 2011 drought. Throughout this period, western areas were exceptionally dry, and water elevations fell to record levels in downstream areas like Lake Houston—the reservoir into which Spring Creek drains.

Even though the watershed is not directly adjacent to the coast, the area is still well within the range of hurricanes and other large storms coming in from the Gulf of Mexico. The generally warm climate allows for a diverse array of flora and fauna but can exacerbate some water quality issues influenced by temperature (*e.g.*, DO).

Soils

The soil mix[15] of the Spring Creek watershed represents the juncture of different landscapes the water bodies traverse. In general, soils south of Spring Creek are dominated by fine loamy soils mixed with coarse loam especially around the headwaters of Willow Creek. Loamy sediments are predominant in the riparian areas along the main stem of Spring Creek as well as its northern tributaries and is mixed throughout with smaller areas of sandy soil. Beyond the riparian areas, land north of Spring Creek transitions from loamy to clayey soil types. The transition of soil drainage characteristics of the specific soil complexes reflects the transect between what were traditionally prairie areas in the southwest, and forested areas more common in the north and east reaches of the watershed (**Figure 11**). Erosion of soils is prominent in the alluvial sediments along the waterways, an area which is mined in this watershed for sand and/or gravel.

[15] A key to the soil types represented in the map can be found at the link provided in this note. Data provided by: Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Accessed on 5/3/2021 at: https://websoilsurvey.nrcs.usda.gov/. Soil survey dates and methods can differ from jurisdiction to jurisdiction and across time periods.

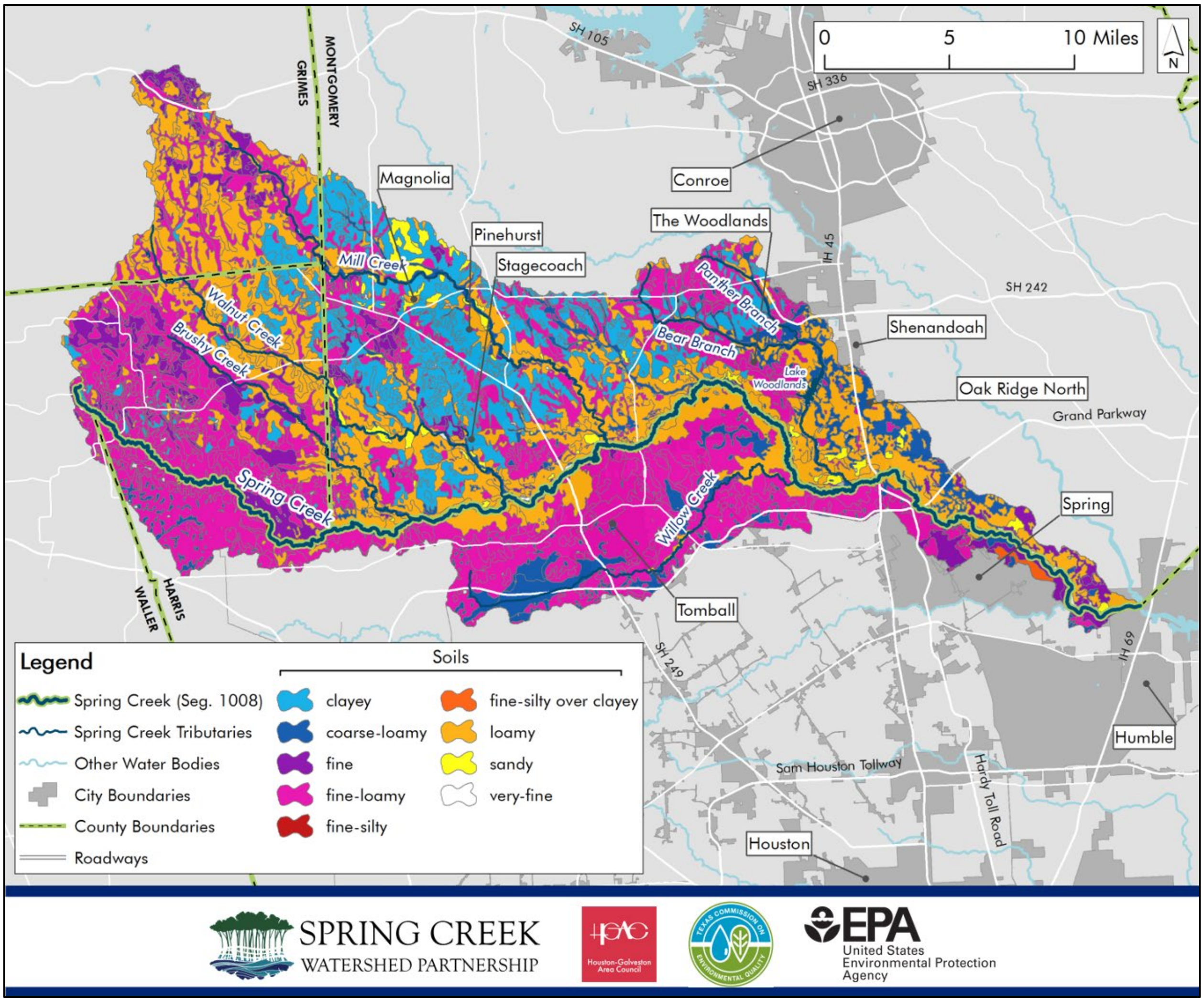


Figure 11. Soils in the Spring Creek watershed

Habitat and Wildlife

The Spring Creek watershed is like the Houston region in general, in that it straddles a transitional zone between several different ecosystems, encompassed in five designated ecoregions[16] (areas of similar climate, habitat, and landscape indicated in **Figure 12**). The majority of the watershed falls within the Southern Tertiary Uplands (EPA Level IV ecoregion 35c) and the Flatwoods (EPA Level IV ecoregion 35f) which both fall under the broader South-Central Plains (EPA Level III ecoregion 35) designation. The southernmost reaches of the watershed are dominated by Northern Humid Gulf Coastal Prairies (EPA Level IV ecoregion 34a) of the Western Gulf Coastal Plain (EPA Level III ecoregion 34). Finally, the westernmost portion of the watershed overlaps with Southern Post Oak Savannah (EPA Level IV ecoregion 33b) of the East Central Texas Plains (EPA Level III ecoregion 33), and

[16] Based on EPA Level III (broad) and Level IV (more specific) Ecoregion data accessed on 5/3/2021 at: https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states

a small portion of the northernmost tip of the watershed intersects the Southern Blackland/Fayette Prairie (EPA Level IV ecoregion 32b) of the Texas Blackland Prairies (EPA Level III ecoregion 32). Mixed grasses and other vegetation characteristic of the western portions of the Houston-Galveston region are common in the southwestern portion of the watershed. These areas transition into denser riparian forests concentrated in the northwest and expanding along waterways that approach the confluence with the West Fork of the San Jacinto River. These riparian areas are characterized by vegetation reflecting a mix of deciduous and coniferous trees and a variety of grass species similar to the northern and eastern extent of the region. Most important, however, to understanding the actual current habitat in the watershed is the extent of modified land cover, primarily urban/suburban that represents much of the eastern watershed. This modified habitat tends toward monocultures (live oaks, crepe myrtles, and similar residential plantings) and less overall habitat value than the remnant areas of western prairie and riparian corridor.

The broad range of landscapes, including those modified by human activity, host a diverse array of animal and plant species. Moderate winter temperatures and the location of the watershed in the Central Flyway for migratory birds support a dense and varied community of bird species year-round. Local bird species include wading birds (*e.g.*, great blue heron, white ibis), a wide variety of passerine species, and several raptors (*e.g.*, red-tailed hawk, bald eagle, barred owl). Notable local conservation areas include natural or restored lands like the Bayou Land Conservancy holdings east of SH 249, large mixed-use park areas (*e.g.*, Montgomery County Preserve, George Mitchell Preserve), and a patchwork of private conservation easements and similar single-landowner conservation parcels. Typical mammal species include white-tailed deer, Virginia opossum, raccoons, coyotes, eastern grey squirrels, striped skunks, nine-banded armadillos, and numerous species of rodents and bats. The watershed is also home to many common reptiles and amphibians, including *Nerodia* water snakes, red-eared slider turtles, and bullfrogs.

Of particular concern to the watershed are some of the invasive species that are making it home. In addition to exotic plants (*e.g.*, Chinese tallow) and various invasive animals, feral hogs (*Sus scrofa*) are a growing issue for the Houston region and are present in the Spring Creek watershed. Feral hogs threaten native wildlife species through direct competition for food and destruction of habitat. Large feral hog populations can cause damage on agricultural lands and are also a nuisance for suburban and exurban residential areas. Hogs tend to congregate in and around water bodies, causing damage to the riparian corridor and depositing fecal waste directly into the water body.

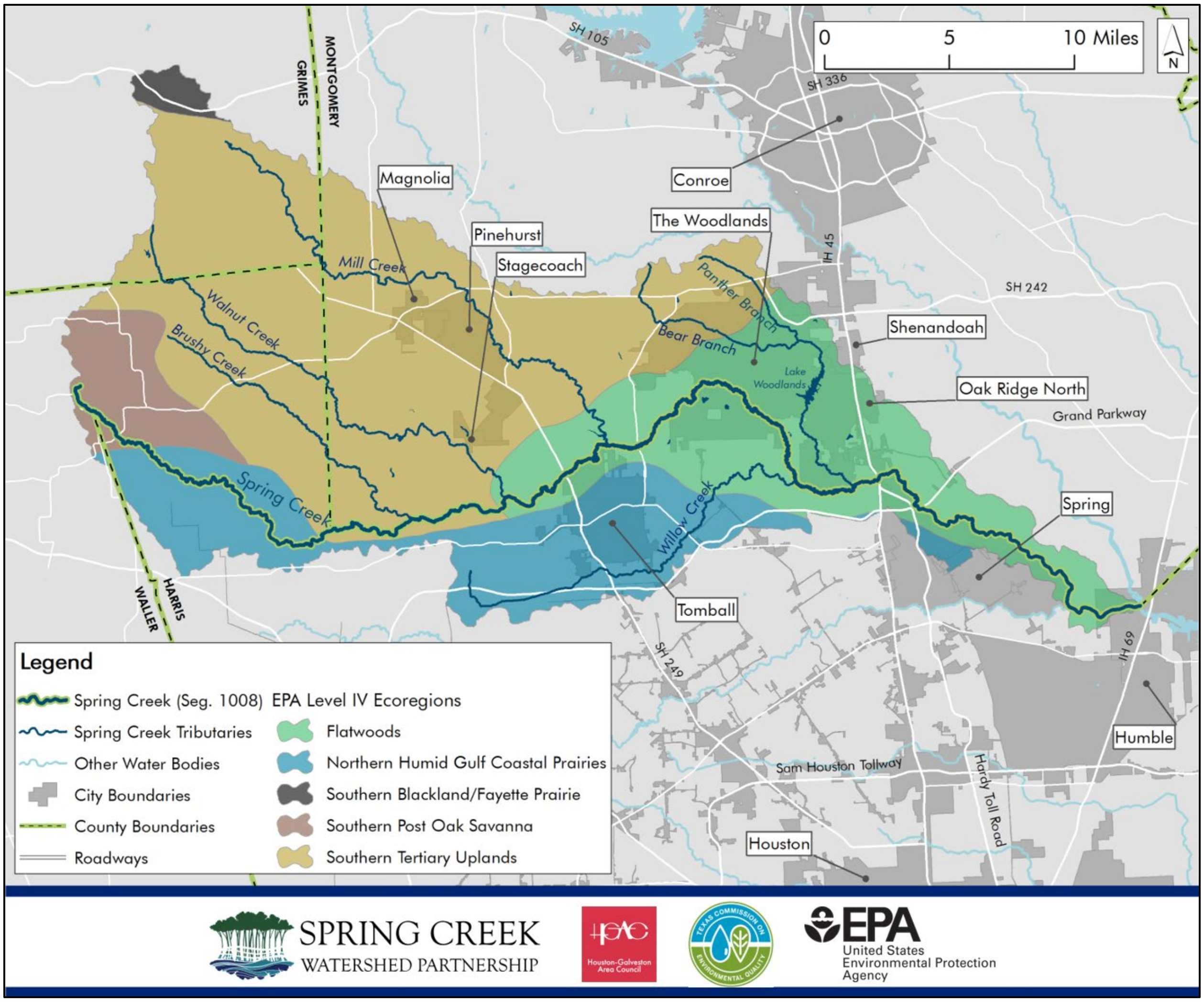


Figure 12. EPA Level IV Ecoregions in the Spring Creek watershed

Land Cover and Development

The mixture of natural landscapes in the Spring Creek watershed is further diversified by the modifications made to the land by human development. The character and balance of land cover in the watershed greatly influences the density and transmission of pollutant sources, and considerations for implementing solutions.

Land Cover

In general, the watershed transitions from undeveloped areas in the western third of the watershed, through a middle transitional zone of small rural communities west of SH 249, to dense suburban/commercial areas for most of the remaining eastern third of the watershed (**Figure 13**).

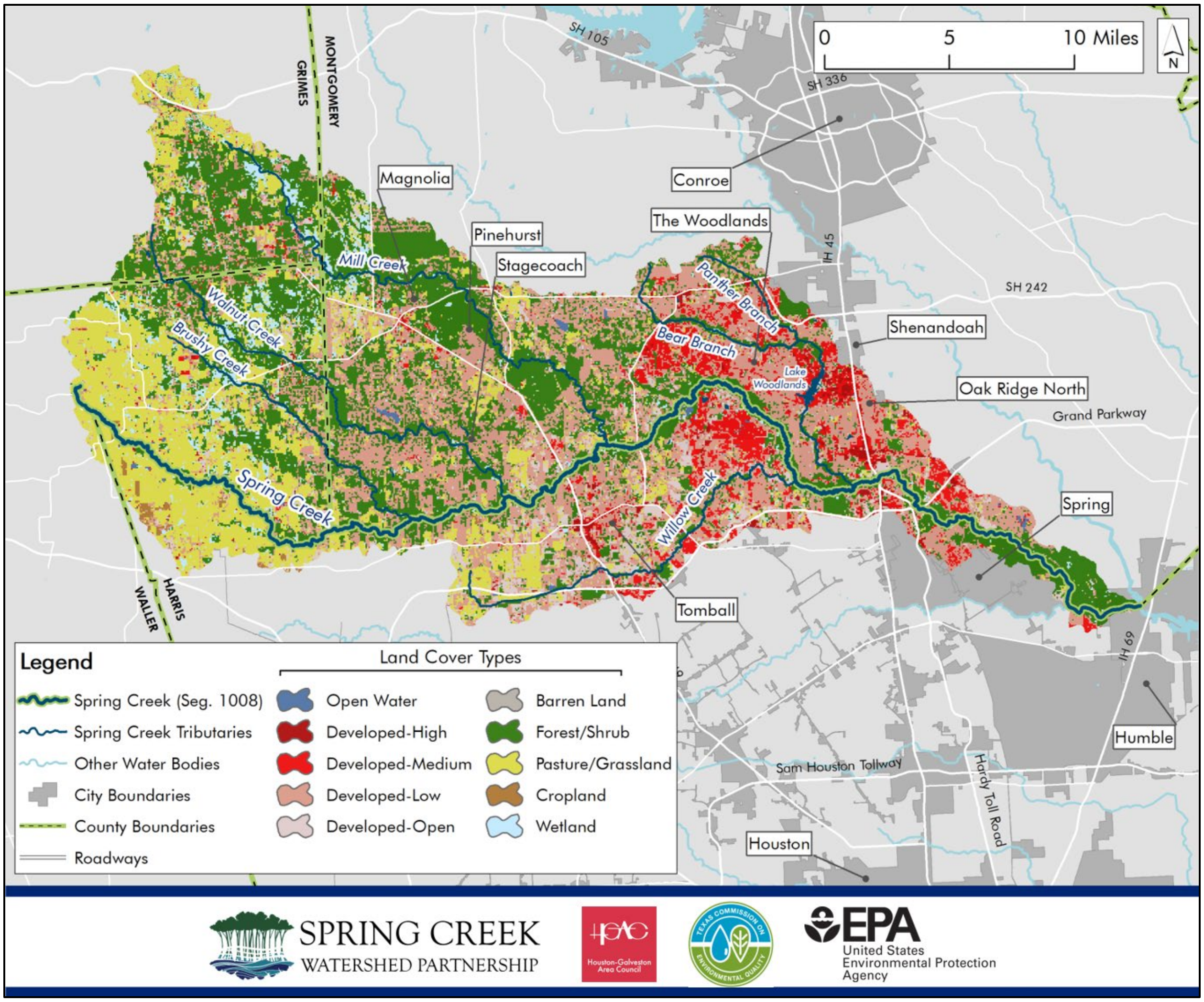


Figure 13. Land cover in the Spring Creek watershed

Table 3. Land cover as a percentage of watershed area

Land Cover Category	Percentage of Watershed Area
Open Water	0.41%
Developed-High Intensity	1.57%
Developed-Medium Intensity	5.59%
Developed-Low Intensity	29.07%
Developed-Open Space	5.63%
Barren Land	0.40%
Forest-Shrub	32.37%
Pasture-Grassland	19.76%
Cropland	0.65%
Wetland	4.55%

Harris and Montgomery County have experienced rapid change in recent decades, with growth pushing up and out from the Houston area around the I-45 corridor, and out from the Conroe area. The most prominent change in land cover types has been the conversion of agricultural and undeveloped land uses to residential areas. Change in the Grimes and Waller County portion of the watershed has been less extensive with the primary conversion being from agricultural activities to fallow land, light residential, or small scale industrial/commercial development. These trends are expected to continue for the foreseeable future.

While developed land uses make up a substantial portion (~42%) of the total area of the watershed, natural (~57%) and agricultural uses (<1%) account for more than half the remaining area (**Table 3**)[17]. The percentages are more telling when identified at a subwatershed level, with subwatersheds 1, 2, 3, and 4 being dominated by agricultural and natural land cover types, and subwatersheds 5, 6, 7, and 8 being mostly developed land cover (see **Figure 5** for subwatershed areas). The mix of land cover and uses in different areas of the watershed emphasizes the WPP focus on selecting locally-appropriate measures to address local challenges, identifying multiple areas in the watershed at which to monitor progress, and the need to coordinate with a broad array of partners throughout the watershed area.

Agriculture

Agriculture is generally in decline in most of the watershed area, with most remaining production taking place in the northwest portion of Harris County or the southern end of subwatershed 5 (Willow Creek). The transition away from agriculture to other land uses affects estimated future shifts in pollutant sources and land cover. In both counties, economic pressure from encroaching development, declining commodity prices, and the impacts of the 2011 drought are reasons commonly cited by the stakeholders for the decline of agricultural activity in the area[18].

- **Grimes County** – Agriculture in Grimes County was the historical foundation for local communities[19]. Early settlers farmed a variety of crops and livestock, but the introduction of cotton and plantation agriculture in the 1800s led to its overwhelming dominance until the early 1900s. During that time and through

[17] Data for this analysis represents 10-class data produced by H-GAC in 2018. National Land Cover Database and other typical land cover datasets did not have data current enough for this WPP effort given the area's growth rate.
[18] Data reflected in this section is from 2017, the latest data available. Based on anecdotal accounts from stakeholders and partner agencies, the declines in production have continued if not accelerated in the interim.
[19] Handbook of Texas Online, Charles Christopher Jackson, "Grimes County," accessed 5/3/2021 at: http://www.tshaonline.org/handbook/online/articles/hcg11

the modern era, cattle ranching and timber have been a prominent focus of the county's production. According to the 2017 United States Department of Agriculture (USDA) Census of Agriculture[20], Grimes County saw a 5% increase in the number of farms, but an 18% decrease in the amount of land under production since 2012. Market value of sold products dropped by 1%. Reflecting the greater reliance on cattle ranching, Grimes County has a large percentage of farms in larger size classes with over 64% of the farmland in pasture. However, the majority of farms (78%) are under 180 acres. Current production value is weighted heavily (>70%) toward livestock. Over 60% of farmers are new or beginning with the slight majority (53%) between the ages of 35 and 64.

- **Harris County** – Agriculture in the Harris County area of the watershed was an historical mainstay of the local economy. Farming was common in early communities in western Harris County, with rice, cotton, various row crops, and ranching making up the historical agricultural profile of the area. According to the 2017 USDA Census of Agriculture[21], Harris County saw a 14% decrease in the number of farms, and an 8% decrease in the amount of land under production since 2012. Market value of sold products dropped by 22% in the same period. Most farms in the county are under 180 acres (92%) and many are under 50 acres (80%). However, there are several operations of 1,000 acres or larger. Current production value is heavily weighted toward crops (73%) as opposed to livestock (27%), but this is not reflected by total acreage for each type, with pastureland making up 62% of the total farmland, and cropland (24%) and other uses being smaller shares, proportionally. Only 5% of farmland is irrigated, and while agriculture is in overall decline in the county, over a third of the 3,106 producers are new and beginning. While these numbers are county-wide, discussions with stakeholders, and the concentration of agricultural activity in the western portion of the county, indicate that they are relatively representative of the western watershed area.

- **Montgomery County** – Agriculture in Montgomery County was an historical mainstay of the local economy[22]. Farming and timber were early activities, with cotton, tobacco, various row crops, and ranching making up part of this

[20] Derived from the USDA 2017 Census of Agriculture State and County profiles for Texas, accessed on 5/3/2021 at:
https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Texas/
[21] See Footnote 20.
[22] Derived from "Montgomery County – Birthplace of the Texas Flag", retrieved on 5/3/2020 at: https://montgomery.agrilife.org/

historical agricultural profile of the area. According to the 2017 USDA Census of Agriculture[23], Montgomery County saw a 1% increase in the number of farms, but a 7% decrease in the amount of land under production since 2012. Market value of sold products increased by 8% in the same period. Most farms in the county are under 180 acres (90%) and many are under 50 acres (69%) Current production value is largely weighted (74%) toward livestock. Cattle are the predominant livestock product by value. As with neighbors in Grimes County, most farmers (66%) are new or beginning with a majority (63%) between the ages of 35 and 64.

- **Waller County** – Agriculture in Waller County was the historical foundation for local communities and continues to be a greater economic force than in adjacent Harris County, relative to the overall economic output of the counties. Overall character of cropland and transition is like Harris County, though less economic pressure from development currently exists in the watershed area of Waller County. According to the 2017 USDA Census of Agriculture[24], Waller County saw only a 2% decrease in the number of farms, but a 20% decrease in the amount of land under production since 2012. Market value of sold products increased in this period by 14%. Like Harris County, most farms in Waller County are under 180 acres (87%), though a smaller number are under 50 acres (64%). Farmed land area is similarly weighted toward pastureland (56%), with cropland being a smaller share (28%). However, the share of sales for each type are disproportionate to their land area, with cropland representing 75% of sales value, and livestock being 25%. Only 3% of farmland is irrigated.

Recreation

Spring Creek is a popular destination for a variety of recreational activities as one of the only two undeveloped creeks in Harris County (the other is Clear Creek). Local partners have invested significant time and effort in developing natural spaces for recreation benefits. Many of the prominent parks and natural areas[25] are adjacent to the creek system and are points of access for recreation (**Figure 15**). Both recreational and subsistence fishing is popular along the waterway, and in lakes in adjacent parkland[26].

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[23] Derived from the USDA 2017 Census of Agriculture State and County profiles for Texas, accessed on 5/3/2021 at: https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Texas/

[24] See Footnote 25.

[25] This map is not exhaustive of all parks in the watershed.

[26] More information on some of the access points and guidance for fishing can be found on Harris County Precinct 4's website at: https://www.hcp4.net/parks/fishing/

Among the most significant natural areas in the watershed is the Spring Creek Greenway[27], the longest connected urban forested corridor in the nation. Though parts of the Greenway project are still ongoing, the 14.5 miles of trails open to the public are currently well used. When complete, the trails will total a distance of 40 miles and connect the area between SH 249 and I-69. This project represents a collaboration between Harris County Precinct 4 and Montgomery County Precinct 3 with partnership from other local entities such as The Woodlands Township and the Bayou Land Conservancy.

The Township of The Woodlands is recognized as one of the top master planned communities in the nation and supports 148 parks in addition to over 220 miles of hike and bike trails[28]. Furthermore, approximately 28% of the total acreage remains natural and consists largely of forested area.

The Bayou Land Conservancy is a land trust that currently protects over 14,000 acres in 63 preserves throughout the Houston Region, 13 of which occur along Spring Creek. Their objective is to preserve land along streams to control flooding, maintain clean water, and provide habitat for wildlife. Volunteers with the Bayou Land Conservancy's Spring Creek Nature Trail Stewards maintain natural surface trails on the north side of Spring Creek which are popular among area residents.

Figure 14. Nature enthusiasts on the Spring Creek Nature Trail

[27] For more information, see: https://www.hcp4.net/parks/scg/ and https://www.bayoulandconservancy.org/spring-creek-greenway

[28] For more information, see: https://www.thewoodlands.com/

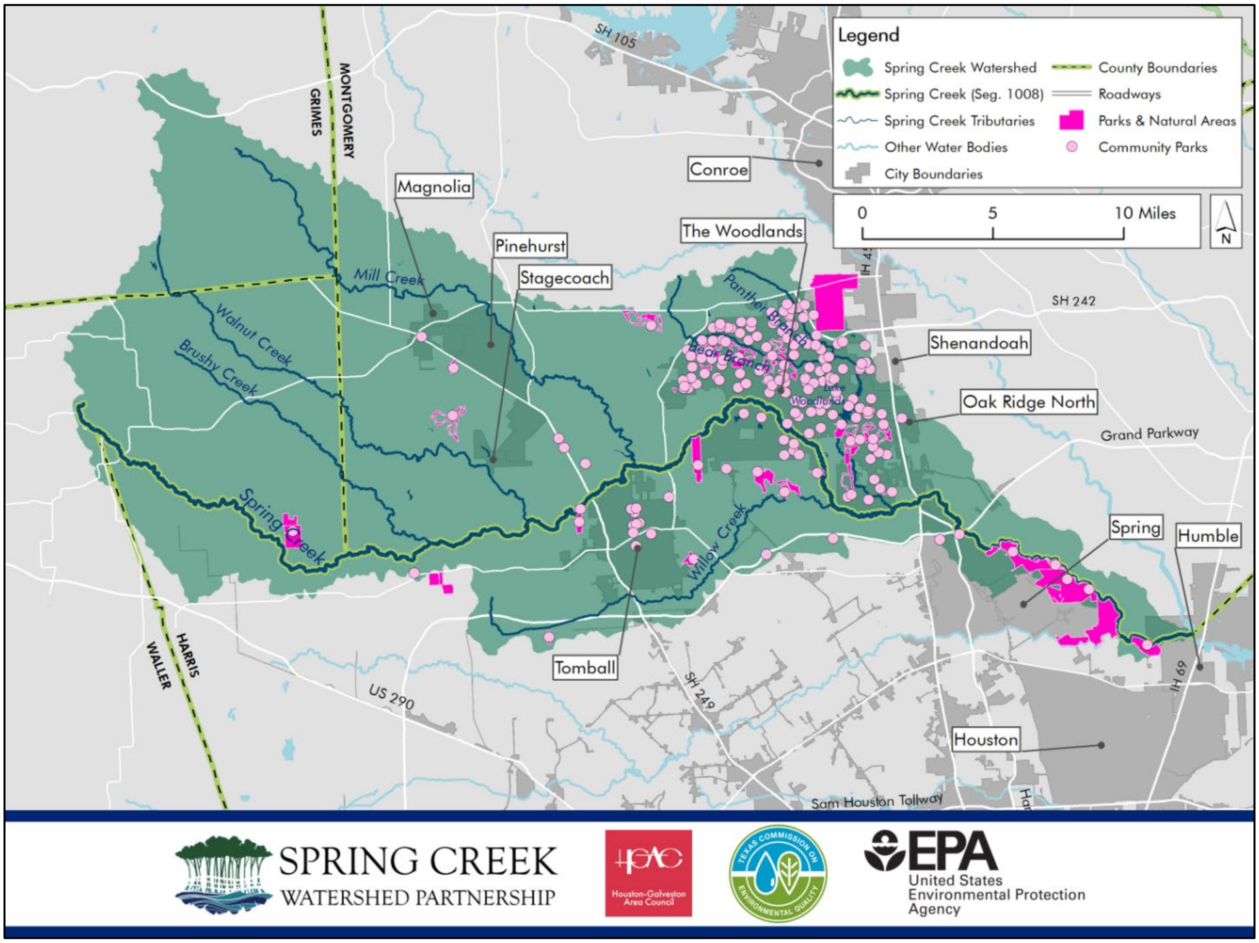


Figure 15. Parks and natural areas in the Spring Creek watershed

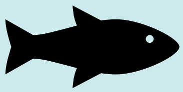
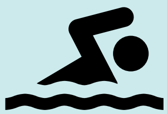
Water Quality

For the State of Texas' routine water quality assessments of its water bodies, water quality parameters are strictly defined and tied to the uses we derive from a waterway (**Table 4**). However, water quality for local stakeholders includes other factors specific to the values their community places on their local waterway, and they may have concerns not reflected in ambient water quality monitoring that range from other contaminants like trash to more qualitative concepts such as sense of place and aesthetic quality. This WPP recognizes that the defined water quality parameters discussed herein should be considered alongside other stakeholder concerns and valuations.

Water Quality Standards

For the lakes, creeks, streams, rivers, bays and bayous of Texas, water quality is evaluated based on SWQSs. Under the delegated authority of the CWA, TCEQ develops the SWQSs and is responsible for ensuring they are met. The intent of the standards is to establish explicit goals and limits to ensure Texas' surface waters continue to support recreation, drinking water supply, aquatic communities, and other established uses.

Table 4. Designated uses for water bodies

	The **aquatic life use** designation reflects the ability of the waterways to support aquatic ecosystems and habitat. Compliance with this use is determined by the availability of DO and an assessment of the diversity and health of existing ecological communities (fish, macrobenthics, and their habitat). High levels of chlorophyll-a, and elevated levels of nutrients, can indicate potential issues related to low DO.
	The **contact recreation use** designations indicate the waterway is used for recreational activities, such as swimming, that involve a greater chance of ingesting water. The basis of the SWQS for contact recreation standards is to protect public health. Ubiquitous fecal indicator bacteria organisms (*E. coli* and Enterococcus) are used as indicators of the potential contamination level from fecal pathogens. In freshwater systems like the Spring Creek watershed, elevated levels of *E. coli* are a sign the waterway does not meet the SWQSs.
	The **public water supply use** designation indicates a waterway is used for public water supply. The assessment of compliance for this use is a measure of the suitability of the waterway to serve as a current or future drinking water source. A variety of criteria are used to evaluate this use, including temperature, total dissolved solids, DO, pH range, fecal indicator bacteria, chlorine, and sulfates levels.
	The **general use** designation reflects the overall health of the waterway as measured by criteria for temperature, pH, chloride, sulfate, and other parameters.

The vast network of surface water bodies is divided into segments, which are cohesive groupings of waterways and associated tributaries. The primary classified segment in the Spring Creek watershed is Segment 1008 (Spring Creek). Major tributaries or waterways of interest within these classified segments are delineated as subordinate unclassified segments. Unclassified segments in this watershed include 1008A (Mill Creek), 1008B (Upper Panther Branch), 1008C (Lower Panther Branch), 1008E (Bear Branch), 1008F (Lake Woodlands), 1008H (Willow Creek), 1008I (Walnut Creek), and 1008J (Brushy Creek). Other contributing waterways and drainage networks also contribute to the system but are either not designated as unclassified segments by TCEQ or are not actively assessed.

Surface water segments are further divided into assessment units (AUs), the fundamental targets for assessments that determine whether a water body is in compliance with applicable standards. AUs are designated as the segment number followed by the AU number (e.g., 1008_01 for Spring Creek, AU 1). AUs in the Spring Creek system (**Table 5**; **Figure 16**) include:

Table 5. Spring Creek segments and assessment units

Segment	Assessment Units
Spring Creek - 1008	01, 02, 03, and 04
Mill Creek - 1008A	01
Upper Panther Branch - 1008B	01, and 02
Lower Panther Branch - 1008C	01, and 02
Bear Branch - 1008E	01
Lake Woodlands - 1008F	01, 02, 03, and 04
Willow Creek - 1008H	01
Walnut Creek - 1008I	01
Brushy Creek - 1008J	01

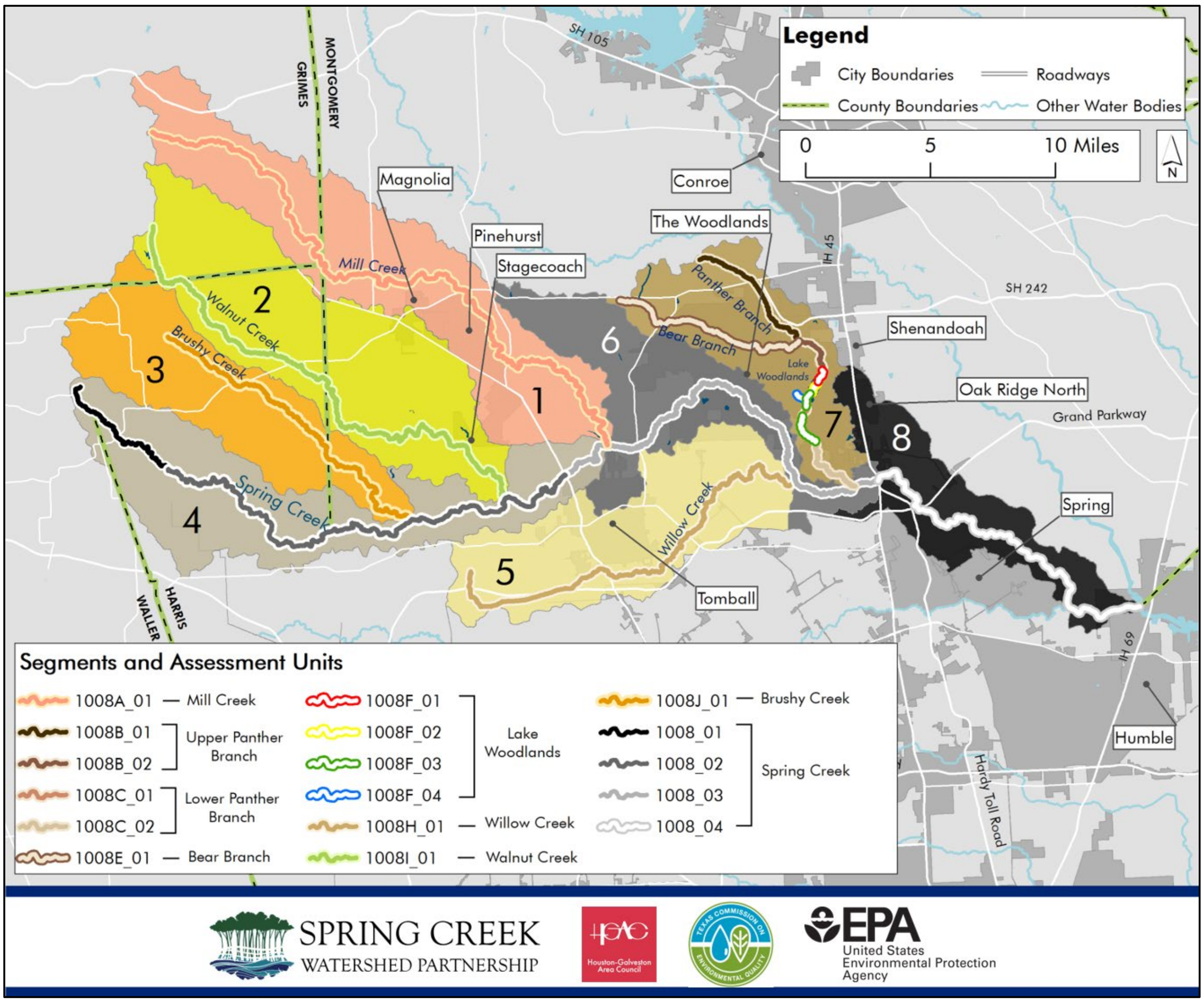


Figure 16. Segments and AUs in the Spring Creek watershed

Assessments are made based on data collected under the state's Clean Rivers Program (CRP) and other quality-assured data. TCEQ conducts assessments every two years for the state's water bodies, reviewing the previous seven years of data against the designated uses for the waterways. The results are included as part of TCEQ's 2020 Texas Integrated Report of Surface Water Quality (2020 Texas Integrated Report). The results of the assessments of the Spring Creek AUs only reflect ambient surface water quality, not the quality of tap water provided by utilities in the watershed, which is not the focus of this WPP.

State of the Water

The water quality of the Spring Creek system is affected by numerous factors, including human activities, natural processes, availability of rainfall, and releases and natural seepage from impoundments to which it is connected. Based on assessment of water quality data[29], many of the AUs in the watershed have existing water quality challenges. As development continues over the coming decades, additional sources of contamination may exacerbate these issues if no mitigating action is taken.

Impairments and Concerns

When a water body is unable to meet one or more of the SWQSs, it has an **impairment** for that standard. When an impairment may be imminent, or when substandard water quality conditions exist for a parameter that does not have an established numeric standard, the water body may be listed as having a **concern**. For example, water bodies are protected from excessive nutrient levels using screening levels. When concentrations of certain nutrients are above these screening levels, the water quality is characterized as a concern. Water quality in Spring Creek and its tributaries is typical of challenges seen in other freshwater creeks and bayous in the area[30].

According to recent versions of the Texas Integrated Report, current assessed water quality issues in Spring Creek and its assessed tributaries include elevated levels of *E. coli*, and concerns related to potential indicators or precursors of low dissolved oxygen (**Table 6**). The contact recreation impairment exists across many of the watershed's AUs and is the primary focus of this WPP. Concerns related to elevated levels of nitrogen and phosphorus compounds are also widespread, and though less common, concerns over dissolved oxygen have also been observed.

The 2020 impairments and concerns reflect the current formal assessment status by TCEQ and are the starting point for evaluating water quality in the watershed.

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[29] For more information on detailed water quality assessments and modeling, refer to Section 3 of this document. For in-depth information on water quality trends in the watersheds, please refer to the *Water Quality Data Analysis Summary Report* available on the website for this WPP project at: https://springcreekpartnership.weebly.com/uploads/1/3/0/7/130710643/10159_3.3_spring_creek_data_analysis_summary_report.pdf

[30] References to assessments and water quality status refer, unless otherwise noted, to the 2020 Texas Integrated Report of Surface Water Quality, the most current report available at the time of publication.

Overall water quality data analysis includes data through 2018 and is current with the 2020 Texas Integrated Report.

Table 6. Impairments and concerns in the Spring Creek watershed, 2016-2020

Texas Integrated Report Year	Assessment Units Impaired for *E. coli*	Concern Parameter and Affected Assessment Unit(s)				
		DO (grab)	Nitrate	Total Phosphorous	Cadmium	Fish Community
2016	1008_02, 1008_03, 1008_04, 1008B_02, 1008C_01, 1008C_02, 1008E_01, 1008H_01, 1008I_01, 1008J_01	1008C_02, 1008F_01, 1008J_01	1008_03, 1008_04, 1008B_02, 1008C_01, 1008H_01	1008_03, 1008_04, 1008B_02, 1008C_01, 1008C_02, 1008H_01	1008B_01	1008_02
2018	1008_02, 1008_03, 1008_04, 1008C_01, 1008C_02, 1008H_01, 1008I_01, 1008J_01	1008C_02, 1008F_01, 1008I_01, 1008J_01	1008_03, 1008_04, 1008B_01, 1008C_01, 1008C_02, 1008H_01	1008_03, 1008_04, 1008B_01, 1008C_01, 1008C_02, 1008H_01	1008B_01	1008_02
2020	1008_02, 1008_03, 1008_04, 1008C_01, 1008C_02, 1008H_01, 1008I_01, 1008J_01	1008F_01	1008_04, 1008B_01, 1008C_01, 1008H_01	1008_04, 1008B_01, 1008C_01, 1008C_02, 1008H_01	1008B_01	1008_02

Other Concerns

While the primary focus of this WPP is to address water quality impairments and concerns, all water bodies have a range of issues that impact human and wildlife uses. The WPP model is inclusive of other stakeholder concerns as part of a broader effort to improve the waterway. During the development of this WPP, stakeholders identified several other issues as being secondary priorities for implementation activities.

Trash

While illegal dumping is not reported by the stakeholders to be a widespread issue in the watershed, there were hot spots identified in the development of the WPP. Ambient trash from stormwater was raised as a concern as well.

Sediment

The sinuous channels of the waterways of this system have intermittent sand or gravel banks in many places. These alluvial sediments are attractive to aggregate mining operations whose activities have increased in the last decade. While this issue is not as pronounced as it is in the West Fork San Jacinto River, sediment load from Spring Creek has been studied in the past as a potential issue for the San Jacinto. Increased development and decreased riparian buffers will likely lead to faster runoff velocities, increased erosion, and decreased filtration. Increased sediment can impact the benthic habitats of aquatic life, shelter bacteria, and increase water treatment costs in addition to exacerbating flooding concerns. Of regional importance is the potential impact of sediment on the water supply capacity of the Lake Houston reservoir.

Flooding

Even prior to the flooding and storm events of recent years, local stakeholders expressed concern over drainage, flooding, and potential channel modifications. While flood management is outside the scope of this WPP, changes to flow regimes or increased flooding can alter the impact of pollutant sources. These concerns are being included in this WPP based on their potential water quality impact, and the need to coordinate these efforts with the many flood mitigation projects underway or planned for the system. The primary concern of this WPP is that water quality considerations are included in future decisions that may affect flooding or hydrologic modification of the waterways.

Conservation of Natural Areas/Function

Even prior to the flooding and storm events of recent years, local stakeholders expressed strong concern over continuing loss of natural areas. Using natural infrastructure to improve water quality, flood mitigation, maintain rural character, and protect natural landscapes and habitat was a standing concern among the stakeholders.

Section 3

Identifying Pollutant Sources

Photo Credit: Jessica Casillas

Section 3. Identifying Pollutant Sources

The process of identifying, characterizing, and quantifying causes and sources of pollution in a watershed provides a rational basis for devising effective solutions to improve water quality. The Partnership used a variety of tools, combined with local knowledge and guidance, to investigate the water quality challenges facing the Spring Creek watershed. The purpose of these efforts is to provide local stakeholders the information and context to make informed and effective decisions for their communities.

Investigation Methodology

The process of investigating causes and sources of pollution in the watershed used a series of successive steps to bridge the gap between the known existence of impairments and concerns, and the calculation of defensible estimations of causes and sources of pollution to meet the needs of the stakeholders[31].

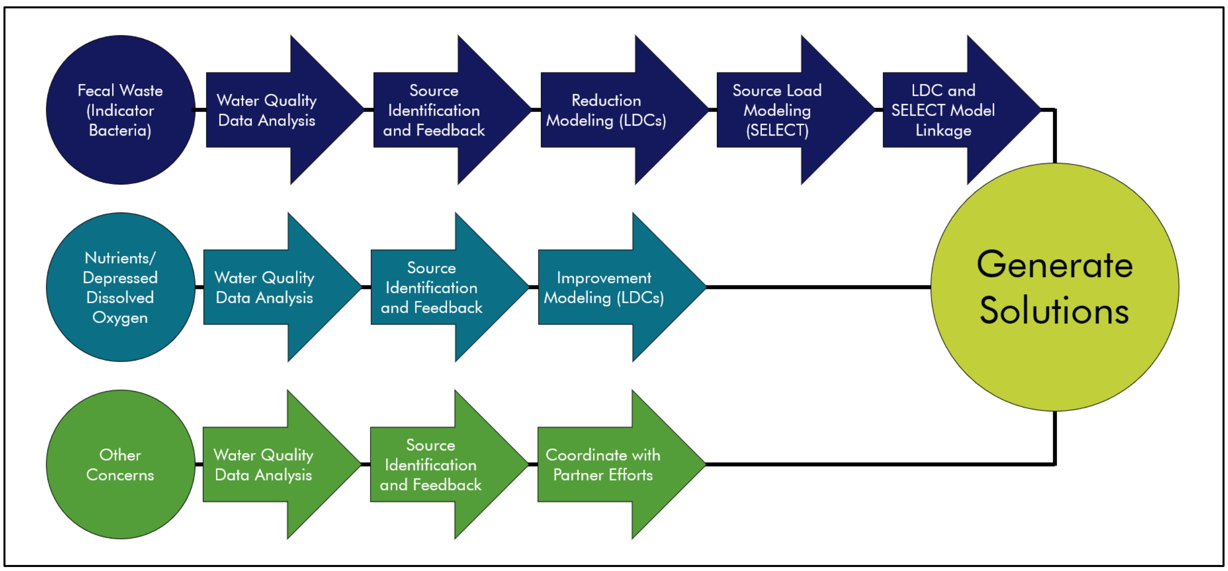

Figure 17. Pollutant source investigation flow chart

Water Quality Goals

The applicability of each step to different pollutants/conditions of concern is based on the water quality goals established by the stakeholders (see Section 1) and is noted in parentheses for each step.

- **Water quality data analysis (all water quality issues)** — Project staff identified status and trends in ambient water quality monitoring data and discharge data from

[31] More detailed information on the development of this investigation methodology and selection of models can be found in the Bacteria Modeling Report, located at: https://springcreekpartnership.weebly.com/uploads/1/3/0/7/130710643/10159_4.3_spring_creek_bacteria_modeling_report_032321.pdf

wastewater treatment plants. These analyses identify the extent and variability of water quality issues and highlight differences between areas in the watershed.

- **Source identification and feedback (all water quality issues)** — The Partnership used local knowledge, data from other efforts, field reconnaissance, and map analysis to identify potential sources. These steps help to shape subsequent analyses by focusing efforts on sources of priority in the watershed.
- **Source load modeling (fecal waste)** — H-GAC worked with the Partnership to estimate the potential amount of fecal waste/*E. coli* generated in the watershed using computer models guided by local knowledge and feedback. These efforts identified the potential total fecal loads, mix of sources responsible, and variation between different areas of the watershed.
- **Reduction/Improvement modeling (fecal waste, DO)** — H-GAC worked with the Partnership to estimate the amount of improvement needed to meet water quality standards for various areas in the waterway. Results were generated by computer models using then-current water quality monitoring data. These processes generated the percent reduction for *E. coli* and the percent improvement for DO levels (see Section 4).
- **Source and improvement linkage (fecal waste)** — As the primary focus and sole impairment in the watershed, fecal indicator bacteria estimates were needed to establish numeric reduction goals for *E. coli*. This process applied the percent reduction targets from the improvement modeling to *E. coli* source load estimations to generate the amount of source load that needed to be reduced to achieve the water quality standard (see Section 4).
- **Coordinate with partner efforts (other concerns)** — Most specifically in the case of flood mitigation, the primary focus of developing recommendations for concerns outside the scope of this WPP was coordinating with partners.
- **Emphasize human wastewater as a priority** – While models may downplay the contribution of human wastewater, the stakeholders emphasized the greater risk human waste carries, the greater likelihood it is to be in proximity to our communities, and the potential for acute overflow events that do not reflect average daily loads.

Water Quality Analysis

Assessing water quality data sources is the first step in narrowing the search for the causes and sources of pollution. The Partnership reviewed analyses of 1) ambient water monitoring data; 2) volunteer water quality monitoring data; 3) discharge monitoring reports (DMRs) and sanitary sewer overflow (SSO) data from wastewater treatment facilities; and 4) results from similar projects in the area. While these analyses are summarized here, greater detail on the methods and results can be found in the *Water*

Quality Data Analysis Summary Report[32] prepared for this WPP. The primary goals of the analyses were to better understand water quality conditions, characterize the quality of wastewater contributions, and identify the availability of sufficient data for the models. The analyses focused on a five-year period of data to represent the most current conditions, but also relevant trends in recent years.

Figure 18. Water quality monitoring by the Clean Rivers Program

Ambient Water Quality Monitoring Data

Ambient water quality data are collected at over 400 sites in the 13-county Houston-Galveston region by H-GAC, local partners, and TCEQ as part of the Clean Rivers Program[33]. Most monitoring stations are sampled by CRP partners[34]. Waterways are inherently dynamic systems, and water quality at any given time can vary greatly dependent

[32] Available on the project website at: https://springcreekpartnership.weebly.com/uploads/1/3/0/7/130710643/10159_3.3_spring_creek_data_analysis_summary_report.pdf

[33] More information about this state-wide water quality monitoring program can be found at: https://www.tceq.texas.gov/waterquality/clean-rivers

[34] More information about the specific monitoring and programmatic details of the local CRP can be found at: https://www.h-gac.com/clean-rivers-program/information/

on conditions at the time[35]. However, a history of ambient water quality samples helps characterize the range of conditions that may be present in a waterway and is important for the identification of trends over time. The final determination of the regulatory status of each segment is based primarily on these ambient data. Goals and decisions for this WPP were established in part due to the regulatory status, and therefore ambient data is an important source of information for informing stakeholder decisions.

