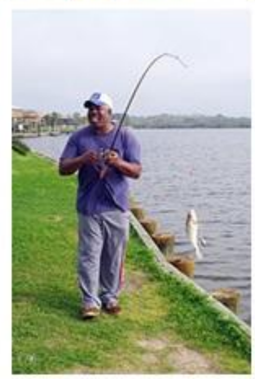
Cedar Bayou Watershed Protection Plan

Prepared for the Cedar Bayou Watershed Partnership by the Houston-Galveston Area Council

7/16/2015







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Acknowledgements

The Cedar Bayou Watershed Protection Plan is the culmination of the efforts of a diverse and committed group of stakeholders and local partners. This collaborative, community-based approach to protecting the public healthy, economy, and ecology of the Cedar Bayou area would not have been possible without their dedication and persistence.

The Cedar Bayou Watershed Partnership wishes to sincerely thank the members of the project's Steering Committee, past and present. These leaders from different backgrounds share a common commitment to their community.

Steering Committee Members

Mr. Andrew Allemand
Ms. Charlene Bohanon
Mr. Royal D. Burnside
Mr. Lewis Odell Casey
Mr. Gil Chambers
Ms. Daniele Cioce
Mr. Bill Cobabe
Ms. Cindy Coker
Mr. Joshua Donaldson
Mr. David Fowler
Mr. Ryan Granata
Mr. Jonathon Holley
Ms. Diane Jones
Mr. and Mrs. Jerry Jones
Ms. Sharon Kamas
Ms. Wilyne Laughlin
Mr. Jim Lard
Ms. Alisa Max
Councilman David McCartney
Ms. Jean McCloud
Mr. Lindy Murff
Commissioner Gary Nelson
Mr. Guido Persiani
Mr. Joe Presnall
Mr. Ladd Puskus
Mr. Glenn Sabadosa
Commissioner Rusty Senac
Mr. John Schrader
Ms. Adele Warren

The support of an engaged group of local organizations is the backbone of this watershed effort. These partners have been integral to the development and guidance of this watershed protection plan.

Local Partners

Bayer
Bayou Preservation Association
Baytown Area CAP
Cedar Bayou Navigation District
Chambers County
City of Baytown
City of Mont Belvieu
City of Beach City
Crosby ISD
Environmental Health Specialties
Cedar Bayou Friends
Galveston Bay Estuary Program
Galveston Bay Foundation
Harris County
Harris County Flood Control District
Harris County Soil and Water Conservation District
Houston-Galveston Area Council
Huffman ISD
Liberty County
Lower Trinity Soil and Water Conservation District
Murff Turf Farms
NRG Cedar Bayou generating facility
Trinity Bay Soil and Water Conservation District

Front Page photo credits, clockwise from top left: Justin Bower, Jerry Jones, Justin Bower, Jeff Murray, Justin Bower

Members of regional, state and national agencies committed to local watershed initiatives have provided invaluable technical assistance and insight as a Technical Advisory Committee for the project.

Technical Advisory Committee

Texas Commission on Environmental Quality
United States Army Corps of Engineers, Galveston District
Texas Parks and Wildlife Department
USDA Natural Resources Conservation Service
Texas A&M University AgriLife Extension and AgriLife Research
United States Geologic Survey
Texas Farm Bureau
Galveston Bay Estuary Program
Texas Forest Service
Texas Department of State Health Services

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This project exists because of the investment of funding and time from the Texas State Soil and Water Conservation Board (TSSWCB), the U.S. Environmental Protection Agency (EPA), and the Galveston Bay Estuary Program (GBEP) of the Texas Commission on Environmental Quality (TCEQ). Lastly, our gratitude goes out for every stakeholder who takes the time to attend a meeting, share their knowledge or help spread the word.

Partnership watershed tour group, 2012

STATEMENT OF PURPOSE

Cedar Bayou has long been the lifeblood of the communities that sprang up along its banks. Its northern headwaters fuel a historic agricultural community, while its navigable southern reaches support thriving industrial, commercial and recreational economies. The prairie, wetlands, and forests through which it flows contain critical habitat and resources for the ecosystems of Galveston Bay and the Upper Texas Gulf Coast.

Over the last several years, however, the ability of the waterway to support the human and aquatic communities that rely on it has degraded. In 2008, Cedar Bayou was designated by the Texas Commission on Environmental Quality as having levels of fecal bacteria that posed a risk for contact recreation, and for being unable to fully support aquatic life. At the same time, fish consumption advisories in the Galveston Bay system raised public health concerns about elevated levels of PCBs and dioxins.

In response to these and other concerns, a diverse group of local stakeholders formed the Cedar Bayou Watershed Partnership under the guidance of the Texas State Soil and Water Conservation Board and the Houston-Galveston Area Council. The primary goal of the Partnership was to develop a Watershed Protection Plan to restore and maintain water quality in Cedar Bayou and its tributaries.

The purpose of the Cedar Bayou Watershed Protection Plan is to identify priority water quality issues, investigate their causes and sources, and recommend a comprehensive set of voluntary measures for addressing them based on sound science and local decision-making. The Plan originates from the local community and is designed to serve as a roadmap to achieving their goals of protecting the public health, economies, and ecosystems that depend on the health of Cedar Bayou.

To ensure that it remains responsive and relevant to the changing needs of the Bayou and its local stakeholders, the Cedar Bayou Watershed Protection Plan is intended to be a living document. The Plan will be regularly evaluated to monitor its success and make revisions as needed. Its future implementation and evolution will be guided by an active and empowered local stakeholder group.

Cedar Bayou Watershed Partnership

TABLE OF CONTENTS

List of Acronyms

AWRL	Ambient Water Reporting Limit
BMP	Best Management Practice
CADDIS	Causal Analysis/Diagnosis Decision Information System
CAFO	Concentrated Animal Feeding Operation
CBND	Cedar Bayou Navigation District
CRP	Clean Rivers Program
CWA	Clean Water Act
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
CBF	Cedar Bayou Friends
GBEP	Galveston Bay Estuary Program
GIS	Geographic Information System
GPS	Global Positioning System
HCFCD	Harris County Flood Control District
H-GAC	Houston-Galveston Area Council
HL&P	Houston Light and Power
LA	Load Allocation
LDC	Load Duration Curve
NASS	National Agricultural Statistics Survey
NCDC	National Climatic Data Center
NELAC	National Environmental Laboratory Accreditation Conference
NOAA	National Oceanic Atmospheric Administration
NOS	National Ocean Survey
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	(United States Department of Agriculture) Natural Resources Conservation Service
OSSF	On-Site Sewage Facility

PCBs	Polychlorinated biphenyls
PS	Point Source
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SLOC	Station Location
SOP	Standard Operating Procedure
SSO	Sanitary Sewer Overflow
SSOI	Sanitary Sewer Overflow Initiative
SWAT	Soil and Water Assessment Tool
SWCD	Soil and Water Conservation District
SWMM5	Storm Water Management Model 5
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
SWQS	State Water Quality Standards
TAC	Technical Advisory Committee
TCEQ	Texas Commission on Environmental Quality
TPWD	Texas Parks and Wildlife Department
TPDES	Texas Pollutant Discharge Elimination System
TSSWCB	Texas State Soil and Water Conservation Board
TSWQS	Texas Surface Water Quality Standards
USACE	United States Army Corps of Engineers
USGS	United States Geologic Survey
WQI	Water Quality Inventory
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility

EXECUTIVE SUMMARY OF THE CEDAR BAYOU WATERSHED PROTECTION PLAN

The headwaters of Cedar Bayou start as small streams in agricultural fields on the eastern edge of the Houston metropolitan area. By the time the bayou passes through the urban hub of the City of Baytown over 60 miles to the south, the Bayou has become a wider navigable waterway supporting thriving industrial, commercial and recreational economies. Its network of 128 open stream miles of main channel, drainage conveyances and tributaries collect the rain as it flows on and over the land. Cedar Bayou carries a piece of everything that happens on those lands with it down to its mouth and the entrance to Galveston Bay.

This is a placeholder page for the Executive Summary. The Summary will break down the entire WPP into a few pages of highlights designed to briefly walk reader through the impetus for the project, its findings, the recommendations it makes, and the path to water quality improvement that will follow it. The Summary has been prepared under separate cover and will be integrated prior to the formal Public Comment period. Table ES1 is included for ease of reference during early review.

To include Table ES1 as follows

Table ES1 – Guide to WPP contents

WPP Section	Description	EPA Element[1]	Location
Section 1 – Introduction to Watershed Planning	An introduction to watershed concepts and the use of watershed planning techniques to address water quality issues.	NA	Pp. X-X, Appendix X
Section 2 – The Cedar Bayou Watershed	A summary of the physical (geography, climate, etc.), human (land use, political geography), and water quality aspects of the Cedar Bayou Watershed.	NA	Pp. X-X, Appendix X
Section 3 – The Cedar Bayou Watershed Partnership	An overview of the membership, goals, values of the Cedar Bayou Watershed Partnership and the development of the Cedar Bayou WPP.	NA	Pp. X-X, Appendix X

[1] Further information on the 9-Element EPA model for WPPs can be found at http://www.epa.gov/region9/water/nonpoint/9elements-WtrshdPlan-EpaHndbk.pdf.

Section 4 – Identifying Potential Sources	An evaluation of the extent and relative prominence of causes and sources of water quality issues.	• Element A – Identify the causes and sources of pollution.	• Pp. X-X, Appendix X
Section 5 – Water Quality Analysis and Estimated Bacteria Reductions	An assessment of Cedar Bayou's water quality data and a description of the bacteria reduction estimates derived from computer modeling efforts.	• Element B – Estimate of load reductions.	• Pp. X-X, Appendix X
Section 6 – Solutions	Solutions identified 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	• C - Pp. X-X, Appendix X • D - Pp. X-X, Appendix X
Section 7 – Education and Outreach	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. X-X, Appendix X
Section 8 – Implementation	The schedule and milestones for implementation activities.	• Element F – Schedule for implementation • Element G – Interim measureable milestones	• Pp. X-X, Appendix X • Pp. X-X, Appendix X
Section 9 – 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. X-X, Appendix X • Pp. X-X, Appendix X

Section 1 – An Introduction to Watershed Planning

1 – INTRODUCTION

WATERSHEDS

A watershed is defined as all the area of land that drains to a common body of water. Watersheds can range in size from the massive drainage basin of the Mississippi River to small subwatersheds that may cover a few square miles of your local neighborhood. Large watersheds can be broken down into smaller watersheds, and so on. Regardless of the scale, they all reflect the extent of land that "sheds water" to a given water body. In reality, though, they are more than just the collected pieces of ground over which rain flows. Watersheds are dynamic systems, not just boundaries on a map. A watershed is also 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 on the land influences the quality of the water that flows over it and into its water bodies.

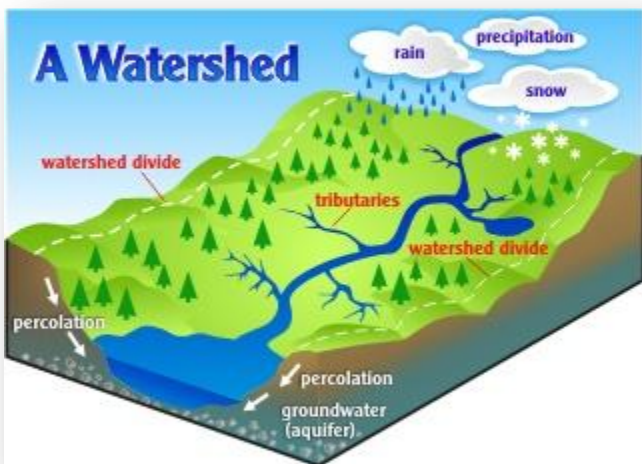


Figure 1 – Diagram of a watershed

WATERSHEDS AND WATER QUALITY

The surface water that drains from watersheds, sometimes called runoff, carries with it traces of where it has been. There is a direct link between what happens on the land in watersheds, and the quality of the water they supply to our waterways.

> **Water Quality** is a description of the chemical, physical and biological properties of water. It is often used as a measure of how suitable water is for the uses we or nature draws from it. Substances or processes that alter water quality in such a way as to render it unfit for one or more designated uses are called contaminants or pollutants.

Pollution can come from a wide variety of sources, depending on the character of a given watershed. However, pollution generally falls into one of two categories based on how it enters the waterway.

Point Source Pollution describes contaminants that directly enter the waterways from a discrete source, like a single pipe or outlet. Examples of point source pollution can include outfalls from factories, discharges from wastewater treatment facilities (WWTFs), and even concentrated animal feeding operations (CAFOs). These sources contribute to water pollution in all flow conditions, though they may be especially important during low flows. Early water pollution regulation in the United States focused primarily on point sources, and in Texas point source dischargers are regulated by Texas Pollutant Discharge Elimination System (TPDES) permit. While point source pollution has diminished as a contaminant source, it can still negatively impact waterways.

Figure 2 – Point source

Nonpoint Source (NPS) Pollution comes from sources that do not have a single direct source. These natural and manmade contaminants are typically carried off the land into waterways by rain during storm events. Because these sources do not have a single point of origin, their impact is usually based on the accumulation of contaminants in runoff over large areas. Because NPS pollution is often introduced into waterways through rainwater runoff, its impact is greatest during storm flow conditions. Examples of NPS pollution include fertilizers washing off agricultural fields or residential lawns, pet waste in urban runoff, wastes from wildlife and non-domestic animals like feral hogs, human waste from malfunctioning onsite sewage facilities (OSSFs), and excessive sediment running off construction sites. The diffuse, cumulative nature of NPS pollution makes it more difficult to regulate. Since the advent of control on point sources, NPS pollution has become a leading water quality issue.

Figure 3 – Runoff carrying sediment

The Case for Clean Water

Poor water quality can affect communities in a variety of ways. Polluted water can have an economic impact on communities with strong fishing, oystering, and recreational economies. Even the perception of polluted water can reduce tourist and recreational spending. Additionally, pollution can endanger human health, which can have personal and economic impact on a community. The State of Texas' water quality standards are based on the ability of a waterway to meet specific designated uses. When the water quality in a waterway cannot support a specific use, it can necessitate regulatory responses and potentially an added mandate for cities and businesses operating permitted point source discharges. In areas where surface water is used for public water supply, polluted water can increase treatment costs and impact the palatability of the drinking water. Lastly, degraded water quality can harm the communities of plants and animals that rely on water bodies for habitat and sustenance. Restoring water quality in impaired waterways, and preservation of good water quality where it already exists, benefits the social, economic, and environmental fabric of the community.

Figure 4 – Hydrocarbons on water surface

The Watershed Approach

Watersheds are determined by the topography of the land rather than political boundaries. As such, they often cross multiple political jurisdictions. Because 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 water pollution limits the ability of individual political entities to wholly address sources of contamination in their waterways. In order to address the diverse mix of point and nonpoint sources of pollution that may occur in a waterway, a watershed-based approach is necessary. A watershed approach focuses on managing sources of contamination for the system as a whole. The benefits of a watershed approach are the ability to reduce redundant efforts by multiple political jurisdictions, focus resources on shared priorities, and utilize federal, state, and regional resources to meet water quality goals. In Texas, the watershed approach to addressing water quality issues is most often employed through the development of a watershed protection plan.

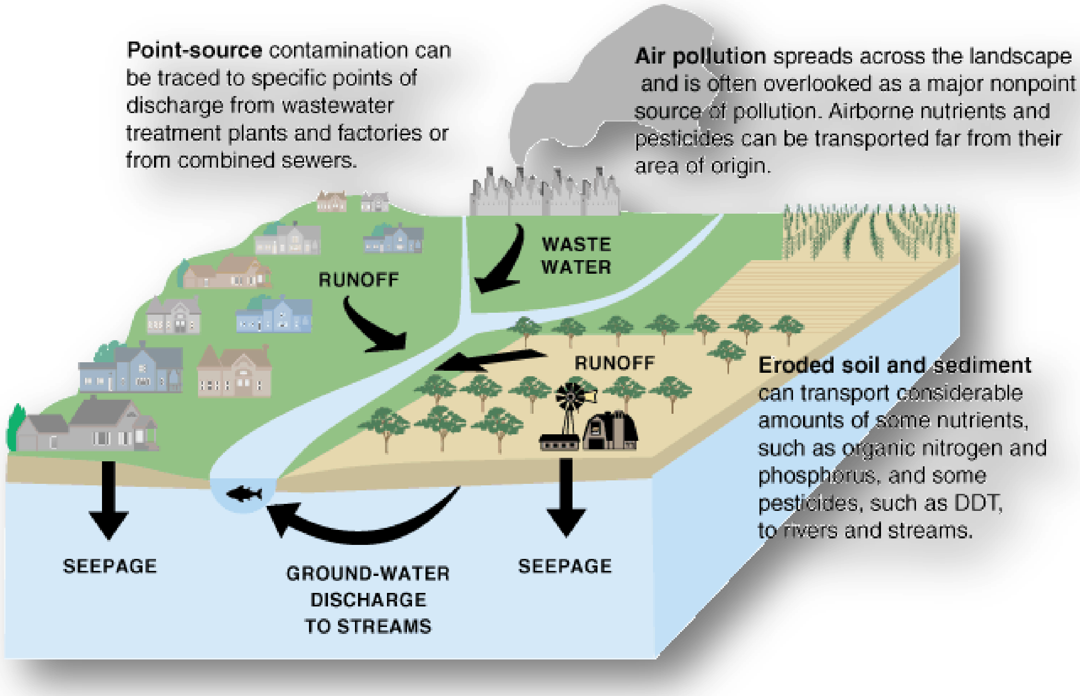


Figure 5 – Example of pollution sources in watersheds

WATERSHED PROTECTION PLANNING

Watershed protection plans (WPPs) are guidance documents that serve as a road map for local communities to take active stewardship of their surface water resources. Developed as the product of locally led planning projects, WPPs use sound science and stakeholder knowledge to identify and characterize water quality priorities and devise comprehensive 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 personal stake in their waterways. In Texas, most WPPs are built on the United States Environmental Protection Agency's Nine Element model, which outlines several key steps to characterizing a watershed, understanding its water quality challenges, and devising appropriate solutions (see Figure 6).

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, who may be impacted by the water quality issues or the WPP recommendations. Stakeholders can include local residents, elected officials, municipalities, counties, landowners, recreation enthusiasts, businesses, and community groups. 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, which require matching funds or in-kind time from local stakeholders.

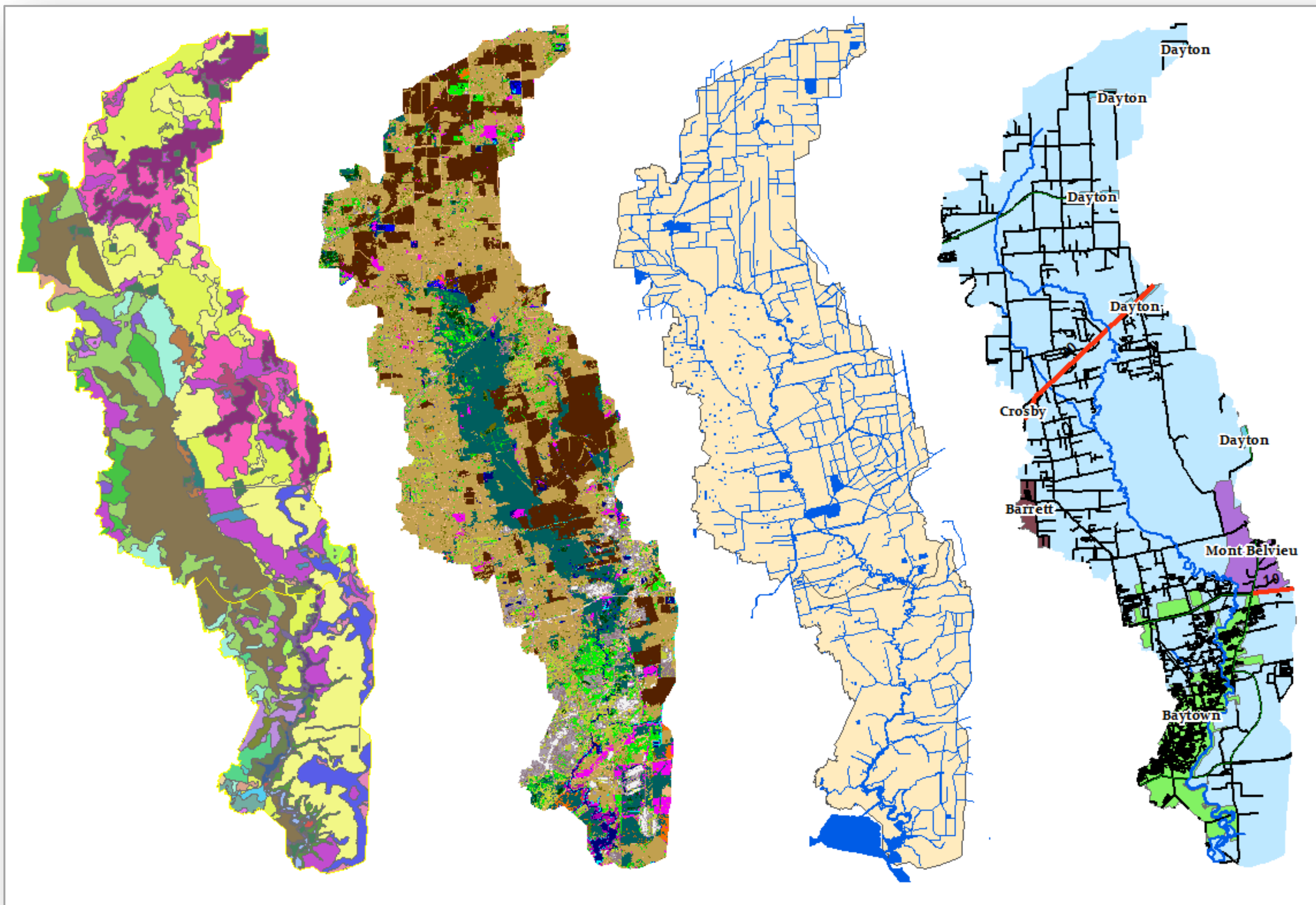
A. Identify the causes that need to be controlled to achieve load reductions
B. Estimate the load reductions from management measures
C. Management measures that need to be implemented to achieve load reductions
D. Technical and financial assistance needed to implement the WPP
E. Information and education that will be used to encourage public understanding and involvement in WPP
F. Timeline for implementing management measures
G. Measurable interim milestones to determine whether management measures are being implemented
H. Criteria that can be used to determine if load reductions are occurring
I. Water quality monitoring to measure effectiveness of implementation against above criteria

Figure 6 – EPA nine elements of watershed-based planning

A Watershed Protection Plan for Cedar Bayou

Water quality concerns for Cedar Bayou led to the formation of the Cedar Bayou Watershed Partnership (Partnership) in 2011. 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 community. This Watershed Protection Plan is the culmination of their multi-year planning effort conducted by the Partnership to restore and maintain the water quality in Cedar Bayou and its tributaries. 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.

Section 2 – The Cedar Bayou Watershed



2 – The Cedar Bayou Watershed

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.

Physical and Natural Features

Figure 7 – Cedar Bayou Tidal at Tri-city Beach Road

Stream Segments of the Watershed

The main channel of Cedar Bayou is approximately 65 miles long, but when combined with its network of tributaries and drainage channels represents over 128 miles of open stream miles. The Bayou's headwaters originate in the top of the San Jacinto-Trinity Coastal Basin east of Lake Houston, and west of the City of Dayton in Liberty County. At its northern extent, the Bayou is characterized by three branches of small, ephemeral streams. The Bayou gradually broadens as it approaches Galveston Bay. The Bayou is navigable to barge traffic from Galveston Bay to the Highway 146 Bridge northeast of Baytown. For the majority of its length, Cedar Bayou forms the boundary between Harris County to the west, and Liberty and Chambers Counties to the east. Prior to its confluence with the Galveston Bay system, Cedar Bayou expands to include a series of estuarine lakes at its mouth. Because it connects directly to Galveston Bay, the portion of the Cedar Bayou system below Interstate 10 is tidally influenced.

The TCEQ divides Cedar Bayou into two designated segments: Cedar Bayou Above Tidal (Segment 0902) and Cedar Bayou Tidal (Segment 0901).

Cedar Bayou Above Tidal (0902)

The official segment originates approximately 4.6 miles above FM 1960 in Liberty County and terminates 1.4 miles above Interstate 10, at which part it represents the border between eastern Harris and western Chambers Counties. The gradient of salinity between the tidally influenced portion of the Bayou to the south and the freshwater stretch of the Above Tidal segment can shift based on precipitation, tidal stage, or seasonal changes. However, the southern terminus of segment 0902 roughly approximates the point at which tidal influence ends. Along much of the northern third of the waterway, the path and banks of Cedar Bayou have been heavily modified[2] and do not have notable natural tributaries. The bed and banks of the channel are bermed in the vicinity of FM 1960. This portion of the segment is primarily fed by manmade drainage conveyances and limited sheet flow directly from the land adjacent to it. Much of the middle portion of the segment enjoys a dense riparian buffer interrupted only by the Highway 90 transportation corridor and other minor roads. Adlong Ditch, a large drainage conveyance, is one of the few primary tributaries to this segment. North of FM 1942, the main channel of the Bayou crosses under a water supply canal by way of siphon. At the end of the segment, the Bayou passes through the urban/industrial areas west of the City of Mont Belvieu. The 145 square miles of watershed for the Above Tidal segment represent approximately 75 percent of the total Cedar Bayou Watershed.

Figure 8 – Horses on residential ranch property

Figure 9 – Maintained channel

[2] In addition to historical modification of the channel and its tributaries, significant modification of the main Above Tidal channel was conducted in the early 1950s.

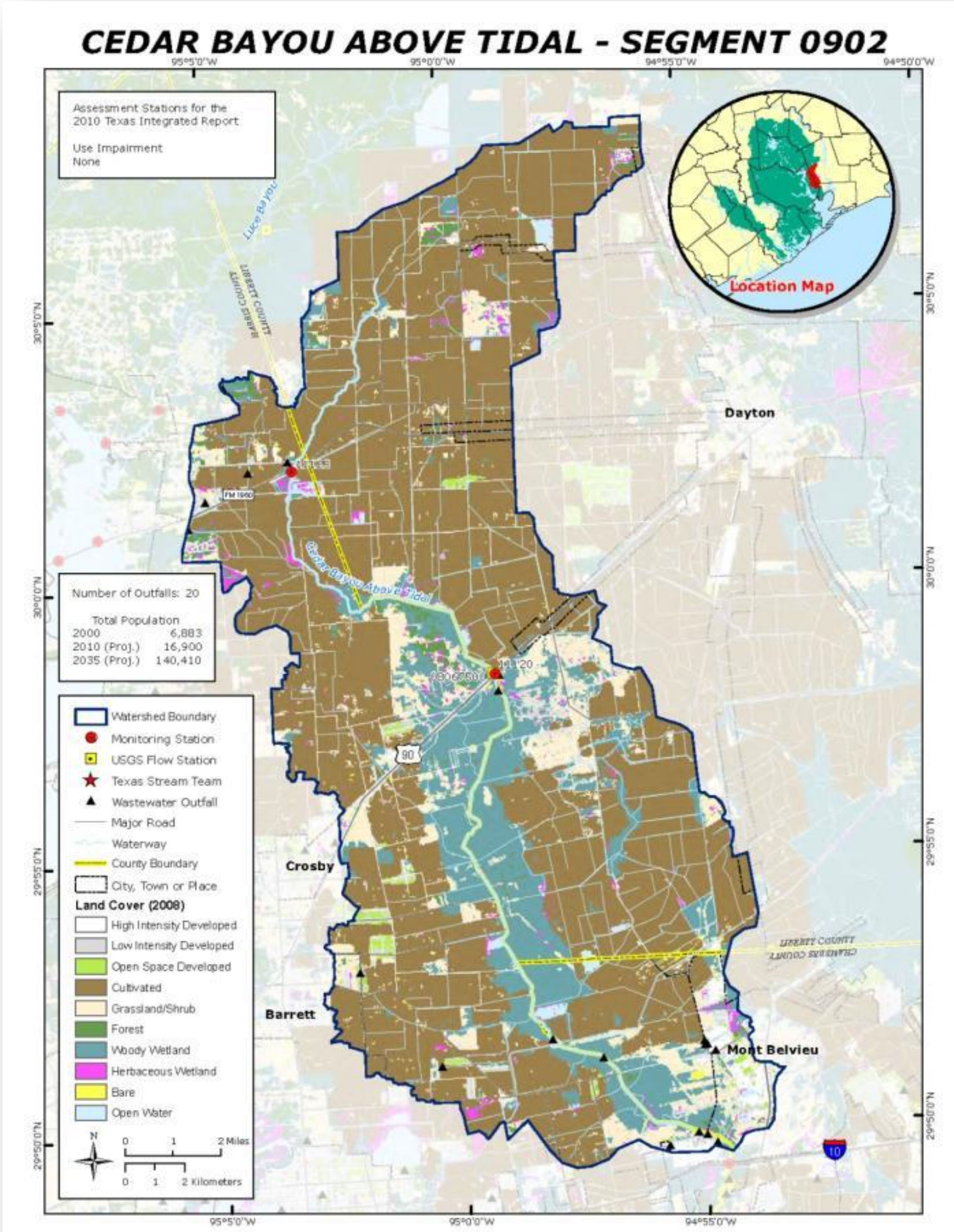


Figure 10 – Land use map of Cedar Bayou Above Tidal (Segment 0902)

Cedar Bayou Tidal (0901)

The Tidal segment of Cedar Bayou (Figure 12) originates 1.4 miles above Interstate 10 at the end of the Above Tidal segment 0902, and terminates at its confluence with Upper Galveston Bay. The entire stretch of this segment represents the border between eastern Harris and western Chambers Counties. The Bayou broadens appreciably in the Tidal segment, becoming a navigable waterway as it passes under the Highway 146 Bridge northeast of the City of Baytown. Primary tributaries of this segment include Cary Bayou in the City of Baytown, Sutton Gully, Sawtooth Gully, Jams Gully, and Pine Gully. However, with the exception of Cary Bayou, these are small, shallow and sometimes intermittent streams. In addition to natural tributaries, the Bayou receives stormwater flow from the City of Baytown, which is regulated under a TPDES Phase II stormwater permit, and other industrial areas on its banks. South of the City of Baytown there is a manmade conveyance channel (the “HL&P Cut”) that serves as a lateral connection between Cedar Bayou and the upper reaches of Galveston Bay prior to the confluence further downstream. In the final stretch of the segment, past the urban-industrial hub of Mont Belvieu/Baytown and the HL&P Cut, the Bayou meanders into a series of small estuarine Lakes. The main channel of the Bayou passes through Negrohead Lake, Ijams Lake, and Ash Lake directly before the Galveston Bay confluence. The Chambers-Liberty Counties Navigation District and the Cedar Bayou Navigation District maintain the navigable channel of the Bayou from its confluence with Galveston Bay north to the industrial complexes adjacent to the City of Baytown. The 54 square miles of watershed area that drain to this segment represent approximately 25 percent of the total Cedar Bayou Watershed.

Figure 11 – Barge on Cedar Bayou Tidal

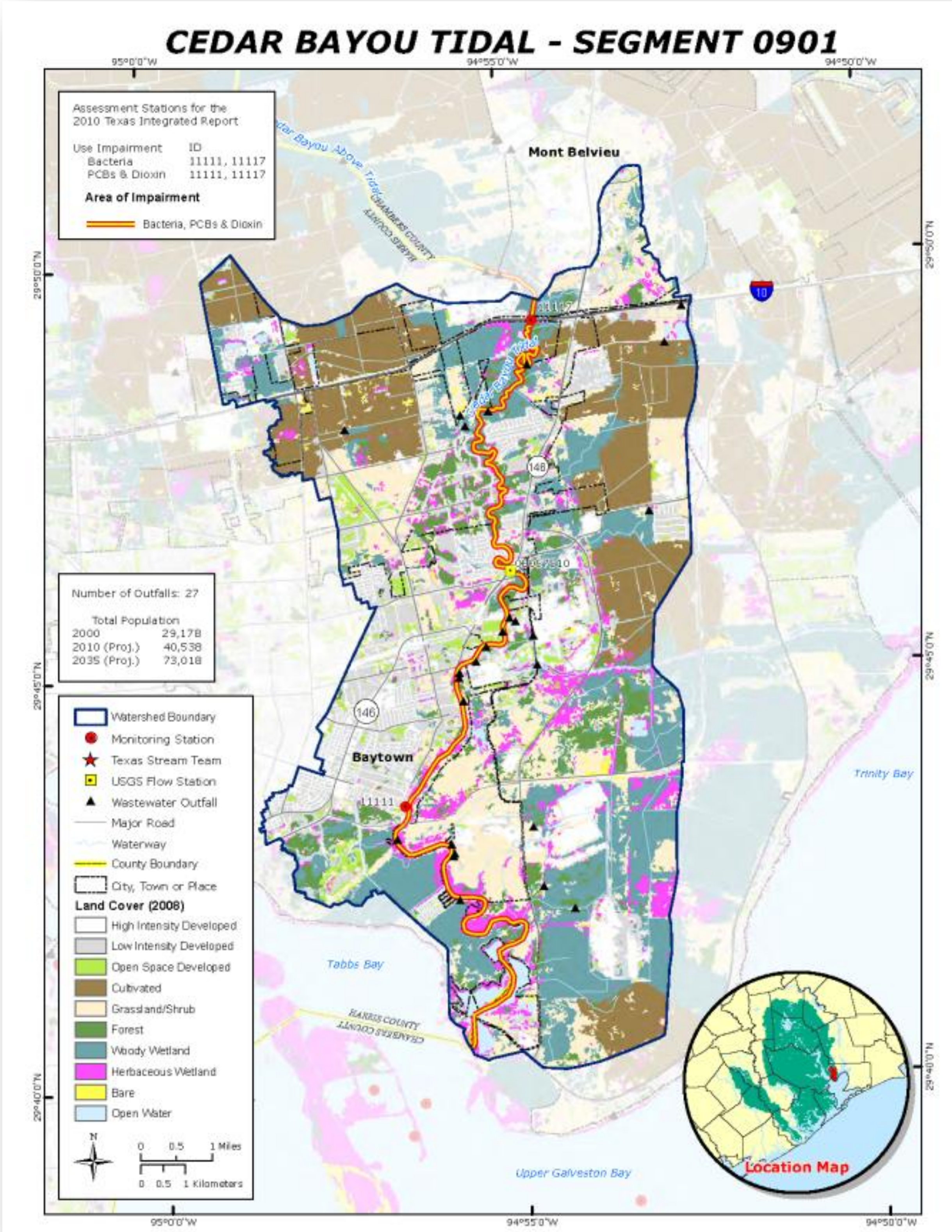


Figure 12 – Cedar Bayou Tidal (Segment 0901)

WATERSHED BOUNDARY

Forming the majority of the San Jacinto-Trinity Coastal Basin, the 200 square mile Cedar Bayou Watershed is located between the larger watersheds of the San Jacinto River to the west and the Trinity River to the East. In turn, these waterways and others form part of the 24,000 square mile watershed of the Galveston Bay. The Cedar Bayou watershed comprises all the land that drains to Cedar Bayou or its network of tributaries and drainage channels. Watershed boundaries are based on topography, but in the flat coastal plain of the Upper Gulf Coast, relative change in land surface is fairly minimal. In addition, the modifications made to the land can change pre-existing drainage patterns and artificially reshape the watershed's natural boundaries. Cedar Bayou's watershed is unique in the intensive level of modification that has occurred to both the main channel and its tributaries, which includes berms along the upper reaches, reorientation of some stretches, altered drainage systems in agricultural areas, manmade stormwater systems in urban areas rerouting flow to outfalls, a water supply canal that bisects the watershed, and the complicated hydrology of the Bayou's lower reaches.

