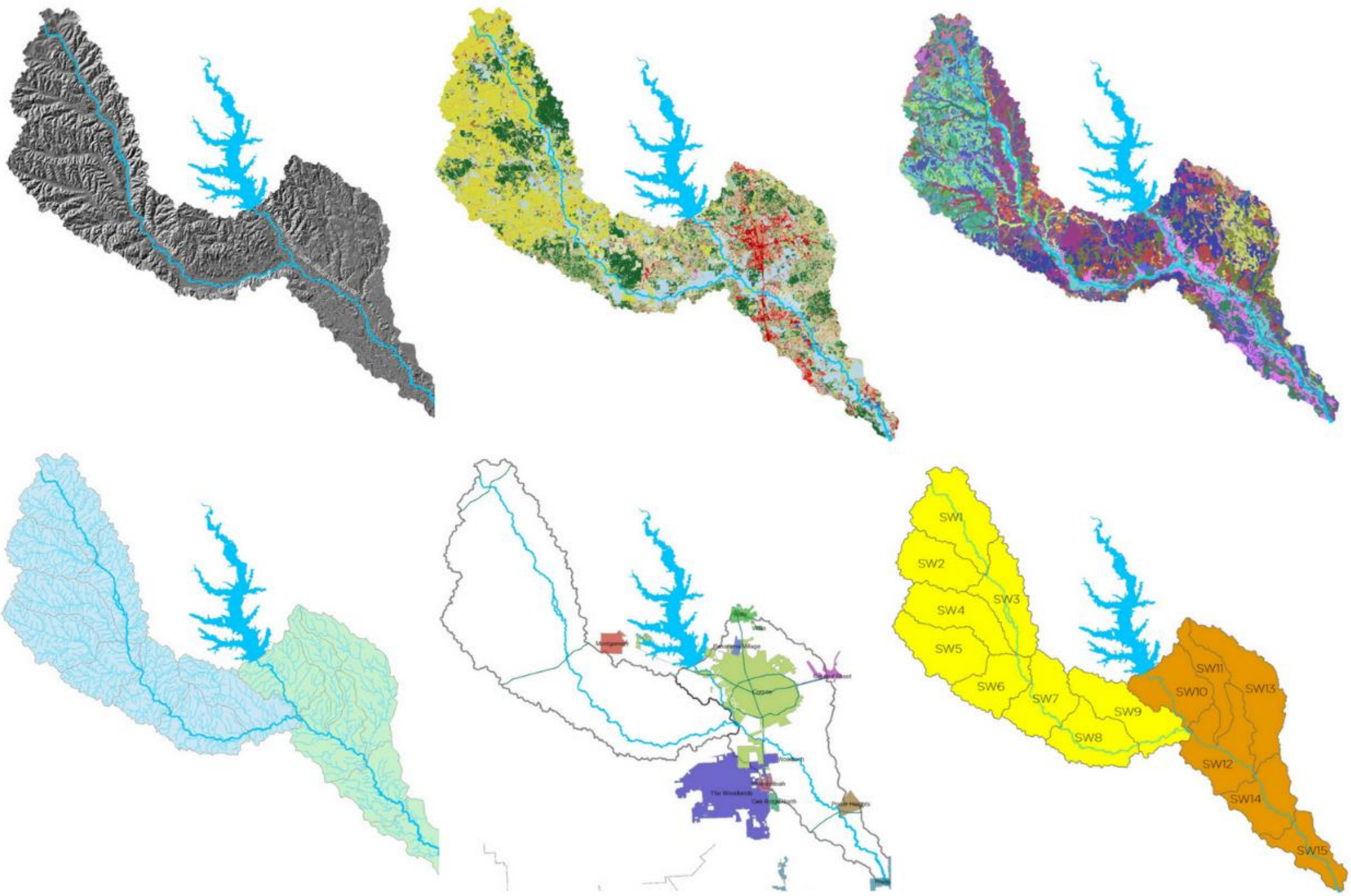
A

WATERSHED PROTECTION PLAN FOR THE

WEST FORK SAN JACINTO RIVER

AND LAKE CREEK WATERSHEDS



WEST FORK WATERSHEDS PARTNERSHIP

H-GAC Houston-Galveston Area Council

Galveston Bay Estuary Program

TCEQ

EPA United States Environmental Protection Agency

West Fork San Jacinto River and Lake Creek Watershed Protection Plan

Developed by the Houston-Galveston Area Council for the

West Fork Watersheds Partnership

September 2018

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Acknowledgements

The West Fork San Jacinto River and Lake Creek Watershed Protection Plan is the result of the knowledge, persistence, and hard work of a dedicated group of local stakeholders. This collaborative, locally-led effort would not have been possible without their contributions and guidance.

Steering Committee

The West Fork Watersheds Partnership (Partnership) wishes to sincerely thank the members of the project's Steering Committee, past and present. These individuals and organizations provided leadership and commitment to ensure the continuity and success of the project.

Glenn Buckley, Lake Creek Greenway Partnership

Hannah Cruce, Texas Forest Service - Houston

Becky Martinez, Bayou Land Conservancy

Dave McCourquodale, City of Montgomery

Scott Nichols, Montgomery County

David Parkhill, San Jacinto River Authority

Brian Koch, Texas State Soil and Water Conservation Board

Alice Best/Niki Ragan, Texas Parks and Wildlife Department – local (past)

Frank Green, Montgomery County (past)

Julia Germany, Resident (past)

Frank Parker, City of Magnolia (past)

Bruce Bodson, Bayou Land Conservancy (past)

Stephanie Proesser, Bayou Land Conservancy (past)

Technical Advisors

The Partnership also wishes to thank members of regional, state, and national organizations that have provided invaluable technical assistance, guidance, and feedback for this project. These technical advisors helped ensure that our effort was relevant and comparable to broader initiatives and provided resources to inform our stakeholders' decisions.

Galveston Bay Estuary Program

Harris County Soil and Water Conservation District

Houston-Galveston Area Council Clean Rivers Program

Montgomery County Soil and Water Conservation District

Navasota Soil and Water Conservation District

Texas A&M University AgriLife Extension, AgriLife Research, Texas Water Resources Institute

Texas Commission on Environmental Quality

Texas Forest Service

Texas Parks and Wildlife Department

Texas State Soil and Water Conservation Board

Texas Stream Team

USDA U.S. Forest Service

USDA Natural Resources Conservation Service

Trust for Public Land

Texas Master Naturalists

Local Stakeholders

The West Fork Watershed Partnership wishes to especially thank both the local organizations and individuals who have been involved in the development of the watershed protection program. Their local knowledge and participation are crucial elements in protecting the public health, economy, and environment of their waterways and communities.

Randy Acreman, San Jacinto River Authority
Zafar Ahmed, City of Houston
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Ryan Bare, Houston Advanced Research Center
Matt Barrett, San Jacinto River Authority
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Christine Cooper, City of Conroe
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Robert Floyd, Resident
Julia Germany, Resident
Jim Gras, Landowner/Rancher
Tom Graziano, Landowner/Rancher
Frank Green, Montgomery County
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Fabian Heaney, City of Houston
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Lisa Marshall, Galveston Bay Estuary Program
Becky Martinez, Bayou Land Conservancy
Dave McCorquodale, City of Montgomery
Miles McKinney, The Woodlands Township
Seth Miles, City of Conroe
LaNelle Miller, Resident
Davies Mtunda, San Jacinto River Authority
Richard Myers, Municipal Utility District 83
Paul Nelson, Lone Star Groundwater Conservation District
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Jennifer Seale, Texas Master Naturalists
Hughes Simpson, Texas Forest Service
Shane Simpson, San Jacinto River Authority
Monica Singhania, Texas Forest Service
Scott Taylor, City of Conroe
Richard Tramm, Porter Special Utility District
Krien VanBerkinoes, Lake Creek Greenway
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Paula Warren, Harris County Judge Emmett's Office
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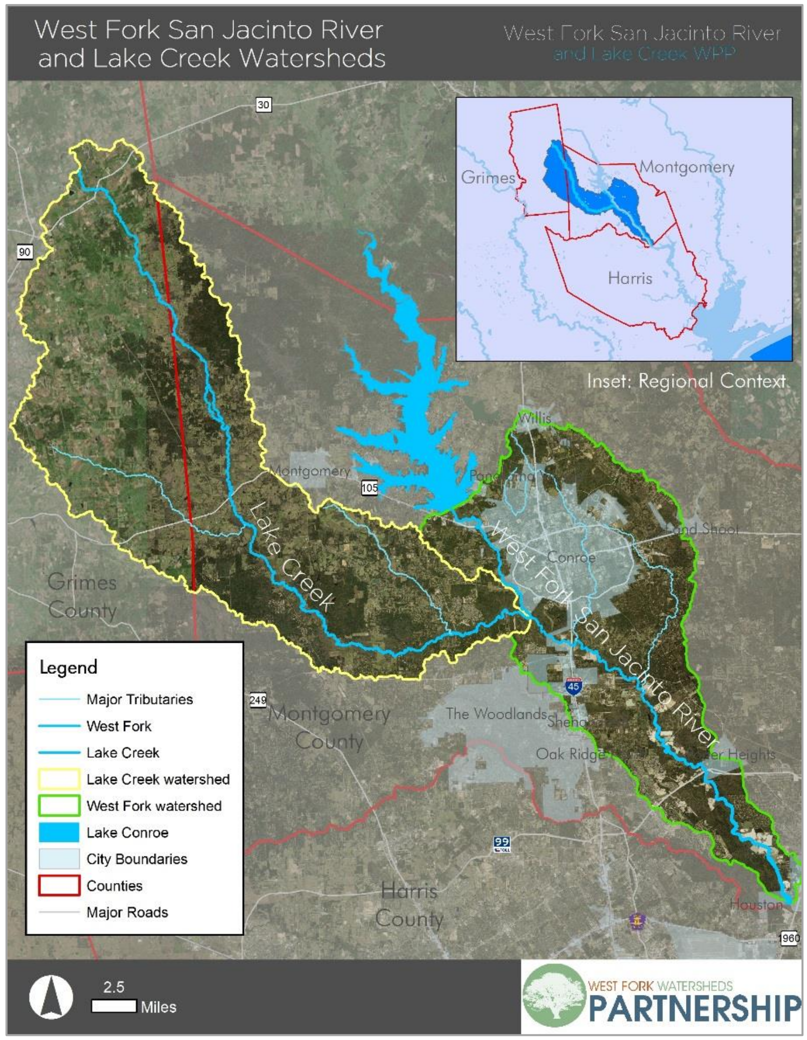
Several ancillary documents providing additional detail about the analyses and processes the Partnership undertook to develop this WPP are hosted on the project website. They include:

- **Modeling Quality Assurance Project Plan** – *the quality assurance document indicating the manner and methods in which project modeling efforts will be conducted to ensure results reflect project data quality objectives.*
- **Water Quality Data Collections and Trends Report** – *a detailed report on the analysis of various water quality data used to characterize the conditions in the project are waterways.*
- **Modeling Methodology Report** – *a description of the process of identifying and selecting models to evaluate water quality improvement goals.*
- **Bacteria Modeling Report** – *a detailed summary of the development and implementation and results for the bacteria modeling efforts.*
- **Nutrients and DO Modeling Report** – *a report on the development and implementation of the nutrients and DO modeling efforts.*

Figure 1 - A shaded stretch of Lake Creek

Executive Summary

The West Fork of the San Jacinto River (West Fork) lies between Lake Conroe and Lake Houston, connecting the communities of this burgeoning transportation corridor. Lake Creek is its primary tributary upstream of the confluence with Spring and Cypress Creeks at Lake Houston.



Together, these waterways drain over 540 square miles of diverse land uses in Montgomery, Grimes, and Harris counties and serve a crucial role as a conduit of drinking water supply between the lakes.

The watersheds of the West Fork and Lake Creek are an essential part of the local communities and economies, supporting recreation, fisheries, and a diverse ecology.

Water Quality Challenges

This WPP is focused on the watersheds of the West Fork (Segment 1004) and Lake Creek (Segment 1015). Both waterways face challenges meeting state standards for surface water quality. Elevated levels of fecal bacteria and low DO levels potentially impact human health and the environment for area communities and stakeholders. In addition, other pollutants like excess nutrients (nitrogen and phosphorus compounds), sediment, and trash in the water are known issues for these waterways. According to the 2014 Texas Integrated Report, two assessment units in the West Fork of the San Jacinto, are impaired for elevated bacteria (1004_01 and 1004_02). Crystal Creek, a tributary flowing into the West Fork, is also impaired for bacteria (1004D_01). The only water quality parameter of concern in the West Fork is for elevated nitrates (1004_01).

Within the Lake Creek watershed, only Mound Creek (1015A_01) is impaired for elevated bacteria. Two assessment units within Lake Creek (1015_01 and 1015_02), have concerns for depressed dissolved oxygen. The sources of bacteria and other contaminants in these watersheds are widespread, diffuse, and diverse in origin, making them more difficult to address through traditional approaches focusing on single entities and regulation. Pollutant sources will continue to increase as area growth drives future development in the watersheds, exacerbating the existing situation. Project estimates indicate that by 2030, necessary reductions of fecal bacteria will range from 31% to as high as 68% in some areas of the watersheds.

Local concerns over the future of the West Fork and Lake Creek led to the development of this watershed protection plan (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 West Fork 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 bacteria, which can directly impact human health, and low dissolved oxygen, which impacts aquatic life and recreational fisheries. Activities to address bacteria sources and other concerns were identified and discussed by the local 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, private property rights should be respected in all considerations, 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 the continuation of an engaged and active 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 is based on a policy of adaptive management, in which results of efforts are used as feedback for modifying approaches to meet new challenges and changing conditions.

Contact Information

For more information about the West Fork Watersheds Partnership or this watershed protection plan, please call or visit us at the contacts below.

713-499-6653 or 713-627-3200 (Justin Bower)

www.westforkwpp.com

www.facebook.com/westforkwatershed

Table ES 1 is a guide to the contents of the WPP. Additional information on specific items can be found in Appendix A.

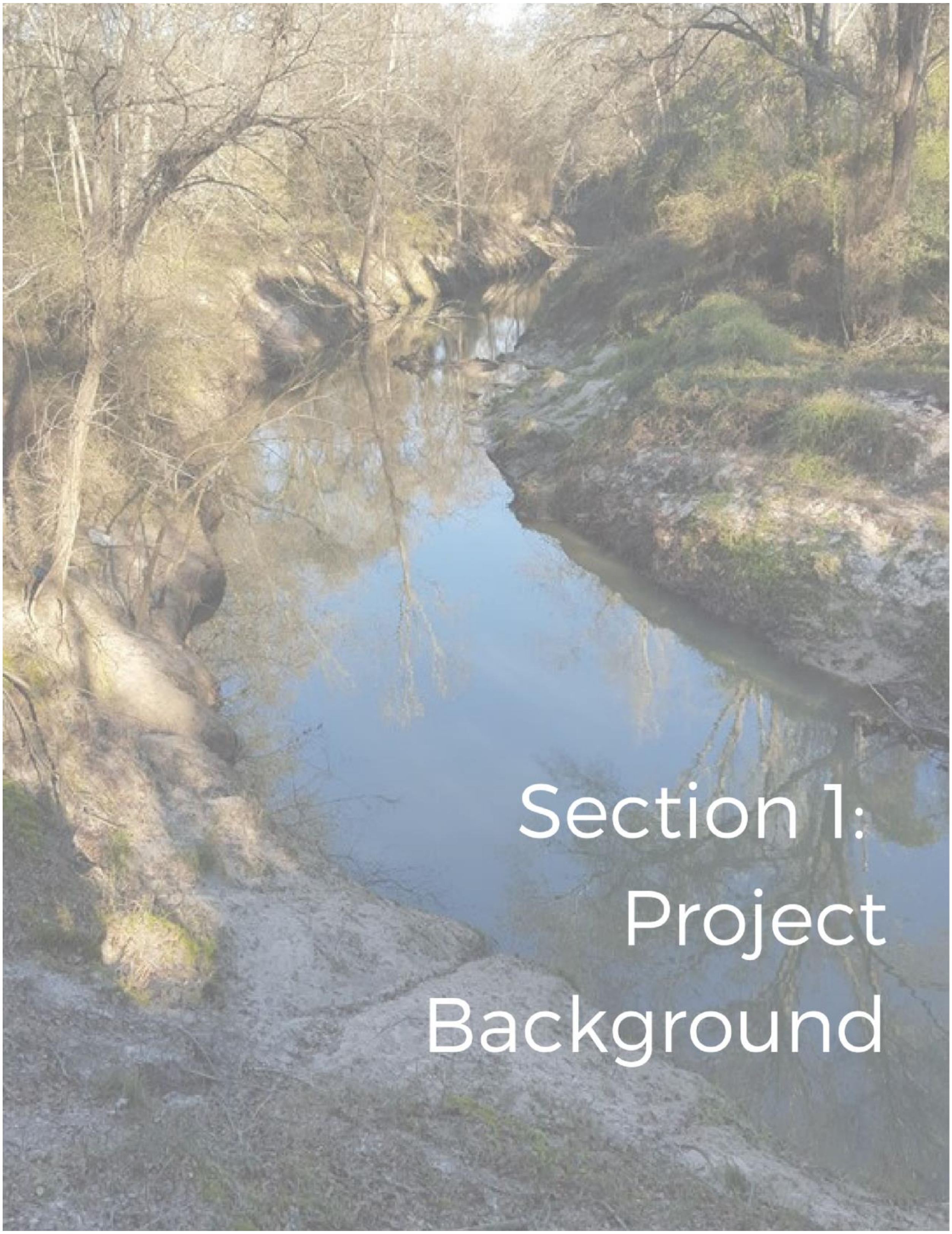
Table ES 1 - Guide to WPP Content

WPP Section	Description	EPA Element	Location
Section 1 – Project Background	An introduction to the watershed planning process for the West Fork and Lake Creek.	NA	pp. 1-8
Section 2 – Watershed Characterization	A summary of the physical (geography, climate, etc.), human (land use, political geography), and water quality character of the watersheds.	NA	pp. 9-38
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. 39-106
Section 4 – Improving Water Quality	Establishing the amount of pollutant source loads needed to achieve water quality goals.	• Element B – Estimate of load reductions.	pp. 107-123, Appendix B
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. 124-153, Appendix C
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. 154-165
Section 7 – Implementation	The schedules for implementation, and measurable milestones for tracking progress.	• Element F – Schedule for implementation • Element G – Interim measurable milestones	pp. 166-180
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. 181-186

List of Acronyms and Abbreviations

AgriLife Extension	Texas A&M University AgriLife Extension
AgriLife Research	Texas A&M University AgriLife Research
BLC	Bayou Land Conservancy
BMP	Best Management Practice
BPA	Bayou Preservation Association
CAFO	Concentrated Animal Feeding Operation
CRP	Clean Rivers Program
CWA	Clean Water Act
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EMC	Event Mean Concentration
FEMA	Federal Emergency Management Agency
GBEP	Galveston Bay Estuary Program
GBF	Galveston Bay Foundation
GIS	Geographic Information System
HARC	Houston Advanced Research Center
HCFCD	Harris County Flood Control District
H-GAC	Houston-Galveston Area Council
HUC	(USGS) Hydrologic Unit Code
Integrated Report	Texas Integrated Report of Surface Water Quality
LCGP	Lake Creek Greenway Partnership
LDC	Load Duration Curve
LSGCD	Lone Star Groundwater Conservation District
MUD	Municipal Utility District
NASS	National Agricultural Statistics Survey
NELAC	National Environmental Laboratory Accreditation Conference
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	(United States Department of Agriculture) Natural Resources Conservation Service
OSSF	On-Site Sewage Facility
Partnership	The West Fork Watersheds Partnership

PS	Point Source
SCA	Student Conservation Association
SJRA	San Jacinto River Authority
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SLOC	Station Location
SOP	Standard Operating Procedure
SSO	Sanitary Sewer Overflow
SSOI	Sanitary Sewer Overflow Initiative
SWCD	Soil and Water Conservation District
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
SWQS	State Water Quality Standards
TAMU	Texas A&M University
TCEQ	Texas Commission on Environmental Quality
TFS	Texas A&M Forest Service
TMN	Texas Master Naturalists
TPWD	Texas Parks and Wildlife Department
TPDES	Texas Pollutant Discharge Elimination System
TSSWCB	Texas State Soil and Water Conservation Board
TST	Texas Stream Team
TSWQS	Texas Surface Water Quality Standards
TWON	Texas Well Owner Network
TWRI	Texas Water Resources Institute
West Fork	West Fork San Jacinto River
WJPA	Woodlands Joint Powers Association
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility


Section 1:
Project
Background

1 – Project Background

Background

The West Fork Watersheds Partnership (Partnership) developed this watershed protection plan (WPP) to address water quality issues in the West Fork of the San Jacinto River (West Fork) and Lake Creek. The purpose of this planning effort is to use a watershed approach to identify and reduce sources of contamination in the watersheds through effective, voluntary solutions. This section details the background for this project and the planning process undertaken by the stakeholders.

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.

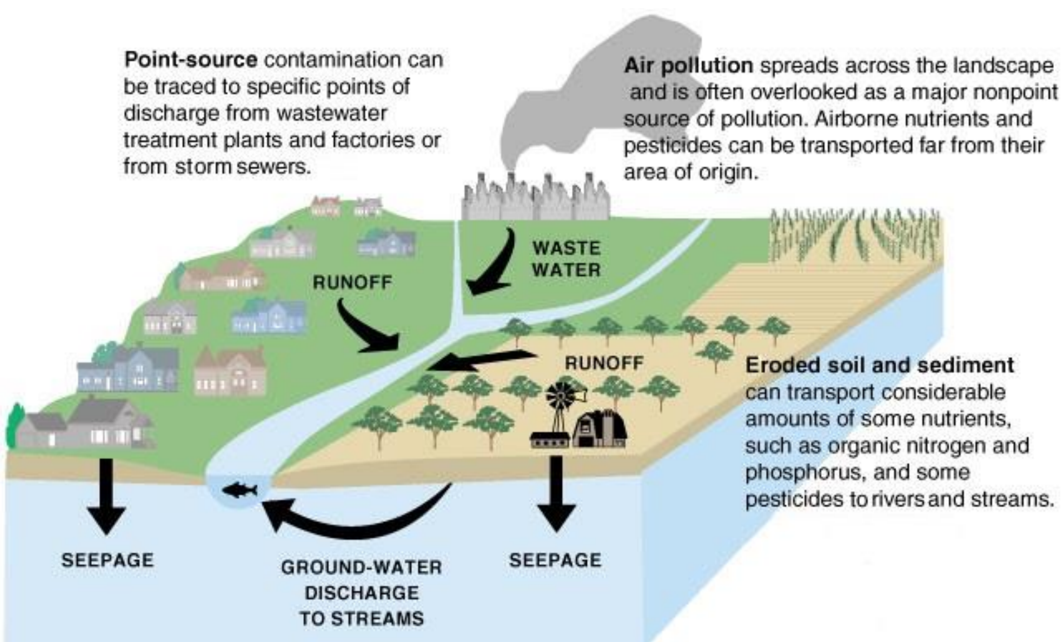


Figure 2 - Pollution sources in a watershed[1]

[1] Image courtesy of United States Geologic Survey (USGS).

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 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** seeks to address water quality issues by focusing on both the waterways and their watersheds 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 are that it: 1) reflects the connection between land and water, 2) can help coordinate efforts by multiple political jurisdictions and focus resources on shared priorities; and 3) can help stakeholders understand potential future impacts to waterways based on the changing character of their watersheds. 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 are built on the United States Environmental Protection Agency's (EPA) Nine Element model[2], which outlines several key steps to characterizing a watershed, understanding its water quality challenges, and devising appropriate solutions. Developed as the product of 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[3]. 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.

[2] More information on the 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

[3] 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).

WPPs are best served by a diverse group of stakeholders who can represent the 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 the 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 grants, some of which require matching funds or in-kind time from local stakeholders.

Figure 3 - Stakeholders consider pollutant sources in a watershed

A Watershed Protection Plan for the West Fork and Lake Creek

Water quality issues in the West Fork (Segment 1004) and portions of Lake Creek (Segment 1015), and local concern over the impact of future changes in these watershed areas, were the impetus for undertaking a watershed-based plan. Previous projects in the area, including the Lake Conroe WPP[4], the East and West Forks of the San Jacinto River Total Maximum Daily Load (TMDL)[5], and the West Fork San Jacinto Watershed Greenprint, had established there was local interest and commitment to address water quality. The desire to evaluate these areas on a local

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

[5] More information on this project can be found at http://www.h-gac.com/community/water/tmdl/east-and-west-forks-of-the-san-jacinto-river-tmdl-and-implementation-plan.aspx

level, and to consider other local concerns, led to the formation of the West Fork Watersheds Partnership (Partnership) in 2016. The WPP model was chosen for its ability to address other local concerns in addition to state water quality standard (SWQS) impairments, and for its voluntary nature. While both Spring and Cypress creeks are also tributaries to the West Fork, the WPP project area was set as only the West Fork and Lake Creek segments because the former tributaries enter the West Fork system almost directly at its confluence with Lake Houston, and thus do not impact the majority of the main channel[6].

The West Fork Watersheds 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 the TCEQ and the Galveston Bay Estuary Program (GBEP), funded through a Clean Water Act §319(h) grant from the 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 the basis 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 met between 2016 and 2018 to discuss and provide feedback on a variety of water quality issues[7]. 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 (www.westforkwpp.com) and Facebook site (www.facebook.com/westforkwatershed). 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[8]. Topical Work Group meetings were held 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. 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. In addition to formal

[6] H-GAC and TCEQ have already started on preliminary work to address water quality issues in Spring and Cypress creeks as part of future WPP efforts.
[7] More information on the individual meetings and process can be found at www.westforkwatershed.com
[8] Which is available for review at https://westfork.weebly.com/uploads/9/6/6/3/9663419/public_participation_plan_west_fork_wpp.pdf

Partnership and stakeholder meetings, project staff supported the efforts of the Partnership by engaging the public at local outreach events throughout the project.

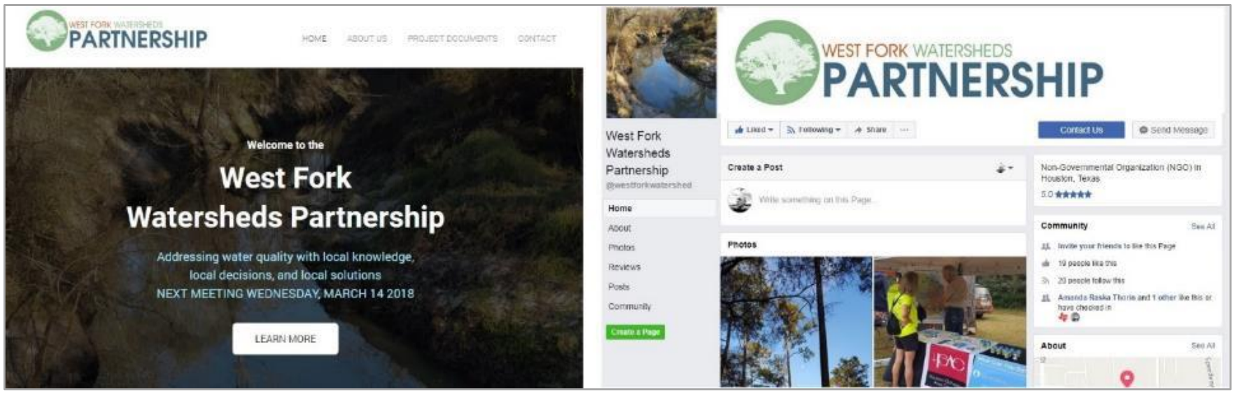


Figure 4 - West Fork Watershed Partnership web site and Facebook page

Water Quality Goals

As part of developing the WPP, the Partnership established a set of water quality goals that shaped their approach. Subsequent sections of this WPP expand on the details of how recommendations designed to meet these aims were established and 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 to 15-year window. Based on the level of water quality issue, the likely path of development in the watersheds, 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 indicator bacteria species *Escherichia coli (E. coli*), 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 watersheds, 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 SWQS for contact recreation of a 126 cfu/100 ml *E. coli* geomean. 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 bacteria[9] levels at or below the contact recreation standard.

- ***Improve dissolved oxygen*** – Dissolved oxygen (DO) levels are important for maintaining aquatic communities. The goal is to characterize precursors to depressed DO (e.g., excess nutrients) and recommend solutions to reduce them and improve DO levels.
- ***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 standards associated with them though they may lead to a DO impairment. Because no DO impairment exists, 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 bacteria 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, and sediment.

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 waterways** - While the West Fork and Lake Creek are part of this same system, they are waterways 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 will be made by local stakeholders.
- **Voluntary solutions –** The WPP will only include recommendations that are voluntary. Neither the Partnership nor the project team (H-GAC/TCEQ/GBEP) can or will exercise any regulatory mandate through this WPP.
- **Respect for private property –** Respect for private property should be a foremost concern for any recommendation or consideration. The project will work to support private property owners on issues of mutual benefit but will not seek to impose through the recommendations or action taken by the Partnership, any burden or infringement on their property rights. The focus of the WPP is to provide information and resources rather than mandates.

[9] Throughout this WPP, "bacteria" should be taken to mean fecal bacteria (specifically, *E. coli.*) as an indicator of fecal waste and associated pathogens.

- **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.
- **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.

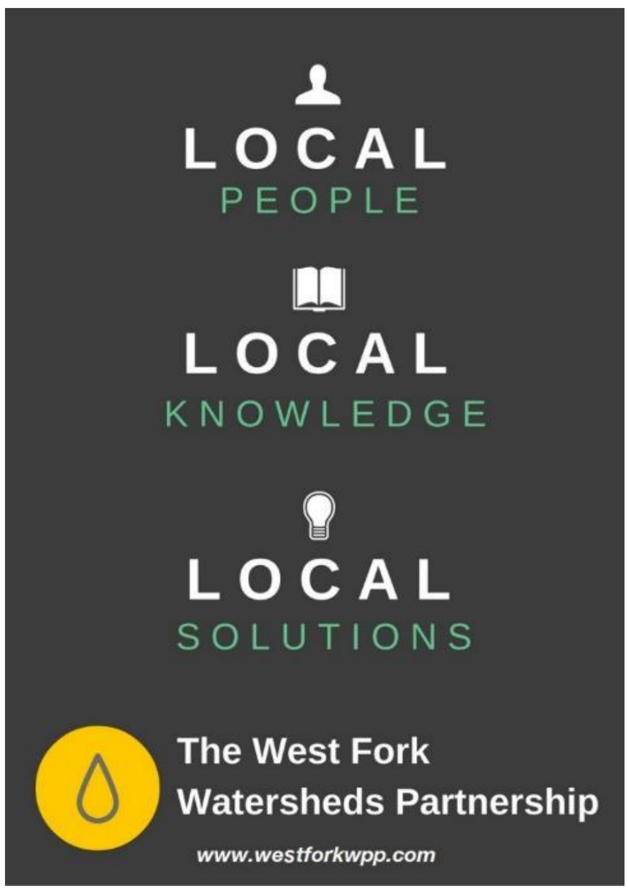
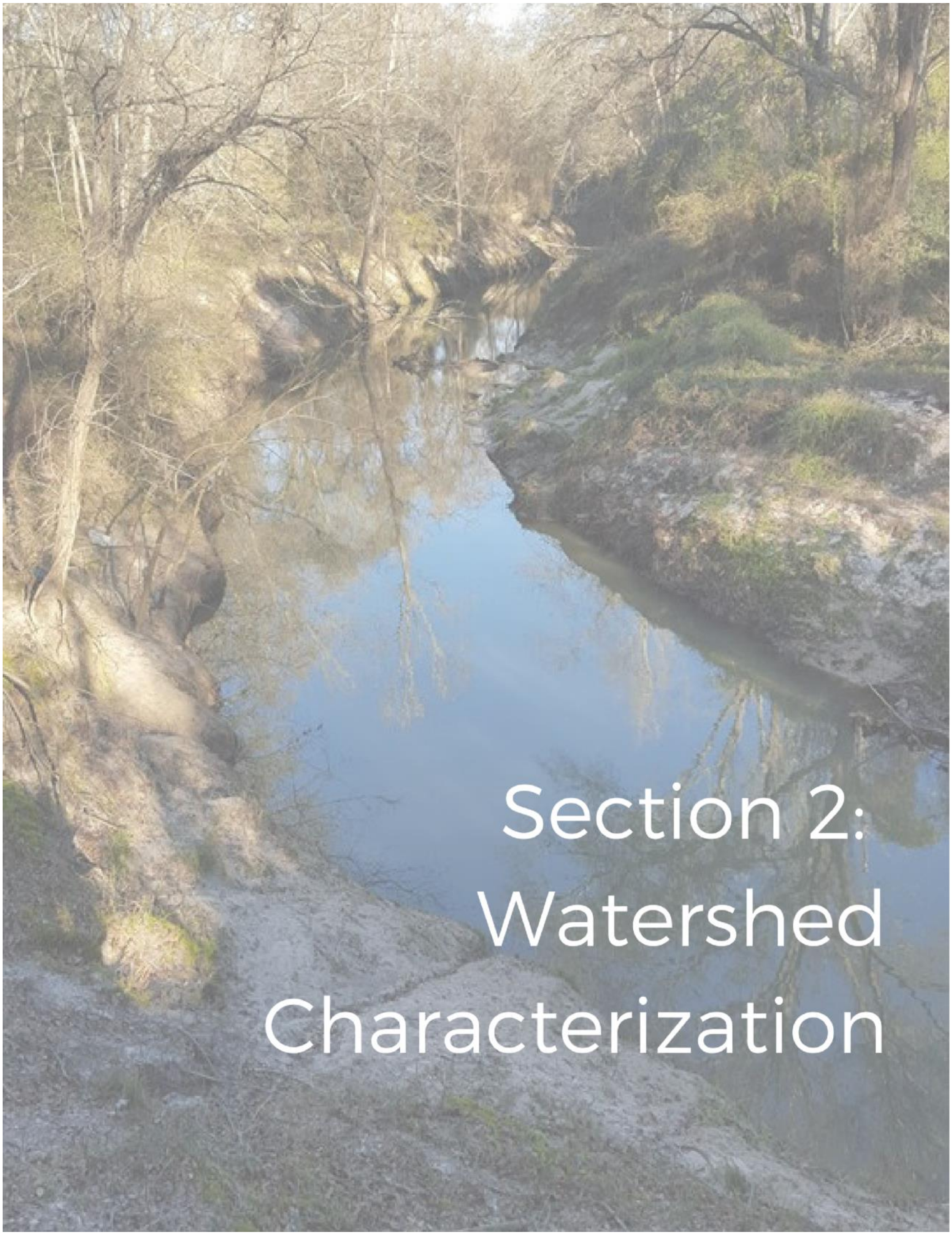


Figure 5 - Local focus of the West Fork Watershed Partnership



Section 2: Watershed Characterization

2 - Watershed Characterization

The character of a watershed is the sum of the natural features and processes of the land, the human elements that interact with them, and the relationship these factors have with water quality. Understanding the relationship between the waterways and the land that drains to them is the first step in understanding the causes and sources of pollution and identifying effective means to address them. Evaluating all the elements and factors that shape the connection between the land and water is part of the watershed approach to improving water quality.

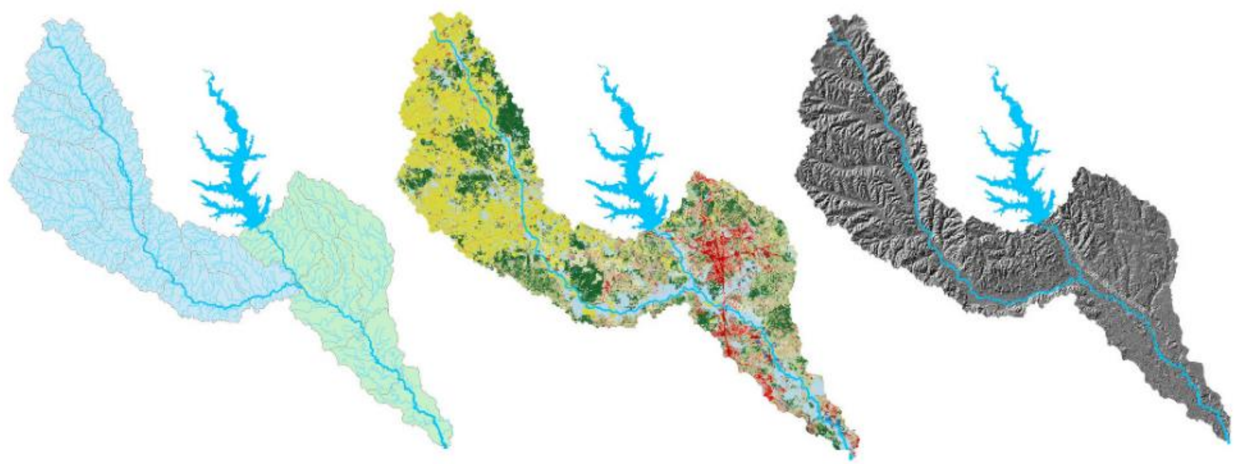


Figure 6 – West Fork watersheds: hydrology, land cover, and elevation

Geography

The watersheds of the West Fork of the San Jacinto River are located in the Upper Gulf Coast of Texas, containing portions of northern Harris County, Montgomery County, and eastern Grimes County. On the north side the Houston-Galveston region, this drainage area is connected to the Houston metropolitan area by the burgeoning I-45 transportation corridor. The West Fork (Segment 1004), and its tributary segments Lake Creek (Segment 1015), Spring Creek (Segment 1008), and Cypress Creek (Segment 1009) make up the western portion of the San Jacinto River basin between Lake Conroe to the north, and Lake Houston to the south (Figure 7).

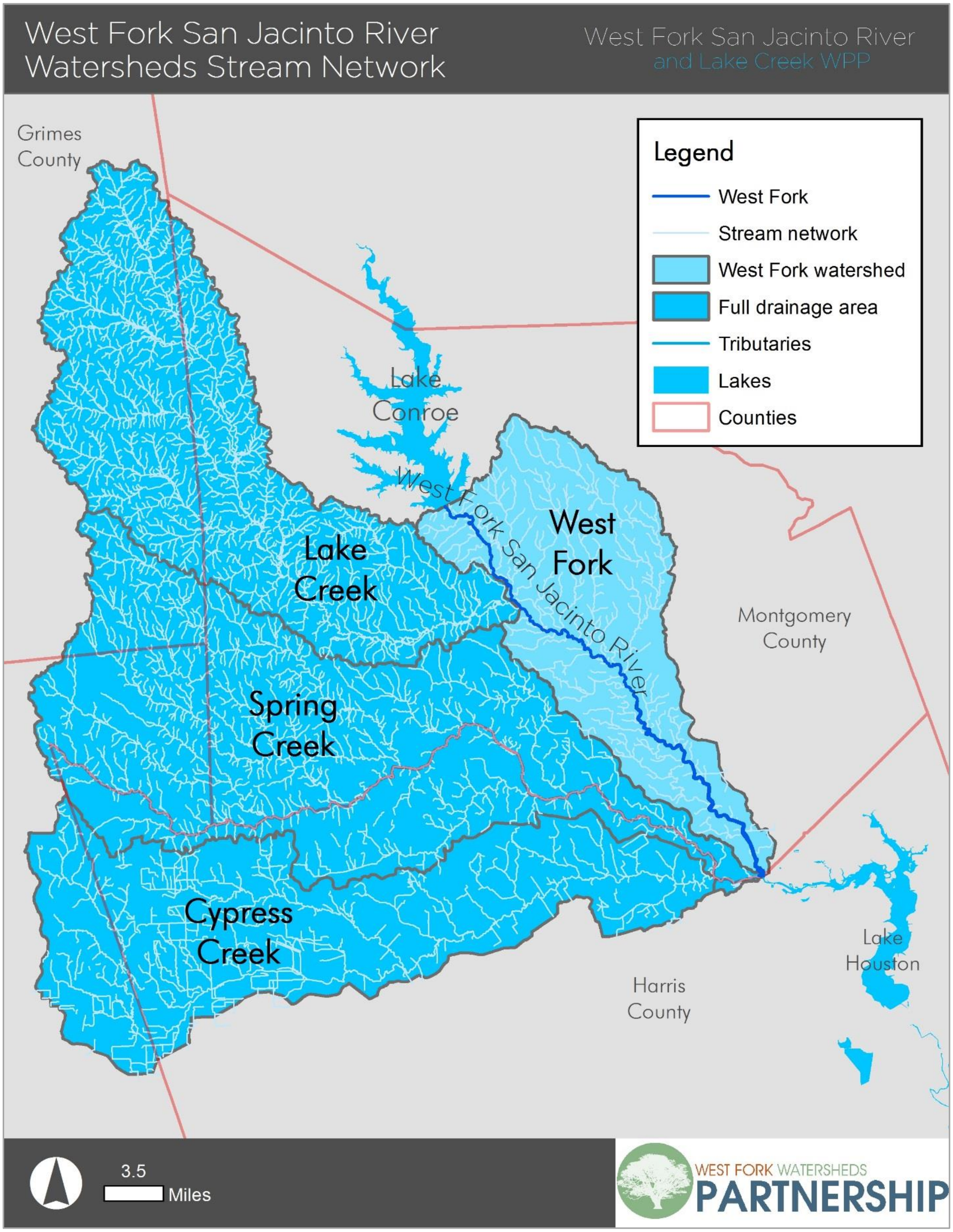


Figure 7 - Watersheds of the West Fork San Jacinto River

WPP Watershed Area

The full drainage area of the West Fork watersheds combined is 1,295 square miles, larger than the state of Rhode Island. The full stream network of the four segments is a vast 2,892 linear miles of waterways. Each of the primary tributaries for the West Fork system (Lake Creek, Spring Creek, and Cypress Creek) are themselves large drainage systems, with widespread networks of smaller tributaries. In addition, the system receives controlled flows from the dam at the south end of Lake Conroe, whose watershed could be included in an expanded watershed area for the West Fork system.

However, Spring and Cypress creeks enter into the West Fork system almost simultaneously with its confluence with Lake Houston, and therefore do not provide flow to an appreciable portion of the main stem of the West Fork. While the Lake Conroe watershed contributes flow to the system, being the origin of the West Fork segment, it is considered hydrologically distinct[10] from this WPP watershed area due to the dam structure between Lake Conroe and the West Fork. The assessment of Lake Conroe flows and quality as a boundary condition and input to this watershed is discussed further in Section 3. Only Lake Creek and the smaller tributaries within the West Fork watershed provide natural flow to the main channel. Therefore, this WPP is focused on the drainage area downstream of Lake Conroe, and upstream of the confluence of the West Fork with Spring and Cypress Creeks. While these two watersheds are only a portion of the larger system, they still cover an area of 539 square miles and have approximately 1,476 linear miles in their combined stream network.

Watershed Delineation

The watersheds of the West Fork and Lake Creek were delineated using a combination of existing data, map review, and field observations[11]. The final WPP watershed boundaries (Figure 8) generally follow the United States Geological Survey (USGS) HUC 10 watersheds, with minor modifications to account for human alteration of drainage and the hydrologic boundary of the Lake Conroe dam. The portion of the HUC watershed for Lake Conroe south of the dam was added to the West Fork watershed, as its drainage is to the West Fork segment. Delineation of the subwatersheds within the two primary segments is discussed in more detail in Section 3's discussion of water quality modeling efforts but are derived from USGS HUC 12 subwatersheds. To ensure relatively similar sizes, some HUC 12 areas were amended along

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[10] The assessment of Lake Conroe flows and quality as a boundary condition and input to this watershed is discussed further in Section 3.

[11] USGS HUC 8/10/12 watershed data layers, H-GAC proprietary watershed layers were compared and found to be relatively consistent. To ensure comparability to other projects and based on best professional judgement, project staff selected the USGS data. Modifications were made based on evaluations of natural and artificial barriers or conveyances to drainage visible on maps, and confirmed as needed with field visits.

existing drainage divisions within those areas. The delineation of the watersheds was reviewed with the Partnership for concurrence.

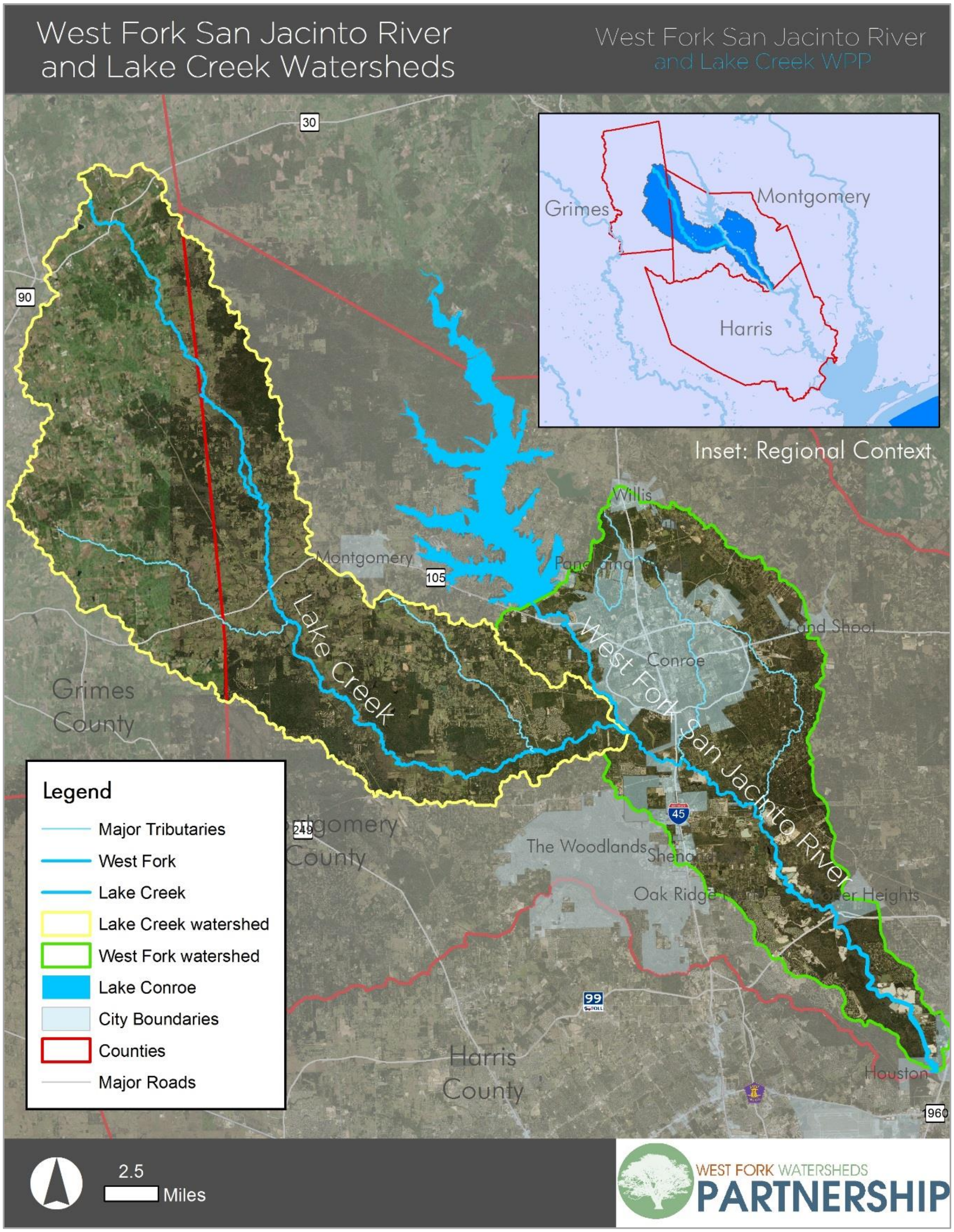

Figure 8 - The West Fork and Lake Creek Watersheds

West Fork San Jacinto River

Bounded to the north by the dam and outlet of Lake Conroe, the West Fork traverses a sinuous, 38-mile path through central Montgomery County to Lake Houston (Figure 9).

Drainage Area and Stream Network

Covering an area of 207 square miles, the West Fork encompasses a network of over 408 linear miles of freshwater streams of varying size just within its own segment watershed (Figure 10).

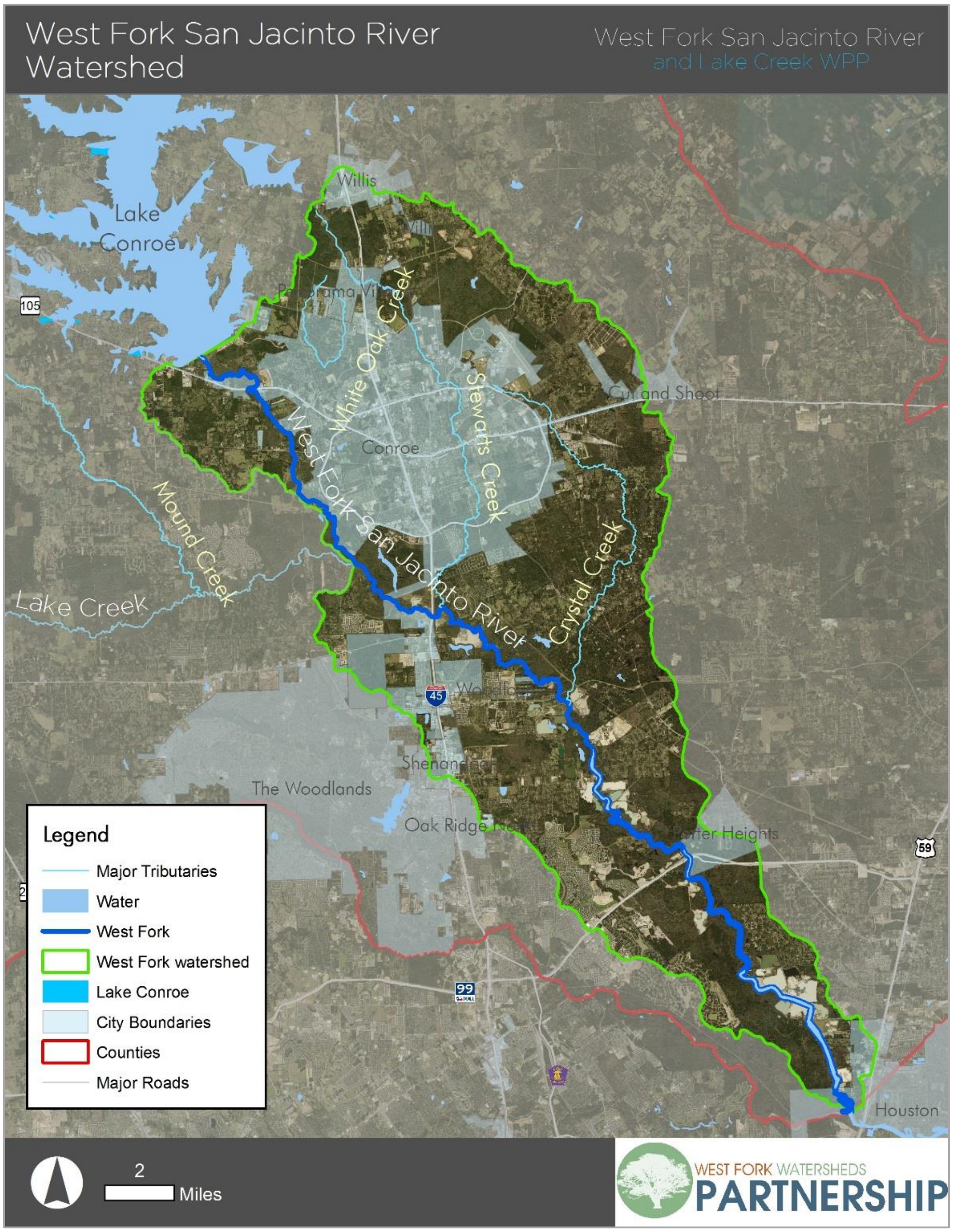

Figure 9 - West Fork watershed

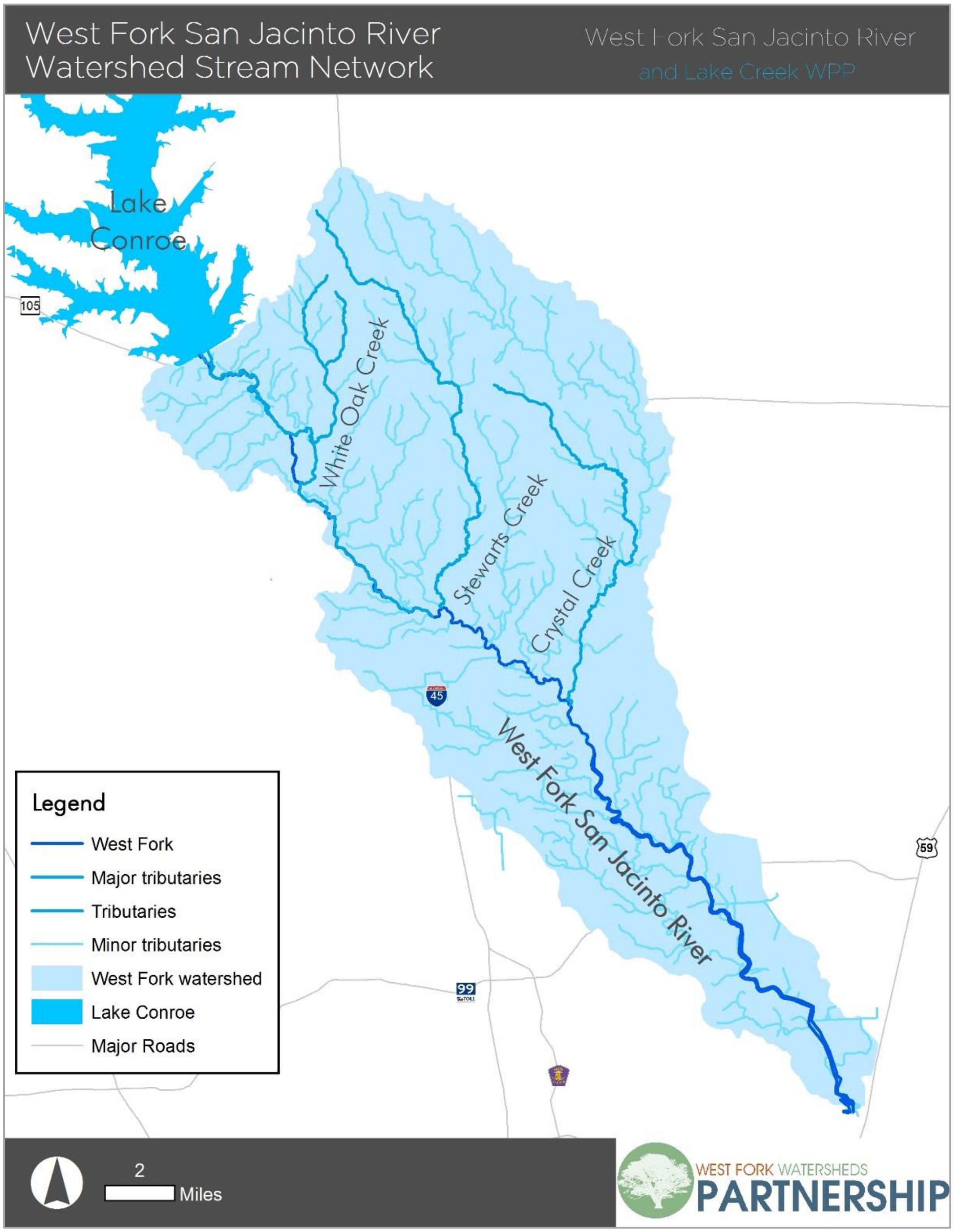

Figure 10 - West Fork stream network

The main channel of the West Fork is a relatively small (for a major river) but capacious waterway, serving a variety of uses in addition to its role as a conveyance for public drinking water supply from Lake Conroe to Lake Houston. Recreational paddling and fishing are common on the waterway, and it supports a high quality aquatic ecosystem. While significant development has taken place within the watershed, much of the course of its drainage network remains relatively unmodified. Despite the rapid and expansive development along the I-45 corridor, the waterway maintains a healthy riparian buffer along much of its length, with broad forested sections in its middle and lower reaches.

The primary tributaries[12] within the West Fork Segment 1004 watershed (as shown in Figures 9 and 10) include, from northwest to southeast:

- White Oak Creek (Segments 1004A and 1004B) – White Oak Creek drains a moderately developed area in the northwest portion of the City of Conroe.
- Stewart's Creek (Segment 1004E) – Stewart's Creek drains part of the eastern portion of the City of Conroe.
- Crystal Creek (Segment 1004G) – Crystal Creek drains a larger area of mixed development to the east and southeast of the City of Conroe.

Political Geography

The West Fork watershed includes a mix of land uses, including several urban and suburban areas. The primary urbanized area is the City of Conroe (population 82,286[13]) which lies almost wholly within the segment's watershed. Small portions of the Woodlands Township and the City of Houston overlap with the watershed. However, these three urban centers form an axis of development along the transect of the I-45 corridor.

Several smaller communities, including Cut and Shoot, Oak Ridge North, Panorama Village, Shenandoah, Willis, Woodloch, and Porter Heights fall at least partially within the watershed (Figure 9). Additionally, a mix of small master-planned communities, commercial development, and other residences in unincorporated areas of Montgomery County are within the watershed, primarily along the I-45 corridor. There are 38 municipal utility districts (MUDs) and other special districts in the watershed. In the southeastern portion of the watershed, east of I-45 there is a mix of larger acreage properties and some suburban development extending from the Porter community east of the southern tip of the watershed. Development is pushing west from the City of Conroe and the I-45 corridor along various transportation corridors into the Lake Creek watershed.

Almost the entirety of the watershed, except for a small parcel of land in its southerly extent, is in Montgomery County. One overlapping jurisdiction of note is that of the San Jacinto River Authority (SJRA), who maintains Lake Conroe, and whose jurisdiction covers the entire San Jacinto River Basin outside of Harris County[14]. SJRA's role in regulating flows from Lake Conroe

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[12] The primary tributaries discussed here are the unclassified segments which are assessed by TCEQ, which are the more prominent tributary systems in the watershed. Additional named tributaries (e.g. Woodson's Gully) exist in the watershed but are considered part of the general drainage network for the purpose of this WPP.

[13] Population numbers are based on the US Census Bureau's 2016 population figures, accessed at https://www.census.gov/programs-surveys/popest/data/tables.2016.html

[14] http://www.sjra.net/about/

and other authorized tasks in the basin can influence the boundary conditions of the watershed through dam releases. Another water management entity involved deeply in water management in the watershed is the Lone Star Groundwater Conservation District, who regulates groundwater withdrawals in Montgomery County. A required reduction in the use of Gulf Coast aquifer groundwater resources has created the need for increased use of alternative supplies, including surface water from the West Fork, supplies of Lake Conroe water, and water from other groundwater aquifers in this area.

Water Rights and Flood Mitigation

Water quality is the focus of this WPP, rather than issues of water supply or flood management. However, because the West Fork watershed is a conduit for public water supply and includes developed areas with pollutant sources in or adjacent to floodplains, both water resources activities can potentially impact water quality and their consideration provides context for understanding the waterway.