The Spring Creek system is heavily monitored, with 20 active monitoring stations: six on the main body, one on Brushy Creek (1008J), one on Walnut Creek (1008I), one on Mill Creek (1008A), two on Willow Creek (1009H), one on Bear Branch (1008E), two on Upper Panther Branch (1008B), four on Lake Woodlands (1008F), and two on Lower Panther Branch (1008C; **Figure 19**; **Table 7**). Data for all stations are representative of ten years of sampling and are enough to describe the conditions during the study period.

Table 7. CRP monitoring station locations in the Spring Creek watershed

Station	Site Location
11312	Spring Creek at Riley Fussel Rd.
11313	Spring Creek Bridge at I-45
11314	Spring Creek at SH 249
11323	Spring Creek at Rosehill-Decker Rd.
17489	Spring Creek at Kuykendahl Rd. northeast of Houston
18868	Spring Creek at Roberts Cemetery Rd. west-northwest of Tomball
20463	Brushy Creek at Glenmont Estates Boulevard
20462	Walnut Creek at Decker Prairie-Rosehill Rd.-northwest of Tomball
21957	Mill Creek at FM 149 north of Tomball
11185	Willow Creek at Gosling Rd.
20730	Willow Creek at Tuwa Rd. 859 m downstream of FM 2920 Rd.
16631	Bear Branch Bridge 300 m north of Shadow Bend and Research Forest Dr. intersection
16629	Upper Panther Branch 80 m upstream of 5402 Research Forest Dr.
16630	Upper Panther Branch 60 m downstream of 5402 Research Forest Dr.
16481	Lake Woodlands at western reach in The Woodlands
16482	Lake Woodlands at south end in The Woodlands
16483	Lake Woodlands at mid-point in The Woodlands
16484	Lake Woodlands at north end in The Woodlands
16422	Lower Panther Branch 270 m downstream of Sawdust Rd.
16627	Lower Panther Branch at footbridge 265 m upstream of Sawdust Road

[35] For this section, 24-hour DO data is discussed. In terms of technical terminology under CRP, 24-hour DO sampling is not considered "ambient" data, but rather, "biased sampling" because it is often collected during certain seasonal timeframes. Due to the nature of the 24-hour data for this project, and the basic categorization of this report, it is discussed as ambient data.

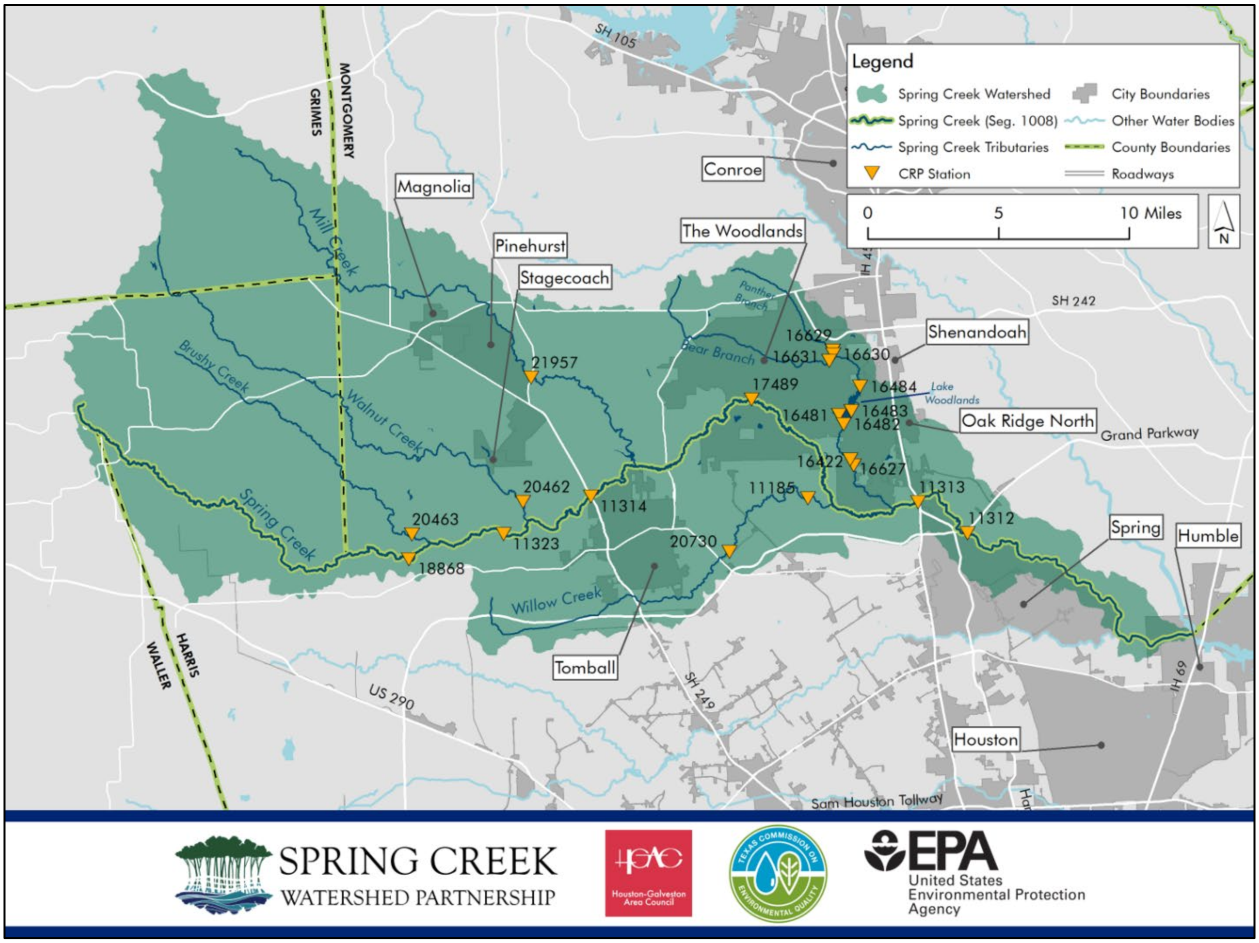

Figure 19. Spring Creek watershed monitoring stations

Constituents of Concern

Routine ambient water quality monitoring under the CRP includes sampling for a suite of conventional, bacteriological, and field parameters. For this evaluation, a subset of those parameters most closely related to the goals of the WPP and characterization studies has been selected for in-depth analysis. The parameters reviewed were:

- ***E. coli*** — a bacterial indicator of the presence of fecal wastes, and an indicator of the safety of waterways for human recreation.
- **DO (grab)** — an indicator of the ability of the waterway to support aquatic life.
- **Temperature** — an indicator of a waterway's ability to hold oxygen, and a means for correlating other indicators to conditions in the waterways.
- **pH** — an indicator of the acidity or alkalinity of water, which may affect aquatic life and other uses.

- **Chlorophyll-*a* (Chl-*a*)** — an indicator of aquatic plant productivity and action, which can indicate areas in which algal blooms or elevated nutrient levels are present, and thus potentially depressed DO.
- **Nitrate (NO_3-N) and Nitrite (NO_2-N)** — a measure of nitrogenous compounds and indicator of nutrient levels (and thus potential DO impacts).
- **Ammonia Nitrogen (NH_3-N)** — a measure of specific nitrogenous compound that can impact aquatic life and is an indicator of nutrient levels and potentially of improperly treated sewage effluent.
- **Total Phosphorus (TP)** — an indicator of nutrient levels, especially in relation to potential for algal blooms and depressed DO in elevated levels.
- **Total Suspended Solids (TSS)** — a measure of the number of suspended particles in water that indicates the potential of light infiltration in the water column and the presence of particulate matter which *E. coli* may use as substrate.

The analyzed data covers 2009-2019 to show a broad historic view. The primary questions this evaluation sought to answer relate to:

- The sufficiency of the data to characterize conditions,
- The spatial component of variations in water quality conditions,
- The extent of water quality issues, and
- Trends in water quality conditions, including any observable seasonal patterns.

H-GAC completed the assessment on the segment level, with attention to any unclassified tributaries which may be experiencing water quality issues.

Monitoring Analysis

A summary of ambient data represented as the geomean of each parameter for its period of record (2009-2019) is shown in **Table 8** below. This dataset is from TCEQ's Surface Water Quality Monitoring Information System and the period of record is designed to match that of the load duration curves mentioned in Section 4. These results are not comparable to that of the 2020 Texas Integrated Report which uses a different period of record (2011-2018) and assessment methodology for determination of Texas Surface Water Quality Standards attainment.

Table 8. HGAC Trend analysis of water quality data collected between 2009 and 2019

Parameter	Criteria	Unit	Geomean Results by Segment								
			1008	1008A	1008B	1008C	1008E	1008F*	1008H	1008I	1008J
E. coli	126	cfu/ 100mL	228.41	73.35	73.35	150.85	146.56	42.37	207.05	201.73	232.58
DO (grab)	Various	mg/L	6.88	6.26	6.26	6.38	6.39	8.51	7.73	6.04	5.52
pH	9 (high) 6.5 (low)	NA	7.44	7.4	7.4	7.71	7.49	8.45	7.62	7.34	7.05
Chl-*a*	14.1	µg/L	1.89					16.31			
NO_3-N	1.95	mg/L	0.64	1.94	1.94	2.27	0.31	1.07	6.09		
NO_2-N	NA	mg/L	0.04								
NO_3-N + NO_2-N	NA	mg/L	0.22	2.22	2.22	2.45	0.38	1.23		0.23	0.09
NH_3-N	0.33	mg/L	0.06	0.14	0.14	0.14	0.12	0.11	0.11	0.1	0.12
TP	0.69	mg/L	0.24	0.73	0.73	1.08	0.27	0.87	1.65	0.21	0.15
TSS	NA	mg/L	16.51	8.42	8.42	18.61	17.09	18.09	11.48	17.55	9.77

Note: Cells filled in with the darker shade indicate geomeans that exceed criteria or screening levels, while cells filled in with the lighter shade represent results that are in less than the criteria or better than the screening level. Lack of shading indicates the data is not being compared to criteria or screening levels. Stripes indicate cells without any values. 1008F* is Lake Woodlands and screened at reservoir levels. This trend analysis does not reflect analysis or conclusions from the Texas Integrated Report.

Water Quality Parameter Trends

By examining all parameters collected from surface water samples in the Spring Creek watershed and how measurements for those parameters have changed over time, trends in the data were determined. Statistically significant ($p < 0.0545$) trends observed in these analyses are summarized in **Table 9** below. Cells filled in with the darker shade indicate trends that could be negatively impacting water quality such as increasing nutrient levels and decreasing dissolved oxygen. Results for parameters with stable trends over time are not represented in **Table 9**. Consequently, parameter measurements that exceeded water quality standards but remained consistently high throughout the study period (such as *E. coli*) may not be captured by the summary.

Table 9. Water quality trends by segment

Segment	Parameter	Trend	N
Spring Creek, 1008	DO (grab)	Increasing	470
Spring Creek, 1008	Nitrate and Nitrite	Increasing	52
Spring Creek, 1008	Total Phosphorus	Decreasing	461
Mill Creek, 1008A	DO (grab)	Increasing	43
Mill Creek, 1008A	Nitrate and Nitrite	Decreasing	43
Upper Panther Branch, 1008B	Ammonia Nitrogen	Increasing	66
Upper Panther Branch, 1008B	DO (grab)	Increasing	198
Lower Panther Branch, 1008B	Ammonia Nitrogen	Increasing	66
Bear Branch, 1008E	Ammonia Nitrogen	Increasing	33
Bear Branch, 1008E	DO (grab)	Increasing	98
Bear Branch, 1008E	Total Phosphorus	Increasing	33
Lake Woodlands, 1008F	Ammonia Nitrogen	Increasing	132
Lake Woodlands, 1008F	*E. coli*	Decreasing	132
Lake Woodlands, 1008F	TSS	Decreasing	128
Willow Creek, 1008H	*E. coli*	Increasing	177
Willow Creek, 1008H	pH	Decreasing	175
Brushy Creek, 1008J	DO (grab)	Increasing	37
Brushy Creek, 1008J	pH	Increasing	39

Note: Cells filled in with the lighter shade represent trends that support good water quality such as decreasing fecal indicator bacteria levels and increasing dissolved oxygen. Lack of shading indicates results that are predicted to be of neutral impact to water quality.

Relationship to Flow

Parameter measurements and their relationships to flow conditions were considered in this analysis. Further work on the relationship between flow, bacteria, and DO was completed as part of the model development explained in Section 4. According to the results of the models, surface water in the Spring Creek watershed is likely impacted by nonpoint source pollution. This is indicated by fecal indicator bacteria concentrations that are observed to increase with flow magnitude.

Ambient Data Analysis Summary

Of the ambient water quality parameters observed, geomean values for fecal indicator bacteria levels measured between 2009 and 2019 exceeded state water quality standards most frequently. Of the segments with geomeans that exceeded criteria, Willow Creek (1008H) showed an increasing trend in *E. coli* over time. Only Mill Creek (1008A), Upper Panther Branch (1008B) and Lake Woodlands (1008F) showed geomean values for *E. coli* within criteria levels. In fact, *E. coli* levels in Lake Woodlands have followed a significant decreasing trend over time.

Nutrients also seem to pose a challenge to water quality in the Spring Creek Watershed. Total phosphorous geomeans exceeded screening levels on Panther Branch (1008B and 1008C), Lake Woodlands (1008F) and Willow Creek (1008H). Nitrate nitrogen geomeans were also found to be above screening levels on the lower portion of Panther Branch (1008C) and Willow Creek (1008H). Spatially, these exceedances occur in the eastern third of the watershed where developed areas are most prevalent.

Low levels of DO are a concern noted in the 2020 Texas Integrated Report that are not necessarily captured in this analysis. This is most likely due to the overlap of datasets observed—The 2020 Texas Integrated Report observed data collected from 2011-2018 whereas this analysis uses 2009-2019 as the study period.

Targeted assessment and application of best management practices could be expected to reduce or remove impairments and concerns in these watersheds.

Stream Team Monitoring

While the WPP relies on quality assured data for trends analyses and model inputs, volunteer data provided by local Texas Stream Team (TST) monitors can be a valuable supplement to routine monitoring sites by providing hints at conditions in areas outside the existing data. One of the most valuable elements of TST data is the observational information from the volunteers. There are four active TST sites in the Spring Creek watershed. Project staff reviewed the data at the beginning of the project to help define areas of interest and to guide informal decisions on field reconnaissance. The data will be used in conjunction with formal data sources and analyses to help identify WPP effectiveness going forward.

Wastewater Treatment Facility Discharge Data

Discharges from wastewater treatment facilities (WWTFs) are regulated by Texas Pollutant Discharge Elimination System (TPDES) permits from TCEQ which require stringent limits for effluent quality. Human waste can cause human illness, so identifying trends in permit exceedances for *E. coli* by WWTFs is important in understanding overall impacts to human health related to contaminated waterways. Additionally, effluent (especially if improperly treated) can be a source of nutrient or other precursors to depressed DO. At the time of this study, there are 61 permitted WWTFs with 76 outfalls in the Spring Creek Watershed (**Figure 20**; **Appendix B**. Wastewater Treatment Facilities).

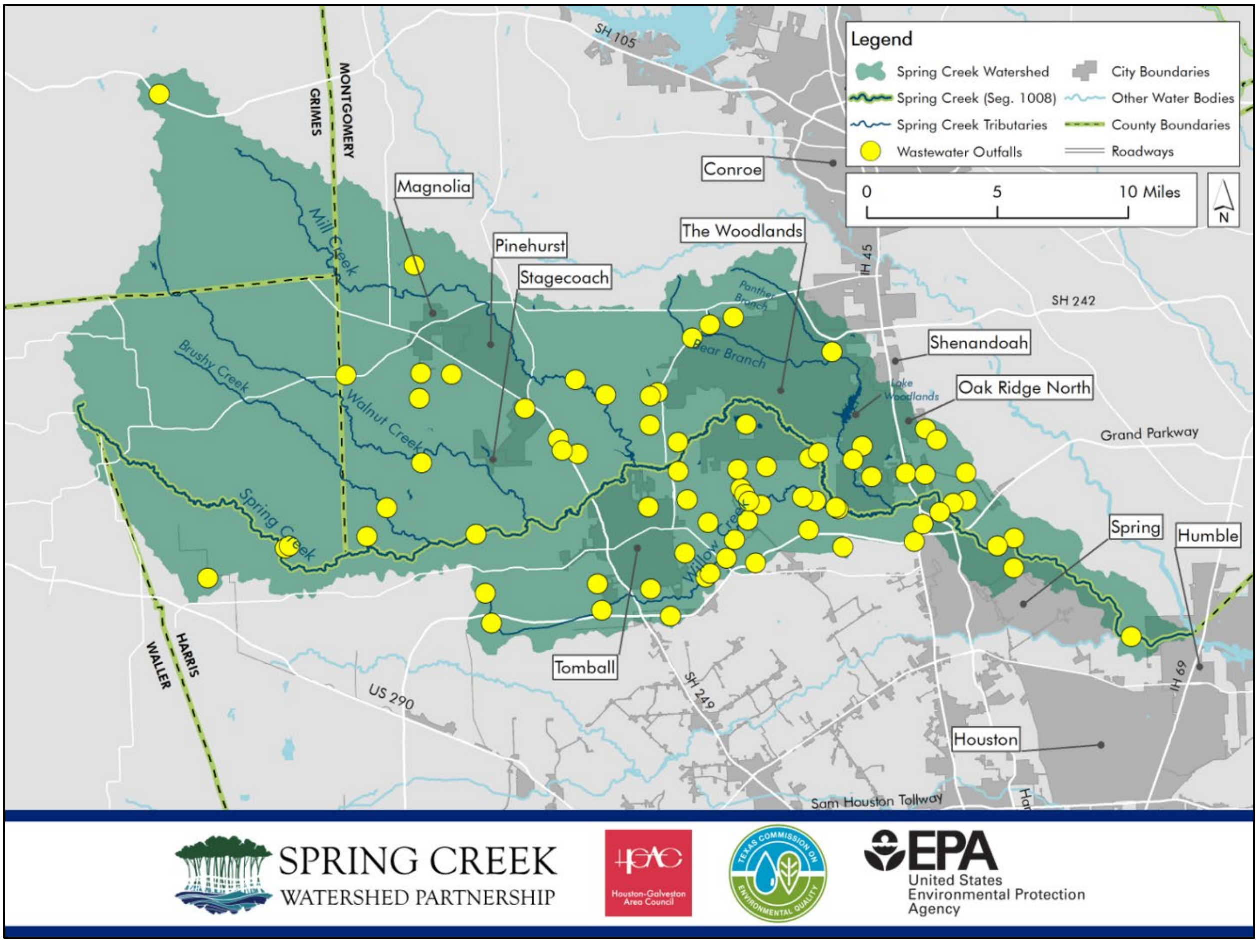

Figure 20. WWTF outfalls in the Spring Creek watershed

Discharges from WWTFs are monitored on a regular basis (with a frequency dependent on facility size and other factors). The data from these required sampling events are submitted to (and compiled by) TCEQ as DMRs. As with any self-reported data, there is an expectation that some degree of uncertainty or variation from conditions may occur, but these DMRs are the most comprehensive data available for evaluating WWTFs in the watershed.

Project staff evaluated[36] DMRs from TCEQ reported between 2014 and 2019 by WWTF permit holders in the Spring Creek watershed. Five parameters common to most WWTF permits were assessed including: *E. coli*, TSS, ammonia nitrogen (NH_3-N), DO, and five-day carbonaceous biochemical oxygen demand ($CBOD_5$). While some parameters are themselves constituents of concern, all are indicators of the presence or potential presence

[36] For more detail, see the Water Quality Data Analysis Summary Report on the project website at: https://springcreekpartnership.weebly.com/uploads/1/3/0/7/130710643/10159_3.3_spring_creek_data_analysis_summary_report.pdf

of untreated/improperly treated waste[37]. The parameter evaluations were based on the regulatory permit limits specific to each facility, and consider the number of exceedances by each facility, in each year, in each segment, and as a percentage of the total samples.

E. coli

Effluent discharge from WWTFs is assessed for compliance with the TPDES permitted limits. For this analysis, DMR data were compared to TPDES permit limits for bacteria across segments, facility types, years, and seasons. The values for exceedances of geomean and single sample limits in Table 10 were calculated for each facility depending on their specific permit limits. Several facilities in the watershed have more stringent bacteria limits than SWQS (e.g., 63 cfu/100mL) as required in a TMDL. However, when the WWTF bacteria loading was estimated in the SELECT process, an assumed effluent concentration of 126 cfu/100 mL was used for all facilities to get a high-end estimate for loading that the stakeholders felt was more appropriate. Exceedance statistics are summarized in **Table 10**.

Table 10. DMR bacteria exceedance statistics, 2014-2019

Parameter	Number of Facilities	Percent of Facilities	Percent of Reports
Facilities in DMR Dataset	61		
Facilities Reporting Bacteria	61		
Total Records	6,082		
Less than 1% Violations	32	52.5%	
1% to 5% Violations	20	32.8%	
5% to 10% Violations	6	9.8%	
10% to 25% Violations	3	4.9%	
Greater than 25% Violations	0	0.0%	
Exceedances of Geomean	24		0.4%
Exceedances of Single Grab	88		1.4%
Total Exceedances	112		1.8%

Note: Several facilities in the watershed have more stringent permit limits (e.g., 63 cfu/100mL) required in a TMDL. For DMR analyses, the actual permit limit for each facility was used.

Overall, the results of the analyses of DMR *E. coli* data indicated that the total number of exceedances reported was small relative to the total number of DMR reports submitted for the period of 2014 to 2019 (112 out of 6,082 records). Further, only 9 facilities out of 61 exceeded the bacteria standard in >5% of their

[37] In consideration of the nutrient loading capacity of the facilities, it should be noted that many nutrient parameters are not standard facility permit limits, and thus may not be tested. Based on review of correlations between nutrient parameters and flow for many stations, the analyses did show a likelihood of facilities as nutrient loading sources for non-permit limit parameters, particularly in effluent-dominated streams.

samples. Maximum grab values were more commonly exceeded than geomean limits which suggests high variability in the data. Seasonality was not observed to be significant in shaping trends in bacteria concentrations. Evaluations of facility size relative to number of exceedances revealed that small plants (<0.5 million-gallons per day (MGD)) reported the most violations of any size category for both the geomean and single sample standards. This may be in part due to relative frequency of monitoring, wherein large facilities monitor more frequently and have more data to include in a geomean calculation, or it may be due to operational differences between larger staffed facilities and smaller unstaffed facilities. While WWTFs may be appreciable contributions under certain conditions and in localized areas, the DMR analysis indicates that they are not likely a significant driver of segment bacteria impairments due to the comparatively few exceedances. However, due to the relatively higher risk of pathogens from human waste, and proximity to developed areas, WWTF exceedances are still a point of concern for stakeholders.

Dissolved Oxygen

DO levels in WWTF effluent help indicate the efficiency of treatment processes. DO is generally more stable in effluent than it can be in ambient conditions because it is less subject to natural processes and variation in insolation. DO is measured in milligrams per liter (mg/L), and the permit limits can vary based on the receiving water body and other factors. Unlike other contaminants, DO limits are based on a minimum, rather than maximum level, and represent a grab sample as opposed to a 24-hour monitoring event. Generally, permit limits for the data reviewed ranged between 4-6 mg/L. Evaluations for compliance with the permit limits were for all records, between years, and by season. 61 plants reported DO results during this period. The outcomes are summarized in the tables below. **Table 11** summarizes the overall statistics of DO data reported by WWTFs in the Spring Creek watershed.

Table 11. DMR DO exceedance statistics, 2014-2019

Parameter	Number	Percent of Records
Facilities in DMR Dataset	61	
Facilities Reporting DO	61	
Total Records	4,082	
Total Exceedances	20	0.5%

Very few (20 of 4,082 total reports) samples fell below the minimum standard. After arranging the data temporally, no annual or seasonal trends were observed in the reported data. However, in light of the low occurrence of exceedance relative to the overall dataset, determining trends from these values may not accurately represent

DO dynamics in the Spring Creek Watershed. Due to the findings of this analysis, it is unlikely that low DO levels in the waterways of the Spring Creek Watershed are being driven by WWTF effluent. As with the results of the bacteria analysis, it is important to note that periodic impacts to DO levels may occur on a localized level but may not be well represented in this broad analysis. While the impacts of WWTFs on DO levels may not be a chronic or widespread issue in the watershed, an analysis of DO values reported in DMRs is still a critical component of this project especially as it pertains to identifying localized impacts. In addition, the levels of direct oxygen-demanding constituents ($CBOD_5$ and ammonia-nitrogen) present in wastewater discharges can have a more prolonged downstream impact on instream DO concentrations than effluent DO concentrations.

Total Suspended Solids

To determine the efficiency of wastewater treatment in removing solids, TSS is evaluated. Bacteria use suspended particles as a protected growth medium and can therefore occur in greater concentrations when TSS is high. Additionally, TSS can be useful as an indicator that inefficient treatment may have led to other waste products (nutrients, *etc.*) being elevated in effluent. Permit limits for TSS include a concentration based (average) limit in mg/L and a total weight-based limit in pounds per day. Both average and maximum monitored results exist for most facilities. Evaluations for compliance with concentration and total weight permit limits were made for the overall dataset and for annual and seasonal data. The summary of reports made for TSS measurements, and the number of exceedances of the concentration and weight limits are presented in **Table 12** below.

Table 12. DMR TSS exceedance statistics, 2014-2019

Category	Number	Percent of Records
Facilities in DMR Dataset	61	
Facilities Reporting TSS	61	
Total Records	8,090	
Exceedances of Concentration	88	1.1%
Exceedances of Weight	38	0.5%
Total Exceedances	126	1.6%

Compared to the total number of reports submitted between 2014 and 2019, the total frequency of exceedance is very small (less than 2%). Viewing the data annually, there does not seem to be any significant pattern to either concentration, weight or combined total violations. Of the four seasons, samples exceeding the concentration and weight standards seem to be most prevalent during the winter months. Though periodic, local impacts may not be captured by these results, water quality throughout the Spring Creek watershed is unlikely to be impacted by TSS from WWTFs at the watershed level. Seasonal analysis showed that samples exceeding the concentration and weight limits occurred with the highest frequency in winter months, but the overall percentage of samples exceeding the limits compared to the total number of reports was negligibly small. Despite this, observing TSS in WWTF effluent is still worth considering when moving forward with best management practices for water quality. As mentioned previously, TSS is often correlated with nutrient and bacteria levels, and can be tracked as a measure of WWTF improvement.

Ammonia Nitrogen

Ammonia nitrogen is a component that indicates negative impacts to water quality due to nutrient loading. Further, it can be toxic to humans and wildlife. Deficiencies in wastewater treatment that lead to improperly treated sewage entering waterways can be indicated by elevated levels of ammonia nitrogen. Similar to TSS, concentration and weight measurements are used to assess compliance of ammonia nitrogen levels with permit limits. In **Table 13** below, the results of samples reported to be in exceedance of the limits as reported between 2014 and 2019 are summarized.

Table 13. DMR ammonia nitrogen exceedance statistics, 2014-2019

Category	Number	Percent of Records
Facilities in DMR Dataset	61	
Facilities Reporting Ammonia Nitrogen	61	
Total Records	8,092	
Exceedances of Concentration	129	1.6%
Exceedances of Weight	65	0.8%
Total Exceedances	194	2.4%

The results of the analyses of ammonia nitrogen reported by Spring Creek watershed WWTFs between 2014 and 2019 show that exceedances do not follow any annual pattern but are more common in spring and summer months with summer capturing the highest frequency of concentration and weight violations. However, the total number of exceedances reported for ammonia nitrogen comprise less than 3% of the total reported values. This indicates that WWTFs are generally operating within permit limits and that ammonia inputs from WWTFs are not likely a chronic issue of importance for Spring Creek waterways. Periodic, localized impacts may not be as apparent when using a broad scope analysis. Ammonia nitrogen may still have use as an indicator of WWTF efficiency much in the same way as TSS and will therefore continue to be considered for best management practices in the watershed.

Oxygen Demand

$CBOD_5$ measures the depletion of oxygen over time by biological processes and indicates the efficiency of treatment. It is not a pollutant itself but is informative of the water quality of effluent from WWTFs. In **Table 14** below, the exceedances of concentration and weight limits for $CBOD_5$ in relation to the total number of reported values are summarized.

Table 14. DMR $CBOD_5$ exceedance statistics, 2014-2019

Category	Number	Percent of Records
Facilities in DMR Dataset	61	
Facilities Reporting $CBOD_5$	61	
Total Records	8,164	
Exceedances of Concentration	17	0.2%
Exceedances of Weight	11	0.1%
Total Exceedances	28	0.3%

$CBOD_5$ exceedances were relatively rare in this DMR dataset compared to the other observed parameters. No annual pattern was observed and though exceedances were most frequent seasonally in the winter, the small number of exceedances limits the applicability of any trends. From this analysis, it can be assumed that WWTFs are not likely a chronic source of poor $CBOD_5$ values in the waterways of the Spring Creek watershed. As with previous analyses however, it should be noted that determining periodic and localized impacts may require further investigation.

Discharge Data Analysis Summary

Exceedances for all constituents compared to their permit limits were revealed in this analysis. However, plants in the Spring Creek watershed were largely found to be in compliance with their permit limits for the majority of the period of study. It is unlikely that WWTFs are an appreciable source of contamination in the watershed on a chronic, wide-ranging scale. However, this broad analysis may underrepresent localized impacts of WWTF outfalls. For example, a spatial examination of individual facility locations and their respective sizes and exceedances of bacteria permit limits yielded results indicating high percentages of exceedance from small facilities west of the most developed parts of the watershed. This spatial analysis also showed that facilities of various sizes reporting exceedances between 5 and

10% of their total records were located on the more developed eastern half of the watershed.

WWTFs may not be the largest source of bacteria, but effluent from these facilities has an inherently higher pathogenic potential than other sources due to the treatment of human waste. Additionally, unlike other sources of natural and diffuse fecal waste in the watersheds, WWTF effluent has both regulatory controls and voluntary measures by which improperly treated wastewater may be addressed. Given the nature of WWTF effluent as a human pollutant, and our direct ability to influence its character, WWTF bacteria should be considered as a potential focus for some best management practices. While other constituents (*e.g.*, nutrients) are not necessarily any more harmful than other sources in the watershed, the principle of direct control of effluent applies to their consideration as well.

Sanitary Sewer Overflows

Though SSOs occur episodically, they represent a high-risk vector for bacteria contamination because they can have concentrations of bacteria several orders of magnitude higher than treated effluent. Untreated sewage can contain large volumes of raw fecal matter, making it a significant health risk where SSOs are sizeable and/or chronic issues. The causes of SSOs vary from human error to infiltration of rainwater into sewer pipes. Data used for these analyses is self-reported and may vary in quality. Even in the best of circumstances, the ability to accurately gauge SSO volumes or even occurrences in the field is limited by several factors. Actual SSO volumes and incidences are generally expected to be greater than reported due to these fundamental challenges. Known causes of SSOs were broken into four broad categories with several subcategories each, to reflect the breakdown in TCEQ's SSO database. It should be noted, however, that this categorization depends on the accuracy of the data reported by the utilities. Additionally, while a single cause is typically listed on the SSO report, many SSOs are caused by a combination of factors.

This study considered five years of TCEQ SSO violation data for 2014-2019. There were 131 SSO records from 26 facilities considered for the watershed area. Of those 26 facilities, 11 facilities had ≥5 SSOs, and of those 11 facilities, 5 facilities had ≥10 SSOs. However, number of SSOs did not correspond well to volume of SSOs. Only 4 facilities had a cumulative SSO volume greater than 50,000 gallons, and only one of those facilities had a number of SSOs >5. Below, tables and figures reflect the breakdown of SSOs by year and cause, for number and volume, respectively.

As shown in **Table 15**, there was not a strong trend in number of SSOs over time. In terms of cause by number, the general category of weather-related issues accounted for 23.7%

of the overall total, malfunctions and operational issues accounted for 35.9%, blockages accounted for 29.8%, and 10.7% were listed as unknown causes.

Table 15. Number of annual SSO events

CAUSE	2014	2015	2016	2017	2018	2019
Weather	**1**	**0**	**8**	**7**	**9**	**6**
Rain / Inflow / Infiltration	1		8	1	9	6
Hurricane				6		
Malfunctions	**5**	**5**	**10**	**6**	**13**	**8**
WWTF Operation or Equipment Malfunction	2		4	1	5	1
Power Failure	1	1	1	2	1	
Lift Station Failure	2	1	3	1	3	3
Collection System Structural Failure		3	1	2	4	4
Human Error			1			
Blockages	**6**	**9**	**5**	**1**	**10**	**8**
Blockage in Collection System-Other Cause	3	5	2	1	6	2
Blockage in Collection System Due to Fats/Grease	1	3	3		3	4
Blockage Due to Roots/Rags/Debris	2	1			1	2
Unknown Cause	**0**	**2**	**3**	**1**	**5**	**3**
TOTAL	**12**	**16**	**26**	**15**	**37**	**25**

While numbering SSO events informs how frequently these overflows impact the watershed, volume of overflow is an indicator of the magnitude of impact. The results summarized in **Table 16** indicate that as with number of events, there was no real temporal trend in volume of events. Of note, though 2017 had the second lowest total overflow volume reported over the five years of study, over 80% of the overflow volume was associated with a hurricane event (Hurricane Harvey). Apart from that isolated event and a high volume of overflows caused by blockages in 2015, malfunctions were the most common cause of high-volume overflows throughout the study period.

Table 16. Annual SSO events by volume (in gallons)

CAUSE	2014	2015	2016	2017	2018	2019
Weather	**500**	**0**	**44,300**	**58,700**	**12,301**	**10,294**
Rain / Inflow / Infiltration	500		44,300	300	12,301	10,294
Hurricane				58,400		

Malfunctions	**31,010**	**19,300**	**87,748**	**11,090.5**	**150,374**	**52,723**
WWTF Operation or Equipment Malfunction	26,000		2,050	0.5	724	10,000
Power Failure	3,000	300	2,500	10,000	2,500	
Lift Station Failure	2,010	1,500	62,300	100	53,850	35,023
Collection System Structural Failure		17,500	500	990	93,300	7,700
Human Error			20,398			
Blockages	**20,750**	**50,000**	**4,880**	**2,400**	**80,350**	**8,915**
Blockage in Collection System-Other Cause	17,000	23,500	3,395	2,400	22,100	5,980
Blockage in Collection System Due to Fats/Grease	1,950	25,500	1,485		8,250	1,915
Blockage Due to Roots/Rags/Debris	1,800	1,000			50,000	1,020
Unknown Cause	**0**	**1,970**	**77,060**	**100**	**925**	**36,500**
Total	**52,260**	**71,270**	**213,988**	**72,290.5**	**243,950**	**108,432**

Of the total volume of overflows reported from 2014-2019, malfunctions were responsible for 46.2%. Blockages comprised 21.9% of the overall volume, weather contributed 16.5% and unknown causes led to the remaining 15.3%. These overall contributions are important to consider in a general sense for estimating impacts to the watershed area.

Report Data Analysis Summary

Of the 26 facilities that reported SSOs between 2014 and 2019, 11 had ≥5 SSOs (5 of those had ≥10). The number of occurrences was not necessarily indicative of overflow volume. Only one of the 4 facilities reporting a cumulative SSO volume greater than 50,000 gallons had >5 SSOs. There was not a strong annual or seasonal trend in number or volume of SSOs. In terms of general cause, malfunctions and operational issues accounted for the highest number of events and overflow volume respective to the other general categories of weather, blockages, and unknown causes.

While this data is useful, it should be noted that it is also self-reported and may vary in quality. Overflow volumes and numbers of events may be greater than the values recorded in the report data. In addition, causes may be overgeneralized due to multiple factors ultimately resulting in SSOs.

In watersheds where bacteria and nutrient loading are of particular concern, the impacts of SSOs are important to understand due to their concentrations of untreated human waste. These events pose a high risk to human health especially due to their proximity to urban populations. Further, despite their episodic occurrences, SSOs can be extreme loading sources in the sense of volume introduced in a short time frame. Though SSOs do not have the same potential to have chronic impacts on waterways as effluent from high volume WWTFs, for the aforementioned reasons, it is still critical to consider SSO management among the best management practices selected to improve water quality in the Spring Creek watershed.

Other Water Quality Studies

The Spring Creek watershed has been the focus of several water quality efforts in addition to this WPP and ongoing TCEQ and CRP monitoring. While the results from these studies can point to nuance in water quality issues, data from these studies is spread out over differing time periods and derived from different methodologies. For that reason, the data may not be directly comparable to the water quality analyses of this report (or subsequent modeling results). Regardless, the findings of these efforts are informative in directing the investigations of this WPP. The Partnership reviewed results from the following projects:

Lake Houston TMDL

TCEQ projects that culminated in the Fifteen Total Maximum Daily Loads for Indicator Bacteria in Watersheds Upstream of Lake Houston[38] and subsequent implementation plan[39] covered a broad area of the Lake Houston watersheds, including Spring Creek and Willow Creek. The findings of the TMDL analyses are less current or granular than the analyses generated for this WPP but indicate a similar pattern of impairments and concern.

Summary of Water Quality Analyses

This review of water quality data is foundational for understanding and characterizing water quality concerns in the Spring Creek watershed, and for informing subsequent stakeholder decisions. The analyses served to answer questions regarding the sufficiency of the data, the extent and severity of water quality trends, seasonality of water quality issues, and the potential impact of wastewater effluent and SSOs.

Data meeting the criteria for sufficiency were used to determine what constituents of water quality are of greatest concern and the extent to which their impacts have been observed throughout the area waterways. 2020 Texas Integrated Report results for this watershed and the dataset from 2009-2019 also analyzed for this WPP, identified high levels of the fecal indicator bacteria *E. coli* as the most pervasive impact to water quality. Further, elevated nutrient (nitrate nitrogen and total phosphorous) levels observed in the highly developed eastern third of the watershed present challenges to water quality. Depressed

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[38] Available for review at: https://www.tceq.texas.gov/downloads/water-quality/tmdl/houston-galveston-recreational-42/82a-lake-houston-tmdl-addendum-one.pdf

[39] Available for review at: https://www.tceq.texas.gov/downloads/water-quality/tmdl/houston-galveston-recreational-42/42-houston-region-bacteria-iplan-approved.pdf

DO levels were also highlighted in several segments in the 2020 Texas Integrated Report. The dataset from 2009-2019 also analyzed for this WPP did not show those concerns. This is most likely due to different datasets that did not cover the same time period. The 2020 Integrated Report period of record covered 2011-2018 and is a seven-year sample period. The HGAC analysis of the 2009-2019 dataset uses more recent data and shows an increasing trend in DO.

Permitted wastewater effluent was unlikely to be a widespread or chronic water quality issue but requires further investigation on limited spatial scales and timeframes. However, understanding these discharges is still critical to the development of this project as WWTFs without permit limits for certain nutrients act as source loads—particularly in effluent-dominated streams. Further, as treatment facilities for human waste, improper treatment indicators identified in DMR analyses can have greater implications for risk to human health.

An analysis of SSO reports from the Spring Creek watershed indicated that 42.3% of reporting plants experienced 5 or more SSO events between 2014 and 2019. Plants reporting 10 or more events throughout the study period accounted for 19.2% of the data. Number of events did not correspond to magnitude of overflow volume, however. For both frequency of SSO events and volume of overflow, malfunctions were among the most common for the general cause categories. However, it is important to note that while only one cause is usually listed on the report, multiple compounding factors can lead to SSOs. Ultimately, causes listed in SSO reports are prone to a degree of subjectivity as opposed to more quantitative measurements. While the episodic overflow volumes reported during these events are relatively small compared to the scale of effluent produced by WWTFs, SSO inputs are of particular concern due to the untreated nature of the sewage associated with them and the subsequent risk to human health.

As future growth projections indicate that increased development in the watershed is likely, the balance of pollutant sources and current hydrologic processes could be altered significantly in the coming years. These changes could result in further water quality impacts without intervention. Subsequent efforts should be made to identify causes and sources of the primary constituent of concern (indicator bacteria), and to characterize nutrient sources further to identify areas within the project watersheds most vulnerable to pollutant loadings and/or best suited for the implementation of management strategies.

Source Identification

Using the information generated through the water quality data analyses, the next step in characterizing pollution in the watershed was to evaluate potential causes and sources. The results of this source identification and prioritization process assisted the Partnership in understanding the range of potential sources and guided the subsequent modeling efforts that estimated the loads from fecal waste and nutrient sources. Fecal waste sources were the primary focus of these efforts, but potential sources of depressed DO, nutrients, and other stakeholder concerns were also considered in relation to potential solutions.

Fecal Waste Source Identification

Waste from all warm-blooded animals is a potential source of *E. coli* contamination. *E. coli* are not necessarily themselves the source of potential health impacts; however, they signify the presence of fecal waste as well as a host of other pathogens associated with fecal waste. There is a wide array of potential fecal waste sources in the watershed. The potential mix of sources in a watershed can vary greatly in both spatial and seasonal contexts. The preliminary process of identifying potential fecal waste sources in a watershed is discussed as being a "source survey"[40]. The results of the survey shaped further analysis under the source modeling efforts of the project.

Source Survey

Characterizing fecal waste pollution in watersheds, and development of analyses to estimate potential loading, requires a consideration of potential sources. In any watershed with a mix of land uses, fecal waste can be produced by a broad mix of sources; this is especially true in a large, diverse watershed like Spring Creek. The existence and location of some sources are known from existing data (e.g., WWTF outfalls), while many nonpoint sources need to be evaluated from a mix of literature values, land cover analysis, imagery and road reconnaissance, and a robust process of stakeholder review and feedback. As part of developing the source survey, the Partnership completed the following assessments:

- **Known Source Characterization** — Existing data was used to generate information on discrete (usually permitted) sources. Data sources included[41]:
  - WWTF outfall locations and DMRs (TCEQ outfall locations and DMR records)
  - Permitted on-site sewage facility (OSSF) locations (H-GAC proprietary data provided by local governments)

[40] For greater detail on the source survey and subsequent bacteria modeling outcomes, please refer to the Bacteria Modeling Report, available online at: https://springcreekpartnership.weebly.com/uploads/1/3/0/7/130710643/10159_4.3_spring_creek_bacteria_modeling_report_032321.pdf

[41] More information on data sources and quality objectives can be found in the project quality assurance project plan (QAPP), available online on the project website at: https://springcreekpartnership.weebly.com/uploads/1/3/0/7/130710643/10159_modelingqapp_executed.pdf

  - Concentrated animal feeding operations (CAFOs) (TCEQ CAFO locations and violations data from TCEQ Central Registry records)
  - SSOs (TCEQ SSO database)
- **Land Cover Analysis** — Staff reviewed national land cover datasets and H-GAC proprietary land cover datasets to determine the mix of land cover types within the watershed, and within each subwatershed, in a spatial context. The watershed includes a mix of land cover types, so no sources were eliminated based on lack of land cover (*i.e.*, available habitat/use). Statistics and spatial coverage developed during this analysis were used as the basis of populating diffuse sources whose assumptions were tied to specific land cover types in modeling efforts.
- **Imagery Reconnaissance** — Staff utilized aerial imagery, online map assets (Google Maps, Google Maps Street View, Google Earth) and stakeholder feedback to identify any specific locations, specific sources, or issues to raise with stakeholders for further clarification. Examples of items derived from this analysis were:
  - Presence of horse stables
  - Small, unincorporated communities
  - Recreation use
  - Developmental projects in the watershed
- **Road Reconnaissance** — Staff also conducted ongoing road reconnaissance throughout the watershed specific to this task and as part of all activities in the watershed. Specific items noted or affirmed during road reconnaissance included:
  - Presence of deer in appreciable numbers in lightly developed areas
  - Progress of development (especially in the headwaters attainment area)
  - Sign of feral hog activity in some areas
  - General character of observable agricultural activities
- **Stakeholder Feedback** — Stakeholder engagement was a primary focus of the source survey. Local knowledge was a key aspect of understanding source composition in the area. Project staff engaged stakeholder consideration of sources through:
  - Direct discussion of sources at Partnership meetings
  - Direct discussion of sources at source-based Work Group meetings
  - One-on-one meetings with local stakeholders
  - One-on-one meetings with state and regional experts/agencies (*e.g.*, the Texas Parks and Wildlife Department (TPWD), TSSWCB, and others)

Stakeholder feedback specific to the identified sources is discussed later in this section, relative to each source. In general, stakeholder feedback upheld staff expectations of usual sources, and helped refine extent and scale of expected source contributions (*e.g.*, rates of dog ownership, presence of deer in developed areas, hog activity levels, horse stable activity, presence of specific problem sites/dumping). The ultimate selection of sources to include in the model was based on stakeholder decisions and affirmation of H-GAC's proposed modeling methodology, through the revision process.

The estimated extents of the source survey general categories reflect preliminary understandings, rather than the modeled outcomes or final stakeholder feedback (**Table 17**). Note that these extents reflect current estimated status, and some sources may be expected to increase or decrease in the period assessed by this modeling effort. The results of the fecal waste source survey were used to guide the development of the load estimation modeling described later in this section.

Figure 21. Recreation in Spring Creek

Table 17. Fecal waste source survey

Category	Source	Origin	Estimated Extent
Human Waste	WWTFs	Improperly treated sewage from permitted outfalls	Minor
	OSSFs	Failing OSSFs	Minor to Moderate (locally)
	SSOs	Untreated sewage from wastewater collection systems	Minor to Moderate (locally)
	Direct Discharge	Untreated wastes from areas without OSSF or WWTF service	Minor
	Land Deposition	Improperly treated or applied sewage sludge	Minor
Agriculture	Cattle	Runoff or direct deposition	Moderate
	Horses	Runoff or direct deposition	Minor to Moderate (locally)
	Sheep & Goats	Runoff or direct deposition	Minor
	Pigs	Runoff	Minor
	CAFOs	Improperly treated discharge from permitted facilities	Not Expected
Wildlife	Deer	Runoff or direct deposition	Minor to Moderate (locally)
	Birds	Direct deposition	Minor, No Data
	Bats	Direct deposition	Minor, No Data
	Other Wildlife[42]	Runoff or direct deposition	Moderate, No Data
Domestic Animals	Dogs (pets)	Runoff	Major
	Dogs (feral)	Runoff	Minor (locally)
	Cats (pets)	Runoff	Not Expected
	Cats (feral)	Runoff	Not Expected to Minor
Invasive Animals	Feral Hogs	Runoff or direct deposition	Moderate
Other	Dumping	Runoff or direct deposition	Minor (locally)
	Sedimentation	Erosion or mining operations	Not Applicable[43]

[42] Other wildlife is used throughout this document as a means of designating all wildlife populations for which sufficient data does not exist and could not be assessed (unlike colonial birds and bat colonies). Stakeholder decisions regarding an assumption for this source is discussed in greater detail in its corresponding section.

[43] While not a source of fecal bacteria, suspended sediment in waterways can decrease die-off from insolation, etc.

Estimating *E. coli* Loads

Understanding the distribution and relative prominence of various sources of fecal waste is crucial to empowering stakeholders to make informed decisions about potential solutions. To quantify the potential number of fecal indicator bacteria being generated in the watershed, the Partnership used a combination of stakeholder knowledge and computer modeling. The goal was to identify how much *E. coli* was being generated by each source, and how those sources were distributed in the watershed.

Spatially Explicit Load Enrichment Calculation Tool

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) is a Geographic Information System (GIS)-based analysis approach developed by the Spatial Sciences Laboratory and the Biological and Agricultural Engineering Department at Texas A&M University[44]. The intent of this tool is to estimate the total potential *E. coli* load in a watershed and to show the relative contributions of individual sources of fecal waste identified in the source survey. Additionally, SELECT adds a spatial component by evaluating the total contribution of subwatersheds, and the relative contribution of sources within each subwatershed. SELECT generates information regarding the total potential *E. coli* load generated in a watershed (or subwatershed) based on land use/land cover, known source locations (WWTF outfall locations, OSSFs, *etc.*), literature assumptions about nonpoint sources (pet ownership rates, wildlife population statistics, *etc.*) and feedback from stakeholders. The potential source load[45] estimates are not intended to represent the amount of *E. coli* actually transmitted to the water, as the model does not account for the natural processes that may reduce pollutants on their way to the water, or the relative proximity of sources to the waterway.

Project staff used an adapted SELECT approach to meet the specific data objectives of this project. The implementation of SELECT used for this modeling effort builds on the original tool by adding two modified components.