To address the challenge of defining the watershed boundaries for this Plan, the Partnership compared various existing data sets from the United States Geological Survey (USGS), the Clean Rivers Program (CRP), and the Harris County Flood Control District (HCFCD) to topographical delineations completed by the Houston-Galveston Area Council (Figure 13). In addition, project staff conducted a series of field reconnaissance visits and identified manmade barriers to drainage such as canals, major roads, berms and levies, drainage ditches, and urban stormwater systems. The final watershed boundary was based on the HCFCD boundary layer (as shown in orange in Figure 14) because it was the most accurate to existing conditions and was produced at the most granular level.

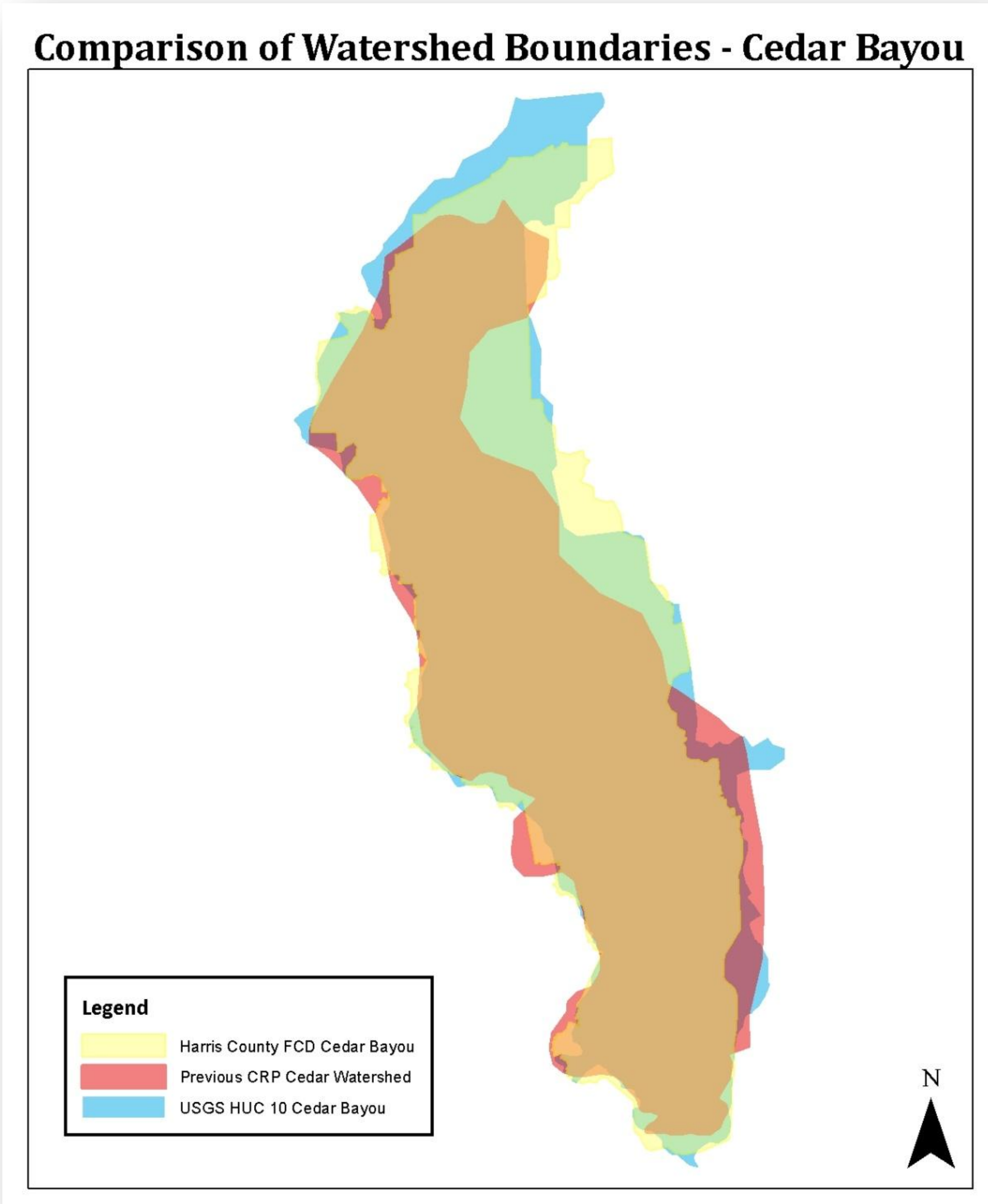


Figure 13 – Comparison of watershed boundaries from different data sources

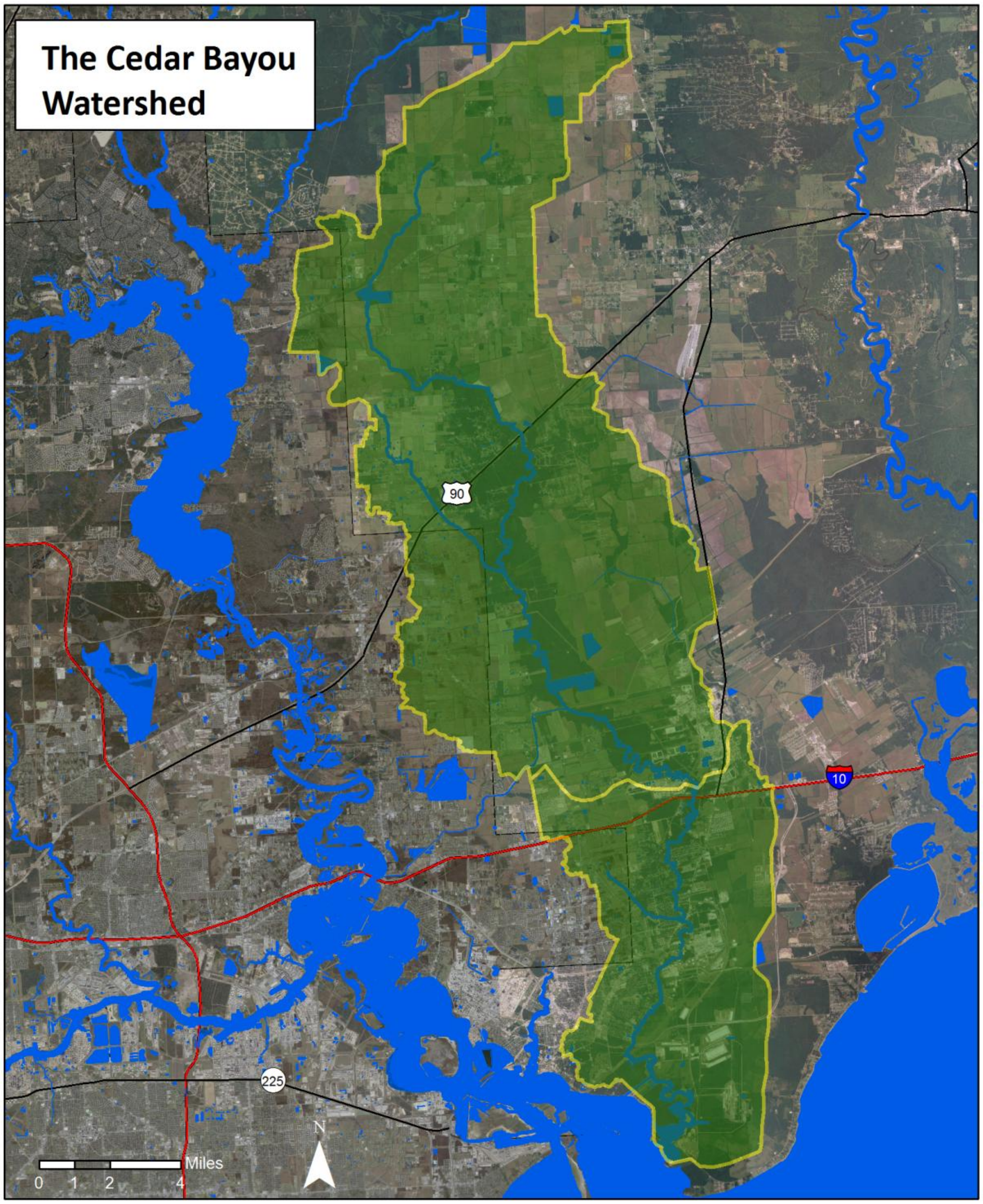


Figure 14 – Cedar Bayou watershed project area

Because new development and changes in land use can alter drainage patterns, watershed boundaries are inherently dynamic. Future updates of this Plan may consider whether the drainage area of the watershed has been altered in intervening years.

Subwatersheds

Watersheds can be broken down into smaller components called subwatersheds. Subwatersheds are often delineated by identifying major tributaries and their respective watersheds. In the Cedar Bayou Watershed, there are few large natural tributaries, and much of the hydrology of the watershed has been modified for drainage and human uses. The Partnership delineated subwatersheds based on water quality sampling locations and other hydrologic boundaries to create a set of subwatershed areas representative of the diversity of land uses and development types in the watershed (Figure 15). These delineated areas were used as the basis to determine their respective contributions to the water quality issues of the watershed as a whole. For the purpose of this project, ten subwatersheds were delineated and evaluated. The subwatersheds were delineated based on sampling station locations (which were chosen to represent points of meaningful transition between land uses), major tributaries, and other factors.

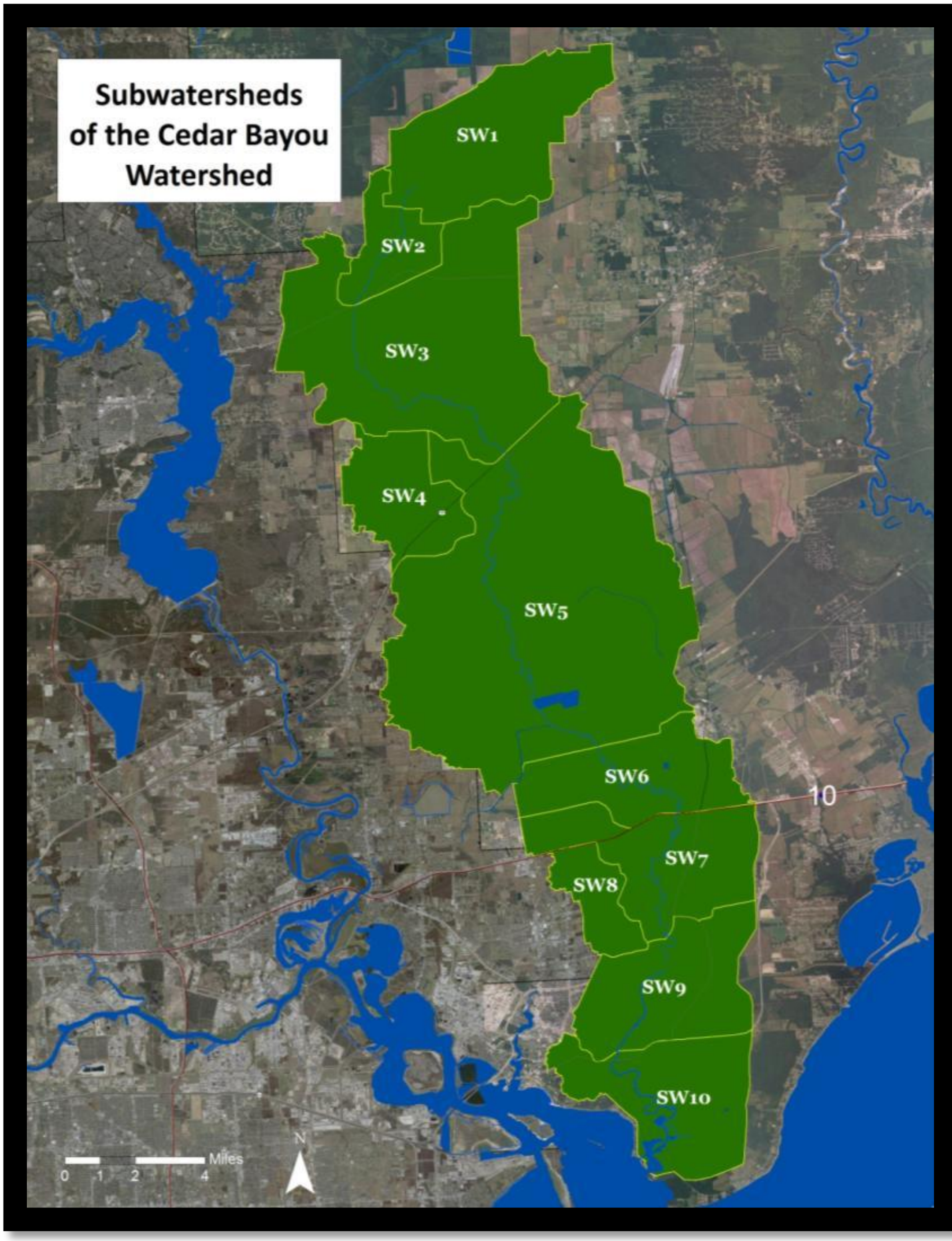


Figure 15 – Subwatersheds of the Cedar Bayou Watershed[3]

[3] The subwatersheds are designated in the map with a SW (for subwatershed) prefix, and then a numerical value representing the general progression from the headwaters to the mouth.

TOPOGRAPHY

As part of the Gulf Coast Plain, there is minimal absolute change in elevation in the Cedar Bayou Watershed, and only moderate relative change between the headwaters and the mouth. In general, the watershed is composed of relatively flat, sea-level coastal wetlands at its mouth, low lying coastal plains throughout its middle, and flat to slightly undulating plains in the north. Elevations in the watershed vary between sea level and 36 meters[4].

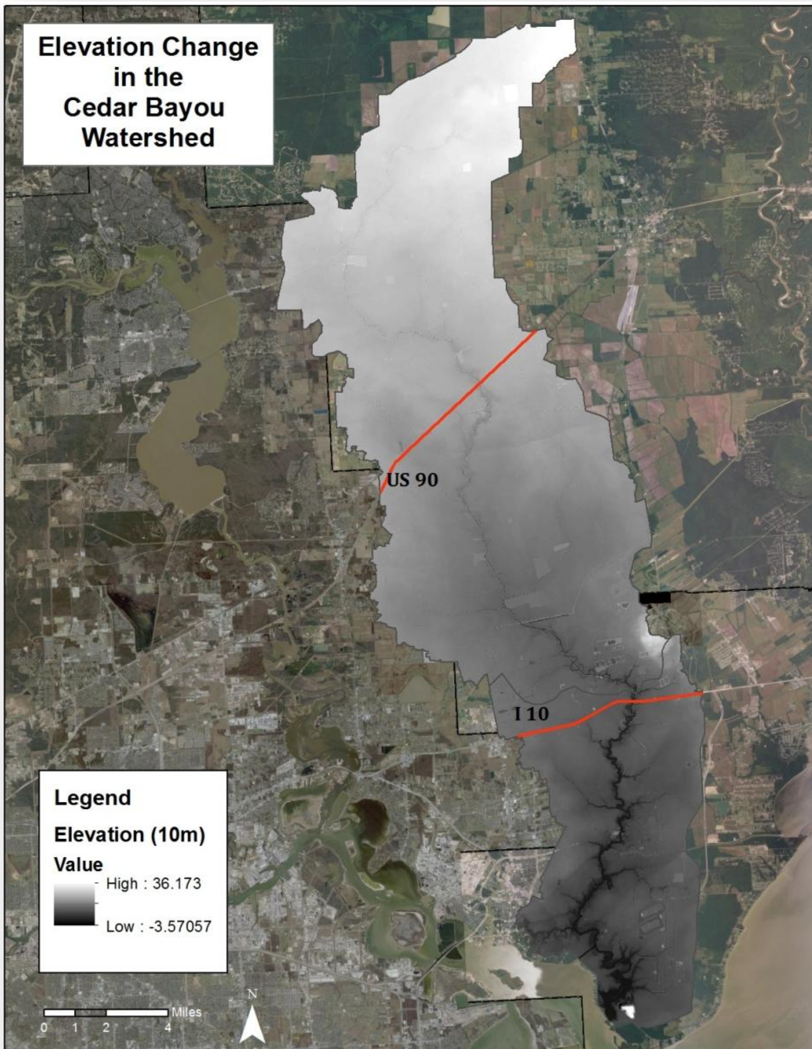


Figure 16 – Elevation change in the Cedar Bayou Watershed

The watershed lacks prominent natural hydrological divides. Some of the most prominent topographical barriers are manmade modifications like berms, canals, and major transportation

[4] The data used to develop elevations represents the state of the watershed subsequent to subsidence that has occurred over the past decades.

corridors. The Cedar Bayou Watershed's relative flatness, particularly in its Tidal segment, makes it especially vulnerable to the hydrologic impact of change in elevation due to development or natural events.

SOILS

Soil types vary widely throughout the watershed, but are generally typical of soils types found throughout the Gulf Coast, including a general mix predominated by loams and clays as shown in Figure 18. Typical soils of the Above Tidal segment of the watershed include a mix of loams, clay/silt loams, clays, and associated complexes. Soils in the Tidal segment of the watershed include a variety of clays, clay loams, and related complexes, and are characterized by slower drainage and lesser permeability[5].

The watershed area is located above the Gulf Coast Aquifer system, which consists primarily of discontinuous sand, silt, clay and gravel beds.

Figure 17 – Arable land in the Above Tidal segment

[5] Based on data retrieved from USDA NRCS SSURGO and Web Soil Survey, as accessed 5/21/14. The data represents the September, 2013 data which includes surveys from 2003 on.

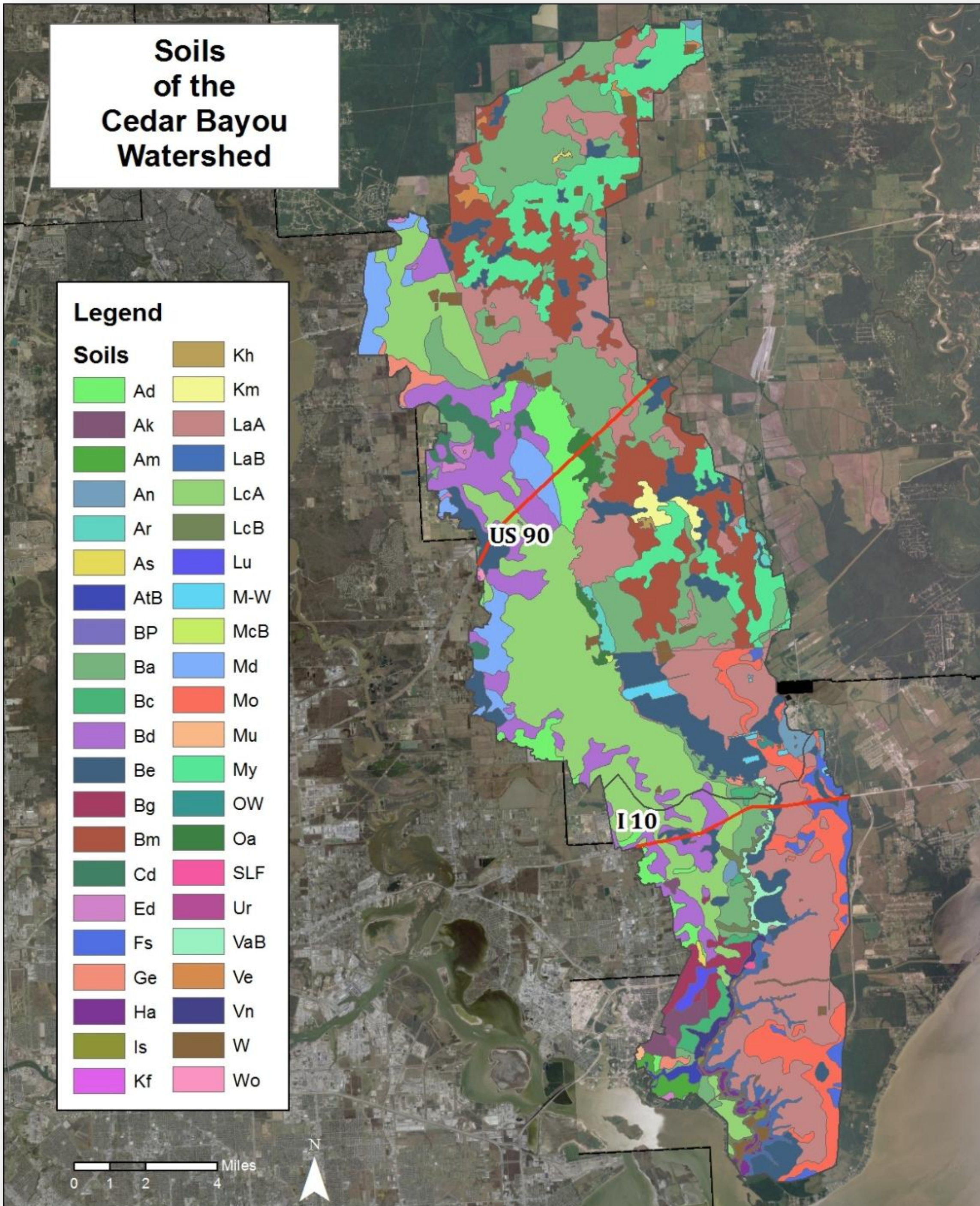


***Figure 18 – Soils of the Cedar Bayou Watershed*[6]**

[6] The legend in Figure 18 refers to the various soil types listed by the codes used for the USDA NRCS soil data. More information on the specific descriptions of these soils can be found by using the web soil survey tool at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

CLIMATE

The climate for the watershed is generally categorized as humid subtropical. Unlike true tropical areas, this region has winter temperatures low enough to generate occasional freezing conditions. Average annual rainfall in the area is between 40" to 54" with increasing levels towards the coast. Temperatures can reach over 100 degrees Fahrenheit in the summer and remain moderate even in the winter. The watershed is particularly vulnerable to avulsive weather events occurring in the Gulf of Mexico, and is seasonally prone to hurricanes and tropical storms.

The perpetually warm climate allows the area to support a diverse array of flora and fauna, but can also exacerbate some water quality issues like depressed dissolved oxygen (DO).

ECOREGIONS

The Cedar Bayou Watershed is part of the Western Gulf Coastal Plain/Gulf Coast Prairies and Marshes Ecoregion, as designated under the EPA's Level III Ecoregion classification (Figure 19). EPA's description of this category indicates that "The principal distinguishing characteristics of the Western Gulf Coastal Plain are its relatively flat coastal plain topography and mainly grassland potential natural vegetation. Inland from this region the plains are older, more irregular, and have mostly forest or savanna-type vegetation potentials. Largely because of these characteristics, a higher percentage of the land is in cropland than in bordering ecological regions. Urban and industrial land uses have expanded greatly in recent decades, and oil and gas production is common." The EPA's Level IV Ecoregion classification further refines this area description by placing the watershed in the Northern Humid Gulf Coast Prairies subcategory, which notes that in this area, almost "all of the coastal prairies have been converted to cropland, rangeland, pasture, or urban land uses" [7].

Plant species in the Cedar Bayou Watershed range greatly from the bottom of the watershed to the top. Highly salt tolerant or halophytic species are common to the coastal marshes and estuarine lakes in the lower reach, including stands of sea grasses and other native vegetation. Typical coastal tallgrass prairie species and loblolly pine stands are still found in the northern extent of the region. Along the riparian corridor of the Bayou, mixed oak forests and tree species suited to moist riparian environments (hydrophilic) can be found, including pinoak. In some areas, previous dredging and channel modification have created spoils banks supporting pines.

[7] As per EPA Class III and Class IV designations, referenced in GIS and other data retrieved from http://www.epa.gov/wed/pages/ecoregions/tx_eco.htm.

Figure 19 – Level III Ecoregions of Texas

WILDLIFE AND HABITAT

The Upper Texas Gulf Coast is host to a diverse array of habitat types. Cedar Bayou's watershed is typical of the general variety of habitat found near the Texas Coast, including coastal marshes, riparian corridors, coastal prairie, open woodlands, pastureland, estuarine lakes, and small bodies of open fresh water. While there are no designated wildlife protection areas in the Cedar Bayou Watershed, the surrounding region hosts several National Wildlife Refuges, Wildlife Management Areas, and other protected areas that share similar habitat types. Much of the watershed has been converted to human use through rural and urban land development, but there are dense, contiguous blocks of undeveloped terrain, particularly in the Above Tidal segment. H-GAC maintains the Eco-Logical mapping tool[8], designed by H-GAC and regional stakeholders to identify high-quality, large contiguous ecological areas. While these areas are considered priorities due to the value of contiguity and size, it is not to suggest that smaller and discontiguous areas of these habitats are not valuable. Small local habitat areas may be of great community importance. The Eco-logical data indicates a variety of such areas in the Cedar Bayou Watershed, including the large riparian corridor of bottomland forest along the central reach of the Bayou, and smaller blocks of undeveloped bottomland forest, coastal prairie, tidal wetlands, and upland forests throughout the watershed (see Figure 20).

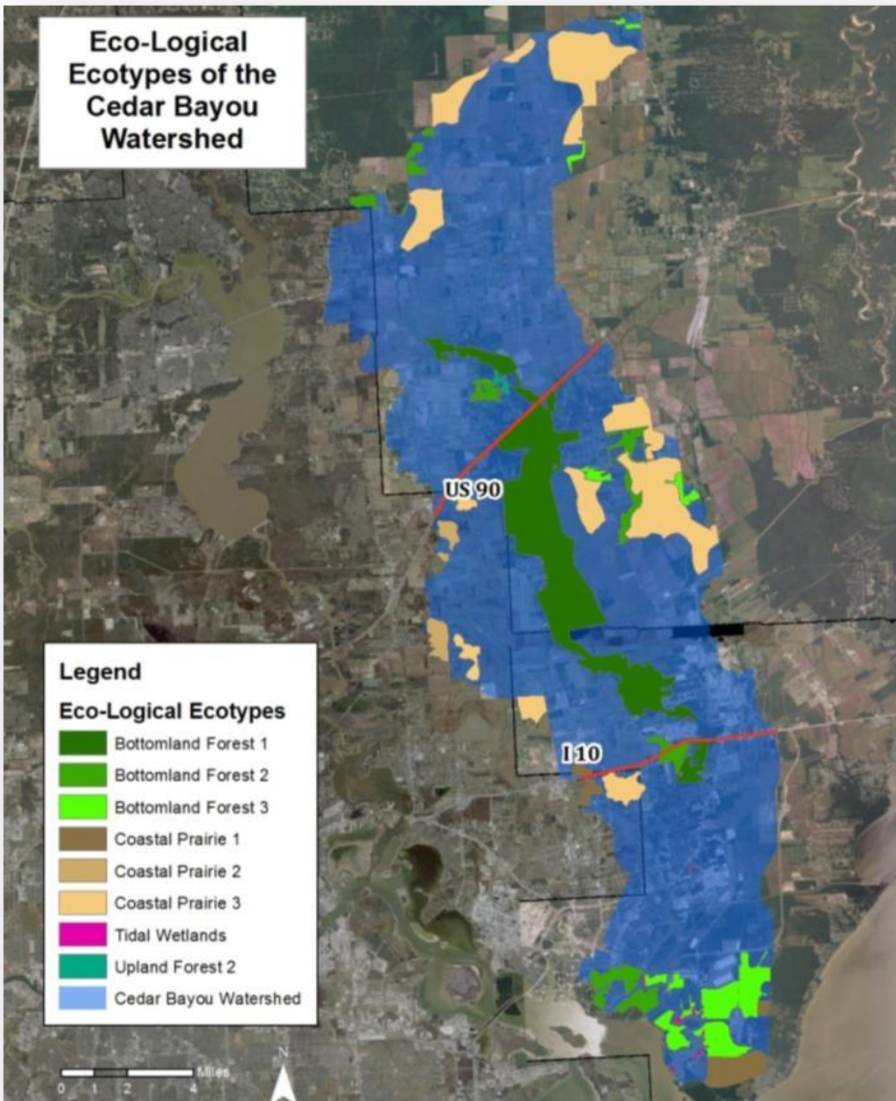


Figure 20 – Eco-Logical ecotypes of the Cedar Bayou Watershed.

[8] More information on this tool can be found at http://www.h-gac.com/community/environmental-stewardship/eco-logical/.

Moderate winter temperatures and large areas of coastal wetlands provide excellent wintering grounds for migrating waterfowl and support a dense community of bird species year-round. Additionally, Cedar Bayou is located in the Central Flyway for migratory birds. Each year in the spring and fall, vast numbers of neotropical birds migrate to and from southerly destinations, funneling through this and other coastal areas before dispersing across North America. In addition to these visiting species, Cedar Bayou hosts many of the common species of the upper Texas Coast, including the herons, egrets, osprey, cormorants, roseate spoonbills, kingfishers, Bald Eagles, ibis, gulls and terns that frequent the estuarine lakes and coastal wetlands of the Tidal segment. The prairie and woodlands of the Above Tidal segment are habitat for a variety of passerine species and raptors, including vultures and hawks.

The Tidal segment also supports a variety of saltwater and salt-tolerant fish and marine life. Typical species expected in this location[9] include Red Drum, Gulf Menhaden, Atlantic Croaker, Speckled Trout, Brown Shrimp, Blue Crab, Flounder, Blue Catfish, and several species of gar. The small lakes and broad channel of the Bayou's Tidal segment are part of the vital habitat that makes Galveston Bay one of the most productive estuaries in the country, and are also home to oysters and mussels which were an important food source for early settlers. The Above Tidal segment has shallower depths and a narrower channel, but still supports common species[10] like Sunfish (*Lepomis sp.*), Mosquitofish (*Gambusi sp*.), Largemouth Bass, minnow species, Inland Silverside, Blackhead Shiner, Blackstripe Topminnow, Alligator Gar, and Channel Catfish, and some species more typically found in marine environments (Gulf Menhaden, Atlantic Croaker)[11].

The watershed supports a moderate community of mammal species, including White-tailed Deer, Virginia Opossum, Raccoons, Coyotes, Eastern Grey Squirrels, Striped Skunks, Nine-banded Armadillos, and numerous species of rodents and bats.

Of particular concern to the watershed are some of the invasive species that are making it home. In addition to exotic plants and other invasive animals, feral hogs are a growing issue for the Houston region and are present in the Cedar Bayou area. Feral hogs threaten native wildlife species through direct competition for food as well as destruction of habitat. Sufficiently 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 waterbody.

[9] Biological data was collected only for the Above Tidal segment, as no macrobenthic community impairment existed for the Tidal segment. Fish noted here are from anecdotal stakeholder reports and known species common to Tidal reaches in the local region.

[10] These species are a sample of the more common species collected during biological sampling in 2013/2014.

[11] Data from biological sampling indicated these marine species were found at site 11118, upstream of the Tidal boundary. However, it is likely that tidal action, changes in precipitation, and a shifting saline boundary may make these species at least seasonally common in the lower extent of the Above Tidal watershed.

Watershed History

History

The history of Texas is equally a history of its waterways. Like many other areas of the state, the growth of the Cedar Bayou Watershed began and remained focused on its namesake waterway throughout the years.

Indigenous History

Prior to European contact and development, the Cedar Bayou area was populated by nomadic Native American tribes of the Karankawa peoples who lived in the coastal areas between Galveston Bay and Corpus Christi. Fish and shellfish from Cedar Bayou were an important source of sustenance and materials for these groups, and the Bayou was used as a navigable waterway for trade. The northern reaches of the watershed may have also included groups of the Caddo peoples, whose southern boundaries overlapped with the northern boundaries of the Karankawa. European contact with the Karankawa dates to at least 1528, although contact in the Cedar Bayou area was likely some time later. The Karankawa were the targets of attempted missionization by the Spanish. After Mexican independence and the first wave of Anglo settlement in 1821, the Karankawa were forced to relocate west of the Lavaca River, and eventually diminished as a people under continuing conflict with the European settlers and other Native American groups like the Comanche[12].

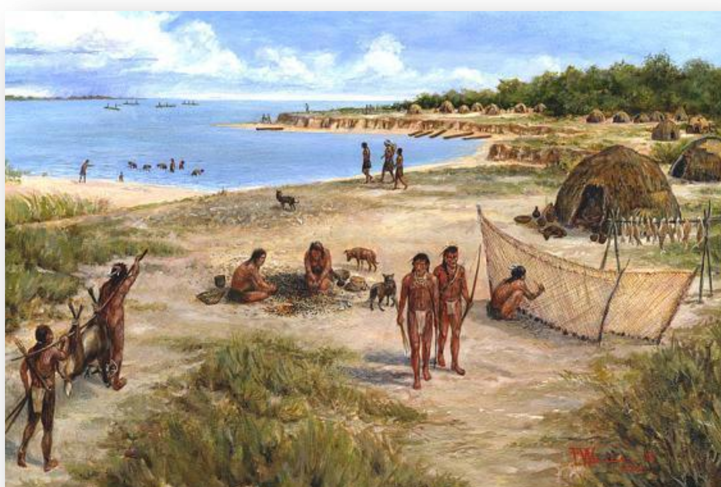


Figure 21 – Indigenous peoples (image courtesy of texasbeyondhistory.net)

[12] Carol A. Lipscomb, "KARANKAWA INDIANS," ***Handbook of Texas Online*** (http://www.tshaonline.org/handbook/online/articles/bmk05), accessed December 05, 2013.

The Establishment of Early Texas

Development of the area by Europeans began in earnest in the early-1800's following the Mexican government's first land grants to Stephen F. Austin "Old Three Hundred", and the establishment of Lynchburg Ferry in 1822. However, while the Houston area was expanding rapidly, the Cedar Bayou Watershed (continuously occupied since at least 1835) remained a sparsely populated collection of minor plantations, brickworks, small shipyards building shallow draft schooners, grist mills, saw mills, and cattle operations until the early 1900's. Lack of rail service and hurricanes were important factors in limiting development. At the end of this period canal development and other improvements expanded agricultural operations, including rice production. One of Texas' most popular poets of the time, John Peter Sjolander, lived and worked in the Cedar Bayou area, and was known as "the Sage of Cedar Bayou"[13]. Sjolander's name, and the name of many other early settlers, can be found on local roads in the area.

Figure 22 – Images and artifacts of the early Baytown area (image courtesy of www.ourbaytown.com)

[13] Timothy Nolan Smith, "CEDAR BAYOU, TX," ***Handbook of Texas Online*** (http://www.tshaonline.org/handbook/online/articles/hrc33), accessed December 05, 2013.

The Oil Boom

A sudden increase in development of the southern portion of the watershed accompanied the 1916 oil boom, which was sparked by the nearby Goose Creek oilfield. The watershed towns of Pelly, Goose Creek and Baytown[14] grew up around the oil strike and the Humble Oil (now Exxon Oil) Refinery that began construction in 1919. By 1947, the three towns had merged into the present day city of Baytown. By the late 1920's, the other major urban area of the watershed, Mont Belvieu[15], had developed around the Barber's Hill oilfield to the northeast. The upper portions of the watershed remained mainly in agricultural production or undeveloped during this time[16].

Figure 23 – Oil production in the Goose Creek oilfield (image courtesy of www.ourbaytown.com)

[14] Buck A. Young, "BAYTOWN, TX," ***Handbook of Texas Online*** (http://www.tshaonline.org/handbook/online/articles/hdb01), accessed December 05, 2013. Published by the Texas State Historical Association.

[15] Robert Wooster, "MONT BELVIEU, TX," ***Handbook of Texas Online*** (http://www.tshaonline.org/handbook/online/articles/hjm15), accessed December 05, 2013. Published by the Texas State Historical Association.

[16] Priscilla Myers Benham, "GOOSE CREEK OILFIELD," ***Handbook of Texas Online*** (http://www.tshaonline.org/handbook/online/articles/dog01), accessed December 05, 2013. Published by the Texas State Historical Association.

The Post-war Era

Since the mid 20[th] century, economic activity in the watershed has continued to focus around the development of petrochemical facilities and other industries. Exxon Mobile, Bayer, Chevron Phillips, USA Steel and other large industrial and commercial centers have been primary employers. Urban development has continued to focus on the urban centers in the southern portion of the watershed. Significant development has arisen between the traditional urban centers and the Interstate 10 corridor as growth from the Houston metropolitan area has continued to expand into the watershed. Development in the northern part of the watershed has increased more slowly, with agriculture slowly shifting from traditional row crops, rice, and cattle operations to an increased presence of turf farming.