Texas grants the right to use waters of the state (including flows in waterways like the San Jacinto River) through water rights permits. There are 21 water rights permits with diversion points in the West Fork watershed, representing a mix of on-channel reservoirs (impoundments) and diversion points. All but a small portion of the permitted diversions are related to SJRA water supply from Lake Conroe. Under current conditions, most of the existing water rights diversions are withdrawn directly from Lake Conroe storage of floodwaters and do not impact downstream flows. However, the extent of releases from Lake Conroe during a drought to supply downstream water uses could potentially affect the balance between flow and pollutant loads.

Stormwater and flood management in Montgomery County is a complex web of overlapping jurisdictions, including the county, SJRA, individual municipalities, etc. The nature of the system held between two lake reservoirs complicates management of flood events, and expansive growth has reduced the capacity of the area to absorb rainfall. Approximately 70 square miles, over a third of the watershed's total area, is within the Special Flood Hazard Areas (100-year floodplain) or 0.2 Percent Annual Chance Flood Hazard areas (500-year floodplains) based on 2015 Federal Emergency Management Agency (FEMA) data[15] (Figure 11). However, recent events like Hurricane Harvey have shown that storms and floods of greater magnitude can always occur and therefore the mapped floodplains do not always accurately account for flooding potential in the watershed. Lake Conroe is not a flood control reservoir, upstream flood events can only be passed through the reservoir to the West Fork through its flood release gates. By filling the reservoir, if it is not already full, and by allowing the reservoir to temporarily rise above its full pool, Lake Conroe can provide some limited reduction of the peak

[15] FEMA 2015 NFHL Floodplains, spatial dataset.

flows that would otherwise occur, and the FEMA maps reflect this fact. Flooding can exacerbate the release of pollutants into waterways. Areas in which flooding is unexpected may be especially vulnerable to erosion or other flood damage and have pollutant sources not designed for potential flooding situations.

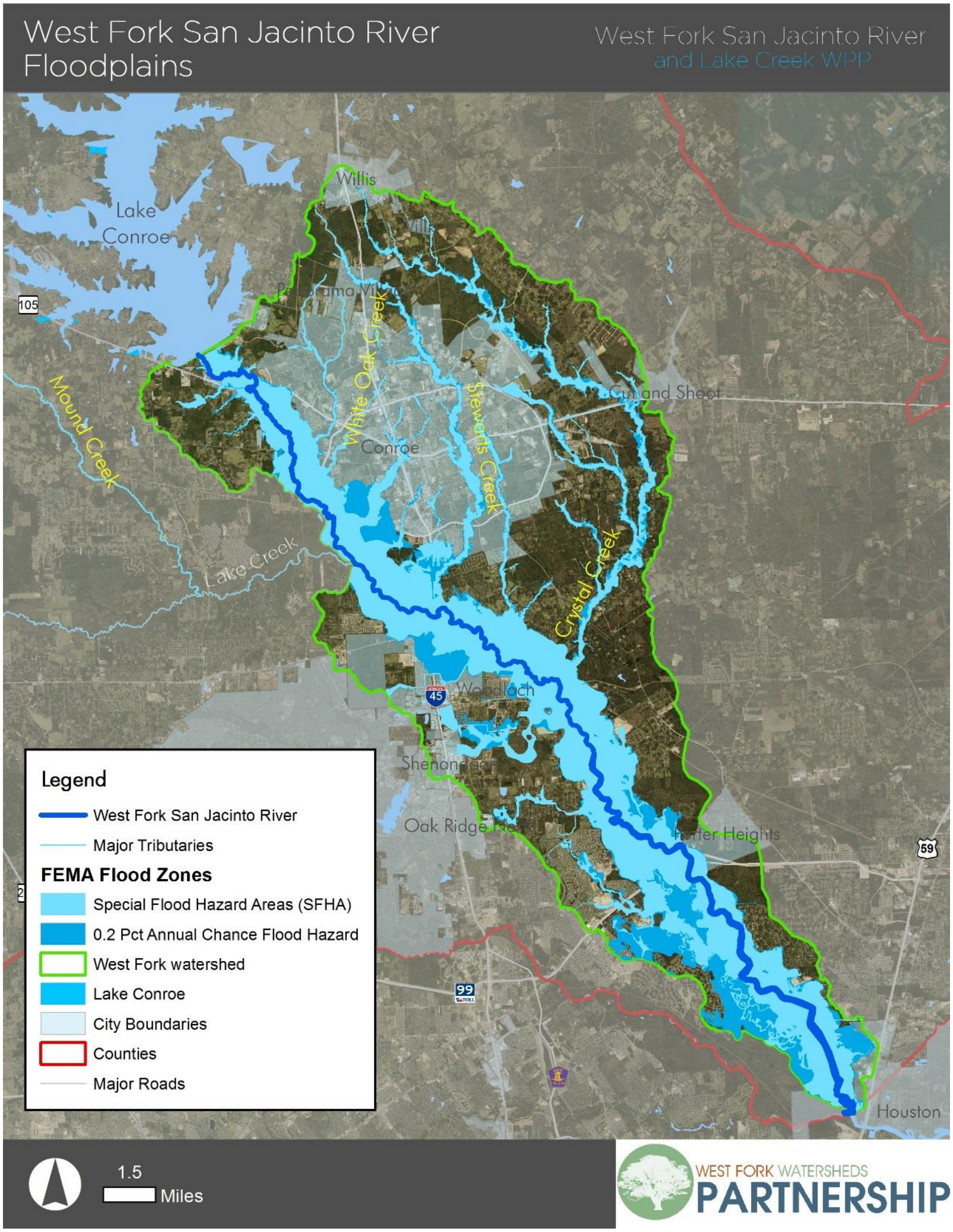

Figure 11 - Floodplains of the West Fork

Lake Creek

From its headwaters in rural areas of western Montgomery County and eastern Grimes County, Lake Creek makes a long bend south to east around the western flank of Lake Houston to its confluence with the West Fork southwest of the City of Conroe (Figure 12).

Drainage Area and Stream Network

While Lake Creek is a tributary of the West Fork below Lake Conroe, its watershed is larger, covering an area of 332 square miles, with a network of 1068 linear miles of freshwater streams (Figure 13).

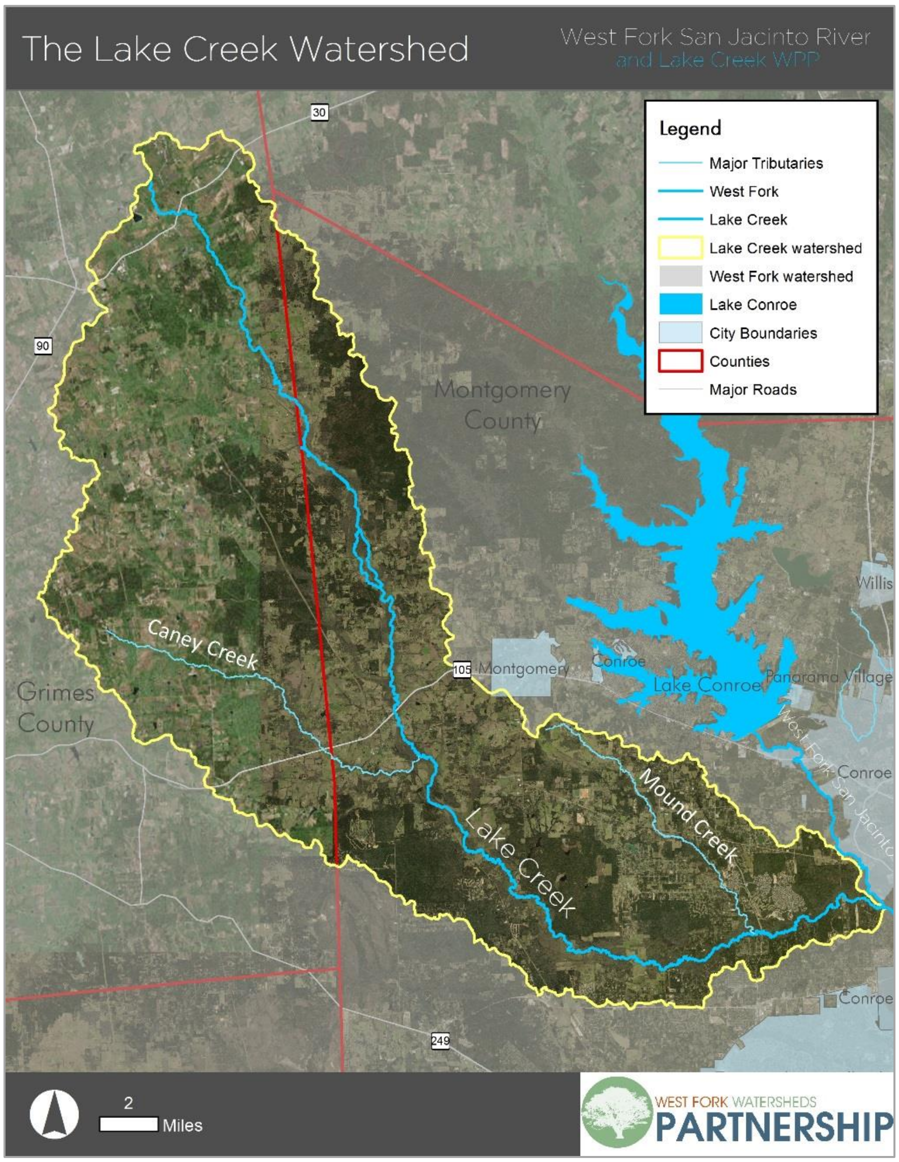

Figure 12 - The Lake Creek watershed

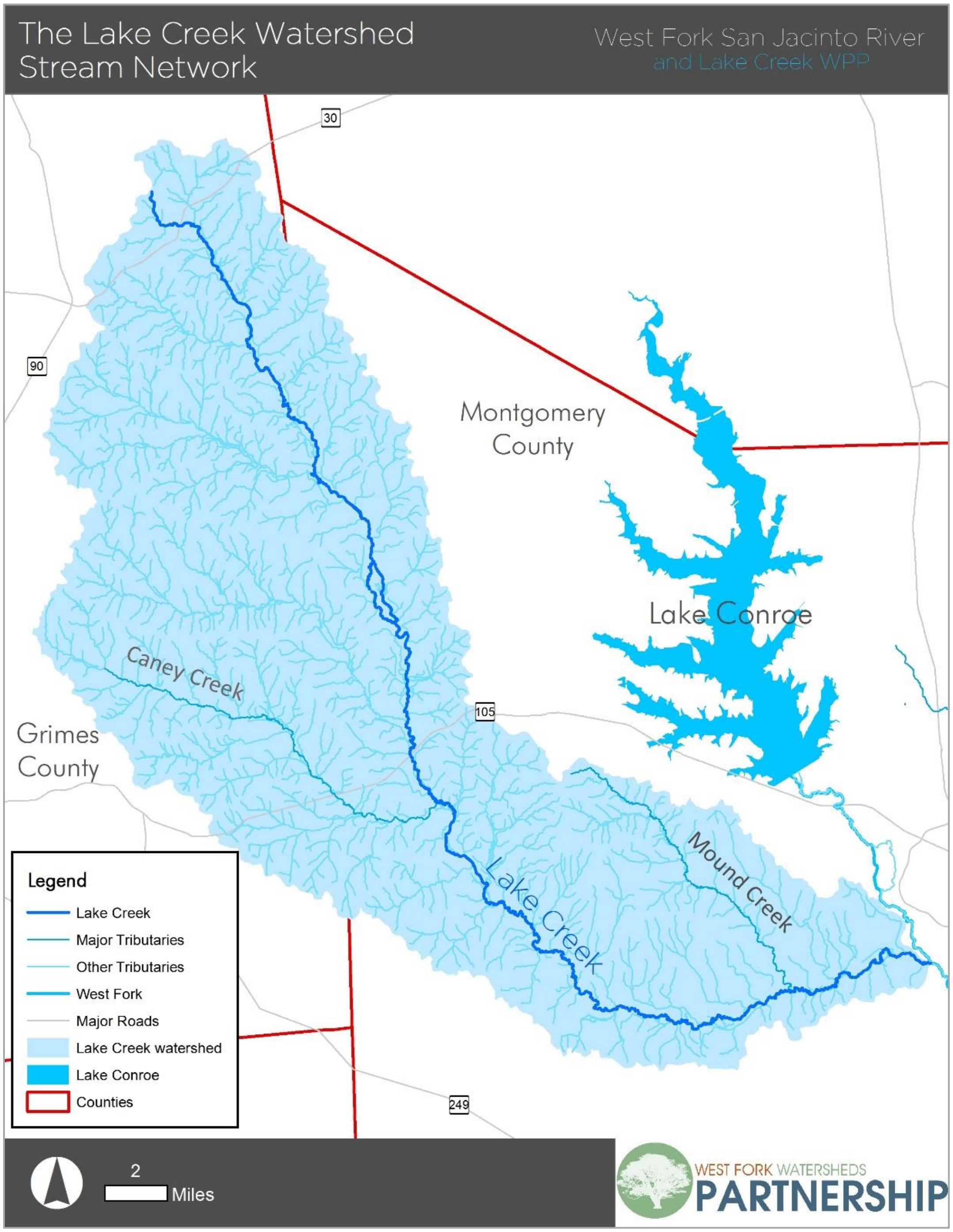

Figure 13 - Lake Creek stream network

The main channel of the Lake Creek varies in breadth but is a shallow waterway for much of its run. Through much of its northern and western reaches it is a small, pastoral watershed fed by a few notable tributaries and a dense network of small, often ephemeral, channels. Its headwaters north of Shiro in Grimes County are almost indistinguishable from shallow field drainage (Figure 14). Lake Creek is notable for the almost continual, dense riparian buffer forests along the denser development of its lower reach. In its middle and upper reaches, riparian buffers are narrower, less pronounced, and somewhat less contiguous.

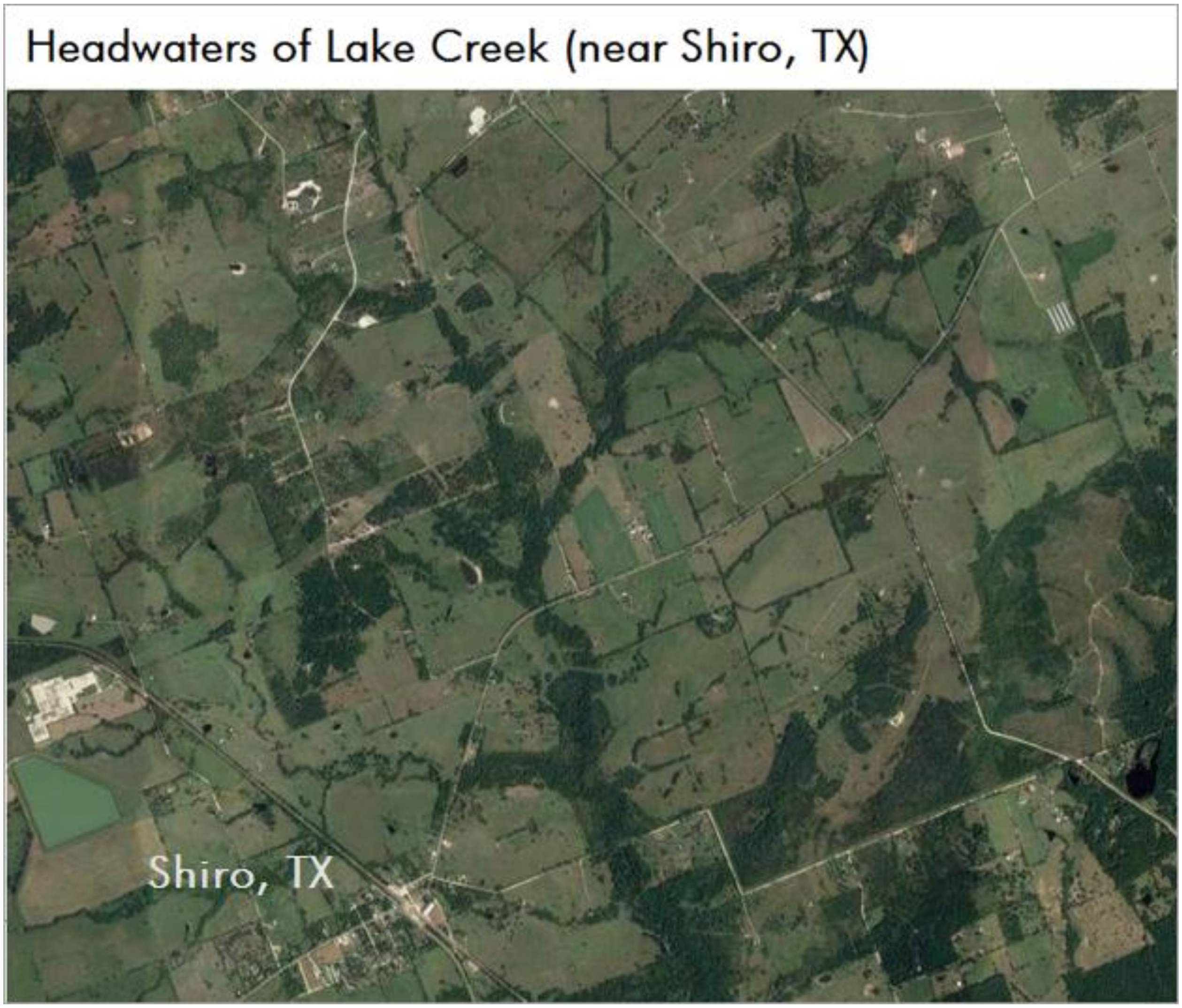

Figure 14 - Headwaters of Lake Creek

Recreational use (paddling, etc.) and fishing are common on the waterway, which supports a high quality aquatic ecosystem and serves as public water supply. While significant development has taken place within the lower portion of the watershed, and its upper portions reflect traditional rural/agricultural development patterns, much of its drainage network remains relatively unmodified.

The primary tributary within the Lake Creek Segment 1015 watershed (as shown in Figure 12) is Mound Creek (Segment 1015A) which drains an area of mixed developmental density in the southern third of the watershed. Other notable tributaries include Caney and Little Caney creeks in the western areas of the watershed, Landrum Creek in the middle northern area of the watershed, and Fish Creek in the southeastern area of the watershed due east of Mound Creek.

Political Geography

The Lake Creek watershed includes a mix of land uses, including suburban areas, but is primarily rural for much of its area. There are no large urban centers in the watershed, although much of the suburban development between Lake Creek, Lake Conroe, and Lake Houston has spread from the City of Conroe and the I-45 corridor along Highway 105 and other major east-west roadways. The City of Montgomery has a slight overlap with the watershed area. Most of the development in the watershed is in the unincorporated areas of Montgomery County or in the six small MUDs in its lower third. Development is pushing west from the City of Conroe and the I-45 corridor along various transportation corridors into the Lake Creek watershed.

Roughly half of the watershed is in Montgomery County, while the northwestern half of the watershed is in Grimes County. Most of the population in the watershed is in the denser areas of the Montgomery County portion. One overlapping jurisdiction of note is that of the San Jacinto River Authority (SJRA), who maintains Lake Conroe, and whose jurisdiction covers the entire San Jacinto River Basin outside of Harris County[16]. Another water management entity who is involved in water management in the watershed is the Lone Star Groundwater Conservation District, who regulates groundwater withdrawals in Montgomery County. Conversion away from groundwater resources spurs the use of alternative supplies, including surface water and other aquifer systems.

Water Rights and Flood Mitigation

There are 21 water rights permits in the West Fork watershed, all but one of which are for on-channel reservoirs. The single diversion point is in the upper reaches of Caney Creek in the headwaters area of the Lake Creek watershed in western Grimes County. In current conditions, the existing water right diversions and permitted storage volumes are unlikely to make an appreciable impact on the waterway on average. However, the maintenance of on-channel reservoirs can impact flow in drought conditions. The concentration of on-channel reservoirs in the more densely developed lower third of the watershed, in conjunction with increased impervious cover in the area, creates a situation in which flow in that area may be less likely to mimic natural flow regimes.

Approximately 17% of the watershed is in the 100- or 500-year floodplains (Figure 15). However, recent events like 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

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[16] http://www.sjra.net/about/

to erosion or flood damage and have pollutant sources not designed for flooding situations. Lake Creek has experienced severe flooding events in recent years, some of which have exceeded floodplains in some areas.

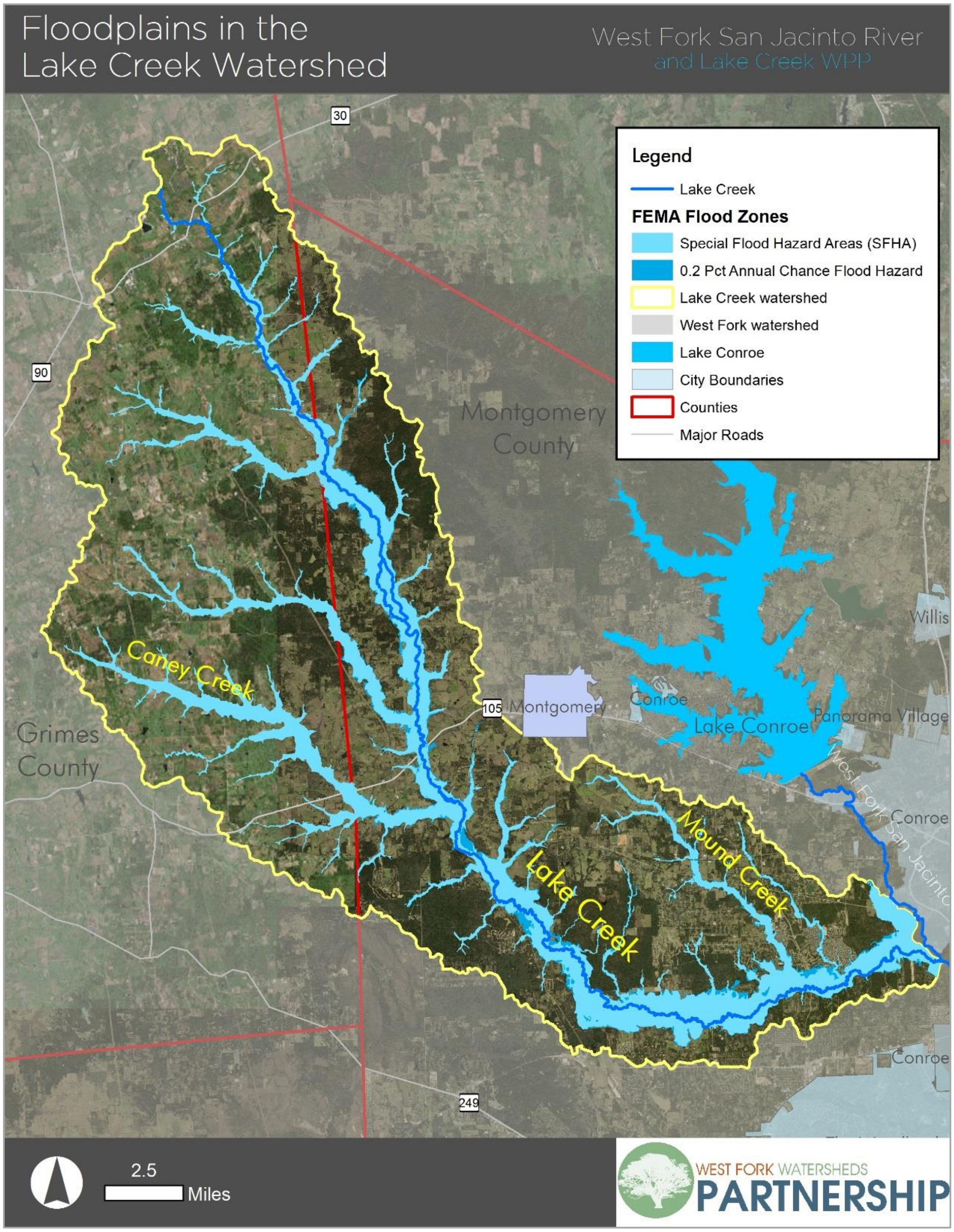

Figure 15 - Floodplains in the Lake Creek watershed

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 watersheds 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 16).

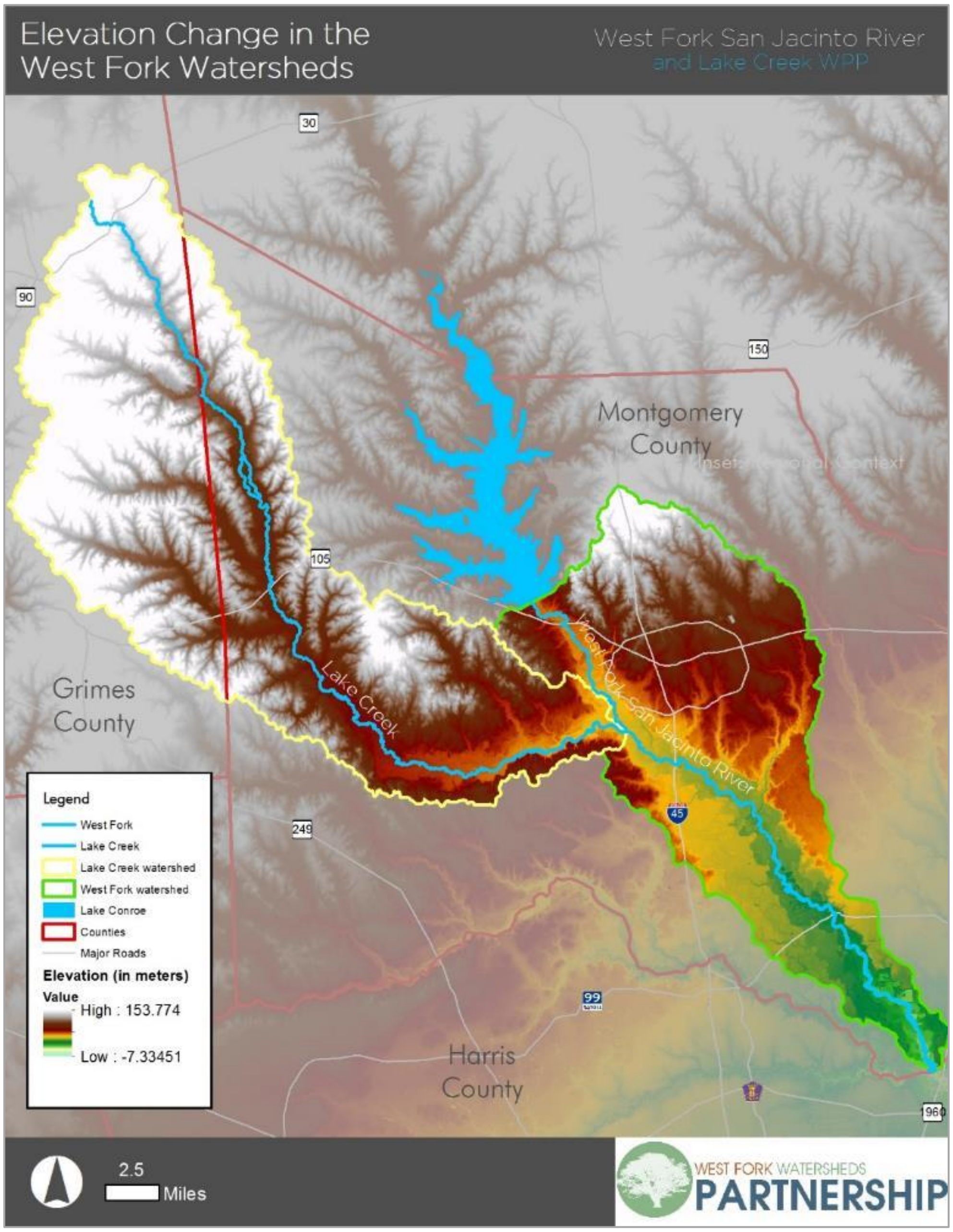

Figure 16 - Elevation Change in the West Fork Watersheds

Elevation generally decreases from northwest to southeast, and from headwaters toward the drainage pathways. There is a 160-meter difference between the highest and lowest points[17] of the combined watersheds. While the West Fork experiences the greatest degree of elevation change overall, Lake Creek has some of the areas of greatest change over distance along its riparian corridor.

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 areas is between 42-50 inches of rain, with northwestern areas being drier on the average than southeastern areas of the watershed. However, drought events can have appreciable effect on the area, as evidenced in the 2011 drought in which western areas were exceptionally dry, and water elevations fell to record levels in Lake Conroe and other area reservoirs and water bodies.

Even though the watershed is not directly influenced by 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., dissolved oxygen [DO]).

Soils

The soil mix[18] of the West Fork watersheds represents the juncture of different landscapes the waterbodies traverse. In general, soils range from dark vertisols in the western prairie areas, to mixed ultisols and alfisols in the central areas, and denser clays and loams as the areas progress toward the southernmost reaches of the watershed. The transition of soils reflects the transect between northwestern prairie areas and southeastern coastal areas in the watershed (Figure 17). Erosion of soils is prominent in the alluvial sediments along the waterways, an area which is extensively mined in this watershed for sand and gravel.

[17] Based on USGS Digital Elevation Model (DEM) 10-meter resolution spatial data

[18] 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. Available online at https://websoilsurvey.nrcs.usda.gov/. Data was not readily available for Grimes County.

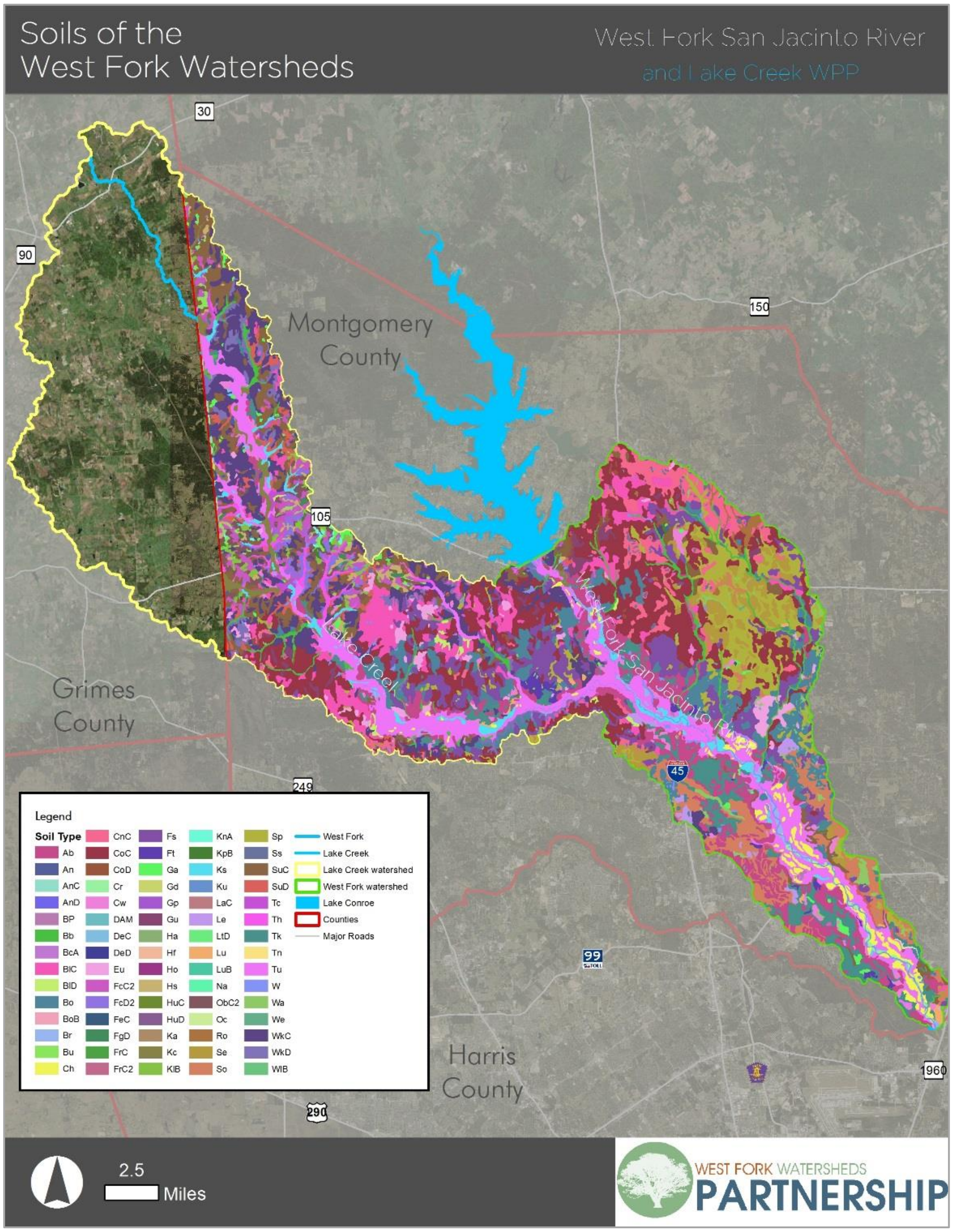

Figure 17 - Soils of the West Fork watersheds

Habitat and Wildlife

The West Fork watersheds straddle a transitional zone between several different ecoregions[19] (areas of similar climate, habitat, and landscape). Western areas of the watershed in Grimes County extend into the Texas Blackland Prairie, traditionally characterized by mixed vegetation of prairie grasses (e.g., Big Bluestem, Indiangrass, etc.) and isolated stands of post oak and

[19] Based on EPA Class III and Class IV Ecoregion data accessed at www.epa.gov/wed/pages/ecoregions/tx_eco.htm.

other similar tree species. The southernmost parts of the watershed abut the Gulf Coast Plain which supports denser stands of trees and coastal prairies and marshes. A small portion of the northern Lake Creek watershed reaches into the higher and drier East Central Texas Plains. However, most of the watershed falls within the South-Central Plains, with vegetation reflecting a mix of deciduous and coniferous trees and a variety of grass species (Figure 18). Within these general categories, the habitats in the watershed differ greatly on a smaller scale, including stretches of vibrant riparian forests and protected habitat for endangered species.

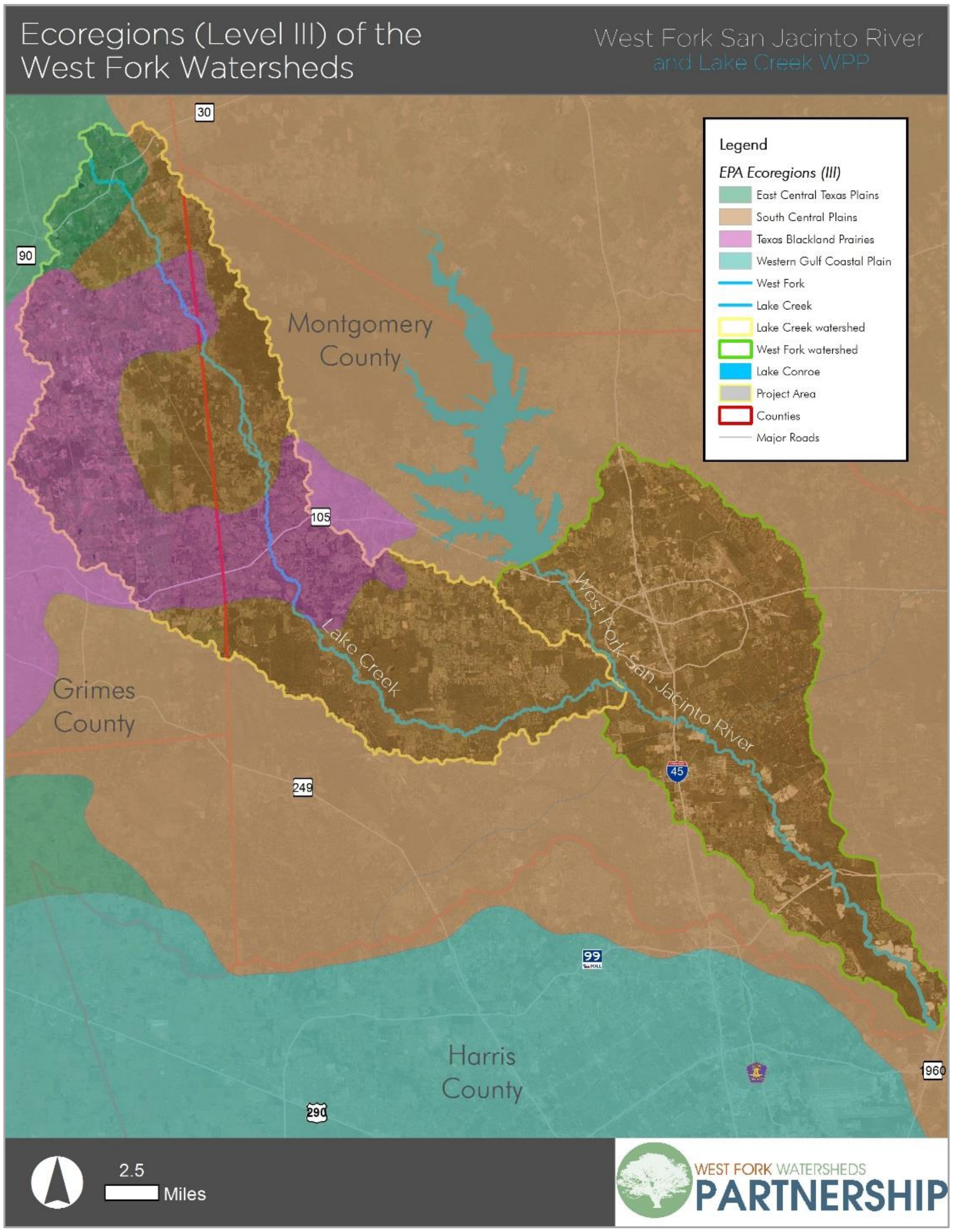

Figure 18 - Level III Ecoregions of the West Fork Watersheds

The broad range of landscapes represented in the WPP area means it is host to a diverse array of animal and plant species. Moderate winter temperatures and the location of the watersheds in the Central Flyway for migratory birds support a dense 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). Of specific interest is the Red-cockaded Woodpecker, an endangered species whose habitat is protected in part by W.G. Jones State Forest, in the West Fork watershed. Other notable local conservation areas include Cooks Branch Conservancy and the Lake Creek Preserve, among others. 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 east Texas 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 tallowtree, water hydrilla) and various invasive animals (e.g., grass carp), feral hogs (*Sus scrofa)* are a growing issue for the Houston region, and are present in the West Fork watersheds. Feral hogs threaten native wildlife species through direct competition for food and destruction of habitat. Large feral hog populations can cause appreciable damage on agricultural lands like those found in the watershed. Hogs tend to congregate in and around waterbodies, causing damage to the riparian corridor and depositing fecal bacteria directly to the water body.

Figure 19 - Feral hogs in a trap

Land Cover and Development

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

Land Cover

In general, the WPP areas transition from undeveloped and agricultural areas in the northwest portion of the watersheds, to urban areas at the confluence of the two systems and the I-45 corridor, and then again to larger contiguous forest and wetland areas in the lower portion of the watershed (Figure 20).

The Lake Creek watershed is dominated by agricultural land uses, with sizeable portions of forest and wetlands. Much of denser development is in areas closer to the confluence with the West Fork and the Conroe area. There is little industrial development of any size in Lake Creek, and most commercial area is focused on the downstream areas. Most of the developed area along the state highway 105 corridor west of Conroe is suburban residential, with generally larger lot sizes.

The West Fork watershed is a mix of developed land cover types in the north but broadens toward the south to include large forested tracts and wetland areas. Not reflected in the overall range of land cover types are the extensive areas of sand and gravel mining along the waterway. Aggregate mining is the primary industrial activity in the watershed. Commercial activity is focused on the axis between the urban center of Conroe, down the I-45 corridor to the Woodlands, and then to Harris County.

Montgomery County has experienced rapid change in recent decades, with growth pushing up the I-45 corridor and out from the Conroe area. The two modes of change most prominent in the watersheds have been the conversion of riparian forests to industrial (aggregate mining) and agricultural and undeveloped land uses to residential areas. Change in the Grimes County portion of the watershed has been less extensive with the primary conversion being from agricultural activities (e.g., ranching operations) to fallow land or light residential development.

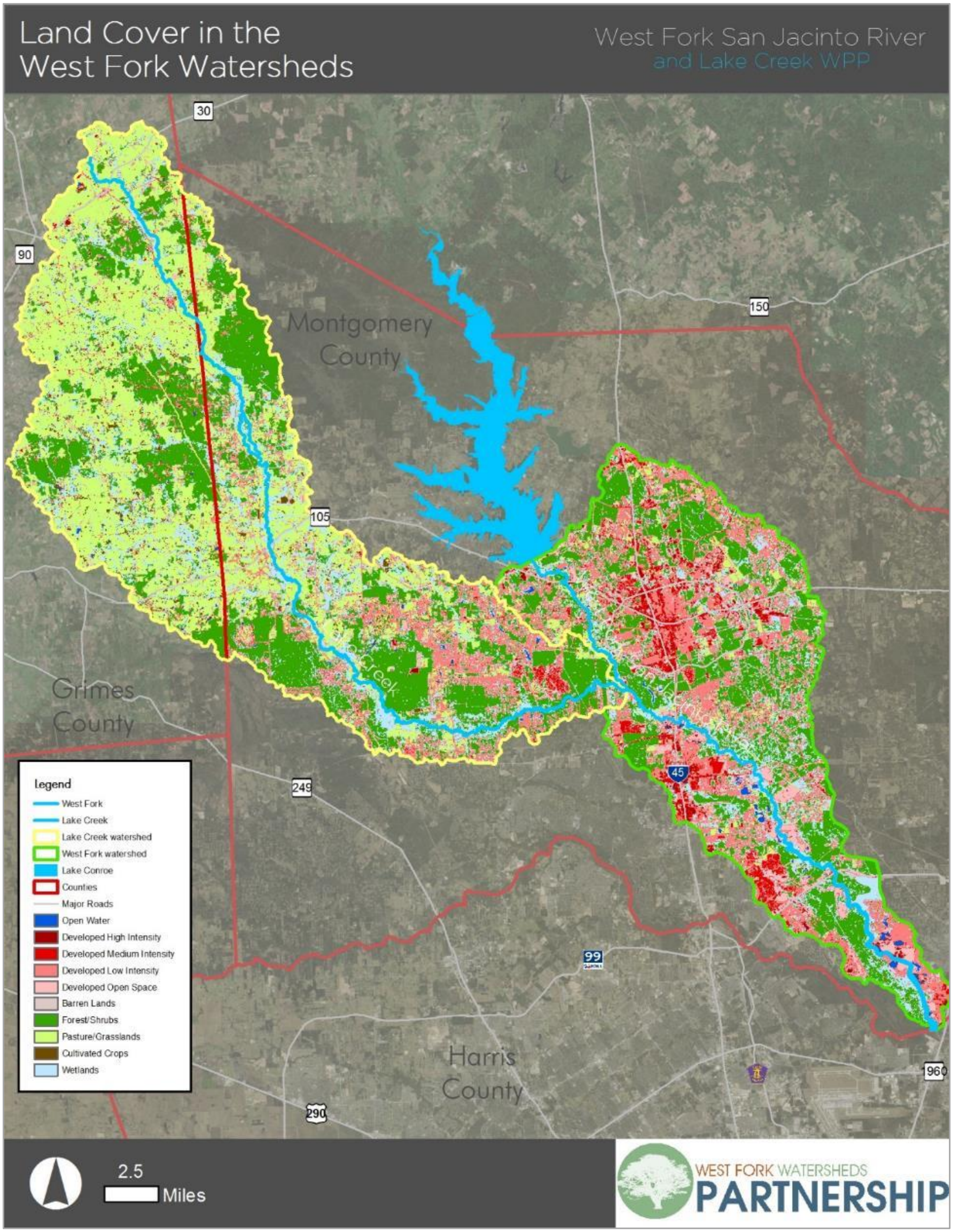

Figure 20 - Land Cover in the West Fork Watersheds

Table 1 represents the relative prominence of land cover types in the component watersheds and total WPP area[20]. The areas of largest divergence for the component watersheds are developed uses and pasture/grasslands, reflecting the unique character of the waterways.

Table 1 - Land Cover as a Percentage of Watershed Area

Land Cover Category	Lake Creek	West Work	All Watersheds
	Percentage of Watershed Area		
Open Water	0.3%	0.6%	0.4%
High Intensity Developed	0.3%	2.0%	1.0%
Medium Intensity Developed	0.7%	7.2%	3.2%
Low Intensity Developed	12.3%	29.7%	19.0%
Developed Open Space	1.8%	4.5%	2.8%
Barren Lands	0.5%	2.3%	1.2%
Forest/Shrubs	27.5%	30.0%	28.5%
Pasture/Grasslands	37.8%	4.8%	25.1%
Cultivated Crops	2.0%	0.3%	1.3%
Wetlands	16.8%	18.5%	17.5%

Agricultural Character

Agriculture is generally in decline in most of the watersheds area, with most remaining production taking place in the western portions of Lake Creek's watershed and, to a lesser degree, in the northeastern portions of the West Fork watershed. The transition away from agriculture to other land uses is meaningful for considerations of 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[21].

Agriculture in Montgomery County

Agriculture in Montgomery County was a 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 historical agricultural profile of the area. According to the 2012 USDA Census of

[20] Data for this analysis represents 10-class data produced by H-GAC in 2016. NLCD and other typical land cover datasets were deemed too outdated for this WPP effort given the area's growth rate.

[21] Data reflected in this section is from 2012, 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.

[22] Derived from "Montgomery County – Birthplace of the Texas Flag", retrieved on 1/3/2018 from https://montgomery.agrilife.org/

Agriculture[23], Montgomery County saw a 15% decrease in the number of farms, and a 9% decrease in the amount of land under production since 2007. Market value of sold products dropped by 44% in the same period. Most farms in the county are under 180 acres (87%) and many are under 50 acres (62%) Current production value is almost evenly split between crops and livestock. Cattle are the predominant livestock product by value. Roughly two thirds of agricultural operators in the county have a primary occupation other than farming, and their average age is 58, indicators that align with the decline of agricultural activity.

Agriculture in Grimes County

Agriculture in Grimes County was the historical foundation for local communities[24]. 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 the modern era, cattle ranching and timber have been a prominent focus of the county's production. According to the 2012 USDA Census of Agriculture[25], Grimes County saw a 9% decrease in the number of farms, and a 5% decrease in the amount of land under production since 2007. Market value of sold products dropped (4%). Reflecting the greater reliance on cattle ranching, Grimes County has a larger percentage of farms in larger size classes, though the majority (75%) are under 180 acres, and over 65% of the farmland is in pasture. Current production value is weighted heavily (>75%) toward livestock. A smaller portion (roughly 65%) of operators in the county have a primary occupation other than farming, and their average age is 61.

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[23] USDA 2012 Census of Agriculture County Profile for Montgomery County, as retrieved on 3/12/17 from: https://www.agcensus.usda.gov/Publications/2012/Online_Resources/County_Profiles/Texas/cp48339.pdf

[24] *Handbook of Texas Online*, Charles Christopher Jackson, "Grimes County," accessed 3/12/17, **http://www.tshaonline.org/handbook/online/articles/hcg11**.

[25] USDA 2012 Census of Agriculture County Profile for Montgomery County, as retrieved on 3/12/17 from: https://www.agcensus.usda.gov/Publications/2012/Online_Resources/County_Profiles/Texas/cp48339.pdf

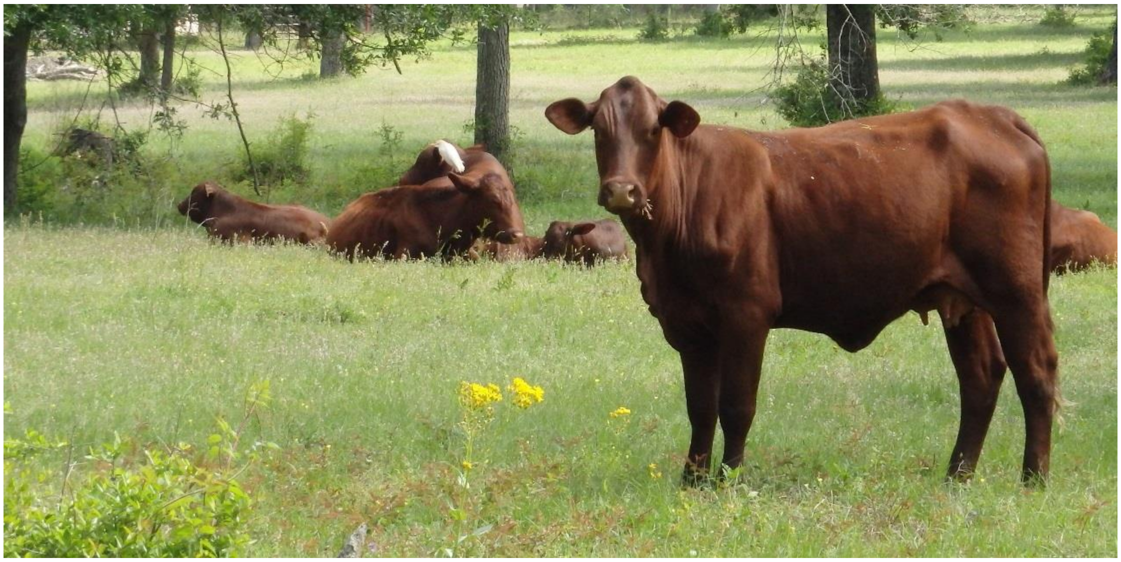


Figure 21 - Cattle in the Lake Creek watershed

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. 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 of 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 Surface Water Quality Standards (SWQS). Under the delegated authority of the Clean Water Act, 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.

The vast network of surface water bodies is divided into segments, which are cohesive groupings of waterways and associated tributaries. The watersheds of the West Fork and Lake Creek are composed of two primary segments, West Fork San Jacinto River (Segment 1004), and Lake Creek (Segment 1015). Major tributaries or waterways of interest within these segments are delineated as subordinate unclassified segments. For the West Fork and Lake Creek, that includes 1004E (Stewart's Creek) and 1004D (Crystal Creek). For Lake Creek, that includes 1015A (Mound Creek).

Surface water segments are further divided into assessment units, the fundamental targets for assessments that determine whether a water body is in compliance with applicable standards. Assessment units in the West Fork and Lake Creek system include:

- West Fork – 1004_01, 1004_02
    - Stewart's Creek – 1004E_02
    - Crystal Creek – 1004D_01
- Lake Creek – 1015_01, 1015_02
    - Mound Creek – 1015A_01

Figure 22 is a simplified network diagram of the segments, unclassified segments, and assessment units of the West Fork and Lake Creek system.

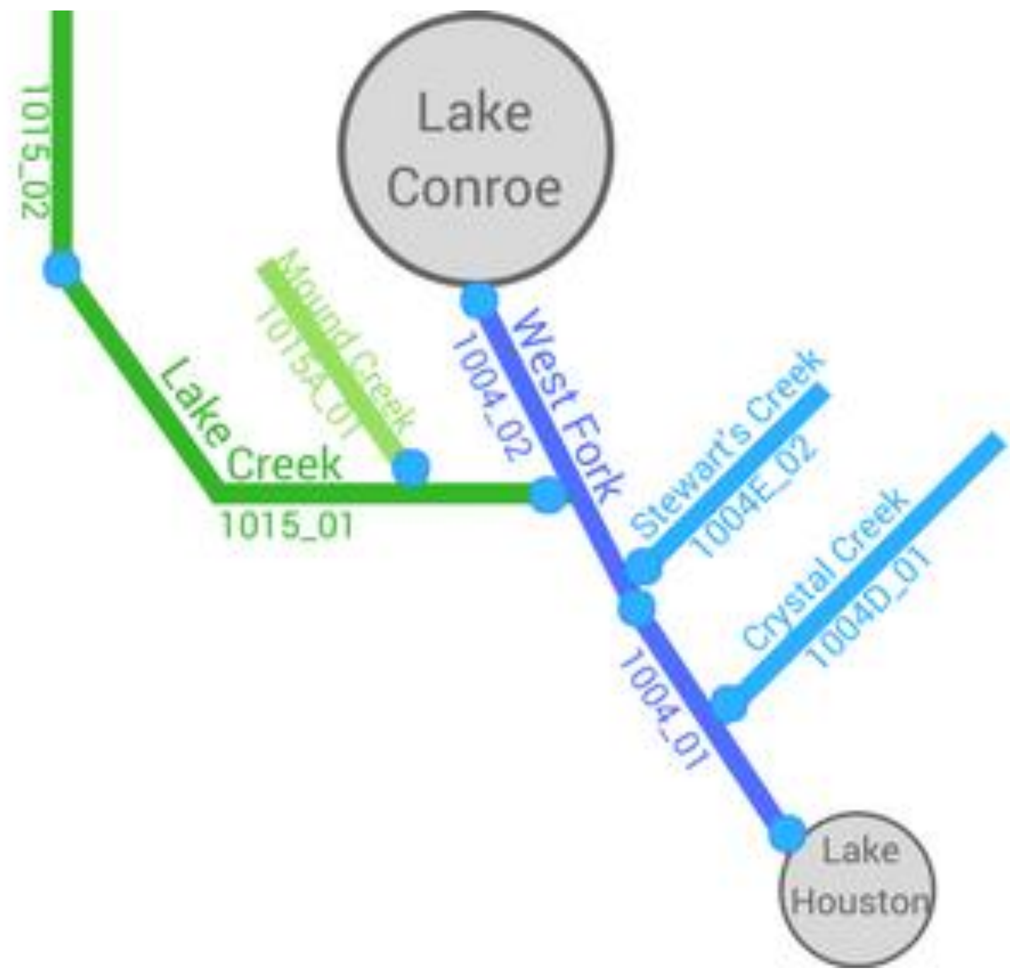


Figure 22 - Network Diagram of Segments and Assessment Units

Assessments are made based on data collected under the state's Clean Rivers Program (CRP) and other quality-assured data. The 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 Texas' *Integrated Report of Surface Water Quality* (Integrated Report). The results of the assessments of the West Fork segments are summarized in Table 2. These results 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.

Designated Uses

The waterways of the West Fork and Lake Creek systems serve a multitude of uses for people and wildlife. Assessments of water quality consider the ability of waterways to support these uses based on set criteria.

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 dissolved oxygen (DO) and an assessment of the diversity and health of existing ecological communities (fish, macrobenthics, and their habitat). High levels of chlorophyll *a* can indicate potential issues related to low DO.

The **contact recreation use** designation indicates the waterway is used for recreational activities, such as swimming, that involve an appreciable chance of ingesting water. The basis of the SWQS for contact recreation standards is to protect public health. Ubiquitous fecal bacteria organisms (*E. coli* and *Enterococcus*) are used as indicators of the potential contamination level from fecal pathogens. In freshwater systems like the West Fork watersheds, elevated levels of *E. coli* are signs of inability of the waterway to meet the SWQS.

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, 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.

State of the Water

The water quality of the water bodies in the West Fork is affected by numerous factors, including human activities, natural processes, availability of rainfall, and dam releases and natural seepage from the Lake Conroe reservoir to which it is connected. Based on assessment of water quality data[26], many of the assessment units of the West Fork and Lake Creek system 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 the West Fork and Lake Creek is typical of challenges seen in other freshwater rivers and bayous in the area, though relatively good compared to waterways in more urbanized areas[27].

- **West Fork –** Current water quality issues in the West Fork and its assessed tributaries Stewart's Creek and Crystal Creek exist for elevated levels of fecal bacteria. This impairment exists across all assessment units. Concerns in this segment are limited to elevated levels of nitrate in the downstream assessment unit of the West Fork's main channel (1004_01).
- **Lake Creek –** Current water quality issues in Lake Creek and its assessed tributary Mound Creek are more varied, reflecting a watershed in transition. The only current impairment in the system is for elevated levels of bacteria in Mound Creek. However, Lake Creek's

[26] 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 Collection and Trends Analysis Report available on the website for this WPP project at:* http://westfork.weebly.com/uploads/9/6/6/3/9663419/west_fork_wpp_water_quality_data_collection_and_trends_analysis_report_final_compressed.pdf

[27] References to assessments and water quality status refer, unless otherwise noted, to the 2014 Integrated Report of Surface Water Quality, the most current report available at the time of publication.

main channel has concerns for depressed DO in both assessment units, and an impaired macrobenthic communities concern in the downstream assessment unit (1015_01). These listings potentially reflect the impact of the denser development in the lower part of the Lake Creek watershed.

A summary of the impairments and concerns listed for the assessment units of the West Fork in the last two Integrated Reports are found in Table 2. In the table, "Concern Level" indicates whether a concern is based on the potential for non-attainment of a standard in the future (CN, concern for near non-attainment), or if it is related to a contaminant or condition for which standards do not exist, but for which screening levels have been established (CS, concern for screening level). A blank status indicates no concern. These impairments and concerns reflect the current formal assessment status by the State and are the starting point for evaluating water quality in the watersheds. The gap of time between these assessments (the 2014 Integrated Report includes data through 2012) and the evaluations conducted under this WPP (Section 3) means that current conditions may not be wholly in line with the assessment status.