- **Buffer Approach** — The stock SELECT model assumes all *E. coli* generated within a watershed will have the same impact on instream loads. For example, loads generated 2 miles from a waterway are counted the same as equivalent loads generated within the riparian corridor. Realistically, loads generated adjacent to the waterways are more likely to contribute to instream conditions. However, SELECT does not provide a means by which to model fate and transport factors. In a situation in which a particular source is generally located farther from the waterway, it may be overrepresented compared to

[44] Additional information about SELECT can be found at: http://ssl.tamu.edu/media/11291/select-aarin.pdf

[45] References to loads in this section, unless specifically stated otherwise, should be taken to refer to (potential) source loads, rather than instream loads. As indicated previously, SELECT does not generate instream loading estimates, just the potential source load prior to factors affecting the fate and transport of pollutants.

a source generally located adjacent to the waterway. For example, if OSSFs in a watershed produced 50 units of waste, but were generally located far from the water, while livestock in a waterway produced the same amount of waste, but generally in the riparian corridor, SELECT would treat these potential loads as equal. For stakeholders making decisions on prioritizing best management practices (BMPs) and sources, this is a false equivalency. To strike a balance between project focus on simple but effective modeling and a desire to understand the potential impact of transmission, this implementation of SELECT differentiates between loads generated inside a buffer area surrounding waterways, and loads generated outside this area. The buffer approach assumes 100 percent of the waste generated within 300 feet of the waterway as being transmitted to the watershed without reduction. Outside of that buffer, only 25 percent of the waste is assumed to be transmitted to the waterway[46]. Sources that lack specific spatial locations (unlike permitted outfalls) are assumed to be distributed uniformly in appropriate land uses, inside and outside the buffer. For example, the total number of deer in the buffer is derived from multiplying the assumed density by the numbers of acres of appropriate land use within buffered areas. This approach is designed to provide a very general conception of the effect of distance from the waterway.

- **Future Projections** — The Spring Creek watershed is undergoing rapid developmental change. Sources estimated based on data collected as of the year 2018[47] are expected to expand in the future. Therefore, *E. coli* reductions based on current conditions would be inadequate to meet future needs. This implementation of SELECT uses regional demographic projection data to estimate future conditions through 2045 in 5-year intervals[48]. Land use change is the primary driver for estimating changes in source contribution, and spatial distribution of loads[49].

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[46] Buffer percentages were based on previously approved WPPs and reviewed on multiple occasions with project stakeholders.

[47] References to "current" modeled conditions throughout this document refer to 2018 estimations, based on the available data at the time of the modeling effort.

[48] 2045 was chosen as a horizon year to coincide with the extent of the regional demographic model projections at the time and also in consideration of likely planning horizon for partner efforts and developmental projects.

[49] All future projections have some level of uncertainty that cannot be wholly controlled for. The H-GAC Regional Growth Forecast (http://www.h-gac.com/regional-growth-forecast/default.aspx) demographic model projections are widely used in the region and in similar WPPs, and thus considered the best available data for making these projections. Some wildlife sources have additional levels of uncertainty because the model assumes that change between land uses eliminates populations tied to the former land use. However, there is not adequate data or analytical approaches within the scope of this project to determine the potential that wildlife populations will change or consolidate by literature values alone. For example, the model assumes a set density of feral hogs per unit of area, populated in appropriate land cover types. Feral hog populations are assumed to stay static because there is insufficient data to make assumptions about rate of population growth. Additionally, if an area containing feral hogs converts to developed land cover, the hogs

Watershed conditions can change greatly from year to year based on rainfall patterns, agricultural activities, increased urbanization, and other landscape-scale factors. To balance this inherent degree of variation and uncertainty, stakeholder feedback on sources, model assumptions, and results were used heavily through the generation of the analysis and its eventual use as a prioritization tool for selecting BMPs. The goal of the SELECT modeling in this WPP effort, other than the general characterization of source loading, is to aid in prioritizing which sources to address by showing their relative contributions and locations. The loads generated by SELECT are combined with reduction percentages derived from the models explained in Section 4 to generate source reduction loads. There is an inherent level of uncertainty in any modeling of a dynamic system, but the approach used in this WPP is balanced against the end use of the information to support stakeholder decisions.

The analysis design for this process includes four primary steps:

1) Development of a source survey using known locations/sources, suspected sources derived from projects in similar areas, and stakeholder feedback,
2) Stakeholder review of proposed sources and preliminary population/loading assumptions,
3) Implementation of the model and internal quality review, and
4) Stakeholder review of results and model revision as necessary (**Figure 22**).

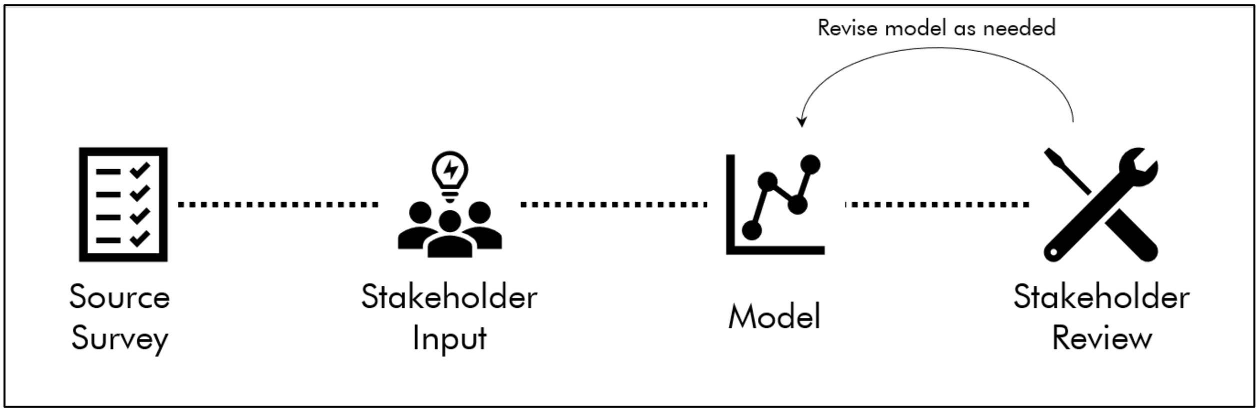

Figure 22. SELECT modeling process

attributed to that area are eliminated from the calculations. In real conditions, this may instead lead hogs to consolidate in greater densities in remaining habitat up to some carrying capacity. This project acknowledges that uncertainty, and the stakeholders discussed potential methods to address it. However, no sufficient data sources or modeling methods within the scope of this project have been identified to account for wildlife population dynamics. Continual assessment of wildlife populations as a source is recommended in the adaptive management recommendations of the WPP to help overcome this uncertainty.

The following subsections detail the sources modeled, including the data used and the feedback received from stakeholders. The maps indicate the relative distribution of source loads and populations, while the charts indicate the relative contribution of different sources. The loadings are given in numbers of *E. coli* per day, using scientific notation[50]. The map for each specific source is not comparable to other sources; they show the relative distribution for a given source by color gradation, rather than color being tied to absolute load. The maps also reflect the use of the buffer approach. A 300-foot buffer around each waterway (appearing as a series of lines on the map) displays loading in these areas separate from the greater land area using the same color scale. Note that major waterways are represented in blue for spatial reference. Colors associated with the loading value within the riparian buffer for each subwatershed are consistent but are partially obscured by the main channel vectors.

In viewing the maps, it is important to consider that they display both relative loading by area within a subwatershed (riparian areas versus areas outside the riparian) and between subwatersheds. Lastly the map coloration is based on relative load density (load per acre). Larger subwatersheds will have larger loads, all things being equal. Load density maps help equalize discrepancies in subwatershed size and make fair comparisons.

Wastewater Treatment Facilities

Wastewater utilities serve a number of communities throughout the watershed and occur in various sizes and capacities. For areas outside city boundaries, centralized waste treatment is most commonly managed by municipal utility districts and other districts. Discharge monitoring report data was available for 61 WWTFs within the watershed and was incorporated into the SELECT model. Size of WWTFs vary greatly throughout the watershed and ranged between capacities of less than 0.1 MGD to 10 MGD.

WWTFs in the Spring Creek watershed are not expected to be major contributors to fecal indicator bacteria loading. However, as the risks associated with human waste processed by WWTFs can be considerable in the event of improper treatment or other localized incidents, it is important to consider estimates of potential WWTF loadings in the overall SELECT model. These estimates are derived by multiplying the total discharge capacity of each facility by the state water quality standard for fecal bacteria. For future projections, models continued to estimate fecal bacteria loads at the state standard but adapted flow rates to reflect the projected increase in the number of households within service area boundaries. As many facilities discharge well below their maximum permitted rates, this results in a potential

[50] For example, 1.0E+12 is equivalent to 1.0 x 10^{12}, or 1 trillion. E+9 would be billions, E+6 millions, *etc.*

overestimation of fecal bacteria loading from this source. As noted previously, this method is still deemed appropriate for this watershed in order to account for exceedances or variations throughout daily discharges that could have greater impacts to public health.

Current WWTF loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into Spring Creek are represented in **Figure 23**. As loads were estimated solely from outfall data within the riparian buffer, all spatial results are indicated within the buffer zone surrounding the watershed stream network (no data is available for the land area beyond the buffer). Color intensity indicates loading severity relative to the other streams and may not be directly comparable between this modeled parameter and the remaining sources examined with SELECT analyses. Actual loading estimates by subwatershed are represented in **Table 18**. In **Figure 24**, forecasted total watershed loads from WWTFs are plotted in five-year increments through the year 2045.

Table 18. Wastewater facility outfalls and loadings by subwatershed

Subwatershed*	# of Outfalls	*E. coli* Load Estimate	Subwatershed Percent of Total Load
1	9	1.66E+09	2%
2	7	2.03E+09	2%
3	1	1.91E+07	0%
4	6	3.05E+08	0%
5	24	1.76E+10	20%
6	12	7.67E+09	9%
7	6	3.49E+10	39%
8	13	2.45E+10	28%
Total	**78**	**8.87E+10**	**100%**

*See Figure 5 for subwatershed names and location

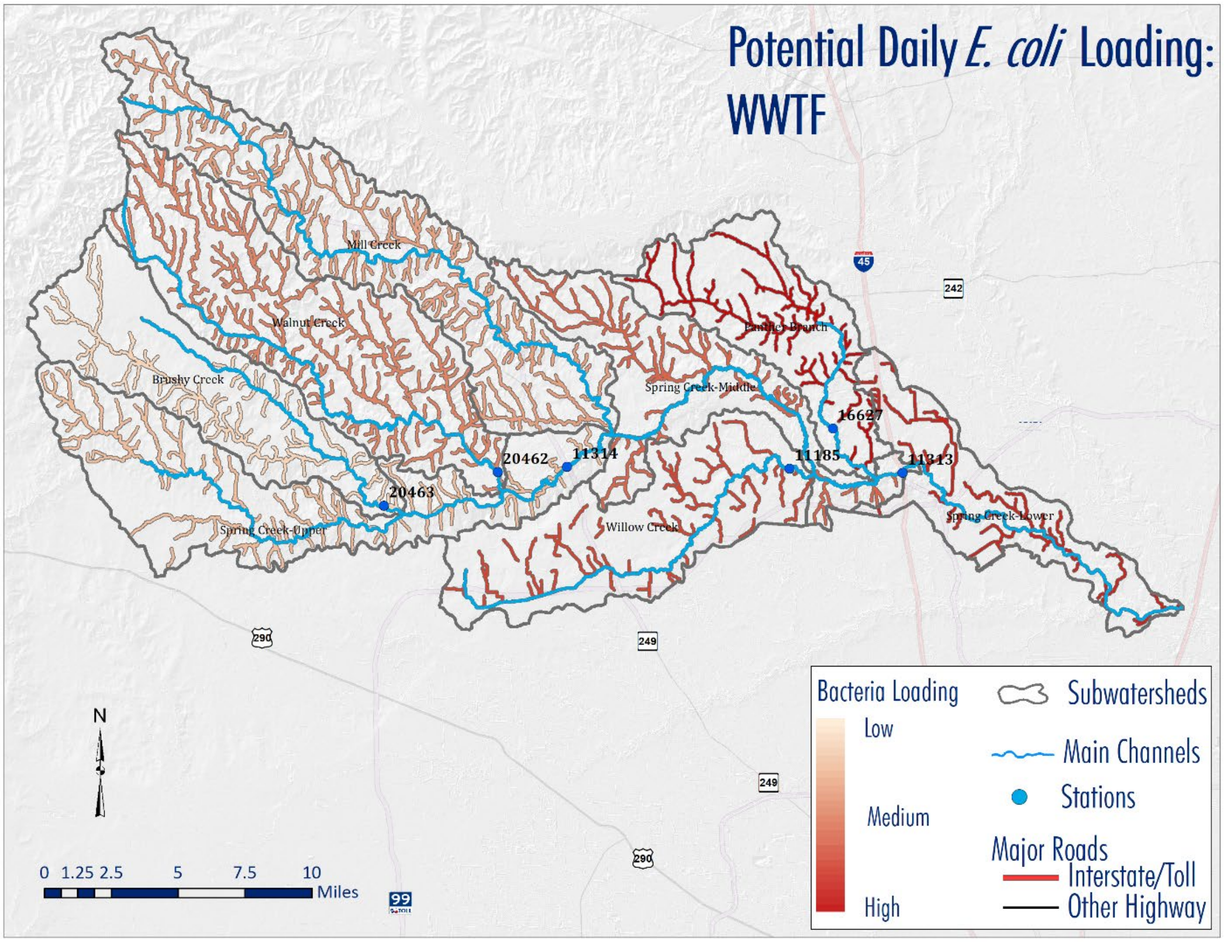

Figure 23. *E. coli* loadings from WWTFs by subwatershed

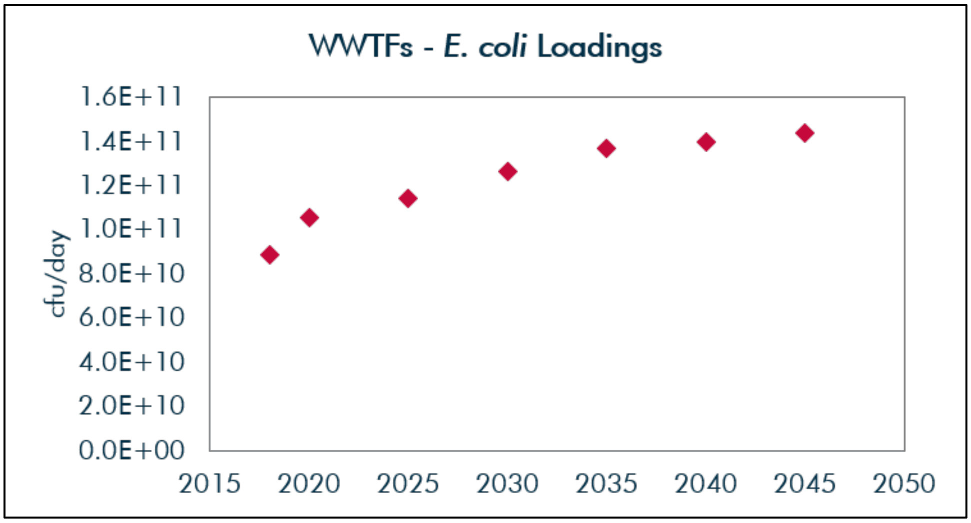

Figure 24. Future *E. coli* loadings from WWTFs

On-site Sewage Facilities

While centralized wastewater treatment is more common in developed areas, OSSFs are more likely to be used in parts of the watershed outside service area boundaries such as suburban and rural communities. OSSFs such as conventional and aerobic systems are an efficient and effective way to manage wastewater, however, aging or improperly maintained units run the risk of failing. Significant sources of fecal bacteria can be transmitted to waterways in the event of an OSSF failure.

Estimates of OSSF distribution throughout the Spring Creek watershed were made using the spatial data of permitted OSSFs that were collected under a 604(b) agreement between H-GAC and TCEQ and quality assured under the auspices of that contract. Where portions of the watershed overlapped with areas outside the H-GAC region such as Grimes County, Texas State Data Center population projections were used. This dataset is not comprehensive as some data may be subject to insufficiencies such as a lack of geocoding. This uncertainty is accounted for in the SELECT model through an estimation of any unrecorded or otherwise unpermitted OSSFs in the watershed area based on land use. Unpermitted OSSFs throughout the watershed were estimated by assessing the number of occupied parcels outside service area boundaries that were not indicated in the permitted OSSF database. Loading rates observed from improperly maintained and failed systems were used to estimate total load contribution from OSSFs. Literature values for OSSF failure rates range between 10 and 15%. For the purposes of this report, a conservative estimate of 10% failure rate was applied to the combined total number of permitted OSSFs and unpermitted OSSFs indicated by the current dataset and for each of the five-year interval projections through 2045. This method has been used for watershed projects in nearby areas and was supported by local stakeholders.

Current OSSF loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into Spring Creek are represented in **Figure 25**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 19**. In **Figure 26**, forecasted total watershed loads from OSSFs are plotted in five-year increments through the year 2045.

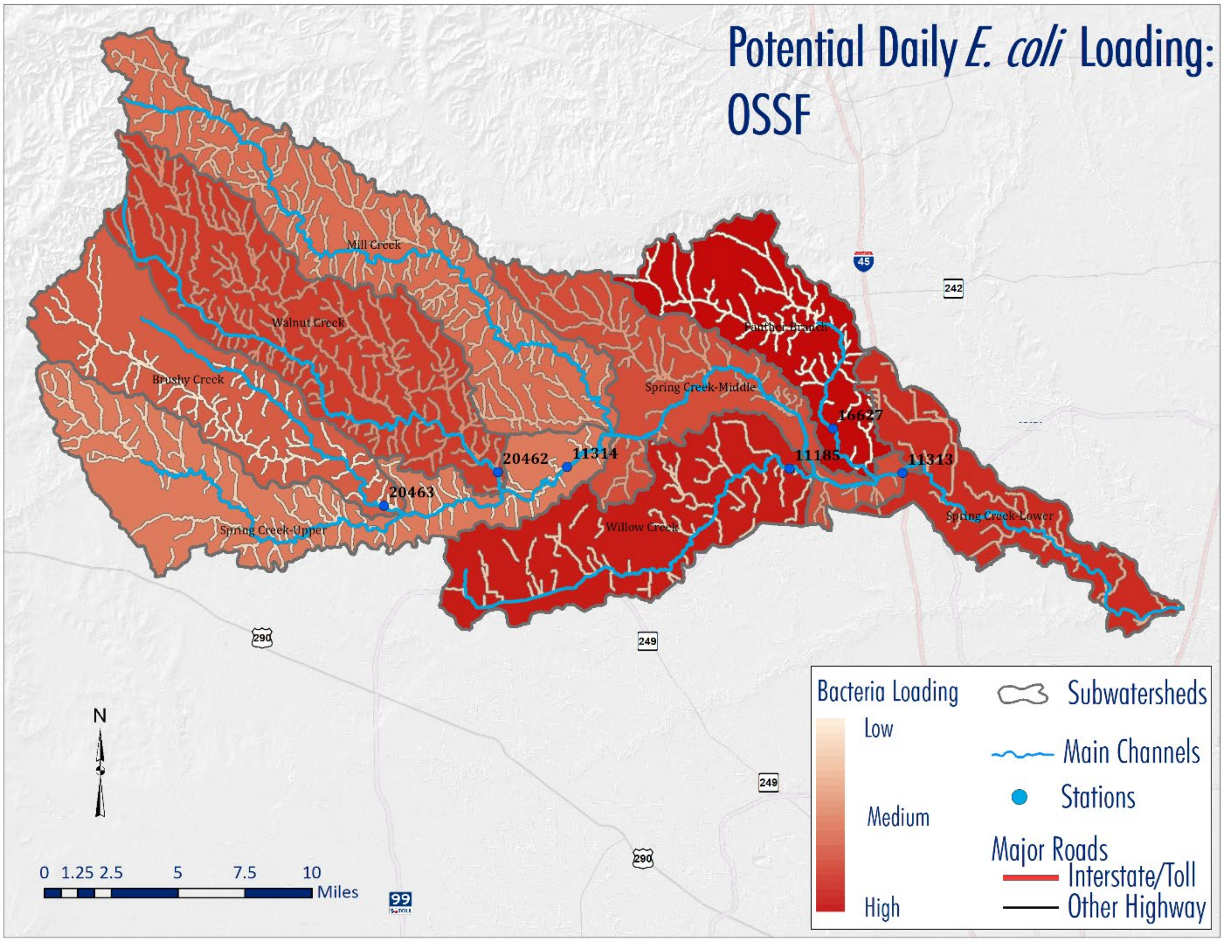

Figure 25. *E. coli* loadings from OSSFs by subwatershed

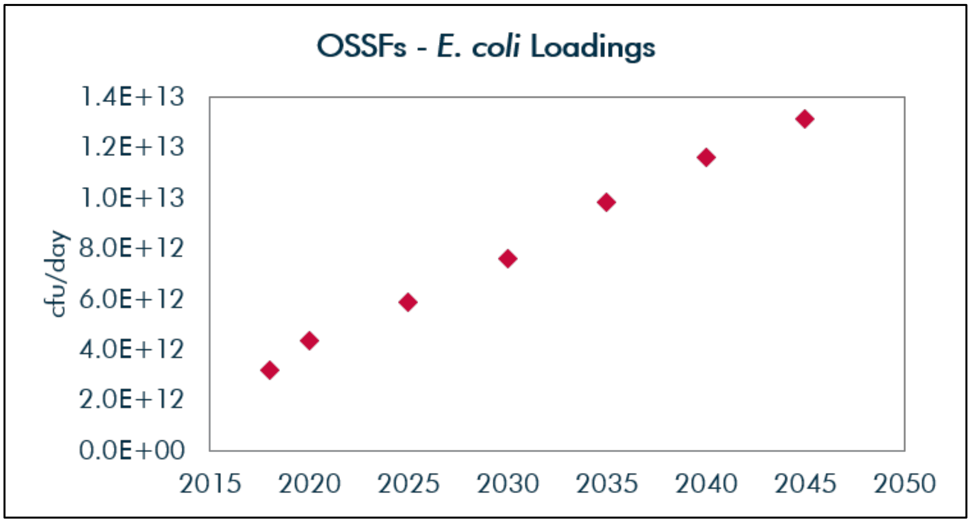

Figure 26. Future *E. coli* loadings from OSSFs

Table 19. OSSFs and loadings by subwatershed

Subwatershed	OSSFs Outside Buffer	OSSFs Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Subwatershed Percent of Total Load
1	2,012	635	1.87E+11	5.89E+10	8%
2	4,070	1,303	3.77E+11	1.21E+11	16%
3	2,199	539	2.04E+11	5.00E+10	8%
4	1,882	544	1.75E+11	5.05E+10	7%
5	4,977	610	4.62E+11	5.66E+10	16%
6	3,758	999	3.49E+11	9.27E+10	14%
7	5,286	398	4.90E+11	3.69E+10	16%
8	4,446	886	4.12E+11	8.22E+10	15%
TOTAL	**28,630**	**5,914**	**2.66E+12**	**5.49E+11**	**100%**

Pet Waste

Domestic and feral dog populations are significant contributors to fecal bacteria contamination in densely developed areas and are a common source of loading in the greater Houston region. Waste from other domestic pets (*e.g.*, cats) is typically managed through collection in waste receptacles, whereas dog waste is more likely to be deposited directly into the environment.

For SELECT analysis, fecal bacteria loading from dog populations will be estimated by assessing pet ownership. Statistical data for Texas established by the American Veterinary Medical Association[51] of 0.6 dogs per household were used in SELECT models. This value was applied to current household data and future projections through 2045. This method has been used in other WPP projects with similar land use and drainage areas. Additionally, stakeholder feedback received during reviews of model results lead to a slight revision of these assumptions based on the specific characteristics of the Spring Creek watershed. Stakeholder insights on recent efforts to control pet waste including development of pet waste station infrastructure, and community use of waste bags, etc. already underway in the watershed. To account for this, the estimated load based on 0.6 dogs per household was further reduced by 20%.

[51] For more information, see: https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx

Current dog loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into Spring Creek are represented in **Figure 27**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 20**. In **Figure 28**, forecasted total watershed loads from dogs are plotted in five-year increments through the year 2045.

Table 20. Dogs and loadings by subwatershed

Subwatershed	Dogs Outside Buffer	Dogs Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Subwatershed Percent of Total Load
1	2,313	750	1.16E+12	1.50E+12	5%
2	3,369	977	1.68E+12	1.95E+12	7%
3	1,319	323	6.60E+11	6.47E+11	2%
4	2,282	498	1.14E+12	9.96E+11	4%
5	10,101	1,433	5.05E+12	2.87E+12	15%
6	8,313	2,002	4.16E+12	4.00E+12	15%
7	20,050	3,425	1.00E+13	6.85E+12	31%
8	13,342	2,179	6.67E+12	4.36E+12	21%
Total	**61,089**	**11,587**	**3.05E+13**	**2.32E+13**	**100%**

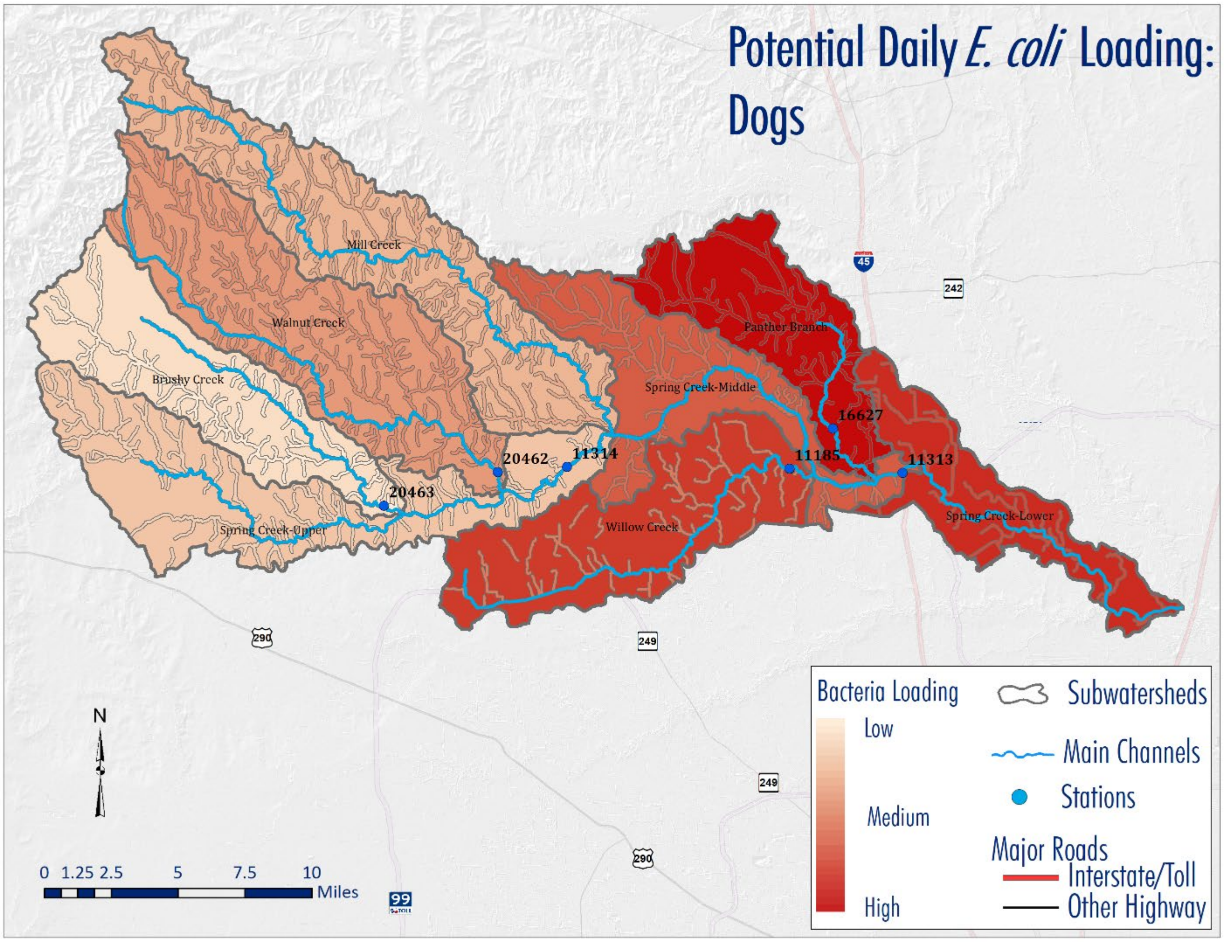

Figure 27. *E. coli* loadings from dogs by subwatershed

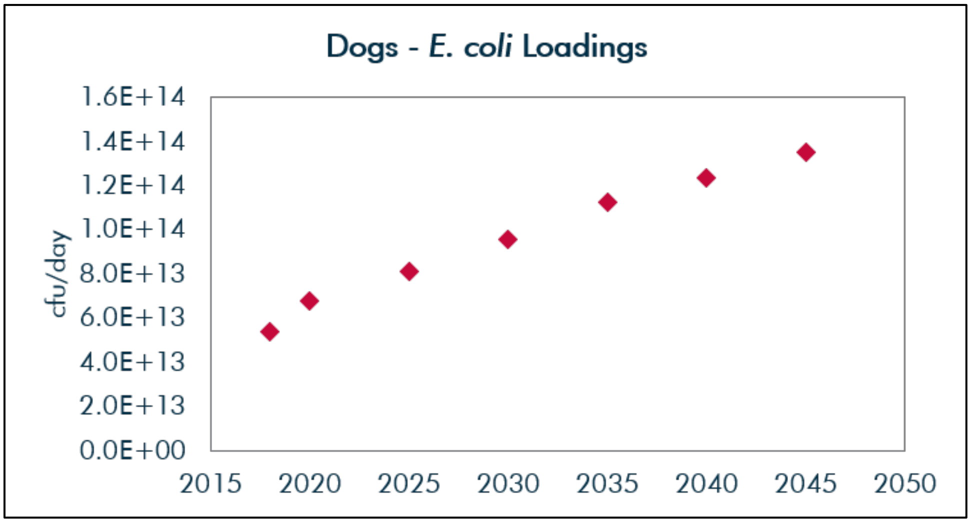

Figure 28. Future *E. coli* loadings from dogs

Cattle

Agricultural land, grassland and pastures are most common in the western reaches of the watershed with smaller concentrated areas of these land cover types distributed throughout. National livestock populations including cattle were most recently assessed in a 2017 census by the United States Department of Agriculture. Census data are available by county and are not specific to the watershed area. To estimate cattle in the Spring Creek watershed, a ratio of each county's portion of the watershed's acreage in appropriate land cover types to that of the respective county as a whole was applied to agricultural census data from each of the four counties. This approach ensures that the density of cattle in a county's applicable land cover acreage (grassland and pasture/hay) was the same as the density in the watershed's applicable land use acreage. After stakeholder review, this initial estimate was modified further to better reflect observed conditions. Stakeholders indicated that initial estimates distributing cattle populations solely in grassland and pasture/hay land cover areas were inaccurate due to an overestimation of the usage of those areas by cattle. To account for fallow lands or smaller parcels of pasture and grassland not grazed by herds, cattle population estimates were adjusted to 90% of the initial estimate in these land cover areas. Further, stakeholders noted that cattle occasionally use forest and shrubland especially when adjacent to waterways. This observation was reflected in the model by distributing 10% of the cattle population estimate into forested areas within the riparian buffer.

Current cattle loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into Spring Creek are represented in **Figure 29**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 21**. In **Figure 30**, forecasted total watershed loads from cattle are plotted in five-year increments through the year 2045.

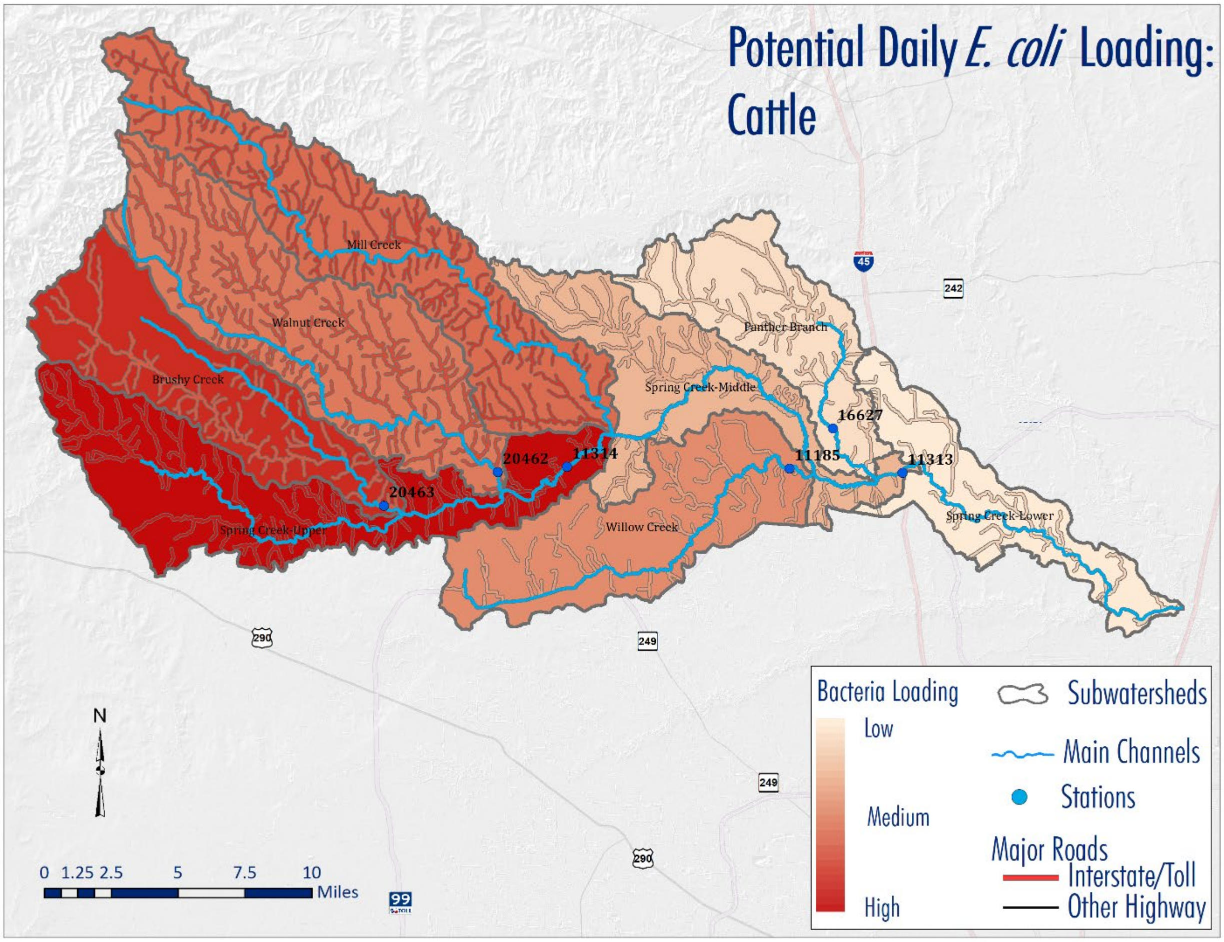

Figure 29. *E. coli* loadings from cattle by subwatershed

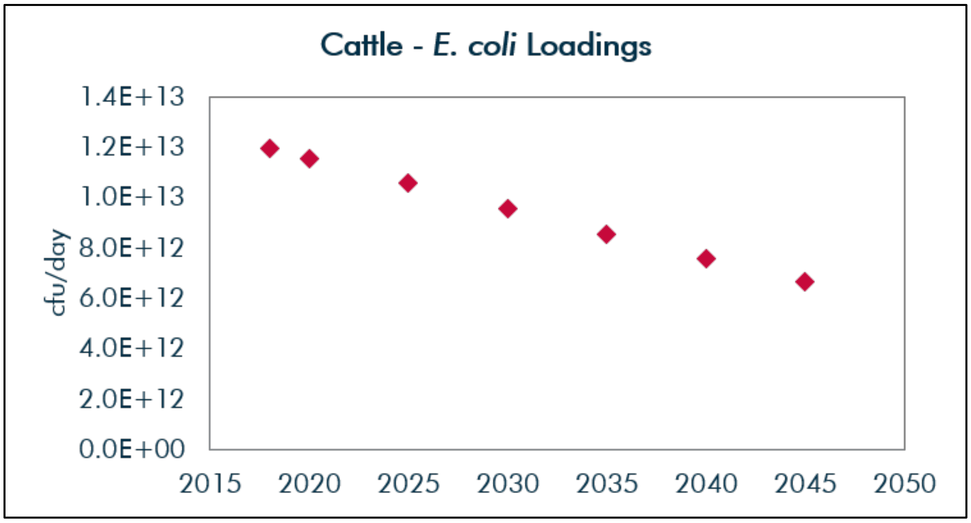

Figure 30. Future *E. coli* loadings from cattle

Table 21. Cattle and loadings by subwatershed

Subwatershed	Cattle Outside Buffer	Cattle Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Subwatershed Percent of Total Load
1	1,105	456	7.5E+11	1.2E+12	17%
2	916	407	6.2E+11	1.1E+12	14%
3	1,996	376	1.3E+12	1.0E+12	20%
4	3,243	655	2.2E+12	1.8E+12	33%
5	798	164	5.4E+11	4.4E+11	8%
6	276	122	1.9E+11	3.3E+11	4%
7	97	63	6.5E+10	1.7E+11	2%
8	61	52	4.1E+10	1.4E+11	2%
Total	**8,492**	**2,295**	**5.7E+12**	**6.2E+12**	**100%**

Horses

Similar to cattle, horse population estimates were calculated based on agricultural census data modified by the ratio of watershed area of relevant land use types to total county area. Based on stakeholder feedback, horse populations were similarly distributed 90% to pasture and grassland, and 10% to forested area within the riparian buffer. This method assesses only the horses designated for livestock use in the watershed. Horses owned for recreational purposes may not be well represented by these estimates.

Current horse loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into Spring Creek are represented in **Figure 31**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 22**. In **Figure 32**, forecasted total watershed loads from horses are plotted in five-year increments through the year 2045.

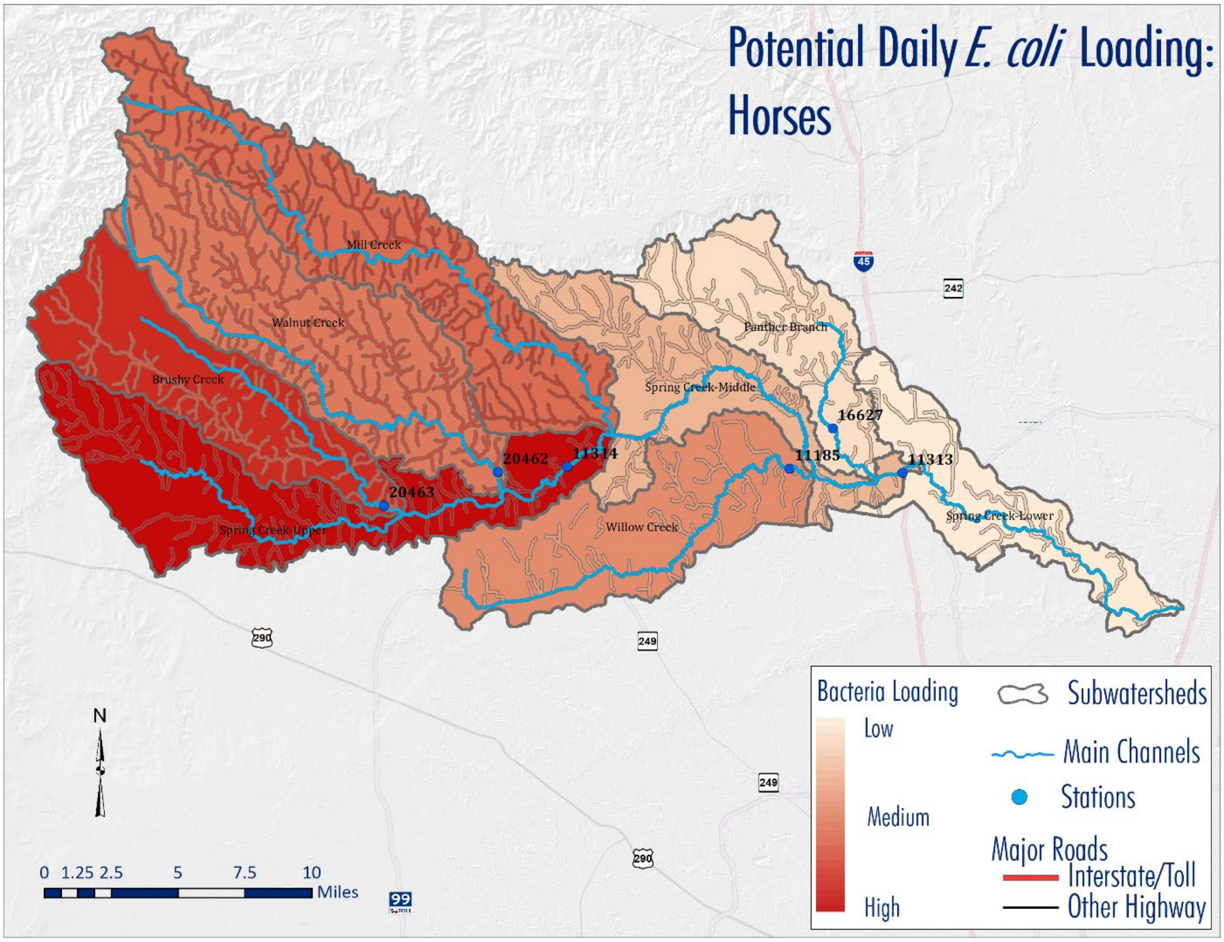

Figure 31. *E. coli* loadings from horses by subwatershed

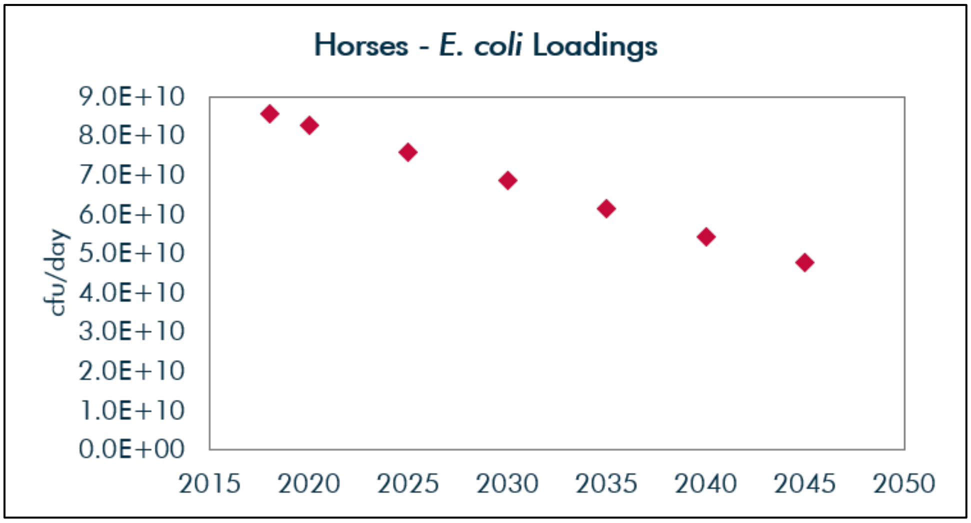

Figure 32. Future *E. coli* loadings from horses

Table 22. Horses and loadings by subwatershed

Subwatershed	Horses Outside Buffer	Horses Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Subwatershed Percent of Total Load
1	102	42	5.3E+09	8.8E+09	17%
2	84	38	4.4E+09	7.9E+09	14%
3	184	35	9.7E+09	7.3E+09	20%
4	299	60	1.6E+10	1.3E+10	33%
5	74	15	3.9E+09	3.2E+09	8%
6	25	11	1.3E+09	2.4E+09	4%
7	9	6	4.7E+08	1.2E+09	2%
8	6	5	2.9E+08	1.0E+09	2%
Total	**783**	**212**	**4.1E+10**	**4.4E+10**	**100%**

Sheep and Goats

Sheep and goat populations represent a smaller portion of the livestock in the watershed, but still retain a presence in rural areas. Both animal populations are grouped into a single statistic in the agricultural census. To estimate the size of these populations, the same method used for cattle and horses was applied to agricultural census data for sheep and goats. Based on stakeholder feedback, sheep and goat populations were similarly distributed 90% to pasture and grassland, and 10% to forested area within the riparian buffer.

Current sheep and goat loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into Spring Creek are represented in **Figure 33**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 23**. In **Figure 34**, forecasted total watershed loads from sheep and goats are plotted in five-year increments through the year 2045.

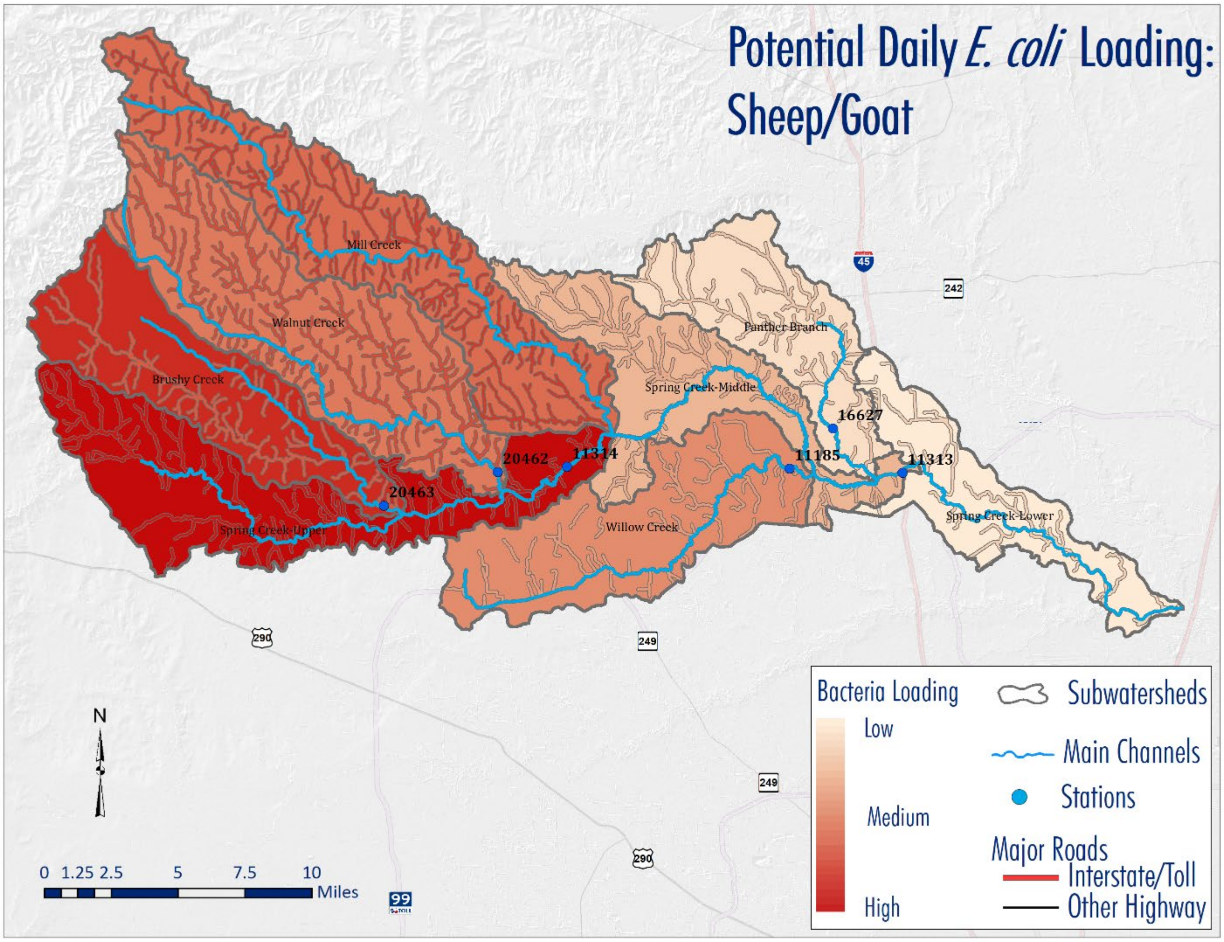

Figure 33. *E. coli* loadings from sheep and goats by subwatershed

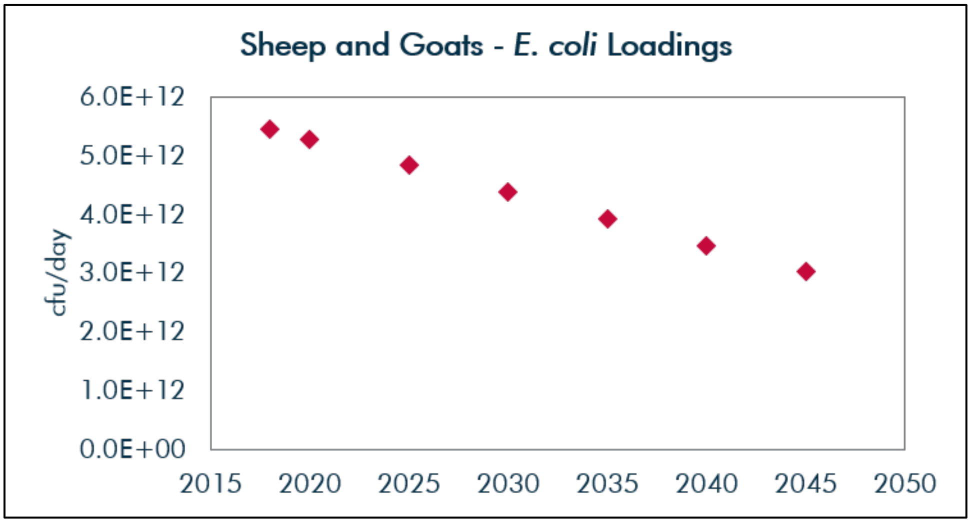

Figure 34. Future *E. coli* loadings from sheep and goats

Table 23. Sheep and goat loadings by subwatershed

Subwatershed	Sheep & Goats Outside Buffer	Sheep & Goats Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Subwatershed Percent of Total Load
1	151	63	3.4E+11	5.6E+11	17%
2	126	56	2.8E+11	5.0E+11	14%
3	274	52	6.2E+11	4.6E+11	20%
4	445	90	1.0E+12	8.1E+11	33%
5	109	22	2.5E+11	2.0E+11	8%
6	38	17	8.5E+10	1.5E+11	4%
7	13	9	3.0E+10	7.8E+10	2%
8	8	7	1.9E+10	6.4E+10	2%
Total	**1,164**	**316**	**2.6E+12**	**2.8E+12**	**100%**

Deer

Forests and open areas in the less developed areas of the watershed provide ample habitat area for white-tailed deer. However, deer are among the few species that are adaptable to the encroachment of developed areas. Loss of natural areas may lead deer to explore larger lots of suburban and light urban development as alternative habitat. Because of this, forested areas and open and low intensity developed areas were considered as possible deer habitat for the purposes of load estimation. To estimate deer populations and their associated fecal bacteria loading potential, Resource Management Unit population density data accessed from the Texas Parks and Wildlife Department assuming 1 deer for every 40.2 acres of forest, shrubland and open developed areas were used. In low intensity developed areas, deer density was assumed to be 1 deer for every 80.4 acres. After consulting with stakeholders, this lower density of 1 deer per 80.4 acres was applied in additional land cover areas including pasture and grassland, wetlands, and barren land. This change was made as stakeholders agreed that deer populations are most concentrated in forested areas but noted seeing deer in areas also used by feral hog populations. Even with this updated approach, population dynamics are not well represented with respect to movements between land cover types and possible increases in density of natural areas after the built environment extends into previously undeveloped spaces.