Figure 24 – Modern residential and commercial development along Cedar Bayou (image courtesy of Jerry Jones)

WATERSHED CHARACTER

POLITICAL GEOGRAPHY

The primary urban centers of the watershed are the City of Baytown, in the southwestern portion of the Tidal segment, and the City of Mont Belvieu whose eastern boundary encompasses some of the area around the Tidal/Above Tidal segment boundary. The populations for the urban centers of Baytown and Mont Belvieu at the start of the watershed planning process in 2010 were approximately 72,000 and 3,800, respectively. Other cities and census-designated places that are at least partially in the watershed include Barrett, Crosby, and undeveloped annexation areas of the City of Dayton. Beach City is directly south of the watershed on the Galveston Bay coastline. However, the majority of the acreage in the watershed is in the unincorporated areas of Harris and Liberty counties, outside of urban centers (see Figure 25).

The watershed area includes portions of eastern Harris County, western Chambers County, and western Liberty County. The area is wholly or partially within several districts or authorities, including the Region H Water Planning Group, the 13-County Houston-Galveston Area Council, the Texas Coastal Management Zone, the Greater Houston Metropolitan Area, the Harris County Flood Control District, and the Cedar Bayou and Chambers-Liberty Counties Navigation Districts.

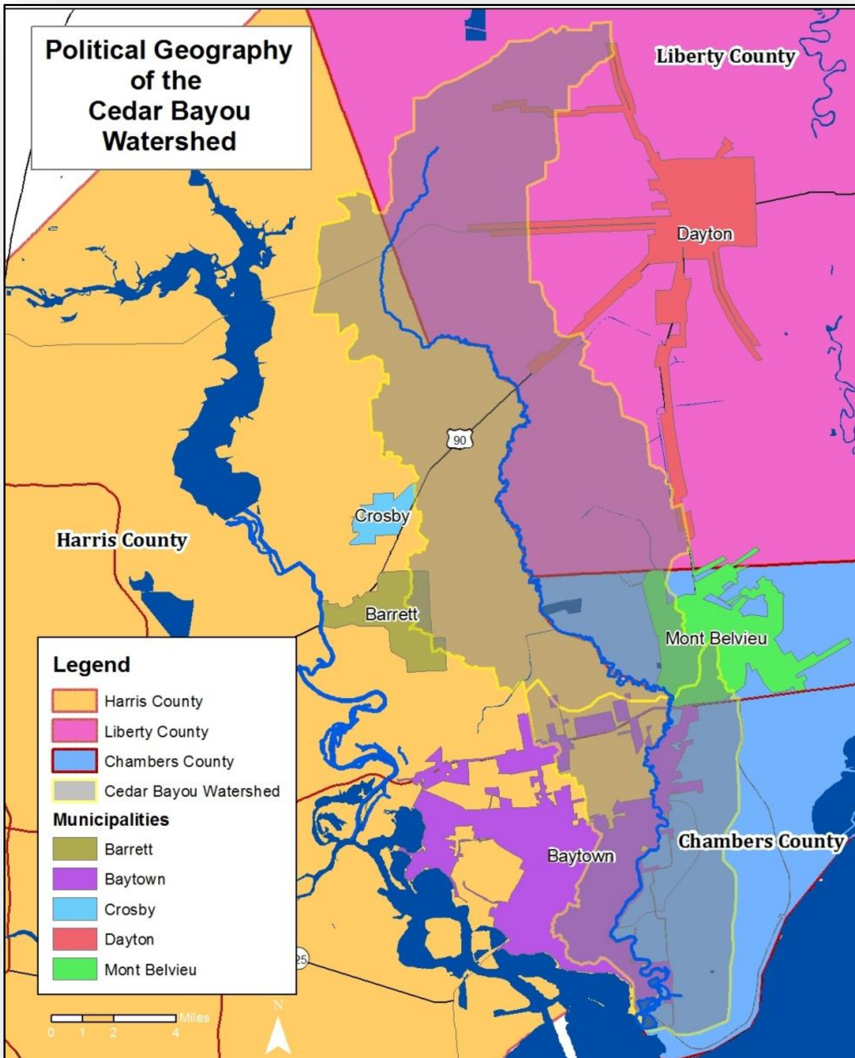


Figure 25 – Political geography of the Cedar Bayou watershed

WATER SUPPLY

The public water supply in the basin comes from sources other than Cedar Bayou. Much of the northern portion of the watershed, as well as the municipal supply for the City of Mont Belvieu, is served by groundwater wells. Surface water supplied for public consumption is primarily provided by the Baytown Area Water Authority from the Trinity River.

Water supplies taken from Cedar Bayou itself primarily serve irrigation and industrial purposes (Figures 27 and 28). In the state of Texas, surface water use other than small domestic uses by properties adjacent to waterways requires a surface water right adjudicated by the state. There are 12 distinct surface water rights holders who are permitted to withdraw from Cedar Bayou (Table 1). The permitted water consumption volumes total approximately 41,000 acre-feet per year, the equivalent of over 13 billion gallons a year, or 36 million gallons a day (MGD). NRG Energy's Cedar Bayou Plant accounts for over 70 percent of the total appropriated water consumption. Unlike some water rights permits, the NRG permit does not have a total withdrawal limit. Its permit limit is based on water consumed (i.e. water not included in return flows) during cooling processes. The average annual withdrawals from Cedar Bayou, over the last 5 years, are approximately 415,609 acre-feet/yr. NRG's average consumption is 2,024 acre-feet/year. However, water withdrawn by NRG is not returned to Cedar Bayou, but instead is released via canal to a holding structure in the Trinity Basin. Regardless, in an average year, NRG represents almost the entire withdrawal volume from the Bayou. Figure 28 illustrates the diversion and consumption rates, 2000-2013. Surface water consumption by the permit holders is almost exclusively for industrial/power generation (73 percent) and irrigation (27 percent). The irrigation volumes are used to irrigate approximately 4,300 acres, and the rights holders collectively have the right to impound approximately 41 percent of the allocated consumption volumes.

Figure 26 – Water intake at NRG Cedar Bayou Generating Station

Table 1 – Surface water rights on Cedar Bayou

Surface Water Rights on Cedar Bayou

Water Rights No.	Owner	Right in Acre-feet/yr.	Use	Priority Date	Permitted Acres for Irrigation	Impoundment Volume in Acre-feet/yr.
3912	Stoesser Farms Inc	4	Irrigation	4/30/1948	1	
3920	BCD Services Inc	100	Recreation	9/5/1963		184
3914	Riceland Properties Inc	235	Irrigation	3/10/1953	106	416
3915	Roy A Seaberg, et al.	308	Irrigation	4/30/1942	104	
3923	Billy E Murff	347	Irrigation	1/20/1970	139	365
3911	Stoesser Farms Inc	525	Irrigation	4/30/1969	150	42
3923	Billy E Murff	606	Irrigation	1/29/1943	243	
3914	Roy A Seaberg, et al.	665	Irrigation	3/10/1953	299	
3922	Cedar Bayou Ltd	700	Irrigation	1/20/1970	240	
3922	Cedar Bayou Ltd	800	Irrigation	1/29/1943	320	
3926	NRG Cedar Bayou Development Co LLC	1,050	Industrial	1/6/1967		
3926	Optim Energy Cedar Bayou 4 Llc	1,050	Industrial	1/6/1967		
3919	FPL Farming Co Ltd	1,152	Irrigation	5/31/1955	427	472
3909	Stoesser Farms Inc	1,402	Irrigation	4/30/1947	429	480
3913	Gin City Land Company Inc	1,542	Irrigation	4/30/1942	993	605
3918	Gin City Land Company Inc	2,500	Irrigation	5/31/1955	853	570
3926	NRG Texas Power LLC	*27,900*	Industrial	1/6/1967		13750

Totals	40,887	Acre-Feet/yr.
	13,325	Million Gallons/yr.
	36.5	Million Gallons/Day

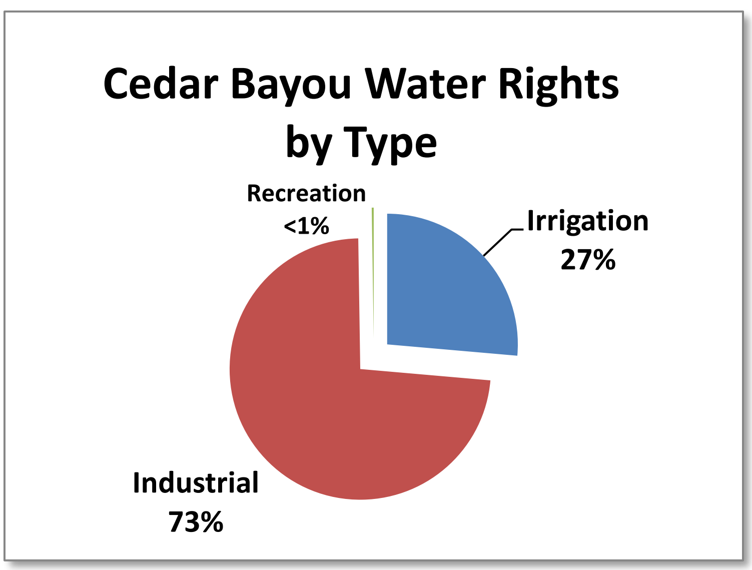
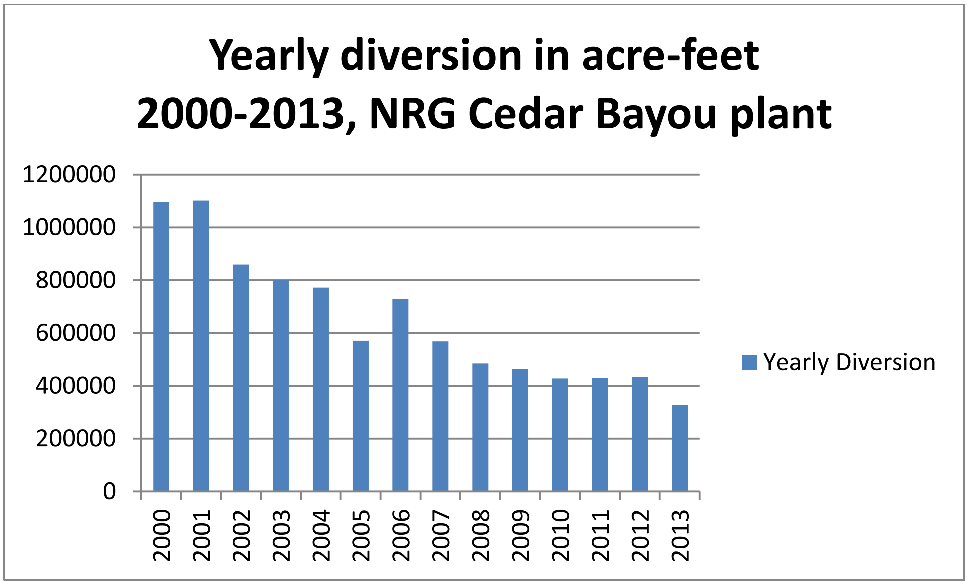


Figure 27 – Cedar Bayou surface water rights, by type



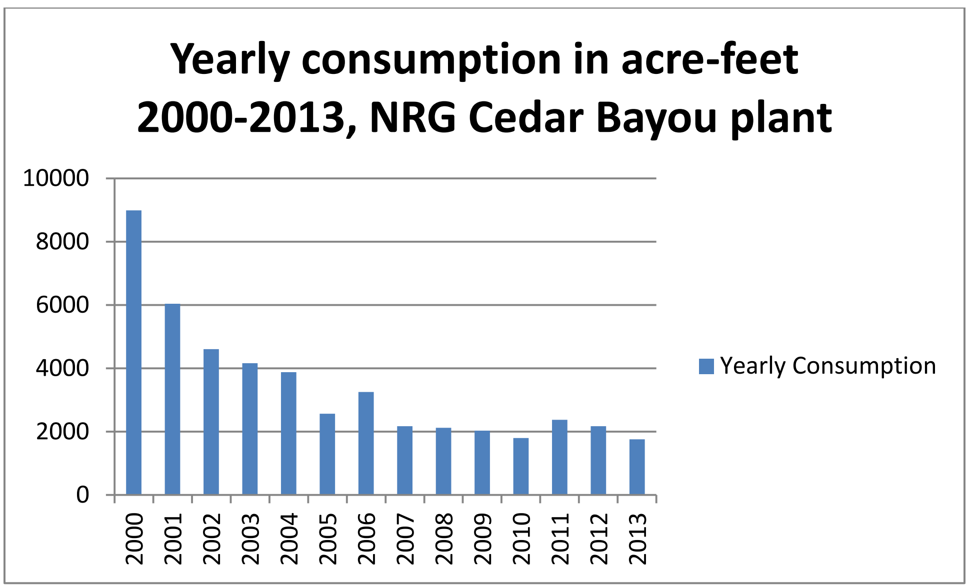


Figure 28 – NRG yearly diversion and consumption, 2000-2013

Agricultural Use

Agricultural uses in the watershed are most dominant in the northern reaches of the Above Tidal segment. Turf grass farms represent an appreciable portion of the land in production, along with traditional row crops, rice production, and livestock operations. There are no permitted CAFOs in the watershed. Approximately 385 acres of farm and ranch lands in the watershed currently have a certified Water Quality Management Plan (WQMP). WQMPs provide technical and financial incentives for agricultural practices that benefit water quality with the Texas State Soil and Water Conservation Board. Agricultural producers are actively served by programs and staff of the Texas Farm Bureau, Soil and Water Conservation Districts (including the Harris County SWCD, Lower Trinity [Liberty County] SWCD, and Trinity Bay [Chambers County] SWCD), the TSSWCB, Texas A&M AgriLife Extension (AgriLife Extension) and AgriLife Research (AgriLife Research) and related County Extension offices, the USDA Natural Resources Conservation Service (NRCS) and various local commodity organizations.

Figure 29 – Rice dryer[17]

[17] Rice dryers are a legacy of the watershed's agricultural legacy. While rice was once a widespread crop in the region, its production has declined in recent years.

LAND USE/LAND COVER

Land use in the watershed varies greatly[18] (Figure 30), and development generally increases in density along a north-to-south transect, although major transportation corridors (e.g., Highway 90, Interstate 10, and the future Highway 99) serve as concentrators of new growth. The Above Tidal portion of the watershed is generally characterized by primarily agricultural and rural residential uses that gradually give way to light suburban development. In the interior of the segment's watershed, a large swath of undeveloped woodlands borders the main channel, starting south of Highway 90. Some industrial and urban uses are found near the boundary with the Tidal segment in the Mont Belvieu area. New and projected development is primarily occurring adjacent to existing urban areas and along the major transportation corridors of Highway 90 and Interstate 10.

The Tidal portion is characterized by a varied mix of land uses. In the northern portion of the segment's watershed, suburban and light agricultural uses gradually give way to dense urban uses and industrial core uses in the Baytown area. For the watershed as a whole, wetlands make up the second largest general land cover class. While a large portion of the petrochemical complexes in the area are found outside of the Cedar Bayou Watershed along nearby Goose Creek, there are several large industrial parcels on the east bank of Cedar Bayou east of Baytown. South of the Baytown area, the land uses include a variety of wetland and undeveloped land cover types. Specific land uses of note in this area include a large solid waste landfill site adjacent to the Bayou's east shore, north of the mouth.

[18] Greater detail on land use/land cover delineation and change over time is discussed in Section 5.

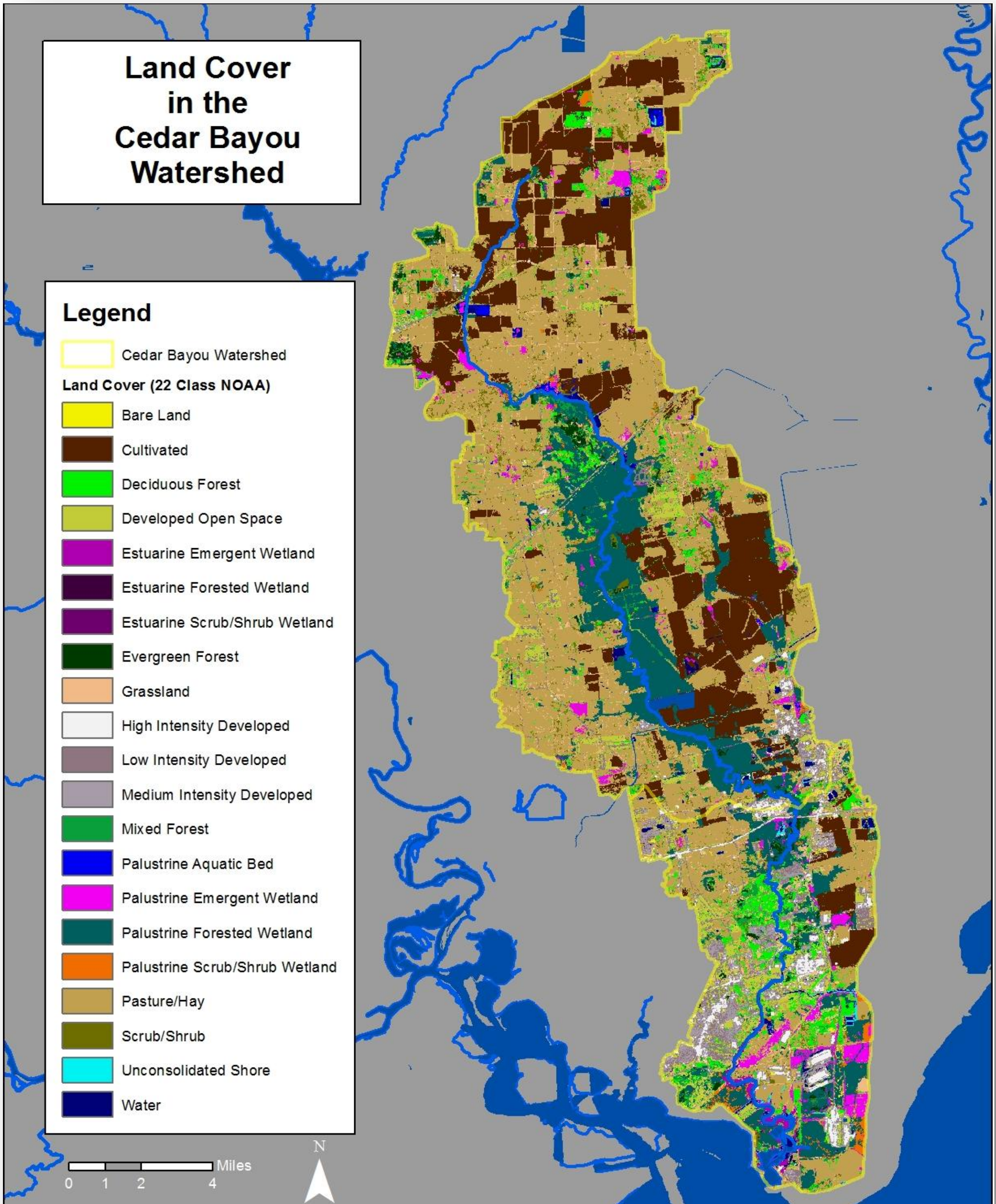


Figure 30 – Land cover in the Cedar Bayou Watershed

WATER QUALITY

Water quality in any waterway can vary greatly by season, time of day, or from year to year. In the most general sense, water quality is a subjective measure. It becomes an important concept, however, when it is used to compare the suitability of the waterway to designated uses based on a human or natural need(s).

WATER QUALITY STANDARDS

For the lakes, creeks, streams, rivers, bays and bayous of Texas, water quality is evaluated on the basis of Surface Water Quality Standards (SWQS). The SWQS were established by the State of Texas as required by section 303 of the 1972 Clean Water Act and subsequent updates. 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 human recreation, drinking water supply, aquatic communities, and other established uses.

Surface water segments are broken into assessment units for the purpose of determining whether a water body is in compliance with applicable standards. Cedar Bayou's two segments, Cedar Bayou Above Tidal (0902) and Cedar Bayou Tidal (0901), and the tributaries thereof, are represented by a single assessment unit each (0902_01 and 0901_01, respectively).

Assessments are made based on data collected under the state's Clean Rivers Program (CRP) and other quality-assured sources. The TCEQ conducts assessments every two years for the state's water bodies, and the results are included as part of Texas' *Integrated Report of Surface Water Quality* (Integrated Report). The results of the assessments of the Cedar Bayou segments are summarized in Table 2.

DESIGNATED USES

Cedar Bayou serves a multitude of uses for people and wildlife. For the purpose of SWQS compliance assessment, Cedar Bayou Tidal is designated for aquatic life, recreation, general, and fish consumption. Cedar Bayou Above Tidal is designated for aquatic life, recreation, general, and public water supply. The uses, and the standards used to assess them, can be adjusted based on new data, and on a site-specific basis.

The aquatic life use designation is a reflection of the ability of the Bayou 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 dissolved oxygen.

The contact recreation use designation indicates that the waterway is used for human recreational activities that involve an appreciable chance of ingesting Bayou water. The basis of contact recreation standards is to protect public health. Select bacteria organisms (*E. coli* and *Enterococcus*) are used as indicators of the potential contamination level from fecal pathogens. For Cedar Bayou Above Tidal, elevated levels of *E. coli* are signs of inability of the waterway to meet the contact recreation standard, whereas *Enterococcus* is used for the Tidal segment.

The upper segment of Cedar Bayou is utilized for the designated public water supply use. The assessment of compliance for this use is a measure of the suitability of the water supply to serve as a drinking water source. A variety of criteria are used to evaluate this use, including temperature, total dissolved solids, dissolved oxygen, pH range, indicator bacteria, chlorine, and sulfates levels.

The fish consumption use designation is measured by levels of PCBs and dioxins in edible fish tissue. PCBs and Dioxins are fat-soluble compounds that accumulate in the fatty tissues of fish and other species, including humans. Because these compounds have carcinogenic and neurological effects in humans, the purpose of assessing this use is to protect public health. Assessment of compliance is related to direct testing of specific fish populations and fish advisories.

The general use designation reflects the overall health of the waterway as measured by criteria for temperature, pH, chloride, sulfate, and other constituents.

These uses are of specific importance to Cedar Bayou's water quality and human interests.

State of the Water

Cedar Bayou's water quality is impacted by numerous factors, including human activities, natural processes, tidal forces, availability of rainfall, and issues in the greater Galveston Bay system to which it is connected. Based on assessment of water quality data, the Above Tidal and Tidal portions of Cedar Bayou have existing water quality challenges. As development continues over the coming decades, additional sources of contamination may exacerbate these issues if no action is taken.

Water Quality

Water quality in Cedar Bayou is typical of other coastal rivers and bayous in the area, though relatively good compared to waterways in more urbanized areas. The Above Tidal segment of the waterway has relatively good water quality, although it has had limited ability to support aquatic communities in the past. The large, undeveloped forest and fields that currently surround the waterway in much of this segment are likely a buffer against contamination from surrounding land uses. The Tidal segment sees a greater degree of human impacts, reflected in elevated levels of indicator bacteria and potential presence of PCBs and dioxins in edible fish tissue. The ability to maintain ecological communities has varied over time, with concerns for DO and chlorophyll *a*. In addition to those contaminants or conditions identified in the Integrated Report(s), water quality concerns voiced by stakeholders include abandoned boats, trash and landfills, sediment, depressed dissolved oxygen, and the hydrological impacts of dredging and barge traffic on the lower Bayou.

Impairments and Concerns

When a water body is unable to meet one or more of the SWQSs, it is said to have an *impairment* for that standard. When an impairment may be imminent, or when water quality conditions exist that do not have a set standard, the water body may be listed as having a *concern*.

Cedar Bayou Above Tidal currently has no impairments or concerns, based on the 2012 Integrated Report. However, an impairment, and subsequently a concern, for Macrobenthic Communities (the ability of the waterway to support a diverse and healthy ecology) were present in past Reports. Additionally, a concern for depressed DO was found in the 2010 Report, but not in the current 2012 Report.

Cedar Bayou Tidal currently has impairments for contact recreation (elevated levels of indicator bacteria), and polychlorinated biphenyls (PCBs)/dioxins in edible fish tissue. These impairments have persisted over the last three Integrated Reports (2008, 2010, and 2012), and have been intermittently present in previous Reports going back to 2000. The PCBs and dioxins impairments are being addressed under TMDLs for the broader Galveston Bay system. In addition, a concern for chlorophyll *a* has existed since 2010.

A summary of the impairments and concerns listed for Cedar Bayou in the last three Integrated Reports are found in Table 2. In the table, “Impairment Status” indicates whether the impairment requires additional data before a regulatory action is taken (5c) or whether a regulatory action is underway (5a). A blank status indicates no impairment. “Year First Listed for Impairment” refers to current impairments. Cedar Bayou has had previous impairment listings come and go in preceding years for some parameters. Similarly, “Concern Level” indicates whether a concern is based on the potential for non-attainment of a standard in the future (CN), 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). A blank status indicates no concern.

Table 2 – Impairments and concerns for Cedar Bayou (Segments 0901 and 0902)

		Impairments			Concerns	
TCEQ Integrated Report	Segment	Impairment Status[1]	Impaired Parameter	Year First Listed for Impairment[1]	Concern Level[2]	Concern Parameter
2008	0901_01 Tidal	5a 5c 5a	Dioxin in edible tissue Bacteria PCBs in edible tissue	2002 2006 2008	*None*	*None*
	0901_02 Above Tidal	5c	Impaired macrobenthic community	2006	*None*	*None*
2010	0901_01 Tidal	5a 5c 5a	Dioxin in edible tissue Bacteria PCBs in edible tissue	2002 2006 2008	CS	chlorophyll *a*
	0901_02 Above Tidal	*None*	*None*	*None*	CS CN	Depressed dissolved oxygen Impaired macrobenthic community
2012	0901_01 Tidal	5a 5c 5a	Dioxin in edible tissue Bacteria PCBs in edible tissue	2002 2006 2008	CS	chlorophyll *a*
	0901_02 Above Tidal	*None*	*None*	*None*	*None*	*None*
Draft 2014	0901_01 Tidal	5a 5c 5a	Dioxin in edible tissue Bacteria PCBs in edible tissue	2002 2006 2008	CS CS	Depressed dissolved oxygen chlorophyll *a*
	0901_02 Above Tidal	*None*	*None*	*None*	CS	Depressed dissolved oxygen

OTHER CONCERNS

While the primary focus of this WPP is to improve and maintain 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 all stakeholder concerns as part of a broader effort to improve the waterway. During the development of this Plan, stakeholders identified several other issues as being secondary priorities for implementation activities.

Abandoned Boats – the lower reach of Cedar Bayou has a variety of abandoned barges, fishing boats, and other nautical wreckage. Stakeholders identified this issue as an impediment to recreation, sediment transport, and navigability. As of 2014, stakeholder efforts and coordination between the Galveston Bay Foundation, General Land Office (GLO), Chambers Recovery Team, and other local partners resulted in the removal of 21 of the abandoned vessels in the Tidal segment. The removal of a remaining barge on private land, and any sunken or abandoned vessels discovered in the future, remains a concern for the stakeholders.

Trash – the shoreline of Cedar Bayou adjacent to urban areas is susceptible to trash from urban storm sewers and sheet flow into the Bayou. Trash reduction events, including ongoing efforts by the Cedar Bayou Friends (CBF), have already been introduced to address this issue in the Baytown area. Additionally, trash inputs from stormwater originating in the urban areas of Baytown area is being addressed under their TPDES Phase II stormwater permit. Stakeholders felt that this was a broader issue and efforts should be expanded to other impacted areas.

Landfills – Waste Management operates a large landfill location on the eastern shore of the southeast extent of the Bayou. Stakeholders raised concerns about potential contamination from leachate or surface flow from the landfill. Additionally, local residents identified a series of small prior landfill sites of unknown status. These sites were identified as potential sources of water quality contamination, although the abandoned landfills were not identified as sources of bacteria.

Sediment – Sediment transport on the Bayou is greatly influenced by the extent of rainfall in the upper watershed, the land uses adjacent to the Bayou, channel modification for navigation, and tidal action in the lower watershed. Stakeholders in the Baytown area identified sediment deposition on the shallower areas of the Bayou adjacent to the navigation channel as a potential issue for habitat and recreation interests.

Depressed DO – During preliminary development of the WPP, stakeholders indicated that fish kills and other algal bloom events were common in some localized areas of the Bayou. While DO is not currently an impairment of concern based on the 2012 Texas Integrated Report[19], increased development in both segments may exacerbate these conditions in the future. Additionally, while nutrient standards do not currently exist, stakeholders felt that nutrient management would be beneficial to address in anticipation of growth and future standards.

[19] Accessed at http://www.tceq.state.tx.us/assets/public/waterquality/swqm/assess/12twqi/2012_303d.pdf.

Hydrological modification and related concerns – Stakeholders were interested in additional consideration of the impact on dredging and increased navigation traffic on the habitat and recreational suitability of the Bayou, particularly in its southern reaches. The Chambers-Liberty Counties Navigation District and the Chambers County Texas Improvement District No. 1 pursued a Marine Highway designation[20] for the connection between Cedar Bayou and the Houston Ship Channel, and additional containerized cargo ports/facilities are planned or underway along the main channel in the Tidal segment. Maintenance dredging is performed on the lower portion of the Tidal segment, within the jurisdiction of the Chambers-Liberty Counties Navigation District. Additional dredging, including modification of the course of the Bayou, is planned (but currently not funded) for the lower reach of the Tidal segment, and identified as potential needs in the City of Baytown's Mobility Plan[21]. The extent and nature of new dredging or spoils placement sites were discussed by stakeholders as items of interest in regard to potential impact they may have on the waterway in the future. Stakeholders also expressed concern about storm surge and contamination being introduced into the Bayou through the existing "cut" channel between the Tidal segment and Upper Galveston Bay south of the City of Baytown.

Figure 31 – Abandoned vessel in tidal Cedar Bayou

[20] The Marine Highway program, managed by the U.S. Department of Transportation's Maritime Administration, seeks to improve and expand the primary marine transportation corridors of the United States to reduce vehicular traffic and congestion on terrestrial transportation systems, expand port and transport capabilities, and incorporate the waterways more fully into the greater U.S. transportation system. Additional information about the program and the details of the designation can be found at http://www.marad.dot.gov/ships_shipping_landing_page/mhi_home/mhi_home.htm. This designation could potentially lead to increased traffic and/or dredging activity in tidal Cedar Bayou.

[21] As detailed on pp. 6-1 to 6-5 of the City of Baytown Mobility Plan, accessed on 5/21/14 at http://www.baytown.org/sites/default/files/01_%20Consolidated%20Chapters_Baytown%20Mobility%20Plan_FINAL_rev15.pdf.

Section 3 – The Cedar Bayou Watershed Partnership

3 – The Cedar Bayou Watershed Partnership

History of the Partnership

Due to degrading water quality documented in monitoring data for Cedar Bayou and local concern regarding water quality issues, H-GAC submitted a proposal for developing a WPP for Cedar Bayou as a Clean Water Act 319(h) Nonpoint Source grant project to the TSSWCB. The TSSWCB and EPA selected the project for funding, and project staff began working with local stakeholders to generate interest in the formation of a stakeholder group. Local governments were interested in participating and there was an active community organization, the Cedar Bayou Friends, already involved in stewardship of the Bayou.

The Cedar Bayou Watershed Partnership was formed in 2010-2011 to guide the process of developing the WPP and to serve as the framework for future collaboration on implementation activities.

Goals

The goals of the Partnership are:

- To guide the development of a WPP for Cedar Bayou;
- To represent the broad array of interests present in the watershed;
- To provide a forum for communication, coordination and cooperation among decision-makers in the watershed;
- To use sound science and local knowledge to assess the causes and sources of water quality issues;
- To develop a suite of voluntary, feasible, and effective solutions; and
- To restore and maintain the water quality of Cedar Bayou such that it meets applicable state standards and addresses other stakeholder concerns.

Figure 32 – Logo of the Cedar Bayou Watershed Partnership

Organization

Over 100 local stakeholders, in addition to numerous regional, state, and federal representatives, have participated in the Partnership. Members and attendees have included representatives from local and regional governments, community and environmental organizations, agricultural producers and organizations (including the three local SWCDs), local residents and landowners, recreational enthusiasts, industrial and commercial entities, and other districts[22].

The organizational structure and membership of the Partnership were reviewed, modified and approved by the stakeholders. Recognizing that stakeholders may have different levels of ability to participate, the stakeholder group worked on a three-tiered structure of increasing commitment.

General Stakeholders

Anyone interested in attending the meetings were welcome, and served as de facto members of the Partnership. General stakeholders voiced their opinions, offered comments, asked questions, and generally supported the efforts of the Steering Committee. All meetings of the Partnership were open to the public, so general stakeholders were not excluded from any meeting, but were not able to vote during formal approvals.

Work groups

The Partnership formed four topical Work Groups to focus on specific areas. At least one Steering Committee member served on each Work Group, along with any other interested parties. Stakeholders with specific knowledge in a related field were asked to consider servicing on the Work Groups. The four Work Groups were:

- Agriculture, Wildlife and Habitat – This Work Group focused on evaluating and addressing contaminant sources arising from agricultural sources, issues regarding wildlife contributions and status, the impact of feral hogs and other invasive species, and habitat degradation or protection issues.

- Wastewater Infrastructure – The purpose of this Work Group was to provide expert advice on managing contributions from sanitary sewer systems and OSSFs.

- Industry and Commerce – This Work Group focused on potential sources of bacteria arising from industrial and commercial activities, as well as opportunities for public-private partnerships and management of riparian buffers at large industrial facilities.

[22] Among the districts represented have been the Cedar Bayou Navigation District, the Huffman Independent School District, the Crosby Independent School District, and various municipal utility districts.

- Human Impacts – The focus of this Work Group's efforts were to evaluate the impacts of urban runoff from stormwater systems and sheet flow from urban areas, and the contributions related to or impacting recreational activities (parks, boating, fishing, etc).

The Work Groups provided valuable advice to the Steering Committee and Partnership as a whole during the consideration of causes and sources of pollution and the development of effective solutions.

Steering Committee

The Steering Committee consisted of a diverse group of local stakeholders who elected to take a leadership role in the Partnership's efforts. The Committee was responsible for final approval of all decisions, and formed the core of attendance for the Partnership's meetings. The Committee conducted all their business at open public meetings, and while votes were taken for key decisions, a focus on consensus was pursued at all times. Committee members signed on to a set of Ground Rules that formed the rules of order for meetings.

Committee members were self-nominated, and project staff reviewed all nominations to ensure the Committee would be a reasonable size, and would adequately represent all interests in the watershed. Prior to the meetings, project staff worked with identified interests and key stakeholders in the watershed to ensure they would submit a representative. The initial round of nominations was for a reasonable number and reflected the diversity of interests. Project staff worked to recruit additional Committee members to ensure agricultural producers and industrial interests were well represented. The Steering Committee included representatives from:

- Local Residents and Landowners
- Harris County
- Chambers County
- Harris County Flood Control District
- City of Baytown
- City of Mont Belvieu
- Galveston Bay Foundation
- Harris County Soil and Water Conservation District
- Lower Trinity Soil and Water Conservation District
- Trinity Bay Soil and Water Conservation District
- Agricultural Producers
- Cedar Bayou Friends
- Crosby ISD
- NRG
- Bayer Corporation
- Cedar Bayou Navigation District
- Local OSSF service industry

The Steering Committee used topical expertise and local knowledge to make decisions for the project. Ultimate authority for approving the content and character of the WPP and the future stewardship of the Watershed Protection Plan rested with the Committee.