Table 2 - Impairments and concerns for West Fork and Lake Creek Assessment Units

	Impairments		Concerns
Integrated Report Year	**Segment**	**Impaired Parameter and Affected Assessment Unit(s)**	**Concern Parameter and Affected Assessment Units**
2012	1004- West Fork	Bacteria (1004_01, 1004_02, 1004D_01, 1004E_02)	Nitrate (1004_01) Orthophosphorus (1004_01)
	1015 – Lake Creek	*None*	Depressed DO (1015_01, 1015_02) Bacteria (1015_01, 1015A_01)
2014	1004- West Fork	Bacteria (1004_01, 1004_02, 1004D_01,	Nitrate (1004_01)
	1015 – Lake Creek	Bacteria (1015A_01)	Depressed DO (1015_01, 1015_02) Impaired macrobenthic communities (1015_01)

Other Concerns

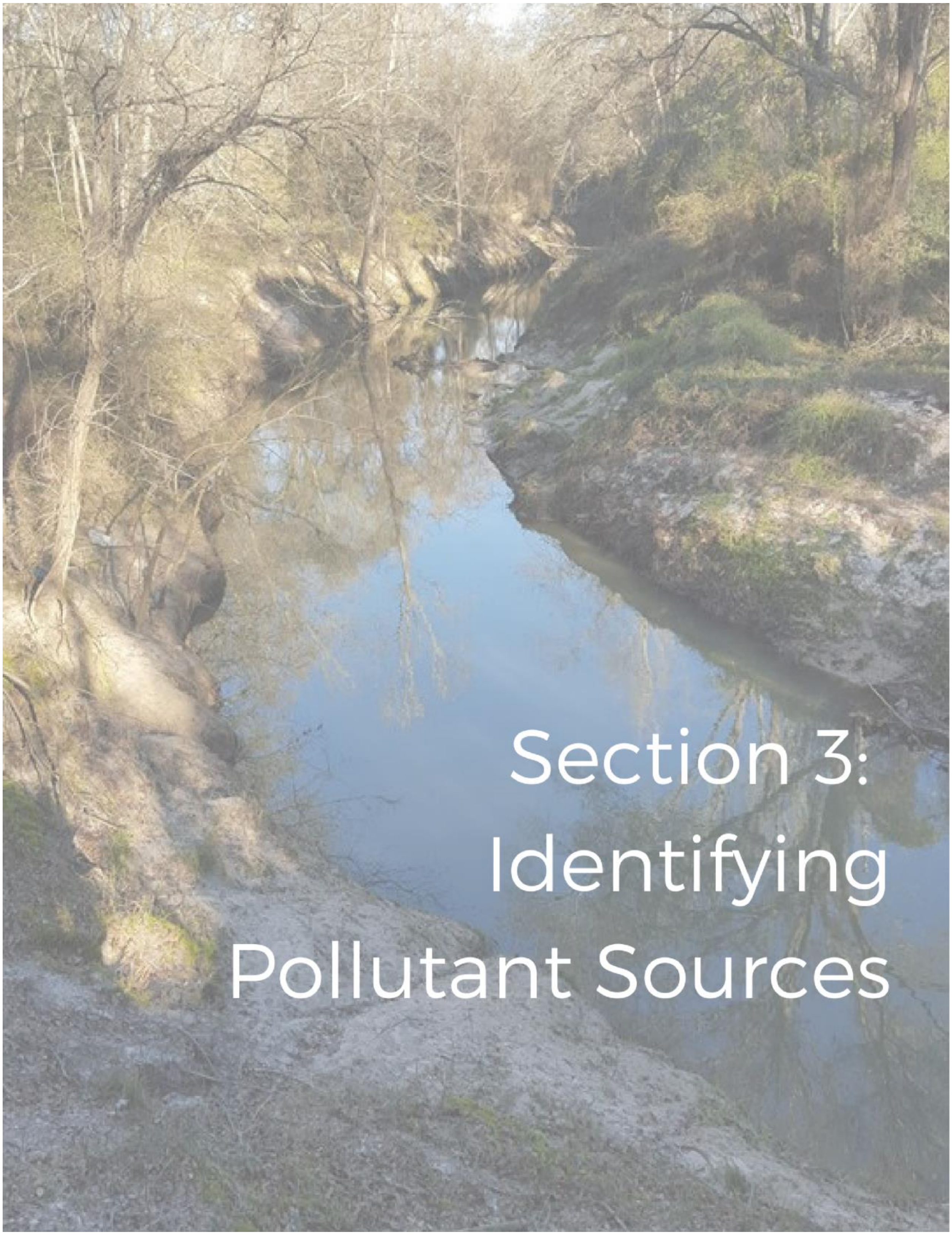
While the primary focus of this WPP is to address water quality impairments and concerns, all water bodies have a broad range of issues that impact human and wildlife uses. The WPP model is inclusive of other stakeholder concerns as part of a broader effort to improve the waterway. During the development 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 and litter from recreation activities were raised as concerns as well.

Sediment – The sinuous channels of the waterways of this system have intermittent sand and gravel banks in many places. These alluvial sediments are attractive to sand and gravel mining operations which have increased dramatically in the last decade. Removal of the vegetation around mining sites, and inadequate stormwater controls for these operations along the river allows for sediments like sand, to be washed into the river and can then flow into Lake Houston after a major rain event. Sediment load from tributaries has been studied in the past as a potential issue for the waterway. Increased development and decreased riparian buffers will likely lead to faster runoff velocities, increased erosion and decreased filtration. Besides the concern of hydrologic changes to the waterway due to sediment load, increased sediment can impact the benthic habitats of aquatic life, shelter bacteria, and increase water treatment costs. Of regional importance is the potential impact of sediment on the water supply capacity of the Lake Houston reservoir.

Hydrological modification and related concerns – 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, but it should be noted that no recommendations directly addressing flood management are included. 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.

Section 3: Identifying Pollutant Sources



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 West Fork watersheds. The purpose of these efforts is to provide local stakeholders the information and context to make informed and effective decisions for their communities.

Figure 23 - Source identification with the Partnership

Investigation Methodology

The process of investigating causes and sources of pollution in the watersheds used a series of successive steps to bridge the gap between the existence of impairments and concerns, and the end goal of having solid information on potential causes and sources[28]. Figure 24 is a flow diagram of how the Partnership conducted investigations and developed recommendations.

[28] More detailed information on the development of this investigation methodology and selection of models can be found in the *Modeling Methodology Analysis* , located at https://westfork.weebly.com/uploads/9/6/6/3/9663419/west_fork_wpp_modeling__methodology_analysis.pdf

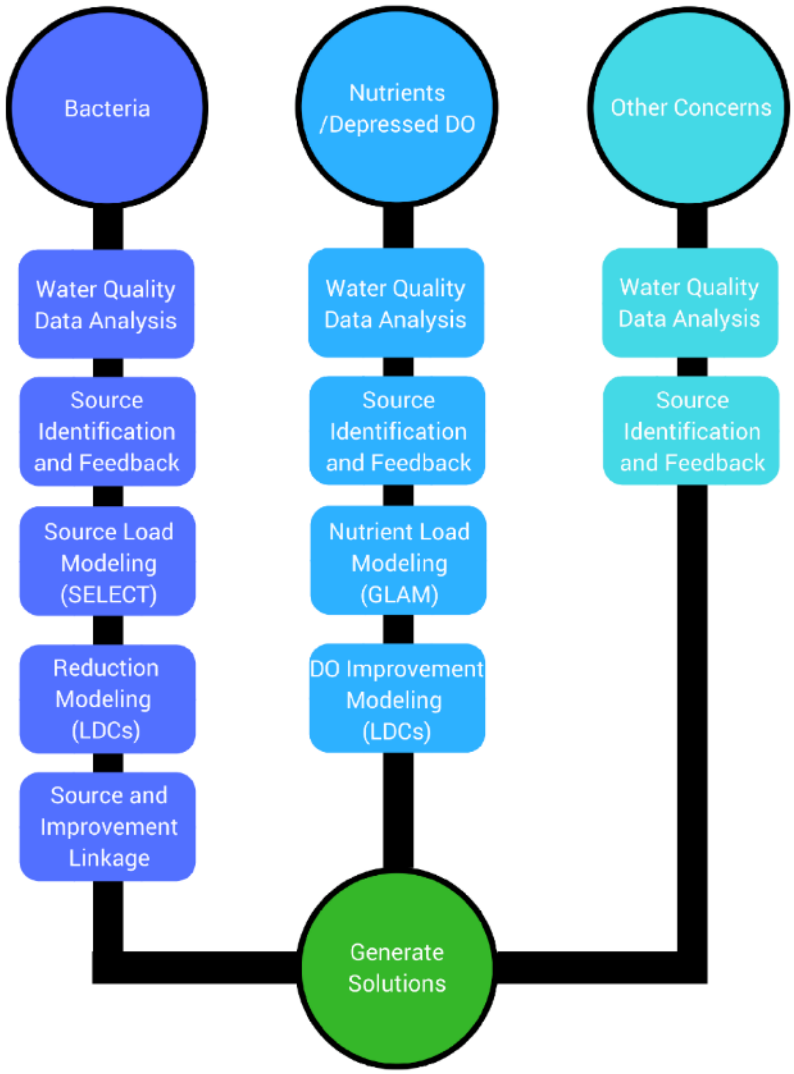


Figure 24 - Pollutant source investigation flow chart

Water Quality Goals

The applicability of each step to different pollutants/conditions of concern is based on the water quality goals[29] established by the stakeholders and is noted in the parentheses for each step.

- **Water quality data analysis (all water quality issues)** – project staff worked with stakeholders to identify status and trends in ambient water quality monitoring data and discharge data from wastewater treatment plants. These analyses help identify the extent and variability of water quality issues and highlight differences between areas in the watershed.

[29] As delineated in Section 1, p.6-7.

- **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 (Bacteria, Nutrients)** – H-GAC worked with the Partnership to estimate the potential amount of pollutants generated in the watersheds using computer models guided by local knowledge and feedback. These efforts identified the amount of pollutants being generated, the mix of sources responsible, and the variation between different areas of the watershed.
- **Improvement modeling (Bacteria, 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 current water quality monitoring data. These processes generated the percent reduction for bacteria and the percent improvement for DO levels (See Section 4).
- **Source and Improvement Linkage (Bacteria)** – As the primary focus and sole impairment, bacteria estimates were needed to establish numeric reduction goals for bacteria. This process applied the percent reduction targets from the improvement modeling to bacteria source load estimations to generate the amount of source load that needed to be reduced to achieve the water quality standard (See Section 4).

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 Collection and Trends Analysis Report*[30] prepared for this WPP. The primary goals of the analyses were to increase the understanding of the extent of 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.

[30] available on the WPP project website at: http://westfork.weebly.com/uploads/9/6/6/3/9663419/west_fork_wpp_water_quality_data_collection_and_trends_analysis_report_final_compressed.pdf

Figure 25 - 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 the TCEQ as part of the Clean Rivers Program[31]. Most monitoring stations are sampled by CRP partners[32]. Waterways are inherently dynamic systems, and water quality at any given time can vary greatly dependent on conditions at the time[33]. However, a history of samples provides a more representative view of the range of conditions that may be present in that waterway. Ambient data is important for characterizing waterways because it represents a range of conditions and has a historical aspect that allows for the identification of trends over time. The final determination of the regulatory status of each segment is based primarily on these ambient data. The goals and decisions for this WPP was established in part due to the regulatory status, and therefore ambient data is an important source of information for informing stakeholder decisions. The current monitoring stations, by collecting entity, are shown for the West Fork and Lake Creek watersheds in Figures 26 and 27, respectively.

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

[32] More information about the specific monitoring and programmatic details of the local CRP can be found at http://www.h-gac.com/community/water/rivers/.

[33] For this report, 24-hour DO data is discussed in this section. 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.

Constituents of concern

Routine ambient water quality monitoring under the Clean Rivers Program 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 was selected for in-depth analysis. The constituents reviewed were:

- *E. coli* – a bacterial indicator of the presence of fecal wastes, and an indicator of the safety of waterways for recreation.
- *Dissolved Oxygen (DO, grab)* – an indicator of the ability of the waterway to support aquatic life
- *24-Hour DO* – an indicator of the change in DO over a daily cycle, and part of the criteria for determining compliance with the aquatic life use water quality standard.
- *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 basicness of water, which may affect aquatic life and other uses.
- *Chlorophyll-a* – an indicator of aquatic plant productivity and action, which can indicate areas in which algal blooms or elevated nutrient levels are present, and potentially depressed DO.
- *Nitrate+Nitrite* – a measure of nitrogenous compounds and indicator of nutrient levels (and thus potential DO impacts).
- *Ammonia Nitrogen* – a measure of specific nitrogenous compound that can affect aquatic life and an indicator of nutrient levels and potentially of improperly treated sewage effluent.
- *Flow (grab)* – a measure of water volume over time
- *Total Phosphorus* – an indicator of nutrient levels, especially in relation to potential for algal blooms and depressed DO in elevated levels.
- *Total Suspended Solids* - a measure of the amount of suspended particles in water that indicates the potential of light infiltration in the water column and the presence of particulate matter on which bacteria may seek shelter.

The period the assessed data cover is 2012-2017, with most of data falling between the 2012-2016 timeframe. The primary questions this evaluation sought to answer relate to: 1) the sufficiency of the data to characterize conditions; 2) the spatial component of variations in water quality conditions; 3) the extent of water quality issues; and 4) 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.

West Fork San Jacinto River (Segment 1004)

There are six monitoring stations on the West Fork waterways (Figure 26), three on the main body, and one each on Crystal Creek (1004D), Stewart's Creek (1004E), and White Oak Creek (1004J). The data for all stations is representative of several years of sampling and is sufficient to describe the conditions during the study period.

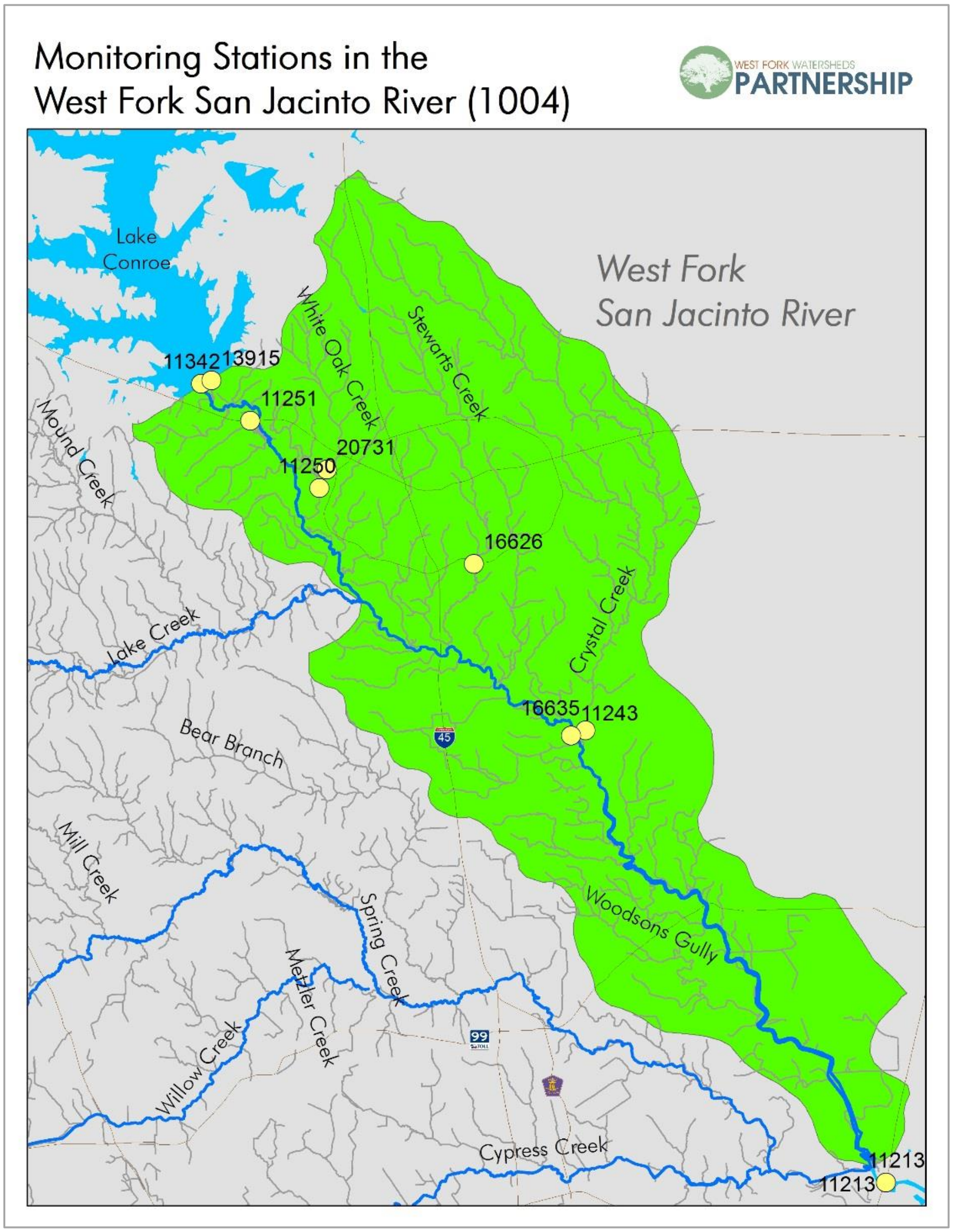


Figure 26 - Monitoring stations in the West Fork (Segment 1004)

Table 3 indicates the constituents in Segment 1004 and its unclassified tributaries for which there are statistically significant trends. The lack of an increase in *E. coli* during this time frame is notable, and the decrease in phosphorus is also a good sign. The increasing chlorophyll-a does not seem to correlate to a decreasing DO trend.

Table 3 - Trending constituents, West Fork

Segment	Parameter	Trend	P-value	Number of Samples
1004	Chlorophyll a	Increasing	0.0007	22
1004	Total Phosphorus	Decreasing	0.0053	95
1004E	E. Coli	Decreasing	0.0369	33

Notable findings in review of the monitoring results include:

- ***E. coli*** concentrations covered a wide range of values, but in most of the project waterways there are ample exceedances of the SWQS, with some of the unclassified tributaries (White Oak Creek especially) having many samples orders of magnitude above the standard. In Segment 1004 specifically, the moving 7-year geomean indicates a continued degradation (which is not reflected in the tributaries, even though they still exceed the standard).
- **Nutrients** (Ammonia, Nitrate, Total Phosphorus, chlorophyll *a*) were generally under screening levels, except for station 11243 which had an appreciable number of exceedances for nitrate and total phosphorus levels. Station 11250 had an increasing trend for chlorophyll *a*, but most of results were still under screening levels.
- **DO (grab)** levels show no appreciable issues with DO screening levels.
- **Other parameters** (temperature, flow, total suspended solids [TSS], pH) did not show any patterns of note or water quality issues, although TSS levels were elevated at times.
- **Overall,** elevated levels of bacteria remain the primary issue for the West Fork San Jacinto River.

Lake Creek (Segment 1015)

There are three stations in the Lake Creek system (Figure 27), two on the main body, and one on Mound Creek. The data for all stations is representative of several years of sampling and is sufficient to describe the conditions in the southeastern half of the watershed during the study period. Additional data would be helpful in fully characterizing the upper half of the watershed, which does not have current monitoring stations.

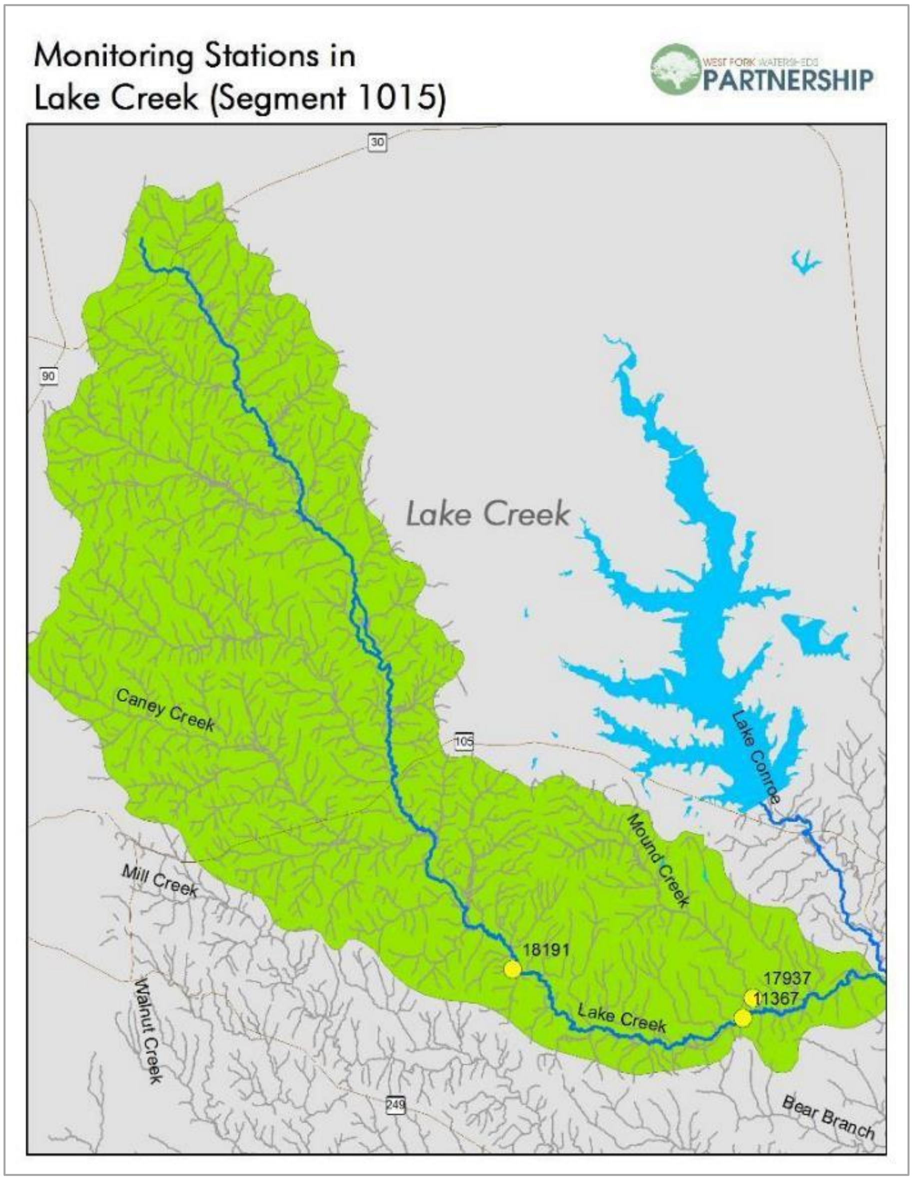


Figure 27 - Monitoring stations in Lake Creek

Table 4 indicates the constituents in Segment 1015 and its unclassified tributaries for which there are statistically significant trends. There were no trends for primary constituents of concern other than pH, which has no direct implication for water quality concerns under this project without a correlation with other issues.

Table 4 - Trends in constituents, Lake Creek

Segment	Parameter	Trend	P-value	Number of Samples
1015	pH	Increasing	0.0151	44

Notable findings in review of the monitoring results include:

- ***E. coli*** samples showed a range of concentrations, and for both the main channel and Mound Creek stations, there were numerous samples in excess of the water quality standard. An analysis of the moving 7-year geomeans indicates no appreciable increase, but levels continue to be above the standard for both 1015 and 1015A[34].
- **Nutrients** (Ammonia, Nitrate, Total Phosphorus) levels were generally under screening levels, with few exceptions for any parameter or station.
- **DO levels** (grab) were often depressed and below the screening level for the main channel, but without issue in Mound Creek.
- **24-hour DO data** indicated that the main channel had varied results, with 75% of events meeting the standard for both minimum and averages. However, the event for both parameters that comprises the 25% was during 2011 and may be explained by dry conditions during a drought of record. The events recorded in Mound Creek indicated compliance.
- **Other parameters** (temperature, flow, TSS, pH) did not have any elevated results of note, although TSS levels on the main channel showed a wide range.
- **Overall**, elevated *E. coli* levels are the continuing primary challenge for Segment 1015, with current data indicating it may be listed for bacterial impairment in the future assessments.

Relationship to Flow

As part of the ambient data analyses, the Partnership considered the relationship of constituent levels to flow conditions. Further work on flow and bacteria was completed as part of load duration curve model development discussed later in this section. However, these ambient analyses pointed out several statistically significant relationships worth noting in characterizing these watersheds. Of specific interest was the relationship between flow and bacteria

[34] See Appendix C.

concentrations. There was a less obvious relationship between flow and bacteria concentrations in the West Fork, indicating a potential mix of bacteria sources affecting different flow conditions (i.e. point and nonpoint source). In Lake Creek, there were consistent nonpoint source indications, as bacteria concentrations increased with flow regularly throughout the stations of the waterway.

Ambient Analysis Summary

The watersheds of the project area exhibit water quality challenges reflective of their developmental status. Monitoring stations in more heavily developed parts of the watersheds tend to correlate to a greater impairment.

Bacteria remains an issue through most of the area, except some areas of Lake Creek. However, lack of monitoring data from northerly reaches should not be taken as an absence of impairment, but rather, insufficiency of data. It is likely that bacteria levels, absent intervention, will continue to increase in Lake Creek as development advances.

Elevated TSS levels in the waterways do not seem directly related to effluent flows (see DMR data analysis in the following pages), though wastewater is likely a component. Additional review may be needed to understand the potential sources of TSS. Anecdotal reports from stakeholders indicate that heavy activity by sand and gravel operations in the riparian corridors may be a significant part of this issue, but sediment load from development in the watershed is also a likely contributor.

While water quality issues persist in these waterways since the 2014 assessment, they are not so considerable that voluntary intervention through watershed-based plans would be fruitless. 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 volunteer. There are three TST sites in the watersheds. There were no results that indicated concerning conditions, but the observational data for the West Fork site at I-45 was useful in characterizing the changing conditions of sediment transport in the waterway. The reports describe a frequent shifting of sediment deposits and channel structure.

Wastewater Treatment Facility Discharge Data

Discharges from wastewater (sewage) treatment plants are regulated by TCEQ water quality permits which set stringent limits for effluent quality. There are 44 permitted WWTFs that discharge to either Lake Creek or the West Fork (Table 5 and Figure 28).

Table 5 - WWTFs in the project area

WWTF	Permit Number	Permitted Discharge (gallons/day)
Hunstman Petrochemical Plant	WQ0000584000	750,000
Maverick Tube - Tenaris Conroe	WQ0002365000	110,800
Chevron Phillips	WQ0002475000	16,000
Hanson Aggregates Woodlands Plant	WQ0002502000	350,000
City of Conroe SW Plant	WQ0010008002	10,000,000
City of Willis	WQ0010315001	800,000
City of Houston Kingwood West	WQ0010495142	2,000,000
River Plantation MUD	WQ0010978001	600,000
City of Panorama Village	WQ0011097001	400,000
Montgomery County MUD 15	WQ0011395001	900,000
Grimes County MUD 1 WWTP	WQ0011437001	25,000
Town of Woodloch	WQ0011580001	150,000
San Jacinto River Authority Woodlands WWTP 3	WQ0011658001	900,000
San Jacinto River Authority Pilot Plant	WQ0011658002	633,600
Lazy River Improvement District	WQ0011820001	100,000
City of Shenandoah	WQ0012212002	3,000,000
Crane Co. WWTP	WQ0012456001	5,000
Westmont Mobile Home Park	WQ0012761001	50,000
Richards ISD	WQ0013527001	5,000
Chateau Woods WWTP	WQ0013700001	400,000
Montgomery County MUD 89 Rembert Tract WWTP	WQ0013985001	380,000
White Oak Ranch WWTP	WQ0014114001	600,000
Woodland Oaks WWTP	WQ0014166001	498,000
Skye Ranch WWTP	WQ0014305001	240,000
Woodland Lake Village WWTP	WQ0014414001	450,000
Montgomery County MUD 83	WQ0014482001	600,000
Montgomery County MUD 88	WQ0014523001	360,000
Creekside WWTP	WQ0014531001	600,000
Montgomery County MUD 105	WQ0014586001	900,000
Montgomery County MUD 99	WQ0014604001	1,500,000
MSEC Enterprises WWTP	WQ0014638001	20,000
Montgomery County MUD 112	WQ0014671001	500,000
Stone Hedge WWTP	WQ0014709001	15,000
Mostyn Manor WWTP	WQ0014711001	500,000
Bender's Landing	WQ0014755001	900,000
Fair Oaks WWTP	WQ0014800001	700,000
Montgomery County MUD 113	WQ0014814001	945,000
Montgomery County MUD 125 WWTP 1	WQ0014989001	960,000
Montgomery County MUD 139	WQ0015089001	510,000
Blaketree MUD 1 WWTP	WQ0015283001	200,000
Montgomery County MUD 96	WQ0015288001	400,000
Woodland Oaks Lost Creek	WQ0015296001	250,000
Montgomery County MUD 127	WQ0015313001	600,000
Magnolia Lake Creek WWTP	WQ0015317001	62,500

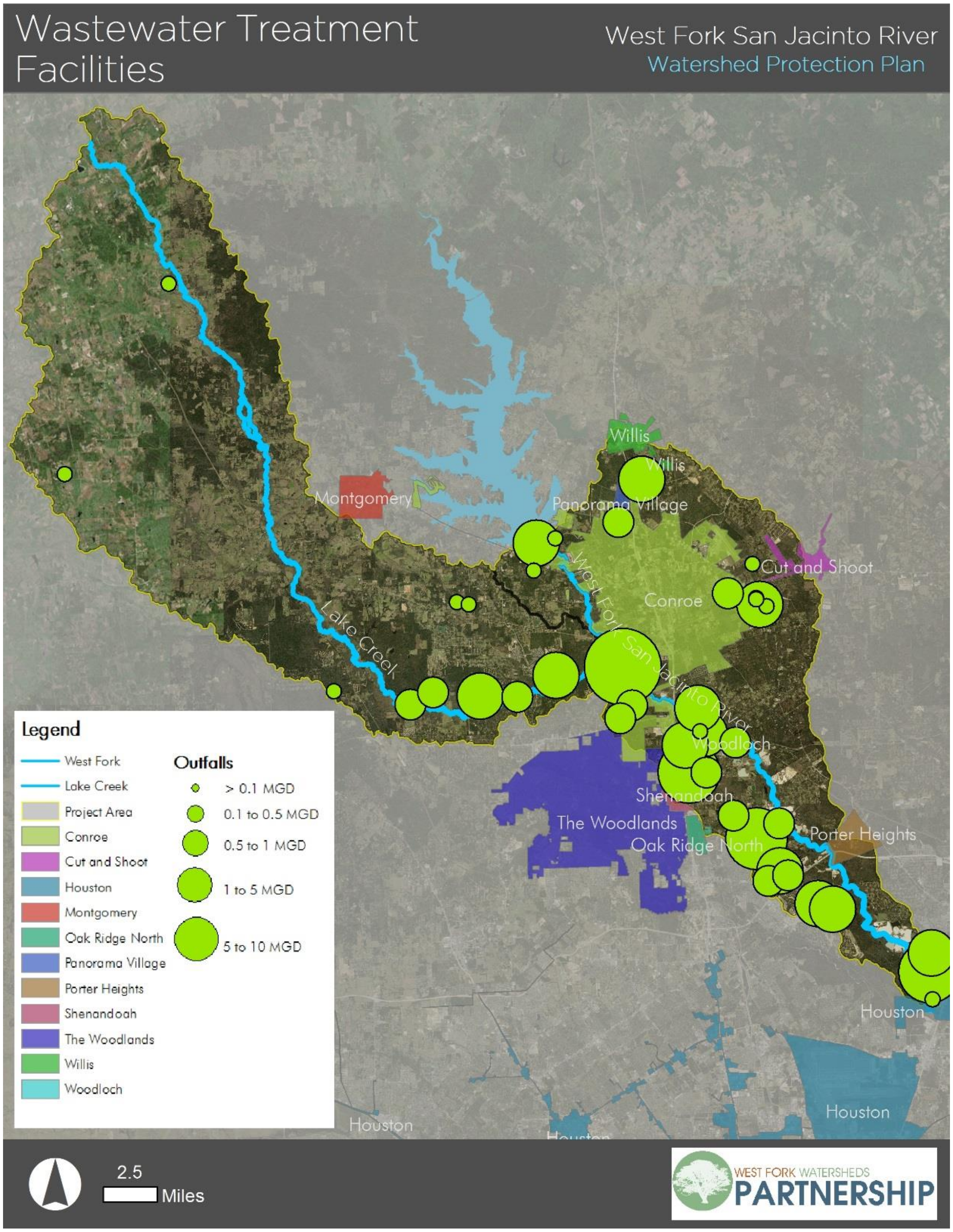


Figure 28 - WWTF in the project area, by size

Most wastewater treatment plants in the region meet their permit limits with few exceptions. However, because human waste has a relatively high risk of causing illness[35], identifying trends

[35] While the project considers many sources of fecal bacteria, recent research has indicated that human waste has a significantly higher risk of causing illness in humans as compared to animal sources. Additional information about this research can be reviewed at http://oaktrust.library.tamu.edu/handle/1969.1/158640?show=full. (Gitter, 2016).

in permit exceedances for indicator bacteria by WWTFs is important in understanding overall impacts to waterways. Effluent (especially if improperly treated) can also be a source of nutrient precursors to depressed DO. Discharges from WWTFs are monitored on a regular basis (with a frequency dependent on plant size and other factors). The data from these required sampling events is submitted to (and compiled by) the TCEQ as discharge monitoring reports (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.

The Partnership evaluated five parameters common to most WWTF permits, as reported in the past five years (2012-2017) of DMRs available from TCEQ. Some parameters are constituents of concern, while the others are indicators of the presence or potential presence of untreated/improperly treated waste. The parameters assessed include *E. coli*, TSS, ammonia nitrogen (NH_3-N), DO (grab samples), and 5-day carbonaceous biochemical oxygen demand (CBOD5).

The parameter evaluations were based on the regulatory permit limits specific to each facility, and considered the number of exceedances by each plant, in each year, in each segment, and as a percentage of the total samples.

Indicator Bacteria (E. coli)

E. coli is an indicator bacterium widely common to the guts of warm-blooded animals. While many strains of *E. coli* are not problematic, they are closely related to the presence of fecal waste and to the host of pathogens present in wastes. The water quality standard for ambient conditions is 126 cfu per 100ml of water (for the geomean of samples) and 399 cfu/100ml (for single grab samples). These standards are general applied as a permit condition for wastewater as well. Evaluations for compliance with the permit limits were compared between segments, between plants, between years, between categories (average or maximum values), and by season.

In general, the results indicated a very small number of exceedances. Maximum values were more commonly exceeded than average/geomean limits, indicating there is likely some variability in effluent conditions. Summer was the season with the greatest number of exceedances for facilities in Lake Creek, but the trend was not apparent in facilities along the West Fork. Plant size was not a statistically significant indicator of potential to exceed limits[36]. While WWTFs may be appreciable contributors under certain conditions or in localized areas, the DMR analysis indicates that they are not likely a significant driver of segment bacteria

[36] Self-reported data obscures underlying uncertainties about variability in conditions. This is exacerbated when comparing manned, larger facilities that are more likely to sample more frequently, and smaller facilities that sample less frequently and are generally unmanned. These results should not be taken to have statistical significance.

impairments due to the comparatively few exceedances and the relatively small volumes of effluent.

Dissolved Oxygen

DO levels in WWTF effluent help indicate the efficiency of treatment processes. DO is generally more stable in effluent than in ambient conditions because it is less subject to natural processes and variation in insolation. DO is measured in mg/L, and the permit limits with which results are compared vary based on the receiving water body and other factors. Unlike other contaminants, DO limits are based on a minimum, rather than maximum level. Generally, permit limits for the data reviewed ranged between 4-6 mg/l. Evaluations for compliance with the permit limits were compared between segments, between plants, between years, between category (average or maximum values), and by season. There were relatively few violations of DO limits. There were no statistically significant seasonal components for the whole area or individual segments. Based on these data and analyses, it is unlikely WWTFs are having any appreciable impact on DO conditions in the waterways, even before the dilution of these small volumes (relative to the larger volumes of the waterways) is considered.

Total Suspended Solids

TSS is an indication of wastewater treatment efficiency in removing solids. Substantial TSS levels in effluent can contribute to fostering bacterial regrowth as bacteria uses suspended particles as a protected growth medium. It can also decrease insolation in the water column and lead to deposition of particles on the substrate, etc. However, it can also 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 weight/day). For this evaluation, only the measured concentration records were considered. Both average and maximum permit limit values exist for most plants. Evaluations for compliance with the permit limits were compared between segments, between plants, between years, and between category (average or maximum values). TSS violations were rare, making up less than 1% of the total sample records. There were no clear differences by segment (when proportional ratio of samples to violations was considered) or by year. In general, TSS results indicate WWTFs are operating within their permit limits and that TSS inputs from WWTFs are not likely a chronic issue for the waterways.

Ammonia Nitrogen

Ammonia (NH_3) is a nitrogenous compound that can be toxic in concentration to people and aquatic wildlife and can contribute to the harmful effects of elevated nutrient loadings. Additionally, excessive NH_3 levels in effluent indicate inefficient wastewater treatment, and may correlate to the presence of improperly treated sewage. Permit limits for NH_3 include a concentration based (average) limit (in mg/l) and a total weight-based limit (in weight/day). For this evaluation, only the measured concentration records were considered. Both average and maximum permit limit values exist for most plants. Evaluations for compliance with the permit limits were compared between segments, between plants, between years, and between category (average or maximum values). NH3 violations were relatively rare, making up 2% of the total sample records, and 2 to 2.5% of the individual segment records. There were no clear differences by segment (when proportional ratio of samples to violations was considered). Distribution by year was relatively even. NH3 results indicate WWTFs are operating within their permit limits and NH3 inputs from WWTFs are not likely a chronic issue for the waterways.

CBOD5

CBOD5 is not a pollutant, but is an indicator of biological oxygen demand, and thus potentially the presence of improperly treated effluent in a sample. Improperly treated effluent will have a high level of CBOD5. Permit limits for CBOD5[37] include a concentration based (average) limit (in mg/l) and a total weight-based limit (in weight/day). For this evaluation, records for both were considered because of the nature of the test. Both average and maximum permit limit values exist for concentration limits for most plants. Evaluations for compliance with the permit limits were compared between segments, between plants, between years, and between category (average or maximum values) for concentration limits. No patterns of exceedance were identified.

Overview of results

While there were exceedances for the evaluated constituents, most of plants met their permit limits most of the time without significant issue. Even allowing for variability in effluent conditions not reflected in the DMR results, it is unlikely that WWTFs are an appreciable source of contamination in the watershed based on the DMR data[38]. Bacteria source modeling support this evaluation, indicating that for *E. coli* specifically, WWTFs are projected to account for a minor amount of overall load.

However, in interpreting these results, it should be noted that while WWTFs may not be the largest source of bacteria, they are likely one of the sources most closely tied to human fecal waste, and therefore have an inherently higher pathogenic potential than other sources. 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 the 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

[37] The “5” refers to the number of days the test is run.
[38] Further discussion of load estimates for WWTFs as a source is found in the portion of this Section describing the SELECT modeling process.

to their consideration as well. This is exacerbated for nutrients given the lack of permit limits for many nutrient parameters, and the potential for WWTFs to be nutrient loading sources in effluent dominated streams.

Sanitary Sewer Overflows

Unlike treated WWTF effluent, sanitary sewer overflows (SSOs) represent a high, if episodic risk, 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 its significant health risk where SSOs are sizeable and/or were chronic issues. The causes of SSOs vary from human error to infiltration of rainwater into sewer pipes. This study considered five years of TCEQ SSO violation data for 2011/2012 through 2016. Date for 2017 was not yet available). One-hundred and eight records were considered for the watersheds area. Table 6 indicates the number of SSOs in each year for each segment. The number of SSOs has increased in recent years, especially in the West Fork.

Table 6 - SSOs by segment and year

Number	Total	2011	2012	2013	2014	2015	2016
1004	78	8	6	14	20	20	10
1015	30	3	4	7	4	4	8
Total	108	11	10	21	24	24	18

While the number of SSOs indicates the frequency with which sewage systems have events, the volume of SSOs indicates the extent of the impact they have (i.e. a small plant with 100 small SSOs may produce a more chronic, but smaller discharge than a large plant with a single SSO of a much larger volume). Table 7 indicates the volume of SSOs by segment, by year.

Table 7 - SSO volume by segment and year, in gallons

Volume	Total	2011	2012	2013	2014	2015	2016
1004	1,463,528	17,994	68,024	23,355	208,315	915,725	230,115
1015	195,950	11,000	5,500	1,050	0	16,500	161,900

Volume by year for each segment varied greatly, and not always in relationship to the other segment (e.g. in 2014 SSO volume in Segment 1004 went up sharply, and down sharply in Segment 1015). This suggests that commonly experienced causes (precipitation levels, etc.) may not be a primary driver for SSOs. Segment 1004's WWTFs have a slightly higher volume per plant on average, but a significantly higher proportion of the SSO volume in both absolute and relative terms. In comparison of both numbers and volumes of SSOs, Segment 1004 stands out as having numbers and volumes disproportionate to its number of WWTFs.

Cause is another important factor in characterizing SSOs. Steps to remediate problem areas are typically designed to meet the originating causes. Much of the watershed has relatively new infrastructure, outside of the Conroe area and some other older communities. SSO causes were broken into 10 categories to reflect the breakdown in the TCEQ's SSO data. It should be noted that this categorization depends on the accuracy of the data reported. While a single cause is typically listed on the SSO report, many SSOs are caused by a combination of factors[39]. Table 8 shows the breakdown of cause by type, number, and segment.

Table 8 - SSO Cause by number and segment

% of Total SSOs	Total SSOs for category	1004	1015	Causes
18.8%	30	29	1	Blockage in Collection System Due to Fats/Grease
3.8%	6	5	1	Unknown Cause
1.9%	3	3	0	Power Failure
9.4%	15	11	4	Collection System Structural Failure
20.6%	33	31	2	Lift Station Failure
3.1%	5	4	1	Human Error
17.5%	28	22	6	Blockage in Collection System-Other Cause
5.0%	8	7	1	WWTP Operation or Equipment Malfunction
5.0%	8	7	1	Blockage Due to Roots/Rags/Debris
15.0%	24	23	1	Rain / Inflow / Infiltration
100	**160**	**142**	**18**	**Total**

By number of SSOs, there is no heavy focus on a specific cause overall. As noted previously, however, volume of SSOs is as important a consideration as number. Table 9 shows the breakdown for volume, type, and segment.

[39] For example, fats oils and grease collecting in lift station motors can cause overflows in high rain events when excess water is in a system. The event may be listed as lift station failure, but FOG and inflow and infiltration of rainwater were also causative elements.

Table 9 - SSO cause by volume and segment

Cause by volume and segment (in gallons)				
Causes	**Total**	**% total**	**1004**	**1015**
Blockage in Collection System Due to Fats/Grease	9.9%	166,508	165,508	1,000
Unknown Cause	4.8%	80,110	110	80,000
Power Failure	0.1%	2,020	2,020	0
Collection System Structural Failure	4.7%	78,240	77,240	1,000
Lift Station Failure	6.7%	112,473	111,973	500
Human Error	1.5%	25,500	22,500	3,000
Blockage in Collection System-Other Cause	2.2%	36,161	33,811	2,350
WWTP Operation or Equipment Malfunction	0.8%	13,285	13,135	150
Blockage Due to Roots/Rags/Debris	1.0%	16,503	15,953	550
Rain / Inflow / Infiltration	68.4%	1,146,861	1,066,861	80,000
Total	100.0%	1,677,661	1,509,111	168,550

While the causes by volume comparison shows a mix of causes, inflow and infiltration (I&I) stands out as a primary share of the total volume. The West Fork is driven strongly by I&I, while Lake Creek is a mix of I&I and unknown causes.

SSO Summary

SSOs are always a concern in watersheds with bacterial impairment and vulnerability to nutrient loading. Their concentrations of untreated human waste pose a disproportionately high risk to human health during recreation, and their episodic nature can make them an acute risk while they are ongoing. In terms of chronic loading, SSOs volumes in the project area are too small on an average basis to move conditions in the waterways in general. For comparison, a single plant of small to moderate size may have a discharge of 3 million gallons a day (MGD), while the sum of all SSOs in the project area for a year is less than 3 million gallons. The SSOs are greater in concentration, but their relatively minor volumes negate them to some degree as a primary source in average conditions. However, given their pathogenic potential, their proximity to urban populations, and the principle of focusing on controllable sources, SSOs should remain as a consideration for remediation efforts in the watersheds. The West Fork is a particularly good candidate for focus on this issue given its relatively high rate and volume of SSOs. SSOs are not likely an appreciable chronic source of bacteria (and other products from the waste stream) but may be effective on a local, episodic basis.

Figure 29 - SSO in progress

Other Studies

The West Fork watersheds have 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 Conroe WPP

The Lake Conroe WPP[40] was completed in 2015 by the SJRA, in coordination with local partners. The WPP does not overlap with the West Fork watersheds project area, but it is important in characterizing the boundary conditions for the West Fork related to the flow from the Lake Conroe dam. Monitoring data at the dam indicated that the water entering the West Fork from the dam was consistently good quality, especially for *E. coli* which was an order of magnitude or greater below the standard. This allowed the Partnership to focus on the WPP project area without specific concern over pollutants from Lake Conroe.

[40] Available for review at http://www.sjra.net/wp-content/uploads/2014/12/Lake-Conroe-Watershed-Protection-Plan.pdf

East and West Fork of the San Jacinto River TMDL

The TCEQ project that culminated in the *Seven Total Maximum Daily Loads for Indicator Bacteria in Lake Houston, East Fork San Jacinto River, West Fork San Jacinto River, and Crystal Creek Watersheds*[41] and subsequent implementation plan (I-Plan) covered a broad area of the Lake Houston watersheds. The findings of the TMDLs for the portions of this TMDL project are less current or granular than the WPP analyses but indicate a similar pattern of impairments and concern.

Lake Creek Watershed Characterization

H-GAC produced a watershed characterization report for Lake Creek in 2015 as part of a Clean Water Act Section 604(b) grant from the EPA, administered by TCEQ. The report used less current data than this WPP effort, but it highlighted many of the same conditions evident in these WPP analyses.

West Fork San Jacinto Watershed Greenprint

H-GAC and SJRA collaborated with the Trust for Public Land on the *West Fork San Jacinto River Watershed Greenprint*[42] , which evaluated the use of conservation activities to promote water quality. While this document was useful in evaluating areas of priority for some recommended solutions, it was not primarily a water quality analysis.

The implementation of this WPP will be coordinated with the Lake Conroe WPP and TMDL I-Plan to the greatest degree practicable.

Water Quality Analyses Summary

The outcome of the various water quality analyses conducted for this WPP provided a nuanced view of a system of waterways facing various challenges related in large part due to the developmental transition of their watersheds. The primary outcomes of the analyses are:

- Ambient water quality monitoring data suggest impairments and concerns noted in the 2014 Integrated Report remain issues, but further degradation in the intervening five years has been minimal in most areas.
- Wastewater data suggests that plants are generally able to meet their effluent permit limits and are unlikely to be an appreciable source of *E. coli* from permitted outfalls. SSOs are prevalent in the watershed, and rainwater infiltration is a primary cause. While they may be locally acute sources, their overall volumes do not represent a chronic, appreciable bacteria load for the watersheds.

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[41] Available for review at https://www.tceq.texas.gov/assets/public/waterquality/tmdl/82sanjacinto/82B-EWFSJ-tmdl-adopted.pdf

[42] Available for review at https://www.tpl.org/sites/default/files/West%20Fork%20Greenprint.pdf.

- Other water quality efforts in the watershed or adjacent areas confirm the general outlook for bacteria. The Lake Conroe WPP established that water entering the West Fork system is of good quality and not a negative boundary condition.
- Existing data is generally sufficient to inform stakeholder decisions and serve as model inputs. The primary data gap identified is the lack of monitoring data in the northern reaches of Lake Creek. This gap is not expected to influence the effectiveness of the modeling or subsequent recommendations of this WPP.

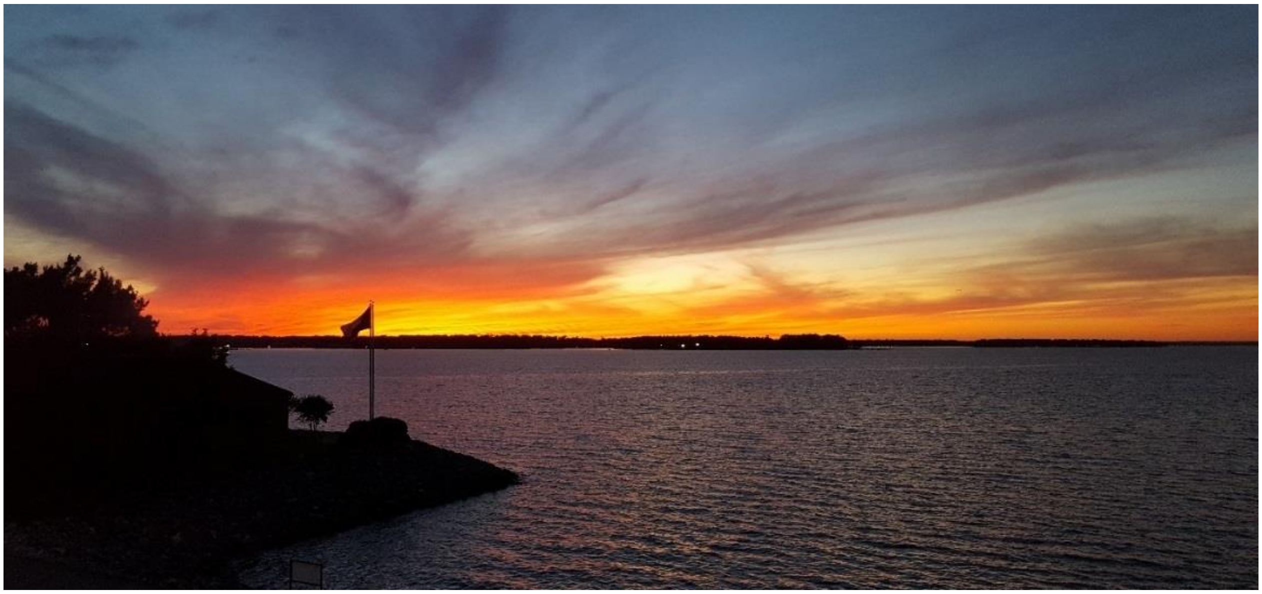

Figure 30 - Lake Conroe from the dam

Source Identification

Using the information generated through the water quality data analyses, the next step in characterizing pollution in the watersheds 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 development of modeling efforts that estimated the loads from bacteria and nutrient sources. Bacteria 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.

Bacteria Source Identification

All warm-blooded animals produce waste-bearing fecal indicator bacteria (*E. coli* in freshwater systems) and are potential sources of contamination. The indicator bacteria are not necessarily themselves the source of potential health impacts; however, they signify the presence of fecal waste and the host of other pathogens the waste may contain. There is a wide array of potential fecal waste sources in the watersheds of the project area. The potential mix of sources in a watershed can vary greatly in both spatial and seasonal contexts. The preliminary process of identifying potential bacteria sources in a watershed is discussed as being a "source survey"[43].

Figure 31 - Livestock in the Lake Creek watershed

Source Survey

Characterizing fecal bacteria 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 indicator bacteria can be produced by a broad mix of sources; this is especially true in a large, diverse set of watersheds like this project area. The existence and location of some sources are known from existing data (e.g., wastewater treatment plant outfalls), while many nonpoint sources need to be evaluated from a mix of land use 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[44] – existing data was used to generate information on discrete (usually permitted) sources. The data sources included[45]:
    - WWTF outfall locations and discharge monitoring reports (TCEQ outfall locations and DMR records)

[43] For greater detail on the source survey and subsequent bacteria modeling outcomes, please refer to the Bacteria Modeling Report, available online at https://westfork.weebly.com/uploads/9/6/6/3/9663419/west_fork_wpp_bacteria_modeling_report_.pdf

[44] As discussed in part as a function of the water quality analyses discussed earlier in this section.

[45] More information on data sources and quality objectives can be found in the project quality assurance project plan (QAPP), available online as one of the project documents at www.westforkwpp.com.

    - Permitted on-site sewage facility (OSSF) locations (H-GAC proprietary data provided by local governments)
    - Concentrated animal feeding operations (CAFOs) (TCEQ CAFO locations and violations data from TCEQ Central Registry records)
    - SSOs (TCEQ SSO database)
- Land Cover/Land Use analysis – National land cover datasets and H-GAC proprietary land cover datasets describe 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 in the later Spatially Explicit Load Enrichment Calculation Tool (SELECT) implementation as the basis of populating diffuse sources whose assumptions were tied to specific land cover types.
- Imagery Reconnaissance – Aerial imagery and online map assets (Google Maps, Google Maps Streetview, Google Earth), assisted in identifying any specific locations, specific sources, or issues to raise with stakeholders for further clarification. Items derived from this analysis were:
    - Presence of horse stables
    - Small, unincorporated communities
    - Recreation use
- Road Reconnaissance – Ongoing road reconnaissance throughout the watershed assisted in verifying remote observations. Specific items noted or affirmed during road reconnaissance included:
    - Presence of deer in appreciable numbers in developed areas
    - Progress of development
    - 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. Stakeholders provided consideration of sources through:
    - Direct discussion of sources at Partnership meetings
    - Direct discussion of sources at source-based Work Group meetings
    - Map exercises with small groups following Partnership meetings
    - One-on-one meetings with local stakeholders
    - One-on-one meetings with state and regional experts/agencies (e.g. Texas Parks and Wildlife (TPWD), TSSWCB, et al.)

Stakeholder feedback specific to the identified sources is discussed later in this section, relative to each source. Stakeholder feedback matched 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, presence of specific problem sites/dumping, etc.). The selection of sources to include in the model was based on stakeholder decisions.

The results of the bacteria source survey are summarized by general category in Table 10. The "estimated extent" reflects preliminary understanding of sources, rather than subsequent modeled outcomes. Where estimated extent includes "(locally)" this is an indication that these sources may be important for specific areas but may not be primary sources overall. Note that these extents reflect current estimated status. Some sources may be expected to increase or decrease in the period assessed by this modeling effort.

The results of the bacteria source survey were used to guide the development of the load estimation modeling (SELECT) described later in this section.

Table 10 - Bacteria Source Survey

Category	Source	Origin	Estimated Extent
Human Waste	OSSFs	Failing/improperly routed OSSFs	Moderate
	WWTFs	Improperly treated sewage from permitted outfalls	Minor
	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 and Goats	Runoff or direct deposition	Minor
	CAFOs	Improper or improperly treated discharge from permitted facilities	Not expected.
	Pigs	Runoff	Minor

Category	Source	Origin	Estimated Extent
	Exotic animals	Runoff or direct deposition	Not expected to minor (locally).
Wildlife and Non-domestic animals[46]	Feral hogs	Runoff or direct deposition	Moderate
	Deer	Runoff or direct deposition	Minor to moderate(locally)
	Birds	Direct deposition	Minor, no data.
	Bats	Direct deposition	Minor, no data.
	Other wildlife[47]	Runoff or direct deposition	No data.
Other Sources	Dogs (pets)	Runoff	Moderate
	Dogs (feral)	Runoff	Minor to moderate (locally)
	Cats (pets)	Runoff	Not expected
	Cats (feral)	Runoff	Not expected or minor
	Dumping	Runoff or direct deposition	Minor (locally)
	Sediment	Erosion or mining operations	NA[48]

Estimating Bacteria Loads

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

[46] Even though feral hogs have established wild populations, they are not considered wildlife for all applicable purposes by the TPWD and other state agencies. The consideration of hogs in the same category as other wildlife should not be construed as suggesting they are viewed as wildlife by this modeling effort or WPP development project. The category solely reflects their status as being different than domestic animals.

[47] As noted previously and discussed in further detail in the wildlife section of the SELECT source characterizations, "other wildlife" is used here and henceforth as a means of designating all potential wildlife populations for which sufficient data does not exist and which could not specifically be assessed (unlike colonial birds and bat colonies).

[48] Significant mining operations and erosion is present in many places in the watershed. While not a source of bacteria, suspended sediment in the water act to decrease bacteria die-off from insolation, etc.

The Spatially Explicit Load Enrichment Calculation Tool (SELECT)

(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[49]. The intent of this tool is to estimate the total potential bacteria load generated in a watershed and to show the relative contributions of individual sources of fecal bacteria identified in the source survey. 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 bacteria 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[50] estimates are not intended to represent the amount of indicator bacteria transmitted to the water, as the model does not account for the natural processes that may reduce bacteria on its way to the water, or the relative proximity of sources to the waterway. To attempt to account for these processes without adding complexity unnecessary to the project goals, a modified form of SELECT was implemented for this WPP.

- **Buffer Approach –** To understand the potential impact of natural process on transmission of wastes to the water, 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% of the waste generated within 300 feet of the waterway as being transmitted to the watershed without reduction. Outside of that buffer, only 25% of the waste is assumed to be transmitted to the waterway[51]. 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 general conceptual view of the effect of distance from the waterway.

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[49] Additional information about SELECT can be found at http://ssl.tamu.edu/media/11291/select-aarin.pdf. Information about the specific implementation of SELECT utilized by this project can be found in the project modeling QAPP and Bacteria Modeling Report available online at www.westforkwpp.com.

[50] References to loads in this section, unless specifically stated otherwise, should be taken to refer to (potential) source loads, rather than instream loads. SELECT does not generate instream loading estimates, just the potential source load prior to fate and transport considerations.

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

- **Future Projections –** The watersheds of the West Fork are undergoing rapid developmental change. Current sources[52] are expected to expand in the future. Therefore, bacteria 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 2040 in 5-year intervals[53]. Land use change is the primary driver for estimating changes in source contribution, and spatial distribution of loads[54].

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, stakeholder feedback on sources, model assumptions, and results was used heavily through the generation of the analysis and its eventual use as a prioritization tool for selecting BMPs. The Partnership reviewed results at multiple stages, and sought advice from external experts (e.g., feedback from Soil and Water Conservation Districts on livestock population estimates).

[52] References to "current" conditions refer to 2015 estimations, based on the available data at the time of the modeling effort.

[53] 2040 was chosen as a target year to coincide with the extent of the regional demographic model projections.

[54] 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/community/socioeconomic/2040-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. 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 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.

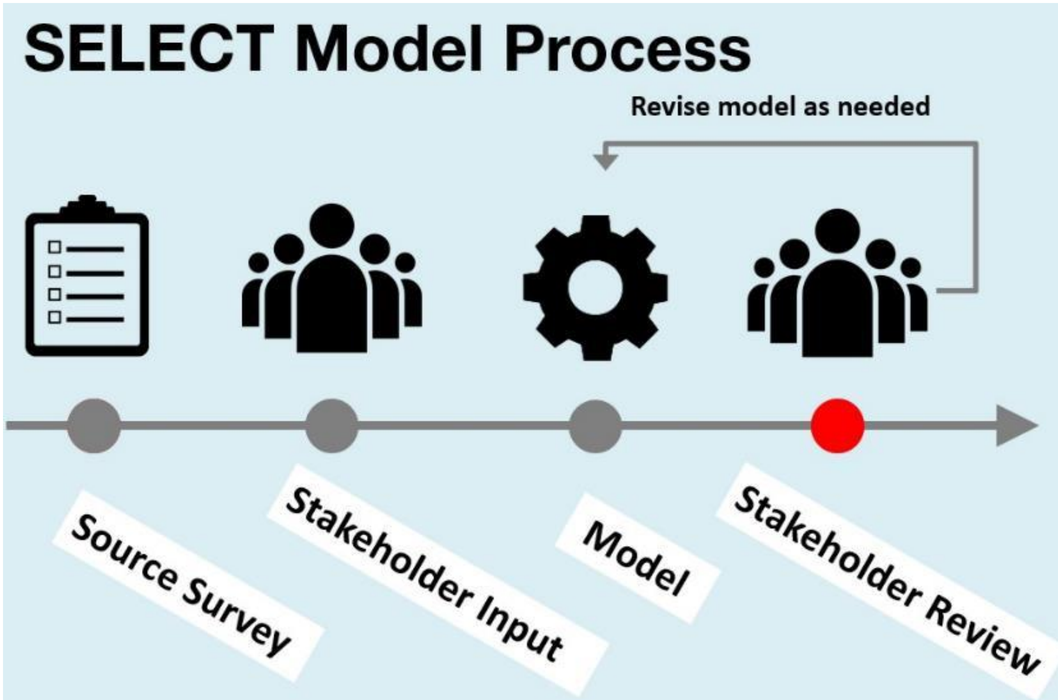

Figure 32 - SELECT Modeling Process

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 bacteria per day, using scientific notation[55]. The maps are 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, with darker patches of color adjacent to the waterways, displaying the higher loads from these areas. The higher loads reflect the buffer approach, indicating the likelihood of a greater amount of load from these areas making it to waterways. While these areas have a greater proportional amount of load, they are also a relatively smaller amount of the total watershed area. 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.