Current deer loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into Spring Creek are represented in **Figure 35**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 24**. In **Figure 36**, forecasted total watershed loads from deer are plotted in five-year increments through the year 2045.

Table 24. Deer and loadings by subwatershed

Subwatershed	Deer Outside Buffer	Deer Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Subwatershed Percent of Total Load
1	633	271	2.8E+10	4.7E+10	22%
2	611	256	2.7E+10	4.5E+10	21%
3	406	107	1.8E+10	1.9E+10	11%
4	464	147	2.0E+10	2.6E+10	14%
5	354	73	1.5E+10	1.3E+10	8%
6	330	109	1.4E+10	1.9E+10	10%
7	244	67	1.1E+10	1.2E+10	7%
8	246	64	1.1E+10	1.1E+10	7%
Total	**3,288**	**1,094**	**1.4E+11**	**1.9E+11**	**100%**

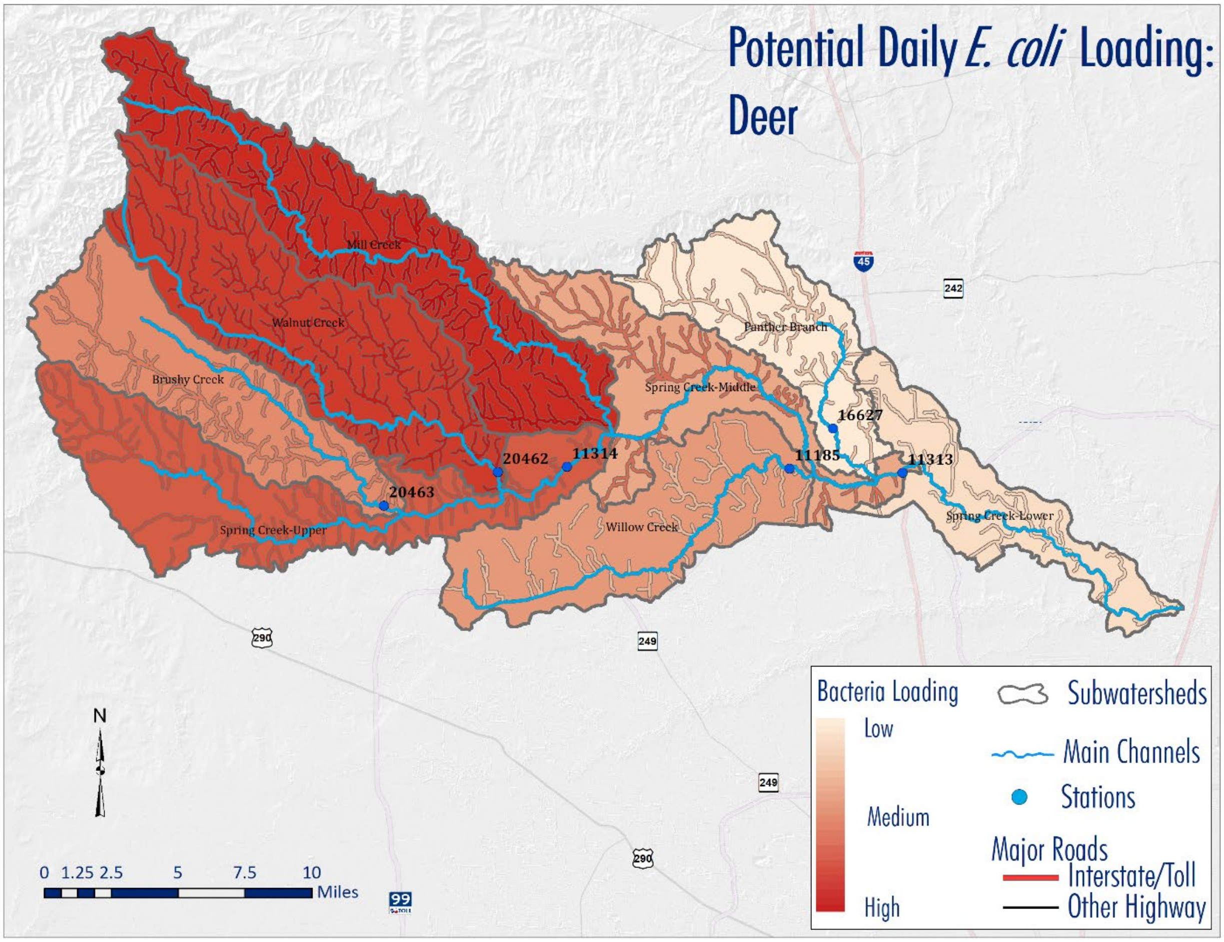

Figure 35. *E. coli* loadings from deer by subwatershed

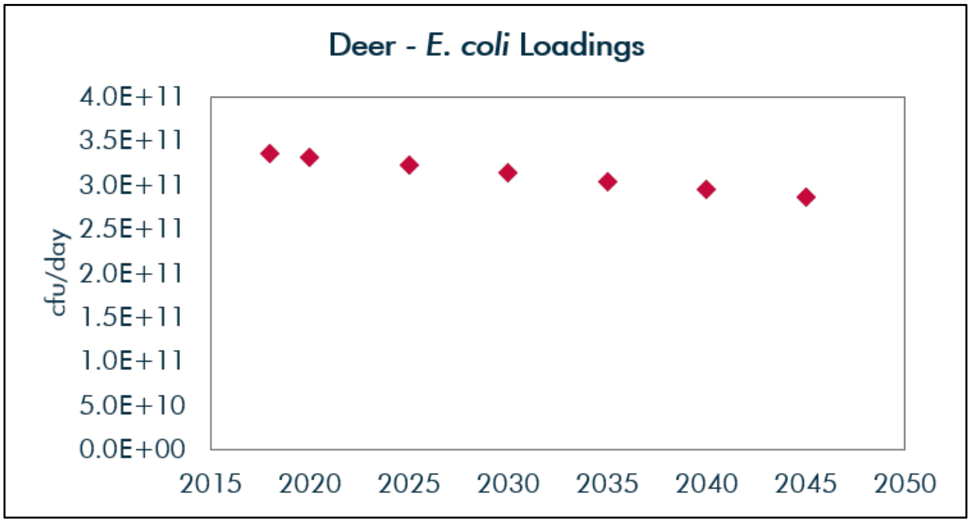

Figure 36. Future *E. coli* loadings from deer

Feral Hogs

In the Houston-Galveston region feral hogs (*Sus scrofa*) are an invasive species that negatively impact agriculture, wildlife species and their habitats, and human landscapes. Efforts to control feral hogs have been carried out by communities within the Spring Creek watershed that have already recognized the environmental pressures associated with their populations. Feral hogs are of particular concern as carriers of diseases that can be dangerous to domestic livestock, pets, and humans. These animals are known to use land around waterways as shelter and transportation corridors between food resources and can generate large volumes of waste where they concentrate.

Though they occur in the highest densities along riparian corridors and other natural areas, feral hogs are pervasive and can be found in all land cover types aside from heavily developed areas and open water. Population density estimates used in the SELECT model for feral hog source loads referenced land cover types in the watershed area based on AgriLife literature values[52]. Though initial estimates accounted for hogs in all land cover areas excluding development and open water, stakeholder feedback about observed hog behaviors and migration in the watershed led to a number of changes. First, the headwaters portion of the watershed which is dominated by mostly natural land cover type was assumed to have greater hog densities than the downstream portion. Secondly, hog densities were assumed to follow a gradient from heavy densities in more natural land cover type to lighter densities with increasing proximity to development. In **Table 25**, the specific allocation of hog population density based on stakeholder recommendations is described.

Table 25. Feral hog population density by attainment area and land cover type

Land Cover Type	**Headwaters** (Upper Spring Creek, Walnut Creek, Brushy Creek, Mill Creek)	**Downstream** (Middle and Lower Spring Creek, Panther Branch, Willow Creek)
Wetlands	16.4 hogs/ square mile	16.4 hogs/ square mile
Forest and Shrubland	16.4 hogs/ square mile	16.4 hogs/ square mile
Grassland and Pasture	16.4 hogs/ square mile	12.7 hogs/ square mile
Cultivated Cropland	12.7 hogs/ square mile	12.7 hogs/ square mile
Barren Land	12.7 hogs/ square mile	12.7 hogs/ square mile
Developed Open Space	12.7 hogs/ square mile	8.9 hogs/ square mile
Low Intensity Developed	12.7 hogs/ square mile	8.9 hogs/ square mile

[52] For more information, see: http://agrilife.org/feralhogs/files/2010/04/FeralHogPopulationGrwothDensityandHervestinTexasedited.pdf

Current feral hog loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into Spring Creek are represented in **Figure 37**. Color intensity of subwatershed areas indicates loading severity relative to the other subwatersheds and may not be directly comparable between this modeled parameter and others. Actual loading estimates by subwatershed are represented in **Table 26**. In **Figure 38**, forecasted total watershed loads from feral hogs are plotted in five-year increments through the year 2045.

Table 26. Feral hogs and loadings by subwatershed

Subwatershed	Feral Hogs Outside Buffer	Feral Hogs Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Subwatershed Percent of Total Load
1	818	333	9.1E+11	1.5E+12	22%
2	813	316	9.0E+11	1.4E+12	21%
3	617	148	6.9E+11	6.6E+11	12%
4	781	213	8.7E+11	9.5E+11	17%
5	418	85	4.7E+11	3.8E+11	8%
6	369	121	4.1E+11	5.4E+11	9%
7	270	75	3.0E+11	3.3E+11	6%
8	267	71	3.0E+11	3.2E+11	5%
Total	**4,353**	**1,362**	**4.8E+12**	**6.1E+12**	**100%**

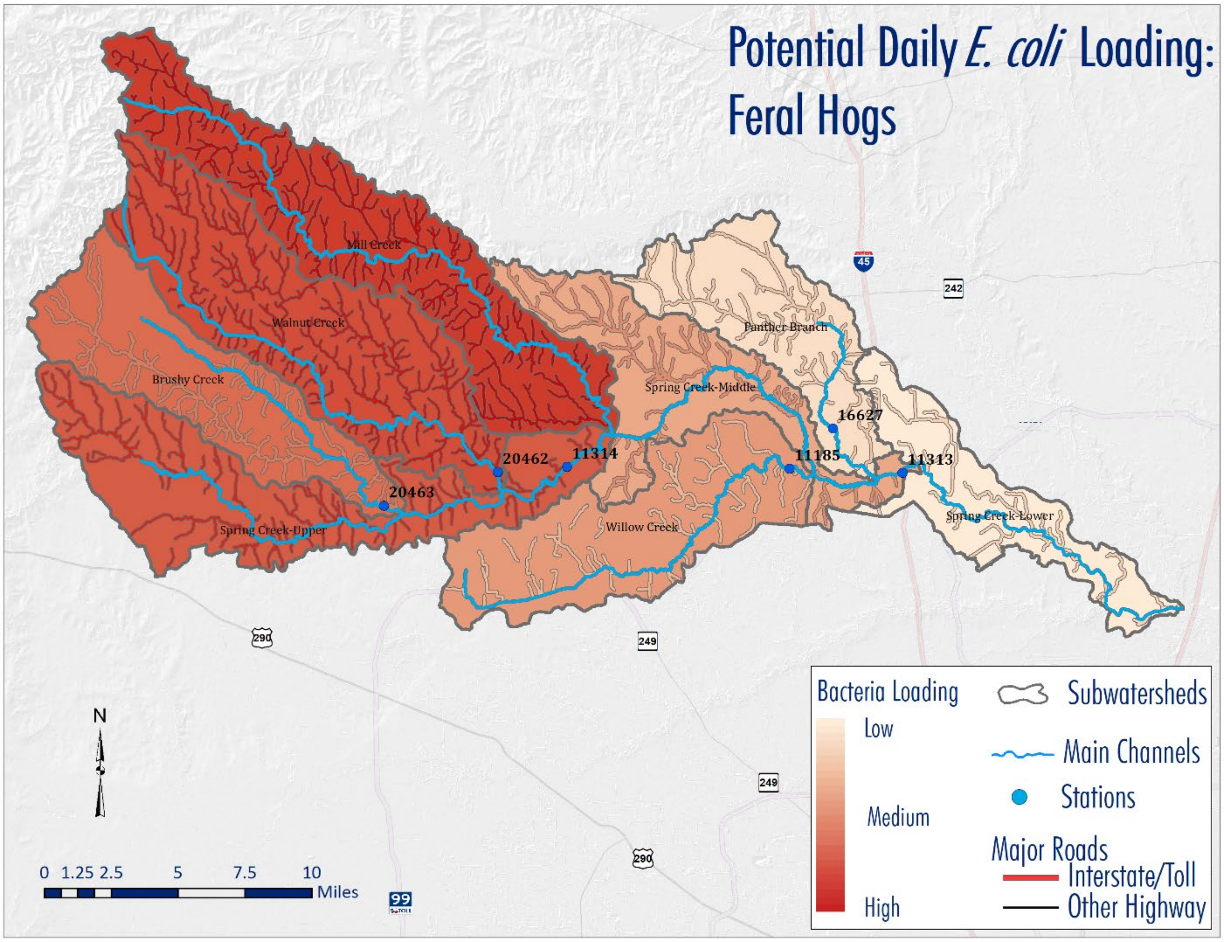

Figure 37. *E. coli* loadings from feral hogs by subwatershed

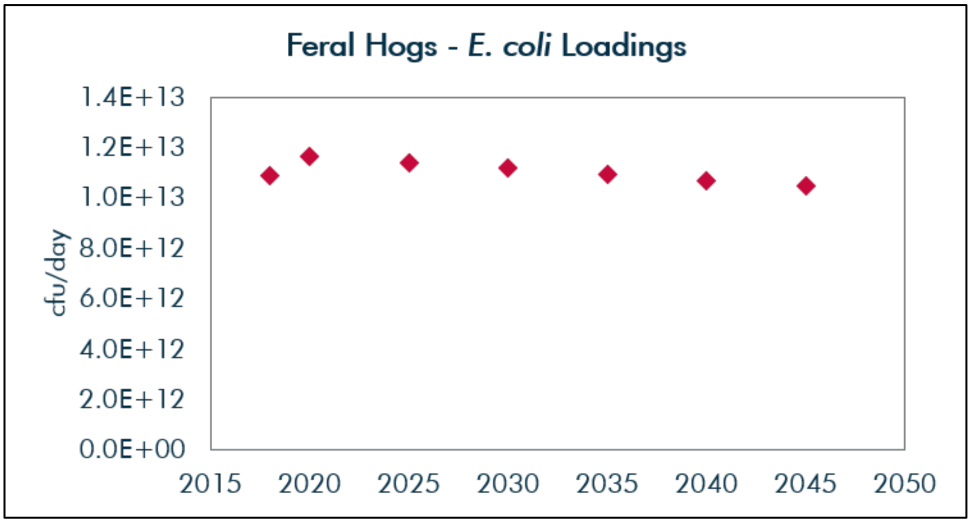

Figure 38. Future *E. coli* loadings from feral hogs

Other Sources of Fecal Waste

The primary other potential sources, and the reasons for not including them in the estimates are elaborated upon here. In general, sources which are not specifically included in the SELECT estimates are still potential targets of mitigation as part of the WPP, especially on a localized scale, depending on the source being discussed. While some of the wildlife populations discussed were not specifically modeled, their contributions are included in this project in the 10% safety margin load estimate.

- SSOs

  Though SSOs occur episodically, they represent a high-risk vector for fecal bacteria contamination because they can have concentrations of fecal bacteria several orders of magnitude higher than treated effluent. Untreated sewage can contain large volumes of raw fecal waste, making it a significant health risk where SSOs are sizeable or chronic issues. Events are self-reported and may vary in quality. Descriptions of frequencies, causes, durations, and volumes of SSOs may be subject to logistical inadequacies such as unknown duration of discharge, and inability to accurately gauge discharge volume. Actual SSO volumes and incidences are generally expected to be greater than reported due to these fundamental challenges.

  After reviewing data compiled in SSO reports submitted by permit holders in the Spring Creek watershed[53], SSO events were not found to follow any specific spatial, seasonal, or annual pattern. Malfunctions and operational issues accounted for the highest number of events and overflow volume respective to the other general categories of weather, blockages, and unknown causes. Frequency of SSOs did not correspond well to volume of SSOs.

  Due to the episodic nature and spatial inconsistency of SSO events, fecal bacteria loads from these sources are not expected to have an appreciable long-term impact on the overall loading for the watershed and were excluded from SELECT model analysis. Though the estimations of SSO impacts in this watershed are not represented by SELECT models, they are no less important to consider in the overall assessment of fecal bacteria loading. The most extreme method of estimating fecal bacteria loads from SSOs would be to calculate loading based on EPA literature values[54] suggested for general causes related to each event multiplied by the highest observed volumes of discharge recorded for each

[53] For more detail, see the Water Quality Data Analysis Summary Report on the project website at: https://springcreekpartnership.weebly.com/uploads/1/3/0/7/130710643/10159_3.3_spring_creek_data_analysis_summary_report.pdf
[54] As referenced at: https://www3.epa.gov/npdes/pubs/csossoRTC2004_AppendixH.pdf

cause. A more conservative method would be to calculate the average daily volume of discharge and use that as the multiplier for cause related load estimates. In other area watershed projects, stakeholders elected to refrain from the aforementioned calculations and treat SSOs as a separate, high-priority item for inclusion in the management strategies outlined in the WPP. SSO data regarding unique events impacting stream segments within the watershed area over the most recent five years of reports provided by TCEQ were used in these assessments. Spring Creek watershed stakeholders elected to adopt this method as well.

- **Human Waste – Direct Deposition**
  In other watershed projects, potential impacts from homeless communities and areas not serviced by centralized or localized wastewater treatment were considered. Based on stakeholder feedback, the populations represented by these groups were not found to be large enough to have appreciable impact.

- **Land Deposition of Sewage Sludge**
  In the event that improper use of manure spreading or violations of sludge application have occurred in the watershed area, action would be required to intervene and reduce the resulting fecal bacteria loading impacts. No such activity is known in the Spring Creek watershed; however, these impacts would likely be addressed in best management practices for agricultural sources of pollution.

- **CAFOs**
  No active CAFOs are in operation within the Spring Creek watershed.

- **Birds**
  The greater Houston area is well known as part of the great Central Flyway migration path used by various bird populations. Many migratory bird species only utilize the land area for short periods of time while in transit, but migratory waterfowl and resident species represent longer-term populations, especially in coastal marshes. Similar watershed projects have evaluated the potential impact of waterfowl in terms of duration, potential fecal bacteria load, and other considerations, and found them to not be significant sources to be modeled. Colonial birds such as swallows have been identified by other watershed projects as potential sources of fecal bacteria load. Unfortunately, little or no data is available to characterize the impacts of fecal bacteria loading from colonial bird sources or to implicate colonial bird influenced fecal bacteria loading as a significant health risks to the watershed community. Beyond lack of data,

relatively small fecal bacteria loads and health risks associated with bird waste compared to human sources further reduce the significance of bird waste impacts. General lack of management strategies available to deal with wild birds have limited the emphasis of this source as a meaningful component of management efforts in similar projects.

- **Bats**
  Though bats are present in the watershed area, only large colonies of these animals are estimated to have an appreciable impact on water quality. No known nesting sites of significant size or density have been indicated in the Spring Creek watershed.

- **Other Wildlife**
  Specific data for wildlife such as coyotes, opossums, rodents, wild cats, skunks, raccoons, and other mammals is not widely available. Similar watershed projects have recognized these wildlife animals as potentially appreciable contributors to fecal bacteria loads but lacked a reasonable method for quantifying their potential impacts. One method of improving understanding of wildlife impacts in the Spring Creek watershed would be to implement fecal bacteria source tracking or assessments of genetic material found in waterways to identify species depositing fecal waste in and around streams. Data collected with this method in other watersheds showed that wildlife impacts are significant[55] and should be incorporated into fecal bacteria reduction strategies. As no such data is presently available for the watershed area of Spring Creek, the understanding of wildlife species in this watershed will be largely informed by anecdotal information provided by stakeholders and general estimations decided by stakeholder input. In nearby Cypress Creek, a novel approach assumed wildlife impacts to be equivalent to a conservative 10% of the other modeled loads assessed in the watershed. The value was generated by finding the total for all other sources in all subwatersheds, setting that total as 90% of the total load, and then assuming wildlife to be the other 10%. Considering the similarities in land use and land cover, scale, and hydrology between the watersheds of Cypress Creek and Spring Creek, this method was also employed here. Stakeholders reviewed these results and agreed that other wildlife are an important component of bacteria loading in Spring Creek but were reluctant to

[55] For example, bacteria source tracking completed by Texas A&M University for Attoyac Bayou showed *E. coli* from wildlife at greater than 50% of load across flow conditions (https://oaktrust.library.tamu.edu/handle/1969.1/152424) and a similar analysis (https://oaktrust.library.tamu.edu/handle/1969.1/149197) conducted for the Lampasas and Leon Rivers showed comparable results.

attribute a firm percentage to their influence. However, recognizing that other sources with little data for quantification estimates are at play in this watershed, stakeholders opted to retain this 10% addition to the total estimated load and refer to it more generally as a safety margin.

- **Cats**
  Domestic dogs are included in the SELECT model analysis as a concern of particular interest to the watershed due to the likelihood of improperly managed dog waste deposited outdoors making its way to streams via runoff. Domestic cat waste management is typically handled indoors and restricted to litter boxes. Therefore, pet wastes from cats were not estimated as part of this project. Feral cats, however, can be a local source when found in sufficiently dense urban populations, though very little data exists to quantify these impacts. Generally, impacts from feral cats may be accounted for in other loading assumptions such as diffuse urban stormwater or as part of the impacts from other wildlife.

- **Dumping**
  Illegal dumping is not typically a widespread or appreciable contributor to fecal bacteria loads in watersheds as these events occur locally or episodically. This factor will still be important for stakeholders to consider addressing in the WPP in terms of aesthetic and other regulatory issues.

- **Sediment**
  Sedimentation has been identified by area stakeholders as a major concern in the Spring Creek watershed especially in areas near the confluence of Spring Creek and Cypress Creek. With increased availability of sediment and other suspended solids in waterways, fecal bacteria may benefit from increases in substrate and decreases in insolation that prevent natural processes of die-off. Sedimentation can also impact dissolved oxygen levels and have pronounced hydrologic impacts on flow. The concerns will be addressed in the WPP.

Summary of *E. coli* Source Modeling Results

SELECT analyses indicated the highest loads from the total mix of modeled sources are concentrated on the eastern side of the watershed in the more highly developed downstream attainment area. In the headwaters attainment area to the west, overall fecal bacteria loads were lower but more heavily influenced by agricultural sources. Future projections for increased overall fecal bacteria loading throughout the watershed are also important to consider in the development of a WPP. Results shown in **Table 27** indicate the estimated current potential loads for all sources by subwatershed. Projected potential load in increments of five years by source are shown in **Table 28**. Assuming no additional action, changes in total load between 2018 and 2045 are shown in **Figure 39**. The year 2030 in **Figure 39**, was set as an *E. coli* reduction milestone/target year and is therefore a different color than the other bars in the graph. Relative changes in source contributions between current and future conditions are shown in **Figure 40** and **Figure 41** respectively.

Without taking action to reduce fecal bacteria sources in the watershed, loads will continue to increase between 2018 and 2045. Noticeable changes in source load contributions between current conditions and those projected for 2045 involve decreased impacts from agricultural activity relative to the expansion of sources associated with human development.

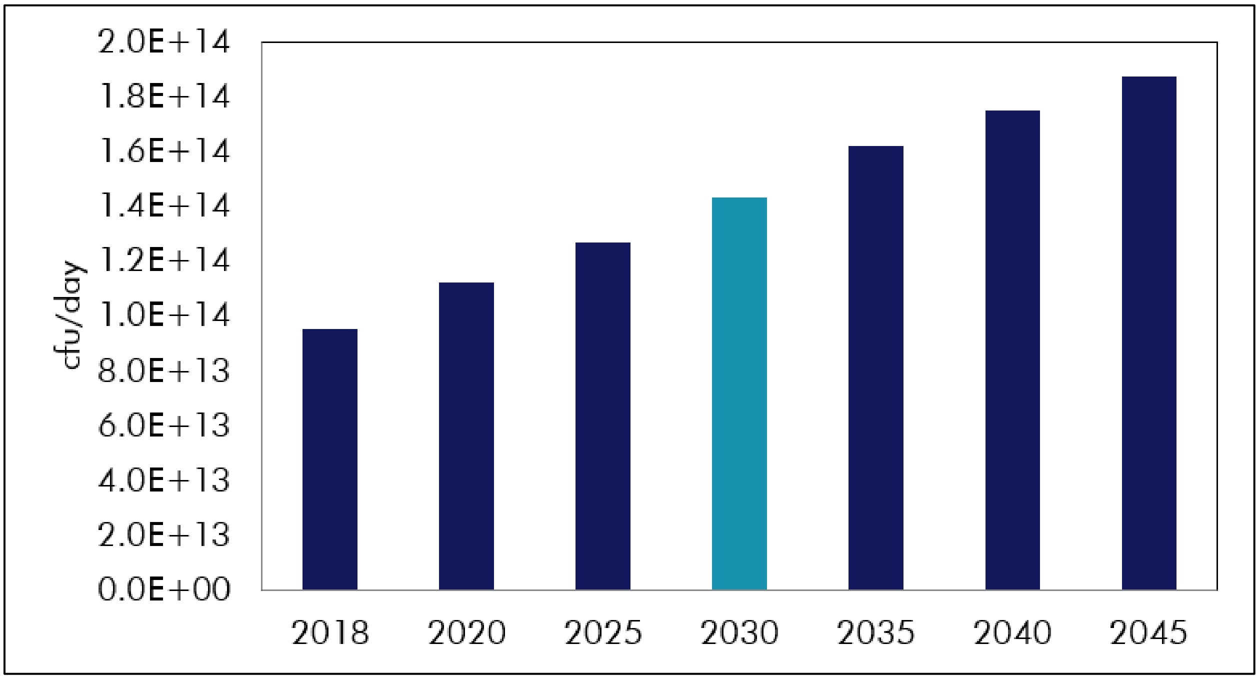

Figure 39. Potential total *E. coli* loads, with no action 2018-2045

Table 27. Current *E. coli* loadings by source and subwatershed

Source	Subwatershed								% Total Load
	1	2	3	4	5	6	7	8	
WWTFs	1.7E+9	2.0E+9	1.9E+9	3.1E+8	1.8E+10	7.7E+9	3.5E+10	2.4E+10	**0**
OSSFs	2.5E+11	5.0E+11	2.5E+11	2.3E+11	5.2E+11	4.4E+11	5.3E+11	4.9E+11	**3**
Dogs	2.7E+12	3.6E+12	1.3E+12	2.1E+12	7.9E+12	8.2E+12	1.7E+13	1.1E+13	**57**
Cattle	2.0E+12	1.7E+12	2.4E+12	4.0E+12	9.8E+11	5.1E+11	2.4E+11	1.8E+11	**12**
Horses	1.4E+10	1.2E+10	1.7E+10	2.8E+10	7.0E+9	3.7E+9	1.7E+9	1.3E+9	**0**
Sheep/ Goats	9.0E+11	7.9E+11	1.1E+12	1.8E+12	4.5E+11	2.4E+11	1.1E+11	8.2E+10	**6**
Deer	7.5E+10	7.1E+10	3.6E+10	4.6E+10	2.8E+10	3.3E+10	2.2E+10	2.2E+10	**0**
Feral Hogs	2.4E+12	2.3E+12	1.3E+12	1.8E+12	8.4E+11	9.5E+11	6.3E+11	6.1E+11	**12**
Safety Margin	9.2E+11	1.0E+12	7.1E+11	1.1E+12	1.2E+12	1.1E+12	2.0E+12	1.4E+12	**10**
TOTAL	**0.92E+13**	**1.0E+13**	**0.71E+13**	**1.1E+13**	**1.2E+13**	**1.1E+13**	**2.0E+13**	**1.4E+13**	**100**

Table 28. *E. coli* loadings by source for all milestone years

Source		2018	2020	2025	2030	2035	2040	2045
Human Waste	WWTFs	8.9E+10	1.1E+11	1.1E+11	1.3E+11	1.4E+11	1.4E+11	1.4 E+11
	OSSFs	3.2E+12	4.4E+12	5.9E+12	7.6E+12	9.8E+12	1.2E+13	1.3 E+13
Pets	Dogs	5.4E+13	6.8E+13	8.1E+13	9.6E+13	1.1E+14	1.2E+14	1.4 E+14
Livestock	Cattle	1.2E+13	1.2E+13	1.1E+13	9.6E+12	8.6E+12	7.6E+12	6.7 E+12
	Horses	8.6E+10	8.3E+10	7.6E+10	6.9E+10	6.1E+10	5.4E+10	4.8 E+10
	Sheep/ Goats	5.5E+12	5.3E+12	4.8E+12	4.4E+12	3.9E+12	3.5E+12	3.0 E+12
Wildlife	Deer	3.4E+11	3.3E+11	3.2E+11	3.1E+11	3.0E+11	3.0E+11	2.9 E+11
Invasive Species	Feral Hogs	1.1E+13	1.2E+13	1.1E+13	1.1E+13	1.1E+13	1.1E+13	1.1 E+13
Other	Safety Margin	9.5E+12	1.1E+13	1.3E+13	1.4E+13	1.6E+13	1.8E+13	1.9 E+13
TOTAL		**0.95 E+14**	**1.1E+14**	**1.3E+14**	**1.4E+14**	**1.6E+14**	**1.8E+14**	**1.9E+14**

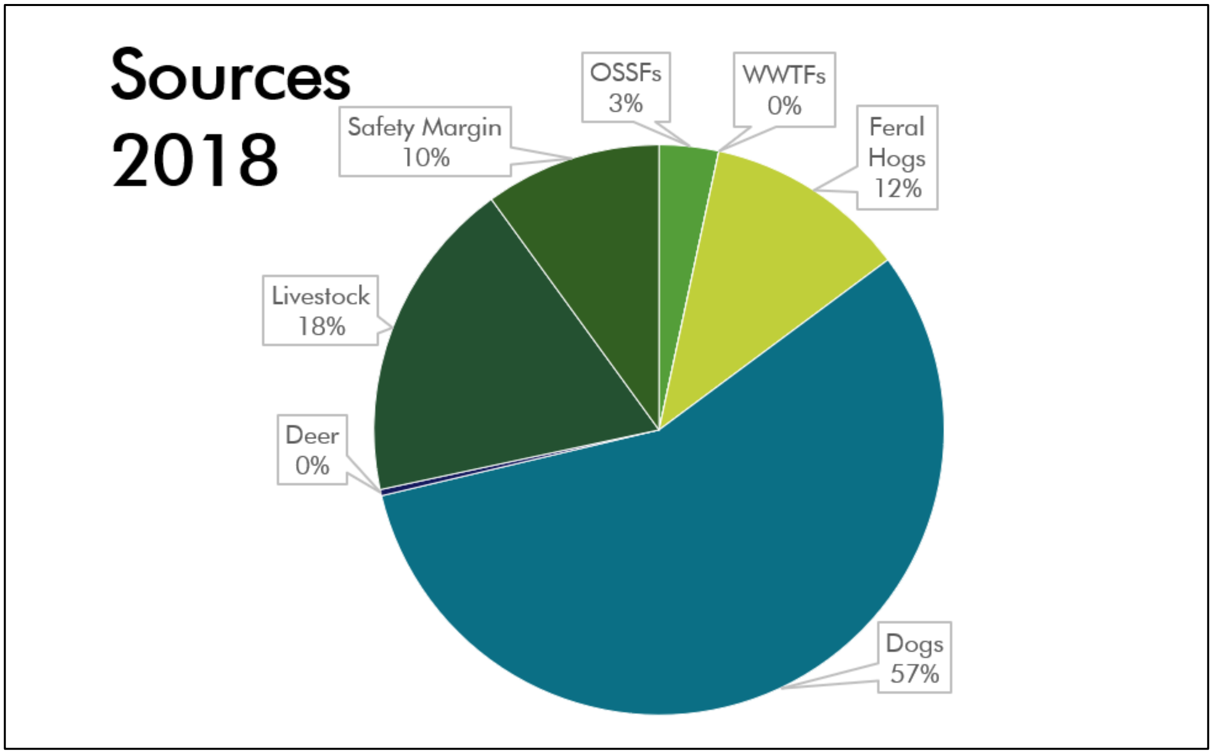

Figure 40. *E. coli* source profile, 2018

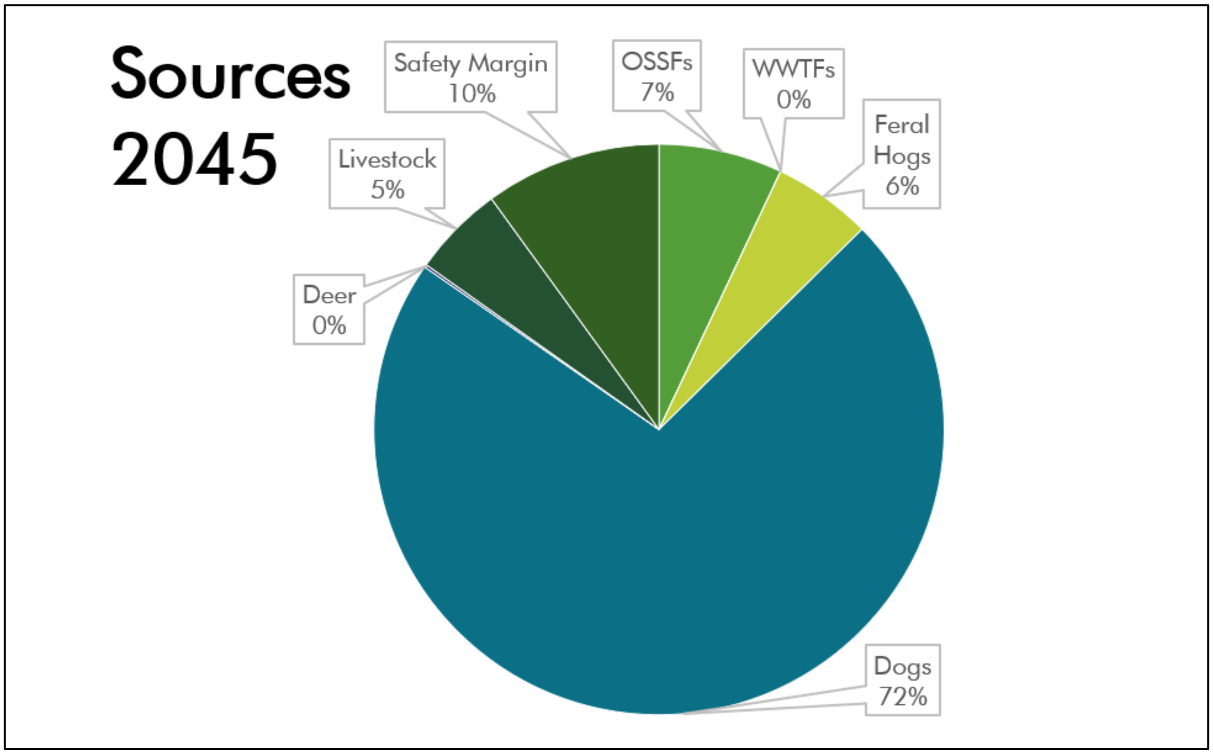

Figure 41. *E. coli* source profile, 2045

Implications of Fecal Waste Source Characterization Findings

The findings of the fecal waste source characterization and modeling efforts for Spring Creek reinforce the image of a watershed in transition. Driven by the general growth of the Houston area, and pushing outward from transportation corridors, the project area has seen significant growth in recent decades and will continue to do so in coming years. Developmental changes will reduce legacy agricultural sources in many areas, especially the headwaters area west of SH 249. The loss of load from agricultural activities will be outweighed by the increases of sources derived from developed areas. The increasing loads highlight the need for intervention through the WPP and other means. Current water quality issues will be compounded by future loads, leading to degrading water quality through the planning period absent any effort to the contrary.

Uncertainty is present throughout the assumptions and methodologies of this modeling approach, as noted throughout this document. Project staff used the best available data and stakeholder feedback to minimize uncertainty wherever possible, but the results should be taken in the context of their use in characterizing fecal waste pollution on a broad scale, and for scaling and siting BMPs. For these purposes, the level of uncertainty and precision of the results was deemed to be acceptable by the stakeholders. Further refinement of results may be needed in the future considering changing conditions. While bacteria source tracking or other analyses quantifying host organism DNA instream were not a function of this project, it may be a consideration in the future to further characterize sources, identify location-specific challenges, and refine the linkage between source loads and instream conditions.

Nutrient Source Characterization

Adequate dissolved oxygen (DO) is essential for supporting aquatic communities. Depressed DO issues can result from a variety of causes. The multitude of potential precursors to depressed DO make it difficult to identify the cause of resulting water quality issues in a waterway. However, excessive nutrient inputs from human use (*e.g.*, landscaping and agricultural fertilizers) are sources that stakeholders have the greatest potential to change. High levels of nutrients entering waterways during rain events can foster blooms of algae. As these algal blooms begin to die off, the decomposition of the algae utilizes oxygen in the water which depresses levels of oxygen available for other aquatic life. Even if it is only part of the overall mix of causes for DO issues, reductions or mitigations of nutrient use will reduce the risk of low DO levels. The Partnership evaluated the available means to characterize nutrients, in the context of the water quality goals they established. Because DO is not designated as an impairment in this watershed, and because many of the sources of nutrients overlap with sources of fecal waste[56], the Partnership focused its investigation efforts on identifying potential solutions and specific areas of concern.

Other Concerns

No specific modeling was conducted for other stakeholder concerns such as flooding, trash, and sediment. However, stakeholder feedback was taken on problem areas, and project staff developed recommendations for coordinating with partner efforts and programs overlapping these concerns as part of the recommended solutions of this WPP.

Flooding

Flooding was a primary concern for stakeholders in the watershed. Based on stakeholder discussions and ongoing conversations with key partners, the project identified several potential areas of overlap with flood mitigation efforts by the Harris County Flood Control District, and United States Army Corps of Engineers (USACE). The potential use of natural infrastructure as supplement to flood mitigation projects, the conservation of open space, and the inclusion of water quality concerns in flood project design were all areas of needed coordination during the implementation of this WPP.

Trash

Sites of appreciable concern were designated by stakeholders. Specifically, the stormwater drainage channel for the Kenswick Forest subdivision, which flows through Jesse H. Jones Park and Nature Center into Spring Creek, is a substantial source of floatables, which enter Spring Creek in great numbers following rain events. Trash in the waterway is an ongoing and visible concern for the stakeholders, especially in denser urban areas of the downstream watershed, where trash enters through stormwater and sheet flow. Project staff identified ongoing efforts in the watershed that would be important points of coordination, with the intent of including trash in water quality conversations, and vice versa.

Sediment

Sediment transfer from within and outside of the watershed was an issue raised by several stakeholders and is mirrored by similar conversations in adjacent watersheds like the West Fork San Jacinto River and Cypress Creek. No formal modeling or assessment was completed to identify erosion/deposition patterns in the watershed. However, given the link to flooding, downstream issues with reducing reservoir capacity in Lake Houston, and the potential for sediment-laden waters to enhance fecal bacteria transport, further coordination is needed.

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[56] Recommendations for best practices for bacteria sources are expected to be beneficial in reducing nutrient contamination as well (*e.g.*, reducing animal waste high in both fecal pathogens and nitrogenous compounds).

Section 4

Improving Water Quality

Photo Credit: Jessica Casillas

Section 4. Improving Water Quality

The success of solutions recommended by this WPP will be due in large part to how well they are scaled and targeted to address the pollutant sources identified in Section 3. The Partnership conducted a water quality modeling effort[57] to determine the amount of improvement needed for each parameter (*E. coli* and DO). The purpose of this effort was to establish how much *E. coli* needed to be reduced, and how much DO levels needed to be improved to meet their respective SWQSs. **Load duration curves** (LDCs) were used in combination with water quality data to determine these results. Based on these analyses, assessments of land cover and pollution sources, and the locations of points at which future compliance would be measured, different attainment areas were identified within the total watershed. Unique improvement goals were generated specific to the magnitude and composition of pollutant sources estimated for each attainment area.

Load Duration Curves for *E. coli* and Dissolved Oxygen

Pollutants can enter the water body from discrete sources or from nonpoint sources in different flow conditions. The amount of water flowing through a water body can affect concentrations of pollutants. LDCs use observed water quality data (see Section 3) to indicate the difference between observed levels of pollutants in a waterway, and the levels at which the applicable water quality standards would be met. The difference then becomes the basis for improvement goals.

The LDC approach uses flow data from a stream gauge or other source to create a flow duration curve. These curves indicate what percentage of days the flow of water meets certain flow levels (*e.g.*, a certain waterway may meet its base flow 100% of the time, but its highest peak flows only 5% of the time). Based on the numeric criteria for a water quality standard, a maximum allowable load of pollutant is calculated for all flow conditions. Lastly, monitoring data for the pollutant are multiplied by flows to produce a load duration curve, which shows how the actual load of a pollutant in the water changes in different flow situations (an example LDC is shown in **Figure 42**). More importantly, the curve indicates under what flow conditions, and by how much, the observed pollutant levels exceed the allowable load. Areas in which the load duration curve line exceeds the maximum allowable load curve line indicate that the standard is not being met in those flow conditions. If the areas of exceedance are primarily in high flow conditions, it is likely that nonpoint sources are most prominent. If areas of exceedance are instead primarily in the low flow conditions, point sources are more likely suspects. In situations where there is

[57] For greater detail on the modeling for *E. coli* and DO discussed in this section, please refer to the Bacteria Modeling Report on the project website at:
https://springcreekpartnership.weebly.com/uploads/1/3/0/7/130710643/10159_4.3_spring_creek_bacteria_modeling_report_032321.pdf

a mix of flow conditions related to exceedances, or in which contaminants exceed the allowable limit in all conditions, a mix of point and nonpoint sources is likely. The amount in which the observed loads exceed the allowable loads is the basis for developing improvement goals.

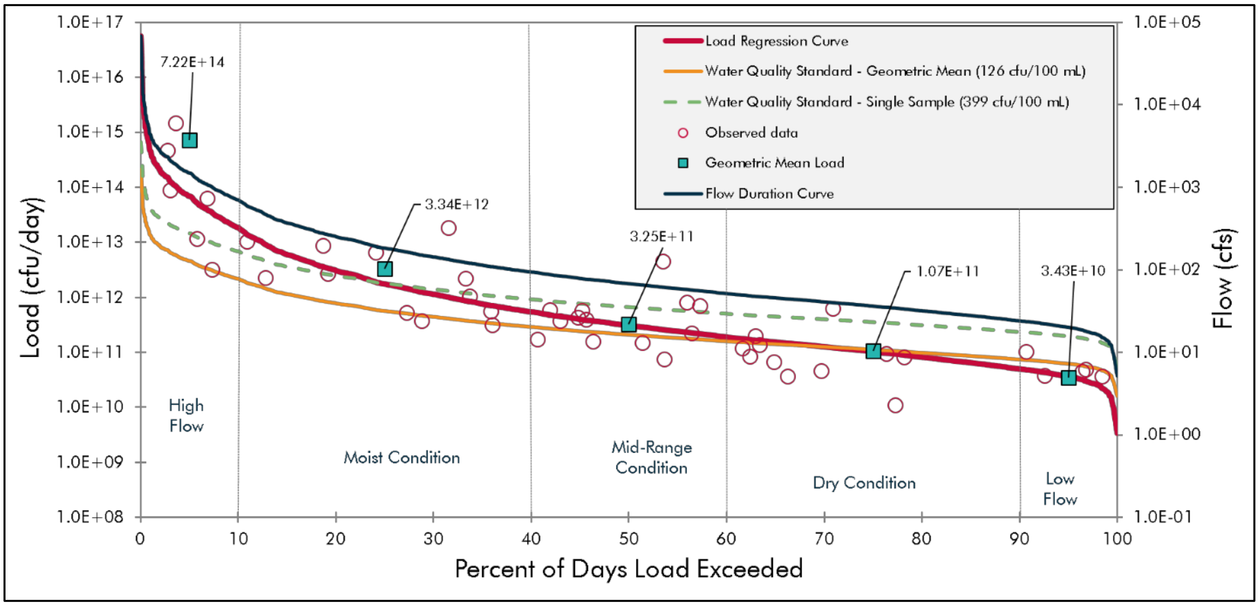

Figure 42. Example of a load duration curve for *E. coli*

Data Development

Project staff developed LDCs for *E. coli* and DO at several monitoring stations throughout the Spring Creek watershed. The purpose of the LDCs was to identify which flow conditions demonstrated exceedances, and to generate goals for *E. coli* reduction and DO improvement.

Site Selection

Site selection for LDCs was based on support for a mix of considerations, including known water quality conditions[58], the need for long-term assessment of progress toward the water quality standard, projected needs for BMP siting decisions, and stakeholder input.

- *Known Water Quality Conditions* — Based on a review of historical ambient water quality trends, wastewater treatment facility discharge monitoring reports, and sanitary sewer overflow information, water quality in the project watershed indicated that conditions in the assessed tributaries and main channel both had

[58] For more information, see the Water Quality Data Analysis Summary Report on the project website at: https://springcreekpartnership.weebly.com/uploads/1/3/0/7/130710643/10159_3.3_spring_creek_data_analysis_summary_report.pdf

a degree of variability and potential for continued exceedance. A single station would not be representative of the variability of conditions based on the water quality review. Therefore, several LDC locations were chosen to represent varying conditions along the waterway. Two stations on Spring Creek were selected to assess water quality in the headwaters as well as the downstream portions of the main stem. Stations on four of the main tributaries (Walnut Creek, Brushy Creek, Willow Creek, and Panther Branch) closest to a confluence with Spring Creek were selected to characterize the influence of the respective subwatershed areas on water quality in the main stem. This design allows for a greater degree of scrutiny of geographic variability of loads in the watershed, and an ability to target reductions more precisely. Evaluating several areas independently ensures area-specific problems would not be lost when diluted by a larger waterway, and that end results reflect variability of conditions throughout the waterway.

- *Long Term Assessment Considerations* — To ensure sufficient periods of record and continued data availability, LDC locations were drawn from existing CRP monitoring stations that have been monitored for at least 10 years and are planned to provide ongoing data. Availability of corresponding long-term streamflow data from USGS gage sites was also considered for site selection. Data from CRP stations and associated USGS gages (**Table 29**, **Figure 43**) selected for LDC analysis include:
    - **Brushy Creek** – Ambient data were collected from Station 20643 (Brushy Creek at Glenmont Estates Boulevard) near Brushy Creek's confluence with Spring Creek. No gauged streamflow data is available on this tributary; however, streamflow was estimated by linear regression. Continuous streamflow values from a nearby USGS gage on Spring Creek (08068275) were plotted against one-time flow recordings logged during sampling events for ambient data. The linear relationship between these values was used to estimate continuous streamflow values.
    - **Walnut Creek** – Ambient data were collected from Station 20642 (Walnut Creek at Decker Prairie-Rosehill Rd.) near Walnut Creek's confluence with Spring Creek. As with Brushy Creek, no gauged streamflow data is available on this tributary, however, streamflow was estimated by linear regression as described in the process used for Brushy Creek.
    - **Spring Creek (Upper)** – Ambient data were collected from Station 11314 (Spring Creek at SH 249) and streamflow data were assessed from USGS gage 08068275.
    - **Willow Creek** – Ambient data were collected from Station 11185 (Willow Creek at Gosling Road) near the confluence with Spring Creek.