Technical Advisory Committee

To ensure local decision-making was the focus of the planning process, regional, state and federal agencies were asked to serve on a Technical Advisory Committee (TAC) rather than as voting Steering Committee members. The purpose of the TAC was to provide liaisons with agencies that had a vested interest in the project or who could provide valuable support and resources for the local stakeholders. TAC membership was ad hoc and unofficial, but TAC members made contributions to the project through topical presentations, providing resources for project staff, and communicating project progress to and from their respective agencies. TAC member organizations included:

- TCEQ
- United States Army Corps of Engineers (USACE), Galveston District
- United States Geologic Survey (USGS)
- Texas Farm Bureau
- Texas Parks and Wildlife Department
- Bayou Preservation Association (BPA)
- Galveston Bay Estuary Program (GBEP)
- Texas Forest Service (TFS)
- Texas Department of State Health Services (DSHS)
- TSSWCB
- EPA
- USDA NRCS
- AgriLife Research and AgriLife Extension

Figure 33 – A Cedar Bayou Watershed Partnership meeting (picture courtesy of Jerry Jones)

Public Participation

A total of X Partnership Meetings, X Work Group Meetings, and X topical meetings were held during the course of the project. All meetings were open to the general public. Attendance for general Partnership meeting averaged between 20-40 attendees.

Public participation was encouraged through multiple avenues including direct contact, email, limited postal notification, organizational newsletters, press releases to local media, Facebook announcements, project web page announcements, limited phones calls, and posters in watershed businesses.

Project staff maintained a project website as a focal point for resources and a depository of documents at www.cedarbayouwatershed.com. A Facebook page was maintained for announcements and photo albums at https://www.facebook.com/pages/Cedar-Bayou-Watershed-Partnership/145035735555989.

Figure 34 – Cedar Bayou Watershed Partnership Facebook page and project website

Water Quality Goals

The stakeholders reviewed a variety of water quality issues for Cedar Bayou, including the existing impairments and concerns of the segment assessments in the IRs as well as stakeholder–generated concerns. During the discussions, the stakeholders agreed on a set of water quality goals (Goals) for the Partnership. The Goals are a summary of the role of the Partnership in addressing various water quality challenges, and the priority these issues take relative to each other.

- Bacteria[23] is the primary concern of the Partnership due to its potential impact on human health, its presence as an impairment for the Above Tidal segment, and its relationship to causes and sources within the scope of the voluntary WPP effort. The focus of this WPP is to remediate excess levels of human and animal waste in the water for the sake of public health, recreational economy, fisheries and oysteries, and regulatory compliance with the WQS of a 126 CFU/100 ml *E. coli* geomean the Above Tidal segment and a 35 CFU/100 ml Enterococcus geomean in the Tidal segment.
- Nutrients, as a variety of phosphorus and nitrogen compounds, are potential sources of depressed dissolved oxygen due to their role in algal blooms. They do not have water quality standards associated with them; they may only be listed as concerns in the Integrated Reports, 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 to be derived as a secondary benefit from many bacteria reduction solutions.
- Dissolved oxygen levels are important for maintaining aquatic communities. No impairment for depressed DO exists in either segment[24]. As with nutrients, it is expected that the bacteria solutions[25] will also serve to reduce sources of DO impairment. Therefore, the stakeholders elected to make DO a secondary concern and no modeling or quantified reductions are associated with it.
- PCBs/Dioxins (in edible fish tissue) are impairments for the Tidal section. However, because these pollutants may involve legacy sources; are typically the focus of regulatory approaches; because their assessment and remediation is outside of the scope of the WPP effort; and because there are active Galveston Bay TMDL projects for each that include the Tidal Segment; the stakeholders elected to take a supporting role. PCBs and Dioxins are not a specific focus of the WPP for these reasons. However, as indicated in Section 6, Solutions, support of efforts for Galveston Bay may coordinate with local stakeholders for education and outreach activities[26].
- Other Issues raised by the stakeholders include trash and marine debris reduction and hydrologic changes to the bayou through dredging. The former is addressed as a secondary concern, and the latter is outside the scope of this effort.

The Goals serve as the priorities and impetus for the rest of the WPP, and informed the selection of solutions.

[23] Throughout this document, references to bacteria should be taken to mean indicator bacteria used to evaluate the suitability of the segment for contact recreation per state water quality standards. In general, it may also be used to reference the host of pathogenic substances in human and animal waste for which it is in indicator.
[24] Although the Draft 2014 IR does show a screening level concern in both segments that was not present in the 2012 IR.
[25] As well as related efforts in the watershed, such as the continued implementation of TPDES stormwater permits.
[26] For example, the Partnership member organization Galveston Bayou Foundation has placed signage at Roseland Park during the WPP development process warning residents about consumption of fish and crab species that may be contaminated with PCBs/Dioxins.

Section 4 –

Identifying Potential Sources

4 – Identifying Potential Sources

Overview

Identifying and quantifying the sources of contamination in a watershed assists stakeholders in developing and prioritizing solutions. In the Cedar Bayou watershed, this process included:

- an evaluation of land cover/land use and projected change;
- a Source Survey of potential causes and sources; and
- computer modeling to identify:
  - flow conditions related to contamination levels (Load Duration Curves – LDCs); and
  - relative contribution and distribution of sources (Spatially Explicit Load Enrichment Calculation Tool - SELECT).

The efforts were guided and reviewed by stakeholders and partner agencies to ensure results were in line with local knowledge of the watershed and sources.

Land Use/ Land Cover Change

The different types of land uses and character of the land cover at a watershed's surface is related to the potential sources of contamination. More importantly, the projected change in those uses/cover types over time identifies potential change in the types of sources present. Evaluation of the change in land use/land cover over time is especially pertinent to watersheds like Cedar Bayou, which are experiencing periods of appreciable developmental change. Current land use/land cover is based on existing data[27], as reviewed by stakeholders and project partners. Figures 35 and 36 show the change in spatial extent of land cover over time for the last 15 years. Table 3 indicates the change in relative proportion of land cover over time for the same period[28]. Minor changes in the classification of some land cover cells from year to year may be the result of inherent uncertainties in the way the raw data is generated and processed. For example, the data indicated that the open water land use category changed by roughly 200 acres between 1996 and 2001, although actual open water areas were not seen to significantly change in that timeframe.

[27] Including various iterations of the National Oceanic and Atmospheric Agency (NOAA) National Land Cover Dataset (NLCD) and H-GAC regional land use data and projections. NOAA NLCDs from 1996 and 2011 formed the basis of the analysis.

[28] Additional description of land use/land cover change in the Cedar Bayou watershed can be found in the Cedar Bayou Watershed Land Cover Change Technical Report, included on digital media with hard copies of this report, or online at http://www.cedarbayouwatershed.com/Documents/LandCoverTechnicalReport.pdf.

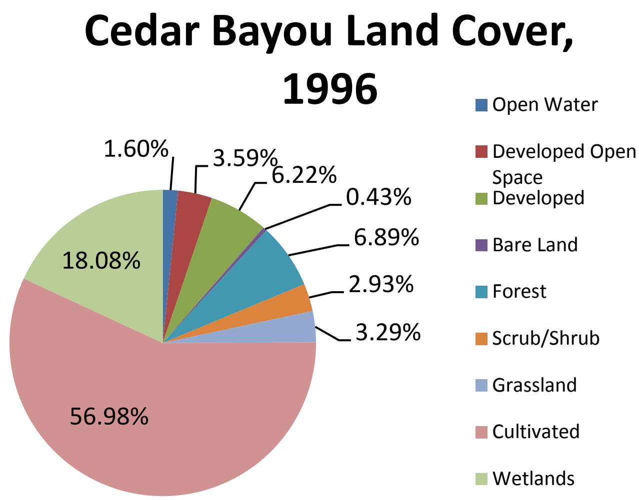


Figure 35 – Cedar Bayou land cover, 1996

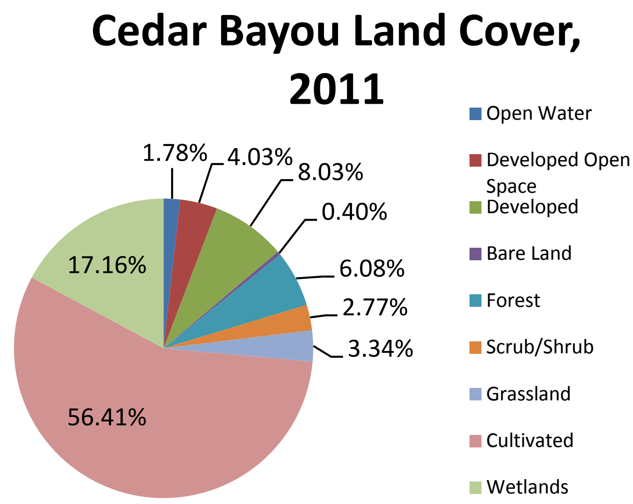


Figure 36 – Cedar Bayou land cover, 2011

In general, the watershed is experiencing growth comparable to other areas on the developmental boundaries of the Houston metro area. Increased commercial and residential development and decreased agricultural activity are expected throughout the watershed (with the exception of a small increase in grasslands). Specific areas of unique development include continued expansion of industrial and commercial areas in the southeast portion of the Tidal segment, and commercial and residential growth along the Highway 90 and Interstate 10 growth corridors. The future development of the Highway 99 corridor will likely add to this impact. The changes indicated in this analysis correspond to trends indicated by stakeholders. Cultivated land, forests, and wetlands saw appreciable decreases, while developed areas saw the largest increases. This trend may exacerbate water quality issues, as wetlands can reduce loadings, while developed areas can relate to increased loadings. With the continuation of this trend, sources related to developed areas are expected to increase in prominence. Identification and prioritization of sources was shaped by this assessment in discussions with project stakeholders.

Table 3 – Land cover change, 1996-2011

	1996		2011		
Class	**Acres**	**Percent**	**Acres**	**Percent**	**Net Change (acres)**
Open Water	2,043	1.60%	2,265	1.80%	222
Developed Open Space	4,576	3.60%	5,139	4.00%	563
Developed	7,916	6.20%	10,226	8.00%	2,310
Bare Land	543	0.40%	505	0.40%	-38
Forest	8,769	6.90%	7,740	6.10%	-1,029
Scrub/Shrub	3,728	2.90%	3,525	2.80%	-203
Grassland	4,187	3.30%	4,252	3.30%	65
Cultivated	72,566	57.00%	71,847	56.40%	-719
Wetlands	23,028	18.10%	21,859	17.20%	-1,169
Total	**127,357**	**100.00%**	**127,357**	**100.00%**	**0**

SOURCE SURVEY

Fecal bacteria and other contaminants of concern can arise from a variety of sources, both discrete (WWTFs, CAFOs, etc) and diffuse (agriculture, urban stormwater, pets, wildlife) in nature. The first step in identifying the causes of water quality impairments was to complete a source survey of all potential sources. In accordance with its Water Quality Goals, the Partnership discussed the existence and prevalence of various potential sources of bacteria[29] throughout the watershed. This evaluation included a series of presentations, map exercises, and conversations with partner agencies. While some potential sources were found to be common throughout the watershed, some were more prevalent in one segment versus another. The results of the source survey are summarized in Tables 4 (Above Tidal Segment) and 5 (Tidal Segment).

[29] Indicator bacteria (and the fecal waste they signify) were the primary contaminant of concern for this project, representing the existing impairment deemed to be within the scope of this voluntary effort. As discussed in Other Concerns, PCBs and dioxins in edible fish tissue are being addressed through TMDL projects for Galveston Bay and the Houston Ship Channel. Due to the unique aspects of PCB and dioxin impairments, they are generally beyond the scope, resources, and character of the watershed protection plan model.

Table 4 – Source survey for Cedar Bayou Above Tidal

Category	Source	Contaminant	Origin[30]	Estimated extent[31]
Urban/Residential	Dogs	Bacteria/Nutrients	NPS; urban stormwater	Moderate
	Cats	Bacteria/Nutrients	NPS; urban stormwater	Minor
	OSSFs	Bacteria/Nutrients	NPS; runoff or direct discharges from failing systems	Moderate
	WWTF (permitted discharges)	Bacteria, Nutrients	PS; permitted discharges	Minor
	WWTF (collection system)	Bacteria, Nutrients	NPS; sanitary sewer overflows/line breaks.	Moderate
	Birds (park waterfowl and bridge colonies)	Bacteria	NPS; runoff or direct deposition	Minor
	Fertilizers	Nutrients	NPS; runoff from lawn application in stormwater	Moderate
	Pesticides	Toxic compounds	NPS; runoff from lawn application in stormwater	Minor
	Industrial/commercial sites	PCBs/Dioxins; other toxic compounds[32]	NPS; contaminated soils or current activity	Minor
	Trash	Trash	NPS; littering/ dumping	Minor
	Land Deposition of Sewer Sludge	Bacteria, Nutrients	NPS; stormwater	Minor
	Erosion	Sediment[33]	NPS; erosion due to land use change	Minor
Agriculture	Cattle	Bacteria	NPS; stormwater or direct deposition.	Moderate
	Horses	Bacteria	NPS; stormwater	Minor
	Sheep and Goats	Bacteria	NPS; stormwater	Minor
	CAFOs	Bacteria	PS; overflows or direct discharges	Non-existent
	Pesticides	Macrobenthic community impairing substances	NPS; stormwater or overspray	Minor
Wildlife and Non-Domestic Animals	Deer	Bacteria	NPS; stormwater or direct deposition	Minor
	Migratory and colonial birds	Bacteria	NPS; stormwater or direct deposition	Minor
	Other wildlife	Bacteria	NPS; stormwater or direct deposition	Minor
	Feral Hogs	Bacteria	NPS; stormwater or direct deposition	Moderate

[30] For the purpose of this table NPS designates a nonpoint source, and PS designates a point source.
[31] The estimated extent reflects the initial discussion with stakeholders and partners. It does not always reflect the modeled results. The primary purpose of the survey is to define sources rather than be a final determination of relative contribution.
[32] For the purpose of this survey, toxic compounds are being considered in relation to the previous macrobenthic impairment/concern in this segment
[33] For the purpose of this survey, sediment is being considered in relation to the previous macrobenthic impairment/concern in this segment.

Table 5 – Source survey for Cedar Bayou Tidal

Category	Source	Contaminant	Origin[34]	Estimated extent[35]
Urban/Residential	Dogs	Bacteria, Nutrients	NPS; urban stormwater	Moderate
	Cats	Bacteria, Nutrients	NPS; urban stormwater	Minor
	OSSFs	Bacteria, Nutrients	NPS; runoff or direct discharges from failing systems	Moderate
	WWTF (permitted discharges)	Bacteria, Nutrients	PS; permitted discharges	Moderate
	WWTF (collection system)	Bacteria, Nutrients	NPS; sanitary sewer overflows/line breaks.	Major
	Birds (park waterfowl and bridge colonies)	Bacteria	NPS; runoff or direct deposition	Moderate
	Fertilizers	Nutrients	NPS; runoff from lawn application in stormwater	Moderate
	Dredging activities	PCBs/dioxins	NPS; re-suspension of contaminated soil or contamination of spoils areas.	Moderate
	Industrial/commercial sites	PCBs/Dioxins; other toxic compounds[36]	NPS; contaminated soils or current activity	Minor
	Trash	Trash	NPS; littering/ dumping	Moderate
	Land Deposition of Sewer Sludge	Bacteria, Nutrients	NPS; stormwater	Non-existent
	Erosion	Sediment[37]	NPS; erosion due to land use change	Moderate
Agriculture	Cattle	Bacteria	NPS; stormwater or direct deposition.	Minor
	Horses	Bacteria	NPS; stormwater	Minor
	Sheep and Goats	Bacteria	NPS; stormwater	Minor
	CAFOs	Bacteria	PS; overflows or direct discharges	Non-existent
	Pesticides	Macrobenthic community impairing substances	NPS; stormwater or overspray	Minor
Wildlife and Non-Domestic Animals	Deer	Bacteria	NPS; stormwater or direct deposition	Minor
	Migratory and colonial birds	Bacteria	NPS; stormwater or direct deposition	Minor
	Other wildlife	Bacteria	NPS; stormwater or direct deposition	Minor
	Feral Hogs	Bacteria	NPS; stormwater or direct deposition	Moderate

[34] For the purpose of this table NPS designates a nonpoint source, and PS designates a point source.

[35] The estimated extent reflects the initial discussion with stakeholders and partners. It does not always reflect the modeled results. The primary purpose of the survey is to define sources rather than be a final determination of relative contribution.

[36] For the purpose of this survey, toxic compounds are being considered in relation to the previous macrobenthic impairment/concern in this segment

[37] For the purpose of this survey, sediment is being considered in relation to the previous macrobenthic impairment/concern in this segment.

The Impact of Flow (Load Duration Curves)

The extent of precipitation, runoff and resulting flow in the watershed can determine the relative prominence of sources. In general, nonpoint sources are most often related to high flow conditions, as they rely on runoff as a means of transmission to the waterways. Point sources tend to be more relatively prominent in low flow conditions, when nonpoint source loads are reduced. Determining the relative prominence of nonpoint versus point sources in the watershed (or subdivisions thereof) can help prioritize solutions.

For the Cedar Bayou Above Tidal segment, load duration curves (LDCs) were used to graphically represent bacteria loads in different flow conditions[38].

LDCs use 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 levels. Based on the water quality criteria for a given contaminant, a maximum allowable stream load is calculated for all flow conditions. Lastly, monitoring data for the contaminant of concern is multiplied by flows to produce a load duration curve, indicating contaminant load across all flow conditions. 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 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, then a mix of point and nonpoint sources is likely.

For Cedar Bayou Above Tidal, indicator bacteria LDCs were developed for the four mainstream sampling stations (see Figure 37). Flow data was taken from USGS stream flow gauge 08067500 located at Highway 90 near Crosby, TX in Harris County. This flow was used directly for the Station 11120 LDCs. Flow for the other three stations in the Above Tidal segment (11123, 11118, and 21081) was developed by extrapolating flow from the Highway 90 site[39]. The LDCs and analysis for each of the four sites is presented in order from northernmost to southernmost sites in the Above Tidal segment.

[38] While the relationship between runoff, flow, and contaminant concern is important in both tidal and non-tidal areas of a waterway, different modeling tools are used to assess each. For Cedar Bayou Tidal, the SWMM5 model was used to make a similar evaluation that included the impact of tidal flows.

[39] Flow was extrapolated by developing ratios between field flow measurements taken during ambient sampling at the non-gauge sites, and the equivalent flow at the gauge at Station 11120 for that same time period. These ratios were used to extrapolate the rest of the flow values for the non-gauge sites.

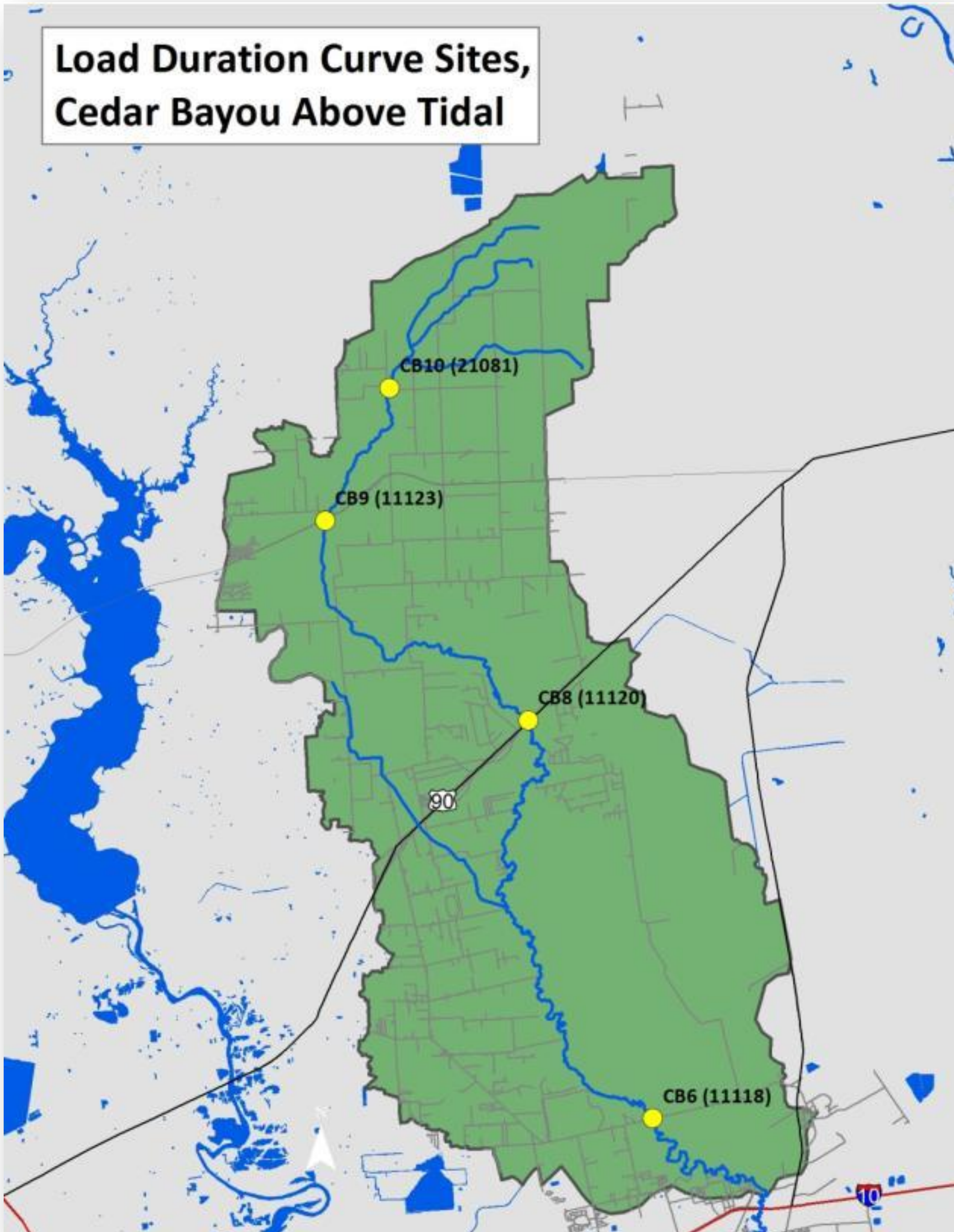


Figure 37 – LDC sites in the Above Tidal watershed

Load Duration Curve for Station 21081 – *Cedar Bayou at CR 624*

Station 21081 is located at the Cedar Bayou crossing at County Road 624 in Liberty County. This station is located near the headwaters of Cedar Bayou. The drainage area upstream of this site is primarily agricultural; rangeland, row crop and turf grass with light residential uses.

Figure 38 – Station 21081, Cedar Bayou at CR 624

Water quality monitoring at this location began during the course of the development of this WPP, and thus is relatively limited compared to existing sites. As indicated in the LDC for this station (Figure 39), the SWQS for indicator bacteria (*E. coli*) is met at all flow levels, with no statistically significant difference.

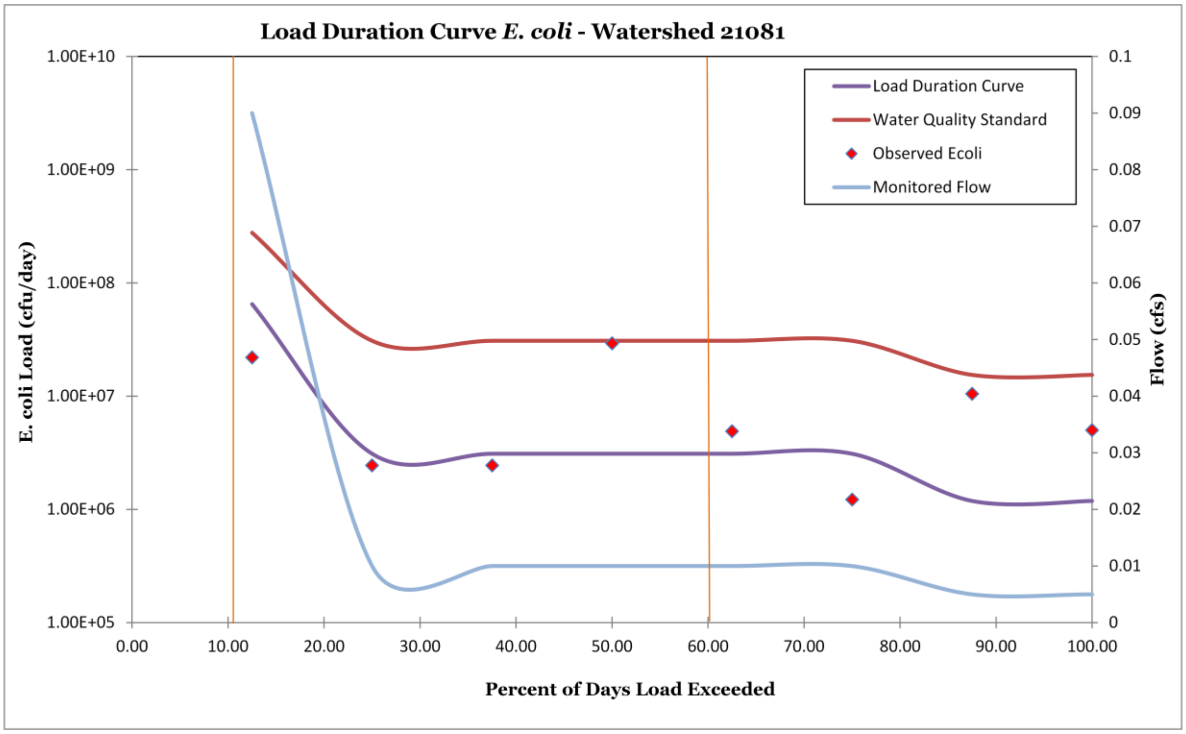


Figure 39 – LDC for station 21081

LOAD DURATION CURVE FOR STATION 11123 – *CEDAR BAYOU AT FM 1960*

Station 11123 is located at the Cedar Bayou crossing at FM 1960 in Harris County. This station is located northeast of Crosby. The drainage area upstream of this site is primarily agricultural. However, commercial and residential development is occurring in the Cosby area and along the FM1960 corridor.

Figure 40 – Station 11123, Cedar Bayou at FM 1960

This is an existing Clean Rivers Program/TCEQ monitoring site, and thus has several years of data. As indicated in the LDC for this station (Figure 41), the SWQS for indicator bacteria (*E. coli*) is met at all flow levels, but higher bacteria levels are seen in high and midrange flows, indicating impacts from nonpoint sources.

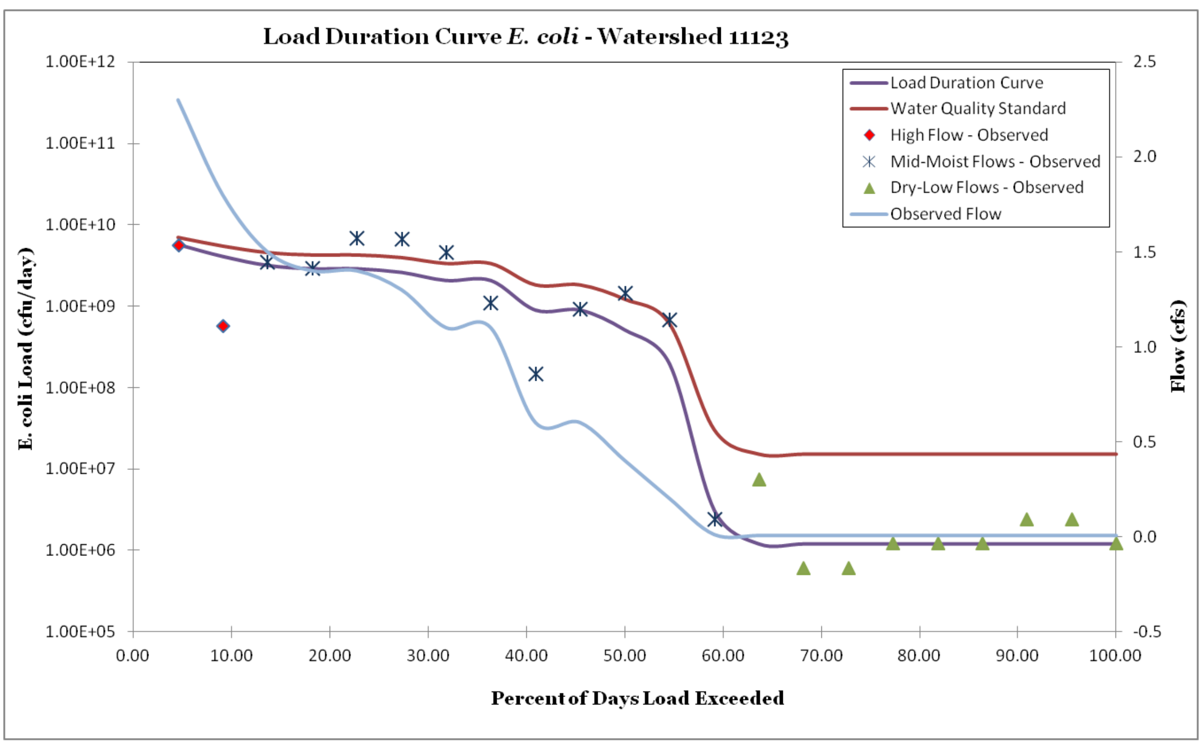


Figure 41 – LDC for station 11123

Load Duration Curve for Station 11120 – *Cedar Bayou at Highway 90*

Station 11120 is located at the Cedar Bayou crossing at Hwy. 90 on the border of Harris and Liberty Counties. The drainage area upstream of this site is a mix of agricultural uses and the commercial/residential development occurring along FM 1960 and Highway 90.

Figure 42 – Station 11120, Cedar Bayou at Highway 90

This is an existing Clean Rivers Program/TCEQ monitoring site, and thus has several years of data. As indicated in the LDC for this station (Figure 43), the SWQS for indicator bacteria (*E. coli*) is exceeded in high flow and some mid flow conditions, indicating appreciable nonpoint sources. However, bacteria levels remain high with periodic exceedances in low flows.

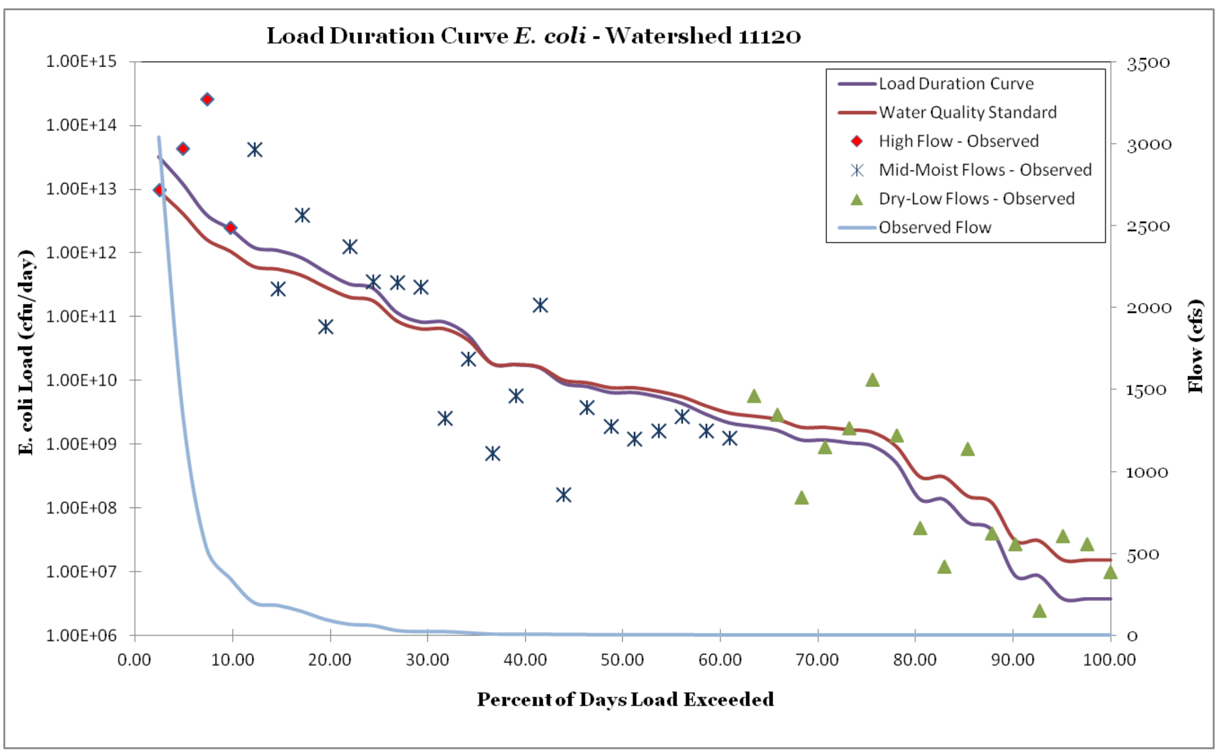


Figure 43 – LDC for station 11120

Load Duration Curve for Station 11118 – *Cedar Bayou at FM 1942*

Station 11118 is located at near the end of the Above Tidal segment, at the Cedar Bayou crossing with FM 1942, east of Mont Belvieu. The drainage area upstream of this site is a mix of uses as the watershed transitions from the rural north to the urban/industrial south. However, the watershed between this station and 11120 includes a dense riparian buffer.

Figure 44 – Station 11118, Cedar Bayou at FM 1942

This is an existing Clean Rivers Program/TCEQ monitoring site, with several years of data. As indicated in the LDC for this station (Figure 45), the SWQS for indicator bacteria (*E. coli*) is exceeded in almost all conditions, except very high flows. This likely indicates a mix of sources.

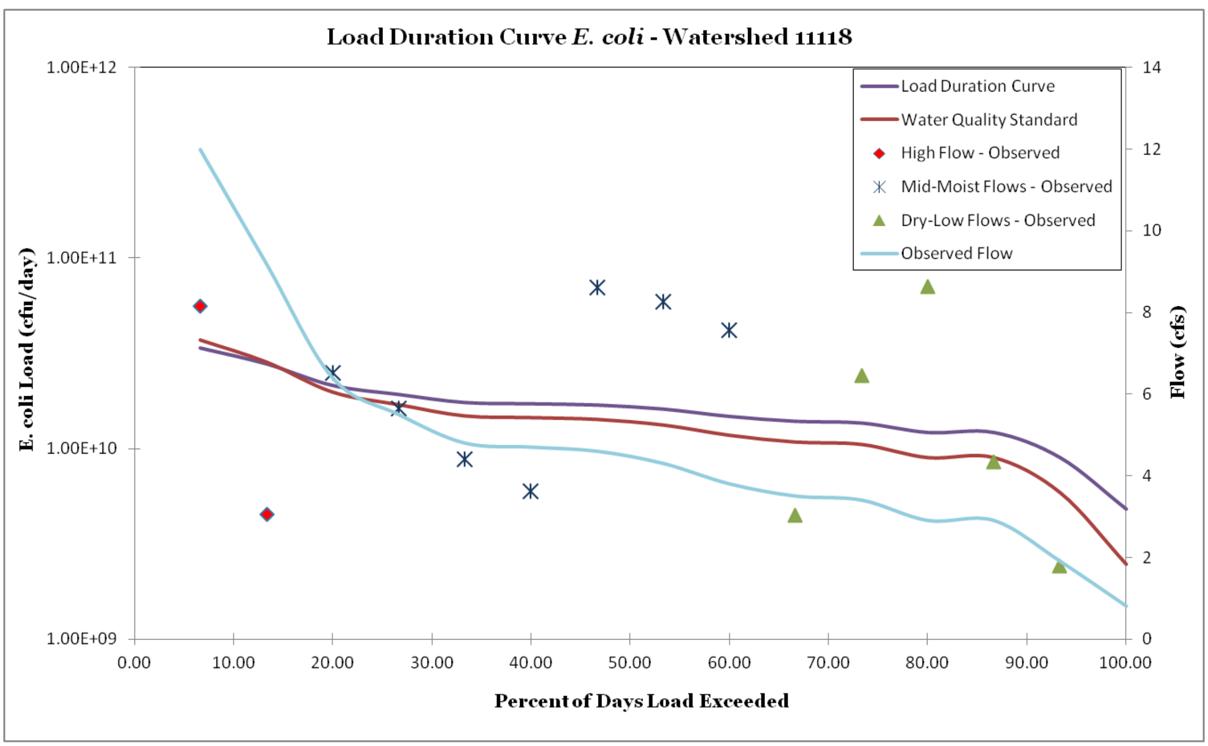


Figure 45 – LDC for station 11118

The LDCs for the four Cedar Bayou Above Tidal stations reflect a changing waterway in both spatial and temporal senses. As the waterway progresses southward bacteria levels exceed the standard more frequently. Through station 11120, the general trend is toward greater bacteria levels in higher flow conditions indicating that nonpoint sources are prominent. Between the Highway 90 and FM 1942 corridors, the growing influence of residential, commercial, and industrial developments along the corridors and major tributaries (e.g., Adlong Ditch) is reflected in high bacteria levels at the end of the segment. These trends also point to a temporal relationship, as those stations whose watersheds are experiencing growth along major traffic corridors are generally related to higher bacteria levels. This trend is indicative of the potential impact of future expansion of development from Houston to the west, and from Baytown and Mont Belvieu to the south. Caveats in this analysis include the potential effects of limitations in flow data (USGS gauge at only one site) and limited monitoring data for some sites.