On-Site Sewage Facilities

Failing or improperly maintained on-site sewage facilities (OSSFs) (septic systems, aerobic systems, and similar treatment technologies) can be significant sources of bacteria and are the

[55] For example, 1.4E+12 is equivalent to 1.4 X 10^{12}, or 1.4 trillion. E+9 would be billions, E+6 millions, etc.

prevailing wastewater solution treatment for large areas of the watersheds, including new development. Montgomery County areas have seen rapid increases in OSSFs as larger lot development has pushed north from the greater Houston area, and west from the I-45/Conroe area. While OSSFs in the area are generally newer, the ubiquitous use of OSSFs in the area and the historic lack of long-term maintenance for those system is a concern for future water quality as systems begin to age. Most of the systems in the watershed area are aerobic type, with some legacy septic tanks and other system types.

Figure 33 - Aerobic OSSF[56]

Permitted OSSF data was taken from existing spatial data compiled by H-GAC from authorized agents[57] (local governments who manage OSSFs for their jurisdiction). Assumptions for unpermitted OSSFs are based on a review of occupied parcels outside of sanitary sewer boundaries for which no permitted OSSF exists. It was assumed that these parcels contained an unpermitted OSSF. Loading rates are based on output from failing/improperly maintained systems. Project staff discussed failure rate with Montgomery County and the San Jacinto River Authority, the primary authorized agents for the area, as well as the Partnership and Human Waste Work Group. Based on the stakeholder knowledge of system status in the watershed, the violation rates their jurisdictions have experienced, and best professional judgement, a 15%

[56] Image courtesy of Texas A&M AgriLife Extension
[57] Data is collected under a 604(b) agreement between H-GAC and TCEQ, and quality assured under the auspices of that contract. Use of this acquired data is detailed in the project modeling QAPP for this project.

failure rate was used for all system types and ages. Stakeholders did not feel further division of failure rates was possible given their knowledge and existing data. Future load projections are based on an increase of systems and system load proportional to increases in households outside the existing service area boundaries for sewer utilities, in five-year increments through 2040.

Some uncertainty exists due to the insufficiency of data concerning both permitted and unpermitted systems. H-GAC's permitted system spatial dataset is not inclusive of all records obtained from authorized agents in the region. In some cases, issues with the data or inability to geocode a record means that records are excluded even if permitted. Additionally, the deductive analysis that identifies unpermitted system locations is intended to represent potential locations rather than known unpermitted systems. During the project, local authorized agents and knowledgeable partners were asked to review maps of known and suspected OSSF locations. No appreciable changes were recommended. It is also assumed that failure rates will stay constant and that sanitary sewer service area boundaries will not expand appreciably. While boundaries may change, there is no feasible way to predict where this will occur. The stakeholders reviewed and confirmed the assumptions and estimates.

Figure 34 shows the current loading distributions for OSSFs in the watersheds. Figure 35 indicates the change in loading over time, through 2040. Table 11 indicates the actual OSSF source loading estimates by subwatershed.

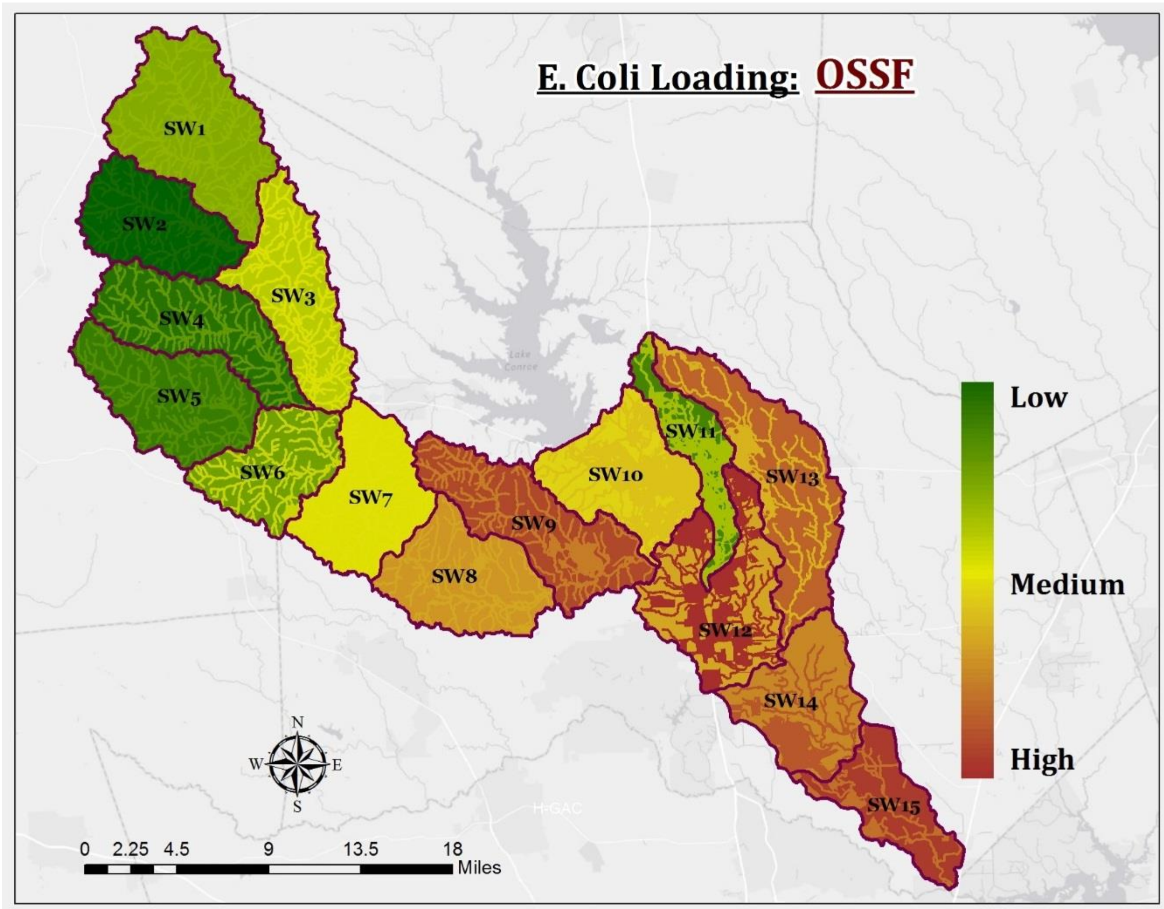

Figure 34 - Bacteria Loading from OSSFs, by Subwatershed

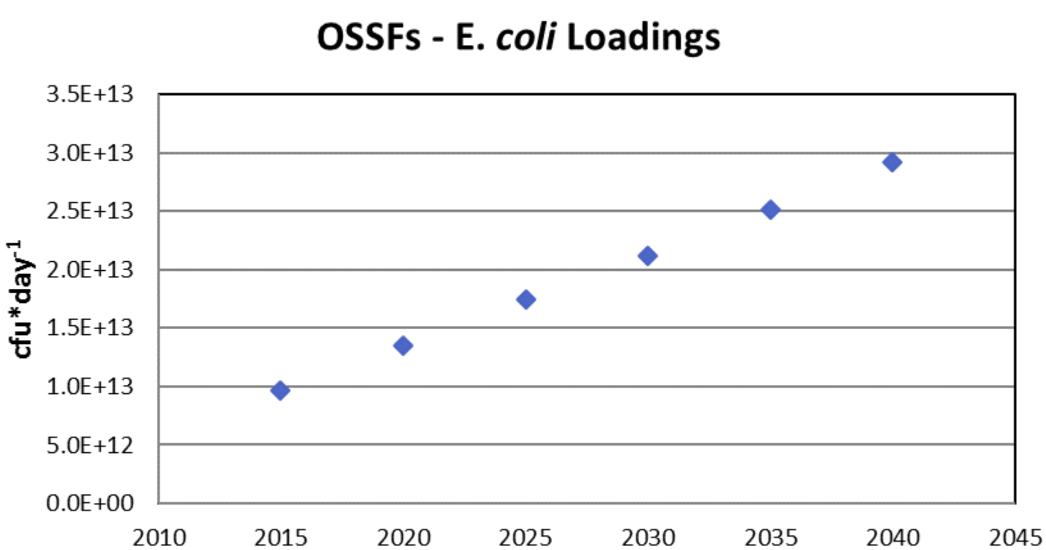

Figure 35 - Future Bacteria Loadings from OSSFs

Table 11 - Current Potential Bacteria Loads from OSSFs by Subwatershed

		SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
# of OSSFs[58]	Outside Buffer	395	127	568	208	226	372	929	3553
	Within Buffer	113	49	236	92	80	147	372	808
E. coli Loading	Outside Buffer	5.50E+10	1.77E+10	7.90E+10	2.89E+10	3.14E+10	5.18E+10	1.29E+11	4.94E+11
	Within Buffer	6.29E+10	2.73E+10	1.31E+11	5.12E+10	4.45E+10	8.18E+10	2.07E+11	4.50E+11
Subwatershed % of total load		1.0%	0.4%	1.9%	0.7%	0.7%	1.2%	3.0%	8.4%

		SW9	SW10	SW11	SW12	SW13	SW14	SW15	**Total**
# of OSSFs	Outside Buffer	5329	1911	298	3209	4122	3604	6248	**31099**
	Within Buffer	992	503	133	3220	648	1112	1007	**9512**
E. coli Loading	Outside Buffer	7.41E+11	2.66E+11	4.15E+10	4.46E+11	5.73E+11	5.01E+11	8.69E+11	**4.33E+12**
	Within Buffer	5.52E+11	2.80E+11	7.40E+10	1.79E+12	3.61E+11	6.19E+11	5.60E+11	**5.29E+12**
Subwatershed % of total load		11.4%	4.8%	1.0%	19.8%	8.3%	9.9%	12.7%	**9.62E+12**

As indicated in Figure 35, OSSF loadings are expected to increase appreciably by 2040. The rapidly changing land uses of the watersheds, especially along the major transportation corridors, is driving the increase in systems. The somewhat unusual heavy reliance on OSSFs, including in master-planned and new suburban communities in Montgomery County, is a local factor influencing the large growth in systems. Balancing this increase, Montgomery County's robust approach to system management and enforcement, which includes initial maintenance contract requirements for new systems and an emphasis on efficient response to complaints, is expected to continue to keep failure rates relatively low. High property values in many of the new development areas using OSSFs are also expected to keep failure rates for aging systems partially in check.

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[58] The number of OSSFs represents the total number of OSSFs, not the failing OSSFs. The base load of 3.7E+9 for a daily load from a failing system is multiplied by the 15% failure rate to get the load from just the 15% of these systems that are failing. Therefore, the equation for calculating the load is (BN*F*L) +(ON*F*L/4), where BN equals the number of OSSFs in the buffer, F equals the failure rate, L equals the base load assumption, and ON equals the number of OSSFs outside the buffer,

Wastewater Treatment Facilities

Permitted wastewater utilities primarily serve the core urban areas in the watershed, including the City of Conroe, and many suburban areas. There are 51 WWTF outfalls in the WPP area, representing 49 unique WWTFs[59]. Only four are industrial; the rest are domestic. They range in size from 10 MGD to discharges less than 0.01 MGD. As noted in the water quality analyses detailed in this section, DMR data indicates exceedances of permit limits are rare, and not strongly related to season or plant size.

WWTFs can be acute, localized sources of note, but no evidence or feedback was received that would indicate any specific, chronic problems of a size that might impact loading estimates[60]. To estimate loadings, the total permitted flows for each subwatershed were multiplied by two times the bacteria standard of 126 cfu/100ml. While most plants discharged well below the standard, this approach was chosen by the stakeholders to ensure a conservative estimate of potential WWTF impact. This will account for times of exceedance and variation of conditions throughout a daily cycle. Loads were applied at the buffer area loading rate to reflect direct outfalls. For future projections, discharges were assumed to be at or below the 252 cfu/100ml assumption used for current projections. Future flows were increased proportional to projected household increase within the existing service area boundary.

Table 12 indicates the actual WWTF source loading estimates by subwatershed. Figure 36 shows the current loading distributions for WWTFs in the watersheds. Figure 37 indicates the change in loading over time, through 2040. These numbers reflect averages and do not consider extraordinary events like Hurricane Harvey, which may temporarily increase potential contamination from these facilities.

Table 12 - WWTF Outfalls and Loadings, by Subwatershed

Subwatershed	Outfalls	Loading (bacteria/day)
1	1	1.19E+07
2	0	0.00E+00
3	0	0.00E+00
4	0	0.00E+00
5	1	5.96E+07
6	0	0.00E+00
7	1	4.77E+08
8	7	7.06E+09

Subwatershed	Outfalls	Loading (bacteria/day)
9	5	3.53E+09
10	5	2.79E+10
11	0	0.00E+00
12	12	1.60E+10
13	7	4.37E+09
14	7	9.99E+09
15	5	1.14E+10
Total	**10**	**8.08E+10**

[59] More information on the distribution, character, and DMR records for these plants is included in the project's Water Quality Data Collection and Trends Analysis Report, as summarized in Section 2 of this WPP.
[60] Feedback regarding localized issues was taken into consideration for the focus of BMPs in implementing the plan but did not rise to the level of potential impacts to loading numbers, as special cases were episodic and localized.

WWTF flows and loadings increase through 2040, but they remain a minor contributor to overall potential loading.

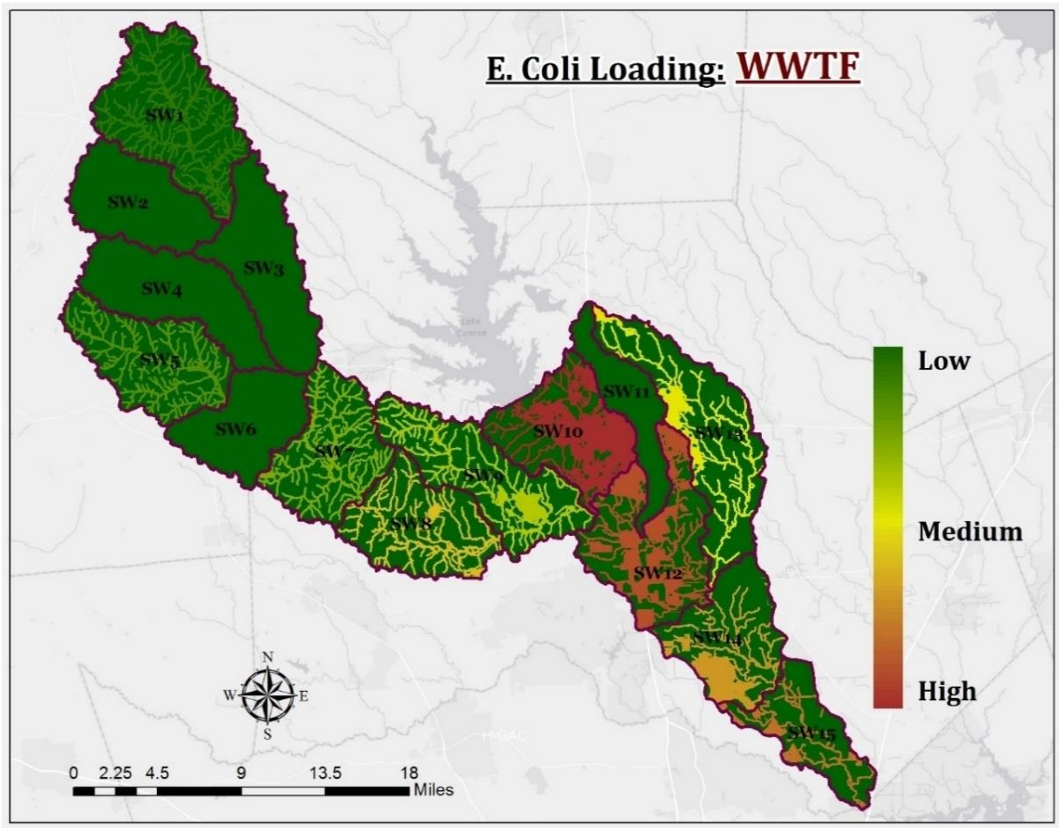

Figure 36- Bacteria Loadings from WWTFs, by Subwatershed

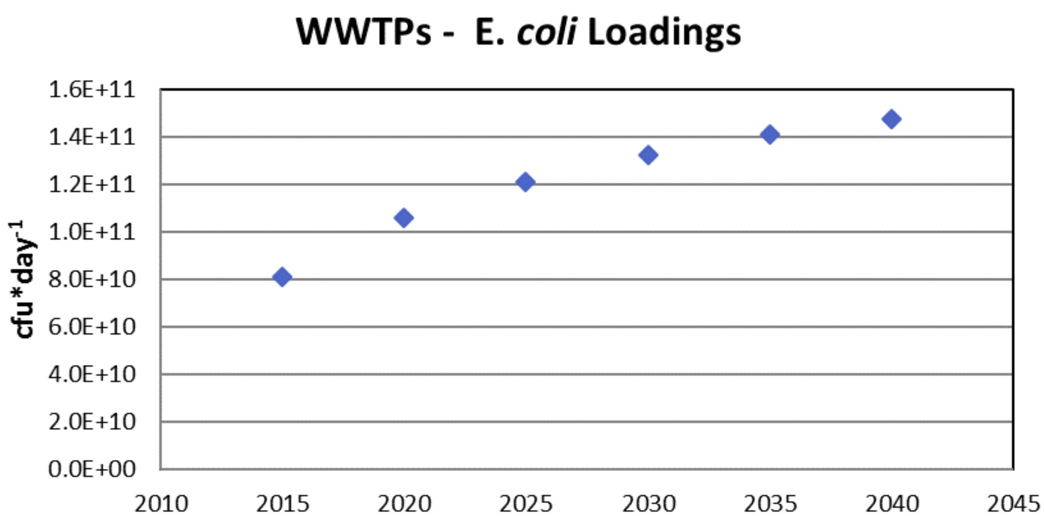

Figure 37 - Future Bacteria Loadings from WWTFs

Sanitary Sewer Overflows

Overflows from sanitary sewer collection systems can introduce large volumes of untreated sewage in short times. At best, they are acute, episodic sources. However, in areas with aging or improperly maintained infrastructure, they can be a chronic source of human fecal waste. Unlike treated wastes discharged by WWTFs, bacteria levels in SSOs are often many orders of magnitude greater. SSOs can result from a variety of causes, including human error in system operation, infiltration of rainwater into sewer pipes during storm events, power failures at lift stations, or blockages in pipes[61].

SSOs within the watersheds were derived from five years of TCEQ data. A fundamental level of uncertainty exists because the data relies on reporting and records from permitted utilities and TCEQ staff. The number, type, duration and volume of SSOs in the data may not fully describe the level of SSO activity in the watershed for several logistical reasons. All SSOs related to a WWTF and receiving stream segment in the watershed area[62] were used to characterize this source. Loading values were based on a consideration of the causes identified for SSOs in the watershed, which were primarily dilute (rainwater-charged releases) or moderate. Concentrations of bacteria can vary greatly based on the composition of sewage at the time of the SSO. EPA literature values[63] were used to identify likely concentrations in SSOs based on the breakout of causes reported. The moderate concentration value was chosen as most representative. Future loads were generated by increasing SSOs proportionately to increases in households within the service areas.

The primary question on how to calculate SSOs stems from their (usually) episodic nature. SSOs in the watershed areas were not generally found to be chronic loads. Therefore, their acute loading is high, but much of the time there is no loading. The stakeholders of the Partnership, local partners, and the work group considered the question of how to estimate SSO flows. The most conservative approach would be to take the highest potential loading and use it as a daily value. However, this would grossly overstate the loading on any given day from SSOs. However, the stakeholders had concerns that using an average of all SSO flow over time (i.e. treating the SSOs as a chronic load averaged over the year to produce a daily load value) would underestimate the impact of SSOs. Because of the documented nature of SSOs in the project area, the stakeholders elected to use the latter approach. The intent was to focus on any identified problem areas as localized, acute sources to prioritize for remediation in the WPP.

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[61] More information on the character and distribution of SSOs is available in the project Water Quality Data Collection and Trends Analysis Report at https://westfork.weebly.com/project-documents.html

[62] While collection systems can straddle boundaries, and WWTFs outside the watershed may have systems partially within it, staff review of spatial distribution of plants in the surrounding area did not lead to an expectation that this was the case in this project area.

[63] As referenced at https://www3.epa.gov/npdes/pubs/csossoRTC2004_AppendixH.pdf

Figure 38 shows the current loading distributions for SSOs in the watersheds. Figure 39 indicates the change in loading over time, through 2040.

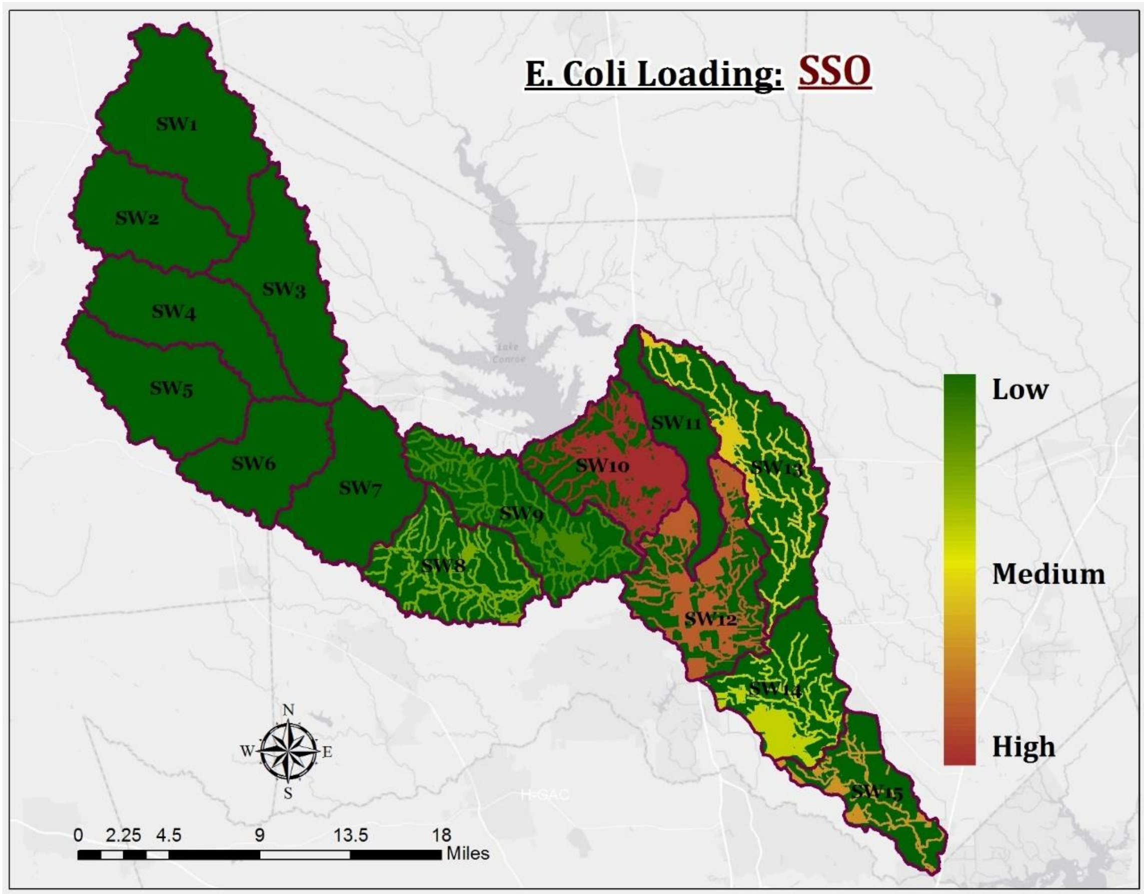

Figure 38 - Bacteria Loading from SSOs, by Subwatershed

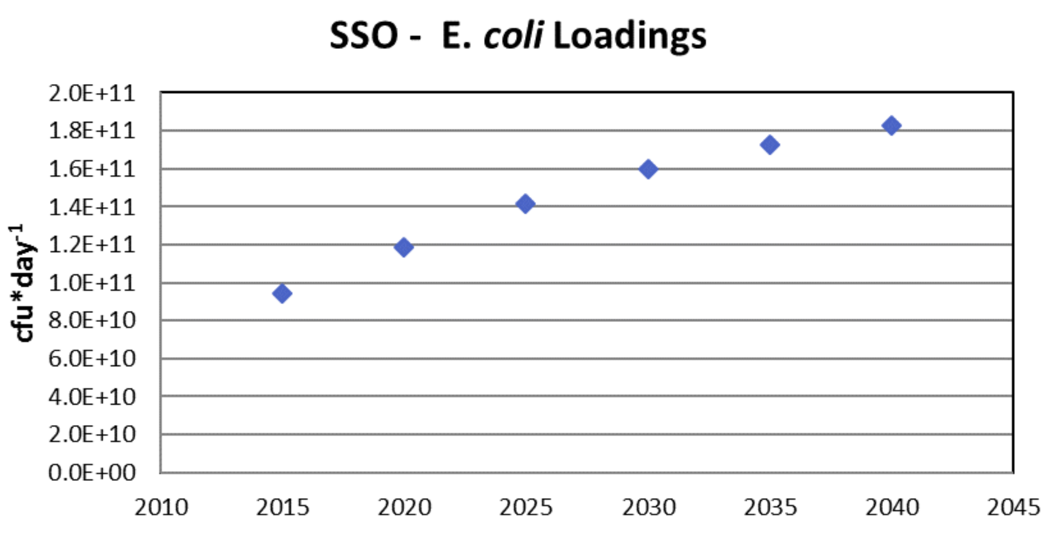

Figure 39 - Future Bacteria Loadings from SSOs

Table 13 indicates the actual SSO source loading estimates by subwatershed.

Table 13 – Current Potential Bacteria Loadings from SSOs, by Subwatershed

Subwatershed	SSOs	Load
SW1	0	0.00E+00
SW2	0	0.00E+00
SW3	0	0.00E+00
SW4	0	0.00E+00
SW5	0	0.00E+00
SW6	0	0.00E+00
SW7	0	0.00E+00
SW8	8	6.95E+08
SW9	5	2.02E+08
SW10	28	7.71E+10
SW11	0	0.00E+00
SW12	20	5.60E+09
SW13	10	3.12E+09
SW14	7	2.59E+09
SW15	17	4.93E+09
Total	**95**	**9.42E+10**

As shown in Figure 39, while SSOs are currently a minor source of load, they grow with population and development. Additional factors like the potential for increase in the rate of SSOs as systems age could not be extrapolated from known data. Comparison of older and newer systems did not produce any statistically significant differences, primarily due to the small data sets. While SSOs may not be a primary source, the stakeholders felt it was important to include them and highlight them because, 1) they are a human waste source, and thus have higher potential pathogenic impact; 2) their peak volumes and concentrations are underrepresented; and 3) they can be pronounced localized sources in areas where direct human contact is more likely (developed areas).

Cattle

Cattle production has been historically prevalent in much of the watersheds area and is concentrated in areas such as the northern and western reaches of the Lake Creek watershed. Cattle populations for the watershed were based on the latest (2012) livestock census data from the USDA's National Agricultural Statistics Service (NASS). Because this county-level data for cattle is not specific to the watershed area, cattle were assumed to be equally distributed throughout the counties. To determine estimated cattle populations in the watershed, project staff:

- Generated 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; and
- Applied this ratio to county cattle populations, establishing a number of cattle proportional to the size of the watershed acreage in that county.

This approach ensures 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. The Partnership expected the initial cattle populations to be overly high. The overestimation was based primarily on the model treating appropriate land cover as under production for cattle, even if it may be fallow. These data were reviewed with the stakeholders and the soil and water conservation districts (SWCD) for each county, and with the topical work group for agriculture. In general, the feedback from these groups was in line with the project's staff's expectations. The stakeholders identified two key factors they felt drove the overestimation; the sizeable negative impact of the 2011 drought on herd size (which was not well reflected in the 2012 NASS data) and the impact of developmental pressure on land value.

Based on stakeholder feedback, project staff reduced cattle numbers in each subwatershed based on the information and local knowledge specific to that watershed. In meetings with SWCDs, board members worked with staff on calculations based on known herds in given subwatersheds to determine rough reduction values. In most cases, this process yielded results close to the stakeholders' initial percent reduction estimates. The reductions ranged from 50-75%[64] showing the sizeable impact of drought and development on agricultural production. The greater reductions in the Conroe area are in part driven by overestimation by the model due to ambiguous land cover along the developmental fringe. There are no CAFOs in the watershed.

The Partnership derived cattle bacteria loads for milestones at every five years starting with current (2015) conditions. Figure 40 shows the current loading distributions for cattle in the

[64] Cattle were reduced by 75% for urban subwatersheds 10,11, and 12; 60% for 1,2,4, and 5; and 50% for all others.

watersheds. Figure 41 indicates the change in loading over time, through 2040. Table 14 indicates the actual cattle source loading estimates by subwatershed.

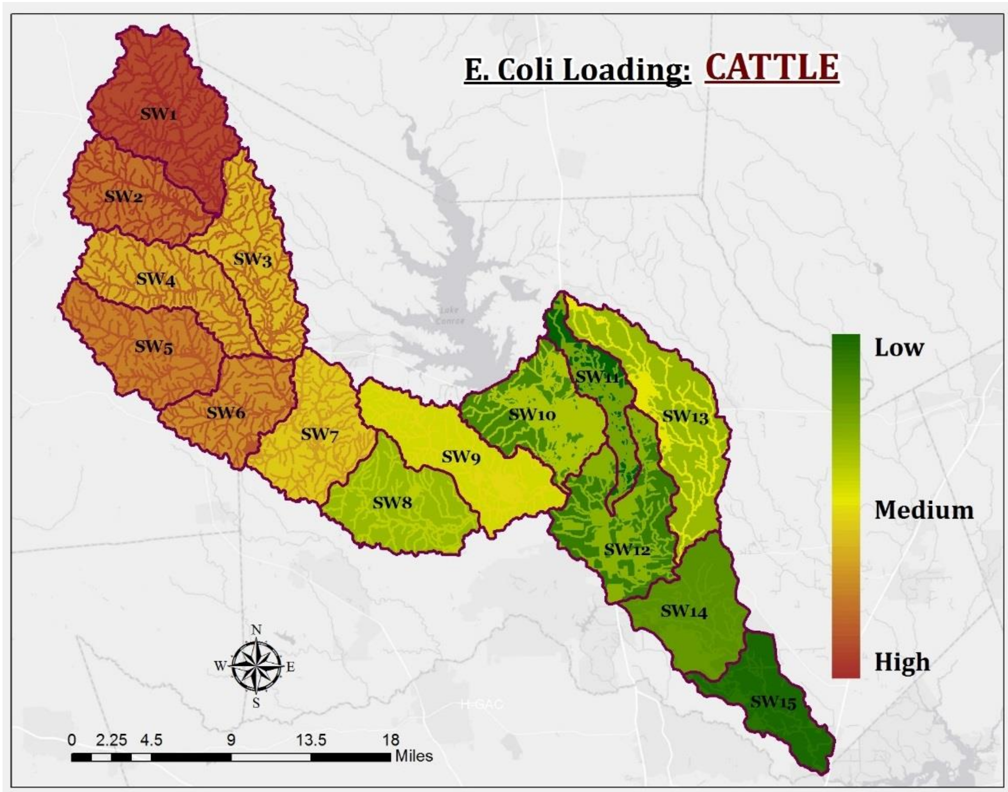

Figure 40 - Bacteria Loadings from Cattle, by Subwatershed

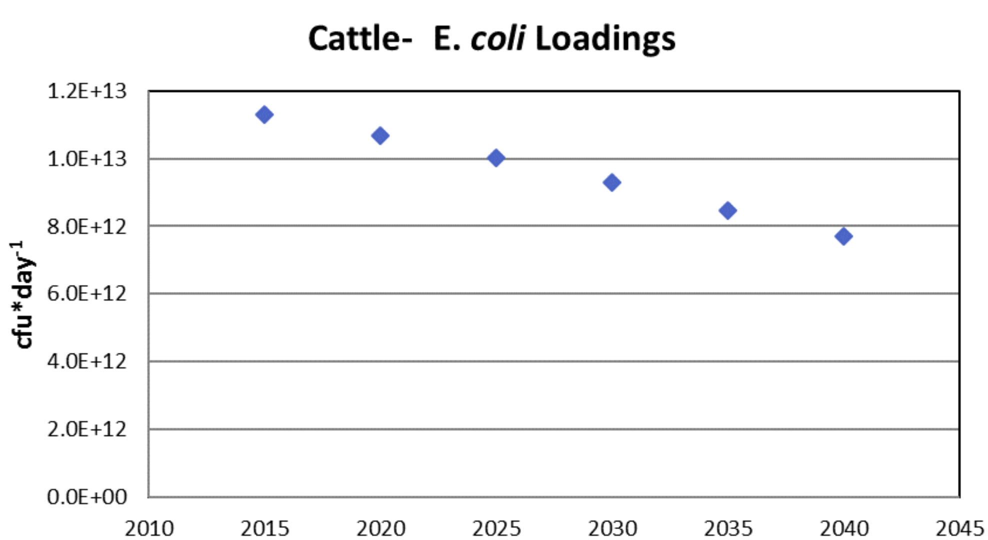

Figure 41 - Future Bacteria Loads from Cattle

Table 14 - Current Potential Bacteria Loads from Cattle, by Subwatershed

		SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
# of Cattle	Outside Buffer	1224	903	518	707	893	817	493	173
	Within Buffer	490	368	258	260	303	303	198	70
E. coli Loading	Outside Buffer	8.26E+11	6.10E+11	3.50E+11	4.77E+11	6.03E+11	5.51E+11	3.33E+11	1.17E+11
	Within Buffer	1.32E+12	9.93E+11	6.98E+11	7.02E+11	8.19E+11	8.17E+11	5.34E+11	1.88E+11
Subwatershed portion of total load		19.0%	14.2%	9.3%	10.4%	12.6%	12.1%	7.7%	2.7%

		SW9	SW10	SW11	SW12	SW13	SW14	SW15	**Total**
# of Cattle	Outside Buffer	312	44	4	25	172	74	8	**6,368**
	Within Buffer	106	56	32	35	81	30	4	**2,594**
E. coli Loading	Outside Buffer	2.11E+11	3.00E+10	2.76E+09	1.69E+10	1.16E+11	5.03E+10	5.08E+09	**4.30E+12**
	Within Buffer	2.85E+11	1.51E+11	8.54E+10	9.45E+10	2.20E+11	8.06E+10	1.16E+10	**7.00E+12**
Subwatershed % of total load		4.4%	1.6%	0.8%	1.0%	3.0%	1.2%	0.1%	**1.13E+13**

As indicated in Figure 41, cattle production and presence in the watersheds is expected to continue to decrease, leading to a corresponding decrease in potential bacteria load. Primary forces behind this change in the model are change of land cover to developed areas, but stakeholder feedback also indicated that rising land value and changing conditions ahead of growth were also pressures on cattle production.

Horses

Unlike cattle populations in the watershed, horses have straddled the divide between rural areas and suburban/exurban development. Dense horse populations are primarily limited to a few stabling operations. Primary modes of ownership include traditional rural populations accompanying existing agricultural operations, and "ranchette" style home sites which may have one or a small number of horses. Based on stakeholder feedback there were no known problem operations or specific areas of concern.

Figure 42 - Horses on Acreage Property

The Partnership derived horse populations using the same methodology as cattle populations, using proportional numbers of county NASS data populations. As with cattle, horse population estimates were first reviewed internally by project staff, then with local experts (SWCDs, etc.), and then with the work group and Partnership. Based on feedback from the SWCDs, and affirmed by stakeholders, reductions ranging from 50-60% were made to horse populations by subwatershed[65]. Based on stakeholder feedback, horse ownership, especially for larger operations, was decreased due to the same drought and land value pressures that affected cattle operations.

The Partnership derived horse bacteria loads for milestones at every five years starting with current conditions. Figure 43 shows the current loading distributions for horses in the watersheds. Figure 44 indicates the change in loading over time, through 2040. Table 15 indicates the actual horse source loading estimates by subwatershed.

As with cattle and other livestock, horse populations are expected to decline as development pushes further into rural areas. However, the extent of reduction is expected to be somewhat less as exurban acreage, including "ranchette" developments, continue to support small horse populations.

[65] Horse populations were reduced by 60% for subwatersheds 1,2,4,5, and 6, and 50% for all other subwatersheds.

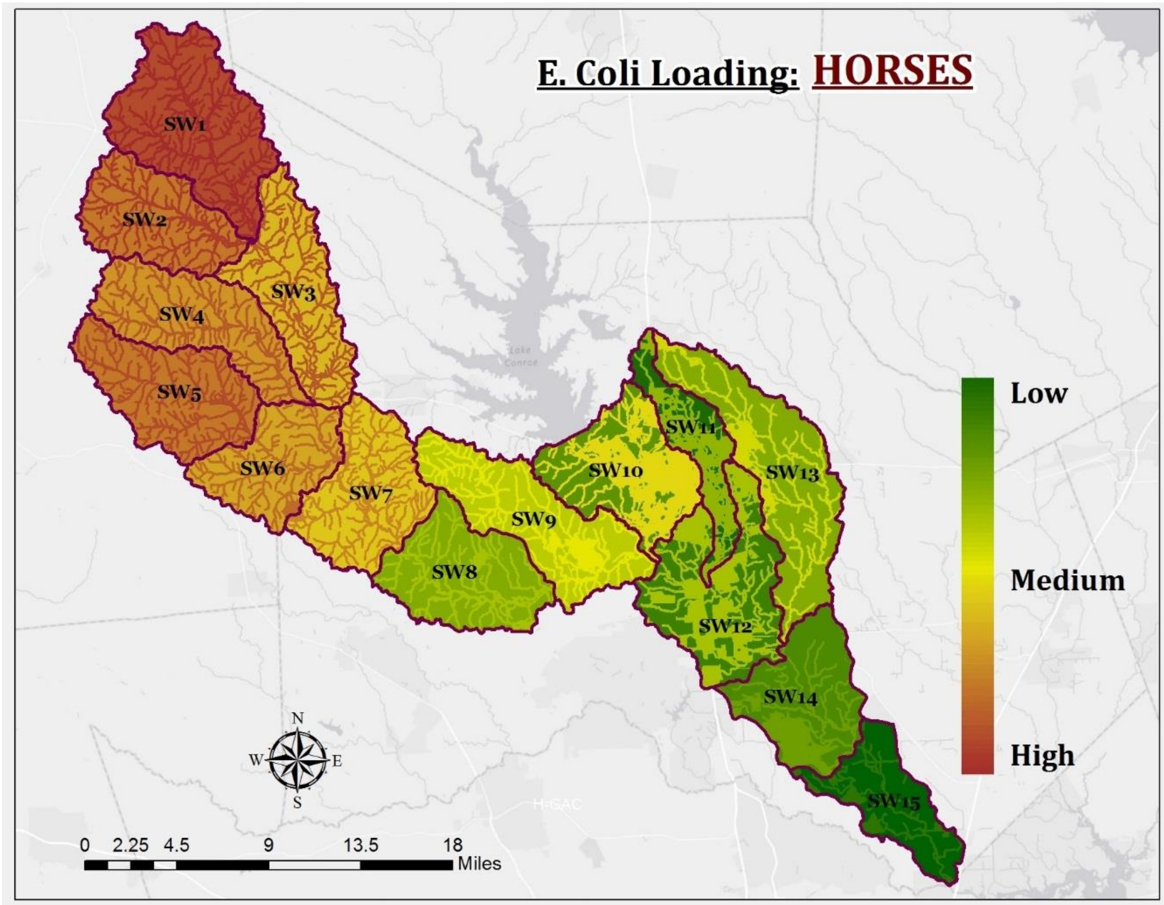

Figure 43 - Bacteria Loading from Horses, by Subwatershed

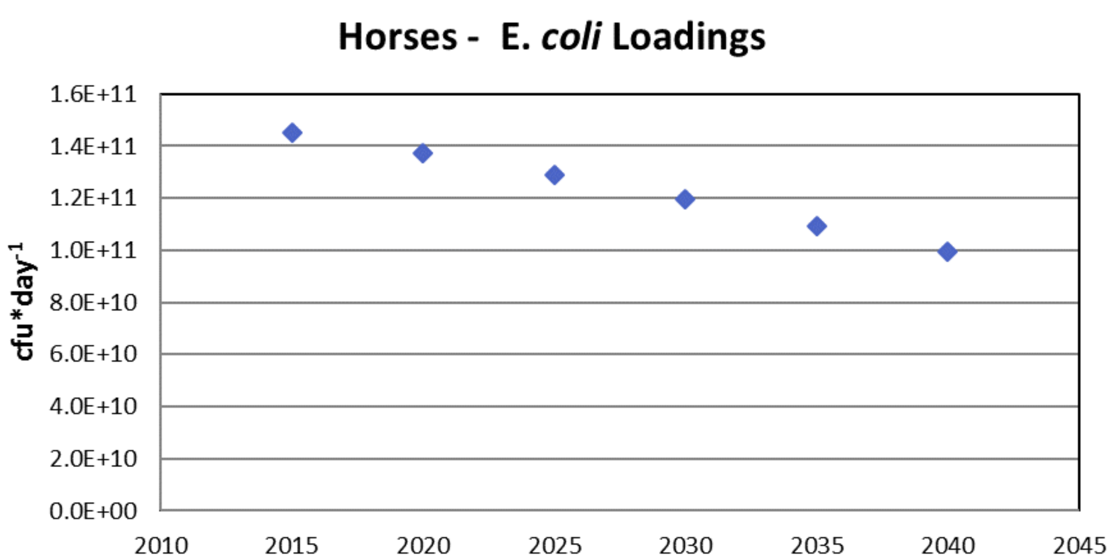

Figure 44 - Future Bacteria Loadings from Horses

Table 15 – Current Potential Bacteria Loadings from Horses, by Subwatershed

		SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
# of Horses	Outside Buffer	200	148	85	116	146	107	81	28
	Within Buffer	80	60	42	42	50	40	32	11
E. coli Loading	Outside Buffer	1.05E+10	7.75E+09	4.44E+09	6.07E+09	7.66E+09	5.61E+09	4.23E+09	1.48E+09
	Within Buffer	1.68E+10	1.26E+10	8.87E+09	8.92E+09	1.04E+10	8.31E+09	6.79E+09	2.39E+09
Subwatershed % of total load		11.8%	8.8%	5.8%	6.5%	7.8%	6.0%	4.8%	1.7%

		SW9	SW10	SW11	SW12	SW13	SW14	SW15	**Total**
# of Horses	Outside Buffer	51	15	4	8	28	12	1	**1,028**
	Within Buffer	17	18	32	11	13	5	1	**455**
E. coli Loading	Outside Buffer	2.68E+09	7.62E+08	2.76E+09	4.30E+08	1.48E+09	6.39E+08	6.45E+07	**5.65E+10**
	Within Buffer	3.62E+09	3.83E+09	8.54E+10	2.40E+09	2.79E+09	1.02E+09	1.47E+08	**1.74E+11**
Subwatershed % of total load		2.7%	2.0%	38.2%	1.2%	1.8%	0.7%	0.1%	**2.31E+11**

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. Stakeholders indicated there were no known large/dense operations or known problem areas in the watershed.

Sheep and goat populations are estimated together because the base NASS data combines them as a single statistic. Stakeholders indicated they did not expect this combination of populations to pose any significant issue for load estimation in the project area. Populations and loads for current and future conditions were estimated in the same manner as was described for cattle and horses. Assessment and revision of the initial population estimates was conducted concurrently with other livestock, and similar reductions were made. Based on stakeholder feedback, sheep and goat populations were decreased due to the same drought and land value pressures that affected cattle and horse operations.

The Partnership derived sheep and goat bacteria loads for milestones at every five years starting with current conditions. Figure 45 shows the current loading distributions for sheep and goats in the watersheds. Figure 46 indicates the change in loading over time, through 2040. Table 16 indicates the actual sheep and goat source loading estimates by subwatershed.

Future projections indicate that sheep and goat populations will decline with other livestock, but without the same residual presence in exurban areas that horses are likely to experience.

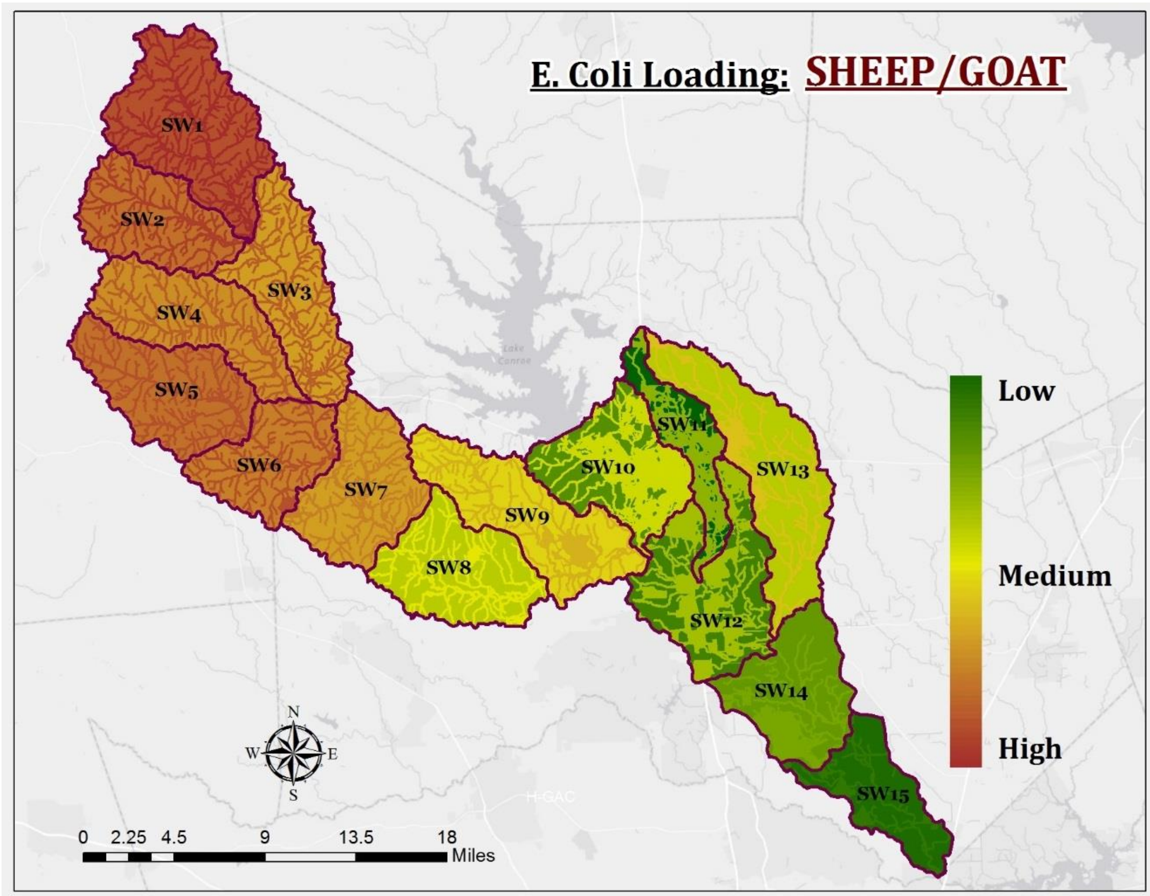

Figure 45 - Bacteria Loadings from Sheep and Goats, by Subwatershed

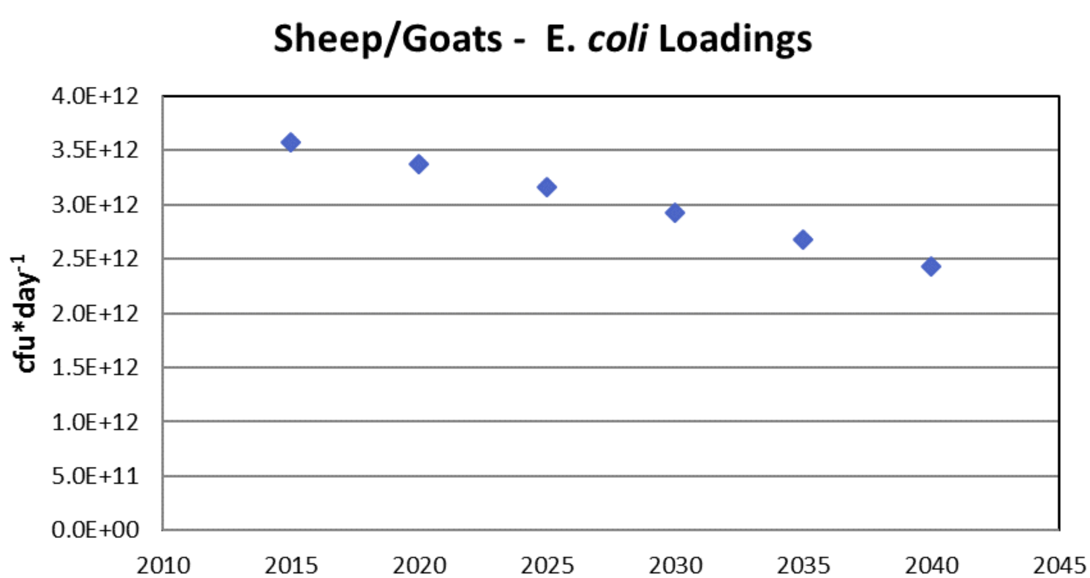

Figure 46 - Future Bacteria Loadings from Sheep and Goats

Table 16 – Current Potential Bacteria Loadings from Sheep and Goats, by Subwatershed

		SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
# of Sheep and Goats	Outside Buffer	116	86	49	67	85	77	47	16
	Within Buffer	46	35	24	25	29	29	19	7
E. coli Loading	Outside Buffer	2.61E+11	1.92E+11	1.10E+11	1.51E+11	1.90E+11	1.74E+11	1.05E+11	3.69E+10
	Within Buffer	4.18E+11	3.13E+11	2.20E+11	2.22E+11	2.59E+11	2.58E+11	1.69E+11	5.94E+10
Subwatershed % of total load		19.0%	14.2%	9.3%	10.4%	12.6%	12.1%	7.7%	2.7%

		SW9	SW10	SW11	SW12	SW13	SW14	SW15	**Total**
# of Sheep and Goats	Outside Buffer	30	4	0	2	16	7	1	**603**
	Within Buffer	10	5	3	3	8	3	0	**246**
E. coli Loading	Outside Buffer	6.65E+10	9.46E+09	8.71E+08	5.33E+09	3.67E+10	1.59E+10	1.60E+09	**1.36E+12**
	Within Buffer	9.00E+10	4.76E+10	2.70E+10	2.98E+10	6.93E+10	2.55E+10	3.66E+09	**2.21E+12**
Subwatershed % of total load		4.4%	1.6%	0.8%	1.0%	3.0%	1.2%	0.1%	**3.57E+12**

Feral Hogs

Feral hogs (*Sus scrofa* and related hybrids) are an invasive species issue throughout the Houston-Galveston region, and specifically within the WPP area. Adaptable, fertile, and aggressively omnivorous, their populations are responsible for significant damage to agricultural production, wildlife and habitat, and human landscapes. Hogs can transmit diseases dangerous to humans, pets, and domestic livestock, and can generate large volumes of waste where they concentrate. The dense riparian forests in much of the project area (especially downstream of I45 on the West Fork, and in forested areas of Lake Creek and Mound Creek) serve as transportation corridors and shelter for hogs, who then roam adjacent areas to feed. Feedback from stakeholders indicated that feral hogs were a persistent issue in the watershed, but anecdotal reports on extent of hog presence and damage differed significantly, even within the same areas.

Hogs were populated in all land cover types in the watershed except developed and open water areas. Densities were assigned based on AgriLife literature values[66] and experience in previous WPP efforts, as affirmed by project stakeholders. Two hogs per square mile were populated in bare land, cultivated, and pasture/hay cover types, and 2.45 hogs were populated in grasslands, forest, shrublands and wetland areas. Future projections were based on land cover change, with loss of hog population as developed areas increased.

The Partnership derived feral hog bacteria loads for milestones at every five years starting with current conditions. Figure 47 shows the current loading distributions for feral hogs in the watersheds. Figure 48 indicates the change in loading over time, through 2040. Table 17 indicates the actual feral hog source loading estimates by subwatershed.

Future conditions reflect a reduction in hog populations and loading. However, the model cannot account for concentration of displaced hog populations in surrounding areas, nor can it project populations dynamics without adding an assumption. Project staff and stakeholders did not have literature values or defensible means to suggest potentially increasing feral hog population based on population increase rather than habitat expansion. Therefore, the modeled projections should be taken to be conservative, as feral hog populations across the state have demonstrated a tendency toward population growth and adaptability to changing developmental conditions.

[66] http://feralhogs.tamu.edu/files/2011/05/FeralHogFactSheet.pdf

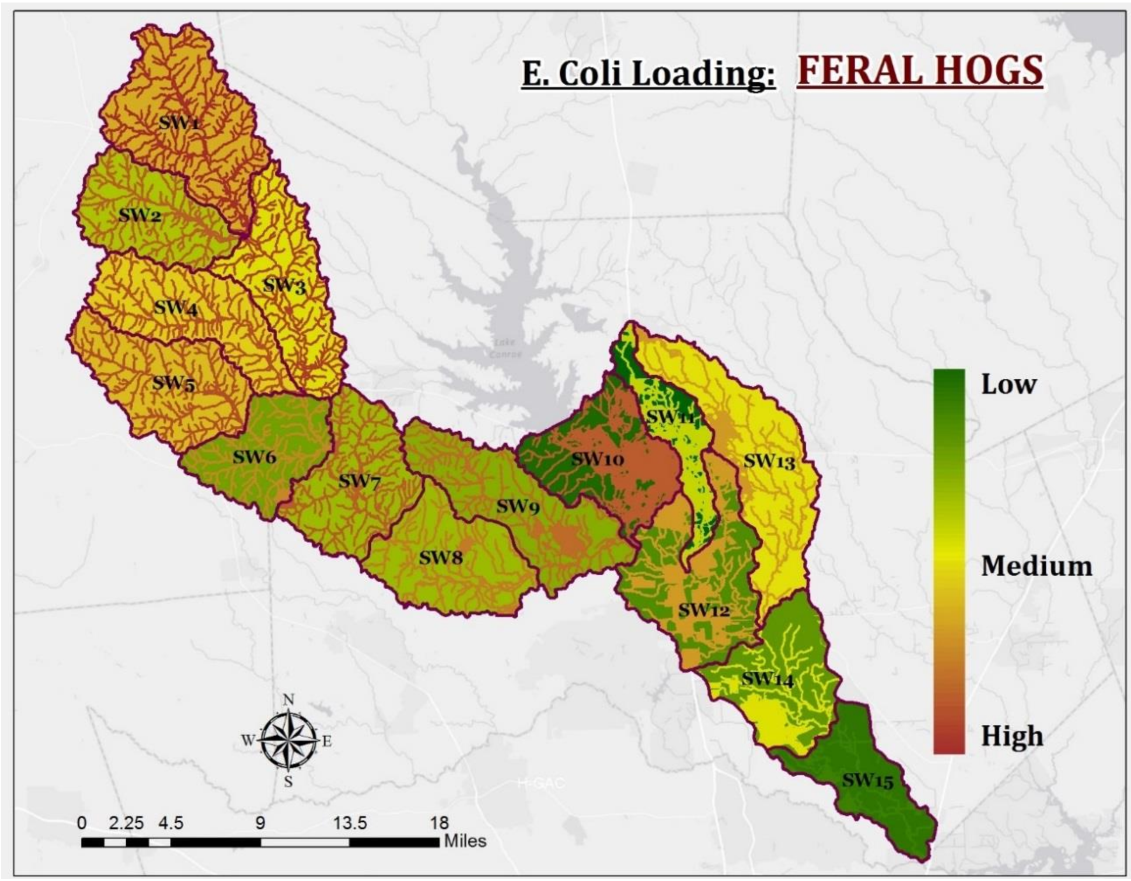

Figure 47 - Bacteria Loadings from Feral Hogs, by Subwatershed

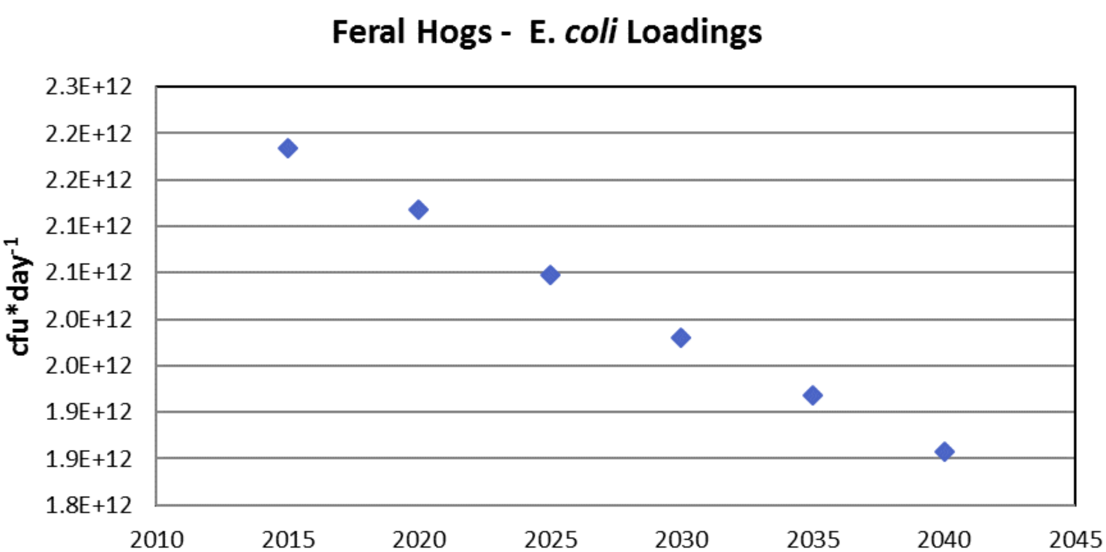

Figure 48 - Future Bacteria Loads from Feral Hogs

Table 17- Current Potential Bacteria Loadings for Feral Hogs, by Subwatershed

		SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
# of Feral Hogs	Outside Buffer	70	47	51	55	57	39	45	45
	Within Buffer	38	24	28	26	28	20	26	22
E. coli Loading	Outside Buffer	7.74E+10	5.24E+10	5.68E+10	6.09E+10	6.33E+10	4.37E+10	4.97E+10	4.98E+10
	Within Buffer	1.69E+11	1.07E+11	1.25E+11	1.17E+11	1.24E+11	9.11E+10	1.14E+11	9.78E+10
Subwatershed % of total load		11.3%	7.3%	8.3%	8.2%	8.6%	6.2%	7.5%	6.8%

		SW9	SW10	SW11	SW12	SW13	SW14	SW15	**Total**
# of Feral Hogs	Outside Buffer	42	23	13	34	53	35	24	**633**
	Within Buffer	23	24	12	20	20	13	8	**333**
E. coli Loading	Outside Buffer	4.63E+10	2.58E+10	1.46E+10	3.84E+10	5.92E+10	3.90E+10	2.71E+10	**7.05E+11**
	Within Buffer	1.01E+11	1.07E+11	5.39E+10	8.98E+10	9.03E+10	5.67E+10	3.66E+10	**1.48E+12**
Subwatershed % of total load		6.7%	6.1%	3.1%	5.9%	6.8%	4.4%	2.9%	**2.18E+12**

Dogs

Domestic and feral dog populations are a significant contributor to bacteria contamination in the greater Houston region, especially in dense developed areas. Unlike cats or other pet species, dog waste is often deposited outside instead of collected in litter boxes. Despite local and regional efforts to promote dog waste reduction, feedback from the stakeholders indicated that many owners did not pick up after their dogs.