Streamflow data were collected from USGS gage 08068325. As the USGS gage is located upstream from the location of the station, a drainage area ratio was used to convert continuous streamflow observed at the USGS gage to an estimation of flows further downstream.

- **Panther Branch** – Ambient data were collected from Station 16627 (Lower Panther Branch at Footbridge 265 M Upstream of Sawdust Road) and streamflow data were assessed from USGS gage 08068450.
- **Spring Creek (Lower)** – Ambient data were collected from Station 11313 (Spring Creek Bridge at I-45) and streamflow data were assessed from USGS gage 08068500.

- *BMP Siting Requirements* — As discussed previously, LDCs were chosen in part to reflect geographic variability. A greater number of LDC locations is beneficial to compare with modeling results to scale and site solutions (*i.e.*, solution requirements can be refined to the subwatershed level based on the specific reduction needs of the LDC assessment area in which the subwatershed falls).
- *Stakeholder Input* — Project staff built the aforementioned considerations into a set of LDC locations, which were reviewed with stakeholders in the preliminary meetings of the Spring Creek Watershed Partnership.

Table 29. LDC site information

LDC Site	CRP Station	USGS Gage	Assessed Area	Number of *E. coli* Samples	Number of DO Samples
Brushy Creek at Glenmont Estates Boulevard	20463	No Gage	Subwatershed 2	38	37
Walnut Creek at Decker Prairie-Rosehill Road	20462	No Gage	Subwatershed 3	39	37
Spring Creek at SH 249	11314	08068275	Subwatershed 4 (and 1 by proxy)	79	83
Willow Creek at Gosling Road	11185	08068325	Subwatershed 5	90	90
Lower Panther Branch at Footbridge 265 M Upstream of Sawdust Road	16627	08068450	Subwatershed 6	33	98
Spring Creek Bridge at I-45	11313	08068500	Subwatershed 7 (and 8 by proxy)	50	66

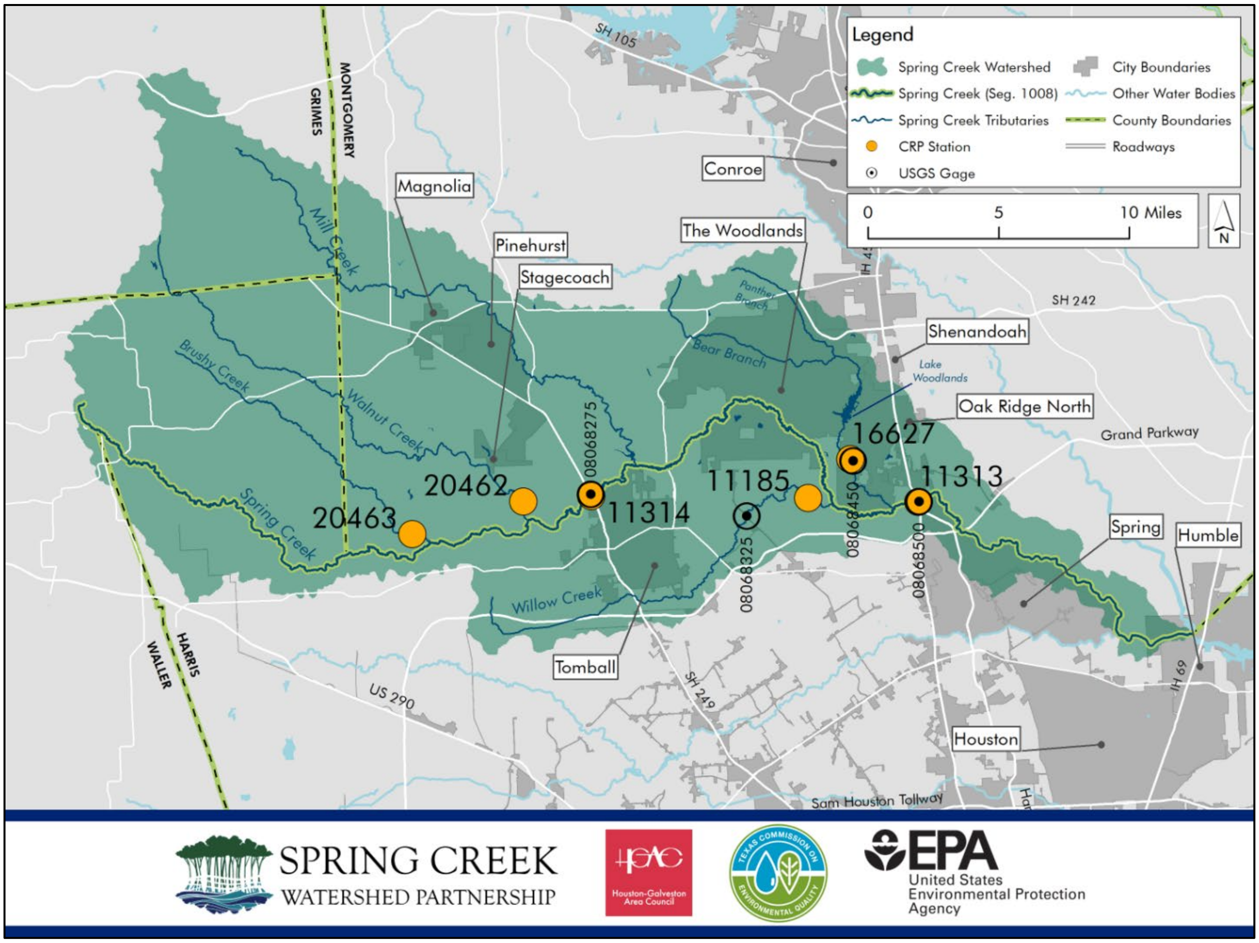

Figure 43. LDC sites

Quality Assurance

Quality-assured ambient water quality results from CRP monitoring were available for all six stations. All stations had at least 10 years of data available (33-90 data points for *E. coli*, and 37-98 data points for DO), which is sufficient to develop the LDCs based on the data quality objectives of the project (**Table 29**). For *E. coli*, both single sample and geomean values were evaluated against their respective criteria, but only geomean values were used in the process of assessing reductions for this modeling effort.

In addition to ambient water quality data, streamflow data is also required (with continuous flow data being preferable) to produce LDCs. Three of the Spring Creek watershed LDC sites (11314, 16627, and 11313) have corresponding USGS gages. On the Willow Creek tributary, Station 11185 occurs downstream of the nearest USGS gage (08068325). To account for this, a drainage area ratio was used to convert continuous streamflow observed at the USGS gage to an estimation of flows further downstream. This process has been used in previous watershed-based plans and meets the quality objectives of the project. No USGS gage data is available for Stations 20642 and 20623 on Walnut Creek and Brushy Creek, respectively. The subwatershed area of these tributaries represents a large portion of the Spring Creek watershed and was therefore critical to characterize with LDC analyses. To accomplish this, a novel approach was used to estimate streamflow. Ambient data recorded at Stations 20462 and 20463 included one-time streamflow measurements from CRP monitoring events. These data were compared to continuous streamflow measured at the closest downstream USGS gage (08068275). The resulting linear relationship between these values was used to estimate continuous streamflow values at the stations on Brushy Creek and Walnut Creek. This process was reviewed internally and with project stakeholders and found to be sufficient for the quality objectives of the project.

Load Duration Curve Implementation

Both the requisite flow and constituent sample data was sufficient to develop LDCs for all locations and will likely continue to support future revisions and the adaptive management process of evaluating WPP success. Results of the LDC analyses were reviewed internally and with project stakeholders. No issues with the data development and implementation were identified based on quality assurance review and feedback. Full profiles for each LDC site are included in the Bacteria Modeling Report[59].

Load Duration Curve Analysis Summary

Results of LDC analyses for Spring Creek have been reviewed internally and subjected to thorough stakeholder analysis. H-GAC staff discussed these results with stakeholders at partnership meetings and in more focused, one-on-one conversations. Stakeholder support and positive feedback support confidence in the estimated levels of fecal bacteria loadings and reduction targets for the Spring Creek watershed.

Overall, the results indicated that while DO may have some assimilative capacity, *E. coli* loads are greatly in excess of the standard in all locations at high flow and moist flow conditions (**Table 30**). Sites on the western side of the watershed (20463, 20462 and 11314) require more moderate reductions relative to those recommended in more developed areas, however, reductions are recommended for a wider range of flow levels (high flows through dry conditions). On the eastern side of the watershed, sites 16627, 11185 and 11313 bore stronger resemblances to each other in that reductions of greater magnitude are required at the highest flow conditions relative to those recommended in

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[59] For more information, please refer to the Bacteria Modeling Report on the project website at: https://springcreekpartnership.weebly.com/uploads/1/3/0/7/130710643/10159_4.3_spring_creek_bacteria_modeling_report_032321.pdf

the west. Dry to low flow conditions are within range of the standard at these sites and only moderate reductions are needed at mid-range conditions for 16627 and 11313.

Table 30. Summary of LDC results

LDC Location	Area Represented	Findings
Brushy Creek (20643)	Segment 1008J; Subwatershed 3	The results of LDC analyses for Station 20463 indicate a need for moderate reductions in fecal bacteria loading at high flow, moist conditions, and mid-range conditions. Brushy Creek demonstrated a greater assimilative capacity DO at higher rates of flow, but this ability was limited as flows diminish.
Walnut Creek (20642)	Segment 1008I; Subwatershed 2	Exceedances of the fecal bacteria geomean water quality standard were observed in all flow conditions except low flows. Station 20462 is the only station of the six observed in this analysis that indicated a need for DO improvements. This only occurred at the lowest flow condition (17% improvement needed), with greater assimilative capacities indicated in all other types of streamflow.
Spring Creek, Upstream (11314)	Segment 1008; Subwatershed 4 (& Subwatershed 1 by proxy)	Like Station 20462, fecal bacteria at Station 11314 require reduction in high flows and moist, mid-range, and dry conditions. Comparative to Station 20462, reduction levels at Station 11314 were higher. *E. coli* geomean loads at low flows were within state standard range. DO was compliant with state standards at all levels of flow with higher assimilative capacities observed at higher rates of flow.
Willow Creek (11185)	Segment 1008H; Subwatershed 5	Results at this station are noticeably different from analyses conducted on stations west of this point in that greater geomean loads are observed throughout the curve. Larger reductions in fecal bacteria are recommended at this station compared to previous stations in high flow and moist conditions, but loading became less severe in mid-range conditions, and finally fell within the standard range for dry conditions and low flows. DO was consistently shown to be within the standard range at all flow conditions observed at this station.
Lower Panther Branch (16627)	Segment 1008C; Subwatershed 6	Results indicate that appreciable fecal bacteria load reductions are needed in high flow conditions, and moderate reductions are needed in moist conditions. No exceedances of the *E. coli* geomean water quality standard were observed in any other flow conditions. DO loads were shown to be consistently within the standard range at this station.
Spring Creek, Downstream (11313)	Segment 1008; Subwatershed 7 (& Subwatershed 8 by proxy)	LDC analyses for this station are similar to those observed in other downstream segments—particularly Station 20462. Exceedances of the *E. coli* water quality standard were observed in periods of high flow and in moist and mid-range conditions. Fecal bacteria geomean loads observed in dry and low flows were within the acceptable standard range. DO loads were within range of the standard at all flow conditions with high assimilative capacity observed throughout.

Improvement Goals for *E. coli* and Dissolved Oxygen

The LDCs provided the basis for setting improvement goals for *E. coli* and DO, in the form of percentage reductions of instream loading (for *E. coli*) and percent improvement in DO levels. For DO, no further linkage to sources was calculated due to the lack of an impairment or widespread water quality concerns, the uncertainty of multiple potential precursors to low DO conditions, and the water quality goals set by the stakeholders. Based on the LDC results, where negative values indicate no improvement is needed and additional assimilative capacity may be present, DO conditions at all six LDC sites had additional assimilative capacity with the exception of a 17% improvement needed on Walnut Creek in low-flow conditions only. However, the data represents ambient sampling, and not 24-hour DO, so variation in conditions is likely to happen throughout the daily cycle. Additionally, DO conditions on tributaries with less flow may vary more widely than those in the main stem.

Attainment Areas

In developing improvement goals, the Partnership considered whether a single, watershed-wide goal for *E. coli*, and one for DO, was appropriate. Based on the varied character of the watershed, and to provide for better monitoring of project progress, the Partnership elected to set separate goals for distinct areas in the watershed.

The LDC sites were intended as the focus of long-term attainment; therefore, project staff proposed two attainment areas, each with specific reduction goals (**Figure 44**). The final selection of attainment areas is designed to reflect the two primary land cover types and associated pollution sources of the watershed, as well as the results of LDC analysis which showed two distinct loading signatures based on site location. For this project, the attainment areas selected represent the headwaters west of SH 249 which are surrounded by “natural” land types (subwatersheds 1, 2, 3, and 4), and the downstream waters east of SH 249 which occur in more developed areas (subwatersheds 5, 6, 7, and 8). Data from Station 11314 will represent the headwaters area while data from Station 11313 will represent the downstream. The stakeholders affirmed this approach, with the understanding that through adaptive management, additional targets may be added if needed (*e.g.*, in the Mill Creek subwatershed which does not currently support a monitoring station that meets quality objectives in terms of period-of-record). The monitoring stations and their associated LDCs and improvement goals for these two areas will be the primary focus of measuring water quality achievements under the WPP.

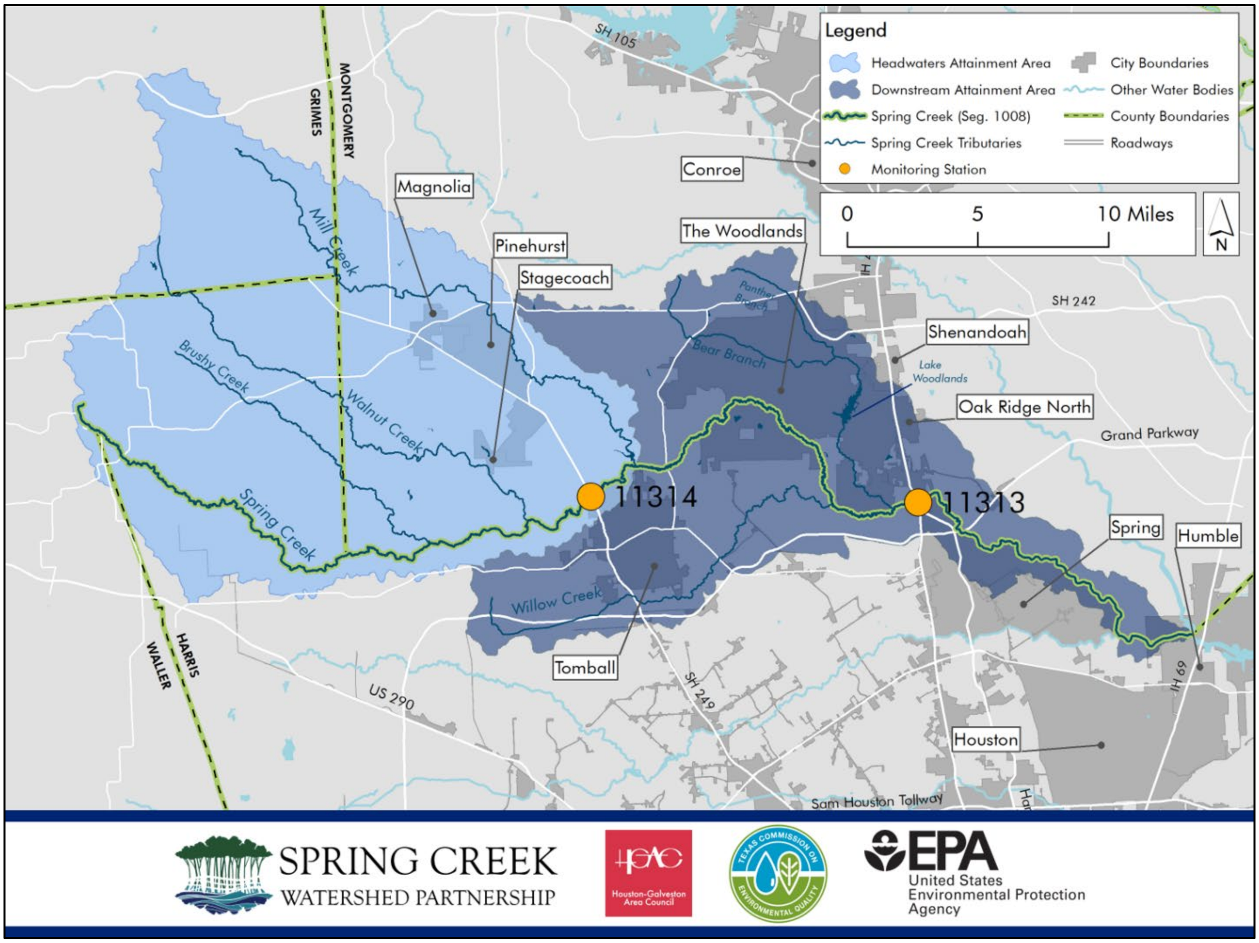


Figure 44. Spring Creek watershed attainment areas

E. coli Source Load Reduction Goals

With the establishment of the two primary attainment areas, the Partnership developed specific *E. coli* reduction targets for current and target year (2030) conditions. The first step was to identify a single improvement goal based on the LDCs for each attainment area.

The design for generating single target reductions for each attainment area[60] was based on a compromise between the worst-case scenario (*i.e.*, equating the reduction need to the **highest** possible reduction need in any flow category) and the least conservative approach (*i.e.*, equating the reduction to the **average** reduction needed based on all flow conditions). H-GAC proposed, and the stakeholders affirmed, a moderate approach in which reduction targets would be established based on a weighted average of the flow conditions in which reductions were needed, for each attainment area. The equation below demonstrates the calculation used to determine this average, where *W* represents the weighting factor

[60] As opposed to the modeled reduction values for each flow category.

(percent of flows) at high flow (*h*), moist (*m*), mid-range (*mr*), dry (*d*), and low flow (*l*) conditions, and *R* represents the reduction value required at each rate of flow.

$$\text{Weighted Average Reduction} = \frac{WHRH + WMRM + WMRRMR + WDRD + WLRL}{WH + WM + WMR + WD + WL}$$

For example, Station 11314 is the farthest downstream station in the attainment area of the headwaters of Spring Creek and was used to represent the area as shown in **Table 31**. At the high flow category which represents the top 10% of flows, an *E. coli* reduction of 81% is recommended. *E. coli* observed in the next 30% of flows (moist conditions) require a reduction of 64% and *E. coli* observed in the following 20% of flows (mid-range conditions) require a 54% reduction. Finally, *E. coli* observed in dry conditions comprising the following 30% of flows only require a 20% reduction. Low flow conditions are not factored into this calculation as no reductions were indicated by the LDC model. The calculation for the weighted average reduction for Station 11314 is shown below:

$$\text{Weighted Average Reduction} = \frac{(10 \times 81) + (30 \times 64) + (20 \times 54) + (30 \times 20)}{10 + 30 + 20 + 30}$$

$$\text{Weighted Average Reduction} = \frac{810 + 1920 + 1080 + 600}{90}$$

$$\text{Weighted Average Reduction} = \frac{4410}{90} = 49$$

This calculation was also used to determine the weighted average fecal bacteria reduction needed at Station 11313 which was selected as the best representative station in the downstream attainment area. While Station 11313 occurs well upstream of the confluence of Spring Creek and the West Fork of the San Jacinto River at the terminal end of the watershed area, it is the furthest downstream station in the attainment area with accompanying stream gauge data. Only weighting factors and reduction targets from high, moist, and mid-range flows were considered as no reductions were indicated by the LDC model at dry and low flow conditions. The resulting value is shown in **Table 31**.

Table 31. *E. coli* load reduction goals by percentage of load

Attainment Area	LDC Station	Subwatersheds	Weighted Average *E. coli* Reduction Target
Headwaters	11314	1, 2, 3 and 4	49%
Downstream	11313	5, 6, 7 and 8	63%

With the exception of a 17% improvement suggested in low flow conditions on Walnut Creek, LDC results for dissolved oxygen did not indicate the need for improvement. No specific percentage goals were developed for dissolved oxygen in the two attainment areas designated for this watershed. However, the LDCs for dissolved oxygen offer a means to evaluate the relative health of the system regarding dissolved oxygen levels, which may be used by stakeholders to shape future decisions about implementation measures. It should also be noted that this data may not represent the full variability of dissolved oxygen conditions, so this should not be taken to indicate no improvement of dissolved oxygen is warranted at the attainment area or overall watershed level.

Model Linkage

SELECT was used to generate potential source loads and characterize the source profile. The percent reduction improvement goals developed under the LDCs were applied directly to the source loads to generate the source load reduction targets. This process was developed with H-GAC and TCEQ project staff and reviewed and accepted by the stakeholders. No granular fate and transport modeling was completed for this project. Instead, the linkage relies on the assumption of a linear relationship between source loads and instream conditions. The percent reduction from the LDCs, rather than an absolute number of *E. coli* to reduce, is used for the linkage.

With the model linkage established, calculating *E. coli* reduction targets required that the stakeholders consider two other primary questions: 1) what milestone year would reduction targets be based on; and 2) how would source load reductions be spread out among the fecal waste sources?

Milestone Year

WPPs typically are written to be executed over a 5 to 15-year period. The existing projections developed during the SELECT analyses allowed the stakeholders to target any of the five-year milestone dates between 2018 and 2045. However, the further out the projections went, the greater the uncertainty. In deciding on a target milestone year, the stakeholders balanced the need to set near term, achievable goals within a period of relative certainty, and the need to account for the amount of future growth projected for the watershed. A 5-year plan would not adequately address the appreciable increase in loads through 2045, whereas a more long-term plan would have to rely on less certain predictions[61]. The Partnership and project staff agreed to target the year 2030, allowing a long-term focus to account for watershed change, while focusing on meaningful interim action. For a WPP approved in 2023, this would represent a 10-year plan life.

Allocating Reductions

The mix of sources present in the watershed, and the shift of relative contribution through 2045, posed a challenge for allocating how reduction targets would be met. Stakeholders

[61] This should not be taken to indicate a failure of the modeling methodology, but a reflection of the potential for unaccountable change the further out a model is used to predict conditions.

considered several options, including: 1) targeting all sources proportional to their contribution (e.g., if in 2030, source X made up 30% of the total load, then 30% of the reduction value would be met by addressing that source.); 2) allocating reduction subjectively based on potential solutions; and 3) allocating reduction based on current relative contribution (rather than 2030). Project staff proposed the first option as an initial guide for the calculation of reduction targets, with the understanding that the WPP would stress opportunistic implementation in addition to adaptive management strategies that will be most feasible in the short term. The proportional allocation was modeled for the whole watershed, subwatersheds, and attainment area groupings, with the proposed allocations to focus on the attainment areas. Stakeholders affirmed the proposal.

Based on these decisions, project staff generated reduction targets for each attainment area, subwatershed, and source. Overall reduction targets for each of the attainment areas and the linkage of the reduction target percentages to the source loadings were used to generate the target source load reductions for estimations as of the year 2018, and for the 2030 milestone year (**Table 32**).

Table 32. Current and 2030 source load reduction targets

Attainment Area	Subwatersheds	Weighted Average *E. coli* Reduction Target	2018 Total Source Load[62]	2018 Source Load Reduction Target[63]	Incremental Load, 2018 to 2030[64]	2030 Total Source Load Reduction Target[65]
Headwaters	1, 2, 3 and 4	49%	3.75E+13	1.84E+13	1.60E+13	3.43E+13
Downstream	5, 6, 7 and 8	63%	5.78E+13	3.64E+13	3.22E+13	6.86E+13

The load reductions needed by source for each of the two attainment areas, were also determined for conditions current as of 2018 and conditions in 2030 (**Table 33**; **Table 34**).

[62] The 2018 total source load is equal to the sum of subwatershed source loads within attainment area.
[63] The 2018 source load reduction target is equal to the 2018 total source load multiplied by the reduction target percentage.
[64] The incremental load is equal to the difference between the 2030 load and the 2018 load.
[65] The 2030 total source load reduction target is equal to the incremental load added to the 2018 source load reduction target.

Table 33. Source reduction loads distributed by source and attainment area, 2018

Source	Headwaters			Downstream		
	SELECT Estimation of Source Load Contribution to Total Daily Load (cfu/day)	SELECT Estimation of Source Percentage of Total Daily Load	Proportionate Source Load Reduction Target Based on SELECT (cfu/day)[66]	SELECT Estimation of Source Load Contribution to Total Daily Load (cfu/day)	SELECT Estimation of Source Percentage of Total Daily Load	Proportionate Source Load Reduction Target Based on SELECT (cfu/day)[67]
WWTFs	4.01E+09	0%	1.96E+09	8.47E+10	0%	5.33E+10
OSSFs	1.22E+12	3%	5.99E+11	1.98E+12	4%	1.25E+12
Dogs	9.74E+12	26%	4.77E+12	4.40E+13	76%	2.77E+13
Cattle	1.00E+13	27%	4.91E+12	1.91E+12	3%	1.20E+12
Horses	7.18E+10	0%	3.52E+10	1.37E+10	0%	8.64E+09
Sheep/ Goats	4.58E+12	12%	2.24E+12	8.74E+11	2%	5.51E+11
Deer	2.29E+11	1%	1.12E+11	1.06E+11	0%	6.69E+10
Feral Hogs	7.87E+12	21%	3.85E+12	3.04E+12	5%	1.91E+12
Safety Margin	3.75E+12	10%	1.84E+12	5.78E+12	10%	3.64E+12
TOTAL	**3.75E+13**	**100%**	**1.84E+13**	**5.78E+13**	**100%**	**3.64E+13**

Table 34. Source reduction loads distributed by source and attainment area, 2030

Source	Headwaters			Downstream		
	SELECT Estimation of Source Load Contribution to Total Daily Load (cfu/day)	SELECT Estimation of Source Percentage of Total Daily Load	Proportionate Source Load Reduction Target Based on SELECT (cfu/day)[68]	SELECT Estimation of Source Load Contribution to Total Daily Load (cfu/day)	SELECT Estimation of Source Percentage of Total Daily Load	Proportionate Source Load Reduction Target Based on SELECT (cfu/day)[69]
WWTFs	8.49E+09	0%	5.46E+09	1.18E+11	0%	8.97E+10
OSSFs	3.15E+12	6%	2.02E+12	4.45E+12	5%	3.40E+12
Dogs	2.46E+13	46%	1.58E+13	7.12E+13	79%	5.43E+13
Cattle	8.09E+12	15%	5.20E+12	1.49E+12	2%	1.14E+12
Horses	5.80E+10	0%	3.73E+10	1.07E+10	0%	8.15E+09
Sheep/ Goats	3.70E+12	7%	2.38E+12	6.81E+11	1%	5.19E+11
Deer	2.13E+11	0%	1.37E+11	1.01E+11	0%	7.70E+10
Feral Hogs	8.24E+12	16%	5.30E+12	2.93E+12	3%	2.24E+12
Safety Margin	5.35E+12	10%	3.43E+12	9.00E+12	10%	6.86E+12
TOTAL	**5.35E+13**	**100%**	**3.43E+13**	**9.00E+13**	**100%**	**6.86E+13**

66 These values are the SELECT model estimated % contribution multiplied by the 2030 load reduction target.
67 See Footnote 70.
68 These values are the SELECT model estimated % contribution multiplied by the 2030 load reduction target.
69 See Footnote 68.

Representative Units and Scaling Implementation

To determine what the source load reduction targets meant in terms of the scaling of solutions, representative units were used. Representative units simplify the conceptualization of load reduction targets by converting load values in cfu/day to practical units. The total number of units that would need to be addressed in each attainment area in 2030 was calculated by dividing the target load reductions by the per-unit *E. coli* load of each source (*e.g.*, one representative unit for pet waste is equal to the daily *E. coli* load produced by one dog) (**Table 35**). All units are rounded up to the nearest whole unit. In SELECT analyses using the buffer approach, the instream load contributed by each source varies by proximity to the waterway. However, when calculating representative units, no spatial distinction was made. This conservative method of converting target load reductions to representative units could over-represent reductions to be made in areas outside the buffer.

Table 35. Representative units to address by 2030, by attainment area

Source	Representative Unit	Representative Unit Daily Load (cfu/day)[70]	Units to Address by 2030, Headwaters	Units to Address by 2030, Downstream
WWTFs	1 million gallons of effluent[71]	4.77E+09	NA[72] (1)	NA (19)
OSSFs	1 failing OSSF	3.71E+09	545	915
Dogs	(waste of) 1 dog	2.50E+09	7,780[73] (6,335)	24,533 (21,718)
Cattle	(waste of) 1 cow	2.70E+09	1,926	421
Horses	(waste of) 1 horse	2.10E+08	NA (177)	NA (39)
Sheep/ Goats	(waste of) 1 sheep or goat	9.00E+09	264	58
Deer	(waste of) 1 deer	1.75E+08	NA (781)	NA (440)
Feral Hogs	(waste of) 1 feral hog	4.45E+09	1,190	502

[70] Daily loads associated with each source are adapted from Teague *et al*. 2009: https://ssl.tamu.edu/media/11291/select-aarin.pdf

[71] The approved bacteria TMDL for 'Watersheds Upstream of Lake Houston' requires that all permitted WWTFs in the Spring Creek watershed achieve a permit concentration standard of 63 cfu/100 mL of *E. coli*,

[72] WWTF, horse, and deer units to address are shown as NA as the Partnership elected to over convert reductions in other sources given the negligible impact of WWTF and horse waste on instream loading, and a lack of viable reduction solutions for deer waste. The numbers in parentheses represent the number of units that would have needed to be reduced if the Partnership had not chosen this course.

[73] Dog waste unit numbers are increased to cover WWTF, horse, deer, and safety margin reduction loads in both the headwaters and downstream attainment areas per stakeholder preference. Because there is no representative unit for the safety margin, that reduction value is not shown. Equivalent reduction values for dogs in the headwaters and downstream are added to the total representative units. The number in parentheses represents the number of dogs required to be addressed if WWTF, horse, deer, and Safety Margin loads were not converted into equivalent values.

Because the safety margin as a category does not have a representative unit, it is not included in this table. Reduction targets for WWTFs, horses, deer, and safety margin were converted into equivalent dog waste in the headwaters and downstream attainment areas to account for negligible instream loads expected from WWTFs and horse waste in addition to stakeholder preference in not selecting specific solutions to target deer and wildlife. While WWTFs and horses are not estimated to contribute significantly to bacteria loading in the Spring Creek watershed, they will still be considered a focus of implementation, education and outreach, and continued monitoring. More information on the stakeholder decision-making process regarding the calculation of reduction targets in terms of representative units can be found in **Appendix E**.

The solutions for livestock are based on the implementation of TSSWCB Water Quality Management Plans (WQMPs) and similar conservation plans through USDA Natural Resources Conservation Service (NRCS). Section 5 provides details on these solutions. To translate the number of livestock units to address into number of plans, project staff worked with TSSWCB and the local Soil and Water Conservation Districts (SWCDs) in this and previous projects to develop an assumed average number of livestock units (50) to be served by each plan. The number of plans is then derived by dividing the number of livestock units by the average units per plan and rounding up to the nearest whole representative plan (**Table 36**). The actual load reduction value for each plan will differ depending on the mix of livestock involved (given their different representative unit loading values).

Table 36. Agricultural plans needed to address livestock loads by 2030

Attainment Area	Total Livestock Units to Address	Total Plans
Headwaters	2,189	44
Downstream	479	10

Source Load Reduction Summary

The findings of the *E. coli* modeling efforts for Spring Creek reinforce the image of a watershed in transition. Driven by the general growth of the Houston area, and pushing outward from transportation corridors, the project area has seen significant growth in recent decades and will continue to do so in coming years. Developmental changes will reduce legacy agricultural sources in many areas, especially the Headwaters attainment area. The loss of load from agricultural activities will be outweighed by the increases of sources derived from developed areas.

The increasing loads highlight the need for intervention through the WPP and other means. Current water quality issues will be compounded by future loads, leading to degrading water quality through the planning period absent any effort to the contrary.

Uncertainty is present throughout the assumptions and methodologies of this modeling approach, as noted throughout this document. Project staff used the best available data and stakeholder feedback to minimize uncertainty wherever possible, but the results should be taken in the context of their use in characterizing fecal waste pollution on a broad scale, and for scaling and siting BMPs. For these purposes, the level of uncertainty and precision of the results was deemed to be acceptable by the stakeholders. Further refinement of results may be needed in the future in light of changing conditions. While *E. coli* source tracking or other DNA source tracking analyses were not a function of this project, it may be a consideration in the future to further characterize sources, identify location-specific challenges, and refine the linkage between source loads and instream conditions.

Figure 45. Sunset in the Spring Creek watershed

Section 5

Recommended Solutions

Photo Credit: Jessica Casillas

Section 5. Recommended Solutions

Sources of pollution in the Spring Creek watershed are widespread, diverse, and expected to increase in the future. Without intervention, water quality will likely continue to degrade. Identifying a path forward that details a comprehensive approach for addressing these water quality issues is a necessary step in linking stakeholder concerns to achievable results. While the situation is challenging, potential solutions exist that can be implemented on a voluntary basis and in a cost-efficient manner.

This WPP is designed to establish a clear link between the causes and sources of contamination, and the solutions identified and scaled to address them. Section 3 quantified the sources that contribute to water quality impairments and Section 4 identified the *E. coli* reductions and DO improvements needed to meet the Partnership's water quality goals. This Section details the voluntary solutions identified and prioritized by the stakeholders and discusses the financial and technical resources needed to implement them. Section 6 links these activities to corresponding education and outreach elements, Section 7 details the timeline and milestones associated with implementation, and Section 8 provides a path forward to evaluate their success.

Identifying Solutions

As detailed in Section 1, the stakeholders established six guiding principles for the recommendations of the WPP. The stakeholders emphasized: 1) recognizing the uniqueness of the areas in the system; 2) making decisions locally; 3) using voluntary solutions; 4) utilizing proven strategies; 5) coordinating with flood mitigation, conservation, and other adjacent activities occurring in the watershed; and 6) incorporating a strong education and outreach campaign. This focus provided a framework for identifying a set of feasible solutions in line with community priorities. These considerations shaped the discussion of potential solutions and the ultimate selection processes.

Stakeholders reviewed a wide range of potential solutions, starting with those identified in existing projects[74] and ongoing local efforts[75]. The diversity of pollutant sources in the watershed required that stakeholders consider an equally wide range of potential solutions sufficient to address each source[76] in proportion to the prominence of the source. This palette of potential solutions served as a starting point for local customization and

[74] Including previous WPPs and TMDL I-Plans conducted in other watersheds, as well as the I-Plan for the Bacteria Implementation Group, under whose auspices the Spring Creek/Lake Houston TMDL project now rests.

[75] Including planned or potential activities of local government partners like the Harris County Precincts and Harris County Flood Control District; NGOs like the Bayou Land Conservancy; regional efforts like USACE studies; private developers, and others.

[76] Deer, migratory birds, and other wildlife for which no feasible solutions existed were not considered under this process, based on stakeholder feedback or regulatory restriction.

development of area-specific actions. Recommendations were discussed at multiple meetings of the Partnership. In the interim, the topic-specific Work Groups refined ideas and added expertise in the form of recommendations to the Partnership for further discussion. The discussions focused primarily on solutions to reduce fecal waste loads, with the assumption that most of the fecal waste solutions proposed would also benefit DO and other water quality goals. However, the Partnership discussed some solutions specific to other concerns. After several rounds of discussion and one-on-one meetings with specific partners, the Partnership formed the set of recommended solutions described herein. Both ongoing projects and new efforts are reflected.

This list of solutions is built around the understanding that the WPP operates on a process of adaptive management that will add or remove solutions based on efficacy, funding levels, changing conditions, or opportunities.

Solution Prioritization

The prioritization of solutions was a primary discussion point for the stakeholders. Funding limitations were a key concern for some structural solutions. In general, the stakeholders favored enhancement or supplementation of existing efforts before the addition of new elements. High priority was placed on solutions that:

- Had potential funding sources;
- Served multiple benefits (*e.g.*, vegetative riparian buffers that reduce the transmission of *E. coli* and nutrients while also slowing storm flows and reducing hydrologic impacts of runoff);
- Were already proven programs with sustaining support from agencies or other organizations;
- Involved or emphasized voluntary conservation;
- Were related to or supplemental to flood mitigation efforts;
- Had a strong outreach and education component or tie-in; and
- Were focused on areas most adjacent to the water.

These priorities are reflected in both the set of recommended solutions, as well as the priorities for their implementation, as discussed later in this section.

Recommended Solutions

In developing solutions, the stakeholders considered the purpose of the solution, the scope of its implementation, the responsible parties[77], the period in which it would be

[77] Throughout this section, references to categories (Counties, Districts) are made unless a specific party is named.

implemented[78], the contaminants addressed, its status as either an existing or new effort, the technical and financial resources needed for implementation, and its potential for reducing *E. coli*. The solutions will be implemented together, or in phases, such that they cumulatively address the *E. coli* reduction goals for each source. Estimated costs reflect the period through 2030. The solutions identified in this section are for direct structural or programmatic elements. Solutions related to education and outreach for each source category are highlighted in Section 6. While solutions are intended to be implemented in all appropriate subwatersheds, proportional to the load from the subwatersheds, specific focus areas are indicated for each source category. Focus areas identify the subwatersheds for which a set of solutions is most applicable. For all solutions the Partnership, as an ongoing point of coordination facilitated by H-GAC or a successor agency, is assumed to be a supporting party, though the level of support will differ based on the solution. Additional information on potential funding mechanisms is included as **Appendix D**.

Figure 46. Twilight in the Spring Creek watershed

[78] The period represented for each solution is the timeframe within the initial 9-year implementation window between an assumed approval in 2023 and the target year of 2030. Many solutions will likely continue to be implemented as ongoing efforts or as needed to maintain water quality after that point.

Wastewater Treatment Facilities and Sanitary Sewer Overflows

WWTFs in the watershed are generally able to meet their bacteria limits, with few exceedances, but enhancements to structural and operational elements and a focus on addressing SSOs can reduce these sources of human fecal pathogens. Based on established jurisdictions for WWTF operation and SSOs, the responsibilities for these recommendations will largely fall to the local utilities and special districts, who provide the overwhelming amount of sanitary sewer service in the watershed. Many of these MUDs, utility districts, water control and improvement districts (WCIDs), private utilities, and other entities are actively engaged in these efforts and have had noteworthy success. Across the watershed, priority is placed on aging systems, smaller systems with less oversight, systems with chronic issues, economically disadvantaged areas, or facilities located in floodplains vulnerable to storm events.

Despite the relatively low daily load from WWTFs and SSOs, these sources are being considered a high priority because of their proximity to developed areas, and the relatively high risk of human waste. The primary focus of WWTF and SSO solutions are continuation and enhancement of utility operations. Supplemental support from the Partnership, or additional activities beyond normal operations emphasize information sharing, funding identification, and prioritization.

These recommendations are in supplement to the existing day-to-day operations of the WWTFs in the area. The following solutions were identified by the stakeholders for WWTFs and SSOs:

- WWTF 1 — Address problem facilities and consider regionalization
- WWTF 2 — Recommend increased testing
- SSO 1 — Remediate Infrastructure
- SSO 2 — Consider additional preventative measures

Educational elements related to WWTFs and SSOs are expanded on in Section 6. Due to the variety of operations in the watershed, cost estimates for these solutions vary widely or are future costs that cannot be predicted. However, the primary focus of funding in this section is existing utility funding resources as augmented with support from the Partnership in identifying and pursuing additional funds. More information about funding sources is available in **Appendix D**.

WWTF 1 – Address Aging Facilities; Consider Regionalization

Purpose: To increase oversight of facilities with discharge violations, and potentially consolidate operations where appropriate to increase economies of scale and phase out outdated treatment infrastructure.

Description: The Partnership will work with local authorized agents and interested utilities to promote remediation of facilities or processes in which exceedances are occurring or likely to occur. This may happen through: routine or augmented investment by the utilities; support from the coordinating entity of the Partnership in identifying or pursuing additional funding resources; or action or recommendation from the counties regarding regionalizing problem, undersized, or aging facilities and infrastructure. No specific problem facilities were identified in the watershed characterization, but as systems age, problem areas may arise.

Priority Area(s): Watershed-wide

Responsible Parties	Period	Contaminant(s) Addressed	Status
Utilities; Cities; Counties	Ongoing-2030	Bacteria, Nutrients	Extends existing management; potential enhancement to existing operations

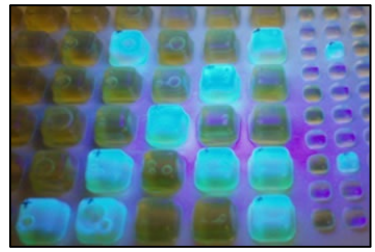
Technical and Financial Resources Needed	Estimated Costs and Funding
The technical resources needed to fulfill these recommendations are sufficient utility staff to address system elements, and Partnership support for funding identification. Financial resources needed for this recommendation are highly variable, but include utility staff time costs, and infrastructure costs as warranted.	Costs involved with WWTP rehabilitation or regionalization are highly variable and not estimated individually here. Funding sources potentially include tax or utility revenue, TWDB loans or grants or other applicable grant programs (USDA Rural Utilities Service, *etc.*).

Bacteria Reduction Capability

This activity directly reduces bacteria, nutrients, and additional concerns stemming from poorly treated effluent. Because there is not a significant pattern of exceedance existing already among watershed WWTFs, future reductions cannot be quantified as they will be dependent on the future state of infrastructure. The primary reduction potential for this task is as a preventative measure.

WWTF 2 – Recommend Increased Testing

Purpose: To increase oversight of certain facilities and enhance nutrients data through increased voluntary testing.



Description: The Partnership will recommend additional bacteria testing to local utilities that do not have daily testing requirements in their TPDES permit. The intent of the increased voluntary testing is to expand the ability to identify operations that would benefit from additional resources. Infrequent testing may mask issues, especially in smaller facilities with less consistent loading. The Partnership also recommends that utilities consider voluntary testing, as appropriate, for a wider suite of nutrients, such as total phosphorus and nitrogenous compounds. This data would help establish the potential impacts of effluent on nutrient loading to the waterway and potentially help prepare facilities for future permit changes, including future statewide additions of other nutrient criteria by TCEQ.

Priority Area(s): Watershed-wide

Responsible Parties	Period	Contaminant(s) Addressed	Status
Utilities	Ongoing-2030	Bacteria, Nutrients	Extends existing functions

Technical and Financial Resources Needed	Estimated Costs and Funding
The technical resources needed to fulfill these recommendations are sufficient utility staff to handle increased voluntary testing. Financial resources needed for this recommendation are the incremental costs of sampling, dependent on the frequencies and constituents involved.	Testing costs are highly variable by the frequency of testing and costs specific to the individual entity involved. Funding sources are expected to be tax or utility revenues of the utility.

Bacteria Reduction Capability

This activity does not directly reduce bacteria; it provides information for decision-makers to address current or future operations to directly reduce pollutants.

SSO 1 – Remediate Infrastructure

Purpose: To physically remediate collection system SSOs through rehabilitation and preventative maintenance.

Description: Utilities will continue to identify and address areas in collection systems prone to SSOs and consider structural and operation changes that will reduce SSOs, including:

- prioritizing rehabilitation of problem elements/areas
- considering additional funding for rehabilitation where appropriate
- pursuing additional grant or loan funding to expand resources for rehabilitation

No specific problem areas were identified by stakeholders, but as systems age, problem areas may arise.

Priority Area(s): Downstream attainment area

Responsible Parties	Period	Contaminant(s) Addressed	Status
Utilities	Ongoing-2030	Bacteria, Nutrients	Enhance existing efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources for remediating SSOs include sufficient staff capacity for investigating problem areas and implementing capital projects or operational adjustments. For grant projects, staff grant administration capacity would be needed. Financial resources for remediating SSOs are typically borne by utilities directly, through rate revenue or *ad valorem* tax revenue. Potential supplemental funding sources include Texas Water Development Board (TWDB) Clean Water State Revolving Fund loans or grants, funding from resiliency-based funding sources from federal agencies as listed in Appendix D, and traditional commercial loan or bond opportunities. Costs are highly variable depending on the size, age, and type of infrastructure and the nature of the causative factor for SSO problem areas. Resources needed include maintaining adequate staff capacity, equipment to conduct inspections and supplement operations, and cost of rehabilitation and contractor services. Residents are responsible for maintenance and repair of their private line connections.	Estimated costs for addressing SSOs are highly variable depending on the extent of the issues, size of the system, and nature of the fix. Example costs from other regional WPPs include mid-sized cities who spend $1,000,000-$5,000,000/year on addressing aging collection system infrastructure. The distributed nature of service in the watershed means costs per utility are likely lower than this estimate, but in conglomerate amount to appreciable investment. Funding sources include tax or utility revenue and loans/grants from TWDB or other programs.

Bacteria Reduction Capability

This activity is expected to reduce SSO activity at chronic locations. Efficiency is variable depending on extent of the local problem and nature of implementation. The primary benefit is expected to be localized, but significant in those localities based on the relatively high risk of untreated sewage. While the total volume of SSO flow that will be reduced cannot be projected, the reduction efficiency is 100% for each gallon of effluent not released.

<table>
<tr><th colspan="4">SSO 2 – Consider Additional Preventative Measures</th></tr>
<tr><td colspan="4">Purpose: To enhance operations and infrastructure capacity to help prevent SSOs.</td></tr>
<tr><td colspan="4">Description: Utilities will consider enhancing their operations and preparations for mitigating SSOs by implementing one or more of the following solutions (if not already in place):

• Evaluate and enhance lift station[79] backup capacity, including backup power or capacity for bypass pumping or other remediations in the event of power outages.
• Consider implementing grease trap inspections where not already required.
• Consider implementing or upgrading a proactive asset management program to evaluate and prioritize rehabilitation needs.
• Revise response procedures/standard operating procedures for identifying and mitigating SSOs in high rain events.
• Consider participation in TCEQ's Sanitary Sewer Overflow Initiative for problem systems.

Priority Area(s): Watershed-wide</td></tr>
<tr><th>Responsible Parties</th><th>Period</th><th>Contaminant(s) Addressed</th><th>Status</th></tr>
<tr><td>Utilities</td><td>Ongoing-2030</td><td>Bacteria, Nutrients</td><td>Enhance existing efforts</td></tr>
<tr><th colspan="3">Technical and Financial Resources Needed</th><th>Estimated Costs and Funding</th></tr>
<tr><td colspan="3">Technical resources for additional preventative measures include sufficient staff capacity to evaluate lift station capacity, implement capital projects, conduct grease trap inspections, oversee asset management efforts, review standard operating procedures for SSOs, and/or make recommendations on operational changes. Staff costs are variable dependent on the size and scope of the project and staff involvement.

Financial resources for enhancing lift station capacity are borne by the utility. Additional financial resources include loan and grant programs.</td><td>Estimated costs are variable, depending on the type and scale of measures selected and implemented.

Funding sources include government tax or utility revenue and loans/grants from TWDB or other grantors.</td></tr>
<tr><th colspan="4">Bacteria Reduction Capability</th></tr>
<tr><td colspan="4">This activity is expected to reduce SSO activity by ensuring lift station functionality in all conditions and enhancing preventative measures. While the total volume of SSO flow that will be reduced cannot be projected, the reduction efficiency is 100% for each gallon of effluent not released.</td></tr>
</table>

[79] Lift stations are an essential part of collection systems in relatively flat regions, transferring waste between pipes at different elevations to maintain flow. However, during power outages or similar events, lift stations can cease to function and be prone to overflow without backup capacity. Utilities will evaluate and consider enhancing their backup capacity (generators, bypass pumps, etc.) for their lift stations to ensure continuity of operations during power outages or other events.

On-site Sewage Facilities

Failing OSSFs are a priority source due to high risks to human health associated with untreated human waste, and their increasing share of total load by 2030. The general intent of the stakeholders was to prioritize failing systems that are unlikely to be addressed otherwise, attempt to prevent future failures through education and outreach to the community and licensed professionals, and direct intervention to economically disadvantaged households through programs such as the Supplemental Environmental Program (SEP)[80]. SEP funding is being provided by both TCEQ and the Harris County District Attorney's Office. In order to qualify, homeowners with failing OSSFs must reside in an eligible county, and have a combined income below 80% of the median for the county.

These solutions are in addition to the existing requirements of watershed counties, including mandatory maintenance contracts for systems and other authorized agents, and the enforcement thereof. It should be recognized that county and authorized agent efforts are the primary foundation for all other efforts. The following supplementary solutions were identified by the stakeholders:

- OSSF 1 — Remediate failing OSSFs (repair, replace, pump, decommission)
- OSSF 2 — Improve and update spatial data to identify priority areas
- OSSF 3 — Convert OSSFs to sanitary sewer where appropriate

All subwatersheds are targeted by these strategies, with a focus on the Tomball area in subwatershed 5. Educational elements (*e.g.*, homeowner workshops) are included in the discussion of education and outreach activities in Section 6.