Figure 46 – Cedar Bayou above Hwy 90

The LDCs indicate the general prominence of nonpoint sources, but their application is limited to the Above Tidal segment due to the varying flow direction of the Tidal segment. Additional modeling was employed to provide greater definition in terms of the relative contributions of individual sources and their spatial distribution for the entire watershed.

SELECT Modeling for Bacteria Sources

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) was developed by the Spatial Sciences Laboratory and the Biological and Agricultural Engineering Department at Texas A&M University. The intent of this tool is to show the relative contributions of individual sources of fecal bacteria identified in the source survey. Additionally, SELECT adds a spatial component by evaluating the total contribution of subwatersheds, and the relative contribution of sources within each subwatershed.

SELECT generates information regarding the total potential 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, wildlife populations, etc.) and feedback from stakeholders. The development of the SELECT modeling approach for Cedar Bayou includes the results of data gathering efforts with local, regional and state partners, and several rounds of review and comment by project stakeholders. The potential load estimates are not intended to represent the amount of bacteria actually transmitted to the water. The load estimates do not account for natural processes that may reduce bacteria on its way to the water, or the relative proximity of sources to the waterway.

Because the Cedar Bayou watershed is in a transitional developmental state, the SELECT modeling effort included both current conditions and projected future conditions. Additionally, a "buffer" approach was used to demonstrate the potential impacts of distance between the source and the waterway. The "buffer" approach assumes 100 percent of the waste generated within 300 feet of the waterway as being transmitted to the watershed without reduction. Outside of that buffer, only 25 percent of the waste is assumed to be transmitted to the waterway. Sources that lack specific spatial locations (unlike permitted outfalls) are assumed to be distributed uniformly in appropriate land uses, inside and outside the buffer. For example, the total number of deer in the buffer is derived from multiplying the assumed density by the numbers of acres of appropriate land use within buffered areas. This approach is designed to provide a very general simulation of the effect of distance from the waterway[40]. The buffer approach has not traditionally been used with SELECT, but has been used in other regional watershed protection plans. It is not based on data regarding actual transmission averages for the unbuffered area, and therefore is a subjective measure. It is intended as a conceptual tool to demonstrate the general likelihood of transmission from areas not directly adjacent to a waterway. Both unbuffered and buffered approaches were developed and reviewed with the stakeholders. For all analyses, both the standard and "buffer" analyses are shown.

[40] Actual variation in transmission rates would depend on a vast number of factors (slope, connectivity of tributaries, rainfall, migration between areas by mobile sources, soil types, vegetation, etc.). Modeling all these factors would exceed the capabilities of SELECT. The simplified buffer approach is not intended as a precise modeling of transmission variation, but as a general demonstration of the concept. It indicates the relative change in source contribution related to distance.

The overall goal of the SELECT modeling is to aid in prioritizing which sources to address by showing their relative contributions and locations. 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 was used heavily through the generation of the analysis and its eventual use as a prioritization tool for selecting BMPs.

SOURCES

All warm-blooded animals produce waste bearing fecal indicator bacteria, and thus are potential sources of contamination. *E. coli* is used as the fecal bacteria indicator in freshwater segments, and *Enterococcus* is used in tidal segments. Both are found universally in the waste of warm-blooded animals. 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 it may contain. As described in the Source Survey (Tables 4 and 5), there are a wide array of potential fecal waste sources in the watershed. The SELECT analysis considers all sources for which data could be feasibly obtained or produced, including cattle, sheep and goats, horses, OSSFs, WWTFs, dogs, feral hogs, deer, and general urban stormwater runoff. Birds, bats, cats, and wildlife other than deer were not modeled due to lack of data and feedback from the stakeholders indicating they were likely not appreciable sources[41]. For example, there are no know bat colonies of appreciable size in the watershed, domestic cats are assumed to shed waste inside, and feral cats are part of the urban stormwater loads. Migratory birds may be present in large numbers during specific seasons, but are not year-round residents and do not produce large volumes of waste. This is in part due to the absence of wildlife refuges or other wintering grounds for large numbers of waterfowl. Swallow colonies under bridges have been identified as sources in other watersheds, but the small numbers of bridge crossings on the waterway, the lack of population data, and the preference of the stakeholders led to their exclusion from the modeling. Lastly, there are no water bird (e.g., Egrets) colonies of appreciable size known in the watershed. Based on TPWD information and stakeholder feedback, other warm-blooded animals are known to be present in the waterway, including coyotes, raccoons, opossums, etc. However, data was not available or able to be generated concerning their densities or locations.

The following sections 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.

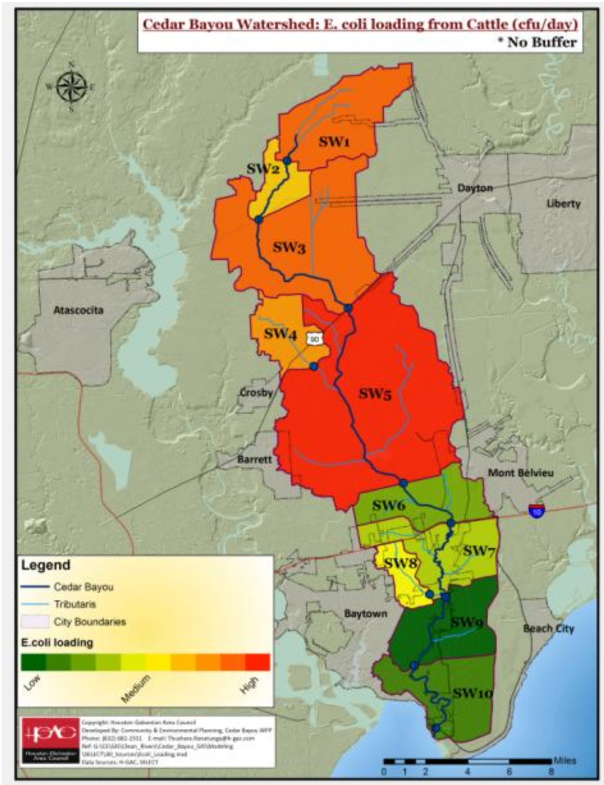
[41] While the inability to include some sources, however negligible, creates some uncertainty in the SELECT results, the general intent of SELECT is not affected. The sources for which data are available are also the sources for which feasible solutions exist. For example, even if good data existed regarding migratory waterfowl, their protection under the Migratory Bird Act and stakeholder preference in avoiding impacts on wildlife would eliminate them from considerations of solutions.

CATTLE

Cattle have traditionally been a staple livestock animal of the area, particularly in the Above Tidal watershed. To estimate cattle populations in the watershed, the latest (2012) livestock census data from the USDA's National Agricultural Statistics Service (NASS) was compiled for all three counties. Because the data for cattle is not specific to the watershed area, the process started with the assumption that cattle were equally distributed through the counties, such that the density of cattle in a county's applicable land use[42] acreage was the same as the density in the watershed's applicable land use acreage. These data were reviewed with the stakeholders and the Soil and Water Conservation Districts for each county. Based on their feedback, cattle numbers were reduced by 40 percent in most of the Tidal subwatersheds, and some of the Above Tidal watersheds. This reduction reflected that cattle production is not equally distributed through the counties, with a majority of the production in Harris and Chambers Counties taking place outside of the watershed area. There are no CAFOs in the watershed, so all cattle were distributed evenly throughout the watershed in the model based on a density per acre derived from the total number of cattle divided by the total number of applicable land uses. Cattle bacteria loads were then derived for each subwatershed, and mapped in relation to the rest of the watershed. The analysis was also run with the "buffer" approach (Figures 48 and 49).

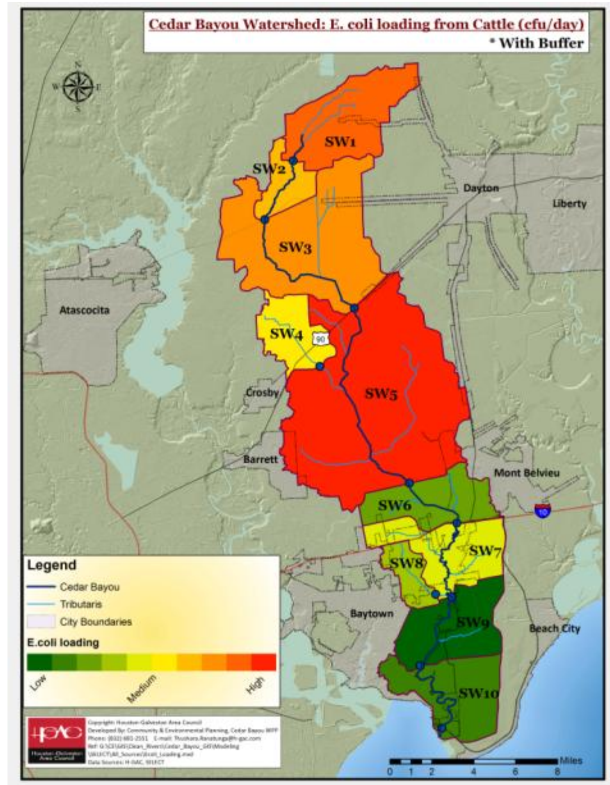
Figure 47 – Cattle grazing in the watershed

[42] Cattle were assumed to be only in land cover types associated with cattle ranching. Based on the 2011 NOAA NLCD dataset, these land cover types included grassland and pasture/hay.



Subwatershed	Number of Cattle	Cattle Loadings
SW1	1032	1.4E+12[43]
SW2	311	4.2E+11
SW3	1553	2.1E+12
SW4	802	1.1E+12
SW5	3337	4.5E+12
SW6	281	3.8E+11
SW7	352	4.8E+11
SW8	295	4.0E+11
SW9	193	2.6E+11
SW10	243	3.3E+11
TOTAL	**8398**	**1.1E+13**

Figure 48 – Relative bacteria loading from cattle, by subwatershed (current)



Subwatershed	Number of Cattle	Cattle Loadings (buffer)
SW1	1032	5.2E+11
SW2	311	2.2E+11
SW3	1553	7.0E+11
SW4	802	2.0E+11
SW5	3337	1.4E+12
SW6	281	1.2E+11
SW7	352	1.1E+11
SW8	295	8.0E+10
SW9	193	7.2E+10
SW10	243	8.1E+10
TOTAL	**8398**	**3.5E+12**

Figure49 – Relative bacteria loading from cattle, by subwatershed (current, buffered)

[43] The loadings are given in numbers of bacteria per day, using scientific notation. 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.

As shown, the reduction in total cattle loading shown by the buffer approach indicates that an appreciable amount of cattle loadings originate outside of the riparian corridor. Due to the changing nature of the Cedar Bayou watershed, including development along major transportation corridors in the Above Tidal watershed, cattle populations and loads are expected to decrease in the coming decades. In all scenarios, cattle loadings are most pronounced in the Above Tidal segment watershed. Based on regional projections, cattle loadings were projected at 5 year intervals through 2040. These projections were completed for both standard and "buffer" approaches[44] (Figures 50 and 51).

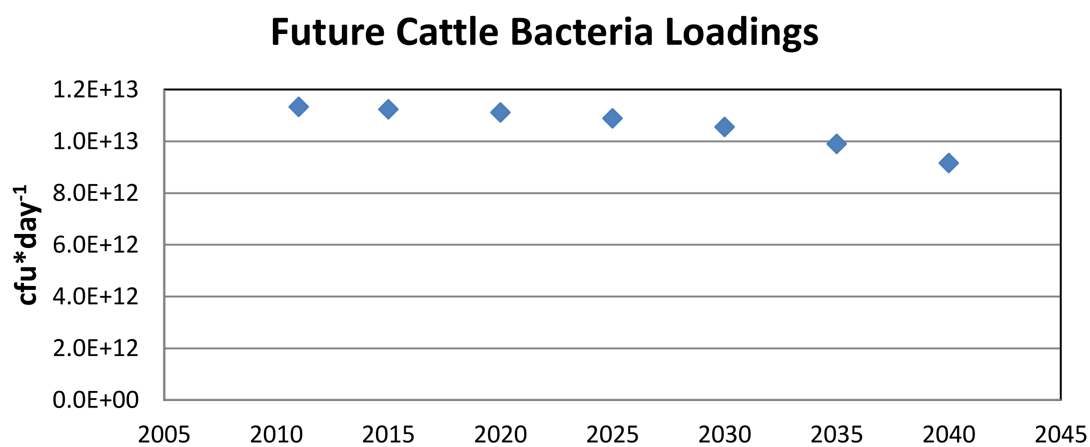


Figure 50 – Future bacteria loads from cattle

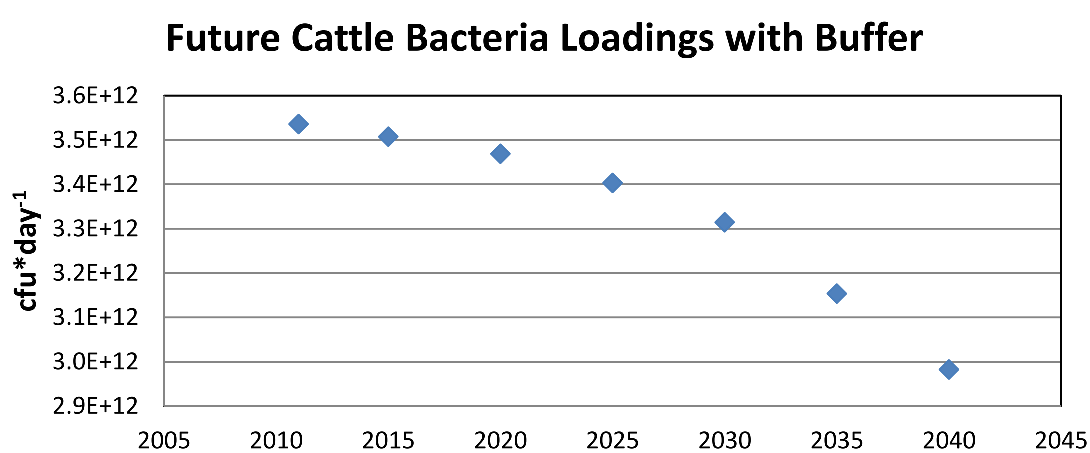
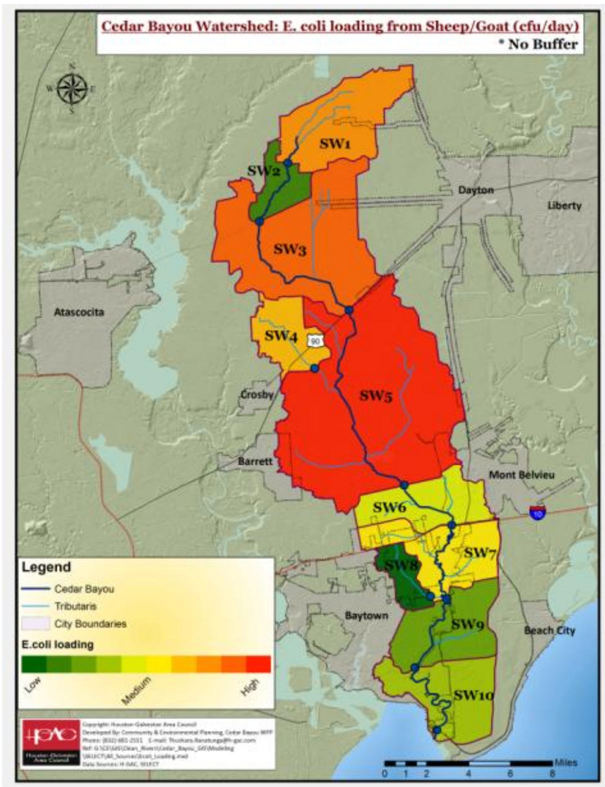


Figure 51 – Future bacteria loads from cattle (buffered)

[44] For the loadings graphs (e.g. Figures 51 and 52), attention should be given to the y axes as the scale may differ from graph to graph. For example, the range for Figure 51 is 0 to 1.2E+13, while the range for Figure 52 is only a portion of that range (2.9E+12 to 3.E+12).

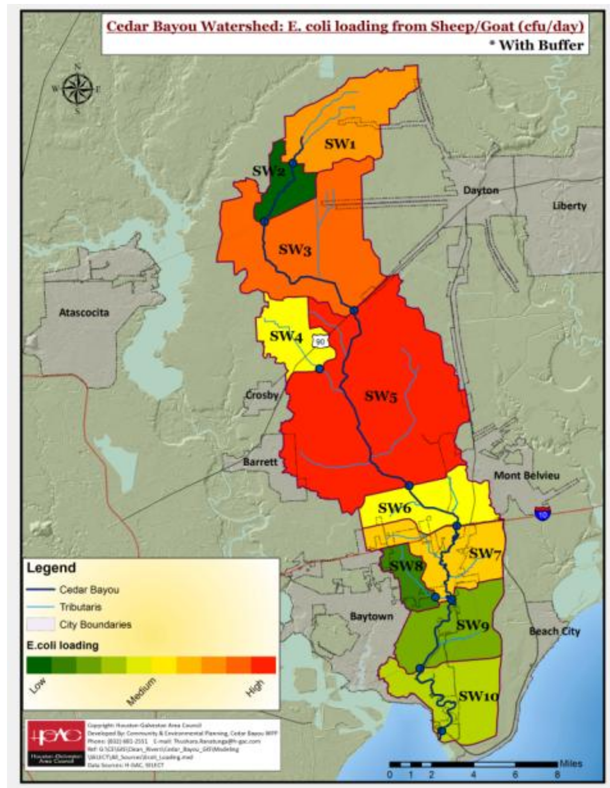
Sheep and Goats

Sheep and goats are combined in the NASS census data, and the stakeholders did not feel they needed to be modeled separately. The populations for the watershed were compiled in the same manner to the cattle populations, deriving a watershed density from county densities and then reviewing these numbers with the stakeholders (Figures 52 and 53). In the case of sheep and goats, the stakeholders did not request reductions in the initial loading projections.



Subwatershed	Number of Sheep & Goats	Sheep & Goat Loadings
SW1	74	3.3E+11
SW2	7	3.0E+11
SW3	185	8.3E+11
SW4	57	2.6E+11
SW5	239	1.1E+12
SW6	34	1.5E+11
SW7	42	1.9E+11
SW8	21	9.5E+10
SW9	23	1.0E+11
SW10	29	1.3E+11
TOTAL	**710**	**3.3E+12**

Figure 52 – Relative bacteria loading from sheep and goats, by subwatershed (Current)



Subwatershed	Number of Sheep & Goats	Sheep & Goat Loadings (buffer)
SW1	74	1.2E+11
SW2	7	2.9E+08
SW3	185	2.8E+11
SW4	57	4.7E+10
SW5	239	3.3E+11
SW6	34	4.7E+10
SW7	42	6.3E+10
SW8	21	1.9E+10
SW9	23	2.8E+10
SW10	29	3.2E+10
TOTAL	**710**	**9.7E+11**

Figure 53 – Relative bacteria loading from sheep and goats, by subwatershed (Current, Buffered)

As with cattle, sheep and goat loadings were most pronounced in the Above Tidal watershed. Similarly to cattle, sheep/goat loadings decreased appreciably with the application of the buffer approach (Figures 54 and 55).

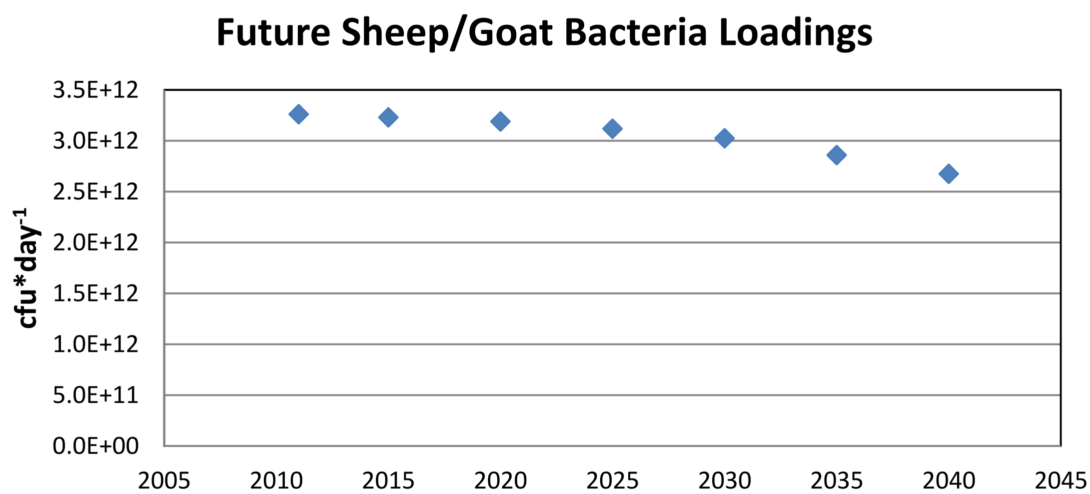


Figure 54 – Future bacteria loads from sheep and goats

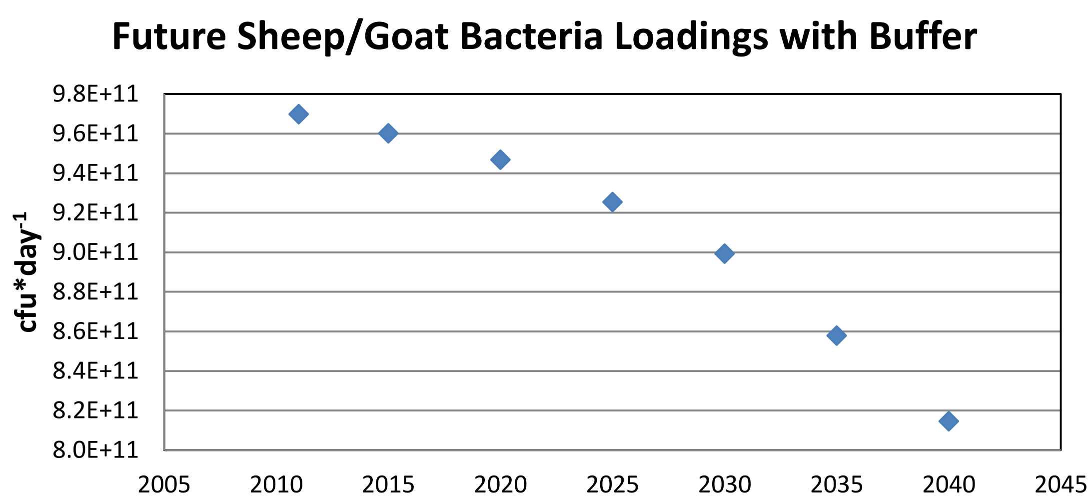
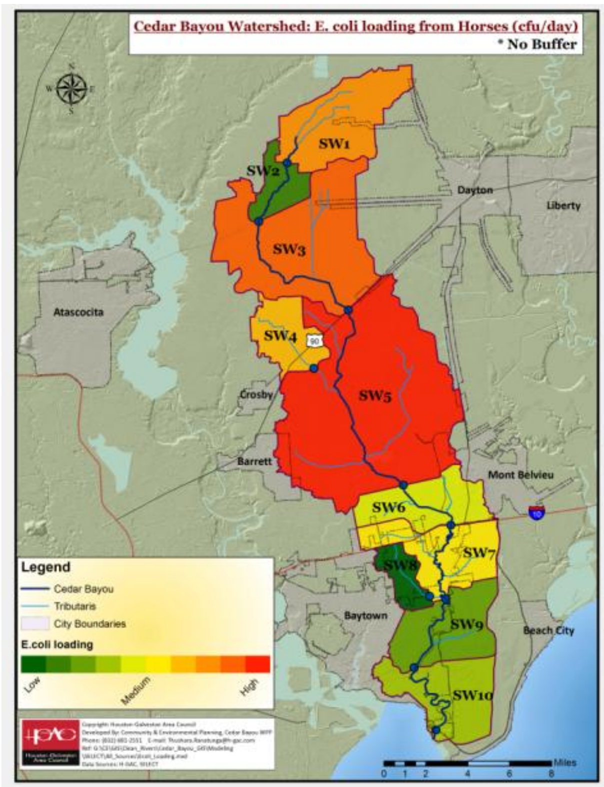


Figure 55 – Future bacteria loads from sheep and goats (Buffered)

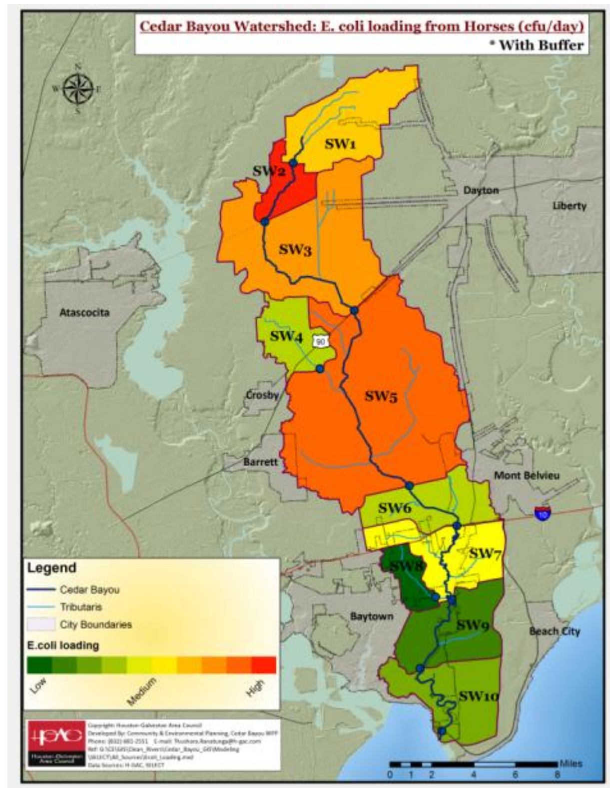
HORSES

Small ranchettes with a horse or two are common in the middle and upper watershed, and based on stakeholder input, have increased greatly in the last decades. Horse populations were estimated from the 2012 NASS agricultural census data and reviewed with stakeholders and partners in the same manner as cattle and sheep/goats (Figures 56 and 57). No reductions in initial estimates were recommended.



Subwatershed	Number of Horses	Horse Loadings
SW1	99	1.0E+10
SW2	70	3.1E+09
SW3	249	2.6E+10
SW4	77	8.1E+09
SW5	322	3.4E+10
SW6	45	4.7E+09
SW7	57	5.9E+09
SW8	28	3.0E+09
SW9	31	3.2E+09
SW10	39	4.1E+09
TOTAL	**1018**	**1.0E+11**

Figure 56 – Relative bacteria loading from horses, by subwatershed (Current)



Subwatershed	Number of Horses	Horse Loadings (buffer)
SW1	99	3.9E+09
SW2	70	3.9E+10
SW3	249	8.7E+09
SW4	77	1.5E+09
SW5	322	1.0E+10
SW6	45	1.5E+09
SW7	57	2.0E+09
SW8	28	6.0E+08
SW9	31	8.9E+08
SW10	39	1.0E+09
TOTAL	**1018**	**6.9E+10**

Figure 57 – Relative bacteria loading from horses, by subwatershed (Current, Buffered)

As with cattle and sheep/goats, horse loadings were most pronounced in the Above Tidal watershed. Similarly to other livestock, horse loadings decreased with the application of the buffer approach[45] (Figures 58 and 59).

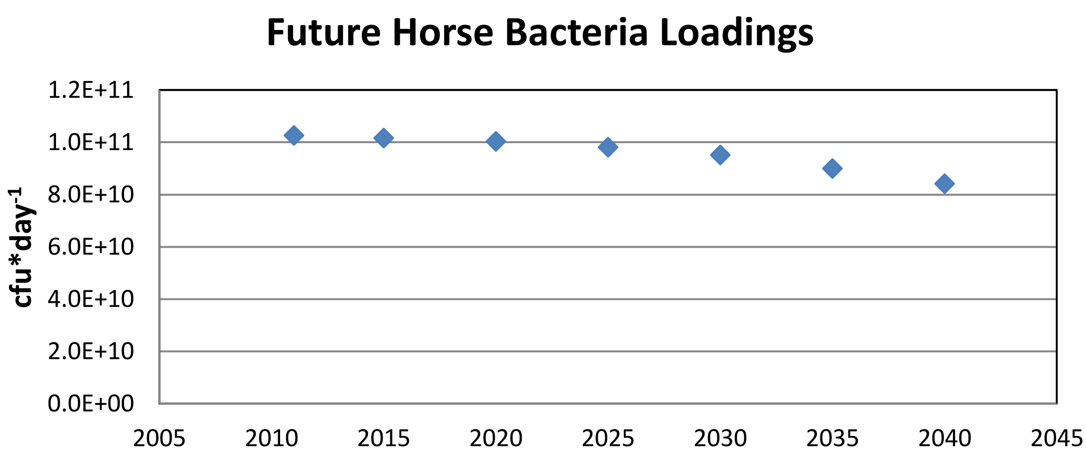


Figure 58 – Future bacteria loads from horses

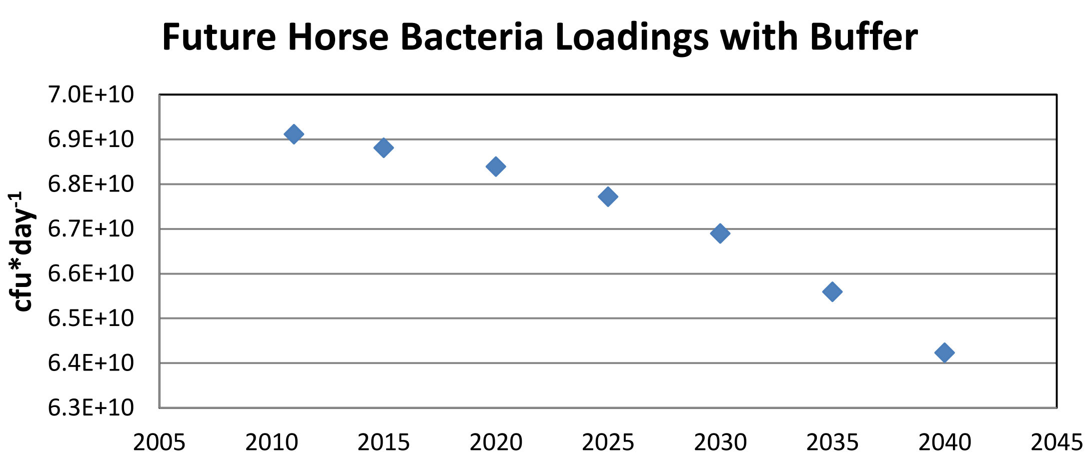


Figure 59 – Future bacteria loads from horses (Buffered)

[45] While all livestock are projected to diminish, stakeholders felt that horse populations may actually increase with the advent of further development in the ranchette style, especially in the Above Tidal watershed. However, no consensus existed as to what time frame, or to what degree this may happen. Absent a reasonable methodology for reflecting this feedback or specific stakeholder request to modify the numbers, no changes were made to initial projections.

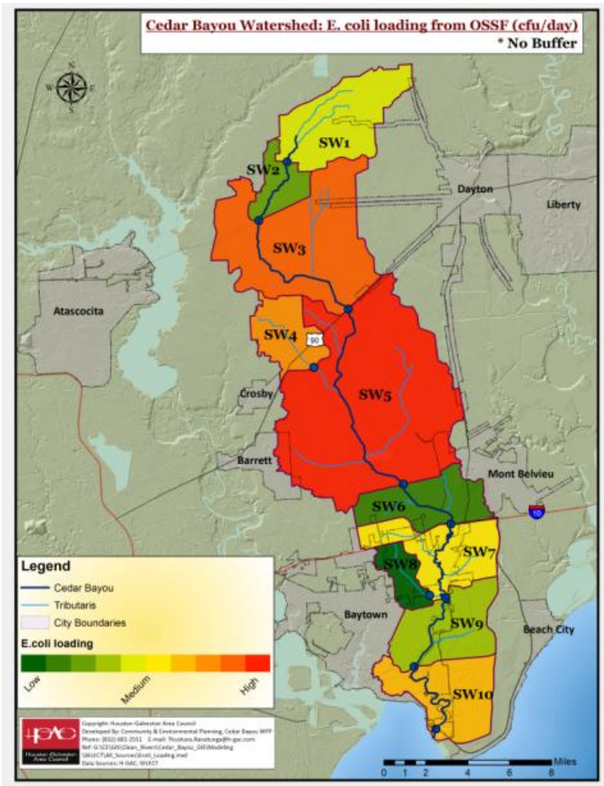
OSSFs

OSSFs can be significant sources of bacteria if they fail or are not maintained properly. While the majority of the urban centers are served by sanitary sewer, OSSFs are the prevailing wastewater solution for large areas of the watershed. Permitted OSSF data was taken from existing spatial data compiled by H-GAC from authorized agents. 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. Failure rates based on literature values (50% for unpermitted systems or systems installed prior to 1989, and 12% for permitted systems) and stakeholder input were applied to each class to generate loads. Load estimates are presented in Figures 61 and 62.

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[46]. It is also assumed that failure rates will stay constant and that service area boundaries will not expand appreciably. While boundaries may change, there is no feasible way to predict spatially where this will occur.

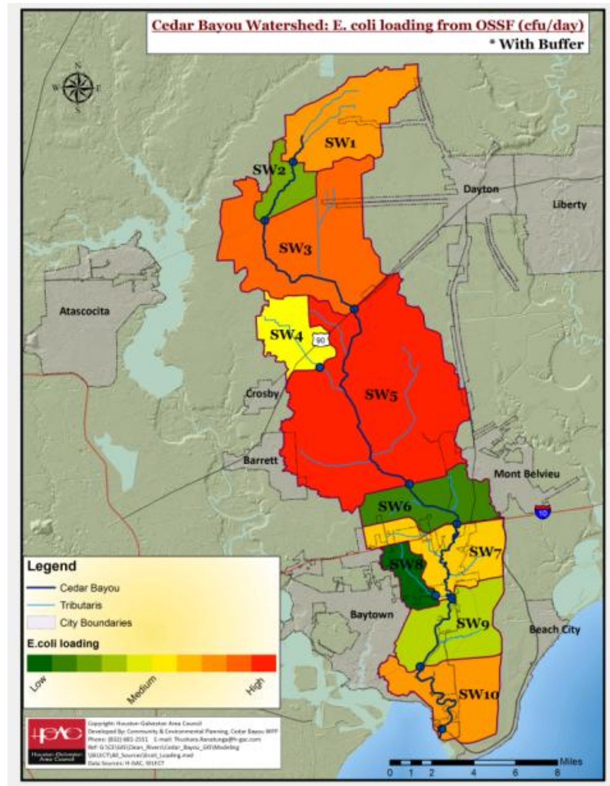
Figure 60 – OSSF being installed

[46] In part due to lack of existing data on unpermitted system locations.