Pet ownership rates are the key to characterizing load in the SELECT analysis. Other WPP projects have used national averages established by the American Veterinary Medical Association (AMVA)[67] or other industry groups, ranging from 0.6 to 1 dog per household. The current assumption proposed by staff was 0.6 dogs per household based on the AMVA's 2012 statistical data for Texas. Stakeholders expressed concern that apartment ownership may not match home ownership rates, and the high number of apartment households might skew the estimation of dog populations. The Partnership conducted a study of 12 apartment complexes in urban and suburban areas and determined that there was an average of 0.5 dogs per household based on property manager estimations. This estimate was close enough to the standard 0.6 dogs per household, assuming there was an undetermined level of tenant underreporting of dog ownership based on property manager feedback, that the stakeholders felt a separate rate for apartment households was not needed. Based on stakeholder feedback, feral dog populations were not widespread, mostly either in less dense rural areas where their waste was not a primary issue, or in the denser urban core of Conroe. No specific data existed or reasonable literature value was found that was applicable to this area/situation. Since the estimation of apartment density could potential have some overestimation, and because feral populations were not considered an appreciable source, the stakeholders affirmed the project team's proposal to use 0.6 dogs per household as a uniform assumption. Specific measures to target each population are included in the recommended solutions.

Future dog populations were derived from household growth projections, using 0.6 as a static assumption of density for all time periods. As with other sources related to household growth, the relative contribution of bacteria from dog waste continues to increase through 2040. There was no stakeholder expectation that dog ownership rates would be significantly different in the future. Dog bacteria loads were derived for milestones at every five years starting with current conditions. Figure 49 shows the current loading distributions for dogs in the watersheds. Figure 50 indicates the change in loading over time, through 2040. Table 18 indicates the actual dog source loading estimates by subwatershed.

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[67] https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx

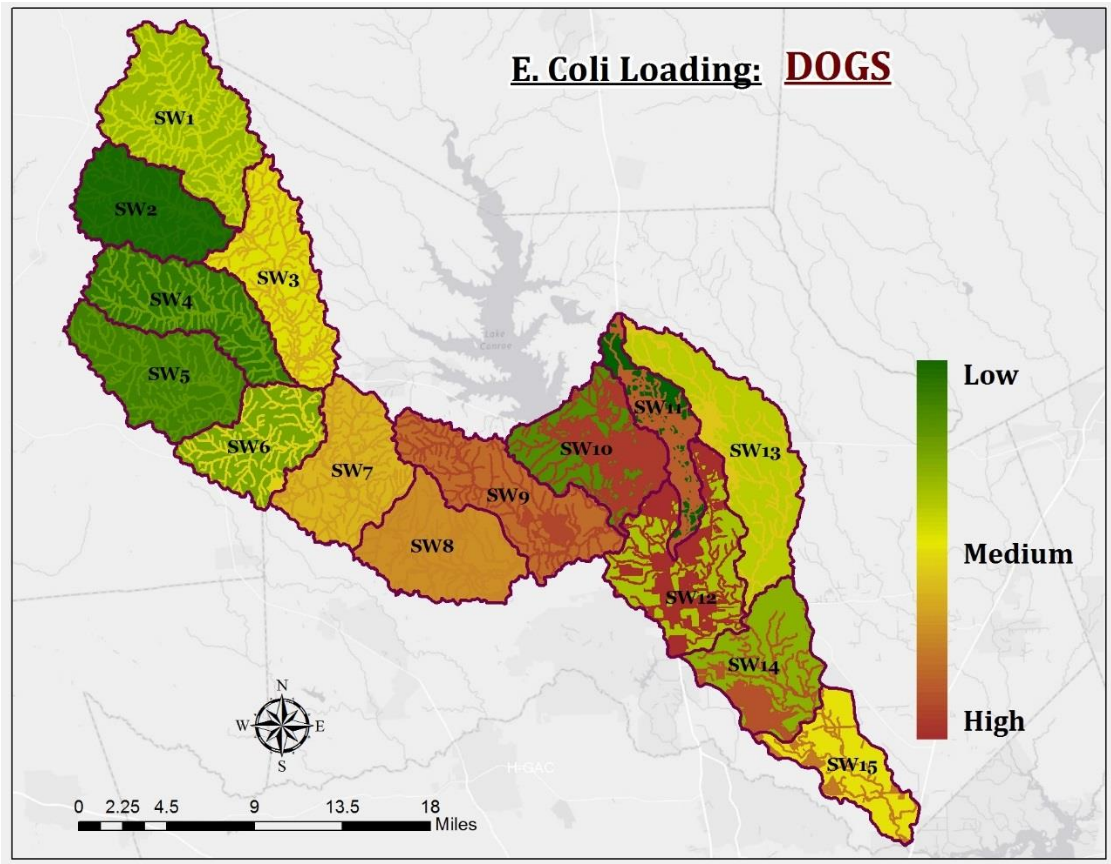

Figure 49 - Bacteria Loadings from Dogs, by Subwatershed

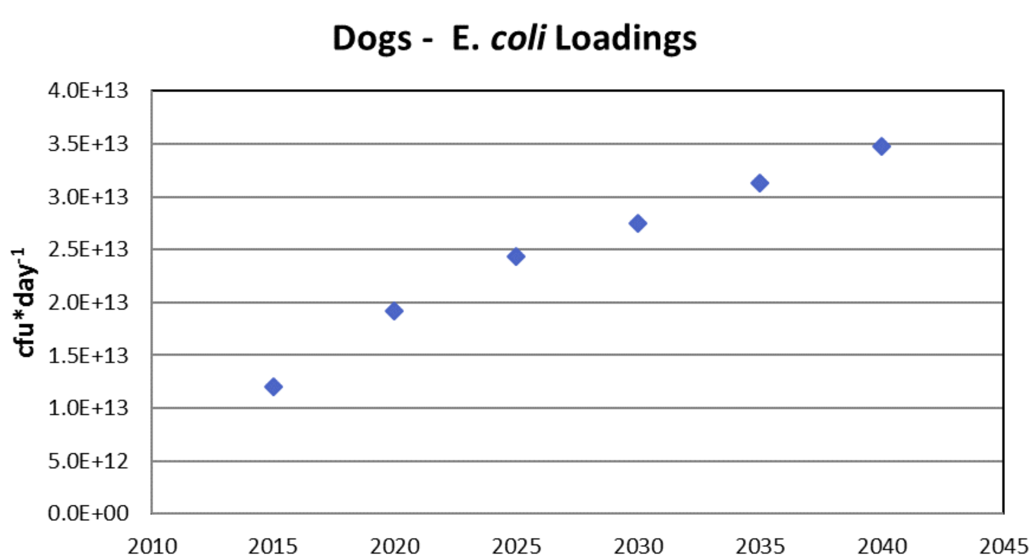

Figure 50 - Future Bacteria Loadings from Dogs

Table 18 – Current Potential Bacteria Loadings from Dogs, by Subwatershed

		SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
# of Dogs	Outside Buffer	198	64	284	104	113	186	470	896
	Within Buffer	57	25	118	46	40	87	220	245
E. coli Loading	Outside Buffer	1.23E+11	3.97E+10	1.78E+11	6.50E+10	7.06E+10	1.16E+11	2.94E+11	5.60E+11
	Within Buffer	1.41E+11	6.13E+10	2.95E+11	1.15E+11	1.00E+11	2.16E+11	5.50E+11	6.13E+11
Subwatershed % of total load		2.2%	0.8%	3.9%	1.5%	1.4%	2.8%	7.0%	9.8%

		SW9	SW10	SW11	SW12	SW13	SW14	SW15	**Total**
# of Dogs	Outside Buffer	1340	1190	429	2064	2103	1895	3126	**14458**
	Within Buffer	353	5758	3388	7993	1007	3486	2597	**25417**
E. coli Loading	Outside Buffer	8.37E+11	7.43E+10	2.68E+10	1.29E+11	1.31E+11	1.18E+11	1.95E+11	**2.96E+12**
	Within Buffer	8.83E+11	1.44E+12	8.47E+11	2.00E+12	2.52E+11	8.72E+11	6.49E+11	**9.03E+12**
Subwatershed % of total load		14.3%	12.6%	7.3%	17.7%	3.2%	8.3%	7.0%	**1.20E+13**

Deer

White-tailed deer (deer) are one of the most common large mammals in the watershed areas. Wooded areas and open grasslands in the rural and undeveloped areas of the watershed provide abundant natural habitat. Because deer are among a handful of species that adapt well to the fringe of human development, large lot suburban and exurban development and even open areas in urban neighborhoods can provide alternative habitat. Based on discussions with TPWD staff, local stakeholder feedback, and land cover analysis, deer populations are widespread in the project area to the point of bordering on nuisances in some areas (urban golf courses, etc.).

The starting point for estimating deer populations is the use of density projections derived from TPWD's Resource Management Unit (RMU) data for deer in this ecoregion. Deer were populated in appropriate land cover types in the model, primarily forested areas and open spaces. The RMU density is then applied to these acreages to determine deer populations. Future deer populations are tied to land cover change. As with feral hogs, there is no assumption made of population dynamics other than removal as habitat is removed[68]. Similarly, there is no assumption of concentration to a carrying capacity as habitat is lost. Deer in developed habitat are removed from projections.

Stakeholder review of preliminary assumptions indicated that there were significant deer populations in light developed areas, and these acreages were populated in the next run of the model. The stakeholders affirmed the revised numbers based on anecdotal experiences and best professional judgement.

Deer bacteria loads were derived for milestones at every five years starting with current conditions. Figure 51 shows the current loading distributions for deer in the watersheds. Figure 52 indicates the change in loading over time, through 2040. The adaptation of deer to developed environments led to only minor fluctuations in deer populations as development converts natural habitat. Table 19 indicates the actual deer source loading estimates by subwatershed.

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[68] It should be noted, that while feral hogs are assumed to be adversely impacted by transition of undeveloped areas to developed areas, deer populations are not (to the same degree.) Their comparative decline or advancement in future projections is explained in part by this difference in modeling assumptions.

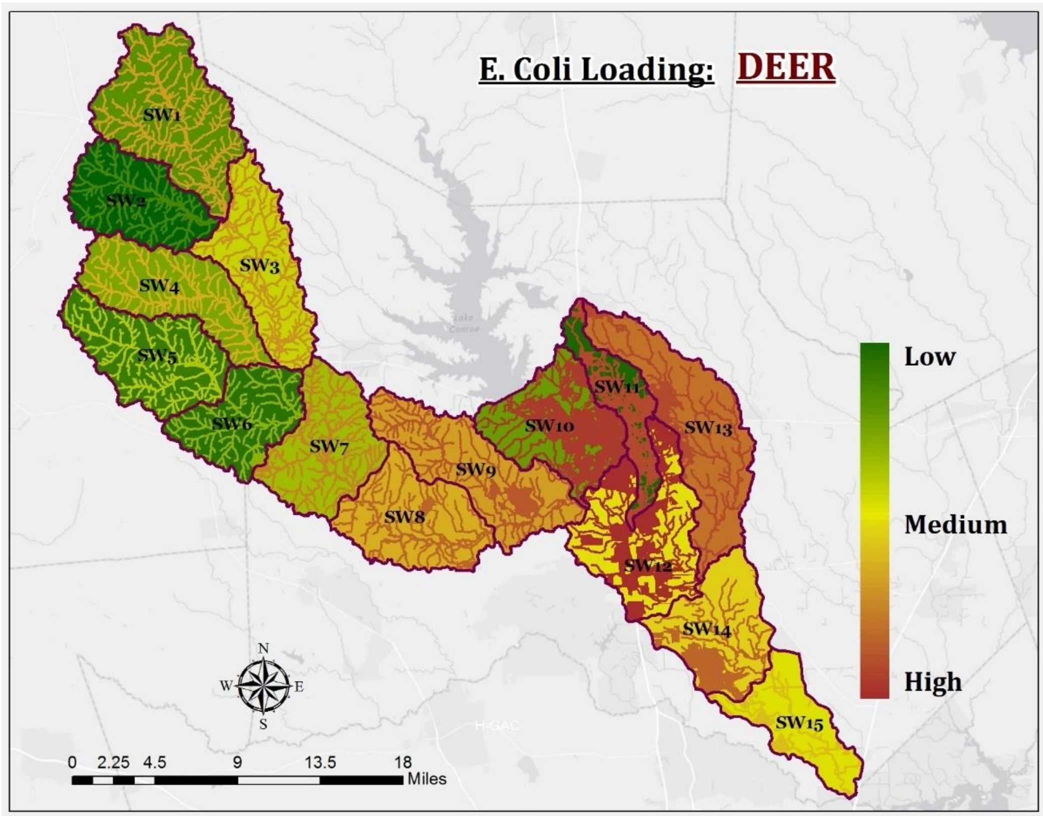

Figure 51 - Bacteria Loadings from Deer, by Subwatershed

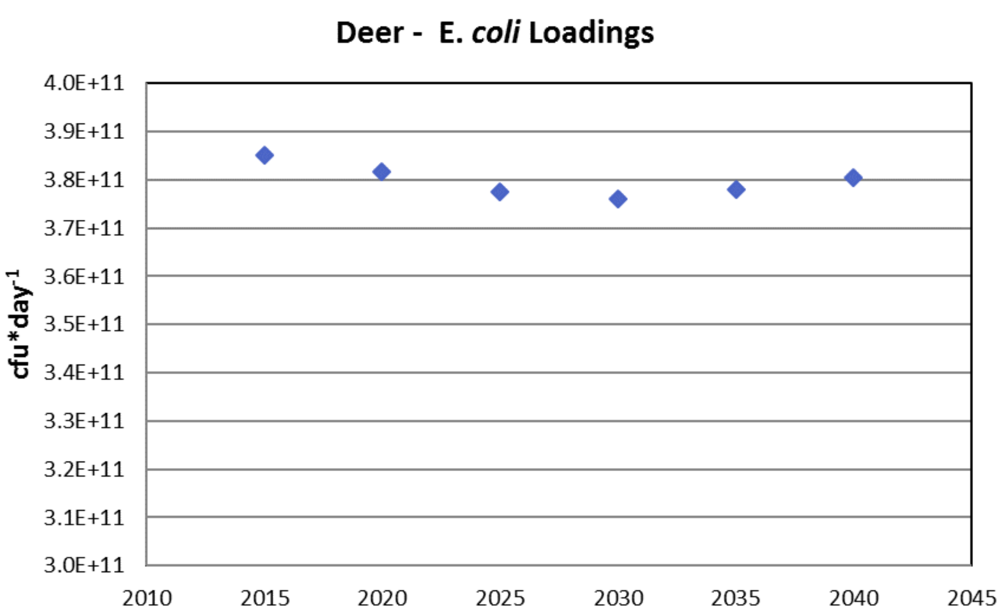

Figure 52 - Future Bacteria Loadings from Deer

Table 19 - Current Potential Bacteria Loadings from Deer, by Subwatershed

		SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
# of Deer	Outside Buffer	127	62	193	157	103	85	186	274
	Within Buffer	71	30	84	68	48	42	93	106
E. coli Loading	Outside Buffer	5.57E+09	2.70E+09	8.46E+09	6.85E+09	4.49E+09	3.70E+09	8.12E+09	1.20E+10
	Within Buffer	1.25E+10	5.28E+09	1.47E+10	1.18E+10	8.34E+09	7.32E+09	1.64E+10	1.86E+10
Subwatershed % of total load		4.7%	2.1%	6.0%	4.9%	3.3%	2.9%	6.4%	7.9%

		SW9	SW10	SW11	SW12	SW13	SW14	SW15	**Total**
# of Deer	Outside Buffer	291	148	80	219	380	222	207	**2733**
	Within Buffer	125	200	132	214	133	106	65	**1518**
E. coli Loading	Outside Buffer	1.27E+10	6.46E+09	3.51E+09	9.56E+09	1.66E+10	9.73E+09	9.07E+09	**1.20E+11**
	Within Buffer	2.19E+10	3.51E+10	2.31E+10	3.74E+10	2.32E+10	1.85E+10	1.14E+10	**2.66E+11**
Subwatershed % of total load		9.0%	10.8%	6.9%	12.2%	10.4%	7.3%	5.3%	**3.85E+11**

Other Sources

The sources described previously make up the loading estimates for the SELECT analyses, but do not represent the totality of sources identified by stakeholders in the watershed. Other potential sources, and the reasons for not including them in the estimates are elaborated on here. In general, sources which are not included in the SELECT estimates are still potential targets of intervention as part of the WPP, especially on a localized scale.

Human Waste – Direct Discharges - Stakeholders discussed the presence of some homeless individuals in some areas, and some small "colonias" areas which may not have wastewater solutions. Based on feedback from the work group and Partnership, the populations represented by the groups were not found to be large enough to have appreciable impact.

Land Deposition of Sewage Sludge - There were no anecdotal or official reports of sludge application violations or known issues with manure spreading identified by the stakeholders or other partners. Potential impacts would likely be dealt with as part of traditional agricultural BMPs (Water Quality Management Plans – WQMPs- etc.).

Concentrated Animal Feeding Operations - There are no CAFOs in the WPP area.

Domestic Swine - Stakeholders and data did not indicate that domestic swine were an appreciable source in the watershed.

Exotic Animals - Stakeholders identified some exotic animal operations in the watershed, but in small numbers. No quality-assured data or other reasonable source existed to characterize these animals as a source. The operations were not known to be an issue, and the potential populations were too small to be sources of concern.

Birds - Bird populations in the region can vary greatly by season. Large migratory populations pass through the Houston area as part of the Central Flyway migration path. However, these populations are transient, staying for days or weeks during two yearly migration seasons. Migratory waterfowl represent longer-term populations, especially in coastal marshes. However, no migratory waterfowl presence of any significant concentration is known in the watershed. Previous WPP efforts have evaluated the potential impact of waterfowl in terms of duration, potential bacteria load/waste load, and other considerations, and found them to not be significant sources to be modeled. Colonial nesting birds have been identified in other WPP projects as sources of bacteria load. Swallows and other similar colonial birds have nest sites on some bridges throughout the watershed. However, no reasonable data, estimation, or methodology for assessing their populations exists. Additionally, no reasonable solutions were identified with project partners that were feasible and acceptable to stakeholders (due in no small part to their status as protected wildlife under the Migratory Bird Treaty Act and other regulations). Contributions from swallow colonies may be contributing to general background levels of bacteria but were not a focus of this assessment for the reasons presented. Colonial water birds (e.g. heron rookeries) have also been identified under other WPP efforts as potential sources when they occur in sufficient density or size. No such large colonial nesting sites are known within the watershed. Birds of potential concern identified in the stakeholder discussions include domestic exotics (e.g. Muscovy ducks) in parks and other detention facilities. However, no reasonable data exists to characterize this source or to suggest they would be either appreciable in impact or likely to contribute greatly to health risk.

Bats - Bats are present throughout the watershed project area, but there are no known large nesting sites of a size or density likely to represent a source of concern. As with other wildlife sources, no likely solutions exist, making the uncertainty of their load somewhat moot.

Other Wildlife - The greatest degree of uncertainty in the SELECT analyses comes from the inability to accurately predict the contributions of other mammalian wildlife (in addition to birds and bats, as discussed, and exclusive of feral hogs and deer). Anecdotal reports from stakeholders, known area species, and observed species during field reconnaissance indicate coyote, rabbit, skunk, many rodent species, nutria, beaver, raccoon, opossum, armadillo, and other common mammals are present in the watershed in appreciable numbers. However, no defensible population data or literature values sufficient to meet project data quality objectives exist to characterize their contributions. Recent bacteria source tracking analyses have indicated wildlife contributions may be more significant than previously assumed, especially in undeveloped areas. A large portion of the Lake Creek Watershed and portions of the West Fork Watershed are good habitat areas for these and other species. Stakeholders elected to move forward with SELECT modeling with the understanding that this source would be underrepresented. To balance this concern, stakeholders and project staff recommended the WPP support future efforts to further characterize this source in conjunction with other efforts, and to identify any problem areas that may need local attention. The protected status of wildlife and lack of feasible solutions to address most wildlife populations limits the ability to deal with these sources in watershed projects unless they are found in concentrated, discrete areas. Stakeholders and project staff considered other options, including utilizing a margin of safety for loading estimates. However, project staff were unable to find defensible data or literature values for what an appropriate margin for wildlife would be. Given the lack of quality data, the concurrence of the stakeholders, the lack of feasible solutions, and the focus on working to narrow the gap as part of broader efforts in the future, this WPP does not estimate or address loading from other wildlife. However, many of the proposed measures (WQMPs, riparian buffers, etc.) will likely reduce ambient bacteria and nutrient loads from other wildlife.

Cats - Domestic cat ownership generally revolves around an indoor model in developed areas, in which cat feces is restricted to litter boxes, unlike dog waste which is more likely to be deposited outdoors. Therefore, cat loads were not estimated as part of this project. Feral cats, however, can be a local source when found in sufficiently dense urban populations. Project staff worked with local stakeholders to review potential data sources and anecdotal reports on feral cat populations. However, no literature values or data appropriate under project data quality objectives was located. In a review of other regional WPPs, feral cat populations were generally included as part of diffuse urban stormwater and were not specifically highlighted as significant sources. As with other sources not specifically modeled, feral cats may still be a focus of implementation efforts dependent on stakeholder decisions.

Dumping - In discussions with stakeholders, illegal dumping was not identified as a widespread issue. Some localized problem areas were identified, but there were no significant accounts of waste dumping that would add appreciably to fecal bacteria levels. The primary focus of dumping concerns was trash and other aesthetic and regulatory issues.

Sediment - Sand and gravel mining operations are common in the riparian corridors of the watersheds, primarily on the main channels of the West Fork and Lake Creek. Excess sediment from these activities and general development in the watershed is common in the waterways, which can provide shelter for bacteria and decrease insolation that may lead to die-off in the water column. Mining operations are not a direct source of bacteria, so no estimation can be completed. Excess sediment introduced into the channel can foster the survival of bacteria from other sources, making it an indirect source for bacteria that might have otherwise not survived. The considerations regarding sediment will be dealt with in the WPP.

Summary of Bacteria Source Modeling Results

The SELECT analyses indicated a mix of sources rather than one or two primary contributors. Table 20 indicates the estimated current potential loads for all sources. Table 21 shows the estimated potential load for each milestone year, by source. Figure 53 shows the change in total load between 2015 and 2040. Figure 54 shows the relative change in source contributions between current and future conditions. Figure 55 shows the WPP area subwatersheds.

Absent a concerted effort to address bacteria sources, the projections indicate that total bacteria loads in the watershed will continue to increase between 2015 and 2040. Between current conditions and those projected for 2040, the mix of sources shifts away from the legacy agricultural activity toward a predominance of sources associated with human development.

The lack of a single key source means implementation will need to be broad-based and utilize a range of practices addressing multiple sources. While this will require a robust and coordinated approach, it also means the Partnership has flexibility and can be opportunistic when resources or opportunities arise to address various sources.

Table 20 - Bacteria Loadings by Source and Subwatershed, Current

Subwater-shed	OSSFs	WWTF	SSOs	Dogs	Cattle	Horses	Sheep/Goats	Deer	Feral Hogs	Total Daily Loading
SW1	1.18E+11	2.38E+07	0.00E+00	3.18E+11	2.15E+12	2.73E+10	6.79E+11	1.81E+10	2.46E+11	**3.56E+12**
SW2	4.49E+10	0.00E+00	0.00E+00	1.21E+11	1.60E+12	2.04E+10	5.06E+11	7.98E+09	1.60E+11	**2.46E+12**
SW3	2.10E+11	0.00E+00	0.00E+00	5.67E+11	1.05E+12	1.33E+10	3.31E+11	2.31E+10	1.82E+11	**2.37E+12**
SW4	8.01E+10	0.00E+00	0.00E+00	2.16E+11	1.18E+12	1.50E+10	3.72E+11	1.87E+10	1.78E+11	**2.06E+12**
SW5	7.60E+10	1.19E+08	0.00E+00	2.05E+11	1.42E+12	1.81E+10	4.49E+11	1.28E+10	1.87E+11	**2.37E+12**
SW6	1.34E+11	0.00E+00	0.00E+00	3.99E+11	1.37E+12	1.39E+10	4.32E+11	1.10E+10	1.35E+11	**2.49E+12**
SW7	3.36E+11	9.54E+08	0.00E+00	1.01E+12	8.67E+11	1.10E+10	2.74E+11	2.45E+10	1.64E+11	**2.69E+12**
SW8	9.44E+11	1.41E+10	6.95E+08	1.41E+12	3.05E+11	3.87E+09	9.62E+10	3.06E+10	1.48E+11	**2.95E+12**
SW9	1.29E+12	7.06E+09	2.02E+08	2.06E+12	4.96E+11	6.30E+09	1.56E+11	3.46E+10	1.47E+11	**4.20E+12**
SW10	5.46E+11	5.57E+10	7.71E+10	1.82E+12	1.81E+11	4.59E+09	5.70E+10	4.15E+10	1.32E+11	**2.91E+12**
SW11	1.15E+11	0.00E+00	0.00E+00	1.05E+12	8.81E+10	2.24E+09	2.78E+10	2.66E+10	6.85E+10	**1.38E+12**
SW12	2.24E+12	3.20E+10	5.60E+09	2.55E+12	1.11E+11	2.83E+09	3.52E+10	4.70E+10	1.28E+11	**5.15E+12**
SW13	9.34E+11	8.73E+09	3.12E+09	4.60E+11	3.36E+11	4.27E+09	1.06E+11	3.99E+10	1.49E+11	**2.04E+12**
SW14	1.12E+12	2.00E+10	2.59E+09	1.19E+12	1.31E+11	1.66E+09	4.13E+10	2.82E+10	9.57E+10	**2.63E+12**
SW15	1.43E+12	2.29E+10	4.93E+09	1.01E+12	1.67E+10	2.12E+08	5.26E+09	2.05E+10	6.38E+10	**2.58E+12**
TOTAL	**9.60E+12**	**1.60E+11**	**9.40E+10**	**1.40E+13**	**1.10E+13**	**1.40E+11**	**3.60E+12**	**3.90E+11**	**2.20E+12**	**4.20E+13**
% of Total	**22.9%**	**0.4%**	**0.2%**	**33.3%**	**26.2%**	**0.3%**	**8.6%**	**0.9%**	**5.2%**	**100.0%**

Table 21 - Bacteria Loadings by Source for all Milestone Years

Category	Source	2015	2020	2025	2030	2035	2040
Human Waste	OSSFs	9.6E+12	1.3E+13	1.7E+13	2.1E+13	2.5E+13	2.9E+13
	WWTFs	1.6E+11	2.1E+11	2.4E+11	2.6E+11	2.8E+11	3.0E+11
	SSOs	9.4E+10	1.2E+11	1.4E+11	1.6E+11	1.7E+11	1.8E+11
Pets	Dogs	1.4E+13	2.3E+13	2.9E+13	3.3E+13	3.8E+13	4.2E+13
Livestock	Cattle	1.1E+13	1.1E+13	1.0E+13	9.3E+12	8.5E+12	7.7E+12
	Horses	1.4E+11	1.4E+11	1.3E+11	1.2E+11	1.1E+11	1.0E+11
	Sheep/Goats	3.6E+12	3.4E+12	3.2E+12	2.9E+12	2.7E+12	2.4E+12
Wildlife and Feral Hogs	Deer	3.9E+11	3.8E+11	3.8E+11	3.8E+11	3.8E+11	3.8E+11
	Feral Hogs	2.6E+12	2.5E+12	2.4E+12	2.4E+12	2.3E+12	2.2E+12
Total		**4.2E+13**	**5.4E+13**	**6.2E+13**	**7.0E+13**	**7.7E+13**	**8.4E+13**

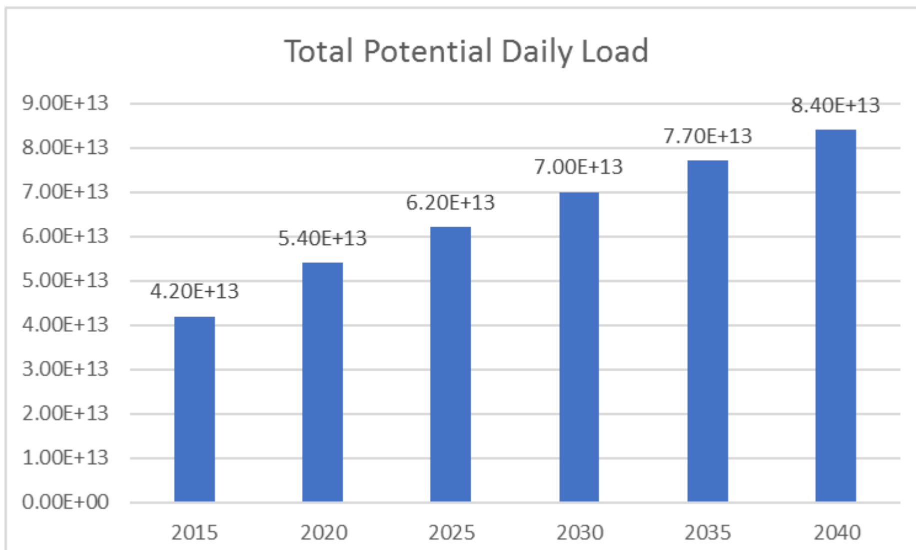

Figure 53- Total Potential Daily Load, 2015-2040

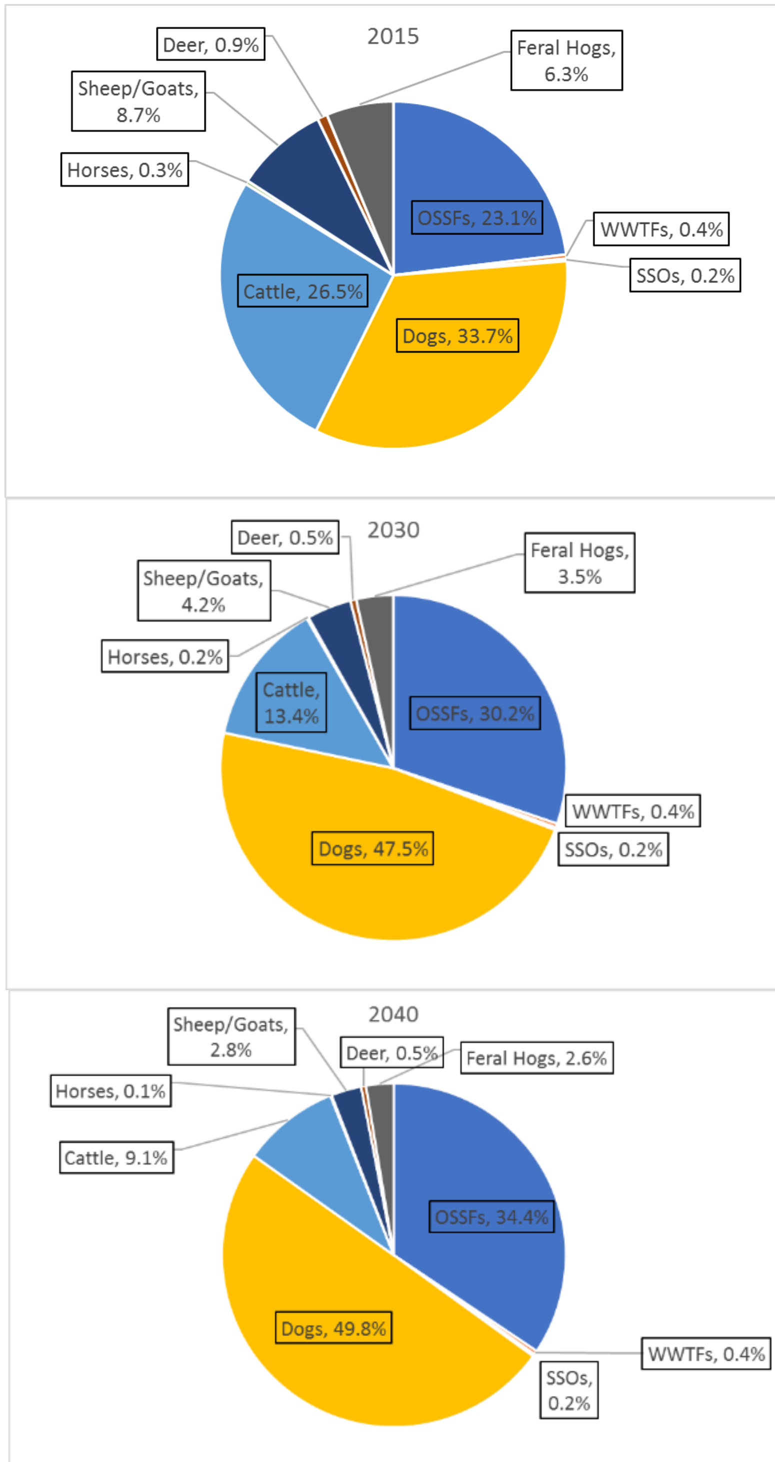

Figure 54 - Change in Source Contribution over Time

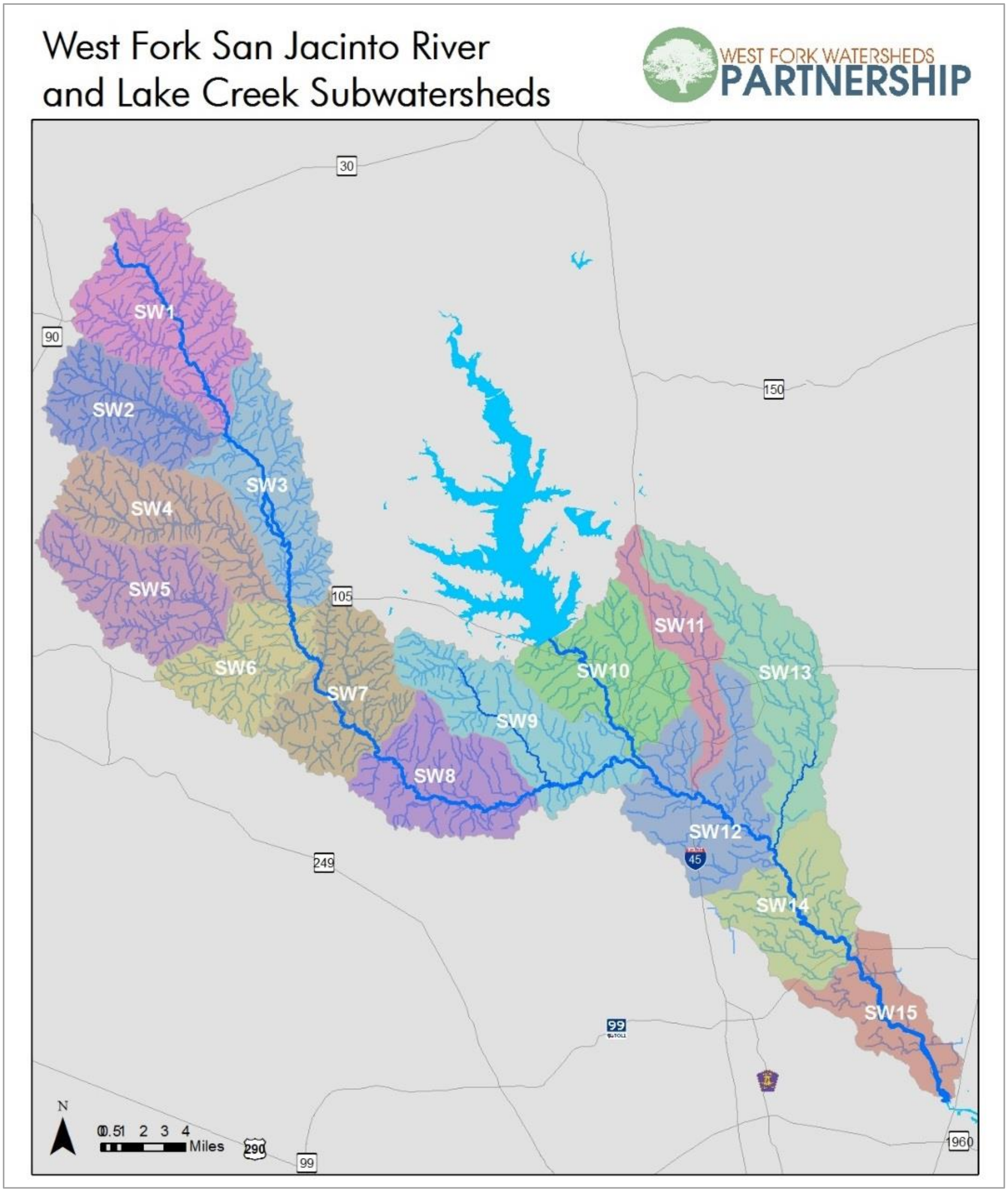

Figure 55 - Subwatersheds of the West Fork watersheds

Nutrient Source Characterization

Dissolved oxygen (DO) is essential for supporting aquatic communities, but unlike bacteria impairments, 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 nutrients from human uses is the source 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. 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 methods to model nutrient loading, in the context of the water quality goals they established. Because DO is not an impairment in the West Fork watersheds, and because many of the sources of nutrients overlap with sources of bacteria[69], the Partnership focused its investigation efforts on characterizing potential nutrient loads through a land cover-based model. The intent of this effort was to provide context and comparison of how nutrient loading varied throughout the watershed as a tool for prioritizing implementation activities.

Nutrient Source Identification

Natural challenges to DO include high temperatures, flat channels without pools and riffles to aerate the water, dead-end channels, low flow, and natural decay of organic materials. Additionally, anthropogenic sources of DO impairment vary greatly, from hydrologic alterations (impoundments, dead-end channels, etc.) to pollutants from developed land use (excessive nitrogen and phosphorus compounds from fertilizers and wastes/effluent, and other industrial oxygen-demanding pollutants). The focus of the nutrient sources identified for this WPP are those within the scope of available implementation measures, which include:

- **Animal wastes** – within the watersheds this includes domestic pets (dogs), livestock (cattle, horses, sheep, goats, etc.), wildlife, and feral non-domestic animals (feral hogs).
- **Human wastes** – within the watersheds this includes wastewater effluent, SSOs, and failing OSSFs.
- **Fertilizers** – within the watersheds this includes residential/commercial landscaping fertilization and agricultural fertilization.
- **Organic debris** – within the watershed, this includes yard wastes, agricultural vegetative waste, and organic debris from trash/illegal dumping.

[69] 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).

Nutrient Model Development

The Partnership developed the proprietary Geospatial Load Assessment Methodology (GLAM)[70] to estimate and evaluate loading of nitrogen (N) and phosphorus (P) from the watershed area using land cover and literature values to generate potential loads. Its primary use in the WPP is to guide selection and siting of implementation measures which have a nutrient component and to serve as a baseline against which to measure future progress.

Because depressed DO is a condition, and not a tangible constituent, a load of DO cannot be established. Based on the character of the watersheds, the most likely precursors to depressed DO are nonpoint source pollutants and the physical properties of the watersheds. Of the potential pollutants, nutrients (nitrogen and phosphorus compounds) are the primary focus of the modeling effort. The DO/nutrient source load modeling need for this project is descriptive rather than prescriptive and not intended to establish complex linkage with instream DO concentrations.

The GLAM model is based on a simplified version of the loading estimation approaches of tools like SELECT and other modeling packages that base loading on land cover/use. GLAM estimation is based completely on land cover, using a set literature value for nitrogen/phosphorus generated per unit of land, per inch of rain, specific to each land cover type. The Partnership reviewed several literature values for nitrogen and phosphorus but decided that the most desirable assumptions are those that are based on local conditions rather than broad national averages. This approach helps ensure similar environments, climates, and other natural features, and better comparability with other local efforts using the same data. Therefore, the underlying assumptions for loading in GLAM are based on event mean concentration (EMC) values (Table 22) used in the Community Health and Resource Management (CHARM) GIS-based mapping application[71] used by the Texas A&M AgriLife Extension's Texas Community Watershed Partners program for the Highland Bayou WPP.

The GLAM approach applied the nitrogen and phosphorus loading values from Highland Bayou to the land cover, by subwatershed, in the West Fork watershed. The resulting calculation provided potential loading estimates for nitrogen and phosphorus at the subwatershed level, and as aggregate values for the watershed. The results are given as a function of rainfall, with the understanding that nutrient loading is tied strongly to runoff events and nonpoint sources. The ability of WWTFs to comply with their permits and the relatively small volumes they represent in the watershed serve as supporting evidence for this working assumption.

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[70] For greater detail on the model selection and methodology approach for nutrient modeling, please refer to the Modeling methodology and Nutrient Modeling Report at https://www.westforkwpp.com

[71] For more information on the CHARM application, please visit https://tcwp.tamu.edu/charm/.

Table 22 - GLAM load assumptions

Land Cover Category	Nitrogen load (in pounds per inch of rain per square foot)	Phosphorus EMCs (in pounds per inch of rain per square foot)
Open Water	3.27748E-06	3.12141E-07
High Intensity Developed	1.01931E-05	1.49134E-06
Medium Intensity Developed	1.01082E-05	1.47747E-06
Low Intensity Developed	9.92868E-06	1.46836E-06
Developed Open Space	9.33561E-06	1.34481E-06
Barren Land	2.70522E-05	3.06938E-06
Forest and Shrublands	5.38443E-06	5.3324E-07
Pasture and Grasslands	9.9885E-06	1.69076E-06
Cultivated Crops	1.13931E-05	2.18499E-06
Wetlands	7.25727E-06	9.7544E-07

Nutrient Model Results

The results of the GLAM assessment indicated that nutrient loading was relatively consistent throughout the watershed (Table 23 and Figures 57 and 58). While specific sources of nutrients are likely to differ from subwatershed to subwatershed, the aggregate impact of different ratios of source and land cover types led to a more even distribution than the Partnership expected. As agricultural activity in the watershed continues to convert to developed land use, this balance may shift. In the meantime, the relatively even distribution indicates that there is greater flexibility in siting solutions in coordination with bacteria reduction efforts (i.e. relatively equal distribution of nutrient loads lets the partnership focus on prioritizing around bacteria, knowing that beneficial impacts to nutrients are likely to be similar no matter what subwatershed is prioritized).

Figure 56 - Algal bloom in watershed tributary

Table 23 - Nutrient loading in total pounds per inch of rain, by subwatershed

Subwatershed	P (Total lbs.)	N (Total lbs.)	Subwatershed P load as percent of total P load	Subwatershed N load as percent of total N load
1	1,875	12,050	10.5%	9.6%
2	1,277	7,964	7.1%	6.3%
3	1,091	7,831	6.1%	6.2%
4	1,240	8,324	6.9%	6.6%
5	1,398	9,031	7.8%	7.2%
6	1,084	7,014	6.0%	5.6%
7	1,126	7,978	6.3%	6.3%
8	990	7,556	5.5%	6.0%
9	1,305	9,484	7.3%	7.5%
10	1,197	8,742	6.7%	6.9%
11	626	4,652	3.5%	3.7%
12	1,432	10,577	8.0%	8.4%
13	1,453	10,780	8.1%	8.6%
14	1,055	7,911	5.9%	6.3%
15	788	5,966	4.4%	4.7%
Total	17,937	125,858		

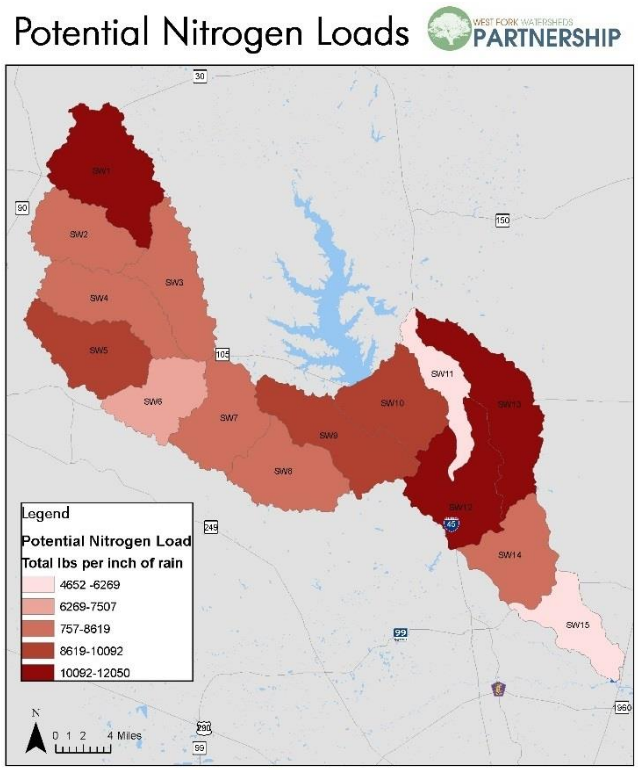


Figure 57 - Potential Nitrogen loads by subwatershed

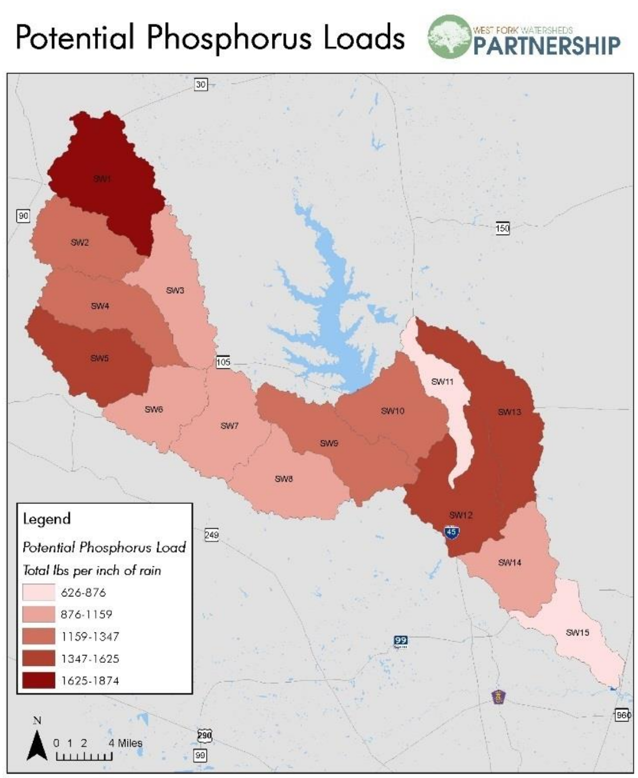


Figure 58 - potential Phosphorus loads by subwatershed

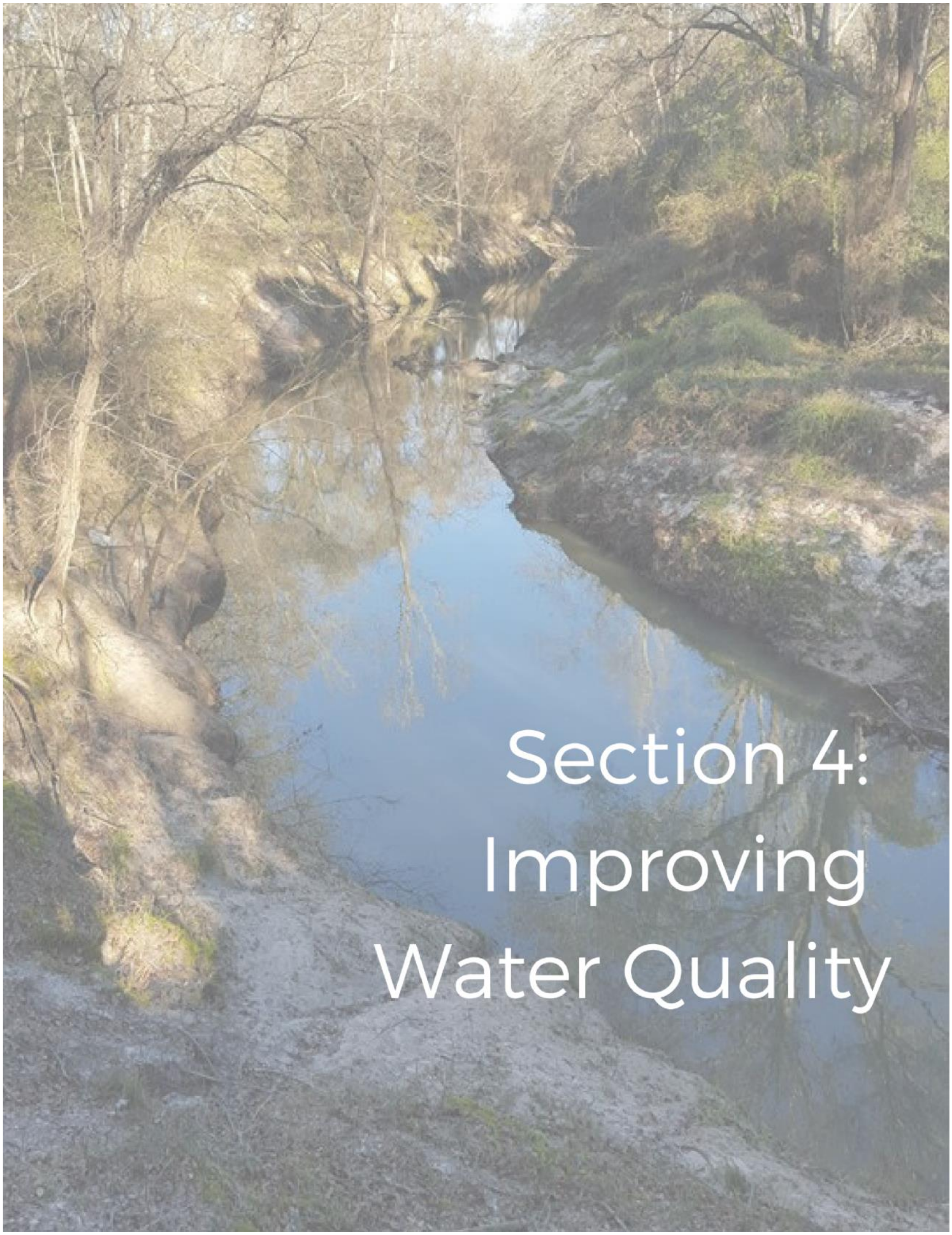
Nutrient Summary

The investigation into nutrient loading was intended to evaluate one piece of the multifaceted DO equation. While some watersheds were outliers, being slightly higher or lower, potential nutrient loading was relatively consistent. Section 5 of this WPP includes recommendations for some nutrient reduction measures. However, most of the solutions recommended for bacteria reduction will also help address elevated nutrient levels.

Source Characterization Summary

Through evaluation of water quality data, the Partnership characterized the current state of water quality and increased its knowledge of the nuance of issues at various points in the watersheds. The source identification processes allowed stakeholders to weigh in heavily with local knowledge on where potential sources were located, and to what extent. Those findings drove the assumptions and revision of the load modeling efforts for bacteria and nutrients. The load modeling through SELECT and GLAM helped establish the relative potential prominence of the sources, their distribution in the watershed, and the total potential loads of pollutants in the watershed. These analyses provided the Partnership with the information it needed to establish reduction goals (Section 4) and generate the recommended solutions to address these sources. A strong emphasis on stakeholder knowledge and review for modeling efforts was incorporated throughout these efforts.

Figure 59 - Wooded section of the West Fork



Section 4: Improving Water Quality

4 – Improving Water Quality

Water Quality Improvement Overview

The success of solutions recommended by this WPP will be due in large part to how well they are scaled and targeted to address pollutant sources. The Partnership conducted a water quality modeling effort[72] to determine the amount of improvement needed for each parameter (bacteria and DO). The purpose of this effort was to establish how much bacteria needed to be reduced in the waterway to meet the SWQS, and how much improvement in DO level is needed to meet the aquatic life use standard. An assessment tool called ***load duration curves*** (LDCs) was used in combination with water quality data to find these results. Improvement goals were generated for separate areas of the watershed, called attainment areas, based on the points at which future compliance would be measured.

Figure 60 - A bend in the West Fork

Load Duration Curves

The amount of water flowing through a water body can affect the concentration of pollutants. LDCs use observed water quality data (see Section 3) to indicate the difference between the levels of pollutant or condition 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. The flow curves indicate what percentage of days the flow of water meets certain flow

[72] For greater detail on the modeling efforts for bacteria and DO discussed in this section, please refer to the *Modeling Methodology*, *Bacteria Modeling Report*, and *Nutrients and DO Modeling Report* at www.westforkwpp.com.

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 is 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 61). More importantly, the curve indicates under what flow conditions, and by how much, the observed pollutant levels are more than 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 in which there is 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 the observed loads exceed the allowable loads is the basis for developing improvement goals.

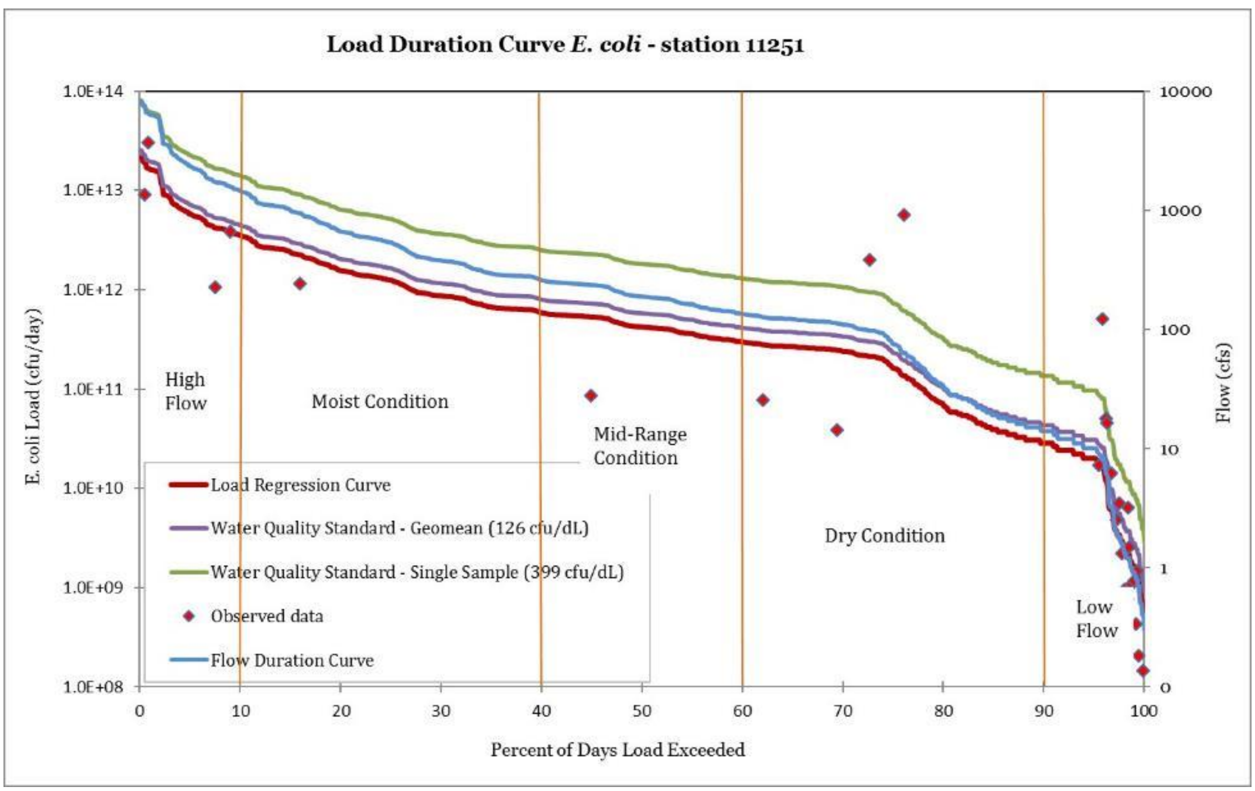


Figure 61 - Example of a load duration curve for bacteria

LDCs for Bacteria

LDC analyses were developed by project staff for bacteria[73] at several monitoring stations throughout both the West Fork and Lake Creek watersheds. The purpose of the bacteria LDCs were to evaluate the flow conditions in which exceedances were happening, and to generate improvement goals for bacteria reduction.

Site Selection

Site selection for LDCs was based on support for a mix of considerations, including known water quality conditions[74], 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 plant discharge monitoring reports, and sanitary sewer overflow information, water quality in both watersheds tends toward greater variability and higher rates of exceedance in the tributaries of the primary segments. Therefore, LDC locations were chosen to represent both the primary segments and tributaries rather than having only one station on the main channel in each watershed. Evaluating both primary segments and tributaries ensures end results reflect variability of conditions throughout the waterway. The site selected to represent the main body of the West Fork is upstream of the final two subwatersheds of the system. Based on a review of water quality data, site (11243) is expected to be representative of variable conditions.
- **Long Term Assessment Considerations -** To ensure long-term assessment, potential LDC locations were drawn from existing Clean Rivers Program monitoring stations. The existing sites were affirmed by the stakeholders to characterize conditions in the waterways.
- **BMP Siting Requirements** – As discussed previously, LDCs were chosen in part to reflect geographic variability. A greater number of LDC locations is beneficial to use of modeling results to scale and site BMPs (i.e., BMP 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** – The Partnership reviewed and provided feedback on the suggested LDC sites. Based on the feedback received, additional LDC locations were appended to the original proposal to provide more detailed information on Mound Creek (17937) and Crystal Creek (16635).

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[73] As a freshwater system, all bacteria values are based on *E. coli* indicator bacteria.

[74] For more information, refer to Section 3 or the *Water Quality Data Collection and Trends Analysis Report* at https://westfork.weebly.com/project-documents.html.

Based on these considerations, project staff conducted five LDC analyses, four of which would be used to generate load reduction targets[75]. The final LDC sites are indicated in Figure 62 and described in Table 24.

Table 24- LDC Locations

LDC Site	CRP Station	USGS Gauge	Assessed Area
Lake Creek	11367	NA[76]	Subwatersheds 1-8
Mound Creek	17937	NA	NA[77]
West Fork San Jacinto North	11251	08067650	NA[78]
West Fork San Jacinto South	11243	08068090	Subwatersheds 9,10,11,12,14,15
Crystal Creek	16635	NA	Subwatershed 13

Data Development

Flow Data - LDCs require a sufficient amount of ambient water quality data, as well as flow data (with continuous flow data being preferable). The mainstem West Fork LDC sites (11251, 11243) had corresponding USGS gauges. However, the Lake Creek gauge did not have enough flow data to generate a flow curve of similar quality. Additionally, no flow gauge is available for the Mound Creek or Crystal Creek LDC sites. The Partnership reviewed and approved the use of existing flow data (grab samples from CRP monitoring events) and the Soil and Water Assessment Tool (SWAT) model to generate extrapolated flow series sufficient to characterize these stations[79]. The modeled period included a 10-year time frame (2005-2015). Flow was

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[75] The first LDC, at station 11251, is intended to represent and evaluate boundary conditions, i.e. primarily the inflow from the Lake Conroe reservoir. Neither the water quality analysis nor LDC indicated any reduction was needed at this station.

[76] Stations 11367, 17937 and 16635 did not have continuous flow data specific to their waterways. Data was derived from implementing elements of SWAT to generate flow series.