Actual implementation will be opportunistic and will seek to emphasize priorities noted in each OSSF solution. Proposed siting of OSSF projects within the watershed to be implemented by 2030 is shown in **Table 37**.

Table 37. Proposed siting for OSSF solutions to be implemented by 2030

Attainment Area	Units to Address, Total	Subwatershed	Units to Address, Subwatershed
Headwaters	545	1	92
		2	149
		3	56
		4	248
Downstream	915	5	270
		6	212
		7	160
		8	273

[80] H-GAC's SEP is used to remediate, repair, pump, or decommission OSSFs for homeowners making less than 80% of the Area Median Income.

OSSF 1 – Remediate Failing OSSFs

Purpose: Reduce bacteria and nutrient contributions from failing OSSFs through physical remediation.

Description: H-GAC will work with watershed counties and OSSF owners to inspect and remediate failing systems through pumping, repair, replacement, or abandonment/conversion to sanitary sewer. H-GAC will use SEP, CWA §319(h), or other grant funding to address priority systems. Authorized agents will work with homeowners to enforce existing requirements concerning OSSF function and inspection. In remediation efforts, priority will be given to failing systems near the waterways.

Priority Area(s): Subwatershed 5

Responsible Parties	Period	Contaminant(s) Addressed	Status
H-GAC; Homeowners; Counties (enforcement); Utilities (for conversion projects)	Ongoing-2030	Bacteria, Nutrients	Expansion of existing efforts (e.g., H-GAC OSSF SEP, residential maintenance)

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resource needs include data on OSSF locations from H-GAC's regional OSSF database, the counties, local utilities/special districts, who may also provide violation information as appropriate. Actual remediation conducted by H-GAC, the homeowner, or another party; enforcement and referrals will be provided by the other responsible parties. Inspection will be conducted as needed by authorized entities based on existing ordinance or other authority. Financial resources required include H-GAC staff time to manage remediation contracts, other parties' staff time in enforcement, and funding for the remediation. Staff time is variable and is not included in cost estimates. Homeowners are expected to provide most of the funding, with other sources supplementing routine maintenance and replacement costs.	Estimated costs are an average[81] of $5,500 per unit, with a total cost of $8,030,000 for 1,460 systems. Funding Sources include routine homeowner maintenance costs, as supplemented by H-GAC SEP and other grant programs (CWA §319(h), etc.).

Bacteria Reduction Capability

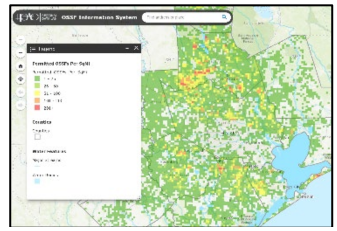
Remediating failing OSSFs is assumed to remove 100% of their daily load. Full implementation of this solution will meet the bacteria reduction goal for OSSFs by 2030.

[81] Average cost numbers were based on a review of OSSF work completed under other projects and approved WPPs in the area, including pump outs, repairs, replacements, and related costs. The range of potential costs for all services mentioned runs from several hundred dollars for a pump out to over $10,000 for replacement of a new system in some areas.

OSSF 2 – Improve Spatial Data

Purpose: Inform decisions about prioritizing OSSF remediation.

Description: H-GAC will work with watershed counties and other local partners to continue to collect spatial data on OSSF locations as part of H-GAC's existing OSSF spatial database[82]. The partners will update and improve designations for priority remediation areas based on the data and other factors (e.g., growth, developmental trends).



Priority Area(s): H-GAC region

Responsible Parties	Period	Contaminant(s) Addressed	Status
H-GAC; Counties; Special Districts; Utilities	Ongoing-2030	Bacteria, Nutrients	Expansion of existing efforts (*e.g.*, H-GAC OSSF database)

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources include existing staff capacity at H-GAC and partner agencies. H-GAC currently maintains the database as part of a CWA Section 604(b) grant project with TCEQ. No additional technical resources are needed for this aspect of the task. Financial resources needed include staff time from local partners to continue to submit and review OSSF data, and to coordinate with H-GAC on maintaining and updating priority areas for H-GAC SEP and other funding in the watershed. Specific focus will be given to economically disadvantaged households and OSSFs in riparian or flood-prone areas.	Estimated costs include existing funding of staff time which is variable depending on workload for this element. Funding sources are the ongoing H-GAC CWA §604(b) grant and local partner staff time.

Bacteria Reduction Capability

This solution does not directly reduce fecal waste pollution but is designed to better inform other solutions (OSSF 1 and OSSF 3; OSSF homeowner workshops) to enhance their effectiveness.

[82] Available for review online at: http://datalab.h-gac.com/ossf/

OSSF 3 – Convert to Sanitary Sewer			
Purpose: Convert old and/or failing OSSFs to sanitary sewer service where available and appropriate.			
Description: Local partners, in coordinating with funding sources like H-GAC's SEP for OSSF remediation, will focus on identifying and pursuing opportunities to convert OSSFs within service area boundaries to sanitary sewer service. Cities will consider promoting or requiring conversion of areas within existing or annexed boundaries. Priority should be given to failing systems, and this recommendation only applies where sanitary service is available/feasible.  **Priority Area(s):** Properties in subwatersheds with existing sanitary sewer systems			
Responsible Parties	**Period**	**Contaminant(s) Addressed**	**Status**
H-GAC; Counties; Special Districts; Utilities; Homeowners	Ongoing-2030	Bacteria, Nutrients	Expansion of existing efforts
Technical and Financial Resources Needed			**Estimated Costs and Funding**
Technical resources include available staff at local governments, H-GAC, and watershed counties to promote and/or process conversion projects. Homeowners or funders will need to have, or contract for, personnel skilled in this specific type of construction. Financial resources include the cost to permit the service connection, construct the service line, and pump/decommission the OSSF. It is expected that a good number of conversions may result in abandoned OSSFs as development of master-planned communities displaces existing residences.			Estimated costs of converting a residence to sewer service are \$3,000-\$5,000. No specific number of OSSFs is slated for this specific action (see OSSF 2). Funding sources include expected routine costs from homeowner, as supplemented by H-GAC SEP or CWA §319(h) grant funding.
Bacteria Reduction Capability			
This solution is expected to provide 100% removal rate by actively converting systems to alternate service.			

Stormwater

Stormwater runoff from populated areas with large amounts of impervious cover can contribute pollutants from a variety of sources that often reach waterways through storm sewers without filtration. While urban stormwater is not an original source, but a conveyance for sources, several solutions exist to mitigate its impacts.

The primary means for addressing these sources in most of the urban areas of the watershed are the Municipal Separate Storm Sewer System (MS4) permits through TCEQ's General Permit (TXR040000). The permits require stormwater utilities to address sources of pollutants they may discharge to impaired waterways[83]. The recommendations of this WPP are not designed to supplant the existing efforts of the MS4s in the watershed. They are intended to supplement those activities, which form the basis of stormwater quality management in the area[84]. MS4 activities are likely to have the most impact on bacteria and nutrient levels in the downstream area. In addition to MS4 permit activities, the stakeholders recommended the following solutions:

- Urban Stormwater 1 — Install stormwater inlet markers
- Urban Stormwater 2 — Investigate drainage channels for illicit discharges
- Urban Stormwater 3 — Promote and implement riparian buffers
- Urban Stormwater 4 — Promote low impact development

Points of focus of this category include education and outreach activities, as reflected in Section 6. Implementation will target the urbanized portions of the downstream attainment area. These recommendations are in addition to the general recommendation by the stakeholders that infrastructure should be properly maintained. For both Urban Stormwater 2 and Urban Stormwater 3, the Partnership recommends that the investigation program and inlet installation program both include reporting of damaged infrastructure as a standard operating procedure. This will help ensure utilities or other property owners are aware of infrastructure problems and can work effectively to address them, which produces both water quality and flood mitigation benefits to the community. It should be noted that targeted monitoring that is complementary to Urban Stormwater 1 is a recommendation for the broader Bacteria Implementation Group[85] (BIG) area, and active projects are

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[83] More information on the permits can be found at: https://www.tceq.texas.gov/permitting/stormwater

[84] No funding other than that from the MS4 permittees themselves is expected to be applied to activities specific to their permit activities. Any mention of funding sources in the solutions identified for this subsection is intended in reference to activities above and beyond permit requirements.

[85] The BIG is an ongoing TMDL effort addressing fecal indicator bacteria for a number of segments in the H-GAC region, including Spring Creek. The WPP provides a more specific focus on Spring Creek, considers additional pollutants and stakeholder concerns, and makes watershed-specific recommendations, but is working in conjunction with the broader BIG effort to reduce fecal contamination in local waterways. Learn more at: https://www.h-gac.com/bacteria-implementation-group

currently underway which may serve as valuable models for this watershed. All efforts under this category will be coordinated to the greatest extent possible with efforts occurring as part of the BIG.

Development of new features in existing rights of way has to be balanced against other uses for our urban corridors, including flood mitigation. Siting of riparian buffers should take this into account. Limitations on vegetation or other measures in drainage easements, or access requirements for maintenance may limit buffers in some areas, or require they be further from the channel.

Figure 47. Volunteers installing storm drain markers in the Village of Grogan's Mill

Urban Stormwater 1 – Install Stormwater Inlet Markers

Purpose: To increase public visibility of stormwater drains as vectors for pollution.

Description: This solution involves installation of stormwater inlet markers, where appropriate for local governments, special districts, homeowners' associations (HOAs), and neighborhoods. Local organizations (*e.g.*, The Woodlands Township Environmental Services Department, Harris County Flood Control District's Stormwater Inlet Marking program[86]) have existing programs for this purpose. This solution reflects partners' intent to continue or expand programs. Inlet markers will be installed based on the requirements of the specific jurisdictions. The intent is to utilize this as a project to engage local volunteers in coordination with outreach efforts.

Priority Area(s): The Woodlands Township, urbanized areas, downstream attainment area

Responsible Parties	Period	Contaminant(s) Addressed	Status
Harris County; Local Governments; Special Districts; HOAs; Local Volunteers	Ongoing with focus on 2023-2027	Bacteria, Nutrients, Sediment, Trash	New or expanded effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources include staff capacity to train volunteers and manage installation programs. This capacity already exists in the watershed. Financial resources include costs of staff time in installation or managing volunteers, and the costs of the inlet markers. Potential sources include existing programs (The Woodlands Township, Harris County), local government/organization funding, CWA §319(h) grant funding, neighborhood HOA funding, or private foundation funding.	Estimated costs include the markers themselves (average of $5 or less when bought in bulk), and time in installation (which will vary dependent on whether staff or volunteers are involved). Total costs depend on the extent of the implementation. Funding sources include existing programs (The Woodlands Township and Harris County provide marking kits upon registration), utility revenues, or non-governmental organization (NGO) partner funds.

Bacteria Reduction Capability
This activity is expected to have an indirect impact on bacteria, nutrients, sediment, and trash by providing structural outreach to residents. No specific reduction efficiency is assumed.

[86] Harris County maintains a Stormwater Inlet Marking program. More details can be found at: https://www.cleanwaterways.org/swim/

Urban Stormwater 2 – Investigate Drainage Channels			
Purpose: To identify and reduce illicit discharges in drainage areas with high bacterial loads.			
Description: This solution involves targeted reconnaissance of waterway and drainage channels by H-GAC or partner agency staff on foot to identify broken infrastructure, illicit discharges, or other pollutant sources. Illicit discharge detection is a minimum control measure for MS4 permits, but targeted reconnaissance based on high bacterial loads and coordination of follow-up to anything found would be efforts above and beyond permit requirements. The models for this recommendation are similar to TCEQ/Galveston Bay Estuary Program (GBEP) projects[87] identifying high bacteria load streams in the Houston urban area. This effort can be paired with monitoring activities. Areas along the I-45 corridor would be opportune sites.  **Priority Area(s):** I-45 corridor, urbanized areas, downstream attainment area			
Responsible Parties	**Period**	**Contaminant(s) Addressed**	**Status**
H-GAC; MS4s; Counties; TCEQ	Ongoing with focus on 2023-2027	Bacteria, Nutrients, Sediment, Trash	New or expanded effort
Technical and Financial Resources Needed			**Estimated Costs and Funding**
Technical resources include staff capacity in investigation of water and drainage channels. Enforcement data and knowledge from the counties and other jurisdictions would aid in choosing sites and channels. Financial resources include costs of staff time and travel expenses. Staff time would likely be only an incremental addition above a base cost for watershed facilitation in implementation by H-GAC or another lead agency (Section 6).			Estimated costs include hourly costs of $40-50 for staff time and overhead. Total costs depend on scale of effort. A $20,000 project could fund 200-300 hours of field investigation and follow-up. Funding sources include grants (CWA §319(h), GBEP, etc.), collaborations with MS4s, or existing partner resources.
Bacteria Reduction Capability			
This activity is expected to have an indirect impact on bacteria, nutrients, sediment, and trash by identifying potential sources, which would then be referred to responsible enforcement jurisdictions.			

Urban Stormwater 3 – Promote and Implement Riparian Buffers
Purpose: To reduce pollution from runoff by maintaining or restoring riparian buffers where appropriate.

[87] The Top 5/Least 5 project, among others, was a GBEP and H-GAC partnership project to detect potential sources of contamination in highly contaminated waterways, and those close to meeting the standard. The project was successful in identifying sources for several waterways in excess of MS4 permit requirements in the area, through targeted monitoring and reconnaissance.

Description: While much of the flow from urban areas enters waterways through MS4s, sheet flow from areas adjacent to the waterways can bring pollutants into the waterway over impervious surfaces. Maintaining a vegetated buffer (forest, native plantings, *etc.*) along waterways can slow storm flows, decrease erosion, filter pollutants, lower temperatures, increase DO, and provide other ecosystem services. When maintained in areas appropriate to drainage needs, riparian buffers are a natural, lower cost infrastructure solution. Implementation can take place on public or private land and use a mix of vegetative approaches. Urban forests and tree canopy within the watershed area can also help mitigate impacts of development. This solution is to maintain or restore areas of vegetative buffer in riparian areas and expand tree canopy in urban areas.

Priority Area(s): Riparian buffers throughout the watershed

Responsible Parties	Period	Contaminant(s) Addressed	Status
MS4s; Local Governments; Special Districts; Texas A&M Forest Service (forestry technical support); NGOs; Landowners	Ongoing-2030	Bacteria, Nutrients, Sediment, Trash	Expansion of ongoing efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources include staff capacity or partner support in design and installation of vegetative barriers (for restoration) or legal support for conservation easements or similar maintenance projects[88]. NGOs like Trees for Houston, American Forests, and Bayou Land Conservancy may be able to offer technical advice on riparian easement management. Financial resources vary depending on the size and type of project, but should consider ownership/acquisition costs, maintenance costs, and restoration costs. Funding sources are dependent in part on the applicant and property type. While this strategy will be implemented across the watershed, stakeholders are supportive of prioritizing the downstream attainment area.	Estimated costs vary greatly depending on the size and type of project. Funding sources include CWA §319(h) grants, NGO/endowment funding, TPWD grants, private land investment, or local government/MS4 funding.

Bacteria Reduction Capability
This activity is expected to have an indirect impact on bacteria, nutrients, sediment, and trash by providing filtration to sheet flow in stormwater runoff events. Filtration capacity is dependent on site-specific factors.

[88] Restoration or expansion of forested areas in and adjacent to riparian zones in urban areas should consider specific practices and resources available from the Texas Forest Service, available at: https://tfsweb.tamu.edu/LandownerAssistance

Urban Stormwater 4 – Promote Low Impact Development

Purpose: To reduce pollutants in stormwater flows through infrastructure that mimics or improves on natural hydrology.

Description: This solution involves promoting and implementing low impact development (LID) design and green infrastructure to filter, slow, and increase infiltration of stormwater runoff. H-GAC and local partners will promote LID through providing model materials on our website, coordinating with local and regional LID projects, and including LID as part of broader discussions of MS4 permits and new development. Local partners may elect to use LID practices in new institutional development (government buildings, parks, *etc.*) Focus areas for this solution are the denser portions of the downstream especially in areas of new development.

Priority Area(s): New developments, downstream attainment areas

Responsible Parties	Period	Contaminant(s) Addressed	Status
H-GAC; MS4s; Counties; Local Governments; Special Districts	Ongoing with focus on 2023-2027	Bacteria, Nutrients, Sediment, Trash	New or expanded effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources include staff capacity to facilitate discussions for promotion and staff capacity among local partners to implement LID projects. Financial resources of promotion include costs of staff time in developing and disseminating LID materials and coordinating discussion. Financial costs of implementing include the engineering, staff, and structural costs of each project which will vary widely by type and scale.	Cost estimates for promotion are included in the general duties of a watershed coordinator (see Section 7), and do not represent appreciable additional costs. Costs for implementation are dependent on the projects undertaken by local partners. Funding sources include local government revenues with potential grant supplement (CWA §319(h), *etc.*)

Bacteria Reduction Capability

This activity is expected to have a direct impact on bacteria, nutrients, sediment, and trash by providing structural barriers. However, reduction capacity is dependent on the practices used. No reduction is assumed specifically for this activity in the WPP.

Pet Waste

Waste from both pet and feral dogs is a substantial source of bacteria and nutrients in the Spring Creek watershed, especially in the more densely developed areas. The general focus of the recommended solutions is to enhance existing pet waste reduction efforts, install new structural elements, and promote spay/neuter programs to reduce unwanted populations. The implementation of these tasks is designed to focus on making pet waste reduction easy and visible to dog owners, especially in public places. In light of this, stakeholders recommended the following solutions:

- Pet Waste 1 — Install pet waste stations in local areas
- Pet Waste 2 — Add dog parks or dog areas in public places
- Pet Waste 3 — Hold spay/neuter clinics to reduce feral populations
- Pet Waste 4 — Increase enforcement of pet waste rules and ordinances

The focus of implementation for these solutions will be on public areas with high traffic from pet owners, including parks, trails, and large multi-family complexes. The priority areas are the urban centers and regional park areas, especially the developed portions of the downstream attainment areas adjacent to waterways. The recommendations are in supplement to existing pet ordinance enforcement by local governments and existing structural elements (pet waste stations, *etc.*). Grouping multiple stations at single locations increases ease of use and visibility.

Pet Waste 1 – Install Pet Waste Stations

Purpose: To reduce pet waste in runoff by encouraging pet owners to pick up after pets in public areas.

Description: Pet waste stations are a widely used, proven technology for reducing pet waste in public areas where dog owners bring their pets. The stations are cost-effective, with low maintenance aside from refilling bags as needed. This solution would install 40 or more pet waste stations in the watershed, which would be installed and continually maintained by the entity receiving them. The pet waste stations would be targeted for high traffic public areas in the watershed, such as the Spring Creek Greenway, other neighborhoods, and county parks, other recreational areas, and new development. Temporary stations at large events are another potential supplement to this effort.

Priority Area(s): Parks, neighborhoods and other high traffic areas, downstream attainment area

Responsible Parties	Period	Contaminant(s) Addressed	Status
Counties; Local Governments; HOAs; Apartment Complexes	Focus on 2023-2027 for installation; 2025-2030 for ongoing use	Bacteria, Nutrients	Expand on existing efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources required are limited to adequate staffing commitment to install and maintain the sites, functions within the scope of the partners' existing capabilities. Financial resources are needed for the purchase of the stations and initial materials (identified sources include existing funding from local partners, CWA §319(h) grants - wholly or in cost-share with partners, and private sector donations through H-GAC); installation and ongoing maintenance (staff time, provided by the receiving partner); and bag refills (provided by the receiving partner, or as appropriate under future grants). Alternative funding sources for initial materials include partnerships with local industry/commercial entities or park volunteer groups. The Partnership will explore with H-GAC the potential to participate in H-GACBuy[89] cooperative purchasing	Estimated costs for 40 pet stations include installation costs of $200 per station, $50 in bags, $200 in labor and materials (total $18,000). Maintenance is estimated at $300/year per station ($168,000 for 14-year period). The total cost is $186,000. Costs for mobile stations at events are variable. Funding sources include local government tax or utility revenues or grants from CWA §319(h) or other sources.

Bacteria Reduction Capability

The number of dogs impacted by this solution will vary based on the location. An average of 50 dogs a day per station served was chosen based on stakeholder description of high-traffic area parks. Assuming half of the dog's daily waste is served, full implementation of this solution would yield 2,000 dogs, or 1,000 representative units, addressed. This would represent a daily bacteria reduction of 2.5E+12 in riparian areas (300-foot buffer), and 6.25E+11 in areas outside the buffer based on SELECT assumptions.

Pet Waste 2 – Expand Dog Parks

[89] More detail about H-GAC's cooperative purchasing program can be found online at: https://www.hgacbuy.org/

Purpose: To provide additional areas for dog owners to bring dogs, to sequester waste and increase the likelihood of owners picking up waste.

Description: This solution would entail partners developing dog park/areas at their properties or developing new specific dog parks. Dog park areas already exist in the watershed (e.g., Cattail Dog Park, Tamarac Park, Rob Fleming Dog Park, Springwoods Village Dog Park). Heavily used recreation areas and other parks adjacent to waterways are prime locations for dog parks or off-leash areas with waste stations. Newly developing private communities with strong amenity focuses are also potential opportunities for expanded parks. Priority areas are based on highest potential use/traffic and population served.

Priority Area(s): New developments, downstream attainment area

Responsible Parties	Period	Contaminant(s) Addressed	Status
Counties; Local Governments; HOAs; Developers; Special Districts	One new park, 2023-2027; another park, 2025-2030	Bacteria, Nutrients	New and expanded effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources needed are sufficient staff capacity for park owners to evaluate potential expansion of dog areas, manage capital projects, and/or seek funding. Financial resource needs reflect the stages for which technical resources are needed. Identified sources of funding include internal revenue of the partners, grants from governmental sources and private endowments, and partnerships with private industry/organizations. Dog park costs are highly variable based on location and composition, and whether new land is acquired, or dog facilities are developed in existing parkland.	Cost estimates for new park acquisition in area plans range from \$500,000 to \$1,000,000+, whereas development of new facilities in existing parks range from \$50,000 to \$300,000. Funding sources include municipal revenues, CWA §319(h) grant funding, TPWD park grant funding, or foundation grants.

Bacteria Reduction Capability

This solution indirectly reduces waste, by sequestering it where it can be more easily addressed by owners and park staff. The number of dogs served is based on the number and scale of parks/park areas added. An assumption of 50% reduction of daily load per dog visiting the park is used based on stakeholder input.

Pet Waste 3 – Promote Spay and Neuter Events

Purpose: To reduce feral dog populations through reproductive controls.

Description: Spay and neuter programs are an effective means of curbing feral and unwanted pet populations[90]. The Partnership will work with a spay and neuter provider to hold local spay and neuter events or promote local services to pet owners through local governments, special districts, NGOs and HOAs. Potential models include existing spay and neuter programs in Harris County and NGOs like Friends For Life[91].

Priority Area(s): Urbanized areas, downstream attainment area

Responsible Parties	Period	Contaminant(s) Addressed	Status
Service provider (such as SPCA[92] or similar); Local Partners	2023-2030, every 5 years (2)	Bacteria, Nutrients	New effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical expertise would be provided by the existing spay/neuter program staff. Similarly, outreach materials already exist for these programs. H-GAC and partners will adapt materials as needed. Various providers have had mobile programs in the area. Financial resources needed include funding for the events from a combination of local government funds, other grant funding, or funding from private endowments, in addition to any contributions received from other interested partners. Funding for the spay/neuter of residential pets would be provided by the residents, or to some degree by the spay/neuter program itself based on its internal funding sources.	Costs estimates for Spay/Neuter education events are $5,000 per event, ($15,000 total) and spay/neuter costs for owners are $40-$150 per animal[93]. Funding sources include pet owners, local partner or non-profit funding, and grants.

Bacteria Reduction Capability
This solution's efficiency will vary based on the number of dogs addressed. A single female dog can have up to three litters a year or an average litter size of seven puppies, yielding up to thousands of dogs in five years or less[94]. Even with a low feral survival rate, this is an appreciable, if not directly quantifiable, reduction. The reduction of each average litter represents a 1.75E+10 daily source load reduction[95].

[90] Harris County has an existing Trap, Neuter, Release program for community (feral) cats. More details are available at: https://www.countypets.com/Pet-Resources/Community-Cat-Program
[91] More information on a model program by this NGO to curb pet populations in underserved communities can be found at: https://friends4life.org/programs-and-events/fix-houston/
[92] Society for the Prevention of Cruelty to Animals (SPCA)
[93] Based on cost estimates provided by the Houston Humane Society, available online at: https://www.houstonhumane.org/clinic/spay-neuter
[94] https://dogpages.net/health/how-many-puppies-do-dogs-have
[95] The reduction represents a total potential source load reduction and does not consider spatial location.

Pet Waste 4 – Consider Increased Enforcement

Purpose: To reduce pet waste through enforcement of existing or new ordinances or other restriction.

Description: Requirements to pick up pet waste vary throughout the watershed in both public and private areas. The focus of this solution is to provide model ordinances and outreach materials, as well as direct engagement, for entities considering increasing their enforcement. Specific attention will be given to apartment complexes and high traffic public areas, especially those adjacent to waterways.

Priority Area(s): Urbanized areas, downstream attainment area

Responsible Parties	Period	Contaminant(s) Addressed	Status
Local Governments; Special Districts; HOAs; Apartment Complexes	Ongoing-2030	Bacteria, Nutrients	New effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Limited technical resources are required for this solution. Model materials already exist and can be adapted as needed. Financial resources needed for the solution are primarily an issue for increased enforcement costs if active enforcement is conducted. Otherwise, costs are limited to staff time in developing and seeking approval for additional restrictions. A primary focus for this watershed is large apartment complexes. Existing models for multifamily property enforcement exist in the watershed.	Cost estimates for developing new ordinances or outreach materials will vary by scope and type. However, H-GAC maintains model materials on its website[96] as do partners like Harris County. Costs for increased enforcement will vary based on the entity involved and scope of enforcement. Funding sources for developing new enforcement or materials are expected to come primarily from the enforcing entity's existing revenue streams. Model materials already developed do not require additional funding.

Bacteria Reduction Capability

This solution is not a direct intervention, but a reinforcement or expansion of restrictions that serve to prevent wastes.

Dogs are a substantial portion of the modeled source load for Spring Creek. While they are concentrated most densely in the downstream area, they are present in good numbers throughout the watershed, and will be addressed by the preceding recommendations wherever opportunities lie. The Partnership's goal is to address dog waste proportional to the number of dogs in any subwatershed, but special attention will be given to riparian areas and high-use public facilities. Discussions during this WPP indicated there are a good

[96] http://www.h-gac.com/pet-waste-pollutes/default.aspx

number of public and private parks adjacent to the creek and its tributaries that would be good candidates for pet waste stations (including enhancement of existing stations), enforcement, or spay and neuter events (**Table 38**)[97]. Proposed siting of pet waste projects within the watershed to be implemented by 2030 includes additional units to convert in order to cover reduction loads from WWTFs, horses, deer, and the safety margin, as noted previously. Units to be addressed without accounting for loads from WWTFs, horses, deer, and the safety margin are represented in parentheses.

Table 38. Proposed siting for pet waste solutions to be implemented by 2030

Attainment Area	Units to Address, Total	Subwatershed	Units to Address, Subwatershed
Headwaters	7,780 (6,335)	1	1,951 (1,588)
		2	2,098 (1,708)
		3	525 (428)
		4	3,206 (2,611)
Downstream	24,533 (21,718)	5	5,105 (4,519)
		6	5,319 (4,709)
		7	6,861 (6,074)
		8	7,248 (6,416)

[97] The number of dog waste units designated to be addressed by subwatershed is based on each subwatershed's proportional contribution to the total pet waste load for its segment area. This proportion is applied to the reduction load for the segment area and divided by the load per BMP unit to produce the number of BMP units per subwatershed. As with other sources, the focus of implementation will continue to be on siting BMPs opportunistically to generate the greatest bacteria reduction for each segment area. Therefore, actual implementation in each subwatershed may differ from these targets based on opportunities and changing conditions in the watershed.

Agriculture

Agriculture maintains a small, declining presence in the watershed. Legacy agricultural areas in the headwaters attainment area maintain populations of livestock in addition to row crops. While modern agricultural practices are often efficient in reducing bacteria and nutrient transmission to waterways, loads from cattle, horses, sheep, and goats are still present in the watershed. Fertilizers are also a potential source of nutrient pollution, and pesticides and herbicides can impact macrobenthic communities and aquatic vegetation. The solutions identified by the Partnership focus on addressing wastes from livestock by expanding and supporting existing, successful programs by TSSWCB, USDA NRCS, and Texas A&M University AgriLife Extension (AgriLife Extension) and Research (AgriLife Research) in coordination with local producers and conservation efforts on agricultural lands by the Bayou Land Conservancy and other NGOs. The intent of these solutions is to provide financial assistance or technical resources for local producers to make voluntary improvements to their property and operations. These improvements are designed to be beneficial to the producer and to water quality. These recommendations recognize the benefits that well-run agricultural lands provide.

The solutions selected by the stakeholders include promoting and implementing voluntary, site-specific management plans for individual farms. The efforts will focus on implementing multiple solutions where appropriate. The focus areas for the solutions below are subwatersheds 1 and 2.

- Agricultural Operations 1 — Develop land management plans including TSSWCB WQMPs and NRCS Conservation Plans
- Agricultural Operations 2 — Implement other land management techniques through financial assistance and technical programs
- Agricultural Operations 3 — Implement horse manure composting program

Agricultural Operations 1 – WQMPs and Conservation Plans

Purpose: Provide technical and financial assistance to agricultural producers to plan and implement land management practices that benefit water quality.

Description: Both the USDA NRCS and TSSWCB offer agricultural producers technical and financial assistance for "on-the-ground" implementation. To receive financial assistance from TSSWCB, the landowner must develop a WQMP with the local SWCD that is customized to fit the needs of their operation. The USDA NRCS offers options for development and implementation of both individual practices and whole farm conservation plans. Priority for WQMPs and other projects will be given to management practices which most effectively control bacteria contributions to the waterways, with a focus on areas adjacent to riparian corridors. Based on site-specific characteristics, plans will include one or more of the TSSWCB's approved practices[98] including but not limited to filter strips, riparian buffers, prescribed grazing, and providing alternative shade and water. More information on the practices is included in Appendix C. Similarly, the USDA NRCS offers conservation planning services through its Conservation Technical Assistance (CTA) program[99] and financial assistance through its Environmental Quality Incentive Program (EQIP) and related programs. These services assist landowners to conserve resources and protect water quality by providing NRCS expertise and financial assistance. In addition to WQMPs and Conservation Plans, NRCS offers a broad range of other land and habitat management programs[100].

Priority Area(s): Agricultural areas concentrated in north Harris County, headwaters attainment area

Responsible Parties	Period	Contaminant(s) Addressed	Status
TSSWCB; SWCDs; USDA NRCS; Agricultural Producers/Landowners	Ongoing-2030	Bacteria, Nutrients, Sediments, Pesticides	Ongoing and expanded effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources required by this solution are the expertise of TSSWCB and USDA NRCS staff involved with their respective programs, and the local knowledge of the agricultural producers. Additional WQMP technician(s) may be needed to assist in plan development depending on demand. H-GAC and other partners will assist in promoting WQMPs to landowners. Financial resources required for this solution vary based on the type and scope of plan implemented. Costs for implementing WQMPs are borne in part by the landowner, and in part by TSSWCB, with up to $15,000 in financial assistance available for qualified WQMPs. Sources of funding for these costs include agricultural producer contributions and TSSWCB allocated funds. Resources for NRCS conservation plans and financial assistance programs include NRCS staff time and related costs, funding from EQIP and other programs, and contribution from the landowner. The funding for these costs is expected to come directly from the respective parties. WQMPs or other plans addressing an average of 50 livestock units will need to be implemented (**Table 36**).	Estimated costs for WQMPs include up to $15,000 per WQMP in financial incentives, with the landowner share of costs being variable. NRCS Conservation Plan costs are estimated at $2,000-$3,000 in NRCS staff time, with landowner costs being variable. Funding sources include existing programs (TSSWCB, USDA NRCS) and landowner funding.

Bacteria Reduction Capability

This solution's bacteria reduction capacity assumes a direct reduction of bacteria loading from lands covered by a WQMP/*etc*. The specific mix of efforts under a given project may affect the overall efficiency, in conjunction with the nature and location of the property.

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98 For more information, see: http://www.tsswcb.texas.gov/en/wqmp

99 For more information, see: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/cp/

100 For more information, see: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/

Agricultural Operations 2 – Maintain or Restore Riparian Buffers

Purpose: To reduce transmission of pollutants by slowing and filtering runoff from agricultural areas.

Description: Vegetative buffers (including filter strips and riparian forests) in areas adjacent to waterways are an effective means of reducing the transmission in runoff of wastes, organic materials, and nutrients from agricultural operations. This solution would seek to promote and implement voluntary landowner and public entity land management to increase the existing healthy riparian buffers of the watershed.

In addition to WQMPs and conservation plans, potential methods of implementation include the utilization of conservation easements held by land trusts, voluntary individual landowner implementation, or participation in a USDA NRCS Farm Bill program (*e.g.*, EQIP or similar). Priorities for this solution are maintaining and expanding buffers in the headwaters attainment area.

Priority Area(s): Riparian areas, headwaters attainment area

Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners/producers (on a voluntary basis); NGOs; Agricultural Agencies	Ongoing-2030	Bacteria, Nutrients, Organic Wastes, Pesticides	Expanded existing effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resource needs include staff capacity at support agencies to provide technical services and knowledge to landowners. Funding resources for this solution are projected to be a mix of landowner costs (including opportunity costs of acreage removed from production and actual costs of installation and/or maintenance); funding under applicable financial incentive programs (WQMP; USDA NRCS Farm Bill programs); and existing staff capacity among support agencies in staff time and travel costs. If used in conjunction with conservation easements, legal and staff costs include establishing and maintaining the easement, potentially through conservation NGOs.	Cost estimates are variable with type and extent of buffer. Costs may be limited to simply not mowing an area (opportunity cost of productive acreage) to restoration/plantings. Funding sources include established programs and property owner contributions.

Bacteria Reduction Capability

Efficiency will vary based on the extent and size of the barrier and its composition. Reduction estimates for fecal bacteria range from 50%[101] to 95%[102].

[101] Rifai, H. 2006. Study on the Effectiveness of BMPs to Control Bacteria Loads. Prepared by University of Houston for TCEQ as Final Quarterly Report No. 1.
[102] Larsen, R.E., R.J. Miner, J.C. Buckhouse and J.A. Moore. 1994. Water Quality Benefits of Having Cattle Manure Deposited Away from Streams. *Biosource Technology* Vol. 48 pp 113-118.

Agricultural Operations 3 – Implement Horse Manure Composting Program

Purpose: To reduce transmission of wastes from non-agricultural horses through collection and composting of wastes.

Description: Recreational horse (*i.e.*, horses not attached to an agricultural operation) ownership is prevalent in the watershed, with several stabling operations in the watershed.

Horse manure is well suited for composting[103] under correct conditions. The Partnership will work with local government, stabling operations, and commercial partners to implement a horse manure composting program to reduce manure piles at existing operations and potentially produce a viable commodity[104] or resource to defray program costs. This will involve a mix of centralized, collected compost and composting sites at individual operations. This solution is focused on stabling operations throughout the watershed.

Priority Area(s): Stabling operations throughout the watershed

Responsible Parties	Period	Contaminant(s) Addressed	Status
Horse Owners; Stabling Operations; Commercial Facilities	Ongoing-2030	Bacteria, Nutrients	New effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical expertise required includes staff capacity of local partners to develop and maintain a composting program and logistics and assist sites with developing composting infrastructure and operations. Potential technical support could be obtained from AgriLife Extension or other partner programs. Financial resources needed will depend on the nature of the final program elements. Estimates for built facilities for a single site vary widely from hundreds of dollars for simple pile systems[105] to tens of thousands for more complicated building structures. Funding for individual site systems may be available from agricultural agencies. A commercial venture with a private or NGO partner may not require additional funding if it utilizes existing capacity.	Costs estimates assume existing staff capacity (at $40-$50 total hourly cost per employee) and resources (vehicles). Funding sources include local government revenue and manure compost sales.

Bacteria Reduction Capability

Efficiency will vary based on the extent of operations. Removal of unmanaged manure is assumed at 100% reduction. Effectiveness may benefit from voluntary audits of facilities to identify priority operations.

[103] For more, see: https://agrilifeextension.tamu.edu/library/ranching/composting-horse-manure/
[104] A variety of estimates on the marketability of composted manure exist. An example is the discussion of value and logistics found in industry publication Stable Management at: https://stablemanagement.com/articles/making-money-on-manure#:~:text=Automated%20Composting&text=This%20greatly%20reduces%20the%20labor,time%20with%20Moon%20as%20needed
[105] An example of a low cost aerobic pile system for a single site can be found here: https://ag.umass.edu/sites/ag.umass.edu/files/fact-sheets/pdf/low_cost_equine_manure_composting_16_01.pdf

Feral Hogs, Deer and Other Wildlife

Feral hogs are a potential source of bacteria in watersheds, especially those with large rural areas. Within this general category of wildlife and non-domestic animals, feral hogs are the primary focus of this WPP because of their relatively high bacteria concentration, the other damages they create, and the availability of feasible solutions to address them[106]. Other animals included in this WPP's estimates of loading for deer and other wildlife[107] sources are not intended to be addressed specifically by this WPP, primarily for lack of effective solutions and stakeholder preference in addressing other sources.

There are ongoing discussions at the state and national level about effective methods to address feral hogs. The recommendations of this WPP focus on solutions within the scope of local implementation, and already known to be best practices. The focus of implementation for the feral hog solution will be in agricultural and open space areas in which feral hog damage is a potent incentive for landowner participation. Reduction of feral hogs is expected to derive directly from landowner efforts, as supported by partner agencies through information and technical services, although the Partnership recommends that local and state governments consider active involvement in feral hog reduction efforts.

While the WPP does not specifically seek to address deer and other wildlife, the stakeholders considered the benefit of providing alternative habitat away from riparian areas to reduce population densities and time spent near waterways. The wildlife solution presented here represents that indirect focus.

The focus for these solutions is watershed-wide, with special attention paid to localized hog problems, or conservation opportunities may exist in the watershed. To one degree or another, hog, deer, and other wildlife populations are found throughout the project area. For feral hogs, deer, and other wildlife, stakeholders recommended the following solutions:

- Feral Hogs 1 — Remove feral hogs
- Wildlife 1 — Conserve or restore upland habitat
- Wildlife 2 — Manage feeding

The Partnership's approach to the feral hog, deer and other wildlife source category includes a strong corresponding focus on education and outreach recommendations, as detailed in Section 6.

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[106] Contributions from deer were also modeled, but the Partnership does not recommend direct solutions for deer due to a lack of feasible solutions or means to achieve them.
[107] Included in the safety margin.

Feral Hogs 1 – Remove Feral Hogs

Purpose: To encourage landowners and local governments to directly reduce feral hog populations through trapping and hunting.

Description: This solution seeks to reduce feral hog populations in the watershed through active hunting and trapping. The primary focus of this effort is on voluntary efforts from individual landowners, but the Partnership recommends abatement activities on behalf of local governments, as appropriate.

Priority Area(s): Watershed-wide

Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners; Local Governments; Special Districts; Agricultural Agencies (technical support)	Ongoing-2030	Bacteria, Nutrients	Expansion of existing efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources needed for this solution are advice and support for landowners engaged in feral hog abatement, and technical knowledge on behalf of the landowners themselves. The primary agency providing technical support on feral hog issues is AgriLife Extension. Financial resources of this project include the staff time and related costs of the partner agencies, and the cost of implementing solutions borne primarily by the landowners on a voluntary basis. No grant funds have been identified to supplement these contributions. Potential other resources include leasing property to hog hunting at a potential net gain of costs.	To reduce an estimated 1,694 hogs, 339 traps would be needed (assuming each trap serves to reduce five hogs). With an average cost of $1,000 for a medium sized trap, this would represent an annual cost of $339,000[108], not inclusive of staff/landowner time. Funding sources include local government and property owners. No specific grant resources were identified for this solution.

Bacteria Reduction Capability

This solution nominally reduces feral hog waste by a maximum daily *E. coil* load of 4.45E+9 for each hog reduced, representing a 100% efficiency. However, this may not account for the volatility of hog population dynamics in which lost members may be replaced through reproduction in excess of population maintenance and does not consider SELECT spatial discounting of source load contributions.

[108] The solution covers a range of practices from hunting to trapping. Assumptions of trap usefulness and costs are based on stakeholder feedback on success rates, and review of varying trap options and pricing. Costs vary from single animal small box traps at $400 to automated drop corral traps at $4000-$5000. Costs do not include time, feed, and other elements. The estimate given should be considered conservative due to the capability of feral hog populations to breed rapidly up to (or beyond) the carrying capacity of the areas they inhabit. Rates of removal below 75% are not likely to have a net reduction of feral hog populations.

Wildlife 1 – Conserve or Restore Upland Habitat

Purpose: To encourage landowners, NGOs, and local governments to conserve and restore upland habitat to relieve wildlife pressures on riparian areas.

Description: This solution seeks to encourage voluntary conservation and restoration of upland habitat away from riparian areas to provide suitable habitat for wildlife away from riparian areas. This solution is intended to coordinate directly with the conservation and land management solutions found later in this section, and will be based on the same approaches, partners, and technical/financial needs.

Priority Area(s): Headwaters attainment areas

Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners; NGOs; Local Governments; Agricultural Agencies (technical support); Developers	Ongoing-2030	Bacteria, Nutrients, Sediment, Flooding	Expansion of existing efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
The primary technical resources needed for this solution are staff capacity for pursuing and implementing voluntary conservation projects or ecosystem restoration. Potential technical resources include existing NGOs in the watershed (*e.g.*, Bayou Land Conservancy), agricultural agencies, and local governmental staff (*e.g.*, county precincts already involved in habitat conservation in parks and public areas like Harris County Precinct 4). Financial resources needed are dependent on the scale. Costs may be limited to opportunity costs of unrealized development potential (conservation), or costs associated with physical remediation of property (restoration). Existing efforts in the watershed provide a basis for estimating costs of restoration activities specific to the western watershed land cover types. New development is an opportunity to increase set asides.	Cost estimates vary based on scale and type of conservation or restoration and area. Funding sources include agricultural agencies (*e.g.*, USDA NRCS Farm Bill programs), other grants, and local governmental or NGO funding (including private donation and in-kind donation of land value from property owners).

Bacteria Reduction Capability

This solution is not intended to directly impact sources, but is expected to generally reduce feral hog, deer, and other wildlife time in riparian areas by providing alternative range. Due to the wide variety of species this may impact, and the potential variety of lands involved, no specific reduction potential can be generated. However, this solution is modeled after existing agricultural best practices designed to reduce cattle time adjacent to streams by providing alternative water/shade. It will contribute to the general reduction of these sources.

Wildlife 2 – Manage Feeding			
Purpose: To encourage landowners to mitigate wildlife concentrations near riparian buffers and avoid attracting invasive species.			
Description: This solution seeks to encourage voluntary implementation of exclusionary devices around deer feeders to deter invasive species such as feral hogs[109]. These measures are especially recommended near riparian areas to avoid concentrating invasive species populations and their waste near waterways. The primary focus of this effort is on voluntary efforts from individual landowners across the watershed. **Priority Area(s):** Populated areas near riparian buffers, downstream attainment area 			
Responsible Parties	**Period**	**Contaminant(s) Addressed**	**Status**
Landowners; Agricultural Agencies (technical support)	Ongoing-2030	Bacteria, Nutrients	New effort
Technical and Financial Resources Needed			**Estimated Costs and Funding**
Technical resources needed for this solution are advice and support for landowners, and participation from the landowners themselves. The primary agency providing technical support on wildlife and feral hog issues is AgriLife Extension. Financial resources of this project include the staff time and related costs of the partner agencies, and the cost of implementing solutions borne by the landowners on a voluntary basis. No grant funds have been identified to supplement these contributions.			Costs for 100 feet of 28" fencing vary between $250-S300 depending on materials, and do not include landowner time. Funding for these measures would come from property owners. No specific grant resources were identified for this solution.
Bacteria Reduction Capability			
This solution is not intended to directly impact sources but is expected to generally reduce feral hog and other wildlife time in riparian areas by discouraging the formation of resident populations of invasive species. Due to the wide variety of species this may impact, and the potential variety of lands involved, no specific reduction potential can be generated.			

[109] For more information, see: https://wildpigs.nri.tamu.edu/media/1153/l-5533-using-fences-to-exclude-feral-hogs-from-wildlife-feeding-stations.pdf

Other Concerns

In addition to the practices recommended for specific sources in the preceding pages, the Partnership recommends several solutions to other local concerns. The recommendations fall into three primary categories:

- Conservation and Land Management
    - Conservation and Land Management 1 — Riparian buffers
    - Conservation and Land Management 2 — Voluntary conservation
    - Conservation and Land Management 3 — Increase Tree Canopy
- Trash/Illegal Dumping
    - Illegal Dumping 1 — Report Chronic Dump Sites and Consider Increased Enforcement
- Flooding
    - Flooding 1 — Coordinate with Ongoing Flood Mitigation Efforts

Conservation and land management activities relate to conserving or developing natural barriers to pollutants entering the water body. These solutions are approached on a voluntary basis. Prioritization is placed on areas adjacent to riparian corridors in the watershed but may include open space areas in the watershed in general. Areas appropriate for restoration activities in more developed areas may also be targeted for conservation activities (*e.g.*, increasing tree canopy, restoring riparian vegetation). Conservation practices recommended by this WPP are wholly limited to voluntary landowner decisions supported by resources from local government, landowners, and conservation NGOs (*e.g.*, Bayou Land Conservancy), and the Partnership. This WPP makes no recommendations concerning recreational trails or development; its sole focus in this category is improving water quality by maintaining or restoring ecosystem services from conserved land. A variety of successful, model conservation activities exist in the watershed.

Trash and illegal dumping are a visible impact on local waterways and were a secondary focus of the Partnership. The WPP's role in trash reduction is primarily in support of the efforts of other agencies or efforts (*e.g.*, local MS4s as part of Texas Pollutant Discharge Elimination System (TPDES) permit activities). Illegal dumping is the primary focus for the Partnership under this category.

Flooding is another concern for the Spring Creek community. The focus of this WPP will be to coordinate with and support the advancement of flood mitigation activities, with an eye toward advocating for inclusion of water quality features.

These recommendations are supplementary to ongoing efforts by the area's local governments, organizations, and MS4s relating to these issues.

Conservation and Land Management 1 – Riparian Buffers			
Purpose: To reduce transmission of bacteria, nutrients, trash, and sediment to waterways by maintaining or implementing vegetated buffers in riparian corridors.			
Description: This solution is supplementary to Urban Stormwater 3 – Promote and Implement Urban Riparian Buffers and Agricultural Operations 2 – Maintain and Restore Riparian Buffers, with a focus on non-agricultural areas.  This solution would engage local landowners and local governments to install and/or maintain vegetative buffers along waterways and drainage channels (as appropriate based on drainage needs). Implementation will differ widely in type and scale. Support for these efforts will be provided for residents by the same agencies and partners indicated in the urban and agricultural versions of this solution. This solution focuses specifically on current and new developments in the headwaters area. **Priority Area(s):** Current and new developments, headwaters area			
Responsible Parties	**Period**	**Contaminant(s) Addressed**	**Status**
Landowners; NGOs; Counties; Local Governments; Special Districts; Agricultural Agencies	Ongoing, with focus on 2023-2025 to prevent degradation	Bacteria, Nutrients, Sediment, Flooding	Expansion of existing efforts
Technical and Financial Resources Needed			**Estimated Costs and Funding**
Technical resources needed for this solution include the existing programmatic resources and staff expertise of the partners identified above, which are considered sufficient to meet this need. Financial resources needed for this solution include the staff resources and landowner contributions previously detailed for the other versions of this solution. Other costs include opportunity costs related to lost property value.			Cost estimates are variable depending on type, size, and location of buffer. Savings in maintenance (mowing, *etc.*) may counter some potential costs. H-GAC offers a riparian buffer planning tool for landowners to estimate potential costs[110]. Funding sources include local government revenues (public buffers), landowner funding, or NGO/local partner funding.
Bacteria Reduction Capability			
This solution's efficiency will vary greatly based on the type, and extent of riparian buffer and local area. Nutrient/sediment removal may be a greater benefit than bacteria removal based on existing literature. However, some literature values indicate fecal bacteria removal rates more than 80-90%[111].			

[110] Available at: http://www.h-gac.com/riparian-buffer-tool/default.aspx
[111] See references under Agricultural Operations 2

<table>
<tr><th colspan="4">Conservation and Land Management 2 – Voluntary Conservation</th></tr>
<tr><td colspan="4">Purpose: To reduce transmission of bacteria, nutrients, trash, and sediment to waterways through voluntary land conservation.</td></tr>
<tr><td colspan="4">Description: This solution is intended to represent the range of efforts and need for increased voluntary conservation projects as a mitigating factor for changing land use. This solution has three primary facets:

• Individual conservation — voluntary efforts by local landowners (including commercial properties) to manage property to maintain natural value, alone or with other entities
• Organizational projects — projects by the local governments, special districts, and NGOs in the watershed to implement voluntary conservation projects
• Developer-driven projects — projects or supplemental elements in new development that maintain or restore natural function or mitigate impacts.
The primary focus of this solution is the headwaters area, especially in riparian corridors and projects like the Spring Creek Greenway.