Subwatershed	Number of OSSFs	OSSF Loadings
SW1	501	5.1E+12
SW2	193	1.9E+12
SW3	1064	1.1E+13
SW4	798	8.1E+12
SW5	2381	2.4E+13
SW6	109	1.3E+12
SW7	558	5.6E+12
SW8	112	5.1E+11
SW9	353	3.4E+12
SW10	789	8.0E+12
TOTAL	**6848**	**6.9E+13**

Figure 61 – Relative bacteria loading from OSSFs, by subwatershed (Current)



Subwatershed	Number of OSSFs	OSSF Loadings (buffer)
SW1	501	1.7E+12
SW2	193	4.4E+11
SW3	1064	2.7E+12
SW4	798	1.2E+12
SW5	2381	4.3E+12
SW6	109	3.1E+11
SW7	558	1.3E+12
SW8	112	0.0E+00
SW9	353	7.7E+11
SW10	789	1.7E+12
TOTAL	**6848**	**1.4E+13**

Figure 62 – Relative bacteria loading from OSSFs, by subwatershed (Current, Buffered)

Based on SELECT analysis, failing OSSFs are a primary source of potential load in the watershed. Even when a buffer approach is applied, OSSFs remain an important source to address. It is unclear whether transition toward aerobic systems will reduce failure rates, or whether increased maintenance needs by homeowners may cause additional issues.

Future OSSF numbers were generated from H-GAC regional population projections for areas outside of sanitary service area boundaries, which are assumed to use OSSFs as their treatment solution. With the expansion of development in the watershed, OSSF loadings are expected to increase, especially in areas away from urban centers in which they will remain the predominant treatment solution. Future loadings are presented in Figures 63 and 64.

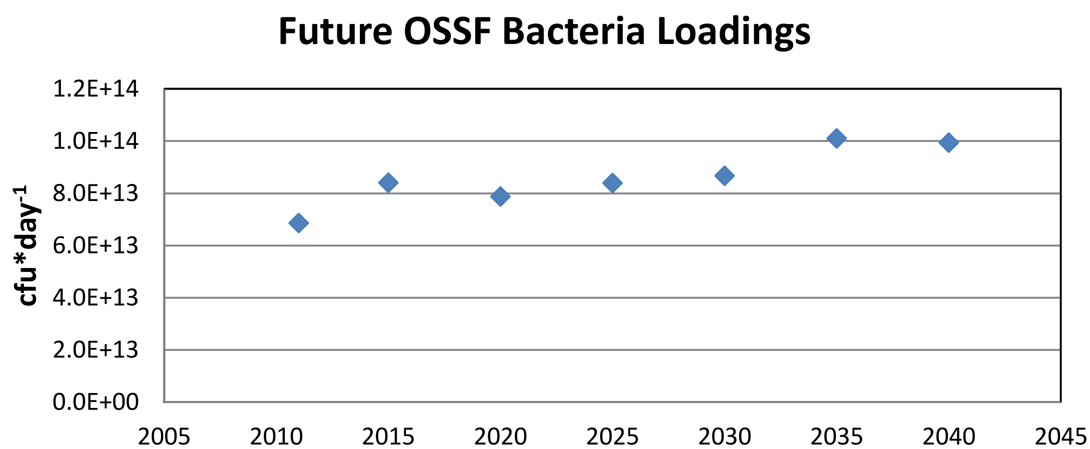


Figure 63 – Future bacteria loads from OSSFs

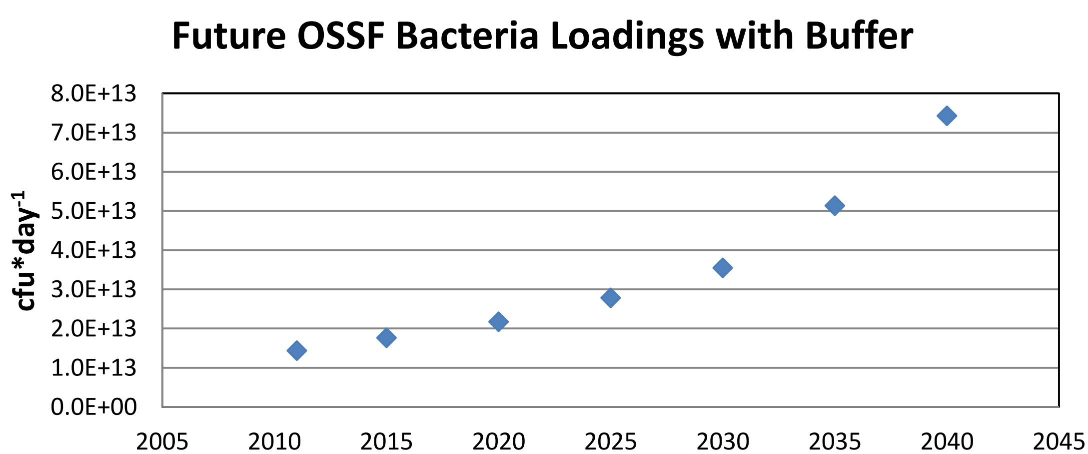
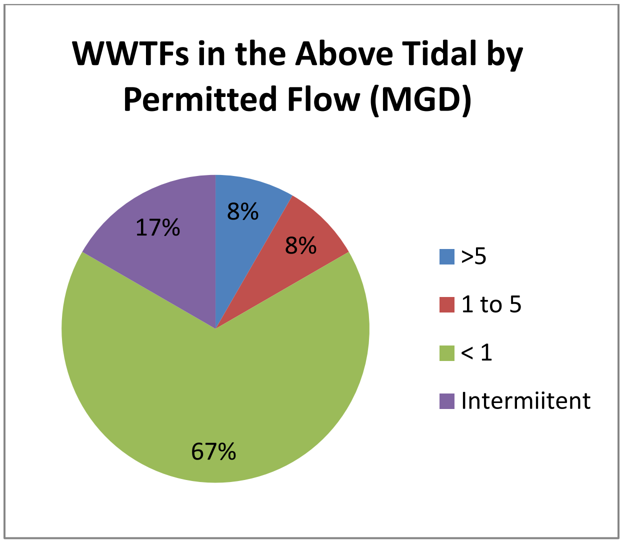


Figure 64 – Future bacteria loads from OSSFs (Buffered)

WWTFs

There are 55 WWTF outfalls, representing 34 unique permitted WWTFs in the Cedar Bayou watershed. 13 WWTFs are found in the Above Tidal portion and 21 in the Tidal portion (Figure 65). 17 of the plants are industrial (5 Above Tidal, 12 Tidal), and 17 are domestic (8 Above Tidal, 9 Tidal). The plants range in size from 6 MGD to discharges less than 0.01MGD, with a total permitted flow of approximately 24 MGD[47]. The outfalls are shown in figures 70 and 71.



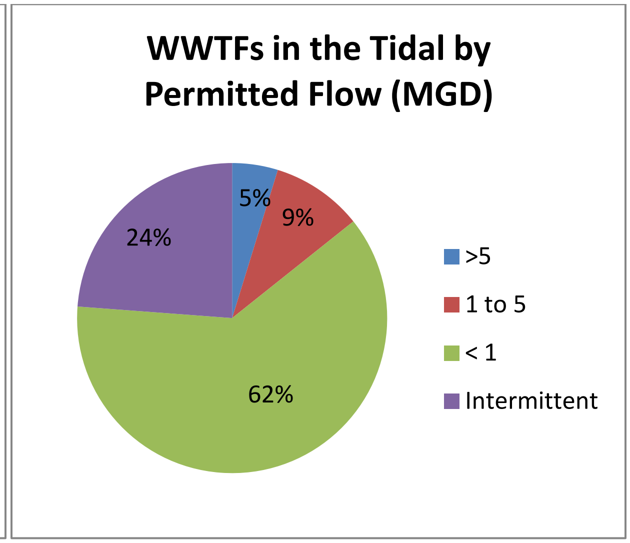


Figure 65 – WWTFs by Permitted Flow and Segment

For the purpose of modeling potential loads from these plants, two approaches were used. The flow data from Discharge Monitoring Reports (DMRs) collected by TCEQ for these WWTFs was multiplied by the allowable bacteria standard to produce the total potential load. However, properly run wastewater treatment plants should have minimal bacteria levels at their outfalls[48] and a review of reported bacteria data in the DMRs indicated that, while some plants had infrequent exceedances, the general trend in permitted discharges was for levels of bacteria well below the standard[49]. For the sake of estimating conservatively[50], including for future projections, discharges were assumed to be at or below the standard. As indicated in the following figures, the bacteria load attributed to WWTFs was so low relative to other sources, that the impact of this conservative estimate was negligible in weight. In general, issues

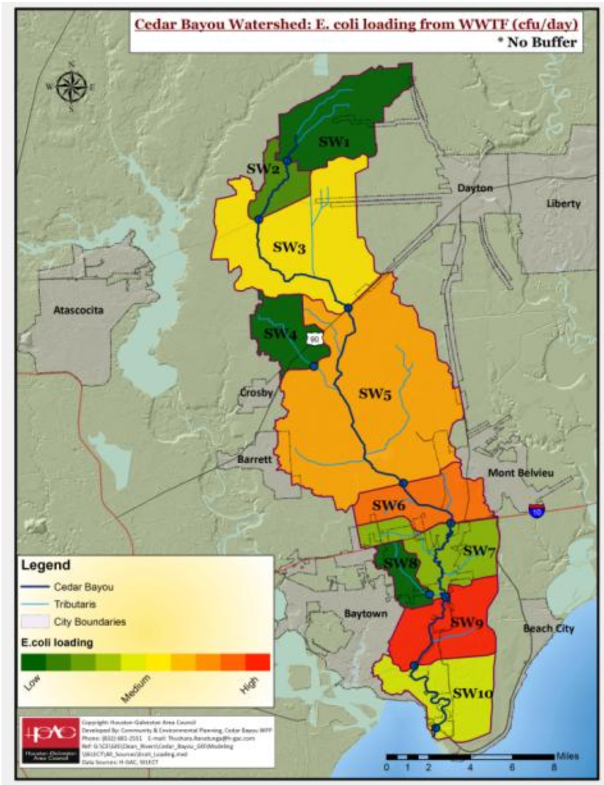
[47] The volumes represent total permitted flow, not inclusive of intermittent flows from industrial users without specific flow limits (usually not appreciable). Actual flows are significantly less.

[48] This source refers to bacteria in the permitted discharge of plants. Overflows in the collection systems are covered under the urban stormwater source.

[49] Greater information on this review of DMRs can be found in Section 5.

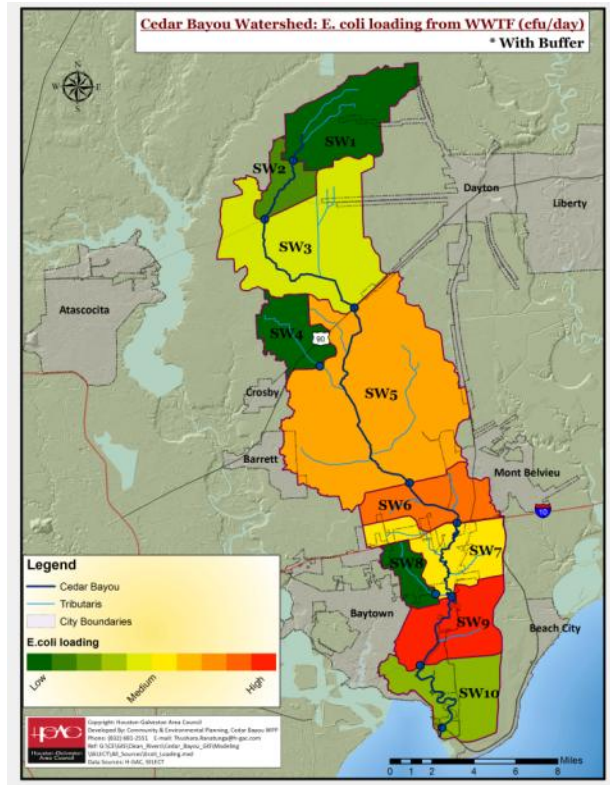
[50] DMR data for bacteria was not available for all plants, and the data that existed was not thorough for all plants. Therefore the SELECT modeling did not rely on this data, but instead used it as a check to see that assumptions were at least as conservative as likely real discharges. In prioritizing solutions, stakeholders considered both the modeled data and the sample of DMR data evaluated in Section 5.

experienced by wastewater utilities primarily involved sanitary sewer overflows (SSOs) in the collection system[42], not discharges from the WWTFs. Loads are estimated in Figures 66 and 67.



Subwatershed	WWTF Loadings
SW1	0.0E+00
SW2	1.7E+07
SW3	5.7E+09
SW4	0.0E+00
SW5	2.7E+10
SW6	8.0E+10
SW7	5.1E+09
SW8	0.0E+10
SW9	1.1E+11
SW10	5.3E+09
TOTAL	**2.4E+11**

Figure 66 – Relative bacteria loading from WWTFs, by subwatershed (Current)



Subwatershed	WWTF Loadings (buffer)
SW1	0.0E+00
SW2	1.7E+07
SW3	5.7E+09
SW4	0.0E+00
SW5	2.7E+10
SW6	8.0E+10
SW7	5.1E+09
SW8	0.0E+10
SW9	1.1E+11
SW10	5.3E+09
TOTAL	**2.4E+11**

Figure 67 – Relative bacteria loading from WWTFs, by subwatershed (Current, Buffered)

Since nearly all the WWTF outfalls are on or near the riparian areas, the addition of the buffer approach did not impact the loadings. While WWTFs are distributed throughout the watershed, the largest concentrations of flows and loading were in the urban areas of the Tidal watershed.

Future projections were based on projected expansion of households within existing service areas[51] (Figures 68 and 69). As with other sources from developed areas, WWTF loads are expected to increase in conjunction with land use change.

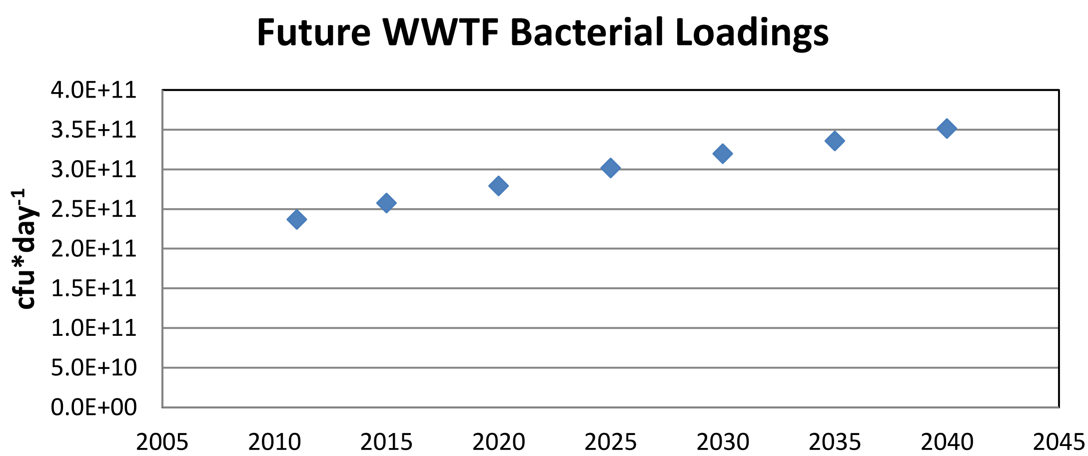


Figure 68 – Future bacteria loads from WWTFs

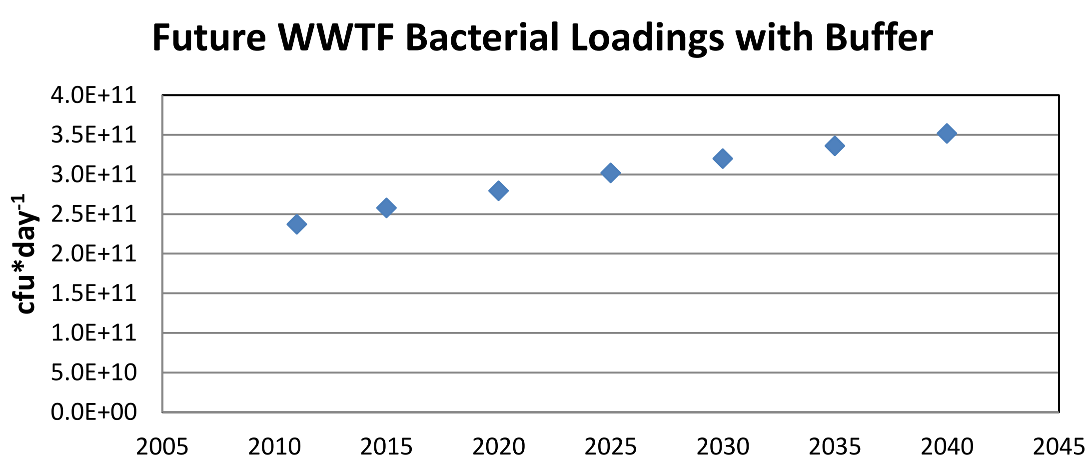


Figure 69 – Future bacteria loads from WWTFs (Buffered)

[51] While insufficient data was available or able to be created to project locations of new service areas or service area expansions, any potential expansion not included in the WWTF projections would be included in OSSF projections, as both rely on new household information.

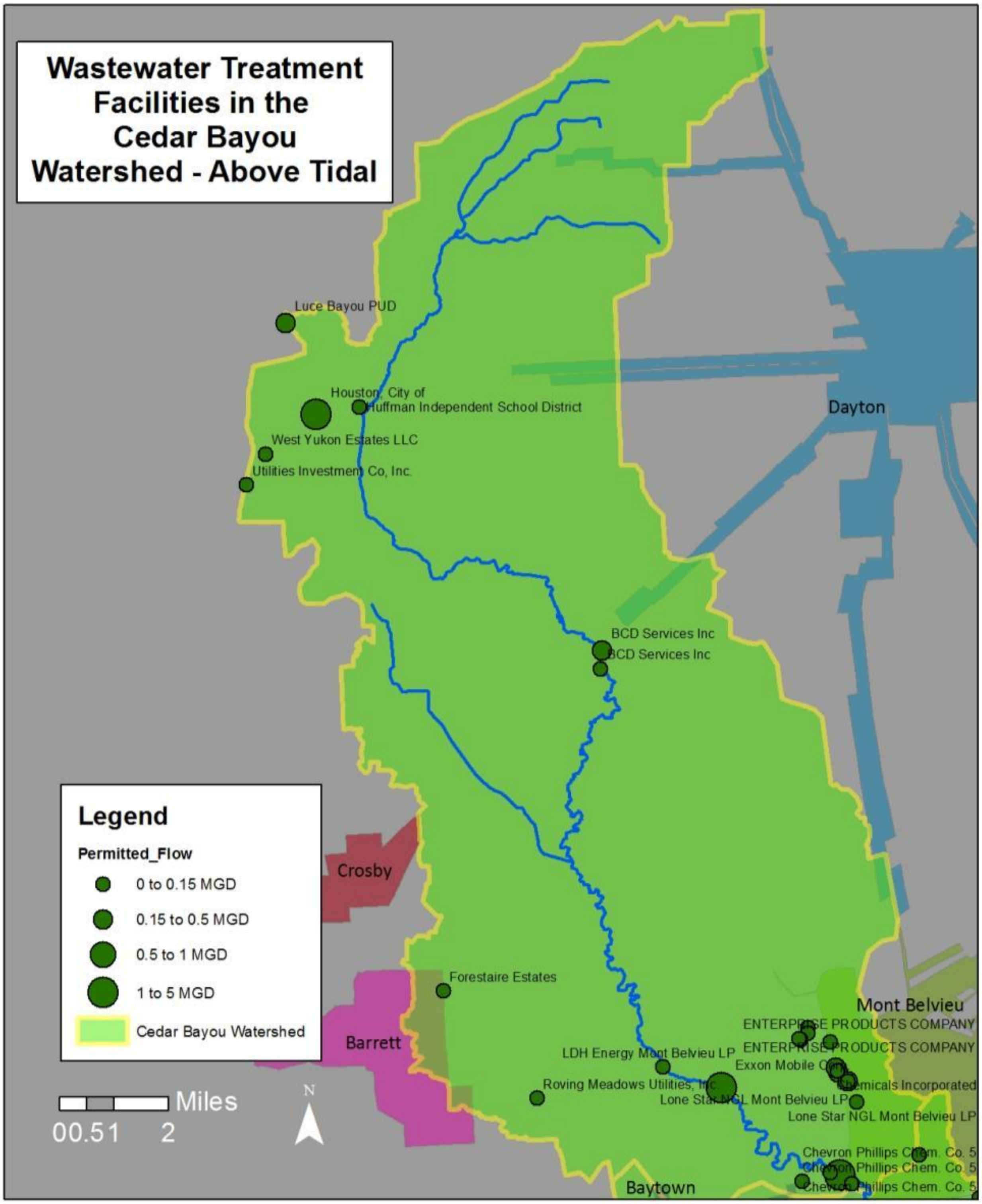


Figure 70 –WWTFs in the Above Tidal segment

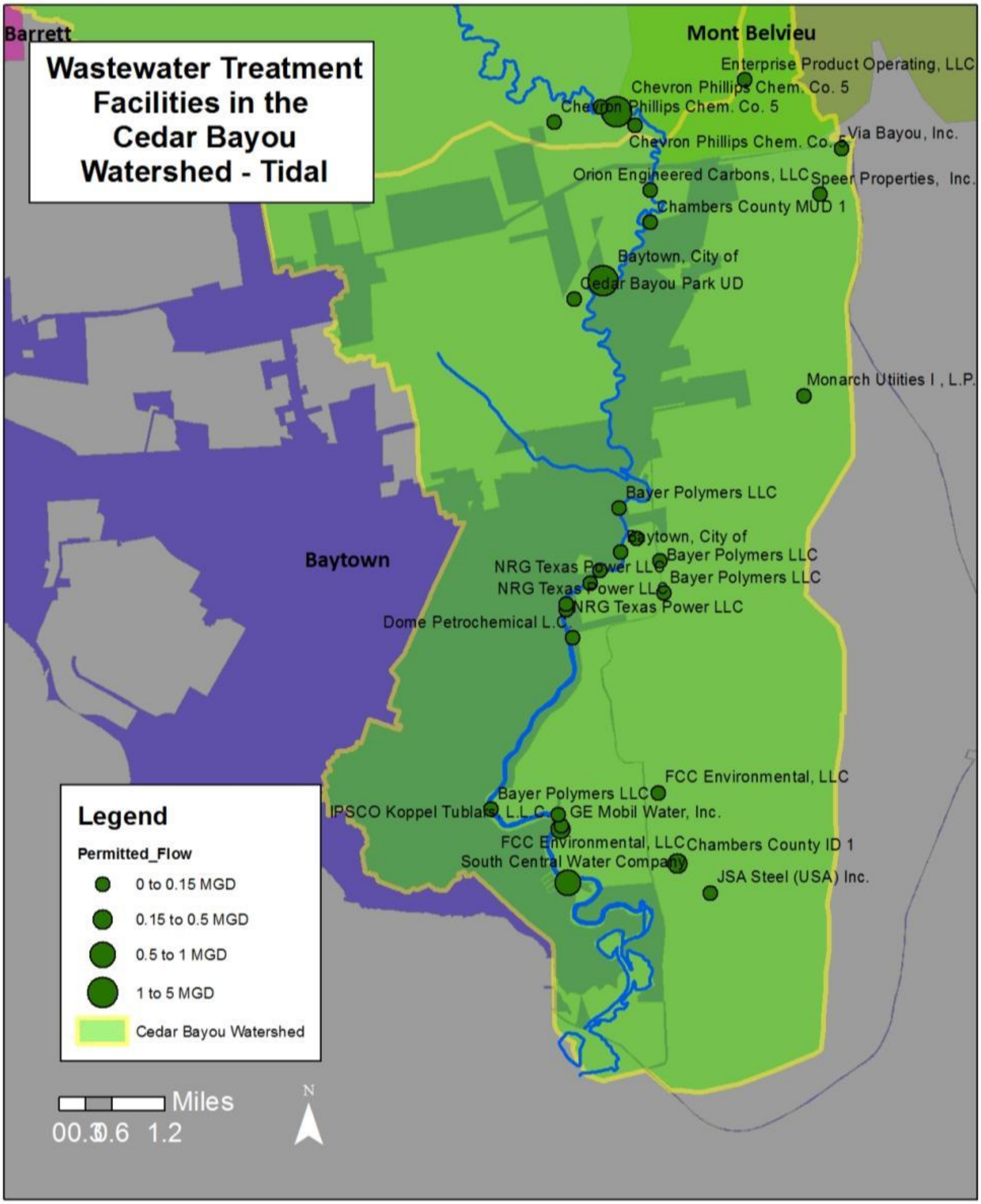


Figure 71 –WWTFs in the Tidal segment

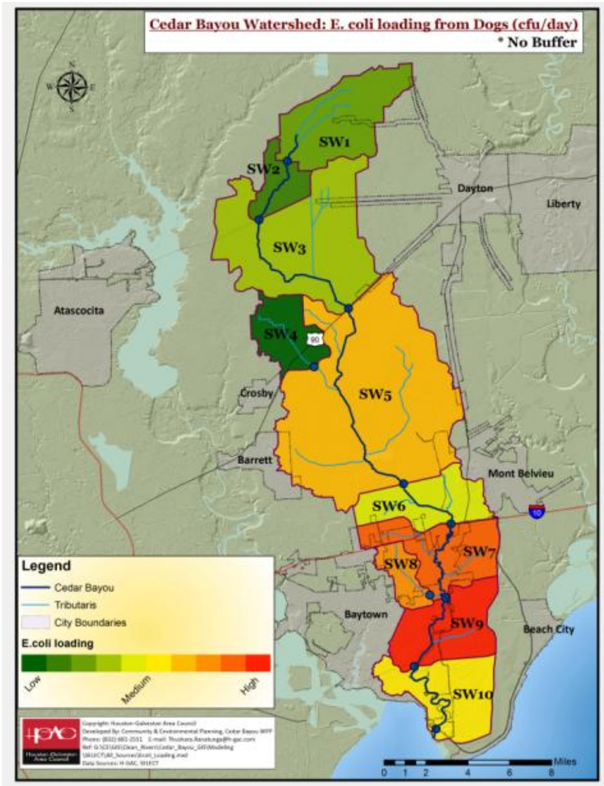
DOGS

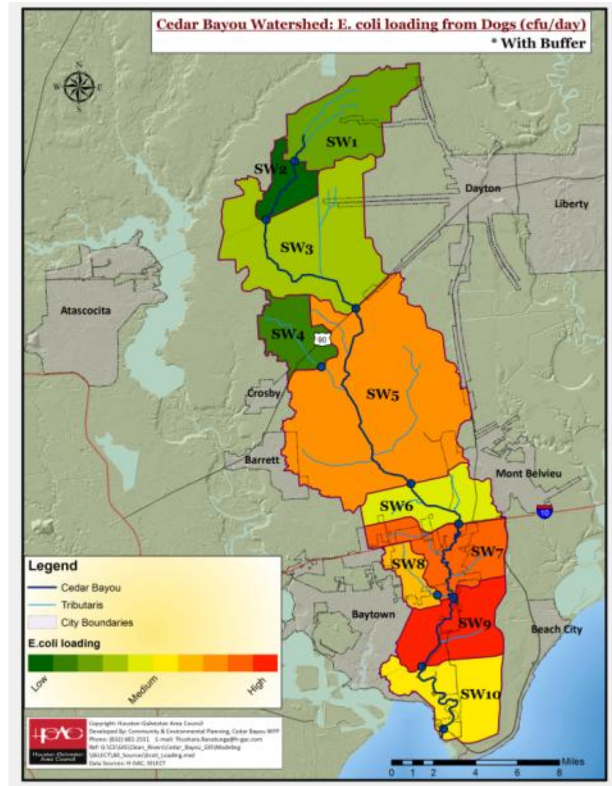
Dog waste is a significant source of water quality contamination in many areas of the greater Houston region. This source is especially pronounced in urban areas with high impervious cover and proportionately higher runoff rates. While education programs exist in the watershed, stakeholder input held that many or most homeowners still did not pick up after their dogs. Dog waste was projected based on literature assumptions of 0.8 dogs per household (Teague, 2009)[52]. Load estimates are presented in Figures 73 and 74.

Dogs were modeled throughout the watershed, although the model cannot easily account for differences in dog/owner behavior in urban areas versus suburban and rural areas. Based on stakeholder input, dogs in urban areas were more likely to be walked in areas of impervious cover, dogs in suburban areas were more likely to defecate at least part of the time in backyards separated from storm sewers, and rural dogs were more likely to be outdoor dogs. For the sake of looking at total potential load, it was assumed that dog waste was deposited in areas with potential to transmit to waterways, regardless of ownership style.

Figure 72 – Examples of watershed outreach ads regarding dog waste

[52] Other national values were as much as double this rate. However, stakeholders were concerned that large numbers of apartments were skewing the number of households, and that apartment dog ownership was less than this rate. An informal survey of Baytown apartment complexes conducted by a stakeholder found that rates of dog ownership (as declared by the owners to management) were lower than the assumption used, indicating 0.2 dogs/apartment. This may not account for dog ownership that is undeclared (many complexes require a fee). The literature value was used for modeling, with the understanding that it is likely a conservatively overestimated representation of total loading, while actual loading may be less. Feral dog populations, which stakeholders indicated were present in urban centers, are not accounted for in this assumption. However, they are assumed to be accounted for in the general urban stormwater source modeling.





Subwatershed	Number of Dogs	Dog Loadings
SW1	437	5.5E+11
SW2	157	1.8E+11
SW3	959	1.2E+12
SW4	696	0.0E+00
SW5	2,414	2.5E+12
SW6	2,203	1.9E+12
SW7	5,652	6.1E+12
SW8	2,289	2.8E+12
SW9	7,508	9.2E+12
SW10	1,833	2.1E+12
TOTAL	**24,148**	**2.6E+13**

Figure 73 – Relative bacteria loading from dogs, by subwatershed (Current)

Subwatershed	Number of Dogs	Dog Loadings (buffer)
SW1	437	3.8E+11
SW2	157	8.7E+10
SW3	959	5.8E+11
SW4	696	2.3E+11
SW5	2,414	9.1E+11
SW6	2,203	6.0E+11
SW7	5,652	2.3E+12
SW8	2,289	8.7E+11
SW9	7,508	2.9E+12
SW10	1,833	6.8E+11
TOTAL	**24,148**	**9.6E+12**

Figure 74– Relative bacteria loading from dogs, by subwatershed (Current, Buffered)

Due to the density of households in urban areas, the Tidal subwatersheds have pronounced loadings from dogs. However, dogs remain among the primary sources throughout the watershed. Application of the buffer reduces the overall estimate of potential load, but does not change the prominence of dog waste as a source.

Future projections for dogs are based on household data from H-GAC's regional projections for the watershed area (figures 75 and 76). As developed areas and populations increase, bacteria loadings from dogs increase correspondingly. The growing density of urban centers, coupled with high impervious cover and direct transmission via storm sewers, makes dog waste a primary concern for these areas.

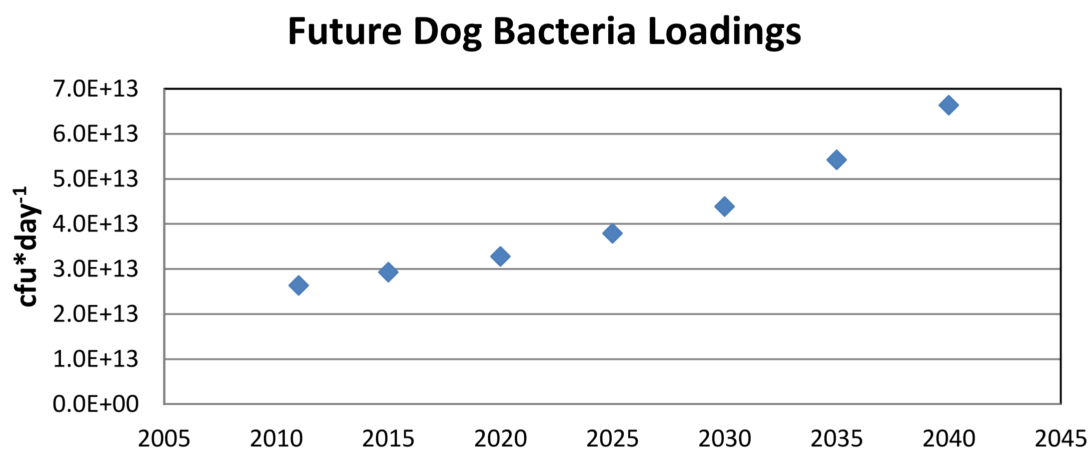


Figure 75 – Future bacteria loads from dogs

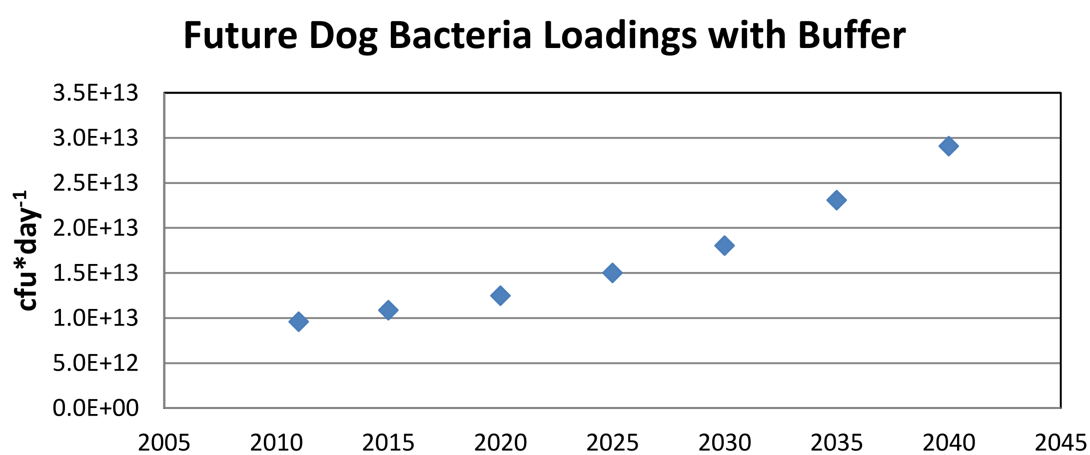
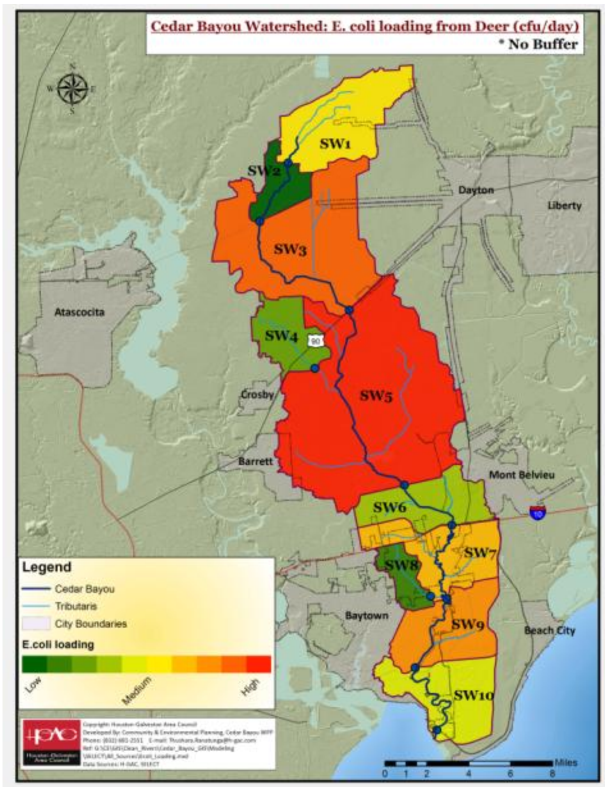


Figure 76 – Future bacteria loads from dogs (Buffered)

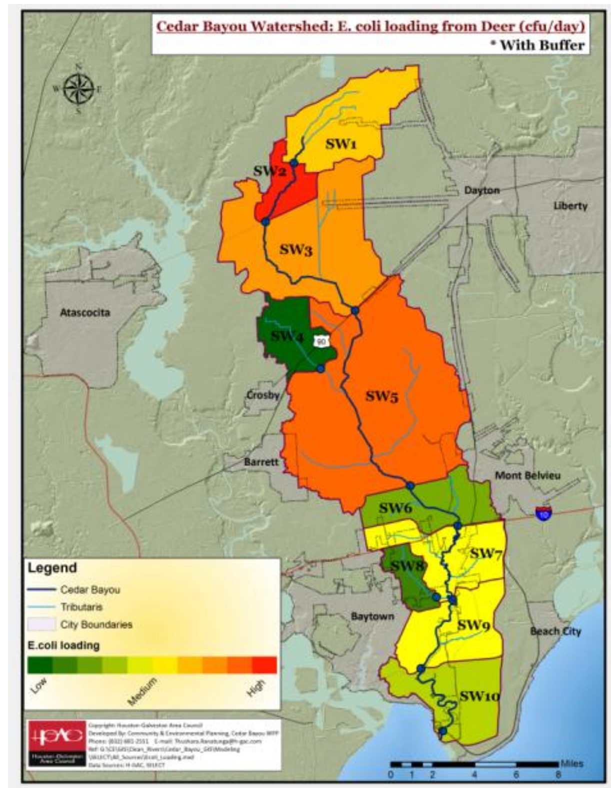
Deer

White-tailed deer are common throughout the Above Tidal portion, with some in the Tidal portion. Stakeholders did not report any specific areas of high concentrations. Deer population densities were taken from this ecoregion's figures from Texas Parks and Wildlife Department's Resource Management Unit data. The densities were applied to grasslands, forests, and shrub/scrub land cover types in the watershed, and were reviewed with stakeholders.