[77] The Mound Creek subwatershed is part of a large modeled subwatershed, covered by station 11243. The LDC site is intended to provide guidance in siting BMPs for the Mound Creek area, which sees greater impairment than the rest of its subwatershed attainment area.

[78] This station represents boundary conditions from Lake Conroe and is not specific to attainment modeling.

[79] More information on the methodology employed to generate the flow data is discussed in the project Modeling QAPP, found at https://westfork.weebly.com/project-documents.html. SWAT was not fully implemented for this task; only the module necessary to generate flow series was used. No additional functionality of SWAT (loading, fate and transport, etc.) was conducted.

generated based on best available spatial data using the same subwatershed delineations as used for the project in general.

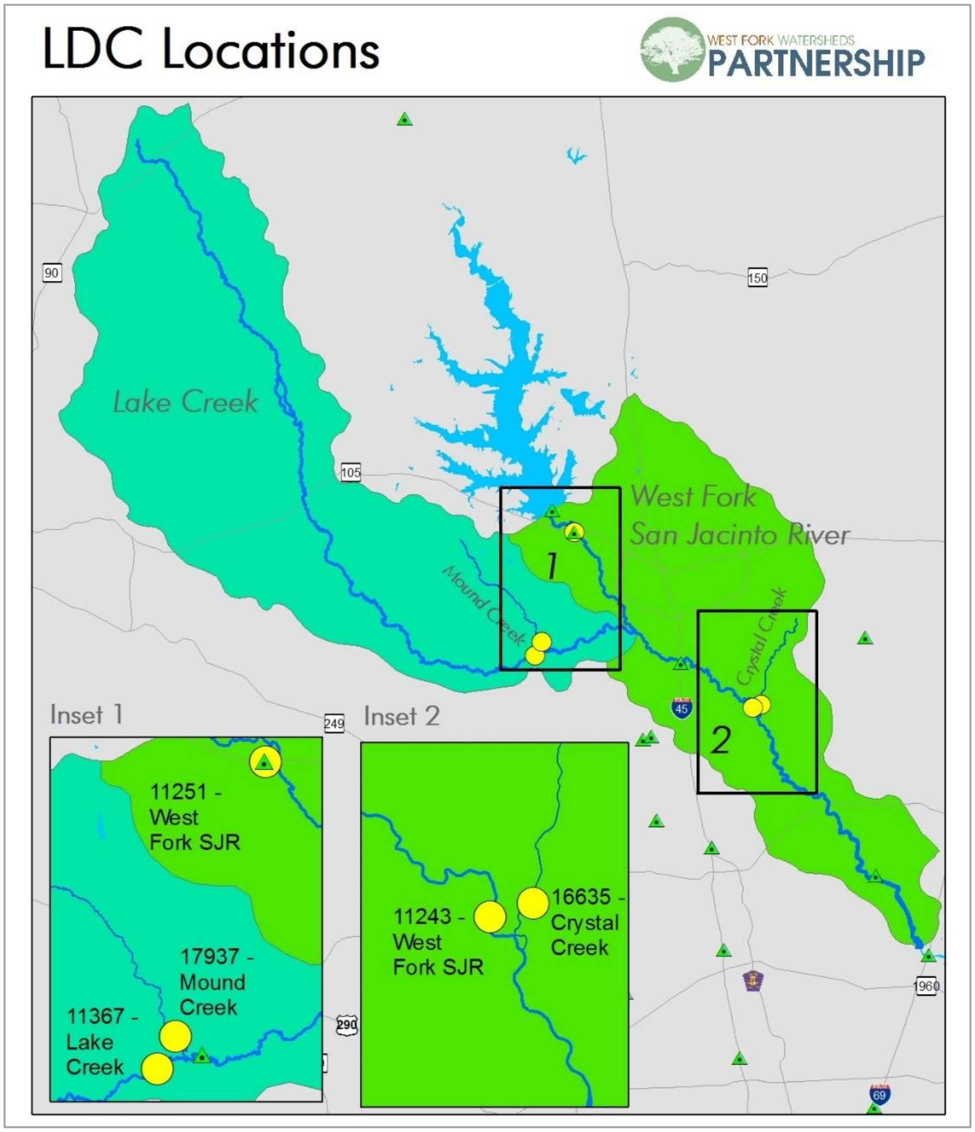


Figure 62 - LDC locations

Ambient Water Quality Data - Quality-assured ambient water quality results from CRP monitoring was available for all stations. Table 25 indicates the number of *E. coli* data points for each station. All stations had at least 7 years of data available (28+ data points), which is sufficient to develop the LDCs based on the data quality objectives of the project[80]. Both single

[80] Ibid.

sample and geomean values were evaluated against their respective criteria, but only geomean values were used in the process of assessing reductions.

Table 25 - Number *E. coli* Samples by Station

LDC Location	Station	Number of *E. coli* Samples
Lake Creek	11367	34
Mound Creek	17937	30
West Fork San Jacinto North	11251	28
West Fork San Jacinto South	11243	45
Crystal Creek	16635	41

While quality assured ambient water quality data was sufficient for all identified LDC sites, continuous flow data was not available at some locations. Project staff utilized elements of the Source Water Assessment Tool (SWAT) to generate flows for these locations.

LDC Implementation

Flow curves and LDCs were generated for each of the target stations and reviewed internally and with project stakeholders. No issues were identified based on quality assurance review and feedback. Full profiles for each LDC site are included as Appendix B[81].

LDC Summary and Bacteria Reduction Targets

After discussing the raw results of the initial round of LDCs, the Partnership decided to add the Mound Creek (17937) and Crystal Creek (16635) sites to provide a more detailed look at variability between different areas and different watershed types. The results showed modest reductions were needed in higher flow conditions, with the exception on the Mound Creek priority area[82], which needs appreciable reductions across most flow conditions. The results presented interesting questions to answer during the SELECT analysis effort. While Mound Creek had some of the denser riparian cover and only moderate development, the higher load reduction needs were in stark contrast to Crystal Creek, whose land uses and general character were relatively similar. Conversely, the West Fork attainment area, which receives flow from the dense urban area of Conroe, as well as the inputs from an urbanizing lower Lake Creek,

[81] And can also be found with additional information in the *Bacteria Modeling Report* at www.westforkwpp.com.
[82] For future improvement goals, Mound Creek is part of a larger attainment area. However, stakeholders elected to consider Mound Creek a priority area within the broader attainment area. LDCs and improvement goals for Mound Creek were developed to illustrate the specific needs of this prioritized area.

showed an overall lower reduction was needed. Table 26 represents a summary of the LDC findings. The general hypothesis carried over into the discussion of sources and the linkage therewith, was that stream flow volume was a primary factor in assimilative capacity in this project area.

Table 26 – LDCs Summary for Bacteria

LDC Location	Area Represented[83]	Findings
West Fork San Jacinto North (11251)	NA (Boundary conditions[84])	Both the water quality analyses and the LDC indicated that no reductions are necessary at this station, even though it had minor exceedances, primarily in lowest and highest flow conditions.
West Fork San Jacinto South (11243)	Segment 1004, other than Crystal Creek	The West Fork's flow profile indicates nonpoint source issues as the primary concern, with most exceedances in high and moist conditions. The LDC indicates reductions of 80% in High Flows, and 20% in Moist Conditions.
Crystal Creek (16635)	Crystal Creek	Crystal Creek also shows most exceedances in high flow conditions, suggesting nonpoint sources are the primary issue. However, only the High Flow conditions indicated a minor (6%) reduction was needed.
Lake Creek (11367)	Lake Creek above 11367	Despite the lack of an official impairment, Lake Creek's LDCs indicate that a small to moderate amount of reduction is needed in its High Flow (37%) and Moist Conditions (11%). The large amount of assimilative capacity in its Dry Conditions and Low Flows indicates that its bacteria loading is primarily from nonpoint sources. It should be noted that this station is upstream of the confluence of Mound Creek and does not reflect loading from that tributary.
Mound Creek (17937)	NA (Mound Creek[85])	Unlike Lake Creek, Mound Creek exhibits a need for reduction across all flow conditions except Low Flows, ranging from 82% (High Flows) to 36% (Dry Conditions). Because Mound Creek's loading is not heavily skewed toward either high or low flow conditions, no specific comment can be made about its likely primary source (point or nonpoint sources).

[83] Attainment areas are shown in Figure 64.
[84] As described in Appendix B, station 11251 is directly downstream of the Lake Conroe Dam (with minor inputs from other sources). Based on available data it needs no reductions and represents the "boundary conditions" between the Lake and the West Fork system.
[85] As described in the full profile in Appendix B, Mound Creek is not tied to an attainment area, but is included for characterizing that area for implementation prioritization decisions.

Improvement Goals for Bacteria

To generate final source load reductions, the percent reduction targets from the LDCs were applied to the source loads from SELECT to generate reduction load improvement goals[86] (Figure 63). Future reduction targets assumed that any estimated additional source loads would be added to current condition reduction target loads (i.e. 100% of additional load added would need to be reduced). The resulting current and future reduction loads were generated for each of the LDC stations that would be used for long term assessment, with the intent of targeting BMPs sufficient to meet these reduction targets specific to each area. Source load reduction improvement goals were developed for each of the 5-year future projection milestones, with a focus on 2030 as the target year for compliance.

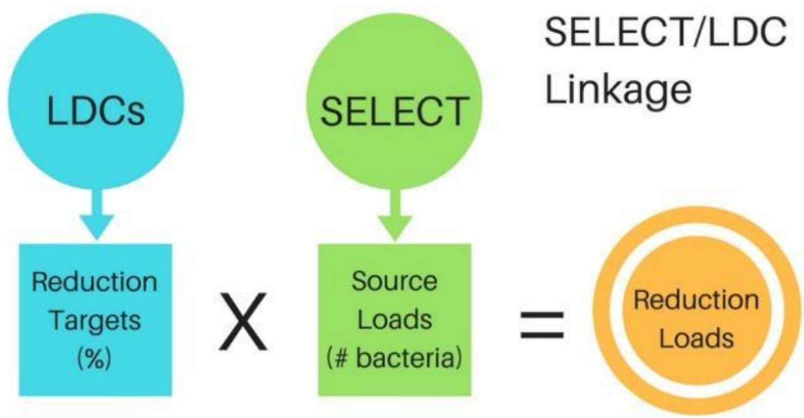


Figure 63 - SELECT/LDC Linkage

The design for generating single target reductions for each attainment area[87] was based on a compromise between the worst-case scenario (highest possible reduction needed in any flow category, specific to each LDC station/attainment area) versus the least conservative approach (average reduction needed based on all flow conditions, general to each watershed). With the stakeholders' concurrence, the Partnership took 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 of the segments and their assessed tributaries. For example, Station 11243 indicated a need for reductions in the two highest flow categories, but not in the

[86] Further detail about the development of this methodology can be found in the *Modeling Methodology* and about its implementation can be found in the *Bacteria Modeling Report* at www.westforkwpp.com. As with other modeling decisions, these methods were developed with TCEQ and reviewed with the stakeholders for their concurrence.
[87] As opposed to the modeled reduction values for each flow category.

other three. The most conservative approach would be to apply the greatest overall reduction to the watershed in general. The least conservative approach would be to average all flow conditions, thus diluting the reductions needed in the highest categories. The approach taken finds the flow weighted average of the two categories needing reduction, (i.e. the conditions driving the impairment), and uses that as a reduction target. Table 27 represents the final bacteria target reductions for the modeled assessment areas and the Mound Creek priority area. The improvement goal for Mound Creek is to illustrate the specific needs of this prioritized part of a broader attainment area. Its designation as a “priority area” reflects stakeholder concerns about the growth of sources in this area and the desire to make it a focus for implementation activities. Figure 64 represents the final attainment areas. These decisions were confirmed with the stakeholders after two rounds of feedback and revision.

Table 27 - Final bacteria improvement goals (current)

Attainment Area	LDC Station	Weighted Average Bacteria Reduction Target (%)
West Fork and Lower Lake Creek	11243	35
Crystal Creek	16635	6
Lake Creek	11367	17.5
Mound Creek	*17937*	*60.4*

The final step in the improvement goal modeling effort for bacteria was to link the improvement goals established in the LDC analyses to the source loads generated in the SELECT analyses to create source load reduction targets.

Model Linkage

SELECT was used to generate potential source loads and characterize the source profile. The % 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 absolute number of bacteria to reduce, is used for the linkage.

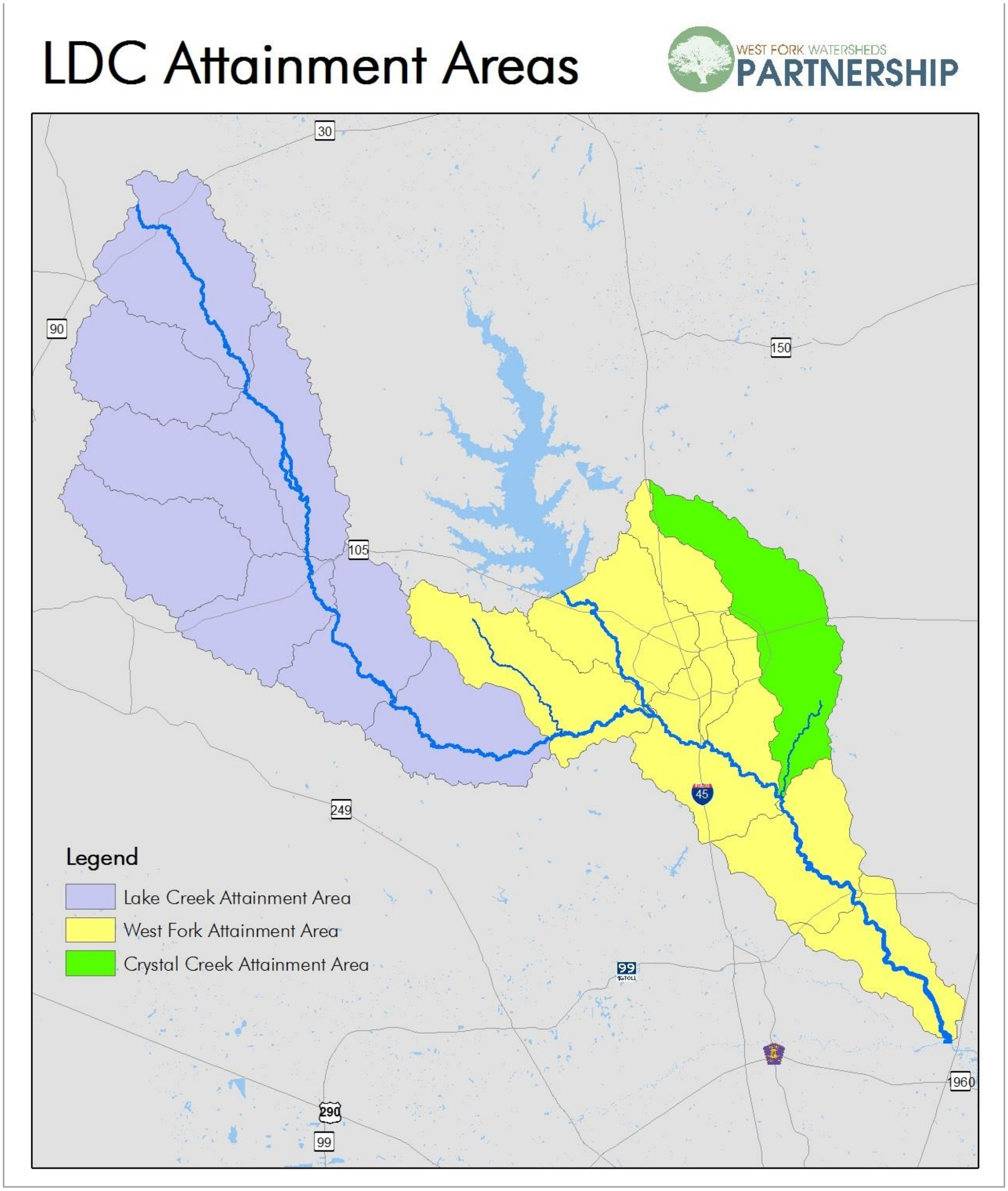


Figure 64 - LDC Attainment Areas

Bacteria Reduction Considerations

With the model linkage established, calculating bacteria reduction targets required that the stakeholders consider three primary questions: 1) what milestone year would reduction targets be based on; 2) would targets be watershed-wide, or specific to certain areas; and 3) how would reductions be spread out among the bacteria sources?

Milestone Year - WPPs typically are written for a 5-to-15-year basis. The existing projections developed during the SELECT analyses allowed the stakeholders to target any of the five-year milestones dates between 2015 and 2040. 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, with the need to account for future growth projected for the watershed. A five-year plan would not adequately address the appreciable increase in loads through 2040, whereas a more long-term plan would have to rely on less certain predictions[88]. Project staff proposed 2030 as a compromise, allowing a long-term focus to account for watershed change, while focusing on meaningful interim action. For a WPP approved in 2018/2019, this would represent a 11-to-12-year plan life. The stakeholders affirmed this proposal.

Attainment Areas - The LDC sites were intended as the focus of long-term attainment; ongoing CRP data would form the bulk of water quality monitoring to determine WPP effectiveness. As noted in the SELECT and LDC analyses, the project area watersheds are varied in terms of reduction need and developmental character. Therefore, project staff proposed three attainment areas (Figure 64), each with specific reduction goals. The three attainment areas are: 1) Lake Creek upstream of Mound Creek; 2) Lake Creek downstream of Mound Creek and the West Fork exclusive of Crystal Creek; and 3) Crystal Creek. The stakeholders affirmed this approach, with the understanding that through adaptive management, additional targets may be added if needed (e.g. breaking out Mound Creek, or Stewart's Creek from the second attainment area).

Allocating Reductions - The mix of sources present in the watershed, and the shift of relative contribution through 2040, posed a challenge for allocating how reduction targets would be met. Stakeholders 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

[88] 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.

staff proposed the first option, with the understanding that the WPP would stress opportunistic implementation and that short-term efforts may focus on sources that are currently pressing (e.g., livestock) even if they are not as significant in the 2030 projections. 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.

Final Source Load Reduction Targets

Based on these decisions, project staff generated reduction targets for each attainment area, subwatershed, and source. Table 28 represents the linkage of the reduction target percentages to the source loadings to generate the target source load reductions for current and 2030 milestones years. Tables 29 and 30 summarizes the allocation of reduction loads by source for each of the three attainment areas for current and 2030 milestone years, using the assumption that reduction for each source would be proportionate to the source's percentage of total load.

Table 28 - Current and 2030 Source Load Reduction Targets

Attainment Area	Subwatersheds	LDC Reduction (current)	Current Source Load[89]	Current Source Load Reduction Target	Incremental load 2015-2030[90]	2030 Source Load Reduction Target[91]
Lake Creek above Mound Creek	1,2,3,4,5,6,7,8	17.5%	2.1E+13	3.7E+12	4.1E+12	7.8E+12
Lake Creek below Mound Creek and the West Fork above Crystal Creek	9,10,11,12,14, 15	35%	1.9E+13	6.6E+12	2.2E+13	2.8E+13
Crystal Creek	13	6%	2.0E+12	1.2E+11	1.6E+12	1.8E+12
Total Load Reductions	All	NA	4.2E+13	1.0E+13	2.8E+13	3.8E+13

[89] Current source load is generated by summing the source loads for the subwatersheds within the attainment area.
[90] The incremental load represents the difference between the 2030 load and the 2015 load. See footnote 46 for explanation of its use in generating 2030 source reduction load target.
[91] The 2030 reduction target is generated through the equation $C_r+(F_l-C_l)$; where C_r= current source reduction load, F_l = future total source load, and C_l = current total source load. The incremental load generated between 2015 and 2030 is added to whatever existing reduction load exists in 2015. This approach is used because LDCs cannot estimate future reduction percentages, and because it is assumed the waterway will not have additional assimilative capacity in 2030.

Table 29 - Current source reduction loads by source and attainment area

		OSSFs	WWTFs	SSOs	Dogs	Cattle	Horses	Sheep/ Goats	Deer	Feral Hogs	Total
Lake Creek Above Mound Creek	Source Load	1.9E+12	1.5E+10	6.9E+08	4.2E+12	9.9E+12	1.2E+11	3.1E+12	1.5E+11	1.4E+12	2.1E+13
	% Total Load	9.3%	0.1%	0.0%	20.3%	47.4%	0.6%	15.0%	0.7%	6.7%	100.0%
	Reduction Load	3.4E+11	2.7E+09	1.2E+08	7.4E+11	1.7E+12	2.2E+10	5.5E+11	2.6E+10	2.4E+11	3.7E+12
Lake Creek Below Mound Creek and West Fork	Source Load	6.7E+12	1.4E+11	9.0E+10	9.7E+12	1.0E+12	1.8E+10	3.2E+11	2.0E+11	6.4E+11	1.9E+13
	% Total Load	35.8%	0.7%	0.5%	51.4%	5.4%	0.1%	1.7%	1.1%	3.4%	100.0%
	Reduction Load	2.4E+12	4.8E+10	3.2E+10	3.4E+12	3.6E+11	6.2E+09	1.1E+11	6.9E+10	2.2E+11	6.6E+12
Crystal Creek	Source Load	9.3E+11	8.7E+09	3.1E+09	4.6E+11	3.4E+11	4.3E+09	1.1E+11	4.0E+10	1.5E+11	2.0E+12
	% Total Load	45.8%	0.4%	0.2%	22.5%	16.5%	0.2%	5.2%	2.0%	7.3%	100.0%
	Reduction Load	5.6E+10	5.2E+08	1.9E+08	2.8E+10	2.0E+10	2.6E+08	6.4E+09	2.4E+09	9.0E+09	1.2E+11
Total Reductions	Reduction Load	2.8E+12	5.1E+10	3.2E+10	4.2E+12	2.0E+12	2.9E+10	6.7E+11	9.70E+10	4.7E+11	1.0E+13

Table 30 - 2030 source reduction loads by source and attainment area

		OSSFs	WWTFs	SSOs	Dogs	Cattle	Horses	Sheep/ Goats	Deer	Feral Hogs	Total
Lake Creek Above Mound Creek	Source Load	3.2E+12	2.2E+10	9.7E+08	9.8E+12	8.1E+12	1.0E+11	2.5E+12	1.4E+11	1.3E+12	2.5E+13
	% Total Load	12.7%	0.1%	0.0%	38.9%	32.1%	0.4%	10.1%	0.5%	5.1%	100.0%
	Reduction Load	9.9E+11	6.8E+09	3.0E+08	3.0E+12	2.5E+12	3.1E+10	7.9E+11	4.2E+10	4.0E+11	7.8E+12
Lake Creek Below Mound Creek and West Fork	Source Load	1.6E+13	2.3E+11	1.5E+11	2.2E+13	9.2E+11	1.6E+10	2.9E+11	2.0E+11	5.6E+11	4.1E+13
	% Total Load	39.1%	0.6%	0.4%	55.0%	2.3%	0.0%	0.7%	0.5%	1.4%	100.0%
	Reduction Load	1.1E+13	1.5E+11	1.1E+11	1.5E+13	6.4E+11	1.1E+10	2.0E+11	1.4E+11	3.9E+11	2.8E+13
Crystal Creek	Source Load	2.1E+12	1.7E+10	6.1E+09	9.8E+11	2.9E+11	3.7E+09	9.2E+10	4.1E+10	1.3E+11	3.7E+12
	% Total Load	57.6%	0.5%	0.2%	26.6%	7.9%	0.1%	2.5%	1.1%	3.6%	100.0%
	Reduction Load	1.0E+12	8.3E+09	3.0E+09	4.8E+11	1.4E+11	1.8E+09	4.5E+10	2.0E+10	6.5E+10	1.8E+12
Total Reductions	Reduction Load	1.3E+13	1.7E+11	1.1E+11	1.9E+13	3.3E+12	4.4E+10	1.0E+12	2.0E+11	8.6E+11	3.8E+13

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 are an average, quantifiable component of each bacteria source. For example, solutions targeting waste reduction for pet dogs would be scaled based on a representative unit of a single dog (i.e. if one had to reduce 10 hypothetical units of bacteria, and each dog represented one hypothetical unit, then one would need to address 10 dogs). Table 31 represents the representative units for each bacteria source, their per unit bacteria source load, and the number of representative units that would need to be addressed in each attainment area. The representative unit load is the full SELECT loading rate (i.e. not reduced for being outside the buffer area). In the case a specific solution is sited in an area outside the riparian buffer, the number of representative units will be less than the actual number of units to address. Likewise, for any solution with a reduction efficiency of less than 100%, the number of actual units to address will be more than the representative units.

Table 31 - Representative units to address in 2030, by attainment area

Bacteria Source	Representative Unit	Representative Unit Daily Load	Units to Address (2030)		
			Lake Creek	West Fork	Crystal Creek
OSSFs	1 Failing OSSF[92]	3.70E+9	304 (292)	3076 (3038)	298 (292)
WWTFs	1 million gallons of effluent[93]	9.54E+9	0.7	16.3	0.9
SSOs	1 SSO[94]	4.93E+9	1	22	1
Dogs	1 dog	2.50E+9	1213	6164	192
Cattle	1 cow	2.70E+9	928	236	53
Horses	1 horse	2.10E+8	148	52	9
Sheep/Goats	1 sheep or goat	9.00E+9	88	23	5

[92] The OSSF numbers are increased to cover the deer reduction loads, per stakeholder preference. Deer loadings are shown, but no units will be addressed.

[93] This representative unit assumes of effluent discharged at twice the standard, as requested by the stakeholders. Additionally, this represents total volumes, not daily flows. Reductions here should not be taken to indicate reduction of actual volumes, but reductions of the load from volumes equivalent to a reduction of volumes (i.e. a decrease in load/concentration in existing volumes that would be equivalent to reducing a volume discharging at 252 cfu/100 ml.)

[94] This representative unit is based on the daily load of an average SSO reported in the SSO data evaluated. The unit is still a single SSO, but the load from that SSO is spread out over 365 days to match the source load daily average.

Bacteria Source	Representative Unit	Representative Unit Daily Load	Units to Address (2030)		
			Lake Creek	West Fork	Crystal Creek
Deer	1 deer	1.75E+8	NA (11.37)	NA (37.29)	NA (5.39)
Feral Hogs	1 feral hog	4.45E+9	90	87	15

The solutions for livestock are based in large part on the implementation of WQMPs and similar conservation plans through TSSWCB and USDA 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 SWCDs 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 (Table 32).

Table 32 - Agricultural plans to address livestock loads (2030)

Attainment Area	Total Livestock Units to Address	Total Plans (rounded up to the nearest plan)
Lake Creek	1,164	24
West Fork	311	7
Crystal Creek	67	2

The cumulative impact of the recommended solutions identified in Sections 5 and 6 will be to address the number of representative units identified in Table 31. The solution, or alternatives identified in future WPP revisions, will meet the load reductions required to meet the SWQS. Where a solution indicates a pollutant removal efficiency of less than 100%, the number of representative units it addresses will reflect the actual removal efficiency (e.g., if a pet waste station removes 50% of the load from 2 actual dogs, it will represent removal of one representative unit for dog waste, or one representative dog).

LDCs for DO

The purpose of the DO LDCs was to evaluate the flow conditions in which DO was depressed, and to generate improvement goals[95].

LDCs for DO were conducted in the same manner as those for bacteria, using the same locations and methodology. The primary difference between these two analyses was that the LDCs for bacteria were used to indicate percent reduction of instream loads, which then translated into source load reduction

[95] Unlike bacteria, DO is a condition rather than a pollutant. It cannot be "reduced", as it inherently indicates too little of a substance is present.

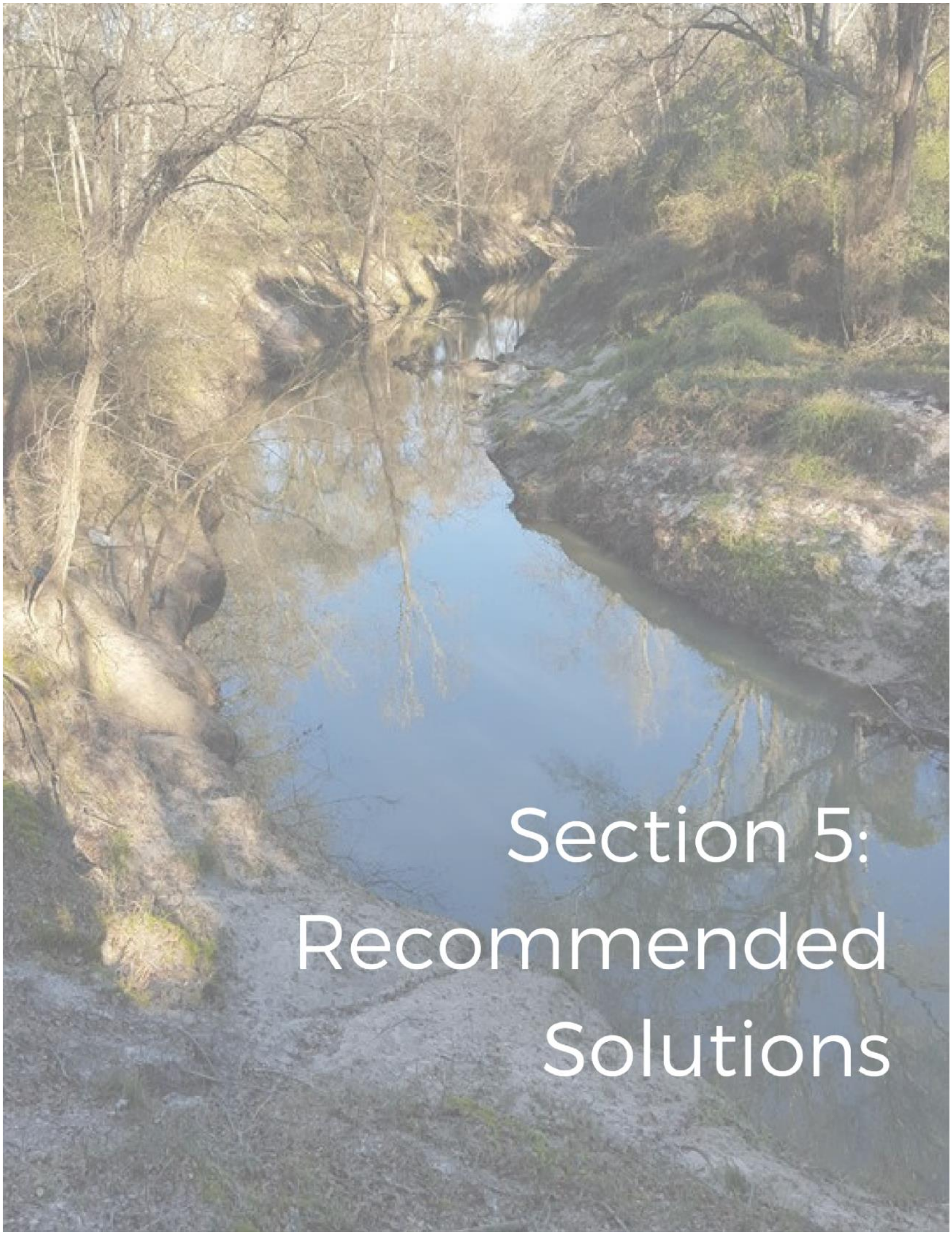
targets. Because DO is the product of multiple precursors, a direct linkage to the nutrient source modeling could not be made in the same way the bacteria LDCs and SELECT were linked. Instead, the area of noncompliance for the DO LDCs were intended to be the set improvement goals, expressed solely as a percent needed improvement.

However, despite the persistent concern for the screening level grab sample, the LDCs for the grab minimum indicated that there was no reduction needed as the current data did not indicate impairment.

The full DO LDCs for each station are in Appendix B.

While the current data may indicate that DO is not at risk of becoming impaired, it is likely a screening level concern for Lake Creek will persist. With the addition of appreciable source by 2030, there is potential for a DO impairment in the future.

Figure 65 - Moonrise over W.G. Jones State Forest


Section 5:
Recommended
Solutions

5 – Recommended Solutions for Water Quality Issues

Concern into Action

Sources of pollution in the watersheds of the West Fork 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[96] 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 bacteria reductions 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 5 links these activities to corresponding education and outreach elements and Section 6 details the timeline and milestones associated with implementation.

Figure 66 - Volunteers collecting trash along waterways

[96] In WPPs, TMDL I-Plans, and other watershed restoration work, solutions are often referred to as best management practices (BMPs), implementation activities (IAs), or management measures. In this WPP these efforts are referred to generally as "solutions". The stakeholders preferred to put an emphasis on outreach that avoided jargon and terms of art such as these.

Identifying Solutions

Guiding Principles

As detailed in Section 1 (pp. 7-8), the stakeholders established six guiding principles for the recommendations of the WPP. The focus on 1) recognizing the uniqueness of the waterways in the system; 2) making decisions locally; 3) using voluntary solutions; 4) utilizing proven strategies; 5) incorporating a strong education and outreach campaign; and 6) having respect for private property, 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.

Identifying Potential Solutions

Stakeholders reviewed a wide range of potential solutions, starting with those identified in existing projects[97] and ongoing local efforts[98]. The diversity of pollutant sources in the watershed required that stakeholders consider an equally wide range of potential solutions sufficient to address each source[99] in proportion to the prominence of the source. This palette of potential solutions served as a starting point for local customization and 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 primary focus of the discussions was solutions to reduce bacteria loads, with the assumption that most of the bacteria 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. Some solutions identified during the project were completed prior to the end of the WPP development process but are reflected here to indicate their role in implementation.

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, or changing conditions.

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 the

[97] 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 East and West Forks of the San Jacinto River TMDL project now rests.

[98] Including planned or potential activities of local partners like the watershed stormwater utilities, the City of Conroe, Bayou Land Conservancy, Montgomery County, et al.

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

enhancement or supplement of existing efforts before the addition of new elements. High priority was places on those solutions that:

- had funding sources that could be linked to them;
- served multiple benefits (e.g., vegetative riparian buffers that reduce the transmission of bacteria 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;
- respected community values of private property, etc.; 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.

Figure 67 - Stakeholders consider potential solutions

Recommended Solutions

In developing the solutions, the stakeholders considered the purpose of the solution, the scope of its implementation, the responsible parties, the period in which it would be implemented[100], the contaminants addressed, its status as either an existing or new effort, the technical and financial resources needed for implementation, and its potential for bacteria reduction. The solutions will be implemented together, or in phases, such that they cumulatively address the bacteria reduction goals

[100] The period represented for each solution is the timeframe within the initial 12-year implementation window. Many solutions will likely continue to be implemented as ongoing efforts or as needed to maintain water quality after that point.

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.

On-site Sewage Facilities (OSSFs)

Failing OSSFs are a priority source due to their large share of overall bacteria loading, and the high potential of human waste to endanger health. The general intent of the stakeholders was to prioritize failing systems that are unlikely to be addressed otherwise, and to attempt to prevent future failures through education and outreach to the community and licensed professionals. These solutions are in addition to the existing requirements of Montgomery County/Grimes County, which include mandatory two-year maintenance contracts for new systems, and other authorized agents, and the enforcement thereof. It should be recognized, however, that those efforts are a primary foundation for all other efforts.

The solutions identified by the stakeholders include:

- OSSF 1 - converting OSSFs to sanitary sewer; and
- OSSF 2 - remediating failing OSSFs (repair, replace, pump, decommission);

The priority areas for this solution are all subwatersheds with existing sanitary sewer systems, with a focus on the West Fork attainment area.

Figure 68 - Sewage from a failed septic tank[101]

[101] Image courtesy of Texas A&M AgriLife Extension.

OSSF 1 - 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 Supplemental Environmental Project (SEP) for OSSF remediation[102], 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[103]. Priority should be given to failing systems, and this recommendation only applies where sanitary service is available/feasible.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; Montgomery County; utilities; homeowners	Ongoing-2030	Bacteria, Nutrients	Enhance an existing, ongoing effort.

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources include available staff at local governments, H-GAC, and Montgomery County 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.	• Estimated costs of converting a residence to sewer service - $3,000. No specific number of OSSFs is slated for this specific action (see OSSF 2). • Funding sources: Homeowner, H-GAC SEP.

Bacteria Reduction Capability

This solution is expected to provide 100% removal rate by actively converting systems to alternate service.

[102] H-GAC's SEP is used to remediate, repair, pump, or decommission OSSFs for homeowners making less than 80% of the Area Median Income.
[103] The City of Conroe does not currently allow new septic systems in areas that are served by the city.

OSSF 2 – Remediate Failing OSSFs

Purpose: Reduce bacteria and nutrient contributions from failing OSSFs.

Description: H-GAC will work with Montgomery County and OSSF owners to inspect and remediate failing systems through pumping, repair, replacement, or abandonment/conversion to sanitary sewer. H-GAC will use Supplemental Environmental Program (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.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; homeowners; Montgomery County (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
Data on OSSF locations will come from H-GAC's regional OSSF database, Montgomery County, local utilities (including SJRA), 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 highly variable and is not included in cost estimates. The funding sources identified are CWA §319(h) grants; H-GAC OSSF SEP (for remediation); authorized agent internal funding; and homeowner contributions.	Estimated costs • Average cost[104] of $5,000. • Total cost of $18,170,000 for 3,634 systems. Funding Sources • H-GAC SEP, Homeowner, Other grants (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.

Proposed siting of OSSF implementation projects is summarized in Table 33[105].

[104] 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.

[105] The number of OSSFs designated to be addressed by subwatershed is based on each subwatershed's proportional contribution to the total OSSF 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

Table 33 - Proposed siting for OSSF solutions by subwatershed

Attainment Area	Total OSSFs to Address	Subwatershed	OSSFs to Address per Subwatershed
Lake Creek above Mound Creek	304	SW1	12
		SW2	5
		SW3	20
		SW4	8
		SW5	8
		SW6	15
		SW7	42
		SW8	194
Lower Lake Creek and the West Fork	3076	SW9	571
		SW10	333
		SW11	116
		SW12	954
		SW14	410
		SW15	692
Crystal Creek	298	SW13	298

each segment area. Therefore, actual implementation in each subwatershed may differ from these targets based on opportunities and changing conditions in the watershed.

Wastewater Treatment Facilities (WWTFs) and Sanitary Sewer Overflows (SSOs)

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 in dealing with WWTF operation and SSOs, the responsibilities for these recommendations will largely fall to the local utilities like the City of Conroe, the Woodlands Township, SJRA, and local MUDs, many of whom are actively engaged in these efforts. Priority is placed on aging systems, smaller systems with less oversight, systems with chronic issues, or facilities located in floodplains vulnerable to storm events.

These recommendations are in supplement to the existing day-to-day operations of the WWTFs in the area. The focus areas are the West Fork and Crystal Creek attainment areas. The recommendations for WWTFs and SSOs:

- WWTF/SSO 1 – Address problem plants;
- WWTF/SSO 2 – Address collection system SSOs;
- WWTF/SSO 3 – Enhance lift station backup capacity;

WWTF/SSO 1 – Address Problem Plants

Purpose: To increase oversight of facilities with discharge violations

Description: The Partnership will recommend to TCEQ that they increase testing and oversight of any plants that develop chronic problems meeting their permit requirements. The Partnership will recommend to problem facilities that they increase testing and/or make operational adjustments.

Responsible Parties	Period	Contaminant Addressed	Status
TCEQ; utilities	2018-2022	Bacteria, Nutrients	Extends existing oversight functions; potential enhancement to existing operations

Technical and Financial Resources Needed	Estimated Costs and Funding
The technical resources needed to fulfill these recommendations are additional enforcement staff for TCEQ, and sufficient utility staff to handle increased testing and/or addressing system elements. Financial resources needed for this recommendation are highly variable, but include TCEQ staff time costs, utility staff time costs, and potential changes to system elements.	Variable (see resources section)

Bacteria Reduction Capability

This activity does not directly reduce bacteria, but it does facilitates other activities (oversight of chronic sources).

WWTF/SSO 2 – Address Collection System SSOs

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, considering grease trap inspections, and evaluating storm preparation protocols. Utilities will also consider participation the TCEQ's Sanitary Sewer Overflow Initiative (SSOI).

Responsible Parties	Period	Contaminant Addressed	Status
Utilities; TCEQ; TWDB	2018-2030	Bacteria, Nutrients	Enhance existing efforts.

Technical and Financial Resources Needed

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 borne by utilities directly, but potential funding sources include Texas Water Development Board (TWDB) loans or grants. Costs are highly variable. 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 and Funding

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 projects include mid-sized cities who spend $1,000,000-5,000,000/year on addressing aging systems.

Funding sources include government revenue and TWDB loans/grants.

Bacteria Reduction Capability

This activity is expected to reduce SSO activity at chronic locations. Efficiency is variable depending on extent and nature of implementation.

WWTF/SSO 3 – Enhance Lift Station Backup Capacity

Purpose: To enhance backup for lift stations in collection systems to prevent SSOs

Description: 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 enhance their backup capacity (generators, bypass pumps, etc.) for their lift stations to ensure continuity of operations during power outages or other events. Utilities may wish to reduce lift stations in general. The City of Conroe is actively in the process of upgrading their generator capacity along these lines.

Responsible Parties	Period	Contaminant Addressed	Status
City of Conroe; other public utilities; TWDB (granting)	2018-2030	Bacteria, Nutrients	Existing effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources for remediating SSOs include sufficient staff capacity to evaluate lift station capacity, implement capital projects, and/or make recommendations on operational changes. Staff costs are variable dependent on the size and scope of the capacity project and staff involvement. Financial resources for enhancing lift station capacity are borne by the City of Conroe and other utilities. Additional financial resources may be available through TWDB loan and grant programs.	Variable, depending on scale (see Resources). Funding sources include government revenue and TWDB loans/grants.

Bacteria Reduction Capability

This activity is expected to reduce SSO activity by ensuring lift station functionality and preventing overflows during power outages. Based on SSO data reviewed for this WPP, between 2-25% of SSOs are related to power failure at lift stations. Therefore, the efficiency of removal of SSO waste is between 2-25%.

Dog Waste

Waste from both pet and feral dogs is a substantial source of bacteria and nutrients in the West Fork watersheds, especially in the urban centers. The general focus of the recommended solutions is to enhance existing pet waste reduction efforts, install new structural elements, and promote spay/neuter. The implementation of these tasks is designed to focus on making pet waste reduction easy and visible to dog owners, especially in public places.

Figure 69 - Pet waste station in public area

The solutions recommended by the stakeholders include:

- Pet Waste 1 - installing pet waste stations in local areas;
- Pet Waste 2 - adding dog parks or dog areas in public places; and
- Pet Waste 3 - holding spay/neuter clinics to reduce feral populations.

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 in subwatersheds 9-14. 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 20 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 City of Conroe and other municipal parks (e.g., McDade Park), Woodforest and other neighborhood parks, and new development. Mobile stations at large events are another avenue.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; local government and neighborhoods	2018-2022, (installation). 2022-2030 (ongoing use)	Bacteria, Nutrients	Expand on existing efforts.

Technical and Financial Resources Needed

Resources required are limited to adequate staffing commitment to install and maintain the sites, functions within the scope of the partners' existing capabilities.

Funding resources are needed for the purchase of the stations and initial materials (identified sources include 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 319(h) grants). Alternative funding sources for initial materials include partnerships with local industry/commercial entities or park volunteer groups.

Estimated Costs and Funding

Pet Waste Stations

- Installation costs of $150 per station, $50 in bags, $200 in labor and materials (total $8,000)
- Maintenance - $300/year per station ($6,000 for 10-year period)
- Total cost of $14,000.

Mobile stations at events

- Costs variable depending on number and type of stations.

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 1,000 dogs, or 500 representative units, addressed. This would represent a daily bacteria reduction of 1.25E+12.

Pet Waste 2 – Expand Dog Parks

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 in their parks or developing new specific dog parks. Dog park areas already exist in the watershed (City of Conroe Wiggins Village and Kasmiersky Parks, among others). McDade Park and other parks adjacent to waterways are prime locations for dog parks or off-leash areas with waste stations, based on available funding and recreational use (no current plans or funding exist for these locations). Newly developing private communities (e.g., Grand Central Park) with strong amenity focuses are also potential opportunities. Priority areas are based on highest potential use/traffic and population served.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; local government; HOAs; Developers; TPWD (granting); TCEQ (granting)	2018-2022 (1 new park area), 2023-2026 (another)	Bacteria, Nutrients	New/expanded effort

Technical and Financial Resources Needed

Technical resources needed are sufficient staff capacity for local governments or 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 (319(h), TPWD) and private endowments, and partnerships with organizations like the Trust for Public Land, et al.

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.

Estimated Costs and Funding

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. However, these may not be indicative of actual area costs. Potential funding sources include municipal funding, 319(h) grant funding, TPWD park grant funding.

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.

Pet Waste 3 – Promote Spay/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[106]. 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 and HOAs.

Responsible Parties	Period	Contaminant Addressed	Status
Service provider (such as SPCA or similar); H-GAC; local government/HOA (venue/promotion)	2018-2030, every 5 years	Bacteria, Nutrients	New effort

Technical and Financial Resources Needed

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.

Funding for the events has been proposed for a combination local government funds, 319(h) grant funds, 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.

Estimated Costs and Funding

Estimated costs for Spay/Neuter education events are $5,000/event, $15,000 total; Estimated costs of spay/neuter for owners at $50-$150 per animal.

Funding sources include pet owners, grant funding, local governments/HOAs

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 5 years or less[107]. Even with a low feral survival rate, this is an appreciable, if not directly quantifiable, reduction.

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[106] The City of Conroe already has requirements for spaying and neutering pets.

[107] http://www.wideopenpets.com/how-many-babies-can-these-pets-have-in-a-lifetime/

Urban 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 by vegetation, etc. 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 the Texas Commission on Environmental Quality's General Permit (TXR040000). The permits require stormwater utilities to address sources of pollutants they may discharge to impaired waterways[108]. The recommendations of this WPP are not designed to supplant the existing efforts of the MS4s in the watershed. It is intended to supplement those activities, which form the basis of stormwater quality management in the area[109], The MS4s' activities are likely to have the most impact on bacteria and nutrient levels in the West Fork and lower Lake Creek. In addition to MS4 permit activities, the stakeholders recommended several additional solutions, including:

- Urban Stormwater 1 - Investigate drainage channels;
- Urban Stormwater 2 - Promote and implement riparian buffers;
- Urban Stormwater 3 – Install stormwater inlet markers;
- Urban Stormwater 4 – Promote Low Impact Development

Figure 70 - Organic debris in storm drain

A heavy focus of this category are education and outreach activities, as reflected in Section 6. The focus areas for implementation are the urbanized areas of subwatersheds 9-14.

[108] More information on the permits can be found at http://www.tceq.state.tx.us/permitting/stormwater.

[109] 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.

Urban Stormwater 1 – 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 "hotspots" and coordination of follow-up to anything found would be efforts above and beyond permit requirements. The model for this recommendation are similar TCEQ/GBEP projects[110] identifying high bacteria load streams in the Houston urban area. This effort can be paired with monitoring activities. The Conroe urban area, I-45 corridor, and development in the southwestern Lake Creek watershed (Mound/Fish Creek areas) would be opportune sites.

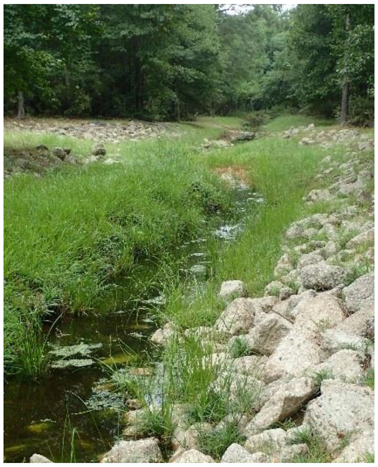
Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; MS4s; Montgomery County; TCEQ: GBEP	2018-2022	Bacteria, Nutrients, Sediment, Trash	New or expanded effort

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 county 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 (see Section 6).	Estimated Costs: • Hourly cost of $25-35 for staff time and overhead. • Total cost dependent on scale of effort. A $20,000 project could fund 2-300 hours of field investigation and follow-up. Funding sources include grants (319(h), GBEP), MS4s,

Bacteria Reduction Capability

This activity is expected to have an indirect impact on bacteria, nutrients and sediment by identifying potential sources, which would then be referred to responsible enforcement jurisdictions.

110 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.



Urban Stormwater 2 – Promote and Implement Urban Riparian Buffers

Purpose: To reduce pollution from sheet flow by maintaining or restoring riparian buffers where appropriate.

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, 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.

Responsible Parties	Period	Contaminants Addressed	Status
H-GAC; MS4s; local governments; TPWD (grants); TCEQ (grants); TFS (forestry technical support); NGOs; private landowners/businesses	2018-2030	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[111]. 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	Estimated costs vary greatly depending on the size and type of project. Funding sources include 319(h) grants; NGO/endowment funding, TPWD grants; private land investment; local government 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.

[111] 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 http://texasforestservice.tamu.edu/LandownerAssistance/

(Image courtesy SJRA)

Urban Stormwater 3 – 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 and neighborhoods. Local organizations (SJRA, Montgomery County, The Woodlands, MS4s, etc.) have existing programs for this purpose. This solution reflects partners intent to continue or expand programs (including SJRA potential expansion to the full West Fork watershed). Inlet markers will be installed based on the requirements of the specific jurisdictions.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; MS4s; Montgomery County; local municipalities; SJRA	2018-2022	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 local government/organization funding, 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.

Bacteria Reduction Capability

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

<table>
<tr><td colspan="2" rowspan="3"></td><td colspan="3">Urban Stormwater 4 – Low Impact Development</td></tr>
<tr><td colspan="3">Purpose: To reduce pollutants in stormwater flows through infrastructure that mimics or improves on natural hydrology.</td></tr>
<tr><td colspan="3">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 model materials on our website, through coordination 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.)</td></tr>
<tr><th>Responsible Parties</th><th>Period</th><th>Contaminant Addressed</th><th colspan="2">Status</th></tr>
<tr><td>H-GAC; MS4s; Montgomery County; local municipalities; SJRA</td><td>2018-2030</td><td>Bacteria, Nutrients, Sediment, Trash</td><td colspan="2">New or expanded effort</td></tr>
<tr><th colspan="4">Technical and Financial Resources Needed</th><th>Estimated Costs and Funding</th></tr>
<tr><td colspan="4">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.</td><td>Costs for promotion are included in the general duties of a watershed coordinator, and do not represent appreciable additional costs. Costs for implementation are dependent on the projects undertaken by local partners.</td></tr>
<tr><th colspan="5">Bacteria Reduction Capability</th></tr>
<tr><td colspan="5">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.</td></tr>
</table>

Agricultural Operations

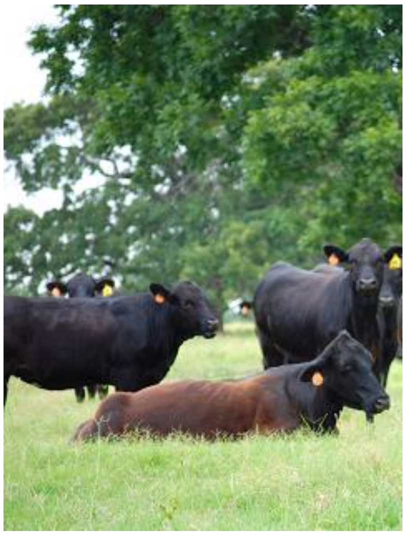
Agriculture is still a strong presence in the watersheds, despite declines in recent years. Legacy agricultural areas in the West Fork watershed and broader areas in production in the western reaches of the Lake Creek watershed maintain healthy populations of livestock in addition to row crops and some timber. While modern agricultural practices are often efficient in reducing bacteria and nutrient transmission to waterways, loads from cattle, horses, and 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 the TSSWCB, USDA NRCS, and AgriLife Research and Extension in coordination with local producers. 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 are made with strong respect for private property and for the benefit well-run agricultural lands provide for a developing watershed.

Figure 71 - Horses in Lake Creek

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 best management practices (BMPs) where appropriate. The focus area for these solutions are subwatersheds 1-8. Recommended solutions include:

- Agricultural Operations 1 - Development of land management plans including TSSWCB Water Quality Management Plans (WQMPs) and NRCS Conservation Plans;
- Agricultural Operations 2 - Implementing other land management techniques through financial assistance and technical programs;

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 NRCS and TSSWCB offer agricultural producers technical assistance as well as financial assistance for "on-the-ground" implementation. To receive financial assistance from TSSWCB, the landowner must develop a Water Quality Management Plan (WQMP) with the local Soil and Water Conservation District (SWCD) that is customized to fit the needs of their operation. The NRCS offers options for development and implementation of both individual practices and whole farm conservation plans. 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[112]. Examples of these practices include but are not limited to filter strips, riparian buffers, prescribed grazing, and alternative shade and water. Additional information on the practices is included in Appendix C. Similarly, the USDA NRCS offers conservation planning services through its Conservation Technical Assistance program[113] 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[114].

Responsible Parties	Period	Contaminant Addressed	Status
TSSWCB; SWCDs; USDA NRCS; agricultural producers/landowners; H-GAC	2018-2030	Bacteria, Nutrients, Sediment, Pesticides	Ongoing and expanded effort

[112] More information on the WQMP program can be found at http://www.tsswcb.texas.gov/en/wqmp.
[113] More information on the CTA and other NRCS programs can be found at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/cp/
[114] More information on NRCS programs can be found here: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/

<table>
<tr><th colspan="2">Agricultural Operations 1 – WQMPs and Conservation Plans (continued)</th></tr>
<tr><th>Technical and Financial Resources Needed</th><th>Estimated Costs and Funding</th></tr>
<tr><td>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 the WQMPs to landowners.

Financial resources required for this solution vary based on the type and scope of plan implemented. Costs for implementing WQMPs is 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. As detailed in Table 32 of Section 4, 33 WQMPs or other plans addressing an average of 50 livestock units will need to be implemented.</td><td>WQMPs
• up to $15,000 per WQMP in financial incentives[115]
• Landowner share of costs is variable.
NRCS Conservation Plans
• Estimated at $2,000-$3,000 in NRCS staff time.
• Resident share variable.</td></tr>
<tr><th colspan="2">Bacteria Reduction Capability</th></tr>
<tr><td colspan="2">This solution's bacteria reduction capacity assumes a direct reduction of bacteria loading from lands covered by a WQMP. The specific mix of efforts under a given WQMP may affect the overall efficiency, in conjunction with the nature and location of the property.</td></tr>
</table>

Due to the nature of NPS pollution and differing needs of individual properties, a combination of BMPs is most commonly required to address bacteria loading from agricultural operations. Selection of BMPs for WQMPs or similar efforts is site specific and tailored to address the physical and operational characteristics of the property. Therefore, it is not feasible to attempt to quantify individual BMPs implemented across all plans prior to WQMP development.

However, to optimize the water quality benefits of plan development and implementation, management practices which most effectively control bacteria and nutrients from livestock, and which are near waterways, will be promoted and given top priority. It must also be stressed that WQMP development and subsequent BMP implementation can only be realized with cooperation and discretion of the individual landowner. Subject to the needs of the site, plans may include one or more of the management practices detailed in Appendix C.

[115] This cost values assumes: 1) the maximum cost per WQMP for all WQMPs; 2) that all agricultural operation solutions are handled solely by WQMPs; and that the average size of the existing WQMPs remains standard for future WQMPs. The average size of farms are 96 acres and 248 acres in Montgomery and Grimes counties, respectively.

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 watersheds.

In addition to WQMPs and conservation plans utilized in solution 1, potential methods of implementation include: utilizing conservation easements held by land trusts; voluntary individual landowner implementation; or as part of an NRCS Farm Bill program (e.g., EQIP or similar). Priorities for this solution are expanding buffers in subwatersheds 1-6, 9, and 15; and maintaining buffers in 6, 8, 14, and 15.

Responsible Parties	Period	Contaminant Addressed	Status
Landowners/producers (on a voluntary basis); Bayou Land Conservancy; USDA NRCS; TSSWCB; AgriLife Extension	2018-2030,	Bacteria, Nutrients, organic wastes, pesticides	Expanded existing effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical expertise required includes staff capacity at support agencies to provide technical services to landowners, and technical knowledge for the 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; 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.	Costs greatly variable with type, location, and extent of buffer. Costs may be limited to simply not mowing an area (opportunity cost of productive acreage) to restoration/plantings.

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 high 50%[116] to 95%[117].

[116] 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.
[117] 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 113118.

Feral Hogs

Wildlife and feral hogs are potentially appreciable 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. 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[118]. This WPP recognizes that other wildlife species represent a background level of bacteria (and nutrient) sources that are not quantified in this project, and that are not addressed. However, because these sources are: 1) often beyond the scope of potential solutions, 2) the stakeholders did not identify evidence of other problem species to address, and 3) their waste is a secondary concern to that of human sources; these sources are not included in this WPP.

There are ongoing discussions at the state and national level about alternative means (e.g., chemical controls, etc.) 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 these solutions will be in agricultural and open space areas in which feral hog damage is a potent incentive for landowner participation. Reduction from 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. The focus areas for these solutions are primarily subwatersheds 1-9, and 13-15. However, hog populations are found throughout the project area.

The solution selected for feral hog abatement include:

- Feral Hogs 1 – Remove Feral Hogs

The Partnership's approach to this source category includes a strong focus on education and outreach recommendations, as detailed in Section 6.

[118] A recommendation for outreach regarding deer is included in Section 6. While deer can be removed, they are a managed wildlife species which creates regulatory challenges to widespread removal efforts (absent aggravating factors like presence of Chronic Wasting Disease, etc.). Additionally, deer populations in the models are located in part in suburban and exurban areas where removal programs may not be possible. The stakeholders did not elect to pursue physical solutions for deer waste for these reasons, and for expected lack of public and political will to enact them.

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 watersheds through active hunting and trapping. The primary focus of this effort is voluntary efforts from individual landowners, but the Partnership recommends abatement activities on behalf of local governments, as appropriate.

Responsible Parties	Period	Contaminant Addressed	Status
Landowners; Local governments; Agricultural agencies (technical support)	2018-2030	Bacteria, Nutrients, Sediment	Expansion of existing effort

Technical and Financial Resources Needed	Estimated Costs and Funding
The primary technical resources needed for this solution are technical 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.	Costs vary based on approach. Based on an estimated population of approximately 1000 hogs, an assumed number of 192 to reduce, and an assumption that each trap would serve to reduce five hogs, 39 traps would be needed as a starting point. With an average cost for $1,000, this would represent an annual cost of $39,000[119].

Bacteria Reduction Capability

This solution nominally reduces feral hog waste by a daily *E. coil* load of 3.71E+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 a population maintenance.

[119] 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. Single animal small box traps from $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.