Priority Area(s): Spring Creek Greenway, riparian areas, headwaters attainment area</td></tr>
<tr><th>Responsible Parties</th><th>Period</th><th>Contaminant(s) Addressed</th><th>Status</th></tr>
<tr><td>Landowners; NGOs; Counties; Local Governments; Special Districts; Agricultural Agencies</td><td>Ongoing-2030</td><td>Bacteria, Nutrients, Sediment, Flooding</td><td>Expansion of existing efforts</td></tr>
<tr><th colspan="3">Technical and Financial Resources Needed</th><th>Estimated Costs and Funding</th></tr>
<tr><td colspan="3">Technical resources needed for this solution include the existing programmatic resources and staff expertise of the partners identified above, which are considered sufficient to meet this need.

Financial resources needed for this solution include the staff resources or individual landowner resources to develop and maintain conservation easements or conservation lands, including staff time, easement or land acquisition costs, and ongoing maintenance funding.</td><td>Cost estimates are variable depending on type, size, and location of properties. Tax savings may offset potential lost land value in easements.

Funding sources include existing project funding[112], new grant sources; developer funding or in-kind value for land set-asides or remediation, and additional investment by public and private partners.</td></tr>
<tr><th colspan="4">Bacteria Reduction Capability</th></tr>
<tr><td colspan="4">This solution's efficiency will vary greatly based on the type, and extent of conserved lands. No specific reduction efficiency is assumed. Reduction is based on the difference between transmission rates of developed land uses and natural land uses. The value of the land conserved and the potential alternative use for the land (suburban development, etc.) determine the difference in potential transmission.</td></tr>
</table>

[112] Projects of note in the watershed include the Spring Creek Greenway project; existing conservation efforts by prominent NGOs (Bayou Land Conservancy), and current partnership opportunities being sought with USDA NRCS and other federal funding sources.

Conservation and Land Management 3 – Increase Tree Canopy			
Purpose: To reduce transmission of bacteria, nutrients, trash, and sediment to waterways by increasing trees in the watershed.			
Description: Trees and tree canopy provide a highly beneficial set of ecosystem services, including increased flood retention and interception by canopy, improvements to air and water quality, decreased heat impacts to waterways, decreased erosion, *etc.* There are a variety of efforts underway in the region to increase the use of trees as natural infrastructure for water quantity and quality.  Stakeholders coordinated with Texas A&M Forest Service and other forestry programs to identify adjacent efforts and practices that would address fecal waste and other concerns. Based on preliminary i-Tree Hydro modeling by Texas A&M Forest Service[113], increasing the number of trees and canopy in the watershed would have appreciable impact on stormwater and associated pollutants, especially in developed portions of the downstream area. This solution will include Partnership support for existing forestry efforts by watershed counties, the Bayou Land Conservancy, and agricultural/silvicultural agencies; and seek to supplement them with additional support in identifying funding, promoting urban forestry to local partners, and partnering on tree planting events where appropriate. A key focus will be coordinating with new development to promote increased tree canopy where appropriate. **Priority Area(s):** Opportunistic placement with a focus on urbanized areas			
Responsible Parties	**Period**	**Contaminant(s) Addressed**	**Status**
Landowners; NGOs; Counties; Local Governments; Special Districts; Agricultural Agencies; Developers	Ongoing, with focus on 2023-2027 to prevent degradation	Bacteria, Nutrients, Sediment, Flooding	Expansion of existing efforts
Continued on Next Page			

[113] Texas A&M Forest Service project liaison Mac Martin worked with H-GAC project staff to provide modeling information on the impact of increased tree canopy and numbers in various areas of the watershed. The purpose of this modeling effort was to provide their technical support in identifying priorities and potential impacts of tree plantings as a land management best practice. The modeling was done with i-Tree, by Texas A&M staff and therefore was not covered under this project's QAPP. The data from this model is not being used to develop reduction goals or removal assumptions as it was not quality assured by this project. However, i-Tree is an established forestry modeling package, and the results are valuable information for potential implementation of this solution.

Conservation and Land Management 3 – Increase Tree Canopy, Continued	
Technical and Financial Resources Needed	**Estimated Costs and Funding**
Technical resources needed for this solution include the existing programmatic resources and staff expertise of the partners identified above. Additional i-Tree modeling may be used to further refine benefits of tree canopy increases at varying locations or percentage increases in canopy. The Partnership will rely on Texas A&M Forest Service, local NGOs, USDA NRCS, and other subject experts for identifying opportunities and potential funding sources. The Partnership will seek to coordinate with existing large-scale planting programs and flood mitigation efforts, including those of the Harris County Precinct 4 to take advantage of existing organizational capacity. Financial resources needed for this solution include the staff resources to manage tree plantings or restoration projects, and the physical costs of the materials for these efforts.	Cost estimates are variable depending on the type and size of forestry practice implemented. Tree costs vary greatly by size, with stock material and labor for a single planting of a 5-gallon tree potentially costing $100 for a small-scale effort, with a large economy of scale for greater efforts that involve cost saving measures like volunteers and corporate donations. Funding resources include a wide variety of grant resources including existing operating resources of flood control entities, forestry agencies, and other technical experts. Potential funding sources should consider the related flood mitigation impacts and associated funding sources that may be available.
Bacteria Reduction Capability	
This solution's efficiency will vary greatly based on the type, and extent of tree planting or restoration practice, its proximity to the riparian areas of the watershed, and the nature of the surrounding land use. Nutrient/sediment removal may be a greater benefit than bacteria removal based on existing literature regarding riparian buffers and tree benefits in general. However, as nonpoint sources are a leading cause of *E. coli* loads in the watershed, and tree benefits include stormwater flow reductions, additional trees should provide a benefit.	

The watershed has extensive existing conservation activity, with the Bayou Land Conservancy maintaining large preserves in the downstream area, local governments like Harris County who have done extensive work on public lands adjacent to the riparian, and a network of other NGOs and local partners. Ongoing efforts by these and other partners form the backbone of conservation efforts in the watershed and are an important aspect of water quality and flood mitigation efforts.

Developers in the watershed stand to play a large role in the future use of natural systems for water quality and flood mitigation. Specific focuses of these voluntary conservation measures include establishing wetland areas in wet or dry detention facilities or including wetland plantings in floodplain mitigation ponds along the corridor. Wetland areas in detention or mitigation facilities can add water quality improvement using existing infrastructure. In large master-planned communities, the ability or desire to use floodplain mitigation ponds as wetland structures would add appreciable water quality benefit without requiring additional land. The Partnership recommends continued exploration with public and private partners into opportunities to expand required elements with voluntary, incremental improvements that benefit water quality. These recommendations are also relevant for the Urban Stormwater 4 – Promote Low Impact Development recommendation to the extent existing facilities in developed areas can add natural elements.

<table>
<tr><th colspan="4">Illegal Dumping 1 – Report Chronic Dump Sites and Consider Increased Enforcement</th></tr>
<tr><td colspan="4">Purpose: To reduce trash in waterways at chronic dump sites by encouraging reporting and increased enforcement.</td></tr>
<tr><td colspan="4">Description: This solution is intended to augment existing county and local efforts to reduce illegal dumping in the following ways:
• Encouraging reporting (see Section 6 for outreach elements)
• Coordinating between the Partnership and local enforcement to ensure reporting for sites
• Consider using cameras to identify dumpers[114]
The solution targets the downstream area, where problem areas were identified by the stakeholders. The primary focus of this solution is chronic dump sites, with emphasis on those adjacent to or near waterways.


Priority Area(s): Kenswick Forest subdivision, downstream attainment area</td></tr>
<tr><th>Responsible Parties</th><th>Period</th><th>Contaminant(s) Addressed</th><th>Status</th></tr>
<tr><td>Counties; Local Governments; H-GAC; Landowners</td><td>Ongoing-2030</td><td>Trash</td><td>New and expanded efforts</td></tr>
<tr><th colspan="3">Technical and Financial Resources Needed</th><th>Estimated Costs and Funding</th></tr>
<tr><td colspan="3">Technical resources needed for this solution are local enforcement capacity, especially through the counties, to respond to reports and enforce violations. Enforcement capacity already exists in the watershed. Technical resources for potential camera-based enforcement would require staff capacity to install, operate and maintain the cameras. The camera systems are relatively simple to install and operate and are assumed to be within existing staffing capacity.

Financial resources needed for this solution include staff time for local enforcement (variable) and costs of camera technology, which may be eligible for existing solid waste grant programs through H-GAC and other sources.</td><td>Cost estimates include the incremental costs to local enforcement, which will be dependent on extent of use; Prior camera programs have spent approximately $500- $1,000 a unit for high end equipment and maintenance.

Funding sources include local government revenues and solid waste grant programs.</td></tr>
<tr><th colspan="4">Bacteria Reduction Capability</th></tr>
<tr><td colspan="4">This solution is not expected to directly address bacteria, although it may be an ancillary benefit.</td></tr>
</table>

[114] While not currently funded, H-GAC and other local partners have successfully utilized camera systems for illegal dumping curtailment in the past. The relatively low cost of camera systems provides an efficient way to monitor problem areas.

Flooding 1 – Coordinate with Ongoing Flood Mitigation Efforts

Purpose: To promote water quality elements in flood mitigation projects and share resources among adjacent efforts.

Description: Flooding is a common issue in the Spring Creek Watershed. In addition to area-wide studies by the USACE and Harris County Flood Control District[115], there are several flood mitigation projects underway such as the Harris County Flood Control District's 2018 Bond Program projects[116].

This solution focuses on areas where flood planning and projects are active and seeks to coordinate WPP efforts with flood mitigation efforts, including the promotion of water quality elements or considerations in these projects. The Partnership will seek to coordinate with new development on water quality features for drainage and detention, as appropriate.

Priority Area(s): Areas where flood planning and projects are active

Responsible Parties	Period	Contaminant(s) Addressed	Status
Harris County Flood Control District; Special Districts; Local Governments; Counties; NGOs	Ongoing-2030	Bacteria, Nutrients, Sediment, Flooding	Current and expanded efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources needed for this solution are primarily found on the flood mitigation entities' side, with the primary WPP role being to coordinate water quality efforts with their work. Continued facilitation of the Partnership would help provide those technical skills, but local technical partners like the Harris County Flood Control District are already actively engaged in these projects. Other potential points of coordination include the Regional Flood Mitigation Committee[117], and the newly formed San Jacinto River Regional Flood Planning Group. Financial resources needed for the Partnership's role are primarily staff time for coordination.	Costs estimates are limited to staff time, scaled as necessary to coordinate effectively with the intended efforts. This is conservatively estimated at approximately 10-20 staff hours per year. Funding sources include new grants for WPP implementation (CWA §319(h), etc.) or local partner contributions.

Bacteria Reduction Capability
This solution is expected to directly and indirectly address fecal waste and other water quality concerns, although it may be a wholly ancillary benefit. Rates of reduction from detention facilities and other flood mitigation projects will vary widely based on the project type. However, several studies[118] have shown appreciable impacts of wet bottom detention and other mitigation practices that incorporate natural infrastructure of natural elements on nutrients and, to a lesser degree, *E. coli*.

[115] Including the San Jacinto Regional Watershed Master Drainage Plan. More information can be found at: https://www.hcfcd.org/Activity/Active-Projects/San-Jacinto-River/C-17-San-Jacinto-River-Watershed-Study
[116] The updated status of projects under the 2018 Bond Program can be found at: https://www.harriscountyfemt.org/cb
[117] http://www.h-gac.com/board-of-directors/advisory-committees/regional-flood-management-committee/default.aspx
[118] Including studies from North Carolina (http://lshs.tamu.edu/docs/lshs/end-notes/indicator%20bacteria%20removal%20in%20stormwater%20bmps%20in%20charlotte,%20nc-3678140698/indicator%20bacteria%20removal%20in%20stormwater%20bmps%20in%20charlotte,%20nc.pdf), and Virginia (Clary, J., R. Pitt, and B. Steets, eds. 2014. *Pathogens in Urban Stormwater Systems*. Reston, VA: ASCE. 289 pp.), among others.

H-GAC and other local partners have an active role in both water quality and flood mitigation programs and will continue to seek opportunities to represent water quality concerns in efforts to curb flooding. The Partnership will specifically seek to identify funding opportunities under several of the large disaster mitigation resources available currently and for the short term, including:

- Community Development Block Grants (mitigation funding opportunities related to 2015, 2016, and Hurricane Harvey competitions),
- Texas Water Development Board Flood Infrastructure Fund, and
- Various Federal Emergency Management Agency (FEMA) disaster mitigation programs.

Solutions Summary

The recommended solutions presented in this section are intended to meet the *E. coli* reduction goals defined in Section 4 and to also reduce nutrient sources, or to address other local water quality concerns not specifically related to the primary pollutants. The solutions represent a variety of options for each primary source, which will be scaled to address the number of representative units identified for each source, in each attainment area.

These recommendations were developed and vetted by a diverse stakeholder group as part of a locally led decision-making process. However, the WPP recognizes that additional efforts are ongoing in the watershed that will be complementary to the recommended solutions. These recommendations are not intended to be exclusive of other potential stakeholder projects and efforts that serve the same goals. They represent areas of overlapping concern and agreement among the various interests of the Partnership. It is expected that the toolbox of solutions will change over time as part of local priorities and the adaptive management process.

Further efforts to engage and educate the public are reflected in Section 6, and specifics about the timelines and logistics of implementation are discussed in Section 7.

Section 6

Education and Outreach

Photo Credit: Jessica Casillas

Section 6. Education and Outreach

Engaging the general public, key project partners, and specific targeted audiences is a crucial component of ensuring the success of the WPP. This section outlines the various educational programs, outreach efforts, and related strategies the Partnership will use to support the implementation of this WPP. The purpose of these efforts is to ensure ongoing stakeholder involvement in the effort as well as to increase public awareness of the water quality issues faced by their community. The recommended engagement elements are presented by the solution category they support.

Engagement Strategies

In keeping with the water quality goals and guiding principles of this WPP, the strategies for engaging with the public are designed to reflect the specific character and needs of the local communities. These strategies provide general guidance for the implementation of the activities discussed in this section.

- **Strategy 1: Facilitation** — To ensure the continuity of the effort and a consistent point of coordination, a designated facilitator(s) will oversee the early implementation of the WPP (see General Outreach below).
- **Strategy 2: Existing Resources** — To maximize the use of resources and effectively reach existing stakeholder bases, the Partnership will endeavor to use existing communication networks and work within existing outreach opportunities and partners as one of the tools to further project goals.
- **Strategy 3: Audience-specific Messaging** — While some outreach is aimed at a broad base of potential stakeholders, the Partnership will focus on making sure its message for individual groups, communities, etc. is tailored to the specific needs and concerns of that group. The underlying assumption in this strategy is that messages are best received when they have an overlapping nexus of value with the audience. A key focus in the watershed is emphasizing the WPP's respect for private property and voluntary solutions.
- **Strategy 4: Adjacent Efforts** — The density of other efforts planned or ongoing in the watershed provides a wealth of opportunities to build connections and benefits from shared resources with adjacent efforts from practice areas like forestry, flood mitigation, and conservation. As with the implementation of solutions, public engagement efforts will seek to build on work of adjacent programs wherever appropriate and seek to cross-promote water quality messages with communication networks of other practice areas.

Figure 48. Outreach at a local event

General Outreach

The Partnership is one of many organizations working toward similar goals in the watershed but focused primarily on the specific aims of the WPP. A fundamental aspect of ensuring implementation success and community support is to promote public awareness and interest in the watershed and the WPP. To accomplish this goal, the Partnership must maintain itself as an active organization, continue to build its "brand" among the public, represent the watershed among regional and state organizations, and seek to coordinate with related efforts to the greatest degree possible. The Partnership will not supplant existing efforts but will support them however possible while seeking opportunities to expand or enhance links to water quality and the goals of the WPP.

Maintaining the Partnership

The Partnership will maintain its varied composition and strong local commitments through continued facilitation of an active group by H-GAC and TCEQ. The importance of this effort is to continue the use of the Partnership as a platform for coordination of watershed efforts. Meeting this goal will require:

- Periodic meetings of the Partnership (at least twice a year),
- Dissemination of information regarding WPP activities among stakeholders through e-mail, newsletters, and/or other appropriate channels (*e.g.*, social media), and
- Individual meetings with strategic partners to maintain commitments and coordinate efforts.

Building the Brand

The Partnership must maintain visible representation of its specific goals in the eyes of the public. To accomplish this goal, the Partnership will:

- Maintain a presence at local events and meetings to share information on the Partnership, and the goals of the WPP,
- Maintain and expand Texas Stream Team monitoring sites and trainings,
- Continue to maintain the project website and expand social media presence,
- Actively support local partners, and
- Seek to build relationships with adjacent practice areas of forestry, conservation, and flood mitigation.

Coordination

The Partnership is one of many watershed-based groups in the area, state, and nation. Finite resources and overlapping areas of interest make coordination of partner efforts a vital part of the WPP which the Partnership will carry out by:

- Participating in and collaborating with groups like the Texas Watershed Coordinator's Roundtable, Regional Watershed Coordinators Steering Committee, Galveston Bay Estuary Program, Clean Rivers Program, and others,
- Supporting other area efforts like the Cypress Creek WPP, the West Fork San Jacinto River and Lake Creek WPP, and the various TMDL projects represented by the Houston Area Bacteria Implementation Group,
- Identifying and/or pursuing funding opportunities that would assist local partners in opportunities of shared interest, and
- Seeking additional data necessary to inform stakeholder decisions or evaluate progress[119].

Existing Outreach in the Watershed

Many local stakeholder organizations and regional, state, and national organizations have ongoing education efforts in the watershed. The Partnership recognizes the value of these ongoing programs to positively impact water quality and public awareness in the WPP area. Specific programs of note are described in the discussion of source-based elements. The Partnership will seek to coordinate and support efforts with partners that include the entities listed in **Table 39**[120].

[119] Specific examples identified in the project include wildlife loading estimates, quantifying the relationship between sediment and bacteria concentrations, erosion rates, and spatial data for features like pipelines and new development.

[120] This list is not intended to be exhaustive, but a representative sample of area efforts currently in progress that overlap with WPP goals. The Partnership will actively seek to engage with partners through existing outreach efforts wherever appropriate, including those not specifically listed here. This is undertaken with the caveat that the Partnership will seek to supplement, enhance, or offer general support to activities completed by partners as part of permit or other regulatory requirements, but will not fund or supplant efforts by those partners.

Table 39. Outreach partners

Outreach Partner	Focus Areas
Bayou Land Conservancy	Conservation, outreach
Bayou Preservation Association	Conservation, water quality, outreach, citizen science, recreation, invasive species management, flood mitigation, trash reduction
City of Houston	Source water protection
Galveston Bay Estuary Program	Galveston Bay, source water protection
Grimes County	Riparian corridors, stormwater, outreach, recreation, OSSFs, illegal dumping, animal control, environmental enforcement
Harris County, Harris County Flood Control District, and Harris County Precinct 4	Riparian corridors, stormwater, outreach, recreation, OSSFs, illegal dumping, animal control, environmental enforcement, flood mitigation
Houston Advanced Research Center	Research, urban forestry, water quality
Houston Audubon	Conservation, wildlife, recreation
Houston Canoe Club	Recreation, conservation, outreach
Houston Wilderness	Gulf-Houston Regional Conservation Plan, outreach
Houston-Galveston Area Council	Watershed management, water quality, forestry, public outreach, OSSFs, trash reduction
Houston Sierra Club	Conservation, water quality, forestry, outreach, recreation
Local HOAs (multiple)	Resident outreach, pet waste, inlet marking
Local MUDs/Special Districts (multiple)	Utilities, stormwater, outreach
Local Soil and Water Conservation Districts (Harris, Montgomery, Navasota)	Agriculture, land management programs
Other Cities and Communities (The Woodlands, Tomball, Spring)	Utilities, stormwater, outreach, resident outreach
Montgomery County	Riparian corridors, stormwater, outreach, recreation, OSSFs, illegal dumping, animal control, environmental enforcement
AgriLife Extension/AgriLife Research/Texas Water Resources Institute	Agriculture, OSSFs, water quality, land management, feral hogs, riparian buffers
Texas A&M Forest Service	Forestry
Texas Commission on Environmental Quality	Water quality, wastewater, nonpoint source pollution
Texas Master Naturalists	Environmental education and outreach, habitat
Texas Parks and Wildlife Department	Wildlife, habitat, water quality
Texas State Soil and Water Conservation Board	Agriculture/silviculture, nonpoint source pollution, water quality, conservation
Texas Stream Team	Water quality, volunteering
The Nature Conservancy	Urban forestry, conservation, habitat, water resources
State and Federal Elected Officials	Constituent outreach, environmental events
United States Army Corps of Engineers, Galveston	Flood mitigation, water quality modeling
United States Department of Agriculture, Natural Resources Conservation Service	Agriculture, land management, habitat, conservation
United States Department of Agriculture, United States Forest Service	Forestry
Waller County	Riparian corridors, stormwater, outreach, recreation, OSSFs, illegal dumping, animal control, environmental enforcement

Source-based Outreach and Education Elements

In keeping with the guiding principle of engaging stakeholders with targeted messages, the Partnership will engage, enhance, or support a series of outreach and education efforts aimed at specific pollutant or solution categories. Unless otherwise specified, costs for coordination and outreach tasks by the Partnership are assumed to be part of the cost of maintaining a facilitator for the watershed. Specific costs are called out where applicable.

Wastewater and Sanitary Sewer Overflows

The focus of outreach and education for permitted wastewater and SSOs is on the local governments and utilities of the watershed. However, the Partnership can help promote messages to their communities to serve water quality goals. The Partnership recommends the following activities as specific, supplementary actions under this WPP.

WWTF E1 – Promote Fats, Oils, and Grease (FOG) Awareness

FOG issues are a source of SSOs and operational challenges for local wastewater utilities. Programs like the San Jacinto River Authority's No Wipes in the Pipes (Patty Potty)[121] and the regional Galveston Bay Cease the Grease[122] campaign already exists. The Partnership seeks to promote these programs and maintain model materials[123] on its website, social media, and at outreach events. Local partners will seek to promote the message through their online presence, utility bills, or through established programs[124]. The promotion will take place throughout the implementation period, and model materials will be added in the first year of implementation.

WWTF E2 – Promote Floodwater Contact Awareness

Flooding is a repetitive issue in some areas of the watershed, and floodwaters may contain untreated sewage if collection systems or WWTFs are compromised. Residents who enter the water during these events should be aware of exposure risks. The Partnership will include materials on its website (first year of implementation) and seek to coordinate with other local flood safety outreach efforts to ensure this message is represented (throughout the implementation period).

On-site Sewage Facilities

There are several existing programs targeting homeowner and practitioner knowledge for OSSFs. The Partnership recommends the following as specific actions under the WPP.

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[121] For more information, see: http://www.pattypotty.com/

[122] For more information, see: http://ceasethegrease.net/

[123] For this and subsequent source category recommendations, materials may include, but not be limited to model flyers, fact sheets, educational program guides, pamphlets, ordinances, technical resources, *etc.*

[124] These efforts are in addition to existing management of utility functions.

OSSF E1 – Hold Residential OSSF Workshops
Both H-GAC and AgriLife Extension have existing OSSF programs aimed at educating the general public and specific audiences on general maintenance and visual inspection of OSSFs. The recommended frequency is at least one workshop every other year throughout the project period. Costs for these efforts range from $450+ per workshop and are paid for by a mix of existing projects (CWA §319(h) grants for both agencies, H-GAC CWA §604(b), and internal organization funding).

OSSF E2 – Participate in County-wide OSSF Workshops for Practitioners
Montgomery and Harris Counties hold annual OSSF workshops for local OSSF practitioners. The Partnership will support the county with publicity and participation as appropriate and seek to support Waller County efforts as well. This activity will happen throughout the implementation period.

OSSF E3 – Provide Model Educational Materials Online
In addition to existing educational materials from the county, AgriLife, and local governments, the Partnership will host or promote materials on its website. Materials will be developed in the first two years of implementation and maintained/updated indefinitely.

OSSF E4 – Texas Well Owner Network (TWON)
The Partnership will work with TWON to hold informational meetings or testing events in the watershed and seek to include an OSSF message related to water well siting. The expected frequency is every seven years, with a focus on the Headwaters area.

OSSF E5 – Signage at Remediation Sites
H-GAC works with the Harris County District Attorney's Office and TCEQ to provide funding to remediate failing OSSFs as part of a Supplemental Environmental Project to benefit economically disadvantaged households. H-GAC will post signage at completed project sites as an outreach tool for generating additional interest. This practice has been successful in other areas.

Urban Stormwater

Education and outreach elements[125] for urban stormwater will include efforts aimed both at MS4s and at diffuse flow off the land directly into waterways in urban areas. Much of the education and outreach for the former is conducted by the MS4s under the TPDES

[125] While inlet stream marking is included in the structural solutions noted in Section 5, this program has a significant education and outreach component and has been successfully used by Harris County and other partners in the watershed to engage organizations and neighborhoods. Implementation of that solution should emphasize its outreach aspects.

stormwater permits. For these areas, the Partnership will seek to coordinate and support, but will not add additional elements[126]. The need for maintaining stormwater infrastructure and LID features requires well informed community members. The Partnership recommends the following activities as specific actions under this WPP.

Urban Stormwater E1 – Expand Texas Stream Team Participation

TST[127] volunteers provide valuable information on local conditions in areas where there is not existing CRP monitoring. The role volunteers play as ambassadors to their community about local water quality is an equally important aspect of TST volunteering. H-GAC and local partners foster local volunteers in these efforts. The goal of this element is to increase TST monitoring efforts by 10 volunteers by 2030.

Urban Stormwater E2 – Promote Urban Forestry as a Solution[128]

Many of the stakeholders and regional partners in the WPP (*e.g.*, Texas A&M Forest Service) promote urban forestry projects for the ecosystem services[129] they produce. The urbanized areas of Montgomery and Harris counties were part of the *Houston Area Urban Forests*[130] project which identified priorities for promoting urban forestry, including as part of stormwater management efforts. Similar projects addressing the link between water quality and forestry are also active through Texas A&M Forest Service and USDA United States Forest Service, including the i-Tree modeling completed for this WPP to quantify tree benefits and inform stakeholder choices. The Partnership will seek to coordinate with ongoing urban forestry projects and programs, including those of the Harris County Flood Control District and the Houston Area Urban Forestry Council[131], and highlight water quality benefits. As appropriate, the Partnership will seek funding and technical support for local partners who are doing restoration or new plantings that have a water quality link[132]. Model materials will be hosted on the Partnership website in the first year of implementation, and the Partnership will promote local urban forestry projects. The Partnership will also coordinate efforts regarding urban forestry with broader regional conservation efforts, including the Gulf-Houston Regional Conservation Plan[133], the BIG, and City of Houston source water protection efforts. Lastly, the

[126] Except for promoting LID, as indicated in Section 5.
[127] For more information, see: https://h-gac.com/texas-stream-team/
[128] These recommendations are supplemental to existing ordinances that address urban trees. Existing ordinances may be used as model materials.
[129] Including but not limited to flood mitigation, water and air quality improvement, heat reduction, erosion control, atmospheric carbon storage, health benefits, and aesthetic benefits.
[130] For more information, see: www.houstonforests.com
[131] For more information, see: https://www.haufc.org/
[132] Specific urban forestry practices and technical resources are available from the Texas Forest Service at: http://texasforestservice.tamu.edu/abouturbanandcommunityforestry/
[133] For more information, see: https://www.gulfhoustonrcp.org/

Partnership will seek to work with new development to promote maintenance, restoration, or development of new forested areas in new development, as appropriate to the surrounding land cover.

Pet Waste

Pet waste is an area in which direct engagement with the public is a necessary component of an effective outreach strategy. Unlike centralized sources like WWTFs, pet waste reduction relies on the individual efforts of thousands of residents. The Partnership recommends the following activities as specific actions under this WPP.

Pet Waste E1 – Pet Waste Dispensers at Local Events

H-GAC currently focuses on pet waste reduction as specific action individual residents can take. To support the message, H-GAC uses refillable dog waste bag dispensers with branding or messaging on the dispenser. These units are a low-cost way to engage community members and facilitate reductions. The dispensers take the place of event giveaways to raise awareness and cost approximately $1.50 each. A standard giveaway would be 50 dispensers per outreach event, on average. For a 9-year implementation period, assuming 6 outreach events per year, this would equate to a cost of $4,050.

Pet Waste E2 – Elementary School Visits

Elementary-age children are a good candidate for educational programs and can influence activities of their parents. H-GAC or other local partners will visit local schools (at least one a year) to put on educational programming appropriate for the age range and subject topic of the classes involved. Past education efforts have included general water quality education with a pet waste message included. Costs for this activity are limited to staff time.

Pet Waste E3 – Provide Model Educational Materials Online

In addition to existing educational materials from local partners, the Partnership will host or promote materials on its website. Materials will be developed in the first two years of implementation and maintained/updated indefinitely.

Agriculture

A wealth of information and programs exists to promote water-friendly practices for agricultural operations. The focus of the Partnership for this category is largely to support the existing efforts of the Soil and Water Conservation Districts, TSSWCB, Texas A&M AgriLife, USDA NRCS, and other agricultural partners in promoting their programs in the watershed. The Partnership recommends the following activities as specific actions under this WPP.

Agricultural Operations E1 – Develop and Implement Education Measures and Materials for Livestock Operations (Non-CAFO)

There are several horse stable operations and livestock operations present in the watershed. The stakeholders identified the need for best practices and educational materials for these facilities. The Partnership will work with the agricultural agencies to identify existing source material and develop educational materials specific to the stabling operations, *etc.* in the watershed within the first two years of implementation.

Agricultural Operations E2 – Hold Agricultural Resources Workshops

The Partnership will hold workshops for local landowners and producers at least once every three years. The workshops will have representation from agricultural and other land management agencies (TSSWCB, AgriLife, USDA NRCS, and others) as a "one-stop shop" for residents to hear about available programs and meet one on one with several agencies.

Agricultural Operations E3 – Support Local Agricultural Conservation

The Partnership will support efforts to develop partnerships or funding sources to implement local conservation initiatives, and future elements of regional conservation plans in agricultural areas, including the H-GAC Regional Conservation Framework[134] program.

Agricultural Operations E4 – Outreach for Recreational Horses

The Partnership will work with existing agricultural outreach efforts (Lone Star Healthy Streams[135], *etc.*) to develop or promote materials for recreational horse owners, either stabled or on acreage lots. This specific focus is to bridge the gap between general outreach and programs aimed primarily at agricultural operations. The intent of the outreach is to modify behaviors regarding horse manure handling and concentrated grazing at stables, with a focus on riparian areas.

Feral Hogs

Feral Hog abatement is a strong concern for properties throughout the watershed, but especially along riparian corridors. Existing outreach programs through AgriLife Extension and other sources are well developed. The Partnership seeks to promote these elements through the website, social media, partner networks, and with event publicity as appropriate. The following programs are of specific interest for the watershed.

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[134] For more information, see: https://www.h-gac.com/regional-conservation

[135] For more information, see: http://lshs.tamu.edu/

Feral Hogs E1 – Lone Star Healthy Streams – Workshops and Feral Hog Resource Manual

The Partnership will promote the AgriLife Lone Star Healthy Streams[136] program by promoting the Feral Hog Resource manual and hosting a workshop in the watershed at least twice during implementation, subject to AgriLife availability.

Feral Hogs E2 – Feral Hog Management Workshop

The Partnership will work with AgriLife Extension in the watershed counties to host a local feral hog management workshop. The expected frequency for this element is at least once every six years, based on AgriLife availability.

Deer and Other Wildlife

Although the Partnership elected not to recommend any direct solutions for reducing deer populations or addressing other wildlife, stakeholders expressed interest in having better data regarding wildlife contributions (see recommendations regarding additional research in Section 7). The Partnership will, however, seek to use existing wildlife events as potential platforms for general outreach. Specifically, the Partnership recommends:

Wildlife E1 – Homeowner Education Materials and Mailing

The Partnership will work with AgriLife Extension to promote distribution of materials for homeowners instructing them on how to use exclusionary devices to deter invasive species such as feral hogs from using deer feeders. The materials will be hosted online and made available at outreach events in the priority areas of the watershed. The Partnership will work with local HOAs and other community groups to include the message in existing communication networks (HOA newsletters, *etc.*).

Land Management

Beyond programs focused on agricultural/silvicultural properties, there are many programs and opportunities to promote or support land management practices that are beneficial to water quality, including Farm Bill programs through USDA NRCS, conservation easements and similar conservation mechanisms. The Partnership recognizes the ample effort already put forth by local partners in developing land management projects for habitat (*e.g.*, Bayou Land Conservancy preserves), recreation (*e.g.*, Spring Creek Greenway) and flood retention. The key focus for water quality is lands adjacent to the waterways. The Partnership will generally support and promote voluntary projects and programs however appropriate and recommends the following outreach activities as a specific action under this WPP.

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[136] For more information, see: http://lshs.tamu.edu/workshops/

Land Management E1 – Promote Riparian Buffers

In addition to the specific action of developing conservation areas, easements, *etc.* in riparian corridors, the Partnership will maintain resources on its website relating to riparian buffers, including a link to the H-GAC riparian buffer planning tool[137] for landowners. Resources will be developed/obtained and hosted during the first year of implementation. The Partnership will seek to promote the Texas Water Resources Institute (TWRI) Texas Riparian and Stream Ecosystem Education Program and Urban Riparian and Stream Restoration Program[138] and similar workshops from Texas A&M AgriLife. Expected frequency is once every five years for these programs. Funding is currently provided by CWA §319(h) grants, and attendee fees. This will focus on both fecal waste and DO benefits in this watershed.

Land Management E2 – Texas Watershed Stewards

AgriLife Extension's Texas Watershed Stewards program is an effective way of developing knowledge among the local communities of watershed issues and actions they can take. The Partnership will work with AgriLife to bring the program to the watershed on an expected frequency of every five years.

Land Management E3 – Conservation Coordination

In addition to long-standing efforts by NGOs and local governments in the watershed, several regional conservation and open space planning projects are currently active in the watershed. The Partnership has, and will continue to, participate meaningfully in the Gulf-Houston Regional Conservation Plan, the Regional Conservation Framework, the Waller County Parks, Trails, and Open Space Master Plan, Bayou Preservation Association Stream Corridor Restoration Committee, and other local efforts that may have implications or opportunities for riparian-oriented conservation in the watershed.

Trash and Illegal Dumping

In addition to enhanced enforcement, the stakeholders recommended that trash reduction is a local priority and serves as a visible form of outreach. Counties and other local jurisdictions will continue to enforce dumping issues. In addition, the Partnership recommends the following actions.

Trash and Illegal Dumping E1 – Trash Bash Site

The Texas Rivers, Lakes, Bays N' Bayous Trash Bash[139] is an annual trash reduction and community outreach event that takes place throughout the region. Upwards of

[137] For more information, see: https://www.h-gac.com/riparian-buffer-tool
[138] For more information, see: http://texasriparian.org/riparian-education-program/
[139] For more information, see: http://www.trashbash.org/

hundreds of volunteers attend each site, where outreach materials and education about water quality accompany the trash reduction elements. The cleanups focus on areas adjacent to local waterways. The Partnership will participate in this annual effort as a direct way of engaging the public on visible examples of water pollution, and in providing an accompanying water quality message.

Figure 49. Trash Bash volunteers at Lake Houston

Section 7

Implementation

Photo Credit: Jessica Casillas

Section 7. Implementation

Implementation is the process of transforming the concerns, ideas, and commitment that went into developing this WPP into tangible action and results. This section details the principles that will guide implementing the solutions identified in Sections 5 and 6, the estimated schedule of implementation, and interim milestones along the way that can be used to gauge progress.

Implementation Strategy

The Partnership balanced the development of potential solutions with the considerations of the logistics of implementation. Some solutions were discarded because they were infeasible to implement, some were focused to specific areas of the watershed, *etc*. The starting point for developing the WPP's implementation strategy is the water quality goals and guiding principles (described in Section 1). From there, the local stakeholders of the Partnership discussed the best ways to translate project ideas into achievable timelines of activity that would be acceptable to the community. The implementation of this WPP will be based on:

- Coordination provided by a watershed coordinator serving as a focal point for WPP efforts;
- Decisions made locally, implemented on a voluntary basis;
- Siting of solutions that considers local needs and conditions, but overall favors areas closest to waterways;
- An opportunistic approach that is flexible enough to maximize resources and opportunities;
- Timelines that consider the changing mix of sources through the implementation period;
- An integrated approach that uses education and outreach to support related solutions;
- A recognition that human waste sources represent a relatively greater pathogenic risk to human health;
- An ongoing focus on adapting plans to meet changing conditions; and
- A special focus on coordinating implementation activities with flood mitigation, source water protection, conservation, and forestry projects in the watershed and region.

Locally Based Watershed Coordinator

Implementing, maintaining, evaluating, and adapting the ongoing and proposed solutions is essential to the success of this project and the future of water quality in the Spring Creek watershed. A local watershed coordinator will be necessary to guide implementation, education, and outreach solutions as the focal point for coordinating these efforts for the WPP. The coordinator will work with local partners to seek opportunities to implement solutions and to find common priorities. The coordinator will maintain a high awareness of and involvement in water quality issues in the area through engagement with related efforts, educational programs, outreach through social media, and communication with the local media. The position will routinely interact with local city councils, county commissioner courts, SWCDs, and other stakeholder groups to keep them informed and involved in implementation activities being carried out in the watershed. Coordinating efforts among key partners will be crucial for success and should be one of the primary roles of the position. The watershed coordinator will also work to secure external funding to facilitate implementation activities and coordinate with partner efforts, specially the existing and planned studies and efforts involving flood mitigation in the system. H-GAC will provide facilitation for the phase of the WPP directly after the submission of the WPP. An estimated $70,000 per year including travel expenses will be necessary for this position, which assumes only a portion of the time of a full-time senior level position, or a greater portion of an entry level position. Initial funding for the watershed coordinator will be incorporated into a CWA §319(h) grant proposal. The Partnership will consider after that point how best to house ongoing facilitation of the Partnership through a watershed coordinator, including consideration of integrating coordination of other local watershed efforts and other local partners.

Comprehensive Strategy for Pet Waste

While human waste sources can produce the greatest human health risk[140], pet wastes are a prominent source of fecal bacteria and nutrients. As the watershed continues to develop, pet wastes will continue to grow in prominence as a fecal waste source. Pet waste represents both a unique challenge and an opportunity because it is a significant contributor, generally concentrated in more densely populated areas with higher impervious cover, and a source that is generally under our control as pet owners (as opposed to wildlife sources).

This WPP recommends solutions and education/outreach activities (Sections 5 and 6, respectively) designed to engage the public and promote proper management of pet wastes. Integration of these elements will be necessary to ensure successful implementation. The strategy for pet waste under this WPP will be conducted based on the following principles.

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[140] Research has indicated that human waste has a significantly higher risk of causing illness in humans as compared to animal sources. Additional information about an example of this research in Texas can be reviewed at: http://oaktrust.library.tamu.edu/handle/1969.1/158640?show=full

Message Support

As possible, structural solutions will be supported by targeted outreach and education to enhance public awareness and utilization. For example, installation of pet waste stations will be accompanied by promotional messages for the specific area (in the form of partner messaging, relevant online venues, or other appropriate means).

Local Integration

As possible, education and outreach efforts will be coordinated with existing events or programs. This ensures a broader reach than more narrowly targeted events and reduces costs and logistics for project resources. For example, H-GAC and other local partners will include pet waste messaging and outreach as part of broader messages at general events or seek a presence at community/regional events where local pet owners may be present (*e.g.*, the Houston Dog Show).

Targeted Implementation

The specific needs of subwatersheds or other areas will be considered in the selection of solutions and outreach messaging that is directed towards their communities. For example, implementation in more densely urban areas may focus more on individual behaviors (picking up after pets) and addressing feral populations, while less dense suburban area messaging may focus on pet waste stations in public spaces and promoting dog park development. In general, the focus of efforts will be heaviest on the downstream area and new development.

Coordination with Adjacent Efforts

Coordination with the adjacent practice areas of flood mitigation, conservation, and forestry will be key to successful implementation of this WPP.

Flood Mitigation

While this effort is focused mainly on issues related to water quality, many of the primary grant funding sources (as referenced in Appendix D) currently available to local partners focus on resiliency and flood mitigation, a water quantity issue. To maintain visibility as an effort and have the opportunity to tie water quality messages and considerations to flood mitigation efforts, the Partnership will maintain a strong focus on coordinating with local partners (Harris County Flood Control District, and others) and actively participating, as appropriate, in public processes linked to the flood mitigation efforts.

Conservation

The strong tradition of conservation in the watershed and existing organizational capacity among local governments and NGOs provides an opportunity to enhance water quality through the ecosystem services provided by conserved land. The Partnership will seek to actively engage with and support conservation initiatives in the watershed and help represent the unique character and needs of the watershed in regional initiatives. Current efforts include the Gulf-Houston Regional Conservation Plan (Houston Wilderness), the Regional Conservation Framework (H-GAC), and others.

Forestry

Based on preliminary modeling, inclusion of forestry practices will have a dramatic impact on stormwater runoff in the watershed. Urban forestry is a growing focus in the Houston region, as evidenced by its inclusion in the City of Houston's recent climate change and resilience planning efforts, with a 4.6 million new tree goal for the city alone, and innovative riparian restoration and linear forest programs. Other regional efforts include:

- Large scale planting programs by the Harris County Flood Control District, CenterPoint Energy, Texas Department of Transportation, and others;
- Significant research and restoration work by Texas A&M Forest Service and conservation NGOs;
- Local collaborations like the Tree Strategy Implementation Group, Stream Corridor Restoration Committee, and Houston Area Urban Forestry Council; and
- Broad regional partnerships like the Texas Forests and Drinking Water Partnership[141].

Project staff have been engaged with local partners in all these pursuits, and the Partnership will continue to participate and actively promote water quality considerations and appropriate areas of the watershed within these efforts.

[141] For more information, see: https://tfsweb.tamu.edu/partnership/#:~:text=The%20Texas%20Forests%20and%20Drinking,important%20and%20interdependent%20natural%20resource

Timelines for Implementation

Implementation of this WPP is intended to take place over a 9-year initial implementation timeframe (2023-2030). Some of the recommended solutions and outreach elements are intended for the whole implementation period, while some are intended for specific timeframes within that period. Some activities recommended by the Partnership are already underway or are likely to initiate prior to the approval of the WPP. The schedules were developed with the stakeholders to ensure that implementation took place at a feasible rate and meshed with other planned activities and priorities.

Interim Milestones for Measuring Progress

The timelines are intended to reflect the period in which each solution will be implemented, along with the responsible entities and costs they will incur. Additional information about each solution, its intended implementation, and estimated costs can be found in Sections 5 and 6[142]. Interim milestones are identified as goalposts to measure the progress of implementation. Whereas water quality and other criteria will be used to measure the effectiveness of implementation (Section 8), interim milestones measure whether implementation is occurring on schedule (**Table 40**). This table will be updated as part of future WPP updates, after each implementation phase, or as needs warrant.

Figure 50. Brushy Creek at confluence with Spring Creek

[142] While not specifically noted in Sections 5 and 6, the Supporting Research tasks identified in Section 8, following, are also included in the planning for implementation.

Table 40. Interim milestones for solutions and outreach activities

Target[143]	Solutions[144]	Overall Implementation Goal[145]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
General (N/A)	General – Watershed Coordinator	Retain a Watershed Coordinator to manage day-to-day coordination, pursue resources, and guide implementation	Partnership[146]	2023 – The Partnership assesses facilitation during early implementation	2023 – Funding application is made for a 2024 start date	2024 – Watershed Coordinator position retained	2026 – Partnership reassess facilitation need after early implementation
Wastewater Treatment Facilities (N/A)	WWTF 1 – Address Aging Facilities and Consider Regionalization	Improve treatment of sewage	Utilities; Cities; Counties	2023 – At least 1 WWTF makes operational/ structural changes resulting in effluent improvement	2026 – At least 1 additional WWTF makes operational/ structural changes resulting in effluent improvement	2030 – At least 1 additional WWTF makes operational/ structural changes resulting in effluent improvement	
	WWTF 2 – Recommend Increased Testing	Enhance monitoring to better characterize effluent	Utilities	2026 – Partnership worked with at least 10 plants to identify capacity for increased testing	2030 – Partnership worked with at least 10 additional plants to identify capacity for increased testing		

[143] Numbers in parentheses indicate the estimated relative units that will be addressed by the solutions for each target as calculated in **Table 35**.
[144] Availability and timing of all solutions, especially those not directly facilitated by the Partnership, are subject to changes in partner schedules in the future. Timing of some events (workshops, *etc.*) may be adjusted based on partner availability as needed.
[145] Target goals are based on Table 30, and may vary based on opportunity, resources, and regulatory changes in the future. All numeric targets (*i.e.*, number of dogs) refer to representative units. Actual units addressed may change based on pollutant removal efficiency, location, *etc.* Outreach and education elements are designated with italics.
[146] Where Partnership appears on this table, it indicates H-GAC, a successor agency, or a watershed coordinator for the WPP acting on behalf of the stakeholders and WPP. While H-GAC is currently acting as the watershed coordinator for the Partnership, this table refers to elements conducted by H-GAC under other projects (CRP, *etc.*) as "H-GAC."

Target[143]	Solutions[144]	Overall Implementation Goal[145]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Wastewater Treatment Facilities (N/A)	*WWTF E1 – Promote FOG Awareness*	*Reduce SSOs by affecting utility customer behavior regarding FOG*	*Partnership; Utilities*	*2023 – Model materials identified and added to website; distribute printed materials at local events*	*2030 – Consistent promotion with partners throughout implementation period*		
	WWTF E2 – Promote Floodwater Contact Awareness	*Reduce exposure to bacteria by educating residents about floodwater contact*	*Partnership; Counties; Special districts*	*2023 – Model materials identified and added to website; distribute printed materials at local events*	*2030 – Consistent promotion with partners throughout implementation period*		
Sanitary Sewer Overflows (N/A)	SSO 1 – Remediate Infrastructure	Reduce contamination from human fecal waste by reducing overflows from WWTF collection systems	Utilities	2026 – 5 fewer SSOs occurred than average since 2020	2030 – 10 fewer SSOs occurred than average since 2020 over implementation period		
	SSO 2 – Consider Additional Preventative Measures	Improve infrastructure capacity, operations, and preventive measures to reduce SSOs	Utilities	2026 – At least 3 utilities have reviewed and/or upgraded backup capacity or other measures	2030 – At least 3 additional utilities have reviewed and upgraded backup capacity or other measures		
On-site Sewage Facilities (1,460)	OSSF 1 – Remediate Failing OSSFs	In conjunction with OSSF 3, address failing OSSFs	H-GAC; Homeowners; Counties (enforcement); Utilities (for conversion projects)	2026 – First half of OSSFs addressed, or failures prevented	2030 – Second half of OSSFs addressed, or failures prevented		

Target[143]	Solutions[144]	Overall Implementation Goal[145]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	OSSF 2 – Improve Spatial Data	Improve OSSF location spatial data to guide remediation efforts	H-GAC; Counties; Special Districts; Utilities	2023 – Partners have reviewed and commented on existing spatial data, which is revised accordingly	2026 – Authorized Agents have continued to provide new data regularly	2030 – Authorized Agents have continued to provide new data regularly	
	OSSF 3 – Convert to Sanitary Sewer	In conjunction with OSSF 1, address failing OSSFs	H-GAC; Counties; Special Districts; Utilities; Homeowners	2026 – First half of OSSFs addressed, or failures prevented	2030 – Second half of OSSFs addressed, or failures prevented		
	OSSF E1 – Hold Residential OSSF Workshop	*Empower homeowners and real estate inspectors to identify the signs of failing/failed OSSFs and promote proper OSSF management to avoid failures*	*H-GAC; Partnership; AgriLife Extension*	*2026 – 2 workshops held*	*2030 – 2 additional workshops held*		
	OSSF E2 – Participate in County-wide OSSF Workshop for Practitioners	*Harris and Montgomery County's annual OSSF workshop provides a point of coordination with practitioners*	*Partnership; Harris County*	*2030 – Annual meetings[147] have been held; Partnership participated*			
On-site Sewage Facilities (1,460)	*OSSF E3 – Promote Model Educational Materials*	*Provide model educational materials online to facilitate education by other organizations*	*Partnership*	*2023 – Model materials identified and added to website; distribute printed materials at local events*	*2030 – Consistent promotion with partners throughout implementation period*		

[147] This education and outreach measure is an activity of Montgomery and Harris counties. The counties may change the nature or frequency of these meetings in the future.