Subwatershed	Number of Deer	Deer Loadings
SW1	39	3.4E+09
SW2	5	8.7E+08
SW3	78	6.8E+09
SW4	18	1.6E+09
SW5	98	8.6E+09
SW6	25	2.2E+09
SW7	42	3.9E+09
SW8	15	1.4E+09
SW9	47	4.2E+09
SW10	33	2.9E+09
TOTAL	**399**	**3.6E+10**

Figure 77 – Relative bacteria loading from deer, by subwatershed (Current)



Subwatershed	Number of Deer	Deer Loadings (buffer)
SW1	39	1.5E+09
SW2	5	9.2E+09
SW3	78	2.2E+09
SW4	18	3.0E+08
SW5	98	2.8E+09
SW6	25	6.9E+08
SW7	42	1.2E+09
SW8	15	3.1E+08
SW9	47	1.2E+09
SW10	33	7.9E+08
TOTAL	**399**	**2.0E+10**

Figure 78 – Relative bacteria loading from deer, by subwatershed (Current, Buffered)

The application of the buffer approach did not decrease deer loadings as appreciably as livestock, in part due to the large tracts of forested area in the riparian corridor where deer are present (Figures 77 and 78).

Deer are one of the species of wildlife who have adapted well to human development and presence, even growing to be a nuisance in some areas. SELECT predicts a minor decrease in deer population related to decreased habitat (Figures 79 and 80). However, if the species proves as adaptable to human areas in this watershed, that decrease may be limited.

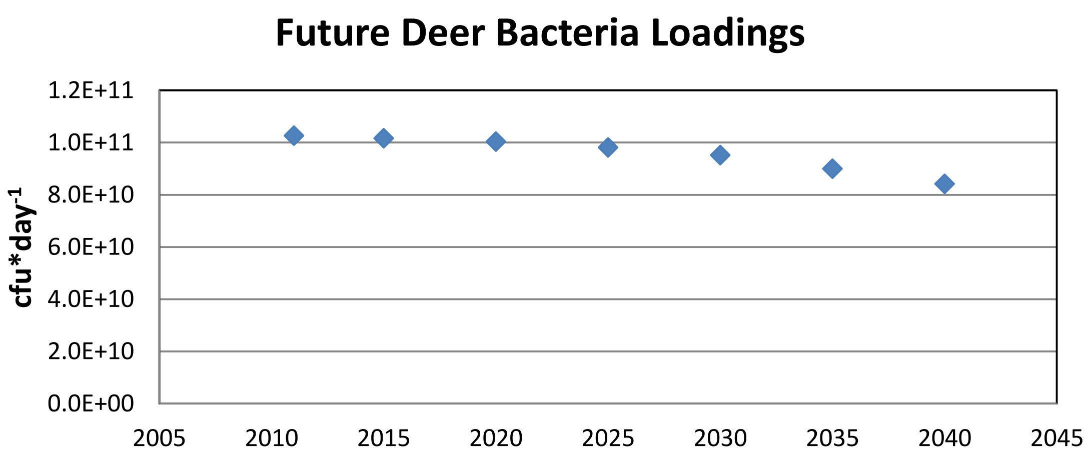


Figure 79 – Future bacteria loads from deer

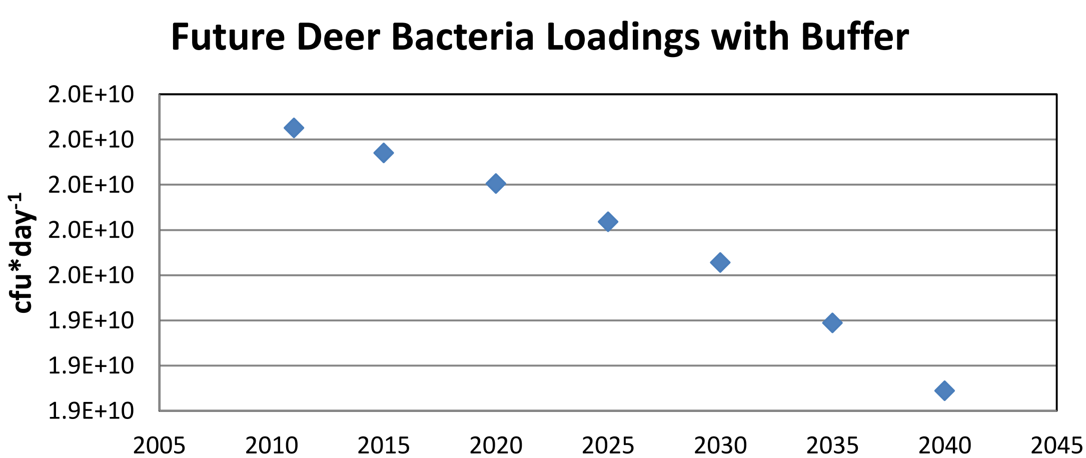


Figure 80 – Future bacteria loads from deer (Buffered)

Feral Hogs

Feral hogs (*Sus scrofa* and related hybrids) are rapidly becoming one of the most pressing invasive species issues in Texas[53]. Adaptable, fertile, and aggressively omnivorous, their populations are responsible for significant damage to agricultural production, wildlife and habitat, and human landscapes. Hogs are able to transmit diseases dangerous to humans, pets, and domestic livestock. Additionally, hog populations can generate large volumes of waste where they concentrate, and in areas they roam through, including developed open space.

Modeling assumptions started with literature estimates of 5 hogs/km^2 (Teague, 2009) and considered values used in preceding watershed projects[54], ranging from 2 to 7 hogs/km^2. Initial stakeholder input was not conclusive, with some areas or individual landowners reporting large hog populations, while others reported few if any hogs or hog damage. For a starting point, AgriLife Research's top range values of 2 hogs/sq. mile (in bare land, cultivated, and pasture/hay land uses) and 2.45 hogs/sq. mile in all other land uses were used[55]. Load estimates are presented in Figures 82 and 83.

The Partnership, local Soil and Water Conservation Districts, and other partners reviewed the resulting population projections and found them to be too low. Based on stakeholder review, hog populations were doubled in all subwatersheds. Feral hogs were populated in bare land, cultivated land, pasture/hay, grasslands, forests, shrubs, and wetland land cover acreages.

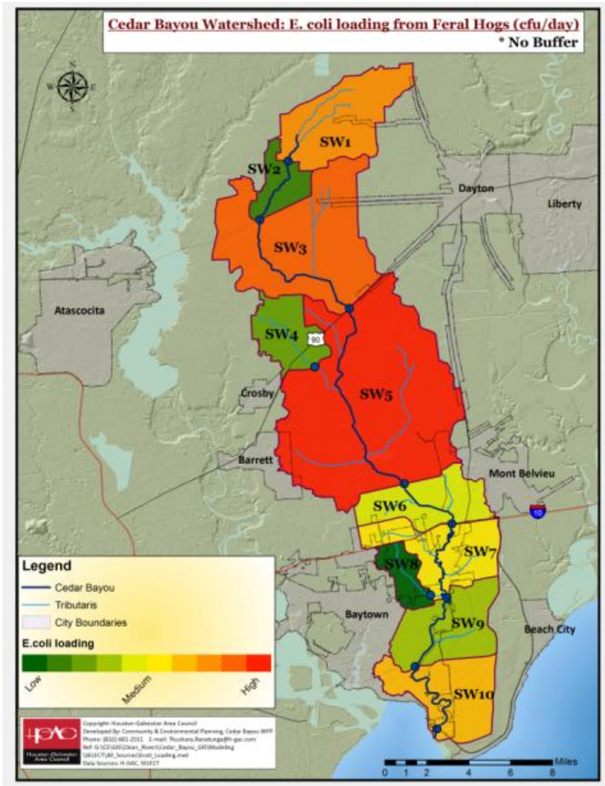
Figure 81 – A sounder of feral hogs[56]

[53] A wealth of information on this nuisance animal in Texas can be found at http://feralhogs.tamu.edu/ and http://www.tpwd.state.tx.us/huntwild/wild/nuisance/feral_hogs/.

[54] Estimates from the Bastrop Bayou WPP, San Bernard WPP, Plum Creek WPP, and other partner efforts were compared to evaluate how hog concentrations have been dealt with in the past.

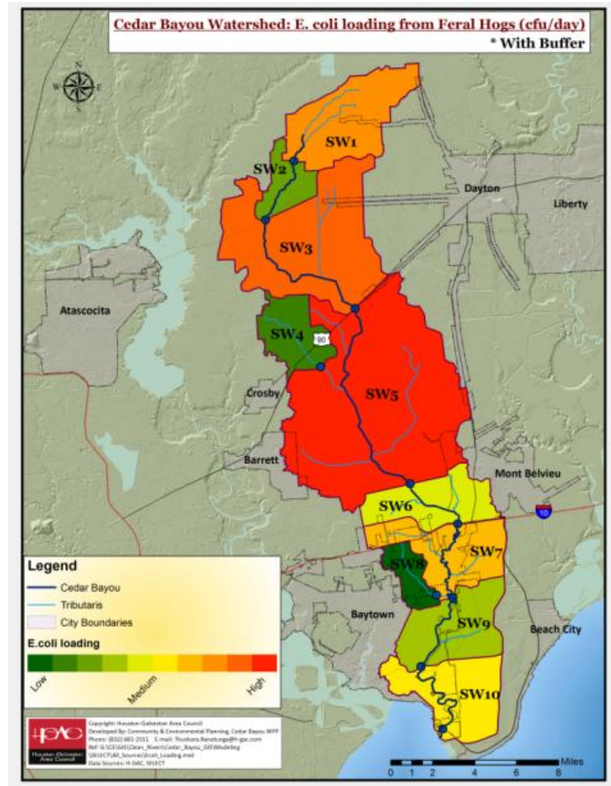
[55] As indicated at http://feralhogs.tamu.edu/files/2011/05/FeralHogFactSheet.pdf. Hogs were not populated in water, shore, or developed areas.

[56] Image courtesy of AgriLife Extension



Subwatershed	Number of Feral Hogs	Feral Hog Loadings
SW1	38	1.7E+11
SW2	12	5.4E+10
SW3	73	3.3E+11
SW4	17	8.0E+10
SW5	132	5.9E+11
SW6	19	8.9E+10
SW7	24	1.1E+11
SW8	7	3.2E+10
SW9	18	8.3E+10
SW10	26	1.2E+11
TOTAL	**365**	**1.7E+12**

Figure 82– Relative bacteria loading from feral hogs, by subwatershed (Current)



Subwatershed	Number of Feral Hogs	Feral Hog Loadings (buffer)
SW1	38	4.1E+10
SW2	12	1.4E+10
SW3	73	7.4E+10
SW4	17	1.3E+10
SW5	132	1.4E+11
SW6	19	2.0E+10
SW7	24	2.5E+10
SW8	7	5.9E+09
SW9	18	1.9E+10
SW10	26	2.4E+10
TOTAL	**365**	**3.7E+11**

Figure 83 – Relative bacteria loading from feral hogs by subwatershed (Current, Buffered)

The loadings attributable to feral hogs are greatly impacted by the application of the "buffer" approach. However, in neither scenario do feral hogs show as being a primary source in relation to OSSFs, dogs, and other sources. Hogs are highly migratory within their home range, spending much time in riparian corridors, but also ranging far afield in search of foodstuffs. SELECT cannot easily account for this migratory pattern, and thus the doubling effect recommended by the stakeholders is assumed to be inclusive of any uncertainty in deposition locations as predicted by SELECT's spatial distribution of the hogs.

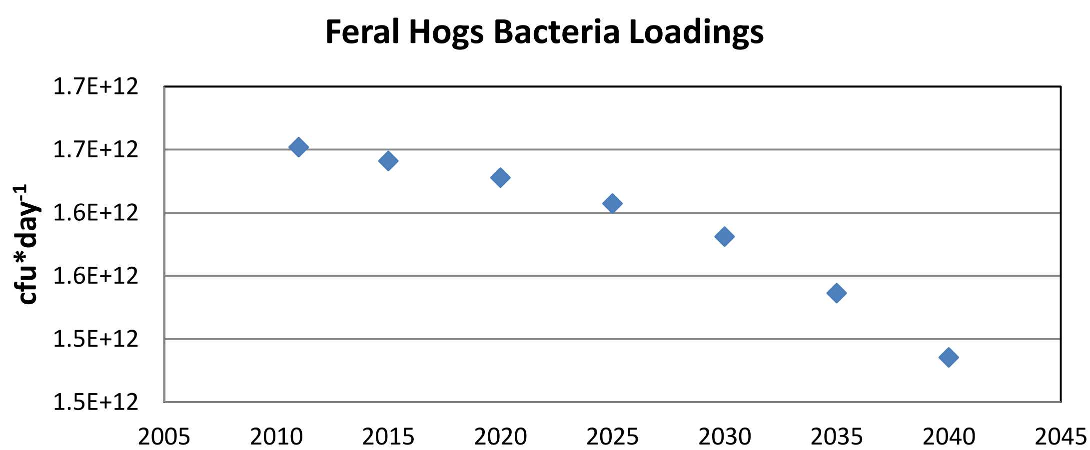


Figure 84 – Future bacteria loadings from feral hogs

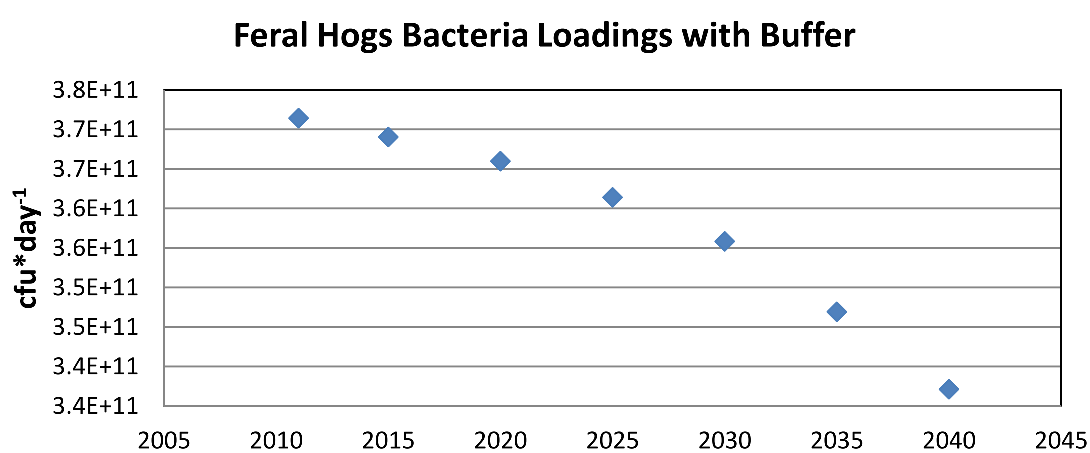


Figure 85 – Future bacteria loadings from feral hogs (Buffered)

Future projections for feral hogs are based on land cover and show slight decreases, mostly due to development of previous habitat (Figures 84 and 85). However, it is unclear if this effect will be balanced by population growth and concentration within the hog communities in the watershed[57].

[57] Feral hog projections are somewhat problematic in SELECT, in part due to lack of good data concerning hog population dynamics. Historically, feral hog population growth has been exponential rather than sustaining static populations. However, without manual intervention, SELECT assumes static populations. Without a feasible way to predict population growth dynamics in the watershed, there is no feasible way to manually alter populations. Additionally, SELECT assumes a

URBAN STORMWATER

Urban stormwater contains a mix of various bacteria sources[58] including feral cats and dogs, pets[59], SSOs, domestic animals kept within city limits, urban OSSFs, and directly deposited human waste. Because urban areas have higher rates of impervious cover, stormwater is unable to infiltrate and be filtered in the same manner as runoff in rural/natural areas. Decreased infiltration and dense development necessitate storm sewer systems or other drainage conveyances to channel stormwater away quickly. Wastes washed into stormwater systems, therefore, are comingled, and directly deposited into waterways as opposed to sheet flow across land surfaces. In the Cedar Bayou watershed, aging sanitary sewer collection system infrastructure in urban areas has documented issues with inflow and infiltration, leading to frequent SSOs.

Runoff estimations were based on the percent impervious cover of the developed area (Exum, 2005) and precipitation averages. Bacteria loads were then generated based on literature values (PBS&J, 2000) relative to bacteria event mean concentrations related to the various impervious cover categories (Figures 87 and 88).

Figure 86– Stormwater inlet drain marker

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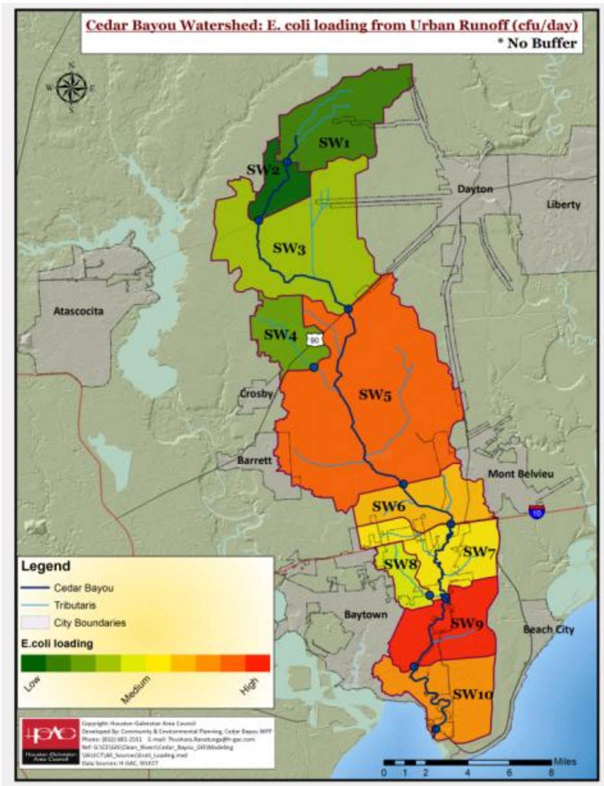
loss of habitat equates to a loss of animals. This assumption does not allow for concentration of populations (i.e. hogs from lost habitats conglomerating in remaining parcels at higher densities). However, without good data on the carrying capacity of various land cover types for feral hog populations, it is unfeasible to later SELECT results to mimic concentration effects. While these issues limit the effectiveness of SELECT in projecting future population, the expected decreased in populations shown in figures 85 and 86 are not drastic enough to impact feral hogs' prominence as a source relative to other sources.

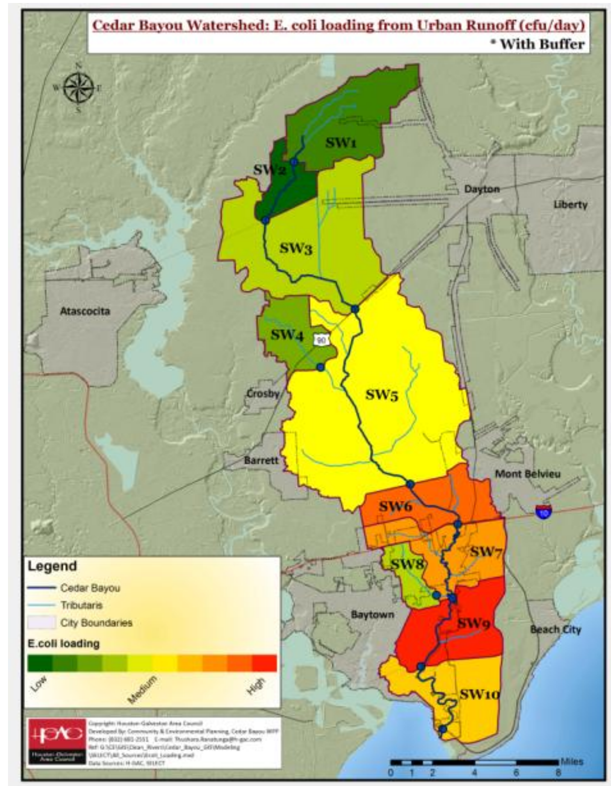
[58] Urban stormwater is also a significant source of nutrients from fertilizers and related substances.

[59] While the potential for overrepresentation of dogs in urban areas exists due to their presence in both urban stormwater and dog loading calculations, there was no feasible way to break out the dog waste from the urban stormwater calculations (the bacteria is mingled in stormwater, and not typed in the 2000 PBS&J study on which the assumptions are based). Additionally, the stakeholders verified the presence of urban feral dog populations for which no good estimates existed, and which were not accounted for in the dog-specific calculations. The stakeholders felt that over-estimating dogs in urban areas was better than underestimating them.



Subwatershed	Urban Stormwater Loadings
SW1	1.6E+10
SW2	1.4E+10
SW3	7.6E+10
SW4	5.7E+10
SW5	3.7E+11
SW6	1.6E+11
SW7	1.5E+11
SW8	1.2E+11
SW9	4.0E+11
SW10	1.9E+11
TOTAL	**1.6E+12**

Figure 87 – Relative bacteria loading from urban stormwater, by subwatershed (current)



Subwatershed	Urban Stormwater Loadings
SW1	5.9E+10
SW2	5.7E+10
SW3	3.2E+11
SW4	1.2E+11
SW5	8.8E+12
SW6	1.1E+12
SW7	1.1E+11
SW8	3.2E+12
SW9	1.9E+12
SW10	9.9E+11
TOTAL	**6.8E+12**

Figure 88 – Relative bacteria loading from urban stormwater by subwatershed (current, buffered)

The core of urban areas is concentrated in the Tidal watershed, and thus loadings for this source are greatest in this portion. Application of the buffer reduces urban runoff loadings relative to unbuffered urban runoff loadings. However, the relative percent contribution of urban runoff as a source increases given the proximity of the urban core to the waterway.

Future projections for urban runoff are based on land cover change to various developed land categories (Figures 89 and 90). As development increases, impacts of stormwater runoff are also expected to increase, unless there are appreciable changes in addressing SSOs and other bacteria sources in the runoff[60].

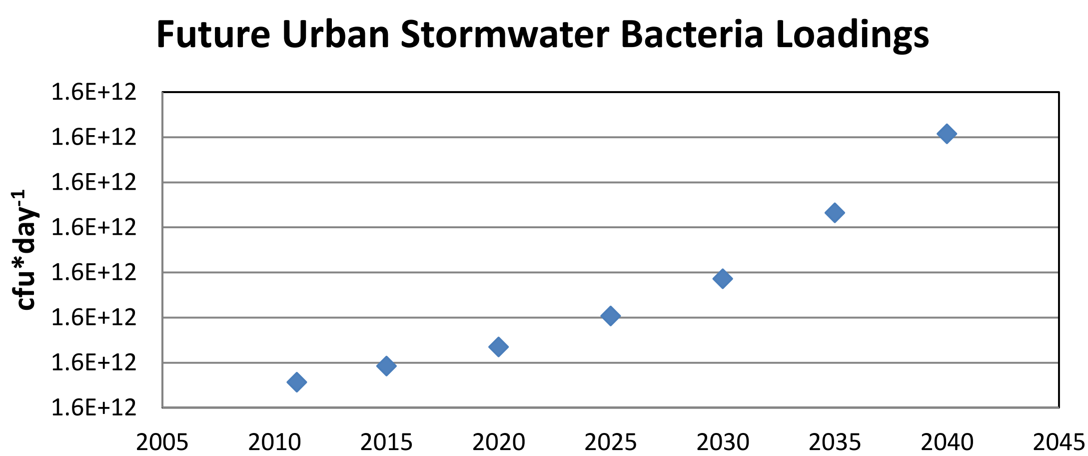


Figure 89 – Future urban stormwater bacteria loadings

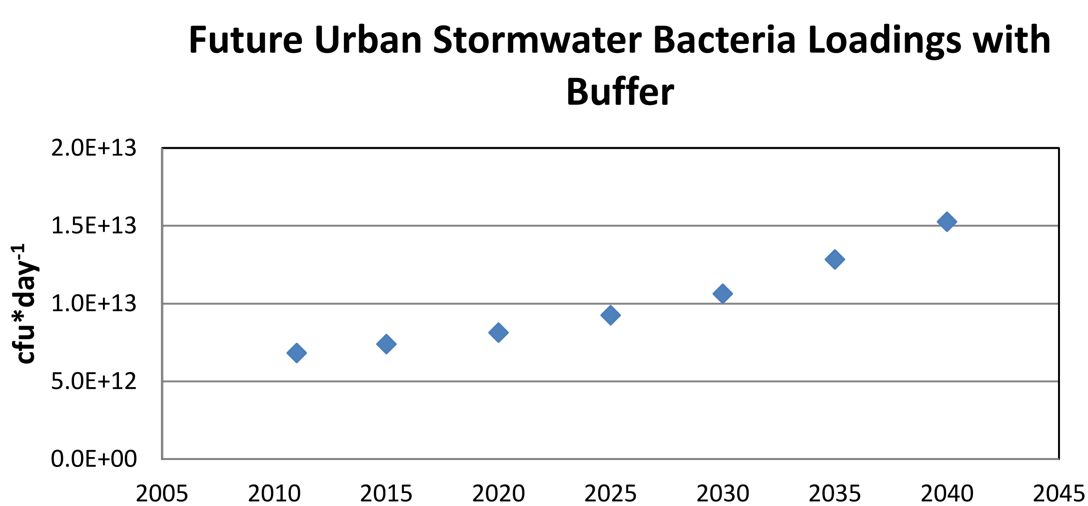


Figure 90 – Future urban stormwater bacteria loadings (buffered)

[60] Prior to the completion of this WPP, the City of Baytown entered into the TCEQ's Sanitary Sewer Overflow Initiative and agreed to make continued investments in rehabilitating elements of their system, many of which fall with the watershed areas.

TOTAL BACTERIA LOADING FOR THE WATERSHED

A primary consideration in identifying and prioritizing solutions for bacterial contamination is the relative contribution of the various sources. Additionally, the change in relative contribution over time is a pressing concern for the timing of solutions. Financial, technical, and human resources are best applied to solutions that will generate the greatest potential decrease in bacteria levels. The following tables and figures represent the summation of modeled loads for three representative years: "current" (2011[61]), mid-term (2025), and long-term (2040). The data are presented for both the "standard" and "buffer" scenario approaches.

Table 6 – Total bacteria loadings for 2011, 2025, and 2040

	OSSFs	WWTFs	Urban Runoff	Dogs	Cattle	Deer	Feral Hogs	Horses	Sheep and Goats	Total
2011	6.9E+13	2.4E+11	1.6E+12	2.6E+13	1.1E+13	3.6E+10	1.7E+12	1.0E+11	3.3E+12	**1.1E+14**
2025	8.4E+13	3.0E+11	1.6E+12	3.8E+13	1.1E+13	3.4E+10	1.6E+12	9.8E+10	3.1E+12	**1.4E+14**
2040	9.9E+13	3.5E+11	1.6E+12	6.6E+13	9.2E+12	3.2E+10	1.5E+12	8.4E+10	2.7E+12	**1.8E+14**

Table 7 – Total bacteria loadings for 2011, 2025, and 2040 (buffered)

	OSSFs	WWTFs	Urban Runoff	Dogs	Cattle	Deer	Feral Hogs	Horses	Sheep and Goats	Total
2011	1.4E+13	2.4E+11	6.8E+12	9.6E+12	3.5E+12	2.0E+10	3.7E+11	6.9E+10	9.7E+11	**3.6E+13**
2025	2.8E+13	3.0E+11	9.2E+12	1.5E+13	3.4E+12	2.0E+10	3.6E+11	6.8E+10	9.3E+11	**5.7E+13**
2040	7.4E+13	3.5E+11	1.5E+13	2.9E+13	3.0E+12	1.9E+10	3.4E+11	6.4E+10	8.1E+11	**1.2E+14**

Overall, Tables 6 and 7 demonstrate two important aspects of potential loads in the watershed. The first is the potential impact of distance on load potential. The standard scenario assumes all loads in the watershed reach the waterways, while the buffer approach assumes a very high level, subjective approximation of the potential impact of transmission rates between things close to the water and those far away. In the comparison of the two tables, it is clear that there is a significant difference in overall load between the two approaches. However, this difference decreases over time. The second aspect involves the comparative increase in loading over time. The "standard" scenario shows a gradual increase, while the "buffer" scenario shows a much more rapid increase. The potential implication of this discrepancy is that growth of sources in the riparian areas is likely to be a driver for bacteria increases in the watershed as a whole. This is derived from the fact that potential load in the

[61] 2011 was chosen as the current year because it represents the latest land cover dataset from which most loadings are derived.

"buffer" scenario, which is more influenced by change in riparian areas, increases far faster than the "standard" scenario, which does not weight riparian areas.

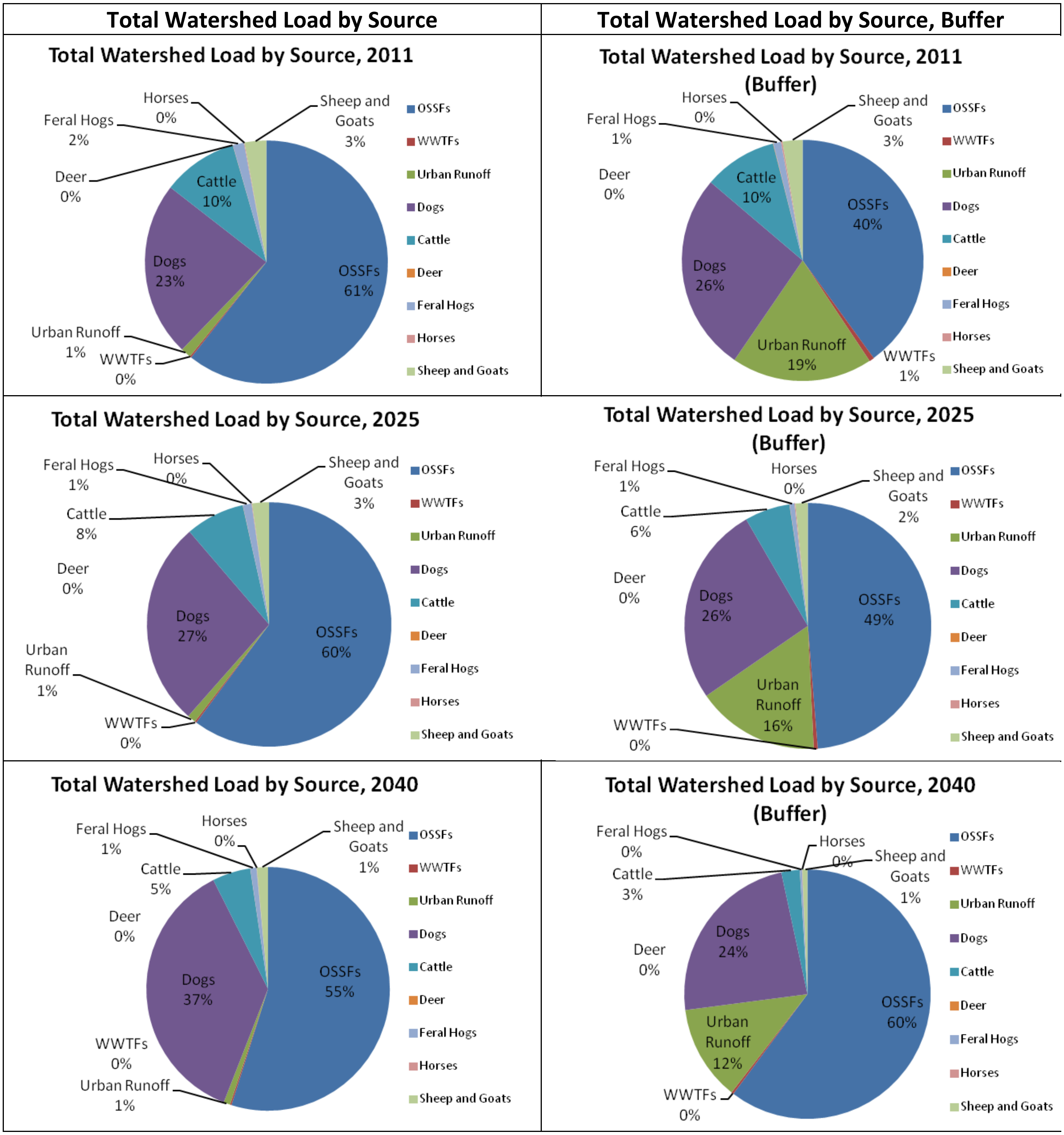


Figure 91 – Total watershed loads by source, over time (standard and buffered approaches)

The change in relative contribution by source over time indicates the same general trends shown in the individual sources (Figure 92). Agricultural operations are generally projected to decrease while sources related to development increase. Throughout the modeled period, however, the general hierarchy of sources remains similar, with dogs and OSSFs being the most prominent sources. The primary difference between the standard and "buffer" scenarios is that in the buffered approach, the likely impact of urban runoff is more pronounced. The proximity of the major urban centers to the riparian corridors of the watershed, especially Baytown and other development in its halo, produce a greater impact from urban sources when weight is placed on the riparian areas. While the "buffer" approach is not intended to be a precise model of likelihood of transmission, it does show a general relationship between proximity and relative contribution of load.

The spatial distribution of load is shown in Figures 93 and 94[62].