Other Concerns

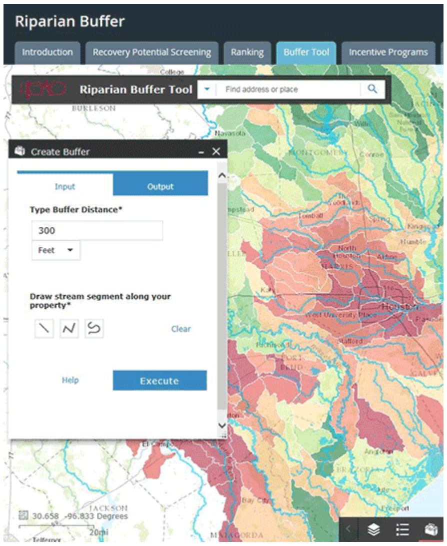
In addition to the practices recommended for specific sources in the preceding pages, the Partnership recommends several solutions to other local concerns. The recommendations fall into two primary categories:

- Land management
  - Land Management 1 – Riparian buffers
  - Land Management 2 – Voluntary conservation
- Trash/Illegal Dumping
  - Dumping 1 – Install cameras for problem areas

Land management activities relate to conserving or developing natural barriers to pollutants entering the water body. These solutions are approached on a completely voluntary basis. Prioritization for areas are riparian corridors in rapidly developing areas (subwatersheds 6-10, 14-15) outside urban centers, and in open space areas in the watershed in general. The West Fork San Jacinto River Greenprint was a local effort that identified stakeholder priority areas for conservation activities in the watersheds, based on potential to positively impact water quality. Early year implementation of the land management activities should refer to this document for potential guidance and analysis of high value conservation areas. However, reference to this conceptual planning tool should not be considered an indication of intent to implement conservation practices in any or all areas it identifies. Conservation practices recommended by this WPP are wholly limited to voluntary landowner decisions supported by resources from local conservation groups (e.g., Bayou Land Conservancy), and the Partnership. The Greenprint should be used as a general area guide, to be further refined by local resident input, concerns, and choices. Of specific concern to the Partnership stakeholders is the need to prevent unintentional consequences of conservation activities for area properties (e.g., trash from recreational uses, etc.) through careful design. 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.

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 TPDES permit activities). Illegal dumping is the primary focus for the Partnership under this category.

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



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 Agricultural Operations 2 – Maintain and Restore Riparian Buffers and Urban Stormwater 2 – Promote and Implement Urban Riparian Buffers.

This solution would engage local landowners to install and/or maintain vegetative buffers along waterways and drainage channels (as appropriate based on drainage needs). This solution includes areas other than urbanized or agricultural lands, and so 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.

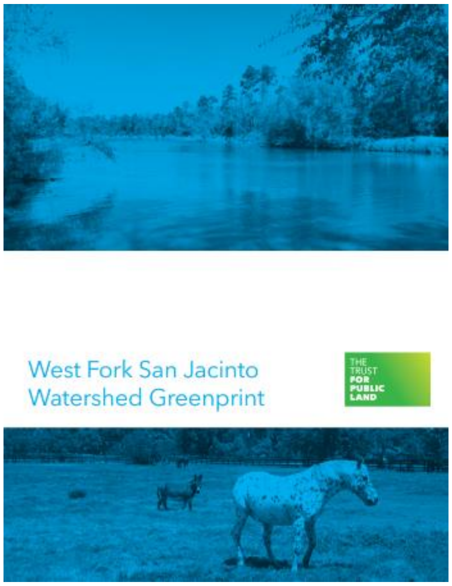
Responsible Parties	Period	Contaminant Addressed	Status
Dependent on location, but may include: H-GAC; USDA NRCS; TSSWCB; Bayou Land Conservancy; local SWCDs; landowners/producers; local governments; industrial partners.	Throughout, with focus on 2018-2023 to prevent degradation	Bacteria, Nutrients, Sediment, Pesticides	New and expanded 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 removing property from other potential uses.	Variable depending on type, size, and location of buffer. Savings in maintenance (mowing, etc.) may counter some potential costs depending on the specific site. H-GAC offers a riparian buffer planning tool for landowners to estimate potential costs[120].

Bacteria Reduction Capability

This solution's efficiency will vary greatly based on the type, and extent of riparian buffer, and the nature of the surrounding land use. 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%.

[120] Available at http://www.h-gac.com/community/water/riparian-buffer-planning-tool.aspx



Land Management 2 – Voluntary Conservation

Purpose: To reduce transmission of bacteria, nutrients, trash and sediment to waterways through voluntary land conservation.

Description: This solution is intended to represent the range of efforts and need for increased voluntary conservation projects as a mitigating factor for new development. This solution has two primary facets:

- Individual conservation – voluntary efforts by local landowners to manage property to maintain natural value;
- Organizational projects – projects by the Bayou Land Conservancy and other organizations in the watershed to acquire voluntary conservation easements.

Responsible Parties	Period	Contaminant Addressed	Status
Landowners, Bayou Land Conservancy, Trust for Public Land, private foundations	2018-2030	Bacteria, Nutrients, Sediment, Pesticides	New and expanded 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 or individual landowner resources to develop and maintain conservation easements or conservation lands.	Variable depending on type, size, and location of properties. Opportunity costs of potential lost economic value in conservation easements may be offset by tax advantages.

Bacteria Reduction Capability

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 between developed land uses and natural land uses. The value of the land conserved and the potential alternative use for the land (e.g. suburban development, etc.) determine the difference in potential transmission.

Illegal Dumping 1 – Install Cameras for Problem Areas

Purpose: To reduce trash in waterways at chronic dump sites by using cameras for enforcement.

Description: This solution is intended to augment existing County and local municipality efforts to reduce illegal dumping by using cameras to identify dumpers[121]. The primary focus of this solution is chronic dump sites, with emphasis on those adjacent or near waterways.

The solution targets installation at three sites during an initial trial period to determine effectiveness.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; Montgomery County; local municipalities	2018-2022 (trial period)	Trash	New and expanded efforts

Technical and Financial Resources Needed

Technical resources needed for this solution are local enforcement capacity, especially through Montgomery County and local municipalities, to enact and implement camera programs. H-GAC's Solid Waste program has previously provided support with similar programs.

Financial resources needed for this solution staff time for local enforcement (variable) and costs of camera technology, which will be provided or augmented by H-GAC.

Estimated Costs and Funding

The incremental costs to local enforcement will be dependent on extent of use; Prior camera programs have spent approximately $1,000 a unit for high end equipment and maintenance.

Bacteria Reduction Capability

This solution's is not expected to directly address bacteria, although it may be an ancillary benefit.

[121] The City of Conroe currently operates a camera program for problem areas as part of code enforcement.

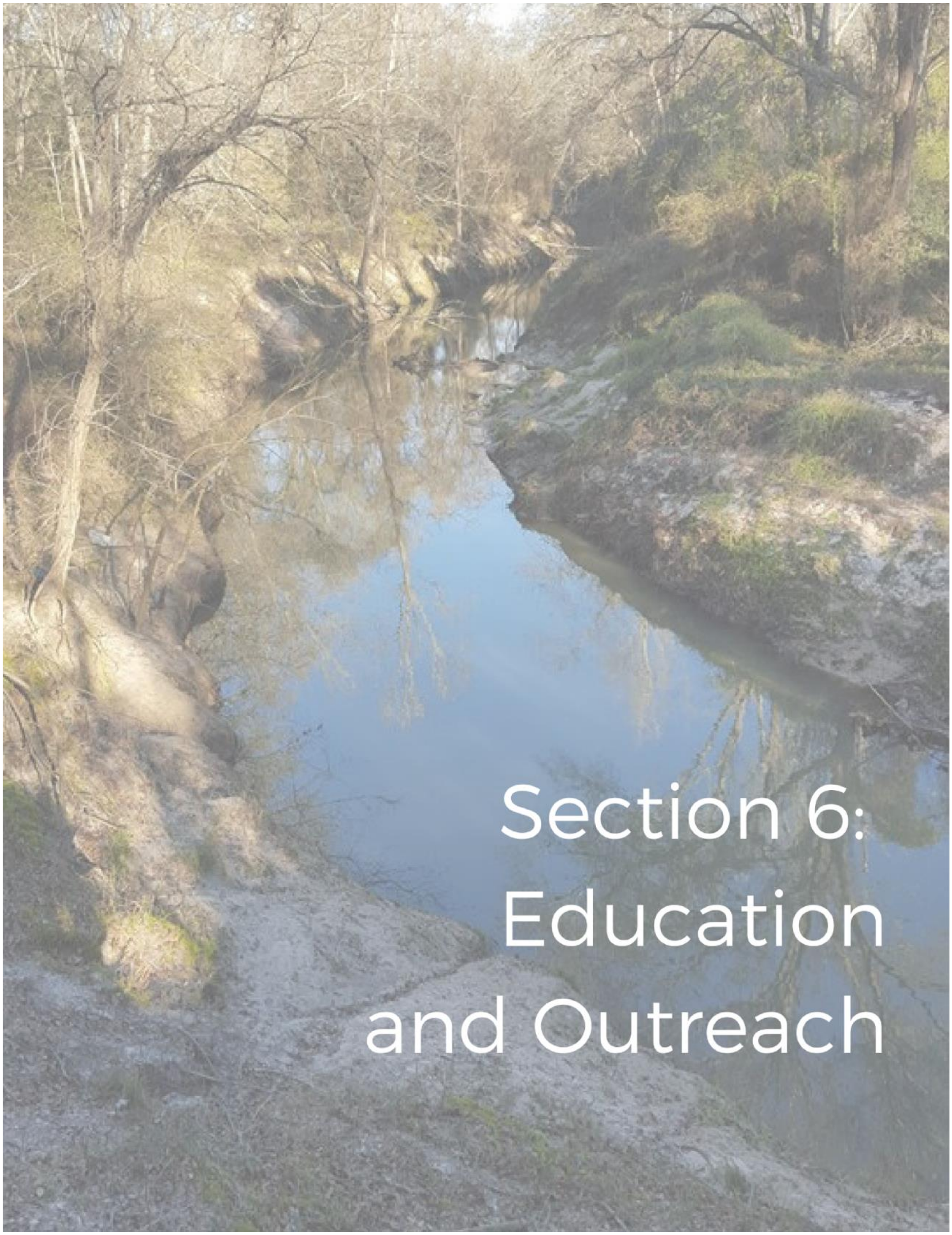
Solutions Summary

The recommended solutions presented in this Section are intended to meet the bacteria reduction goals defined in Section 5 and to also reduce nutrient sources, or to address other local water quality concerns not specifically related to the primary pollutants.

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 watersheds 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.

Figure 72 - Managed lands in W.G. Jones State Forest


Section 6:
Education
and Outreach

6 – Education and Outreach

Engaging both the general public 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 community 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 broad-based and 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 these watersheds is emphasizing the WPP's respect for private property and voluntary solutions.

Figure 73 - Outreach at local events

General Outreach

The Partnership is one of many organizations working toward similar goals in the watershed, but is the primary focal point for 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 seek to supplant existing efforts, but to support them however possible and seek to find opportunities to expand or enhance links to water quality and the goals of the WPP.

Maintaining the Partnership

The Partnership will seek to maintain its varied composition and strong local commitments through continued facilitation of an active group by H-GAC and TSSWCB. 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 and newsletters
- Individual meetings with strategic partners to maintain commitments and coordinate efforts

Building the Brand

The Partnership must maintain a 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 that includes information on the Partnership, the WPP, and their goals.
- Maintain and expand the Texas Stream Team monitoring sites.
- Continue to maintain the project website and social media.
- Actively support local partners.

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's role. To accomplish this goal, the Partnership will:

- Maintain a regional presence with participation in collaboration groups like the Texas Watershed Coordinator's Roundtable, Regional Watershed Coordinators Steering Committee, Galveston Bay Estuary Program, Clean Rivers Program, and others.
- Seek to support other area efforts like the Lake Conroe WPP and the East and West Forks of the San Jacinto River TMDL.

- Identify and/or pursue funding opportunities that would assist local partners in opportunities of shared interest.
- Pursue additional data necessary to inform stakeholder decisions or evaluate progress[122].

Figure 74 - Brand as a focal point for coordination

Existing Outreach in the Watersheds

Many local stakeholder organizations and regional, state, and national organizations have ongoing education efforts in the watersheds. 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[123] the entities listed in Table 34.

Table 34 - Outreach partners

Outreach Partner	Focus Areas
Bayou Land Conservancy	Conservation, general outreach
City of Conroe	stormwater, water conservation, parks/recreation, utilities
City of Houston	Source water protection
City of Montgomery	Utilities, general outreach, stormwater
Galveston Bay Estuary Program	Galveston Bay, source water protection
Harris County and Harris County Precinct 4	Riparian corridors, stormwater, general environmental outreach
Houston-Galveston Area Council	Watershed management, water quality, forestry, public outreach
Lake Creek Greenway Partnership	Conservation, general outreach

[122] 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.

[123] 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.

Outreach Partner	Focus Areas
Local HOAs (multiple)	Resident outreach
Local MUDs/Special Districts (multiple)	Utilities, stormwater, general outreach
Local Soil and Water Conservation Districts	Agriculture, land management programs
Lone Star Groundwater Conservation District	Water conservation
Montgomery County	OSSFs, illegal dumping, animal control, environmental enforcement
Other Cities and Communities (Woodloch, Cut and Shoot, Willis, Shenandoah, Porter Heights, Oak Ridge North, Panorama Village).	Utilities, stormwater, general outreach, resident outreach
San Jacinto River Authority	Lake Conroe WPP, water supply, utilities, OSSFs, general education
TCEQ	Water quality, wastewater
Texas A&M University AgriLife Extension/ Texas Water Resources Institute	Agriculture, OSSFs, water quality, land management, feral hogs, riparian buffers
Texas Forest Service	Forestry
Texas Master Naturalists	Environmental education and outreach, habitat
Texas Parks and Wildlife	Wildlife, habitat, water quality
Texas Stream Team	Water quality, volunteering
The Woodlands Township/ Woodland Joint Powers Association	Utilities, forestry, general environmental outreach
Trust for Public Land	Conservation
TSSWCB	Agriculture/silviculture
USDA Natural Resources Conservation Service	Agriculture, land management, habitat
USDA US Forest Service	Forestry

Figure 75 - TWRI Texas Riparian and Stream Ecosystem Workshop

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.

OSSFs

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

1 - Hold residential OSSF Workshops

Both H-GAC and AgriLife Extension have existing OSSF programs aimed at educating the general public and specific audiences like real estate inspectors (H-GAC) 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 a workshop and up and are paid by a mix of existing projects (319(h) grants for both agencies, H-GAC 604(b), and internal organization funding).

2- Hold County-wide OSSF Workshops for Practitioners

Montgomery County holds an annual OSSF workshop for local OSSF practitioners. The Partnership will support the County with publicity and participation. This activity will happen throughout the implementation period.

3- Provide Model Educational Materials[124] 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.

4- 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 five years.

5 - Enhance OSSF Data

H-GAC and Montgomery County will continue to cooperate on development of spatial (GIS) data for permitted OSSFs in the county and make the data available online for local partners (ongoing effort). H-GAC will work with the County and local communities to develop better OSSF data for unpermitted systems by reviewing analyses with local communities for refinement. This latter effort will happen during the first two years of implementation.

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[124] 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.

Wastewater and SSOs

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

1 – Promote Fats, Oils, and Grease (FOG) Awareness

FOG issues are a source of SSOs and operational challenges for local wastewater utilities. Programs like SJRA's No Wipes in the Pipes (Patty Potty)[125] and the regional Galveston Bay Cease the Grease[126] campaign already exist. The Partnership seeks to promote these programs and maintain model materials 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[127]. The promotion will take place throughout the implementation period, and model materials will be added in the first year of implementation.

2 – Promote Floodwater Contact Awareness

Flooding is a repetitive issue in some areas of the watersheds, and floodwaters may contain untreated sewage if collection systems or WWTFs are compromised. Residents in 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).

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:

1 – 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 that serve no implementation purpose, and cost approximately $1.40 each. A standard giveaway would be 100 dispensers per outreach event, on average. For a 12-year implementation period, assuming 6 outreach events per year, this would equate to a cost of $9,936.

2- Elementary School Visits

Elementary-age children are a good candidate for educational programs and can influence activities by 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

[125] http://www.pattypotty.com/
[126] http://ceasethegrease.net/
[127] These efforts are in addition to existing management of utility functions, including the City of Conroe's Industrial Pretreatment Program, which enforces limits of discharge of FOG. These efforts are complementary to proposed activities.

education efforts have included general water quality education with a pet waste message included. Costs for this activity are limited to staff time.

3- 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.

Figure 76 - Pet waste bag dispensers

Urban Stormwater

Education and outreach elements[128] 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 stormwater permits. For these areas, the Partnership will seek to coordinate and support, but will not add additional elements[129]. The Partnership recommends the following activities as specific actions under this WPP:

[128] While inlet stream marking is included in the structural solutions noted in Section 6, this program has a significant education and outreach component and has been successfully used in the watershed to engage organizations and neighborhoods. Implementation of that solution should emphasize its outreach aspects.

[129] Except for promoting LID, as indicated in Urban Stormwater 4 solution in Section 5.

Expand Texas Stream Team Participation

Stream Team[130] 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 like Bayou Land Conservancy foster local volunteers in these efforts. The goal of this element is to increase Stream Team monitoring by 10 volunteers by 2030.

Promote Urban Forestry as a Stormwater Solution[131]

Many of the stakeholders and regional partners in the WPP (e.g., Texas Forest Service) promote urban forestry projects for the ecosystem services[132] they produce. The urbanized areas of Montgomery County were part of the *Houston Area Urban Forests[133]* 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 TFS and USDA USFS. The Partnership will seek to coordinate with ongoing urban forestry projects and programs, 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[134]. Model materials will be hosted on the Partnership website in the first year of implementation, and the Partnership will promote local urban forestry projects.

Figure 77 - Trees as stormwater features

[130] http://www.h-gac.com/community/water/texas_stream_team/default.aspx

[131] These recommendations are supplemental to existing ordinances (e.g., the City of Conroe's Tree Ordinance) that address urban trees. Existing ordinances may be used as model materials.

[132] Including but not limited to flood mitigation, water and air quality improvement, heat reduction, erosion control, atmospheric carbon storage, health benefits, and aesthetic benefits.

[133] www.houstonforests.com

[134] Specific urban forestry practices and technical resources are available from the Texas Forest Service at http://texasforestservice.tamu.edu/abouturbanandcommunityforestry/

Agricultural Operations

A wealth of information and programs exist 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, 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:

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.

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 (e.g., TSSWCB, AgriLife, USDA NRCS, et al.) as a "one-stop shop" for residents to hear about available programs and meet one on one with several agencies.

Land Management

Beyond programs focused on agricultural/silvicultural properties, there are many programs and opportunities that involve promoting or supporting general land management practices that are beneficial to water quality, including Farm Bill programs through NRCS, conservation easements and similar conservation mechanisms. The key focus for water quality are lands adjacent to and including riparian areas on 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:

Promote Riparian Buffers (Tools and Workshops)

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[135] for landowners. Resources will be developed/obtained and hosted during the first year of implementation. The Partnership will seek to promote TWRI's *Texas Riparian and Stream Ecosystem Education Program* and *Urban Riparian and Stream Restoration Program*[136]. Expected frequency is once every five years for these programs. Funding is currently provided by 319(h) grants, and attendee fees.

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[135] http://www.h-gac.com/community/water/riparian-buffer-planning-tool.aspx

[136] TWRI held both programs in the watershed during the WPP development phase. More information is available at http://texasriparian.org/riparian-education-program/

Texas Watershed Stewards

AgriLife Extension's Texas Watershed Stewards (TWS) program is an effective way of developing knowledge among the local communities of watershed issues and actions they can take. A TWS training was held in the watershed during the development of this WPP. The Partnership will work with AgriLife to bring the program back on an expected frequency of every five years.

Feral Hogs

Feral Hog abatement is a strong concern for properties throughout the watersheds, but especially in exurban and rural areas of Lake Creek. Existing outreach programs through AgriLife Extension and other sources are well developed. The Partnership seeks to promote these elements through website, social, media and with event publicity as appropriate. The following programs are of specific interest for the watershed:

Lone Star Healthy Streams –Workshops and Feral Hog Resource Manual

The Partnership will promote the AgriLife Lone Star Healthy Streams[137] 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 Hog Management Workshop

The Partnership will work with Montgomery and/or Grimes County AgriLife Extension to host a local feral hog management workshop. The expected frequency for this element is once every four years.

Deer and Other Wildlife

Although the Partnership elected not to recommend any direct solutions for reducing deer populations, stakeholders expressed concern about the growth of the deer populations in developed areas. As part of general education and outreach, the stakeholders recommended that targeted homeowner education about issues related to feeding deer (outside of a hunting context), especially in exurban and developing areas of lower Lake Creek and the West Fork. While other wildlife species were not addressed in the WPP, stakeholders expressed interest in identifying their contributions to the watershed. The Partnership recommends:

Homeowner Education Materials and Mailing

The Partnership will work with TPWD to develop appropriate materials for homeowners warning against feeding deer. 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.).

Wildlife Source Estimation for Planning

The Partnership will work with AgriLife, Texas A&M University and other academic institutions, and TPWD to determine the feasibility of establishing general or species-based estimates for wildlife populations not usually address 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.

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[137] http://lshs.tamu.edu/workshops/

Trash and Illegal Dumping

In addition to enhanced enforcement, the stakeholders recommended that trash reduction was a local priority and serves as a visible form of outreach. Montgomery and Grimes County, and other local jurisdictions, will continue to enforce dumping issues. In addition, the Partnership recommends:

Trash Bash Site

The Texas Rivers, Lakes, Bays N' Bayous Trash Bash[138] is a one-day trash reduction and community outreach event that takes place throughout the region. Upwards of 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 addition of a site in the watersheds would provide a direct way of engaging the public on visible examples of water pollution, and in providing an accompany water quality message. Initial costs for establishing sites are $5,000; ongoing costs are provided by sponsors and funding through the Texas Conservation Fund.

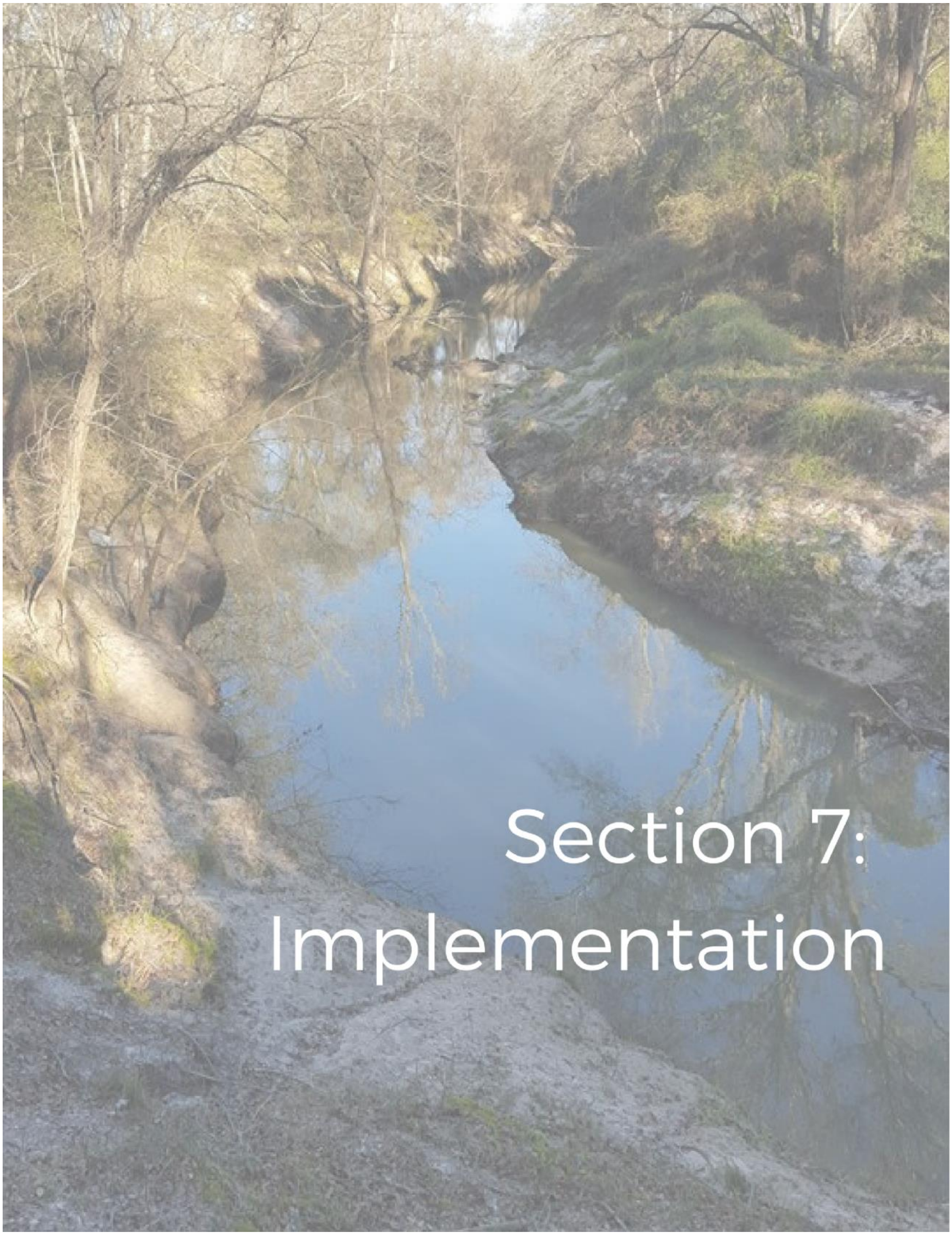
Reporting Portal

The stakeholders identified resident confusion over reporting potential or observed water quality issues to jurisdictions as being an issue of local concern. The Partnership will work with SJRA, City of Conroe, Montgomery County, and other local jurisdictions to develop a reporting portal (either phone, static web, or interactive application based) through which residents could easily identify which entity to call to report dumping or other environmental issues[139].

Figure 78 - Partnership staff engage the public at area events

[138] http://www.trashbash.org/

[139] The inspiration for this element is the GBAN app for the Galveston Bayou Foundation, which allows easy reporting of environmental issues across jurisdictions, but does not extend to Montgomery County.


Section 7:
Implementation

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.

Figure 79 - Sunset in Grimes County

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 unfeasible 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 with a respect for private property;
- siting of solutions that consider local needs and conditions (no "one size fits all"), 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 the greatest pathogenic risk to human health;

- an ongoing focus on adapting plans to meet changing conditions; and
- A special focus on elementary school classrooms for outreach and education.

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 West Fork watersheds. 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 also will work to secure external funding to facilitate implementation activities and coordinate with partner efforts. H-GAC will provide facilitation for the phase of the WPP directly after the submission of the WPP. The Partnership will consider after that point how best to house ongoing facilitation of the Partnership through a watershed coordinator. 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 risk of illness[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 bacteria source. Pet waste represents both a unique challenge and an opportunity because it is a significant contributor, generally concentrated in densely populated areas with higher impervious cover, and a source that's generally under our control as pet owners (as opposed to wildlife sources).

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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 this research can be reviewed at http://oaktrust.library.tamu.edu/handle/1969.1/158640?show=full. (Gitter, 2016).

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:

- **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 sub watersheds 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.
- **Branding –** Recognizable branding or common messaging is beneficial to outreach campaigns. Project partners will seek to develop project specific branding or integrate with existing efforts to increase recognition and attention. For example, "Don't Mess With Texas" is a recognizable brand message even for members of the public who are not involved with trash reduction. It serves as a shorthand for a broader range of efforts.

Timelines for Implementation

Implementation of this WPP is intended to take place over a 12-year initial implementation timeframe (2018-2030), broken into three distinct phases: early (2018-2022), middle (2023-2026) and late (2027-2030). 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. The timelines in Table 35 are intended to reflect the period in which each solution will be implemented, along with the responsible entities and costs they will incur. Solutions in the 2010-2015 range represent partner activities that began or were ongoing during the development of this WPP. Additional information about each solution, its intended implementation, and estimated costs can be found in Sections 5 and 6. This table will be updated as part of future WPP updates, after each implementation phase, or as needs warrant.

Table 35 - Implementation Schedule

Solution Category	Recommended Solution or *Outreach Element*[141]	Responsible Parties	Implementation Period[142]
General	Watershed Coordinator	Partnership[143]	Ongoing
OSSFs	Convert to Sanitary Sewer	H-GAC (SEP); homeowners, Montgomery County (enforcement); utilities	Ongoing
	Remediate Failing OSSFs	H-GAC (SEP); homeowners, Montgomery County (enforcement);	Ongoing
	Hold Residential OSSF Workshop	*H-GAC; Partnership; AgriLife Extension*	*Ongoing - Periodic*
	Hold County Wide OSSF Workshop for Practitioners	*Montgomery County*	*Ongoing - Periodic*
	Provide Model Educational Materials Online	*Partnership*	*Early*
	Texas Well Owner Network Events	*Partnership; TWRI; AgriLife Extension; TSSWCB*	*Ongoing-Periodic*
	Enhance OSSF Data	H-GAC; Authorized Agents	Ongoing
WWTFs and SSOs	Address Problem Plants	TCEQ; utilities	Early (recommendations); Ongoing (actions)
	Address Collection System SSOs	TCEQ; TWDB; utilities	Ongoing
	Enhance Lift Station Backup Capacity	City of Conroe; other utilities;	Early; Middle
	Promote FOG Awareness	*Partnership; SJRA; utilities*	*Ongoing*
	Promote Floodwater Contact Awareness	*Partnership*	*Ongoing*
Pet Waste	Install Pet Waste Stations	H-GAC; local governments; HOAs/neighborhoods	Early (installation); Ongoing (maintenance)

[141] Outreach and Education elements are designated with italics.

[142] Potential periods include Early (2018-2022), Middle (2023-2026), and Late (2027-2030). Projects spanning these are denoted as Ongoing. Items listed with a "-periodic" suffix indicate an outreach element with a periodic frequency.

[143] 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".

Solution Category	Recommended Solution or *Outreach Element*[141]	Responsible Parties	Implementation Period[142]
	Expand Dog Parks	H-GAC; local government; HOAs; Developers; TPWD (granting); TCEQ (granting)	Early (1 new park area); Middle (1 new park area)
	Promote Spay and Neuter Events	SPCA (or similar provider); H-GAC; local government/HOA (venue/promotion)	Ongoing
	Pet Waste Dispensers at Local Events	*Partnership; H-GAC*	*Ongoing*
	Elementary School Visits	*Partnership*	*Ongoing - Periodic*
	Promote Model Educational Materials Online	*Partnership*	*Ongoing - Periodic*
Urban Stormwater	Investigate Drainage Channels	H-GAC; MS4s; Montgomery County; TCEQ/ GBEP (granting)	Early;
	Promote and Implement Urban Riparian Buffers	H-GAC; MS4s; local governments; TPWD (grants); TCEQ (grants); NGOs; private landowners/businesses	Ongoing
	Install Stormwater Inlet Markers	H-GAC; MS4s; Montgomery County; local municipalities; SJRA	Early
	Low Impact Development	H-GAC; MS4s; Montgomery County; local municipalities; SJRA	Ongoing
	Expand Texas Stream Team Participation	*H-GAC; Partnership; Bayou Land Conservancy; Texas Master Naturalists*	*Ongoing*
	Promote Urban Forestry as a Stormwater Solution	*Partnership; Texas Forest Service; H-GAC*	*Ongoing*
Agricultural Operations	WQMPs and Conservation Plans	TSSWCB; SWCDs; USDA NRCS; agricultural producers/landowners; H-GAC	Ongoing
	Maintain or Restore Riparian Buffers	Landowners/producers (on a voluntary basis); Bayou Land Conservancy; USDA NRCS; TSSWCB; AgriLife Extension	Ongoing
	Develop and Implement Education Measures and Materials for Concentrated Livestock Operations (non-CAFO)	*Partnership; TSSWCB; AgriLife Extension*	*Early*

Solution Category	Recommended Solution or *Outreach Element*[141]	Responsible Parties	Implementation Period[142]
	Hold Agricultural Resources Workshops	*Partnership; TSSWCB; AgriLife Extension; USDA NRCS*	*Ongoing - Periodic*
Feral Hogs	Remove Feral Hogs	Landowners; Local governments; Agricultural agencies (technical support)	Ongoing
	Lone Star Healthy Streams – Workshops and Feral Hog Resource Manual	*AgriLife Extension; TSSWCB; Partnership*	*Ongoing - Periodic*
	Feral Hog Management Workshop	*AgriLife Extension; TSSWCB; Partnership*	*Ongoing - Periodic*
Land Management	Riparian Buffers	Dependent on location, but may include: H-GAC; USDA NRCS; TSSWCB; Bayou Land Conservancy; local SWCDs; landowners/producers; local governments; industrial partners.	Ongoing; focus on Early
	Voluntary Conservation	Landowners; Bayou Land Conservancy; Trust for Public Land; private foundations	Ongoing
	Promote Riparian Buffers (Tools and Workshops)	*Partnership; TWRI; TSSWCB/TCEQ (granting)*	*Ongoing - Periodic*
	Texas Watershed Stewards	*TWRI; Partnership*	*Ongoing - Periodic*
Deer and Other Wildlife	*Homeowner Education Materials and Mailing*	*Partnership; TPWD*	*Early*
	Wildlife Source Estimation for Planning	*Partnership; Texas A&M University agencies; other academic institutions; TCEQ; TWDB; TPWD*	*Early; Middle*
Illegal Dumping and Trash	Install Cameras in Problem Areas	H-GAC; Montgomery County; local municipalities	Early (as a trial period)
	Trash Bash Site	*H-GAC; Partnership; SJRA*	*Early (establish site); Ongoing (annual event)*
	Reporting Portal	*Partnership*	*Early*

Interim Milestones for Measuring Progress

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 9), interim milestones measure whether implementation is occurring on schedule. The milestones in Table 36 represent measurable increments of the implementation process.

Table 36 - Interim Milestones for Solutions and Outreach Activities

Solutions[144]	Overall Implementation Goal[145]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
General - Watershed Coordinator	Retain a Watershed Coordinator to manage the day to day coordination, resource identification, and	2019 – The Partnership decides on its intent for facilitation during early implementation	2019 – Funding application is made for a 2020 start date.	2020- Watershed Coordinator position retained.	2022 – Partnership reassess facilitation need after early implementation .
OSSF - Convert to Sanitary Sewer	In conjunction with OSSF-Remediate Failing OSSFs, address 3,678 failing OSSFs.	2022 – 1/3of OSSFs addressed, or failures prevented	2026 – Second third of OSSFs addressed, or failures prevented	2030 – Final third of OSSFs addressed, or failures prevented	
OSSF - Remediate Failing OSSFs	In conjunction with OSSF-Remediate Failing OSSFs, address 3,678 failing OSSFs.	2022 – 1/3 of OSSFs addressed, or failures prevented	2026 – Second third of OSSFs addressed, or failures prevented	2030 – Final third of OSSFs addressed, or failures prevented	

[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 28, and may vary based on opportunity, resources, and regulatory changes in the future. All numeric targets (i.e. x number of dogs) refer to representative units. Actual units addressed may change based on pollutant removal efficiency, location, etc.

Solutions[144]	Overall Implementation Goal[145]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
OSSF - 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.	2022 – two workshops held	2026 – 2 (more) workshops held	2030 – 2 (more) workshops held	
OSSF - Hold County Wide OSSF Workshop for Practitioners	*Montgomery County's annual OSSF workshop provides a point of coordination with practitioners.*	*2030 – Annual meetings [146] have been held.*			
OSSF - Provide Model Educational Materials Online	*Provide model educational materials online to facilitate education by other organizations.*	*2019 – Review existing materials and select suite of model materials*	*2020 – Host materials online; create any materials not already covered.*		
OSSF - Texas Well Owner Network Events	*Educate well owners about potential risks from OSSFs and potential contamination of drinking water wells.*	*2019 – first TWON event held*	*2023 – second TWON event held*	*2028 – third TWON event held*	
OSSF - Enhance OSSF Data	*Provide local decision-makers and the Partnership with accurate data on OSSF locations.*	*2019- begin review of unpermitted systems with local partners*	*2019 – conclude review of unpermitted systems*	*2030 – data updated consistently through period.*	

[146] This education and outreach measure is an activity of Montgomery County. The county may change the nature or frequency of this meeting in the future.

Solutions[144]	Overall Implementation Goal[145]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
WWTF/SSO - Address Problem Plants	Improve treatment of sewage.	2022 – at least one WWTF makes operational/structural changes resulting in effluent improvement	2026 – at least one (more) WWTF makes operational/structural changes resulting in effluent improvement	2030 – at least one (more) WWTF makes operational/structural changes resulting in effluent improvement	
WWTF/SSOs - Address Collection System SSOs	Reduce contamination from human fecal waste by reducing overflows from WWTF collection systems	2022 – eight fewer SSOs occurred than average since 2018	2026 – 16 fewer SSOs occurred than average since 2018	2030 – 24 fewer SSOs occur than average, over implementation period	
WWTF/SSOs - Enhance Lift Station Backup Capacity	Reduce SSOs by enhancing continuity of collection system function.	2022 – at least one utility has reviewed and upgraded backup capacity	2026 – at least two other utilities have reviewed and upgraded backup capacity		
WWTF/SSOs - Promote FOG Awareness	*Reduce SSOs by affecting utility customer behavior regarding FOG.*	*2019 – model materials identified added to website.*	*2030 – consistent promotion with partners throughout implementation period*		
WWTF/SSOs - Promote Floodwater Contact Awareness	*Reduce exposure to bacteria by educating residents about floodwater contact.*	*2019 – model materials identified added to website.*	*2030 – consistent promotion with partners throughout implementation period*		

Solutions[144]	Overall Implementation Goal[145]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Pet Waste - Install Pet Waste Stations	Reduce wastes by facilitating use of bags in public areas.	2022 – at least 20 pet waste stations installed.	2030 – stations maintained by local partners throughout the implementation period.		
Pet Waste - Expand Dog Parks	Increase availability of controlled dog recreation areas to sequester wastes in public areas.	2022 – one new park area developed	2026 – second new dog park areas developed	2030 – third new dog park area developed	
Pet Waste - Promote Spay and Neuter Events	Reduce pollutants from feral populations through voluntary population control.	2022 – one spay/neuter event held	2026 – second spay /neuter event held	2030 – third spay/neuter event held	
Pet Waste - Pet Waste Dispensers at Local Events	*Educate residents about impacts of dog waste and reduce waste in stormwater.*	*2022 – Distribution of 2400 dispensers at 24 local events*	*2026 – Distribution of 2400 (more) dispensers at 24 local events*	*2030 – Distribution of 2400 (more) dispensers at 24 local events*	
Pet Waste - Elementary School Visits	*Educate children on pet waste and other water quality issues.*	*2022 – 4 visits held*	*2026 – 4 (more) visits held*	*2030 – 4 (more) visits held*	
Pet Waste - Promote Model Educational Materials Online	*Provide model materials to facilitate other organizations' education efforts.*	*2019 – Identify needs beyond existing materials*	*2020 – develop and host model materials*		

Solutions[144]	Overall Implementation Goal[145]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Urban Stormwater - Investigate Drainage Channels	Locate potential sources of pollutants in urban channels[147]	2019 – potential priority areas and grant resources identified	2022 – pilot project completed; at least one waterway completed field reconnaissance project.		
Urban Stormwater - Promote and Implement Urban Riparian Buffers	Reduce pollutants in urban sheet flow and erosion through vegetative barriers.	2022 – at least one urban riparian project completed.	2026 – at least one (more) urban riparian project completed	2030 – at least one (more) urban riparian project completed	
Urban Stormwater - Install Stormwater Inlet Markers	Raise awareness and shift behavior of residents served by stormwater systems to reduce pollutants entering drains/waterways.	2022 – at least two neighborhoods have markers added.	2026 – at least 2 (more) neighborhoods have markers added	2030 – at least 2 (more) neighborhoods have markers added	
Urban Stormwater – Low Impact Development	To reduce pollutants in stormwater flows through promoting and implementing infrastructure that mimics or improves on natural hydrology.	2022 – LID materials developed and hosted on website	2026 – at least 1 LID demonstration project installed	2030 – at least 2 LID demonstration projects installed	
Urban Stormwater - Expand Texas Stream Team Participation	*Supplement existing monitoring data with volunteer sites and empower volunteers to acts as water quality ambassadors.*	*2022 – 4 volunteers added*	*2026 – 3 (more) volunteers added*	*2030 – 3 (more) volunteers added*	

[147] 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.

Solutions[144]	Overall Implementation Goal[145]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Urban Stormwater - Promote Urban Forestry as a Stormwater Solution	*Coordinate and promote urban forestry programs and projects for water quality benefits*	*2019 – model materials identified and hosted online*	*2030 – Coordination and promotion consistent throughout implementation period*		
Agricultural Operations - WQMPs and Conservation Plans	Address waste from 1,217 cows, 209 horses, and 106 sheep and goats through 33 WQMPs/Conservation Plans.	2022 – a third of plans (or plans representing a third of the reduction load) addressed by the solution.	2026 – a second third of plans (or plans representing a third of the reduction load) addressed by the solution.	2030 – the final third of plans (or plans representing a third of the reduction load) addressed by the solution.	
Agricultural Operations - Maintain or Restore Riparian Buffers	In conjunction with, or in supplement to, Agricultural Operations - WQMPs and Conservation Plans and Land Management - Riparian Buffers, install or maintain riparian buffers in agricultural areas to reduce transmission of pollutants.	2022 – at least two properties have riparian projects, at least 1 is agricultural	2026 – at least two (more) properties have riparian projects, at least 1 is agricultural	2030 – at least 2 (more) properties have riparian projects	
Agricultural Operations - 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.*	*2019- needs, potential local partners identified.*	*2020 – materials developed and reviewed locally; hosted and disseminated.*		
Agricultural Operations - Hold Agricultural Resources Workshops	*Promote agricultural programs by facilitating one on one meetings with landowners.*	*2019 – first workshop held*	*2022 – second workshop held*	*2025 – third workshop held*	*2028 – fourth workshop held*

Solutions[144]	Overall Implementation Goal[145]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Feral Hogs - Remove Feral Hogs	Implement 39 traps to remove 192 feral hogs from the watershed to reduce pollutants and ancillary damages.	2022 – 13 traps put in place.	2026 – 13 (more) traps put in place	2030 - 13 (more) traps put in place	
Feral Hogs - Lone Star Healthy Streams – Workshops and Feral Hog Resource Manual	*Educate local stakeholders to promote feral hog reduction.*	*2025 – first workshop has been held.*	*2030 – second workshop has been held.*		
Feral Hogs - Feral Hog Management Workshop	*Educate local stakeholders to promote feral hog reduction*	*2022 – one workshop has been held.*	*2026 – second workshop has been held*	*2030 - third workshop has been held*	
Land Management - Riparian Buffers	Promote riparian buffers in all land uses to reduce transmission of pollutants (in conjunction with Land Management – Voluntary Conservation).	2022 – at least two properties have riparian projects	2026 – at least two (more) properties have riparian projects	2030 – at least 2 (more) properties have riparian projects	
Land Management - Voluntary Conservation	Promote voluntary conservation to reduce pollutants from developed areas.	2022 – at least two properties have conservation projects	2026 – at least two (more) properties have conservation projects	2030 – at least 2 (more) properties have conservation projects	

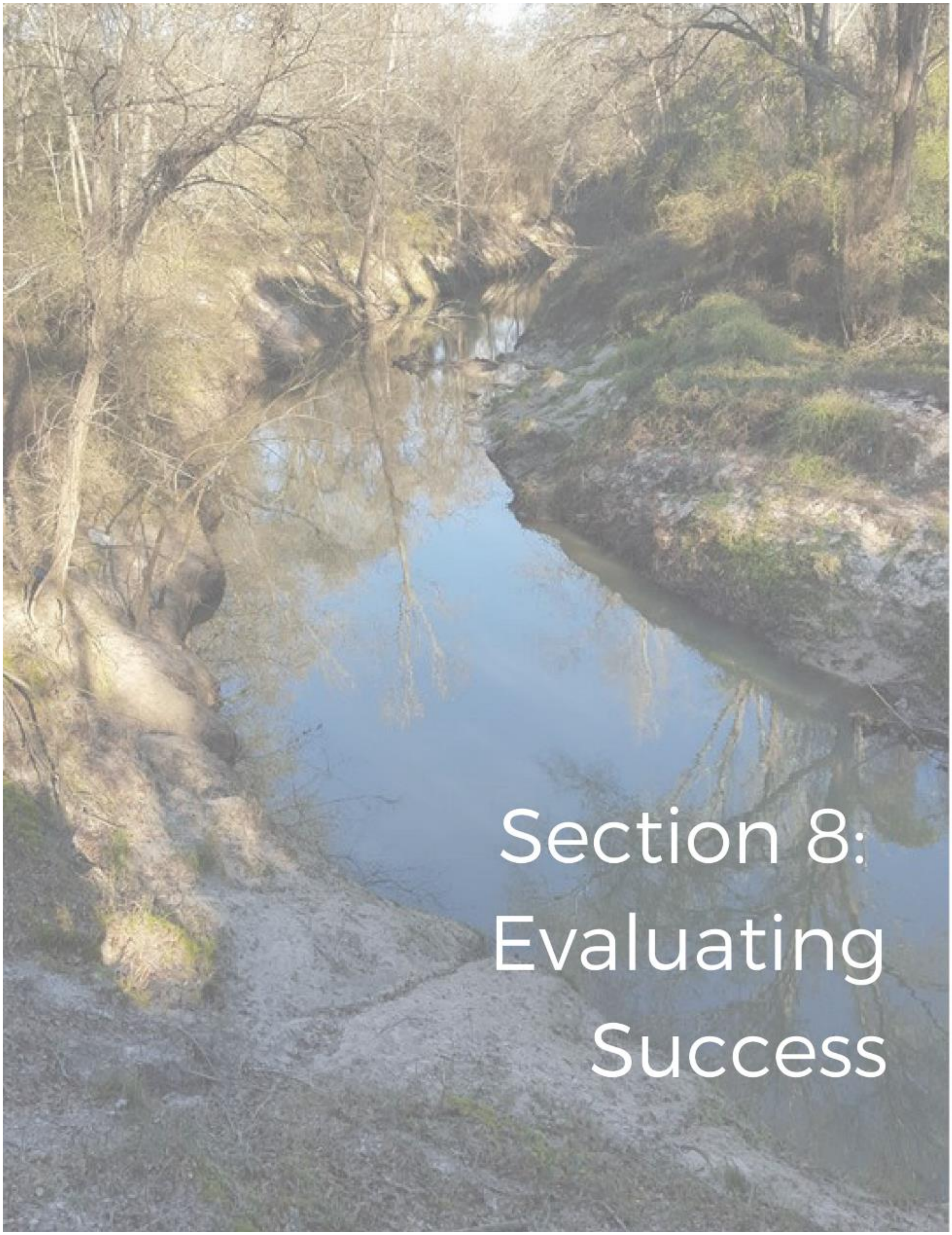
Solutions[144]	Overall Implementation Goal[145]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Land Management - Promote Riparian Buffers (Tools and Workshops)	*Reduce pollutant loads by promoting riparian buffer areas.*	*2018 – hold two workshops*[148]	*2023 – another workshop held*	*2028 – another workshop held*	
Land Management - Texas Watershed Stewards[149]	*Educate stakeholders on water quality/watershed issues.*	*2021 – workshop held*	*2026 – workshop held*		
Deer and Other Wildlife - Homeowner Education Materials and Mailing	*Collect or develop homeowner education materials and develop outreach strategy with local partners to reduce attraction of deer populations to developed areas.*	*2019 – Needs identified, and materials collected or developed and hosted*			
Deer and Other Wildlife - Wildlife Source Estimation for Planning	*Develop better data to further understanding of natural load to waterways to guide future decisions.*	*2019 – potential partners contacted and grant resources reviewed*			
Trash and Illegal Dumping - Install Cameras in Problem Areas	Aid enforcement efforts to reduce trash.	2019 – potential sites and partners identified.	2022 – three sites monitored; pilot results reviewed.		

[148] Two TWRI workshops will have been held in the watersheds in 2018 prior to the approval of this WPP.
[149] A TWS workshop was held in the watershed during the WPP development process.

Solutions[144]	Overall Implementation Goal[145]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Trash and Illegal Dumping - Trash Bash Site	*Reduce trash and educate participants on water quality issues.*	*2019 – Site re-established in watershed.*			
Trash and Illegal Dumping - Reporting Portal	*Facilitate reporting of local issues to aid enforcement.*	*2019 – need and local partners established, and grant resources reviewed.*	*2022 – Portal created and maintained.*		

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 80 - Grasses in a riparian buffer area


Section 8:
Evaluating
Success

8 – Evaluating Success

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 watersheds and by achieving programmatic milestones (outlined in Section 7). Water quality monitoring data and other data related to water quality 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 (H-GAC, TCEQ, et al.) will conduct long-term ambient surface water quality monitoring in the West Fork and Lake Creek. An additional source of supplemental data are the Texas Stream Team volunteers[150]. The Partnership will also evaluate compliance by permitted wastewater discharges using DMR and SSO data reported to TCEQ. Special studies 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 will be conducted by the Partnership at the end of every phase of implementation (2022, 2026, and 2030) or as necessary in interim periods.

CRP Data

Ongoing monitoring in the West Fork and its tributaries includes six long-term sites (three on the West Fork proper, and three on tributaries). Monitoring in the Lake Creek watershed is conducted at three sites (two on Lake Creek, one on Mound Creek). All sites are monitored at least quarterly. The current sites[151] are:

Segment 1004 – West Fork

- **11243, West Fork upstream of SH 242**

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

[151] More information on the sites can be found at https://cms.lcra.org/schedule.aspx?basin=10&FY=2019. The site locations are also indicated in Figures 26 and 27 of Section 3 of this document.

- 11250, West Fork at FM 2854 (west of Conroe)
- 11251, West Fork upstream of SH 105 (northwest of Conroe)
- **11181, Crystal Creek at FM1314**
- 16626, Stewarts Creek downstream of SH Loop 336 (southeast of Conroe)
- 20731, White Oak Creek at Memorial Drive in Conroe

Segment 1015 – Lake Creek

- **11367, Lake Creek at Egypt Community Road (southwest of Conroe)**
- 18191, Lake Creek at FM 149 (south of Montgomery)
- 17937, Mound Creek upstream of the Lake Creek confluence

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 constituents 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 station (shown in bold above) of each of the attainment areas for this WPP[152] is the ultimate focus of evaluation. These sites are 11243 (West Fork and Lake Creek below Mound Creek), 11181 (Crystal Creek), and 11367 (Lake Creek above Mound Creek). However, special attention will also be given to stations 11251 (indicating any changes in the boundary conditions from Lake Conroe) and 17937 (indicating the Mound Creek area). Monitoring will be conducted under an approved quality assurance project plan (QAPP).

Additional Data

In addition to the 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.
- Texas Stream Team volunteers – Stream Team 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.

[152] Indicated in Figure 64, Section 4.

Bacteria Source Tracking

Bacteria source tracking (BST) is a general name for a range of methods that use genetic information to identify the origins of bacteria present in a water body. Identification is based on the presence of indicator bacteria strains specific to different animal types. BST can help characterize uncertainties in modeling efforts (e.g., the "other wildlife" component) and give more information on what sources are represented instream, as opposed to source loads. However, BST 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. It is not included in the current intended monitoring plan for this WPP. However, the Partnership recognizes its potential use as a tool for guiding decisions when opportunity and resources to utilize it exist.

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.

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. Ultimate success in the waterways of the West Fork watersheds is found 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. The indicators are summarized in Table 37.

Compliance with Water Quality Standards

The primary goal of the WPP is to achieve and maintain compliance SWQSs at the attainment area stations. A secondary goal is to ensure source reduction by meeting TPDES water quality permit limits. Therefore, the primary indicators of success are:

- the status of the waterways on the Integrated Report, with specific focus on the SWQSs for contact recreation standard (bacteria) and aquatic life use (DO, etc.). Success is measured by fully supporting all uses and absence of concerns;
- a positive or stable trend in WWTF compliance, as indicated in the DMRs/SSOs.

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 decline will also be considered as interim progress.

Programmatic Achievement

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

- implementing solutions at a pace that is sufficient to meet interim milestones (Section 7);
- 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 37 - Indicators of success

Goal	Indicator of Success	Source of Indication
Compliance with Water Quality Standards	Fully support all designated uses	CRP data; Integrated Report status
	Comply with TPDES permit limits	WWTF DRM/SSO
Implement 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.

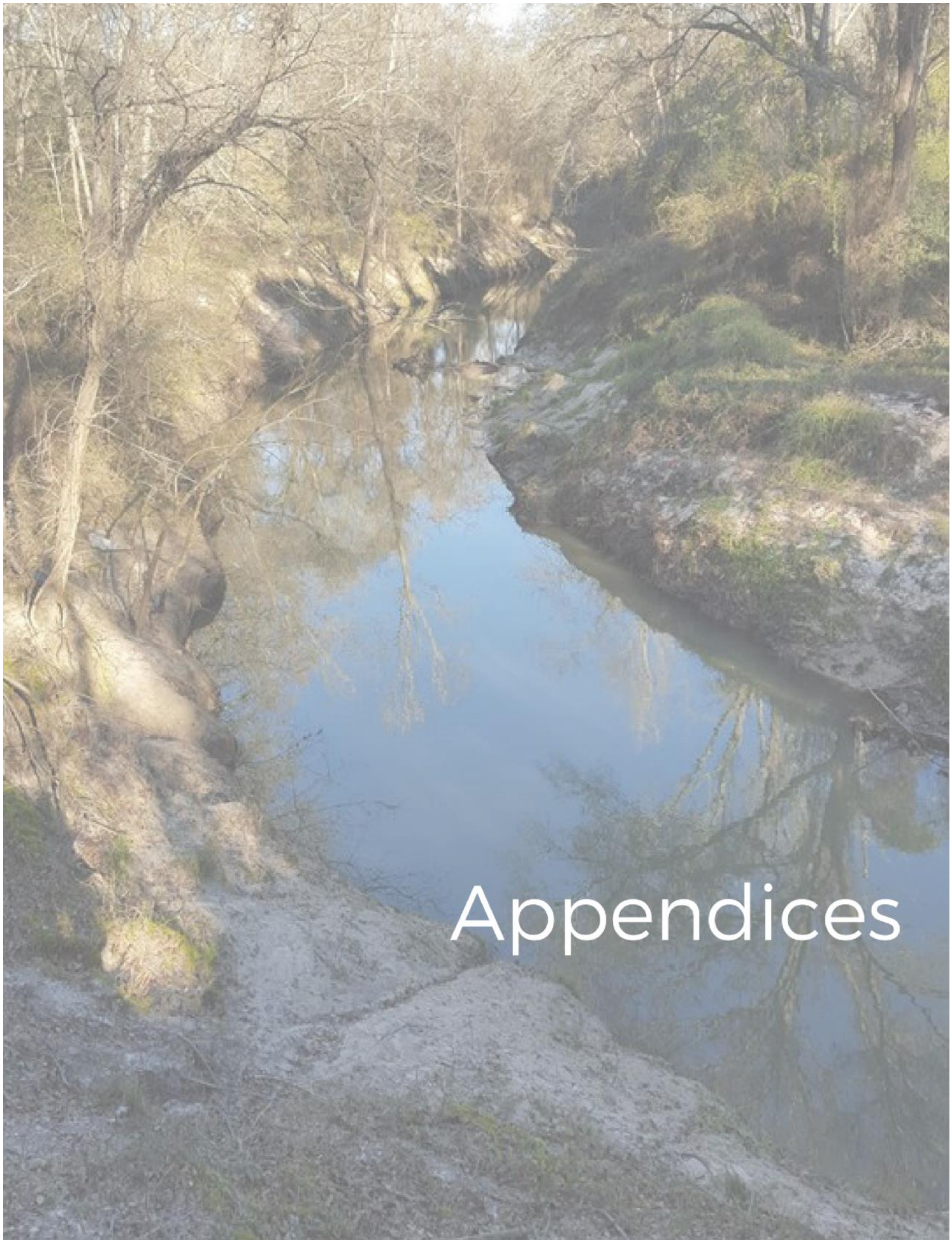
Adaptive management is a structured process by which changes in conditions and evaluation of progress and programmatic achievements are used to identify potential revisions to the WPP.

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. The adaptive management process is summarized in Table 38.

Table 38 - 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. • The WPP may be amended as needed.
Formal WPP Reviews	At least every four years [153] 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 complimentary 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.

[153] Corresponding to the implementation phases of early (2018-2022), middle (2023-2026) and late (2027-2030) implementation. Some partners use different planning cycles. Changes are possible in the interim, however. The four-year milestone is a minimum.


Appendices

Appendix A – WPP Information Checklist

Table 39 - Guide to WPP Information

Name of Waterbody	West Fork San Jacinto River; Lake Creek
Assessment Units	1004_01, 1004_02, 1004D_01, 1004E_02, 1015_01, 1015_02, 1015A_01
Impairments addressed	Bacteria (1004_01, 1004_02, 1004D_01, 1004E_02, 1015A_01)
Concerns addressed	Nitrate (1004_01); Depressed DO (1015_01, 1015_02); Impaired macrobenthic community (1015_01);

Element	Report Section(s) and Page Number(s)
Element A: Identification of Causes and Sources	
1. Sources Identified, described, and mapped	Section 3, pp. 40-106
2. Subwatershed sources	Section 3, pp. 71, 76, 79, 82, 85, 88, 91, 94, 97, 98
3. Data sources are accurate and verifiable	Section 3, pp. 41-57, and throughout individual source sections.
4. Data gaps identified	Section 3, pp. 47, 49, 60 (ambient data); and throughout individual source sections.
Element B: Expected Load Reductions	
1. Load reductions achieve environmental goal	Section 4, pp. 119-123
2. Load reductions linked to sources	Section 4, pp. 119-123
3. Model complexity is appropriate	Section 4, pp. 64-67 (SELECT), and throughout Section.
4. Basis of effectiveness estimates explained	Section 4, pp. 121-123 (use of representative units) and pp. 129-152 (effectiveness of individual solutions)
5. Methods and data cited and verifiable	Section 4, throughout Section.
Element C: Management Measures Identified	
1. Specific management measures are identified	Section 5, throughout Section and summarized in Table 35 starting on p. 172.
2. Priority areas	Section 5, throughout discussion of individual solutions.
3. Measure selection rationale documented	Section 5, pp. 126-128 (general approach)
4. Technically sound	Section 5, throughout discussion of individual solutions.