Target[143]	Solutions[144]	Overall Implementation Goal[145]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	OSSF E4 – Texas Well Owner Network Events	*Educate well owners about potential risks from OSSFs and potential contamination of drinking water wells*	*Partnership; TWRI; AgriLife Extension; TSSWCB*	*2023 – First TWON event held*	*2029[148] – Second TWON event held*		
	OSSF E5 – Signage at Remediation Sites	*Use OSSF remediation sites as outreach to neighbors via signage*	*H-GAC; Harris County; TCEQ*	*2030 – Signage placed at OSSF remediation locations*			
Urban Stormwater (N/A)	Urban Stormwater 1 – Install Stormwater Inlet Markers	Raise awareness and shift behavior of residents served by stormwater systems to reduce pollutants entering drains/waterways	Harris County; Local Governments; Special Districts; HOAs; Local Volunteers	2026 – At least 2 neighborhoods have markers added	2030 – At least 2 additional neighborhoods have markers added		
Urban Stormwater (N/A)	Urban Stormwater 2 – Investigate Drainage Channels	Locate potential sources of pollutants in urban channels[149]	H-GAC; MS4s; Counties; TCEQ	2023 – Potential priority areas and grant resources identified	2026 – Pilot project completed; at least 1 waterway completed, field reconnaissance project	2030 – At least 1 additional waterway completed, field reconnaissance project	

[148] These workshops are expected to occur in 7-year intervals which do not align with usual milestone intervals.
[149] This solution is intended as a supplement to MS4 activities to detect illicit discharges, *etc.* It is expected additional investigations will take place as part of TPDES MS4 permits. This activity will not replace requirements under permits.

Target[143]	Solutions[144]	Overall Implementation Goal[145]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	Urban Stormwater 3 – Promote and Implement Urban Riparian Buffers	Reduce pollutants in urban sheet flow and erosion through vegetative barriers; this strategy coincides with Agricultural Operations 2, Conservation and Land Management 1	MS4s; Local Governments; Special Districts; Texas A&M Forest Service (forestry technical support); NGOs; Landowners	2026 – At least 1 urban riparian project completed	2030 – At least 1 additional urban riparian project completed; Partnership consistently promotes riparian buffers		
	Urban Stormwater 4 – Low Impact Development	To reduce pollutants in stormwater flows through promoting and implementing infrastructure that mimics or improves on natural hydrology	H-GAC; MS4s; Counties; Local Governments; Special Districts	2023 – LID materials developed and hosted on website	2030 – At least 1 LID demonstration project installed		
	Urban Stormwater E1 – Expand Texas Stream Team Participation	*Supplement existing monitoring data with volunteer sites and empower volunteers to acts as water quality ambassadors*	*H-GAC; Partnership; TST Partners*	*2026 – 5 volunteers added*	*2030 – 10 total volunteers added*		
Urban Stormwater (N/A)	*Urban Stormwater E2 – Promote Urban Forestry as a Stormwater Solution*	*Coordinate and promote urban forestry programs and projects for water quality benefits; this strategy coincides with Conservation and Land Management 3*	*Partnership; Texas A&M Forest Service; H-GAC*	*2023 – Model materials identified and hosted online; distribute printed materials at local events*	*2026 – Revised modeling completed to support forestry measures' effectiveness*	*2030 – Coordination and promotion consistent message*	

Target[143]	Solutions[144]	Overall Implementation Goal[145]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Pet Waste (32,313)	Pet Waste 1 – Install Pet Waste Stations	Reduce wastes by facilitating use of bags in public areas	Counties; Local Governments; HOAs; Apartment Complexes	2026 – At least 20 pet waste stations installed	2030 – At least 20 additional stations installed; all stations maintained throughout the implementation period		
	Pet Waste 2 – Expand Dog Parks	Increase availability of controlled dog recreation areas to sequester wastes in public areas	Counties; Local Governments; HOAs; Developers; Special Districts	2026 – 1 new dog park area developed	2030 – Second new dog park area developed		
	Pet Waste 3 – Promote Spay and Neuter Events	Reduce pollutants from feral populations through voluntary population control	Service provider (such as SPCA or similar); Local Partners	2026 – 1 spay/neuter event held	2030 – Second spay /neuter event held		
	Pet Waste 4 – Consider Additional Enforcement	Reduce dog waste by promoting enforcement	Local Governments; Special Districts; HOAs; Apartment Complexes	2026 – The Partnership will have worked with at least 5 local partners to promote enforcement	2030 – The Partnership will have worked with at least 5 more local partners to promote enforcement		
Pet Waste (32,313)	*Pet Waste E1 – Handheld Pet Waste Bag Dispensers at Local Events*	*Educate residents about impacts of dog waste and reduce waste in stormwater*	*Partnership; H-GAC*	*2026 – Distribution of 1,200 dispensers at 24 local events*	*2030 – Distribution of 1,500 additional dispensers at 30 local events*		
	Pet Waste E2 – Elementary School Visits	*Educate children on pet waste and other water quality issues*	*Partnership*	*2026 – 4 visits held*	*2030 – 5 additional visits held*		

Target[143]	Solutions[144]	Overall Implementation Goal[145]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	Pet Waste E3 – Promote Model Educational Materials	*Provide model materials to facilitate other organizations' education efforts*	*Partnership*	*2023 – Model materials identified and added to website; distribute printed materials at local events*	*2030 – Consistent promotion with partners throughout implementation period*		
Agricultural Operations (2,668)	Agricultural Operations 1 – WQMPs and Conservation Plans	Address waste from 2,668 livestock units through 54 WQMPs, Conservation Plans or other agricultural plans	TSSWCB; SWCDs; USDA NRCS; Agricultural Producers/Land owners	2026 – First half of plans (or plans representing half of the reduction load) addressed by the solution	2030 – Second half of plans (or plans representing half of the reduction load) addressed by the solution		
Agricultural Operations (2,688)	Agricultural Operations 2 – Maintain or Restore Riparian Buffers	In conjunction with, or in supplement to, Agricultural Operations 1, install or maintain riparian buffers in agricultural areas to reduce transmission of pollutants; this strategy coincides with Urban Stormwater 3, and Conservation and Land Management 1	Landowners/ producers (on a voluntary basis); NGOs; Agricultural Agencies	2026 – At least 2 rural properties have riparian projects, at least 1 is agricultural	2030 – At least 2 additional rural properties have riparian projects, at least 1 is agricultural		
	Agricultural Operations 3 – Implement Horse Manure Composting Program	Reduce horse manure entering waterways by turning it to beneficial use	Horse Owners; Stabling Operations; Commercial Facilities	2023 – Program developed with local partners	2026 – At least 3 participants in the program	2030 – At least 3 additional participants in the program	

Target[143]	Solutions[144]	Overall Implementation Goal[145]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	Agricultural Operations E1 – Develop and Implement Education Measures and Materials for Livestock Operations (non-CAFO)	*Develop specific recommendations for stabling and other livestock operations to reduce contributions from these sources*	*Partnership; TSSWCB; AgriLife Extension*	*2023 – Needs, potential local partners identified; Materials developed and reviewed locally; hosted online; distribute printed materials at local events*	*2030 – Consistent promotion with partners throughout implementation period*		
Agricultural Operations (2,668)	*Agricultural Operations E2 – Hold Agricultural Resources Workshops*	*Promote agricultural programs by facilitating one on one meetings with landowners*	*Partnership; TSSWCB; AgriLife Extension; USDA NRCS*	*2023 – First workshop held*	*2025[150] – Second workshop held*	*2028[151] – Third workshop held*	
	Agricultural Operations E3 – Support Local Agricultural Conservation	*Increase conservation efforts by lending support and coordination to local partners pursuing opportunities*	*Partnership; USDA NRCS; Other local conservation partners*	*2023 – Collaborate with at least 1 local partner on a project proposal*	*2026 – collaborate with at least 1 additional partner on a project proposal*	*2030 – Collaborate with at least 1 additional partner on a project proposal*	
	Agricultural Operations E4 – Outreach for Recreation Horses	*Reduce pollution from horse manure in stables and individual households*	*Partnership; Texas A&M AgriLife; TSSWCB; local SWCDs*	*2023 – Develop targeted outreach campaign*	*2026 – Work with partners to disseminate materials*	*2030 – Consistent promotion with partners throughout implementation period*	

[150] These workshops are expected to occur in 3-year intervals which do not align with usual milestone intervals.
[151] See Footnote 150.

Target[143]	Solutions[144]	Overall Implementation Goal[145]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Feral Hogs (1,693)	Feral Hogs 1 – Remove Feral Hogs	Implement trapping/other removal programs to remove feral hogs from the watershed, reduce pollutants/ancillary damages	Landowners; Local Governments; Special Districts; Agricultural Agencies (technical support)	2026 – Develop or augment trapping program with local partners	2030 – Expand program to additional properties		
Feral Hogs (1,693)	*Feral Hogs E1 – Lone Star Healthy Streams – Workshops and Feral Hog Resource Manual*	*Educate local stakeholders to promote feral hog reduction*	*AgriLife Extension; TSSWCB; Partnership*	*2026 – First workshop has been held*	*2030 – Second workshop has been held*		
	Feral Hogs E2 – Feral Hog Management Workshop	*Educate local stakeholders to promote feral hog reduction*	*AgriLife Extension; TSSWCB; Partnership*	*2023 – First workshop has been held*	*2026 – Second workshop has been held*	*2030 – Third workshop has been held*	
Wildlife (N/A)	Wildlife 1 – Restore Upland Habitat	Restore upland habitat to provide wildlife alternative areas and reduce concentration in riparian zones	Landowners; NGOs; Local Governments; Agricultural Agencies (technical support); Developers	2030 – Develop at least 1 acre or greater restoration project			

Target[143]	Solutions[144]	Overall Implementation Goal[145]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	Wildlife 2 – Manage Feeding	Encourage voluntary implementation of exclusionary devices around deer feeders to deter invasive species such as feral hogs	Landowners; Agricultural Agencies (technical support)	2026 – At least 1 landowner has volunteered to install an exclusionary device	2030 – At least 1 additional landowner has volunteered to install an exclusionary device		
	Wildlife E1 – Homeowner Education Materials and Mailing	*Work with AgriLife Extension, HOAs and Local Partners to distribute exclusionary device materials for homeowners*	*Partnership; AgriLife Extension; HOAs; Local Partners*	*Ongoing through 2030*			
Conservation and Land Management (N/A)	Conservation and Land Management 1 – Riparian Buffers	Promote riparian buffers in all land uses to reduce transmission of pollutants (in conjunction with Land Management – Voluntary Conservation); this strategy coincides with Urban Stormwater 3, and Agricultural Operations 2	Landowners; NGOs; Counties; Local Governments; Special Districts; Agricultural Agencies	2026 – At least 1 property has a riparian project	2030 – At least 1 additional property has a riparian project		
	Conservation and Land Management 2 – – Voluntary Conservation	Promote voluntary conservation to reduce pollutants from developed areas	Landowners; NGOs; Counties; Local Governments; Special Districts; Agricultural Agencies	2026 – At least one 1+ acre property has a conservation project	2030 – At least 2 additional properties have conservation projects		

Target[143]	Solutions[144]	Overall Implementation Goal[145]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	Conservation and Land Management 3 – Increase Tree Canopy	Reduce storm flow runoff and generate additional ecosystem services by expanding tree canopy in appropriate areas; this strategy coincides with Urban Stormwater E2	Landowners; NGOs; Counties; Local Governments; Special Districts; Agricultural Agencies; Developers	2023 – Develop additional i-Tree modeling and 5-year planting priorities	2026 – Plant trees sufficient to meet the developed 5-year priority	2030 – Plant trees sufficient to meet the developed 5-year priority	
	Conservation and Land Management E1 – Promote Riparian Buffers (Tools and Workshops)	*Reduce pollutant loads by promoting riparian buffer areas*	*Partnership; TWRI; TSSWCB/TCEQ (granting)*	*2026 – Workshop held*	*2030 – Another workshop held*		
	Conservation and Land Management E2 – Texas Watershed Stewards	*Educate stakeholders on water quality/watershed issues*	*TWRI; Partnership*	*2026 – Workshop held*	*2030 – Additional workshop held*		
Conservation and Land Management (N/A)	*Conservation and Land Management E3 – Conservation Coordination*	*Promote and help coordinate conservation efforts in the watershed*	*Partnership; NGOs; USDA NRCS; Other local conservation partners*	*Ongoing; Partnership has been active in all appropriate conservation initiatives in the watershed*			
Trash and Illegal Dumping (N/A)	Trash and Illegal Dumping 1 – Report Chronic Dump Sites and Consider Increased Efficiency	Promote enforcement efforts to reduce chronic dumping sites	Counties; Local Governments; H-GAC; Landowners	2023 – Identify dumping sites and enforcement priorities with local partners	2026 – Address at least 1 chronic site	2030 – Address at least 1 additional chronic site	

Target[143]	Solutions[144]	Overall Implementation Goal[145]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	Trash and Illegal Dumping E1 – Trash Bash Site	*Reduce trash and educate participants on water quality issues*	*H-GAC; Partnership; San Jacinto River Authority*	*Ongoing (annual event)*			
Flooding (N/A)	Flooding 1 – Coordinate with Ongoing Flood Mitigation Efforts	Promote water quality features as supplementary elements in flood mitigation studies and projects	Harris County Flood Control District; Special Districts; Local Governments; Counties; NGOs	2023 – Identify flood mitigation priority projects for water quality enhancements	2030 – Partnership or successor maintains presence in flood mitigation projects through public processes, comments, *etc.*		

It should be noted that developing and ensuring funding to cover the cost of implementation activities without current funding sources is a primary challenge and focus for the successful implementation of a WPP. While the WPP recognizes the need for support from a local coordinator and local partners to identify funding resources, and emphasizes an opportunistic approach to utilizing funding sources, funding will be a primary determining factor in the pace and extent of implementation.

Figure 51. Riparian vegetation on the banks of Spring Creek

Section 8

Evaluating Success

Photo Credit: Jessica Casillas

Section 8. Evaluating Success

The WPP is designed as a roadmap for implementation, charting the course to the Partnership's water quality goals. Progress toward those end goals is measured by the observable changes in water quality in the watershed and by achieving programmatic milestones (Section 7). Water quality monitoring data and other monitoring or reported data related to TPDES permits will be the primary means for measuring observable change. Records of programmatic achievements compared to established milestones will serve as a measure of the level of effort by the Partnership. These sources of data are compared to established criteria to gauge success. A key to successful implementation of this WPP is continual focus on adaptive management, in which evaluations of success are used to revise decisions for better effectiveness.

Monitoring Program

CRP partners and others will conduct long-term ambient surface water quality monitoring in Spring Creek. TST volunteers are an additional source of supplemental data[152]. The Partnership will also evaluate compliance by permitted wastewater dischargers using DMR and SSO data reported to TCEQ. Special studies, including microbial source tracking or other DNA-based categorization of *E. coli* or host species, may be used to supplement these ongoing data collection efforts if the Partnership deems them necessary in the future. The combination of ambient surface water quality data permitted discharge data, and other sources (as appropriate) will be used by the Partnership to understand the end result of WPP actions on the project waterways. Assessments will be conducted in conjunction with CRP annual reporting (Basin Highlights Report/Basin Summary Report) efforts. Formal full water quality evaluations including ambient, DMR and SSO data analyses as shown in the *Water Quality Data Analysis Summary Report*[153] will be conducted by the Partnership at the end of every phase of implementation (2025 and 2030) or as necessary in interim periods.

Clean Rivers Program Data

Ongoing monitoring in Spring Creek and its tributaries includes twenty long-term sites (six on Spring Creek, and 14 on tributaries). All sites are monitored at least quarterly. The current sites are listed in **Table 7** and shown in **Figure 19**, both in Section 3 of this document.

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[152] Stream team data will be used for qualitative assessment, and not as part of formal quantitative assessments of water quality.

[153] Available on the project website at: https://springcreekpartnership.weebly.com/uploads/1/3/0/7/130710643/10159_3.3_spring_creek_data_analysis_summary_report.pdf

The quality-assured data from these sampling efforts are the primary means for evaluating compliance with water quality standards and will serve as the primary indicator of success under this WPP. The ambient parameters sampled are the same as to those sampled during the WPP development project.

While data from all the stations will be reviewed, the most downstream stations of each of the attainment areas (11314 and 11313 for the headwaters and downstream, respectively[154]) for this WPP are the ultimate focus of evaluation. However, special attention will also be given to tributary stations to evaluate whether additional attention or modeling is needed to isolate the tributaries. Monitoring will be conducted under an approved quality assurance project plan (QAPP).

Additional Data

In addition to CRP/TCEQ monitoring, other state, regional, and local sources will be used to evaluate specific aspects of water quality in the waterways. These sources include:

- DMR (TCEQ) – The Partnership will review outfall discharge monitoring data from WWTFs in the watershed.
- SSOs (TCEQ) – SSOs reported to TCEQ will be assessed periodically to evaluate progress in reducing this source.
- TST volunteers – TST volunteer data will be used to supplement CRP data as an indicator of change over time and site-specific areas of concern. Observations made by volunteers can provide important information on localized conditions.

The combination of these data will provide the Partnership with a robust picture of the changing health of the waterways. The ambient stations at the end of each attainment area and the WWTF permit data will be the primary point of comparison to indicators of success for the WPP.

Supporting Research

In addition to the solutions identified in Sections 5 and 6, and the implementation strategies outlined in Section 7, the Partnership identified several areas of data in which additional research was warranted to ensure informed future decisions by the Partnership. These proposed research activities may or may not be pursued by the Partnership but are identified areas of inquiry, under a future QAPP, that would benefit future WPP updates.

Wildlife Source Estimation

The current *E. coli* load totals assume a conservative additional load for warm-blooded animals (not including deer) for which there was insufficient data as part of the safety

[154] Shown in Figure 43, Section 4.

margin category. This source has been an appreciable contributor to instream loads in some other watersheds (especially in more rural areas), exceeding 40-50% in some microbial source tracking studies[155]. Absent any microbial source tracking data for the Spring Creek watershed, and in consideration of its more developed character, a conservative estimate of 10% of total source load in current conditions was assigned to the safety margin which includes undocumented wildlife. However, additional data, in either the form of microbial source tracking information or wildlife population data estimates or established statewide wildlife loading assumptions based on land cover, could refine those estimates. This need is especially relevant given the propensity for wildlife to use stream corridors to traverse developing areas like this watershed. The Partnership will work with Texas A&M University, other academic institutions and TPWD to determine the feasibility of establishing general or species-based estimates for wildlife populations not usually addressed in WPPs. The intent is to establish loading estimates for the background concentrations of fecal bacteria to ensure WPP projections are as accurate to watershed conditions as possible.

Microbial Source Tracking

Microbial source tracking (MST) (also referred to as bacterial source tracking or fecal typing in this context) is a general name for a range of methods[156] that use genetic information to identify the origins of biological pollutants present in a water body. Identification of *E. coli* is based on the genetic detection of bacteria strains specific to different animal types in surface water samples. MST can help characterize uncertainties in modeling efforts (*e.g.*, undocumented wildlife) and provide more information on what sources are represented instream, as opposed to source loads. However, MST or similar methods can have an appreciable amount of uncertainty and reflects the period of time in which samples were collected, so it should be considered in addition to other data sources.

More narrowly focused approaches of testing for host-specific DNA (instead of host-specific bacterial DNA) are also used and may help overcome some uncertainties related to representativeness of *E. coli* strains across the watershed area or across time. The stakeholders recommended that source tracking or analysis of the most applicable type be employed as needed in the Spring Creek Watershed, with an intended focus on specified areas during narrow time frames for purposes such as illicit discharge detection,

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[155] For example, the Watershed Protection Plan for the Leon River Below Proctor Lake and Above Belton Lake indicated that its bacterial source tracking conducted at three stations showed "…between 41 and 55 percent of bacteria sources originate from wildlife or invasive species (*e.g.*, avian species, wild animals, and feral hogs) …". Accessed 5/21/2021 at: http://leonriver.tamu.edu/media/1110/final-leon-wpp.pdf
[156] For the purpose of this discussion, the term is being used to include a broad range of other assays and identification methods using genetic or species-specific markers.

understanding localized spikes, *etc*. The Partnership recognizes the potential value of these tools for guiding decisions when opportunity and resources allow.

Hydrologic Impacts on Water Quality

Several large studies and efforts are currently evaluating various aspects of the hydrology/hydraulics within the Spring Creek system and in adjacent watersheds. Additionally, there is significant investment planned for flood mitigation activities that may change flow patterns in the waterway. The potential for these factors to influence water quality conditions is unknown. While flood mitigation measures are expected to have a relatively positive impact (*e.g.*, settling of pollutants in wet bottom detention basins), water quality impacts have not been a primary focus of the ongoing efforts. The Partnership does not have a specific recommendation, other than ongoing coordination with these efforts, but expressed an interest in subsequent research that might help predict water quality impacts. H-GAC, EPA and USACE are currently involved in a Watershed Management Optimization Support Tool modeling effort that may provide additional detail prior to, or immediately subsequent to, the approval process for this WPP. This information will help guide future decisions and WPP updates, but additional research will likely be needed given the scale of potential flood mitigation efforts in and around the watershed.

Indicators of Success

The Partnership identified key criteria for success for use in evaluating the progress of the WPP. The success indicators are used to measure the effectiveness of the implementation effort and the pace of progress (**Table 41**). Ultimate success in the waterways of the Spring Creek watershed is found in achieving the water quality goals of the stakeholders. However, the changing nature of the watershed may mask some achievements in early years, as pollutant sources continue to increase rapidly even as implementation begins. However, the future focus of the WPP takes these considerations into account. To ensure that progress can be evaluated against this background, programmatic metrics will also be used as indicators of successful progress.

Compliance with Water Quality Standards

The primary, quantitative goal of the WPP is to achieve and maintain compliance with SWQSs at the representative stations for each of the attainment areas. A secondary goal is to ensure source reduction by meeting TPDES permit limits. Therefore, the primary indicators of success are listed below.

- The status of the waterways on the most current Texas Integrated Report, with specific focus on the SWQSs for contact recreation standard (bacteria criteria for primary contact recreation 1), and aquatic life use (DO, *etc*.), are the main benchmarks of success. Success is measured by fully supporting all uses, and progress in abating concerns.

- A positive or stable trend in WWTF compliance, as indicated in the DMRs/SSOs will also indicate successful implementation.

While the goal of the WPP is to move water quality toward compliance, the changing nature of the watershed may mean that in interim years, a reduction of projected degradation will also be considered as interim progress. Based on known development and current trends, westward growth spanning toward the headwaters area is likely to continue to be strong but not necessarily linear. Large blocks of developed area can come online in shorter time frames, meaning sudden influxes of sources rather than steady growth or decline. Increased development west of SH 249, especially, is likely to result in short term increases in source load that may overshadow beneficial actions in the same time frame. This dynamic environment differs from a watershed in which a similar effort each year can be expected to attain and maintain compliance. While the end goal for 2030 remains the focus of the WPP, some interim periods will be better measured by programmatic milestones or water quality change in localized areas related to implementation efforts rather than a broad survey instream quality.

Programmatic Achievement

The ability to maintain the Partnership, fund implementation, and put solutions in place are qualitative indicators of the success of the implementation efforts. Additional program elements include the progress partners make toward related requirements (MS4 permits, *etc.*). These programmatic indicators are:

- implementing solutions at a pace that is sufficient to meet interim milestones,
- a Partnership group that continues to be active and engaged in implementation, and
- acquisition of funding levels and technical resources sufficient to realize implementation goals.

Table 41. Indicators of success

Goal	Indicator of Success	Source of Identification
Quantitative, Compliance with SWQSs	Fully support all designated uses	CRP data; Texas Integrated Report status
	Comply with TPDES permit limits	WWTF DMR/SSO
Qualitative, Implementation of WPP	Solutions implemented (based on implementation milestones)	Partnership records; MS4 Annual Reports; partner information
	Implementation funded sufficiently	Funding sources identified and acquired
	Maintain Partnership	At least annual meetings held

Adaptive Management

As conditions change within the watershed, the practices and approach we use to address water quality issues must adapt. This WPP is a living document used to guide implementation of the solutions developed by local stakeholders. It is designed to be flexible to changing conditions. The WPP will engage in a process of continual review and revision called **adaptive management** to ensure it remains relevant to its purpose and the stakeholders' decisions. Adaptive management is a structured process by which changes in conditions and evaluation of progress and programmatic achievements are used to identify potential revisions to the WPP. Feedback on progress shapes future planning. The Partnership understands that a continual process of review and revision will be needed in the future to ensure the WPP's success. The content and efforts of this WPP will be reviewed at several points during implementation, with the fundamental questions being as to whether the solutions are having their desired effects, and whether progress is being made on water quality standards compliance (**Table 42**).

Table 42. Adaptive management process

Adaptive Management Process	
Component	**Description**
Ad hoc review	Each partner responsible for implementing any activity will do due diligence in evaluating the continuing effectiveness of the activity. This review happens on an informal or project-specific basis. Partners are encouraged to share any insights on what is working well or what is working poorly with the Partnership at large. Facilitation staff will talk regularly with partners to assess progress.
Annual Review	Every year the Partnership will review progress made during that year during a public meeting. The results of the annual reviews will be summarized for dissemination to the stakeholders and the WPP may be amended as needed.
Formal WPP Reviews	At least every four years[157], the Partnership will conduct a formal review and revision (as appropriate) of the WPP. This process will include at least a 30-day review period and open public meeting. The result of the review will be an amended WPP. Criteria for review will include but not be limited to: • Stakeholder feedback on implemented solutions and resources (stakeholders) • Water quality data summary of segment conditions (H-GAC or successor watershed coordinator) • Review of progress in meeting programmatic milestones • Progress in complementary efforts (MS4 permits, *etc.*)
Continuity Review	Two years prior to 2030, the Partnership will discuss during its Annual Review, how it will plan for the next period of implementation (if needed). At this time, the Partnership will identify any modeling, data analysis and collection, or other information needed to make further projections for future implementation periods.

[157] Corresponding to the implementation phases of early (2023-2027), and late (2025-2030) implementation. Some partners use different planning cycles. The 4-year milestone is a minimum.

Appendices

Photo Credit: Jessica Casillas

Appendix A. WPP Information Checklist

Elements in the table below correspond to the 9 minimum elements required by EPA for developing watershed-based plans using Clean Water Act 319(h) grant resources. For more information on these guidelines, please refer to EPA's Handbook for Developing Watershed Plans to Restore and Protect Our Waters[158].

Table A. 1 Guide to watershed protection plan information

Segment Information	
Name of Water Body	Spring Creek (Segment 1008)
Assessment Units	1008_01, 1008_02, 1008_03, 1008_04, 1008A_01, 1008B_01, 1008B_02, 1008C_01, 1008C_02, 1008E_01, 1008F_01, 1008F_02, 1008F_03, 1008F_04, 1008H_01, 10081_01, 1008J_01
Impairments Addressed	Contact recreation/*E. coli*
Concerns Addressed	Nitrate, Total Phosphorus, Dissolved Oxygen (grab)
Element	**Report Section(s) and Page Number(s)**
Element A: Identification of Causes and Sources	
1. Sources identified, described, and mapped	Section 3 • pp. 38-57; water quality analysis and point source contribution descriptions • pp. 57-93; formal source descriptions, modeled loadings, and maps of spatial distribution
2. Subwatershed sources	Section 3 • pp. 57-93; sources are described in terms of their general spatial distribution and loads by subwatersheds • **Table 27** summarizes all loadings by subwatershed
3. Data sources are accurate and verifiable	Section 2 • In general, data used for characterization and mapping is discussed throughout with footnote links to specific sources • pp. 34; description of water quality data and links to the project water quality report Section 3 • pp. 38-57; discussion of water quality monitoring analyses, point source data analyses, and data sources • pp. 57-93; description of sources and loadings with references to data used Section 4 • pp. 95-101; description of LDCs and data sources. • pp. 105-110; application of data sources to load reduction goals discussed Section 8 • pp. 185-190; discussion of data sources to be used for evaluating success

[158] For more information, see: https://www.epa.gov/nps/handbook-developing-watershed-plans-restore-and-protect-our-waters

Element	Report Section(s) and Page Number(s)
4. Data gaps identified	Section 3 • In general, discussion of uncertainty in various modeling and data approaches (pp. 46-49 for WWTF data; pp. 62-64, 88-93 and footnote 45 for SELECT modeling; pp. 85-86 for SSO data) Section 4 • pp. 102-103; discussion of DO precursors Section 8 • pp. 185-190; specific discussion of additional data sources that may be helpful (other wildlife estimations, BST/MST, etc.)
Element B: Expected Load Reductions	
1. Load reductions achieve environmental goal	Section 4 • pp. 105-110; description of linkage of environmental goal (via LDC reductions) to source loads (via SELECT estimations) • Summarized specifically in **Table 32** through **Table 35**
2. Load reductions linked to sources	Section 4 • pp. 105-110; description of linkage of environmental goal (via LDC reductions) to source loads (via SELECT estimations) • Summarized specifically in **Table 32** through **Table 35**
3. Model complexity is appropriate	Section 3 • pp. 57-64; description of modeling approach (p. 61-63 specific to SELECT); link to project modeling report; pp. 62 contains specific description of rationale for modeling approach • Results of modeling indicated above in B1/B2 Section 4 • pp. 95-101; description of LDC modeling approach • pp. 105-110; description of LDC and SELECT linkage
4. Basis of effectiveness estimates explained	Section 4 • pp. 108-109; description of use of representative units Section 5 • pp. 115-150; solution effectiveness/reduction efficiency discussed in the bottom of each recommended solution page Appendix E • Description of use of representative units
5. Methods and data cited and verifiable	Section 3 • Throughout (pp. 38-93); data and methods for water quality analyses, point source analyses, and source estimations discussed with references in footnotes as appropriate and links to project modeling and water quality analysis reports Section 4 • Throughout (pp. 105-110); data for load reduction goals discussed, links to project modeling report included
Element C: Management Measures Identified	
1. Specific management measures are identified	Section 5 • pp. 115-150; specific measures described, including technical and financial support needed, roles and responsibilities, *etc*. *Section 6* • pp. 153-164; specific educational measures described, including responsible parties
2. Priority areas	Section 5 • pp. 115-150; discussion of priority areas for each category of specific focus

Element	Report Section(s) and Page Number(s)
	Section 6 • pp. 153-164; general description of intended audiences/areas for educational activities
3. Measure selection rationale documented	Section 5 • pp. 112-113; specific description of guiding principles for selection and selection process • pp. 151; summary of selection process and intention Section 6 • pp. 153-155; description of Partnership's goals for selected educational measures
4. Technically sound	Section 5 • pp. 115-150; specific measures described, including technical detail Section 6 • pp. 153-164; specific educational measures described Section 7 • pp. 166-169; specific implementation strategies for measures in general, and pet waste as a focus
Element D: Technical and Financial Assistance	
1. Estimate of technical assistance	Section 5 • pp. 115-150; technical assistance needs detailed for each measure in their one-page summaries
2. Estimate of financial assistance	Section 5 • pp. 115-150; financial assistance needs detailed for each measure in their one-page summaries Appendix D • List of potential funding sources related to measures in this WPP
Element E: Education/Outreach	
1. Public education/information	Section 6 • pp. 153-164; description of public outreach activities
2. All relevant stakeholders are identified in outreach process	Section 1 • pp. 3-7; description of initial outreach, forming the Partnership, links to Public Participation Plan for the project Section 6 • pp. 153-164; description of public outreach activities including existing partners/roles and focus areas
3. Stakeholder outreach	Section 1 • pp. 3-7; description of initial outreach, forming the Partnership, links to Public Participation Plan and Stakeholder Outreach Report for the project
4. Public participation in plan development	Section 1 • pp. 3-7; description of initial outreach, forming the Partnership, links to Public Participation Plan and Stakeholder Outreach Report for the project Section 3 • pp. 57-60; description of Partnership process in identifying sources and assumptions (specific to each source, pp. 65-89) Section 4 • pp. 105-110; description of stakeholder choices in reduction linkage, load allocation, etc. Section 5 • pp. 112-114; description of stakeholder participation in measures selection

Element	Report Section(s) and Page Number(s)
	Section 6 • pp. 153-155; description of stakeholder decisions on outreach strategies Section 7 • pp. 166-169; description of stakeholder input on implementation strategies Section 8 • pp. 185-190; description of the Partnership's role in determining how the project evaluates success
5. Emphasis on achieving water quality standards	Section 1 • pp. 6-7; description of specific water quality goals for the project/Partnership All Other Sections • Water quality standards are the focus of water quality analyses (Section 3), the focus of all load reduction calculations (Section 4), the focus of recommended solutions (Section 5 and 6), the focus of implementation strategies (Section 7), and the primary measure of success (Section 8).
6. Operation and maintenance of BMPs	Section 5 • pp. 115-150; discussion of specifics of recommended solutions are included with each solution and/or solution category description
Element F: Implementation Schedule	
1. Includes completion dates	Section 7 • pp. 170-183; implementation schedule
2. Schedule is appropriate	Section 7 • pp. 170-183; implementation schedule
Element G: Milestones	
1. Milestones are measurable and attainable	Section 7 • pp. 170-183; milestones described for all measures
2. Milestones include completion dates	Section 7 • pp. 170-183; milestones described for all measures
3. Progress evaluation and course correction	Section 8 • pp. 185-190; describes all methods uses to evaluate success for the project; pp. 190 specifically describes adaptive management processes
4. Milestones linked to schedule	Section 7 • pp. 170-183; Milestones described for all measures with timeframes indicated
Element H: Load Reduction Criteria	
1. Criteria are measurable and quantifiable	Several sections detail the process of developing load reductions, including (as noted in Element B) Section 3 (source loads), Section 4 (load reductions), and Section 8 (evaluation criteria).
2. Criteria measure progress toward load reduction goal	Section 8 • pp. 185-190; describes evaluation criteria and data sources used to evaluate both water quality and programmatic milestones.
3. Data and models identified	Section 8 • pp. 185-190; describes evaluation criteria and data sources used to evaluate both water quality and programmatic milestones.
4. Target achievement dates for reduction	Throughout the document, the plan states that 2030 is the intended goal year (as noted previously). Section 4 bases load reductions on this timeline. Section 5/6 recommendations are based on time period within this planning horizon. Section 7 schedule and milestones are based on this period. Section 8 evaluation criteria also assumes this date.

Element	Report Section(s) and Page Number(s)
5. Review of progress toward goals	Section 8 • pp. 185-190; details the methods that will be used to evaluate progress regarding water quality • pp. 188-190; details the methods that will be used to evaluate progress regarding programmatic means
6. Criteria for revision	Section 8 • pp. 188-190; describes the indicators of success and adaptive management process
7. Adaptive management	Section 8 • pp. 190; describes the adaptive management process
Element I: Monitoring	
1. Description of how monitoring used to evaluate implementation	Section 8 • pp. 185-189; describes the monitoring plan and other potential data sources
2. Monitoring measures evaluation criteria	Section 8 • pp. 187-189 describes the indicators of success, including water quality/monitoring outcomes
3. Routine reporting of progress and methods	Section 8 • pp. 185-190, describes both the monitoring process and its reporting/evaluation, as well as the project evaluation and formal reviews process with the Partnership (Table 43, *etc.*)
4. Parameters are appropriate	Section 8 • pp. 185-186 describes the monitoring program
5. Number of sites is adequate	Section 8 • pp. 185-186 describes the monitoring program
6. Frequency of sampling is adequate	Section 8 • pp. 185-186 describes the monitoring program
7. Monitoring tied to QAPP	Section 8 • pp. 185-186 describes the monitoring program under CRP QAPP • pp. 186-188 describes the potential use of other data sources
8. Can link implementation to improved water quality	Section 8 • pp. 185-186 discusses the monitoring program • pp. 188-190 discussed water quality indicators of success

Appendix B. Wastewater Treatment Facilities

Table B. 1 Spring Creek watershed WWTF permittees at study initiation

Permittee	Permit Number
City of Tomball	WQ0010616001
City of Tomball	WQ0010616002
Montgomery County WCID 1	WQ0010857001
Harris County WCID 92	WQ0010908001
Northampton MUD	WQ0010910001
Southern Montgomery County MUD	WQ0011001001
San Jacinto River Authority	WQ0011401001
Dowdell PUD	WQ0011404001
Harris County MUD 26	WQ0011406001
Spring Creek Utility District	WQ0011574001
Harris County MUD 1	WQ0011630001
Harris County MUD 1	WQ0011630002
Harris County MUD 82	WQ0011799001
Montgomery County MUD 19	WQ0011970001
Rayford Road MUD	WQ0012030001
Harris County MUD 368	WQ0012044001
Aqua Texas, Inc.	WQ0012303001
J&S Water Company, LLC	WQ0012382001
Aqua Texas, Inc.	WQ0012519001
Monarch Utilities I, LP	WQ0012587001
San Jacinto River Authority	WQ0012597001
Spring Center, Inc.	WQ0012637001
Pinewood Community, LP	WQ0012643001
Trinity SO GP, LLC	WQ0012650001
China Spring Holdings, LP	WQ0012851001
Aqua Texas, Inc.	WQ0012898001
Northgate Crossing MUD 2	WQ0012979004
Aqua Texas, Inc.	WQ0013619001
Wood Trace MUD 1	WQ0013636001
Encanto Real Utility District	WQ0013648001
Magnolia Independent School District	WQ0013653001
1960 Humble Westfield, LTD	WQ0013697001
Inline Utilities, LLC	WQ0013942001
Aqua Texas, Inc.	WQ0014007001
Aqua Texas, Inc.	WQ0014013001
Magnolia Independent School District	WQ0014124001
Utilities Investment Company, Inc.	WQ0014133001
Aqua Texas, Inc.	WQ0014141001
Aqua Texas, Inc.	WQ0014181001

Permittee	Permit Number
Archdiocese of Galveston Houston	WQ0014218001
Harris County MUD 387	WQ0014347001
Harris County MUD 401	WQ0014421001
Is Zen Center	WQ0014491001
Quadvest, LP	WQ0014542001
Harris County MUD 480	WQ0014606001
Montgomery County MUD No 119	WQ0014656001
Navasota Independent School District	WQ0014662001
TWAN Development, LLC	WQ0014776001
Terra Verde Utility Company, LLC	WQ0014901001
City of Magnolia	WQ0014903001
Clover Creek MUD	WQ0014907001
Northwest Harris County MUD 19	WQ0014908001
Northwest Harris County MUD 19	WQ0014908002
Timbercrest Partners, LLC	WQ0014912001
Harris County Improvement District 18	WQ0014964001
Aqua Texas, Inc.	WQ0014973001
Eastwood Hills Mobile Home Park, LP	WQ0014979001
Quadvest, LP	WQ0015003001
Montgomery County MUD 137	WQ0015157001
KTC Interests, LLC	WQ0015246001
Harris County MUD No. 542	WQ0015312001
7E Property Holdings, LP	WQ0015500001

Appendix C. Agricultural Best Management Practices

This appendix details the typical practices implemented in WQMPs and similar agricultural land management projects[159]. Emphasis for this WPP is put on practices that reduce animal wastes or impede transmission of wastes to water.

Table C. 1 Agricultural best management practices

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

[159] Technicians work with local landowners/producers to design WQMPs on a site-specific basis. More information about WQMPs, standard practices, and related TSSWCB programs can be found at https://www.tsswcb.texas.gov/programs/water-quality-management-plan.

Appendix D. Potential Funding Resources

This appendix contains examples of funding resources, by category, that may be utilized to implement aspects of this WPP's recommendations. These resources represent potential external sources of funding other than existing or local contributions (*ad valorem* tax revenue, landowner contributions, *etc.*). The Partnership will continue to track, evaluate, and match grant sources for potential implementation activities as part of the ongoing facilitation of this WPP.

Table D. 1 Potential funding sources

Grant Program	Grantor	Uses
Clean Water Act 319(h) Nonpoint Source grants	TCEQ, TSSWCB	Multiple implementation and outreach activities
Clean Water Act 604(b) water quality management planning grants	TCEQ	Data development, forestry outreach
Flood Infrastructure Fund / Flood Mitigation Assistance Program	TWDB	Flood mitigation, resilience
Clean Water State Revolving Fund	TWDB	Utility infrastructure, related planning
Community Development Block Grant (MIT/DR)	GLO/HUD	Flood mitigation, resilience
Private Foundation Grants	Private Foundations (e.g., Houston Endowment, Hershey Foundation, Powell Foundation, and others)	Multiple, specific to foundations
Various grant programs	TPWD	Wildlife, parks and recreation, farm and ranchland preservation, trails
Building Resilient Infrastructure and Communities (BRIC)	FEMA/Texas Division of Emergency Management	Disaster resilience
WQMP	TSSWCB	Agricultural best practices
Regional Conservation Partnership Program (RCPP)	USDA NRCS	Conservation
H-GAC OSSF SEP	TCEQ/WWTFs; Harris County	OSSF remediation for low-income households
Restoring America's Wildlife Act	TPWD	Federal support for ecosystem restoration and related projects.
Farm Bill Programs (EQIP, and others)	USDA NRCS, local SWCDs	Landowner support for property improvements with environmental benefits, including conservation easements, forest reserves, watershed protection, wetland mitigation, water quality, etc.
Corporate donations	Corporate partners	Varies by entity
Land and Water Conservation Fund	US Forest Service	Conservation

Grant Program	Grantor	Uses
Various grant programs	US Fish and Wildlife Service	Conservation, habitat restoration, wetlands restoration, endangered species
Various grant programs	National Park Service	Outdoor recreation, conservation
Various other grant programs	EPA	Coastal watersheds/estuaries, brownfields, clean water
Wetland and Stream Mitigation Banks	USACE	Wetland and stream mitigation banking
Deepwater Horizon/RESTORE Act Settlement funds	Gulf Coast Ecosystem Restoration Trust Fund, State of Texas (representative)	Conservation, restoration, resilience

Appendix E. Reduction Targets and Representative Units

This appendix provides more detail on the stakeholder decision-making process regarding the calculation of *E. coli* load reduction targets and how these targets were converted to representative units.

Part of the challenge in selecting *E. coli* reduction targets included finding the best method for conceptualizing targets in a way that would improve stakeholders' ability to determine the practicality of achieving those targets by the implementation goal date. The following steps were used to visualize reductions relative to overall loads, determine the feasibility of targeted reductions for each source, and reallocate implementation effort where necessary.

- ***Step 1:*** *Determine source specific E. coli load reduction targets*

  As described in Section 4, the overall load reduction target (RT) in cfu/day for each attainment area within the Spring Creek watershed was calculated using the following equation where:

  PR_{LDC} = percent reduction calculated from weighted average of reductions needed at different levels of streamflow indicated in LDC analyses

  L_{SELECT} = SELECT instream load estimate in cfu/day as of latest observed data (2018)

  IL = incremental load in cfu/day accrued between latest observed data year (2018) and target implementation goal year (2030)

  $$RT = (PR_{LDC} * L_{SELECT}) + IL$$

  Next, stakeholders determined load reductions for each source considered in the SELECT model needed to achieve the overall reduction target. This was done by multiplying the percent contribution of each source to the total instream load estimated for the year 2030 by the RT for each attainment area as shown in **Table 34**. This resulted in source-specific load reduction targets in cfu/day proportional to the contribution of each source to the overall load in 2030.

- ***Step 2:*** *Represent reduction targets as percentages*

  Representing source-specific load reduction targets in cfu/day prevented stakeholders from visualizing these targets in practical terms. Instead, stakeholders elected to view these values as percentages of the total estimated instream load from each source as shown in **Table E. 1** and **Table E. 2** below.

Table E. 1 Reduction targets, headwaters attainment area

Source	Source Contribution to Total Daily Load, 2030 (cfu/day)	Source Load Reduction Target, 2030 (cfu/day)	Load Reduction Target Relative to Contribution to Total Daily Load, 2030 (%)
WWTFs	8.49E+09	5.46E+09	64%
OSSFs	3.15E+12	2.02E+12	64%
Dogs	2.46E+13	1.58E+13	64%
Cattle	8.09E+12	5.20E+12	64%
Horses	5.80E+10	3.73E+10	64%
Sheep/Goats	3.70E+12	2.38E+12	64%
Deer	2.13E+11	1.37E+11	64%
Feral Hogs	8.24E+12	5.30E+12	64%
Safety Margin	5.35E+12	3.43E+12	64%

Table E. 2 Reduction targets, downstream attainment area

Source	Source Contribution to Total Daily Load, 2030 (cfu/day)	Source Load Reduction Target, 2030 (cfu/day)	Load Reduction Target Relative to Contribution to Total Daily Load, 2030 (%)
WWTFs	1.18E+11	8.97E+10	76%
OSSFs	4.45E+12	3.40E+12	76%
Dogs	7.12E+13	5.43E+13	76%
Cattle	1.49E+12	1.14E+12	76%
Horses	1.07E+10	8.15E+09	76%
Sheep/Goats	6.81E+11	5.19E+11	76%
Deer	1.01E+11	7.70E+10	76%
Feral Hogs	2.93E+12	2.24E+12	76%
Safety Margin	9.00E+12	6.86E+12	76%

- ***Step 3:*** *Assess distribution of effort*

  By viewing the reduction targets as percentages, stakeholders were able to decide how to reallocate implementation efforts between sources. For example, deer and other wildlife impacts (accounted for in the safety margin) cannot be directly addressed through implantation actions described in this document. The load burden from these sources must still be addressed in order to achieve the overall reduction target. Stakeholders elected to increase reductions for other sources (in this case, pet waste) in order to absorb these burdens. In this watershed, stakeholders used a similar strategy to address loads from WWTFs and horses. Because these sources are not expected to contribute significantly to the instream load, stakeholders chose to direct more of their efforts to addressing pet waste and again increased the associated reduction target. These adjustments are shown in **Table E. 3** and **Table E. 4** below.

Table E. 3 Reduction targets adjusted for stakeholder preference in implementation effort distribution, headwaters

Source	Source Contribution to Total Daily Load, 2030 (cfu/day)	Stakeholder Adjusted Source Load Reduction Target, 2030 (cfu/day)	Stakeholder Adjusted Load Reduction Target Relative to Contribution to Total Daily Load, 2030 (%)
WWTFs	8.49E+09	0	0%
OSSFs	3.15E+12	2.02E+12	64%
Dogs	2.46E+13	1.95E+13	79%
Cattle	8.09E+12	5.20E+12	64%
Horses	5.80E+10	0	0%
Sheep/Goats	3.70E+12	2.38E+12	64%
Deer	2.13E+11	0	0%
Feral Hogs	8.24E+12	5.30E+12	64%
Safety Margin	5.35E+12	0	0%

Table E. 4 Reduction targets adjusted for stakeholder preference in implementation effort distribution, downstream

Source	Source Contribution to Total Daily Load, 2030 (cfu/day)	Stakeholder Adjusted Source Load Reduction Target, 2030 (cfu/day)	Stakeholder Adjusted Load Reduction Target Relative to Contribution to Total Daily Load, 2030 (%)
WWTFs	1.18E+11	0	0%
OSSFs	4.45E+12	3.40E+12	76%
Dogs	7.12E+13	6.13E+13	86%
Cattle	1.49E+12	1.14E+12	76%
Horses	1.07E+10	0	0%
Sheep/Goats	6.81E+11	5.19E+11	76%
Deer	1.01E+11	0	0%
Feral Hogs	2.93E+12	2.24E+12	76%
Safety Margin	9.00E+12	0	0%

While WWTF and horse waste impacts will effectively be addressed by increased implementation for pet waste reduction, they are still considered to be important components of implementation and will continue to be monitored throughout the project period.

- *Step 4:* *Convert adjusted reduction targets to representative units*

  Finally, stakeholder-adjusted load reduction targets in cfu/day were converted to representative units as shown in **Table 35**. To do this, stakeholder-adjusted load reduction targets were divided by the loads expected from each source at their most basic level (*e.g.*, the representative unit for pet waste is equal to the daily *E. coli* load produced by one dog). These conversions are shown in **Table E. 5** and **Table E. 6** below.

Table E. 5 Reduction targets as representative units, headwaters attainment area

Source	Stakeholder Adjusted Source Load Reduction Target, 2030 (cfu/day)	Representative Unit Daily Load (cfu/day)	Representative Units to Address by 2030
WWTFs	0	4.77E+09	0
OSSFs	2.02E+12	3.71E+09	545
Dogs	1.95E+13	2.50E+09	7,780
Cattle	5.20E+12	2.70E+09	1,926
Horses	0	2.10E+08	0
Sheep/Goats	2.38E+12	9.00E+09	264
Deer	0	1.75E+08	0
Feral Hogs	5.30E+12	4.45E+09	1,190
Safety Margin	0	None	0

Table E. 6 Reduction targets as representative units, downstream attainment area

Source	Stakeholder Adjusted Source Load Reduction Target, 2030 (cfu/day)	Representative Unit Daily Load (cfu/day)	Representative Units to Address by 2030
WWTFs	0	4.77E+09	0
OSSFs	3.40E+12	3.71E+09	915
Dogs	6.13E+13	2.50E+09	24,533
Cattle	1.14E+12	2.70E+09	421
Horses	0	2.10E+08	0
Sheep/Goats	5.19E+11	9.00E+09	58
Deer	0	1.75E+08	0
Feral Hogs	2.24E+12	4.45E+09	502
Safety Margin	0	None	0