Element	Report Section(s) and Page Number(s)
Element D: Technical and Financial Assistance	
1. Estimate of technical assistance	Section 5, throughout discussion of individual solutions and summarized in Table 35 starting on p. 172
2. Estimate of financial assistance	Section 5, throughout discussion of individual solutions and summarized in Table 35 starting on p. 172
Element E: Education/Outreach	
1. Public education/information	Section 6, throughout Section.
2. All relevant stakeholders are identified in outreach process	Section 6, pp. 158-159, and throughout Section for individual efforts.
3. Stakeholder outreach	Section 6, throughout Section.
4. Public participation in plan development	Section 6, pp. 156-159, and throughout Section for individual efforts.
5. Emphasis on achieving water quality standards	Section 6, throughout Section.
6. Operation and maintenance of BMPs	Section 5, and summarized in Table 35 starting on p. 172
Element F: Implementation Schedule	
1. Includes completion dates	Section 7, pp. 172-174
2. Schedule is appropriate	Section 7, throughout Section.
Element G: Milestones	
1. Milestones are measurable and attainable	Section 7, pp. 175-183
2. Milestones include completion dates	Section 7, pp. 175-183
3. Progress evaluation and course correction	Section 7, pp. 175-183, and Section 8.
4. Milestones linked to schedule	Section 7, pp. 175-183
Element H: Load Reduction Criteria	
1. Criteria are measurable and quantifiable	Section 4, 8, Throughout Section 4 (load reduction targets), and throughout Section 8 (evaluating success criteria)
2. Criteria measure progress toward load reduction goal	Section 4, 8, throughout sections (4 for load reduction targets, 8 for assessment of criteria)
3. Data and models identified	Section 3, 4, 8, throughout Sections (3 for load and water quality data, 4 for load reduction target development, and 8 for assessment data identification).
4. Target achievement dates for reduction	Section 7, 8 pp. 175-183 (7), and p. 185 (8)

Element	Report Section(s) and Page Number(s)
5. Review of progress toward goals	Section 8. pp. 187-189
6. Criteria for revision	Section 8. pp. 187-189
7. Adaptive management	Section 8. pp. 187-189
Element I: Monitoring	
1. Description of how monitoring used to evaluate implementation	Section 8, pp. 185-187
2. Monitoring measures evaluation criteria	Section 8, pp. 185-188
3. Routine reporting of progress and methods	Section 8. pp. 188-189
4. Parameters are appropriate	Section 8, pp. 185-189
5. Number of sites is adequate	Section 8, pp. 185-189
6. Frequency of sampling is adequate	Section 8, pp. 185-188
7. Monitoring tied to QAPP	Section 8, pp. 185-188
8. Can link implementation to improved water quality	Section 8, pp. 185-189

Appendix B – LDC Analyses

Bacteria LDCs

This appendix provides the full LDC profiles for the bacteria LDCs, as referenced in Section 4.

Station 11251 – West Fork San Jacinto River (North)

Station 11251 is located on the main channel of the West Fork (Segment 1004) just downstream of the Lake Conroe dam, and generally represents the boundary conditions at the start of the West Fork system. There are inputs upstream of the station, including several WWTFs, and natural seepage and releases from the dam, but a review of potential sources with project partners and stakeholders, as well as relevant discharge monitoring reports from wastewater inputs, indicated source loads to the system were likely minimal. Due to the small amount of watershed represented by the upstream area from the station, the generally good water quality indicated at this station (and by this LDC), and the intent to treat this station as a starting/boundary condition, no specific reduction targets or related attainment area were developed for this LDC. For the purpose of assessing water quality attainment, the section of watershed upstream of 11251 is considered part of the attainment area represented at 11243, downstream.

The drainage area upstream is primarily riparian forest adjacent to the Lake Conroe dam, and some light development along a highway corridor (Figure B1). Figure B2 is the LDC for Station 11251, which indicates a few exceedances at varying flow conditions.

Despite occasional exceedances, the analysis of needed reductions in the five flow categories indicated no reduction was necessary (Table B1).

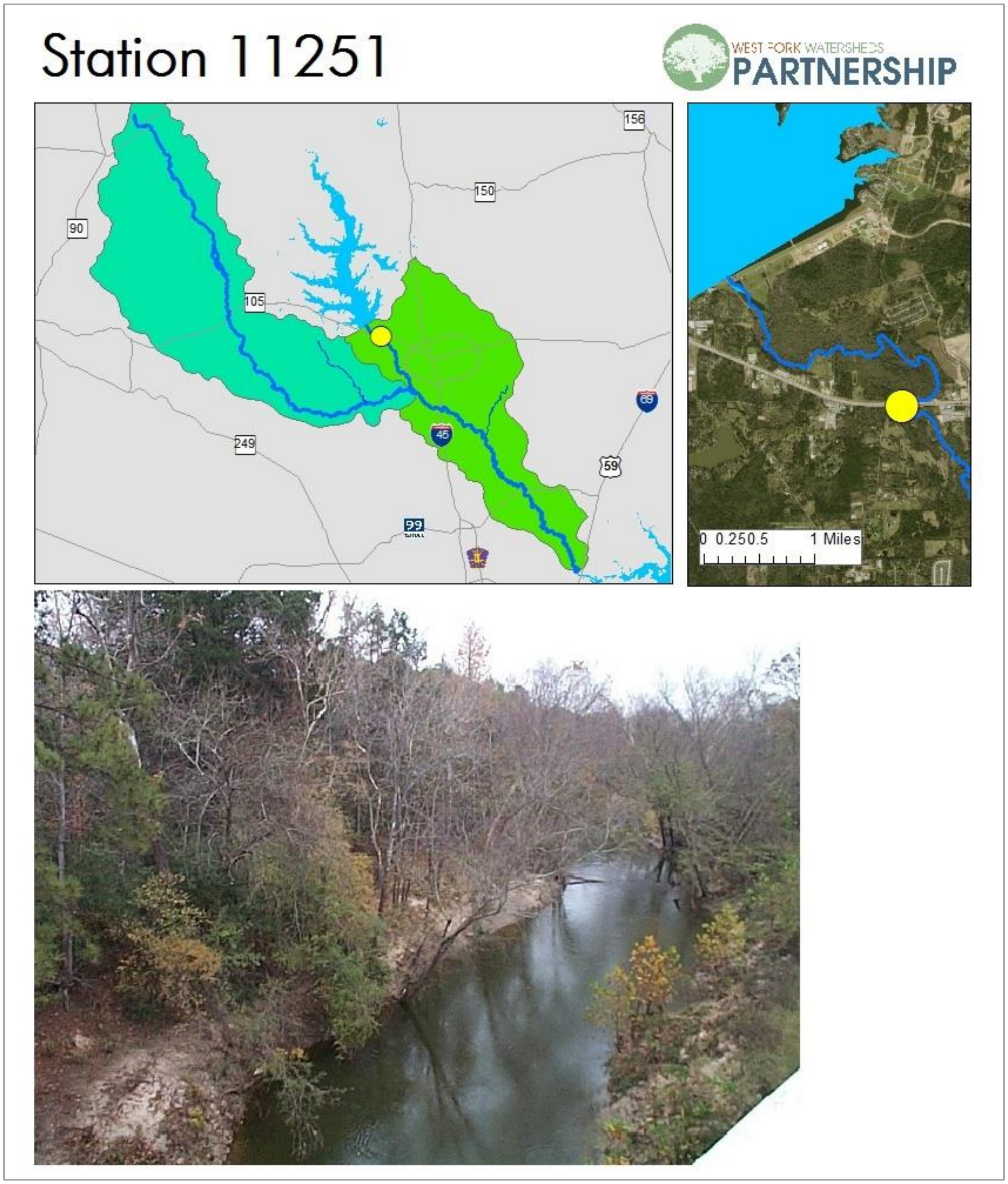


Figure B1 - LDC Site at Station 11251

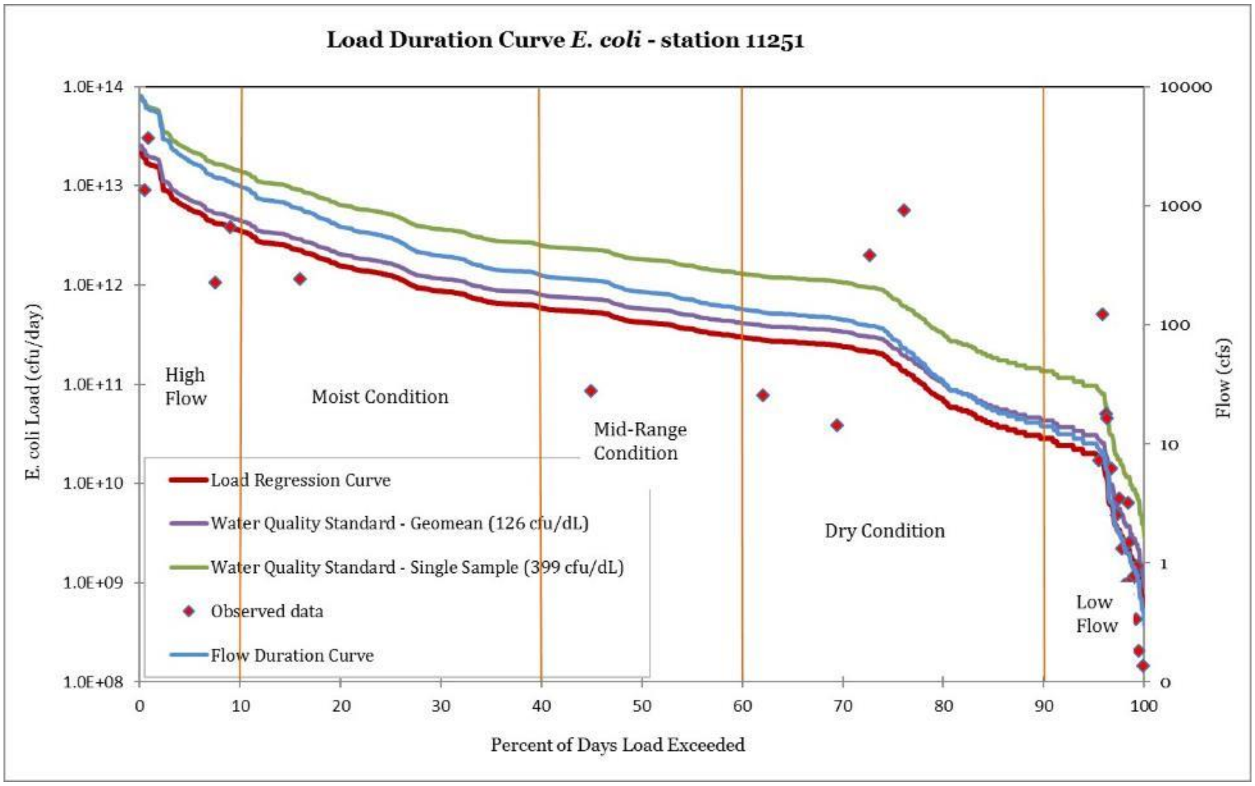


Figure B2 - LDC for Station 11251

Table B1 - Flow-specific values for LDC 11251

Flow category	Percent Exceedance (of flow)	Percent Reduction - Geomean[154]	Percent Reduction – Single Sample
High Flows	0-10%	-24	-292
Moist Conditions	10-40%	-31	-316
Mid-Range Conditions	40-60%	-37	-333
Dry Conditions	60-90%	-43	-353
Low Flows	90-100%	-57	-396

[154] Negative values indicate no reduction is necessary, and assimilative capacity may still exist. Reductions are represented by positive values.

Station 11243 – West Fork San Jacinto River (South)

Station 11243 is located on the West Fork (Segment 1004) just prior to the confluence with Crystal Creek and is the most southerly project monitoring point on the West Fork system[155].

The watershed upstream of this station includes the influence of Lake Creek, tributaries from the urban area of Conroe, and other primary inputs to the system upstream of the confluence with Spring/Cypress Creeks to the south immediately prior to the Lake Houston confluence. A wide mix of land uses is represented, from dense urban environments, suburban development along transportation corridors, heavy commercial development along the I-45 corridor intersecting the watershed on a north-south tangent, as well as large areas of rural/undeveloped areas and the large riparian forests along the lower part of the watershed (Figure B3). Notable development of sand and gravel in the riparian corridor exists along the West Fork.

Figure B4 is the LDC for Station 11243, which indicates a range of conditions, with exceedances most pronounced in highest flow conditions. The analysis of needed reductions in the five flow categories indicated reductions were needed in the high flow and moist condition categories, but not in lower flow categories. This points in general to a predominance of nonpoint sources, but in such a large conglomerated system, it is hard to draw a direct relationship. Nevertheless, between station 11251 and 11243 on the West Fork, bacteria source inputs are enough to create a reduction need, as indicated in Table B2.

[155] It should be noted that there is an appreciable amount of watershed downstream of this station. However, the next most southerly monitoring station is in the confluence of the West Fork and Lake Houston, in an area highly influenced by the Lake. For this project, it was not considered representative of the West Fork watershed in general. Additionally, the concentration of load is closer to the upper, urban parts of the watershed, making this mid-length station more representative of the bacteria impairment. The lower aspect of the watershed includes more undisturbed riparian forest with limited crossings and access other than by boat. Therefore, while this report recognizes that it is not ideal to include downstream areas as part of the attainment area represented by LDC station 11251, the project staff and stakeholders felt it was better to take a conservative approach, erring on over-representing the upper part of the watershed. As a counterpoint to this level of uncertainty, the implementation decisions of the WPP will prioritize the subwatershed of this attainment area that indicate greater potential loads.

Figure B3 - LDC Site for Station 11243

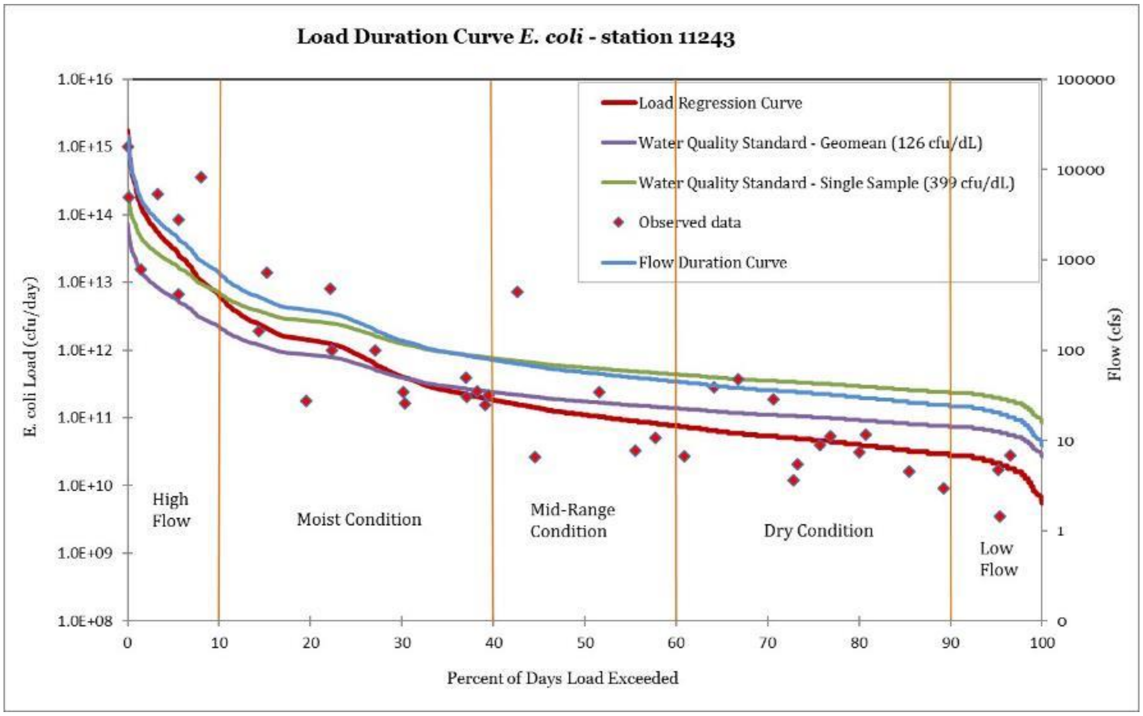


Figure B4 - LDC for Station 11243

Table B2- Flow-specific values for LDC site 11243

Flow category	Percent Exceedance (of flow)	Percent Reduction - Geomean	Percent Reduction – Single Sample
High Flows	0-10%	80	38
Moist Conditions	10-40%	20	-154
Mid-Range Conditions	40-60%	-57	-398
Dry Conditions	60-90%	-120	-597
Low Flows	90-100%	-211	-885

Station 16635 – Crystal Creek

Station 16635 is located toward the end of Crystal Creek (Segment 1004D), prior to its confluence with the West Fork. Crystal Creek drains an area ranging in a clockwise arc around the outskirts of Conroe, from north to southeast. Its headwaters include a mix of light residential, commercial and industrial areas, while its downstream areas have more undeveloped, forested land. In general, the tributary's watershed is lightly developed, although some larger industrial facilities are nearby (Figure B5).

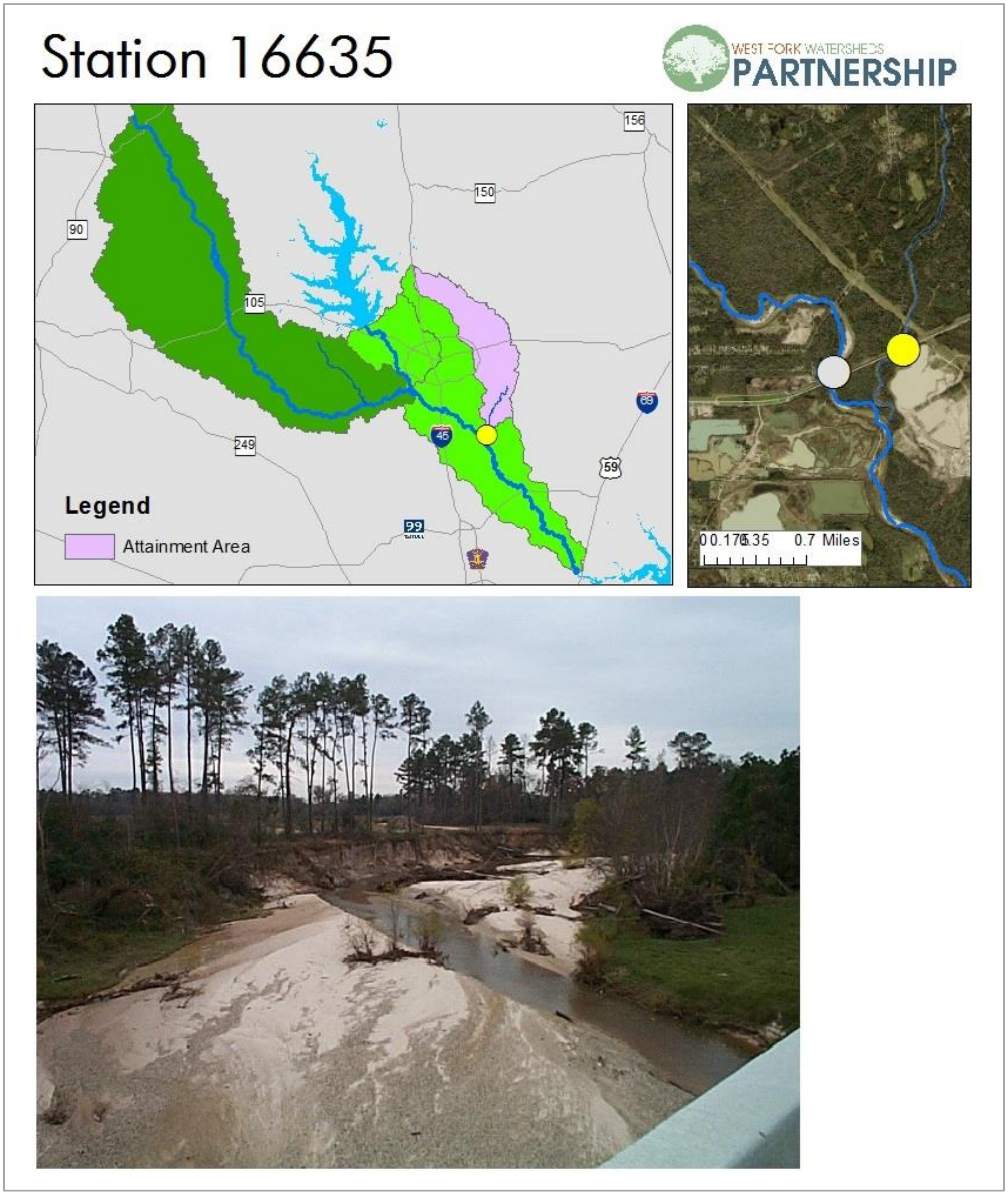


Figure B5 - LDC Site 16635

The LDC for station 16635 indicates that the waterway is generally in compliance with the water quality standard, with occasional exceedances. Only the highest flow category indicated a small need for reductions (Table B3).

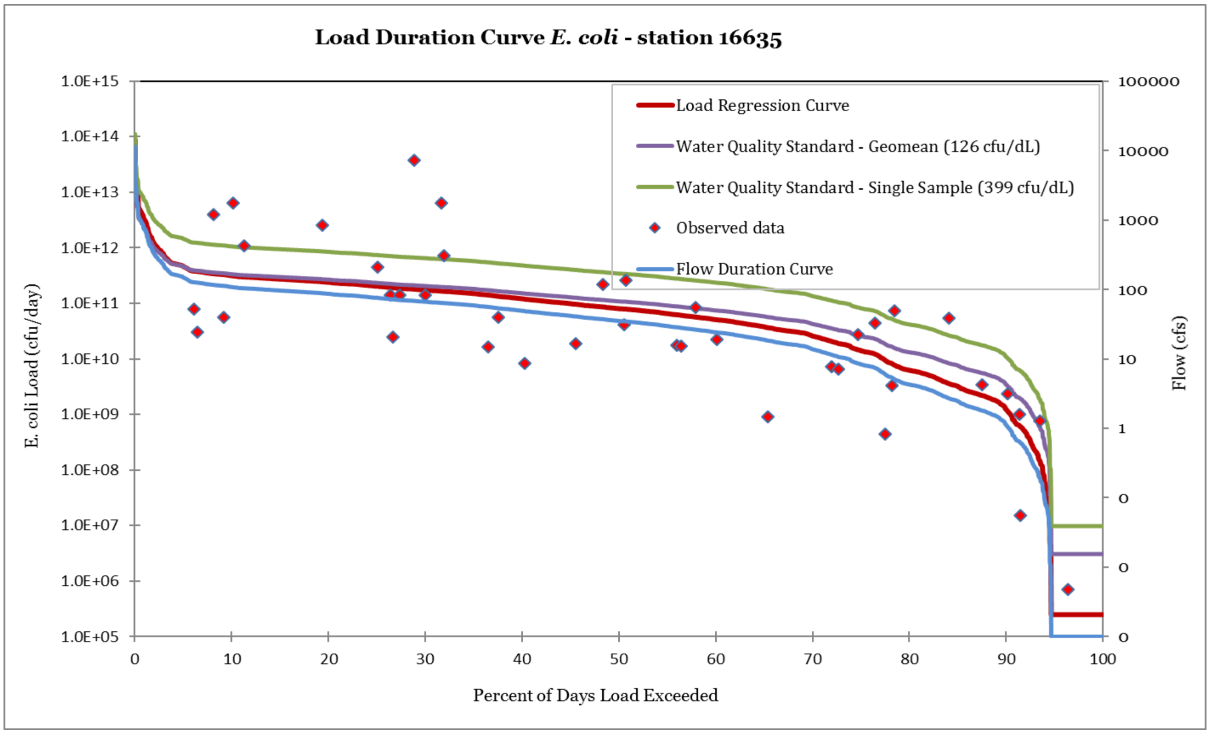


Figure B6 - LDC for station 16635

Table B3 - Flow-specific values for LDC station 16635

Flow category	Percent Exceedance (of flow)	Percent Reduction - Geomean	Percent Reduction – Single Sample
High Flows	0-10%	6	-199
Moist Conditions	10-40%	-15	-265
Mid-Range Conditions	40-60%	-35	-328
Dry Conditions	60-90%	-93	-510
Low Flows	90-100%	-740	-2560

Station 11367 – Lake Creek

Lake Creek (Segment 1015) is the primary tributary to the West Fork system downstream of Lake Conroe and upstream of the confluence with Spring and Cypress Creek. A full segment, Lake Creek is characterized by a dramatic shift in land use between its rural/agricultural headwaters to the expanding suburban and exurban development in its downstream reaches. However, the most southerly monitoring station on the main stem is located prior to the confluence of Mound Creek (Segment 1015A). Therefore, the more developed areas of the Lake Creek segment are included in the station 11243 LDC site described previously, including the Mound Creek segment. The attainment area for Lake Creek proper, therefore, is primarily characterized by rural areas comprising agricultural and light residential uses (Figure B7).

The LDC for 11367 (Figure B8 and Table B4) indicates similar results to the other stations, with modest reductions needed in the higher flow conditions, and infrequent exceedances in other flow categories. Assimilative capacity in moderate flow conditions is small, and additional downstream influence of Mound Creek and more developed areas near the confluence with the West Fork may create a greater need for reduction for the segment than is represented by the project attainment area upstream of 11367. However, long-term assessment sampling is conducted at this station, so this point is the baseline for evaluating implementation progress going forward. To balance the concerns of downstream areas being diluted by their inclusion in the site 11243 West Fork attainment area, a separate LDC was completed for Mound Creek, even though it does not have a separate attainment area.

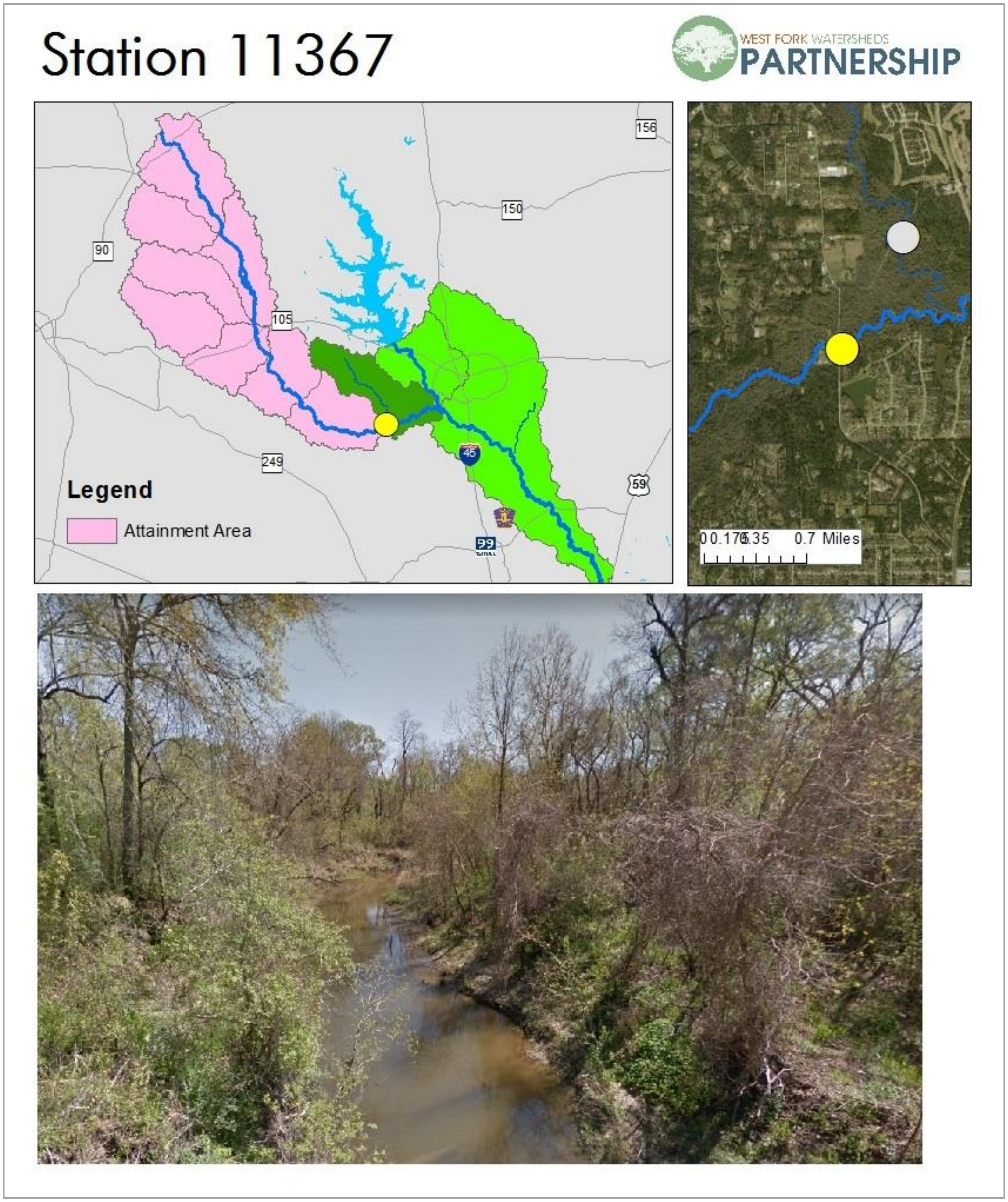


Figure B7- LDC Site 11367

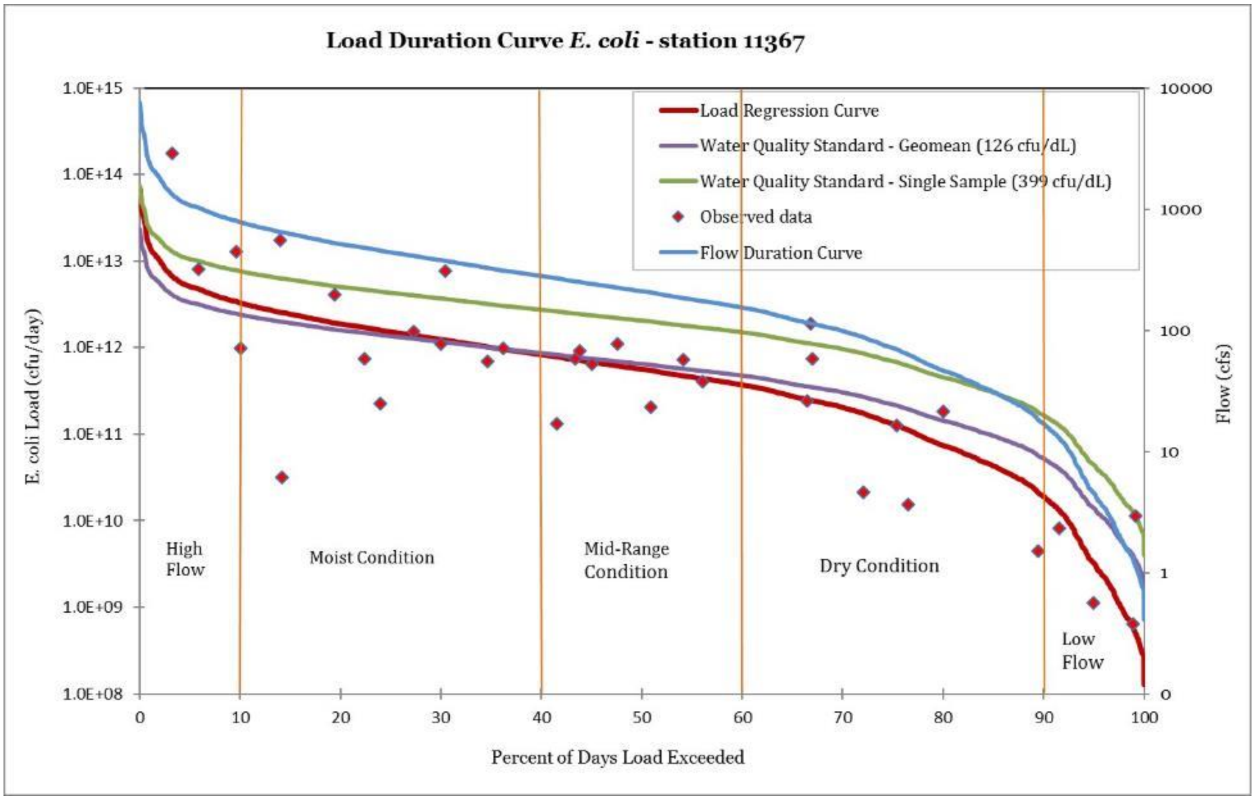


Figure B8 - LDC for Site 11367

Table B4- Flow-specific Values for LDC Station 11367

Flow category	Percent Exceedance (of flow)	Percent Reduction - Geomean	Percent Reduction – Single Sample
High Flows	0-10%	37	-98
Moist Conditions	10-40%	11	-182
Mid-Range Conditions	40-60%	-16	-266
Dry Conditions	60-90%	-78	-463
Low Flows	90-100%	-361	-1361

Station 17937 – Mound Creek

Mound Creek (Segment 1015A) is the primary tributary of the Lake Creek system in the more developed southeastern reach. While Lake Creek is not listed for an impairment in the 2014 Texas Integrated Report of Surface Water Quality (Integrated Report), Mound Creek is. The stakeholders held that this is indicative of the water quality in the tributaries and lower reach where development has spread west on the major transportation corridors. Because the Mound Creek area is part of the larger attainment area that includes the West Fork proper and lower Lake Creek, it is unlikely that its internal impairment translates to a large impact to the two larger waterways into which its flow eventually enters. The disparity between monitoring locations and spatial variation in conditions led to the development of a separate LDC for Mound Creek. While the Mound Creek watershed was considered too small to be its own attainment area[156], the LDC is intended to highlight the need and scale for treating Mound Creek as a priority area. Hereafter, the Mound Creek LDC are will be referred to as the station 17937 priority area, in comparison with the other station attainment areas.

The drainage area for Mound Creek includes suburban/exurban development but also includes broad riparian buffer forests and undeveloped areas along much of its length. Only near its confluence does it pass adjacent to larger developed areas and a golf course (Figure B9).

The LDC for 17937 (Figure B10) highlights the importance of this watershed as a priority area. Unlike the rest of the project areas, which needed modest reductions, the Mound Creek LDC indicates reductions are necessary in all but the lowest flow categories (Table B5). Additionally, these reductions are appreciably larger than in other waterways that were evaluated, including waterways of similar character and land uses like Crystal Creek.

[156] Project staff and stakeholders explored the potential to segregate Mound Creek, but the smallest existing hydrologic subdivisions for the area, the USGS HUC12s, were not granular enough (i.e. Mound Creek shares a subwatershed with other areas). When staff delineated a separate watershed for Mound Creek, the discrepancy between its size and the other project subwatersheds was detrimental to the aim to keep subwatershed size relatively uniform and comparable. The compromise proposed by project staff and accepted by stakeholders was to develop an LDC as an indicator of the scale of reductions necessary internal to Mound Creek, and then use that as a guide when siting BMPs in the subwatershed/attainment area in which it falls.

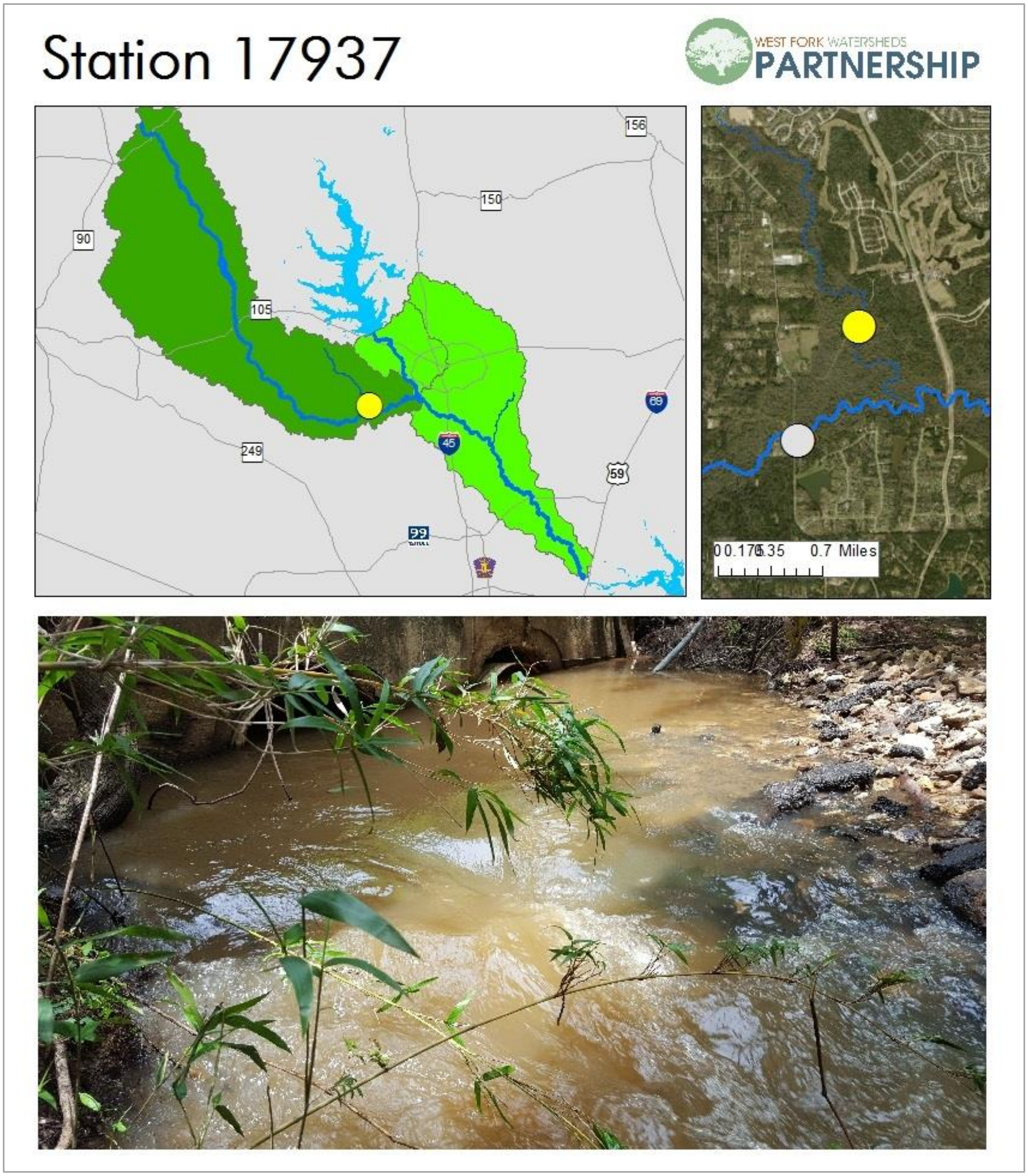


Figure B9 - LDC site for Station 17937

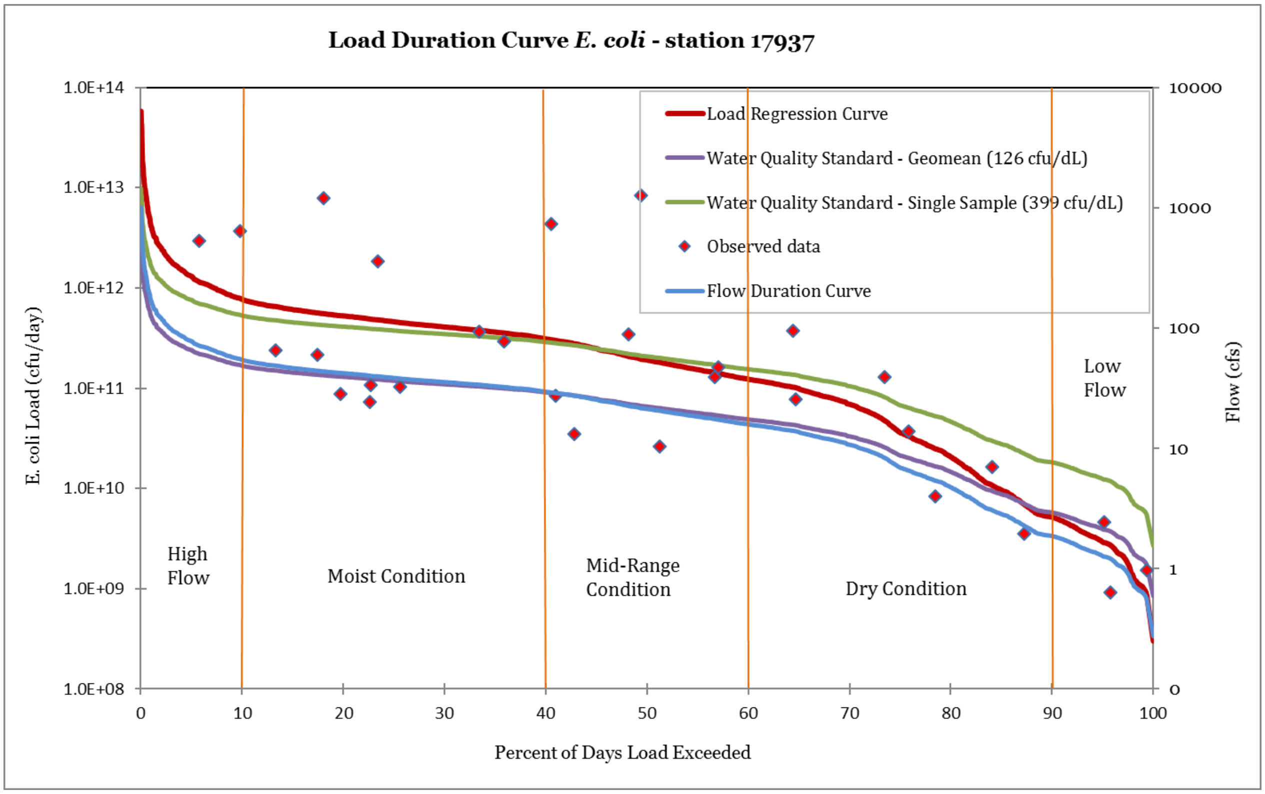


Figure B10 - LDC for station 17937

Table B5 - Flow-specific values for LDC site 17937

Flow category	Percent Exceedance (of flow)	Percent Reduction - Geomean	Percent Reduction – Single Sample
High Flows	0-10%	82	44
Moist Conditions	10-40%	74	19
Mid-Range Conditions	40-60%	66	-9
Dry Conditions	60-90%	36	-104
Low Flows	90-100%	-46	-361

DO LDCs

This appendix provides the full LDC profiles for the bacteria LDCs, as referenced in Section 4.

Station 11251[157]

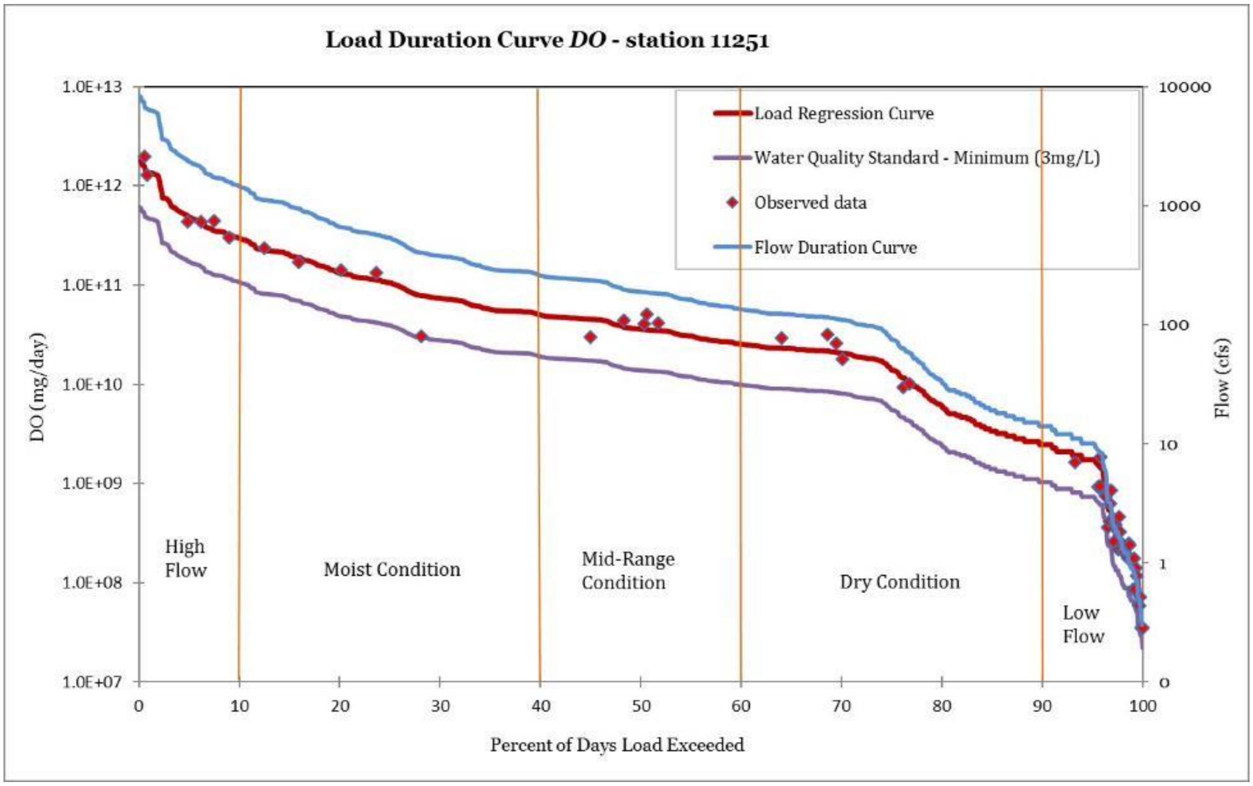


Figure B11 - Station 11251 LDC

Table B6 – DO LDC results, Station 11251

Flow Condition	Percent Exceedance	Percent Improvement
High Flows	0-10%	-185
Moist Conditions	10-40%	-170
Mid-Range Conditions	40-60%	-161
Dry Conditions	60-90%	-151
Low Flows	90-100%	-132

157 Please refer to bacteria LDCs for the corresponding station earlier in this Appendix for site photos.

Station 11243

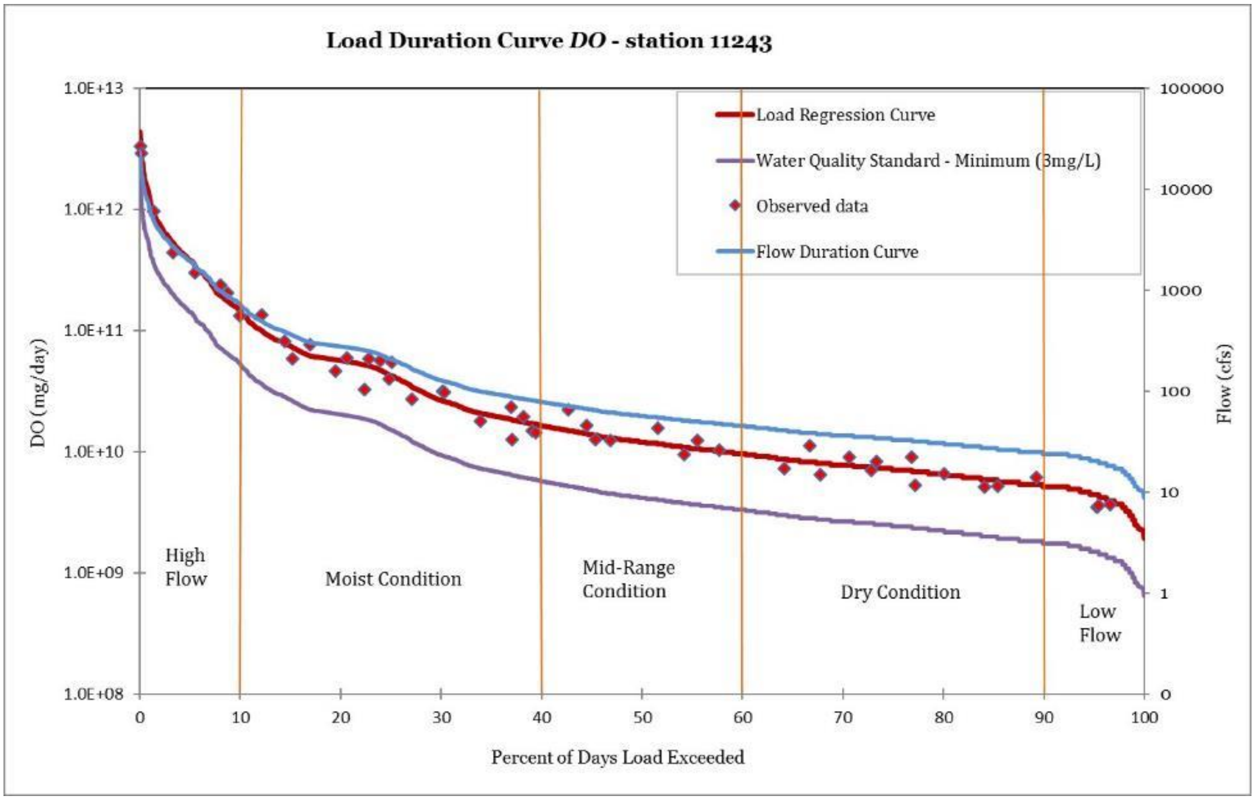


Figure B12- Station 11243 DO LDC

Table B7 - DO LDC results, Station 11243

Flow Condition	Percent Exceedance	Percent Improvement
High Flows	0-10%	-167
Moist Conditions	10-40%	-181
Mid-Range Conditions	40-60%	-189
Dry Conditions	60-90%	-192
Low Flows	90-100%	-196

Station 16635

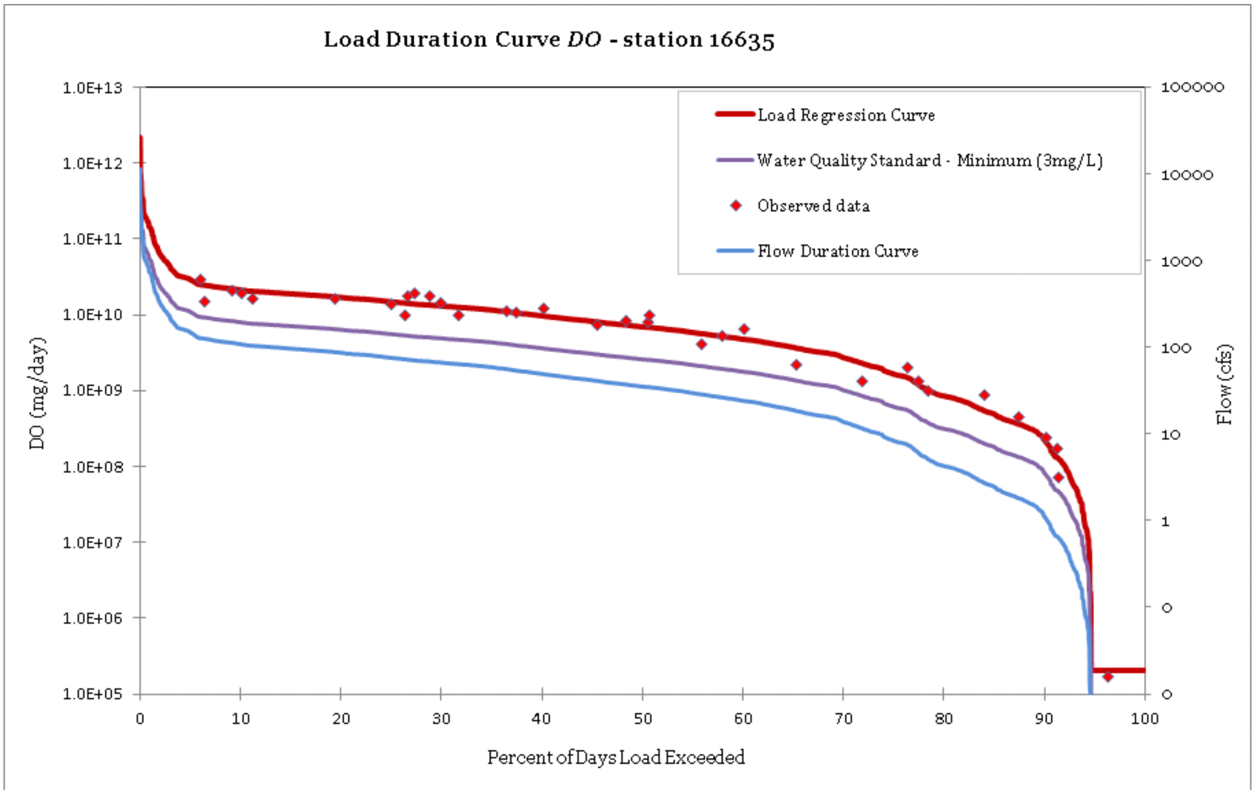


Figure B13 - DO LDC for Station 16635

Table B8 - DO LDC results, Station 16635

Flow Condition	Percent Exceedance	Percent Improvement
High Flows	0-10%	-166
Moist Conditions	10-40%	-167
Mid-Range Conditions	40-60%	-168
Dry Conditions	60-90%	-170
Low Flows	90-100%	-177

Station 11367

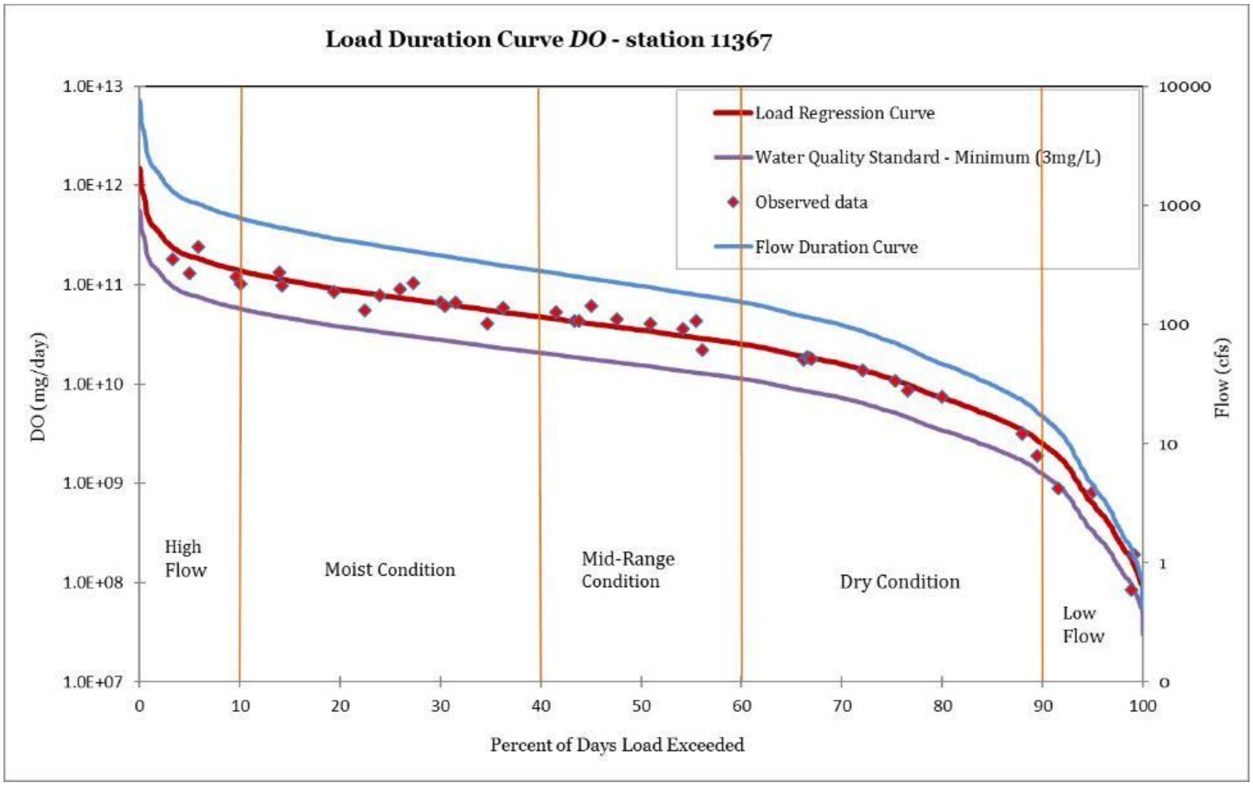


Figure B14 - DO LDC for Station 11367

Table B9- DO LDC Results, Station 11367

Flow Condition	Percent Exceedance	Percent Improvement
High Flows	0-10%	-146
Moist Conditions	10-40%	-135
Mid-Range Conditions	40-60%	-126
Dry Conditions	60-90%	-114
Low Flows	90-100%	-89

Station 17937

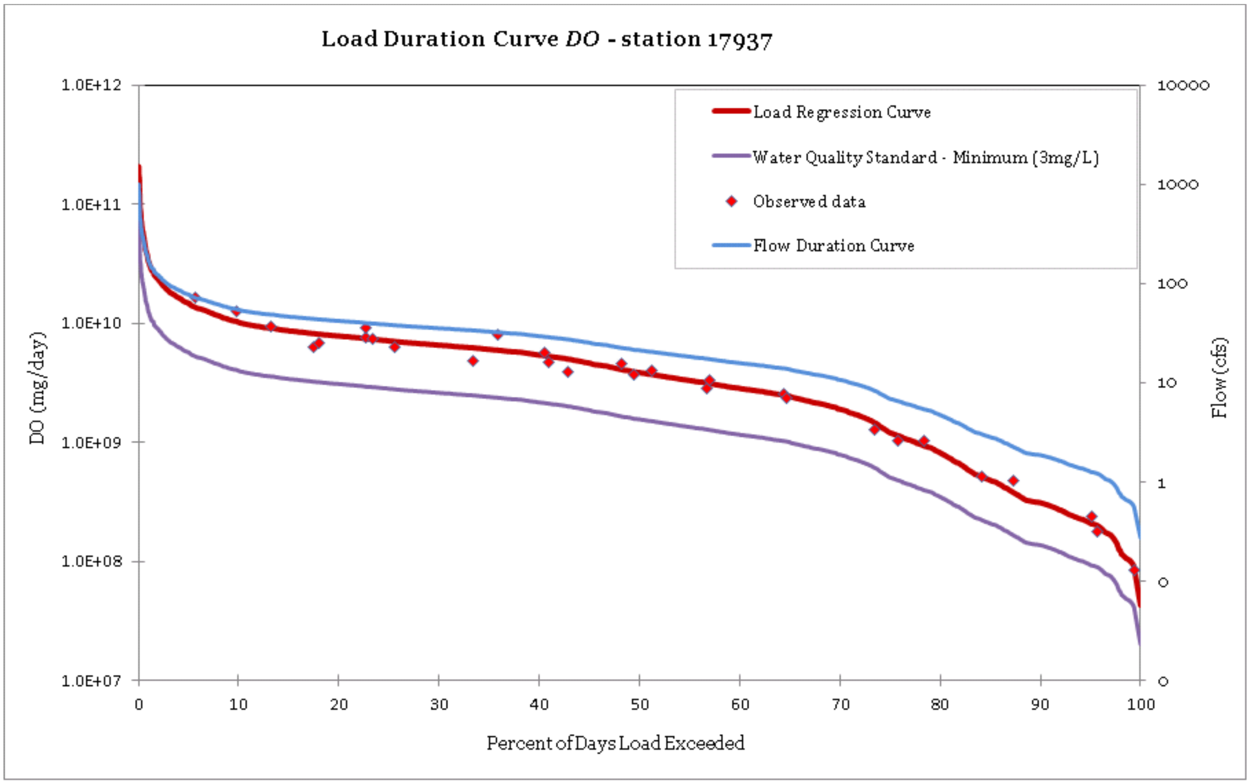


Figure B15 - DO LDC for Station 17937

Table B10 - LDC results, Station 17937

Flow Condition	Percent Exceedance	Percent Improvement
High Flows	0-10%	-160
Moist Conditions	10-40%	-152
Mid-Range Conditions	40-60%	-147
Dry Conditions	60-90%	-137
Low Flows	90-100%	-123

Appendix C – Typical Agricultural Best Management Practices

Table C1 details typical practices implemented in WQMPs and similar agricultural land management projects. Emphasis for this WPP is put on practices that reduce animal wastes or impede transmission of wastes to water.

Table C1 - WQMP 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.

Practice	Description
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.