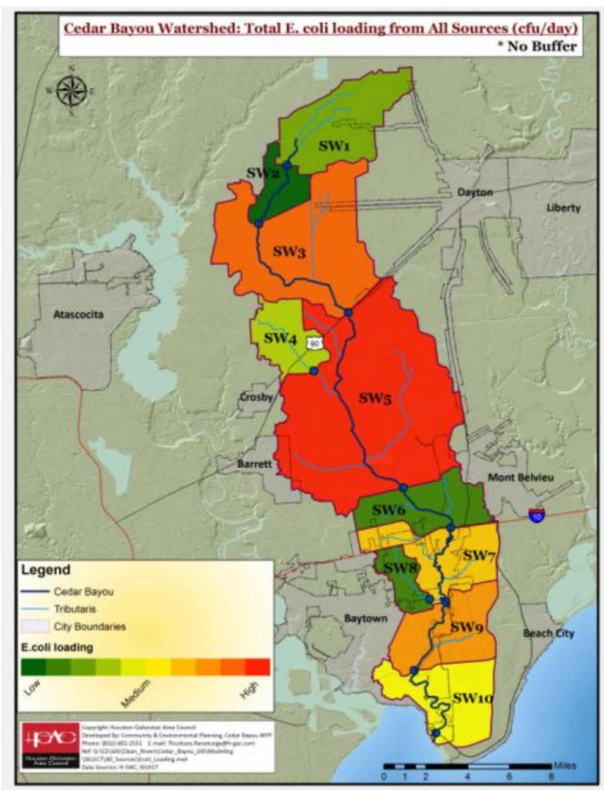


Figure 92 – Current total bacteria loads

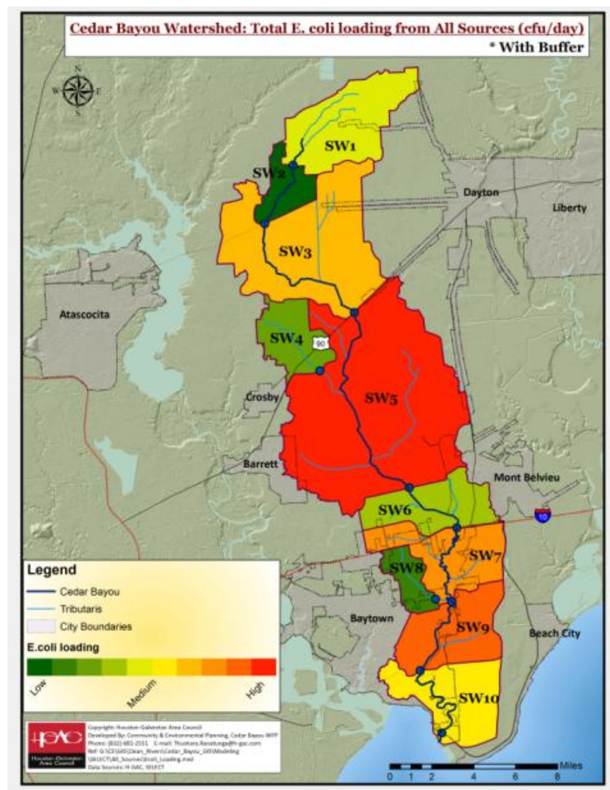


Figure 93 – Current total bacteria loads (buffered)

The projections of future total potential bacteria loads indicate that the impact of increasing development will drive a substantial increase in loading over the next 30 years. All of the assumptions built into the individual sources must be considered, the greatest of which being that these potential

[62] It should be noted that the subwatersheds are not of equal size, and therefore these maps do not speak to the load per area of the subwatersheds. Some Tidal watersheds have higher load densities, but low total loads due to their relatively small size. Subwatershed size was dictated by the location of sampling sites and needs of other modeling efforts.

loads assume no solutions are applied[63], and that development continues to occur in accordance with regional projections. Figures 94 and 95 indicate the change in potential loading over time. While the "buffer" approach indicates lower overall loads, it also projects a greater degree of increase.

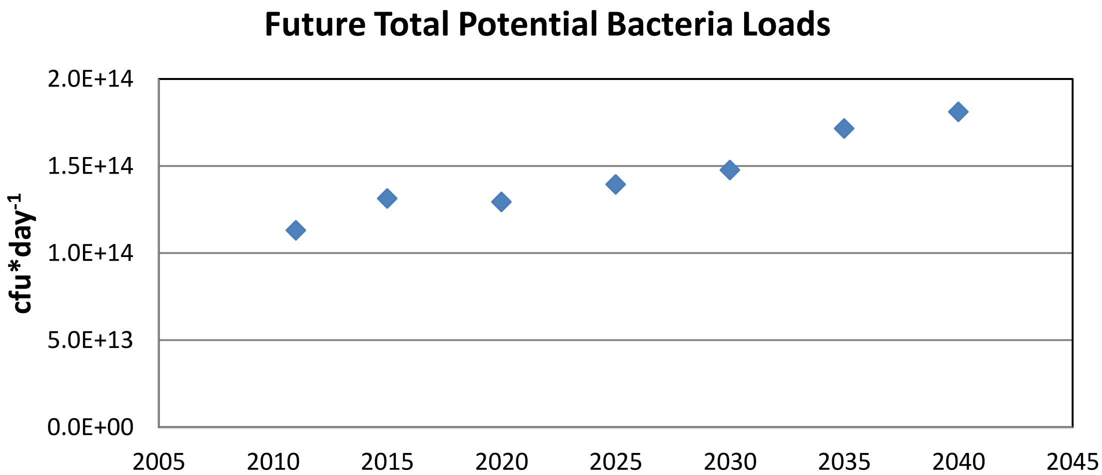


Figure 94 – Total potential bacteria loads over time

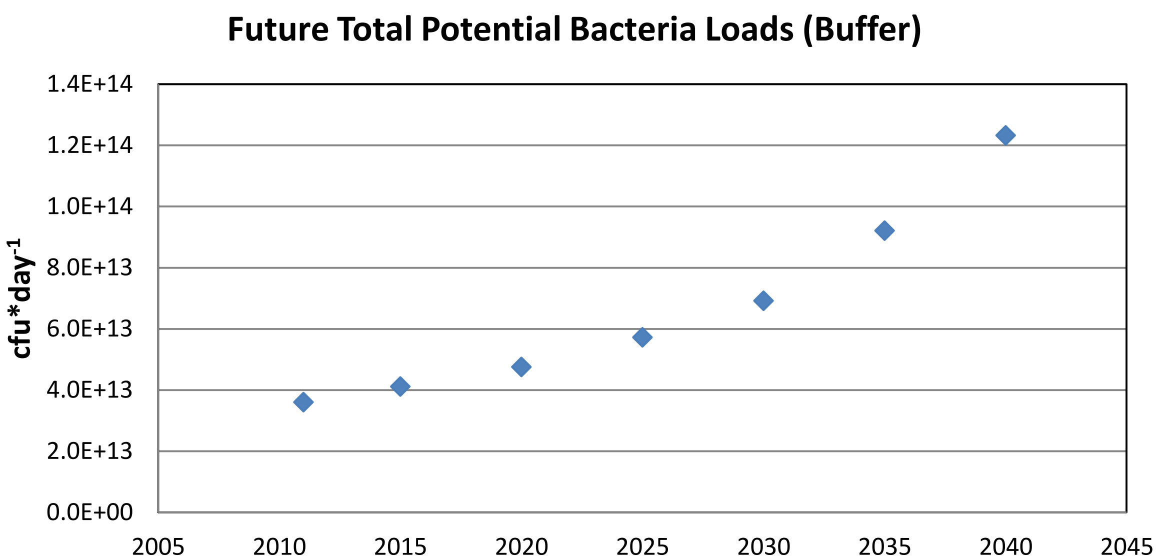


Figure 95 – Total potential bacteria loads over time

[63] Some efforts to curtail bacteria are already underway, and will address aspects of these sources even without intervention. Voluntary actions like education efforts by the Galveston Bay Foundation, City of Baytown, Friends of Cedar Bayou United, and others are already in place. Actions based on regulatory compliance, such as the City of Baytown's TPDES Phase II MS4 (stormwater) permit and their participation in the TCEQ's SSOI have also come into place during the development of this WPP, but are not accounted for in load estimations.

Identifying Sources for Other Concerns

Although the focus of the source identification and quantification process was fecal waste/ indicator bacteria, discussions with stakeholders and partner agencies yielded valuable input on sources for other contaminants and issues of concern in the watershed.

PCBs and Dioxins

While there are few sampling or historical data to suggest that significant sources of PCBs and dioxins are located within Cedar Bayou, it retains an impairment due to its connection to the greater Galveston Bay system. One of the most substantial identified sources of dioxins are the San Jacinto Waste Pits located northwest of the Interstate 10 bridge over the San Jacinto River, "upstream" and to the northwest of the watershed. Fish populations in the Bay system travel in and out of the Bay and the Tidal segments of its direct tributaries, including Cedar Bayou, making them a potential source of contamination (via consumption of edible fish tissue with concentrations of these substances). Sources specific to Cedar Bayou may include unidentified areas of contaminated sediment. Maintenance dredging in the marine traffic areas of the Tidal segment's lower portion could temporarily reintroduce sediment-bound PCBs and dioxins into the water column if they exist as legacy pollutants in the substrate. Dredge spoils are isolated in various sites along the lower bayou. Catastrophic weather events, like Hurricane Ike, could potentially transport contaminated sediment and water into the watershed. Currently there is no data to suggest anything but background levels of PCBs and dioxins exist in the waterway, and no potential source sites have been identified by stakeholders. Regardless, PCBs and dioxin contamination of edible fish tissue are being addressed by TMDL studies for the greater Galveston Bay and Houston Ship Channel system[64]. Stakeholder efforts under this project, as described in the recommended solutions, are limited to education and outreach and supporting the existing efforts. While these contaminants remain a concern to the stakeholders their unique nature and (in the case of dioxins) connection to an existing Superfund site place, remediation efforts are beyond the scope, resources, and nature of the WPP process.

Nutrients and Low Dissolved Oxygen

Nutrients (Nitrogen and Phosphorus compounds) are common to many activities taking place in the watershed. Many of the sources of these nutrients (WWTFs, OSSFs, and agriculture operations) have already been identified, and will be addressed, by the bacteria solutions in this WPP. Other sources in the watershed include lawn fertilizers, agricultural fertilizers, and natural sources (biological processes/decay, atmospheric deposition, etc). Although Cedar Bayou is not impaired for low dissolved oxygen, it does show downward trends as evidenced by the addition of concerns for both segments in the draft 2014 Integrated Report. Low dissolved oxygen levels

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[64] For further information on the TMDL efforts, please refer to the TCEQ web page on the PCB (http://www.tceq.state.tx.us/waterquality/tmdl/78-hsc-pcbs.html) and Dioxin (http://www.tceq.state.tx.us/waterquality/tmdl/26-hscdioxin.html) TMDL efforts.

appear to be primarily related to a combination of increased nutrient levels from aforementioned sources, and the natural cycle of seasonal water temperatures.

Impaired Macrobenthic Communities

The macrobenthic communities' impairment reflects a lack of robustness and diversity in the fish and macroinvertebrate communities of a waterway. These communities can be stressed for a number of reasons, including changes in water conditions, lack of dissolved oxygen, changes in their physical habitat, and changes in flow patterns. Potential impacts in Cedar Bayou include development that increases flow volumes in runoff conditions, changes in water chemistry and/or temperature due to human activities (including use of pesticides and fertilizers), and changes in the structure of the substrate/habitat due to hydrologic factors. Depletion of riparian corridors, and increased and intensified flows during rain events are potential causes. While the waterway is not currently impaired, the impacts of many of these factors are expected to increase in the next decade as growth continues.

Marine and Terrestrial Debris

Marine debris prior to the start of this WPP project was substantially composed of abandoned or sunken vessels. The majority of these vessels have been removed due to coordination among the stakeholders. Terrestrial debris/garbage sources include litter in stormwater from urban sources, as well as several defined dumping locations identified by stakeholders. The western terminus of Tri-City Beach Road, near the mouth of Cedar Bayou, has been a periodic dump site during the development of this WPP. Several of the northernmost monitoring locations have had periodic dumping of game animal remains, feral hog remains, and other organic debris. Interviews with Waste Management staff regarding the landfill at the mouth of the watershed, as well as discussion with local stakeholders, suggest that it is not likely to be an appreciable source of trash due to precautions and regulation of landfill practices.

Sediment

Sediment is naturally transported by waterways, but excessive concentrations can block light in the water column, and change habitat on and in the substrate. On a larger level, high concentrations of sediment can change the hydrological profile and flow conditions of a waterway. Based on stakeholder input and field reconnaissance, potential sources of excessive sediment loads in Cedar Bayou include growth and development in riparian areas and along major transportation corridors, decreases in vegetative cover (and thus sequestration/filtration) in the riparian corridor, and erosion during catastrophic weather events. Movement of water between the bayou and upper Galveston Bay through the "cut" channel north of the bayou's mouth may also be a source of sediment.

Section 5 – Water Quality Analysis and Estimated Bacteria Reductions

5 – Water Quality Analysis and Estimated Bacteria Reductions

Overview

Developing solutions to address water quality issues relies on a well-established understanding of the link between pollution sources and instream water quality. Natural processes impact the fate of contaminants deposited in the watershed as they are transported to Cedar Bayou and its tributaries. Understanding the relationship between sources and observed water quality is crucial to appropriate selection and scaling of solutions. In the Cedar Bayou watershed, this process included:

- An analysis of water quality monitoring data;
- Watershed modeling to determine the relationship between source loads and instream water quality (using the SWAT and SWMM5 models); and
- Development of estimated source load reductions.

The efforts described in this section involved modeling and data analysis by H-GAC and expert consultants, as guided by feedback from the project stakeholders.

Water Quality Monitoring Analysis

As part of the Clean Rivers Program (CRP), Cedar Bayou is routinely monitored for ambient conditions on a quarterly basis. While this data is a snapshot of constantly changing water quality conditions, the long-term result is a longitudinal set of data that shows trends over time. As part of the State of Texas' Integrated Report, seven years of data submitted to TCEQ's Surface Water Quality Monitoring Information System (SWQMIS), including CRP data are used to determine whether Cedar Bayou meets state water quality standards.

As described in Section 2, Cedar Bayou faces a number of water quality challenges in each of its two segments. As of the 2012 IR, the Tidal segment continues to be unable to support the contact recreation standard due to elevated levels of bacteria, and is also listed for impairment due to PCBs and Dioxin in edible fish tissue. Chlorophyll *a* levels were sufficient enough to generate only a concern status. While the Above Tidal segment does not have any current impairments or concerns, it has experienced water quality and habitat issues in the past. At the beginning of the Cedar Bayou WPP development process, the Above Tidal segment was unable to sufficiently support aquatic life (Impaired macrobenthic communities). However, in the intervening time frame, new data prior to the project and during the project effort has indicated that the Above Tidal segment is now fully supporting. While the current approved 2012 IR indicates no concerns, the Draft 2014 IR indicates depressed DO as a screening-level concern for the Above Tidal segment. Similarly, the Tidal segment's assessment under the Draft 2014 IR also includes a DO concern.

To ensure a thorough understanding of the water quality in Cedar Bayou, the WPP development process included an analysis of existing historical data and a multi-faceted, intensive monitoring effort. The monitoring effort included: 1) enhanced ambient water quality monitoring; 2) assessment of discharges from wastewater treatment facilities; 3) biased sampling conducted in storm conditions; 4) 24-hour DO monitoring; and 5) biological sampling to assess the health of aquatic life. This comprehensive effort was conducted to provide as much information to support stakeholder decisions and to provide good data for watershed modeling activities. While not part of the formal data collection and modeling, data from Teas Stream Team volunteers in the watershed was used to identify potential watershed hotspot issues. The details and results of the sampling efforts are summarized as follows.

Monitoring Sites

Historical and continuing CRP monitoring in the watershed occurs quarterly at four sites, with two each in the Tidal and Above Tidal segments. To get a better sense of water quality throughout the watershed the frequency of ambient monitoring was increased to monthly, and six additional sites were added throughout the watershed. H-GAC partnered with the Environmental Institute of Houston-University of Houston, Clear Lake (EIH), an existing CRP partner, to support H-GAC's collection efforts.

In total, ten sites were monitored on a monthly basis over a two year period between 2013 and 2014 for enhanced ambient sampling (five sites were located in the Tidal segment, and five in the Above Tidal; eight sites were on the main stem of Cedar Bayou, one site was on Carey Bayou, and one site was on Adlong Ditch). Four sites (two in each segment) were chosen for 24-hour do monitoring. Two sites in the Above Tidal were selected for biological monitoring. Two sites (one in each segment; one main stem and one tributary) were selected for automated storm flow monitoring. The six additional sites were selected based on several criteria, including a desire to characterize major tributaries, reflect different areas/land uses throughout the watershed, and to provide sufficient data for modeling analyses. The sampling site locations are indicated in figure 96, and described in table 8 (in order from north to south).

Table 8 – Monitoring site descriptions

Above Tidal Sites (Project Site#/TCEQ Station ID)	Monitoring Types	Site Location	Description
CB10/21081	Ambient, Storm Flow	Cedar Bayou Above Tidal at County Road 624	This mainstem site is located west of the City of Dayton, in a primarily agricultural area north of FM 1960. The bayou is a small, wadeable stream at this point.
CB9/11123	Ambient, 24-Hour DO	Cedar Bayou Above Tidal at FM 1960	This mainstem site is located east of Lake Houston. The bayou is still a fairly small waterway at this location and the land uses remain rural/agricultural.
CB8/11120	Ambient, 24-Hour DO, Biological	Cedar Bayou Above Tidal at Highway 90	At this mainstem site the waterway has enlarged slightly, but is still wadeable in most places. Land use has started to shift toward more residential/commercial development along the transportation corridor.
CB7/21080	Ambient	Adlong Ditch at New Road	This tributary site is located along Adlong ditch, a primary tributary on the west side of the bayou. The ditch drains residential and agricultural areas and is primarily channelized.
CB6/11118	Ambient, Biological	Cedar Bayou Above Tidal at FM 1942	This mainstem site is located a few miles north of the I-10 corridor. Its primary land uses are a mix of agriculture, light development, and undeveloped land. It is a medium sized stream at this point.

Tidal Sites	Monitoring Types		Description
CB5/11117	Ambient, 24-Hour DO	Cedar Bayou Tidal at Interstate Highway 10	The upstream land uses at this mainstream site are a mix of industrial, suburban, and undeveloped, with downstream areas being a mix of suburban and industrial.
CB4/21079	Ambient, Storm Flow	Cary Bayou at Raccoon Drive	This tributary site is located on the west side of the bayou in northern Baytown. The land uses in this area are primarily urban and suburban residential and commercial.
CB3/11115	Ambient	Cedar Bayou Tidal at Highway 146	At this mainsteam site the bayou is wide enough to support boat traffic, and marks the northernmost point at which most commercial marine traffic extends. The surrounding land uses are densely urban/suburban.
CB2/11111	Ambient, 24-Hour DO	Cedar Bayou Tidal at Roseland Park	This mainstem site is located in southwestern Baytown. By this point the bayou has widened appreciably, and a navigation channel is maintained in its center. The surrounding land uses are primarily urban on its western banks, and industrial on its eastern banks.
CB1/11109	Ambient	Cedar Bayou Tidal at FM2354 (Tri City Beach Road)	This mainstem site is located just upstream of the mouth of the bayou, at its confluence with the Galveston Bay system. At this point the bayou has widened to a large river with regular marine traffic and several shallow estuarine lakes. This is the most downstream site, and its surrounding land uses are a mix of undeveloped land, industrial uses, and a large landfill directly upstream.

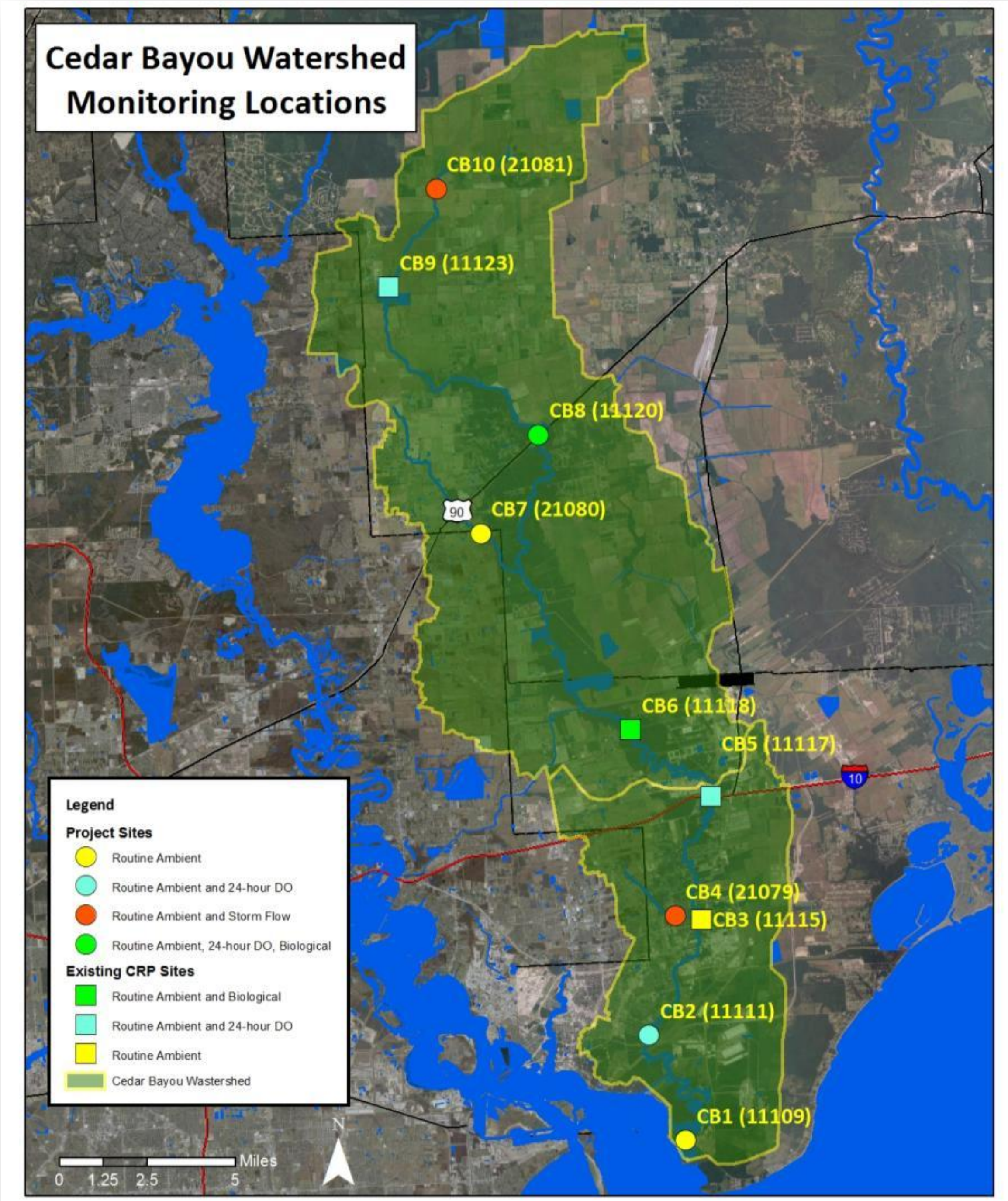

Figure 96 – Monitoring sites in the Cedar Bayou Watershed

ENHANCED AMBIENT MONITORING

Monitoring constituents included the basic characteristics of the waterway (parameters such as ph, depth, flow, temperature, conductivity, and dissolved oxygen) and specific substances of interest (total suspended solids, turbidity, sulfate, chloride, nitrate+nitrite ammonia, ammonia nitrogen, total Kjeldahl nitrogen, chlorophyll *a*, total hardness, orthophosphorus and total phosphorus, and *E. coli* and Enterococcus bacteria).

During the development of the WPP, stakeholders identified the ambient constituents of most concern[65] as being bacteria (*E. coli* and Enterococcus), nutrients (Ammonia [NH3-N], nitrate+nitrite nitrogen, total nitrogen, total Kjeldahl nitrogen, orthophosphorus, and total phosphorus), and dissolved oxygen[66]. Chlorophyll *a* was also evaluated due to its concern status in the Draft 2014 IR, although stakeholders did not specifically express concern about this constituent. These constituents were used in evaluations of change over time at each of the sampling stations[67]. In addition, significant trends were evaluated for the segments as a whole[68].

BACTERIA

Elevated levels of indicator bacteria are the primary contaminant of concern for the Cedar Bayou Watershed Protection Plan. During the enhanced ambient monitoring, both E. coli and Enterococcus were sampled at all stations. Traditionally, *E. coli* is the freshwater indicator, and would be the only bacteria sampled at Above Tidal sites, whereas Enterococcus is the marine indicator, and would be the only bacteria sampled at Tidal sites. The intent in sampling both was to evaluate the relationship between the indicators. Table 9 indicates both the historical analysis (all available data) for the two segments, showing the geomeans for all available data, and the geomeans for the last seven years for each indicator. Table 10 indicates the evaluation of the two years of project data for all the stations as well as the two segments. In general, the historical analysis did not show appreciable difference between geomeans of all available data and geomeans of the last seven years of data. As reflected in the recent IRs, the historical data geomeans for the Tidal section were in excess of the standard, while the geomeans for the Above Tidal were not. This assessment is based on the respective indicator for each segment. It should be noted, however, that the Above Tidal segment was in excess of the Enterococcus standard, but not its actual indicator, *E. coli*. There was no immediate explanation visible in the data for this phenomenon. Project staff evaluated the potential that a higher salt front may

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[65] As noted in Section 2, Water Quality Goals. While PCBs and Dioxin are impairments for the Tidal segment and were of concern to the stakeholders, they are not part of routine ambient monitoring, so they are not discussed here.

[66] The DO parameter of concern for the enhanced ambient monitoring analyses is the DO grab sample screening level, as indicated in the Draft 2014 IR. No concern is present for 24-hour average or minimum DO levels in this assessment. 24-hour sampling is discussed in a subsequent subsection of this section.

[67] Not all of the stations had equal amounts of data, as several of the stations were new and did not have historical data.

[68] Greater detail on the methods, data, and full outcomes of the analysis are contained in the Cedar Bayou Technical Report, available online at http://www.cedarbayouwatershed.com/Project%20Documents.html.

have led to greater E. coli die-off at the most downstream Above Tidal site (11118), leading to a skewing of the *E. coli* data downwards. However, the *E. coli* levels were actually higher at station 11118 than upstream.

In a review of the enhanced project data collected over the 2012-2014 sampling period, the Tidal section still exhibits a current impairment overall, and at each station for Enterococcus. The *E. coli* data indicated that the Above Tidal segment is fully supporting overall, and at each station. However, the range of data for the Above Tidal indicates that roughly 41% of the total project period samples for are in excess of the *E. coli* standard which indicates variation in bacteria concentrations.

Table 9 – Historical bacteria analysis

	Enterococcus Geomeans (in MPN/100mL)		**E. coli Geomeans (in MPN/100mL)**	
Historical Period	Last 7 Years	All Years	Last 7 Years	All Years
Tidal	171	171	248	248
Above Tidal	287	287	89	88

Table 10 – Project period bacteria geomeans

Segment/Station	**Enterococcus (MPN/100mL)**
Tidal	**177**
11109	*118*
11111	*45*
11115	*140*
21079	*472*
11117	*464*

Segment/Station	**E. coli (MPN/100mL)**
Above Tidal	**88**
11118	*126*
21080	*73*
11120	*87*
11123	*59*
21081	*99*

There were no significant trends in bacteria for either segment over the historical analysis. Of the individual stations, only 21081 in the Above Tidal segment showed any significant trend for bacteria, with an appreciable increase in *E. coli* levels.

NITROGEN AND PHOSPHORUS COMPOUNDS

Evaluation of nitrogen and phosphorus compounds found a series of significant trends, but the overall picture of change for the segments is mixed. Table 11 indicates the nutrients for which significant trends exist in each segment, and for each station. In general, the Above Tidal has experienced an increase in ammonia nitrogen and total phosphorus. However, the trends at the individual sites were only consistent for increasing ammonia nitrogen. The data for the Tidal segment indicated increases in ammonia nitrogen, and decreases in total Kjeldahl nitrogen, total phosphorus, and orthophosphorus. The individual sites of the Tidal segment were only somewhat consistent for the ammonia nitrogen increase and the orthophosphorus increases. Overall, the clearest nutrient trend in the watershed is increasing levels of ammonia nitrogen.

Table 11 – Nutrient trend analysis

Segment/ Station	Ammonia nitrogen	Total Kjeldhal Nitrogen	Nitrate+Nitrite Nitrogen	Total Phosphorus	Ortho-phosphorus
Above Tidal	**Increasing**			**Increasing**	
21081	*Increasing*				
11123	*Increasing*	*Decreasing*		*Increasing*	
11120	*Increasing*				
21080	*Increasing*				
11118			*Decreasing*	*Decreasing*	
Tidal	**Increasing**	**Decreasing**		**Decreasing**	**Decreasing**
11117	*Increasing*		*Increasing*		
21079			*Decreasing*		
11115					*Decreasing*
11111	*Increasing*				*Decreasing*
11109					

DO (GRAB)

Depressed levels of DO can negatively impact aquatic communities. Cedar Bayou has had intermittent issues with dissolved oxygen, although no concern existed for either segment in the 2012 IR. However, the Draft 2014 IR does indicate concerns with depressed dissolved oxygen (grab samples[69]) for both segments, based on data from 2005-2012 (this section refers

[69] This section refers to single sample DO results collected in the enhanced ambient monitoring. 24-hour monitoring was also completed, which is described later in this section. The concern for screening level criteria in the 2014 IR is based on grab samples, rather than 24-hour data.

to single sample DO results collected in the enhanced ambient monitoring. 24-hour monitoring was also completed, which is described later in this section. The concern for screening level criteria in the 2014 IR is based on grab samples, rather than 24-hour data). The historical data indicates 73 samples were assessed for the Tidal segment, 9 (12%) exceeded the applicable criteria (4.0 mg/L), with a mean exceedance[70] of 3.21. For the Above Tidal segment, 128 samples were assessed, of which 18 (14%) exceeded the standard (5.0 mg/L) with a mean exceedance of 4.18.

Data collected during the enhanced monitoring effort indicate that DO continues to be an issue for both the Tidal and Above Tidal segments, which had exceedance rates of 8% and 25%, respectively. The statistics for each segment are shown in Table 12.

Table 12 – DO (grab samples), 2012-2014

DO (grab), 2012-2014	Number of Samples	Minimum Value	Maximum Value	Mean Value	Number of Exceedances	Mean Exceedance Value
Tidal	143	1.7	17.2	7.07	27	3.85
Above Tidal	144	0.7	16.2	6.71	36	3.24

CHLOROPHYLL *A*

Chlorophyll *a* is not itself a pollutant, but rather an indicator of algal abundance[71]. Large algal blooms can lead to depressed dissolved oxygen as the short-lived algae die and decay. The Tidal segment's screening level concern for chlorophyll *a* is based on the General Use criteria for the waterway. Historical data for the current TCEQ assessment was collected between 2003 and 2010, in which approximately half of the samples exceeded the 21 micrograms per liter screening level, with a mean exceedance value of 35.9 based on the 2012 Integrated Report. Evaluation of chlorophyll *a* data collected during the project indicates a likelihood that chlorophyll *a* is no longer a concern based on the screening level. Less than 5% of the Tidal samples and less than 3% of the Above Tidal samples exceed the screening level criteria. The statistics for each segment are shown in Table 13.

[70] In terms of dissolved oxygen, criteria refer to minimums, rather than maximums. Therefore, an "exceedance" means a DO value is less than the established criteria.
[71] Specifically, phytoplankton density; per TCEQ's State Water Quality Standards, Title 30, Part 1, Chapter 307.

Table 13 – Chlorophyll *a*, 2012-2014

Chlorophyll *a*, 2012-2014	Max	Mean	Number of Samples	Number of Exceedances	Mean value of Exceedances
Tidal	49	5	116	6	34
Above Tidal	38	4	114	4	27

24-Hour DO Monitoring

Dissolved oxygen values can vary greatly over a 24 hour cycle due to presence or absence of sunlight for photosynthesis, nutrients, and other factors. Typical ambient monitoring data reflects only the daytime values, so 24-hour sampling is used to evaluate the full diurnal cycle. Cedar Bayou has had intermittent issues with dissolved oxygen, although no concern existed for either segment in the 2012 IR. The Draft 2014 IR does indicate concerns based on screening level criteria for grab samples; however, no concern or impairment is indicated for 24-hour DO criteria.

To evaluate the character of the diurnal DO cycle in Cedar Bayou, 24-hour DO monitoring was conducted at two stations in each segment over a two year study period. The monitoring indicated that the Tidal segment was meeting both the 24-hour average and minimum standards with no exceedances. However, the Above Tidal segment exceeded the 24-hour average standard 13 times, which is roughly 30% of all monitored events. Within the Above Tidal segment, station 11123 at the top of the watershed accounted for 9 of the 14 exceedances, with station 11120 at Highway 90 accounting for the other four. These outcomes may reflect the much shallower, less shaded nature of the bayou in its northern reaches. Biological data described later in this section show that the Above Tidal is fully supporting its High Aquatic Use designation. However, this sampling was not conducted at the very top of the watershed, and therefore is not necessarily contradictory to the DO data. The statistics for each segment are shown in Tables 14 and 15. Seasonal variation can be seen in Figure 97.

Table 14 – 24-hour DO monitoring results summary

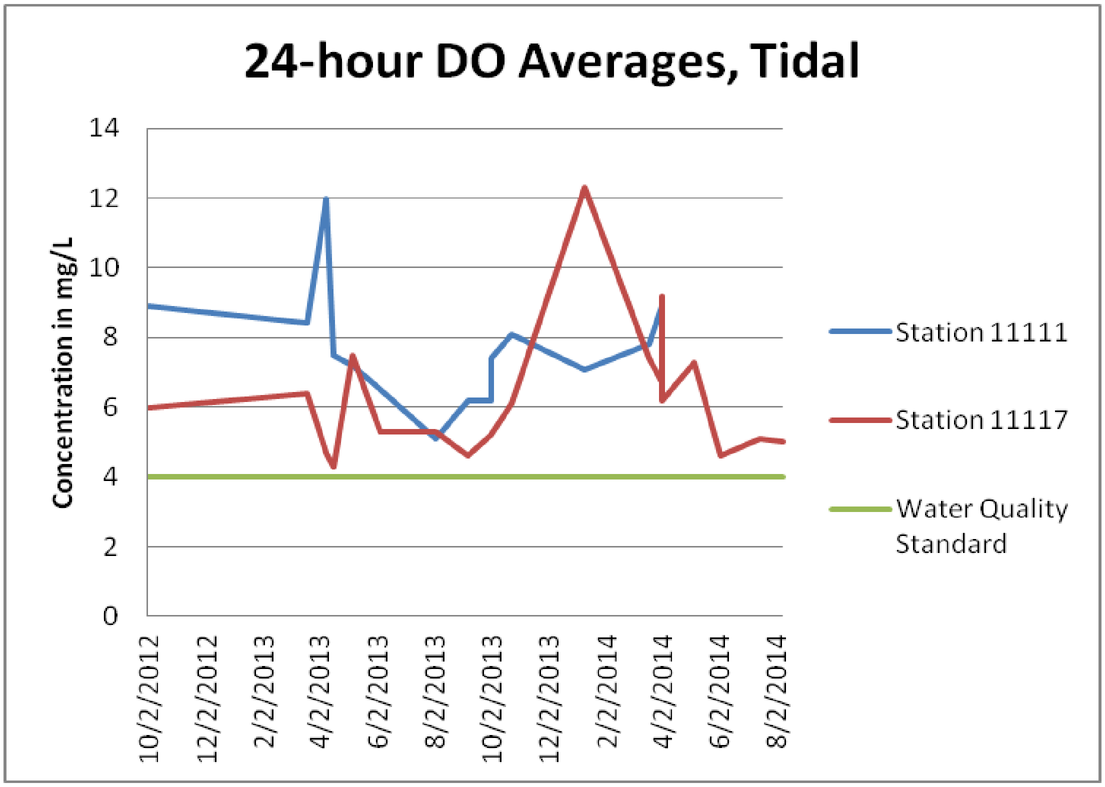
24 hour DO, 2012-2014

24-hour Means	Number of 24-hour Mean Values	Minimum 24-hour Mean Value	Maximum 24-hour Mean Value	Mean 24-hour Mean Value	Number of Exceedances
Tidal	36	4.3	12.3	6.8	0
Above Tidal	43	0.2	14.7	5.9	13

24-hour Minimums	Number of 24-hour Minimum Values	Minimum of 24-hour Minimum Values	Maximum 24-hour Minimum Value	Mean 24-hour Minimum Value	Number of Exceedances
Tidal	36	5.4	16.2	8.3	0
Above Tidal	43	0.9	17.8	7.7	1

Table 15 – Above Tidal 24-hour Average Exceedances, by Station

Station	Exceedances
11123	9
11120	4
11118	0



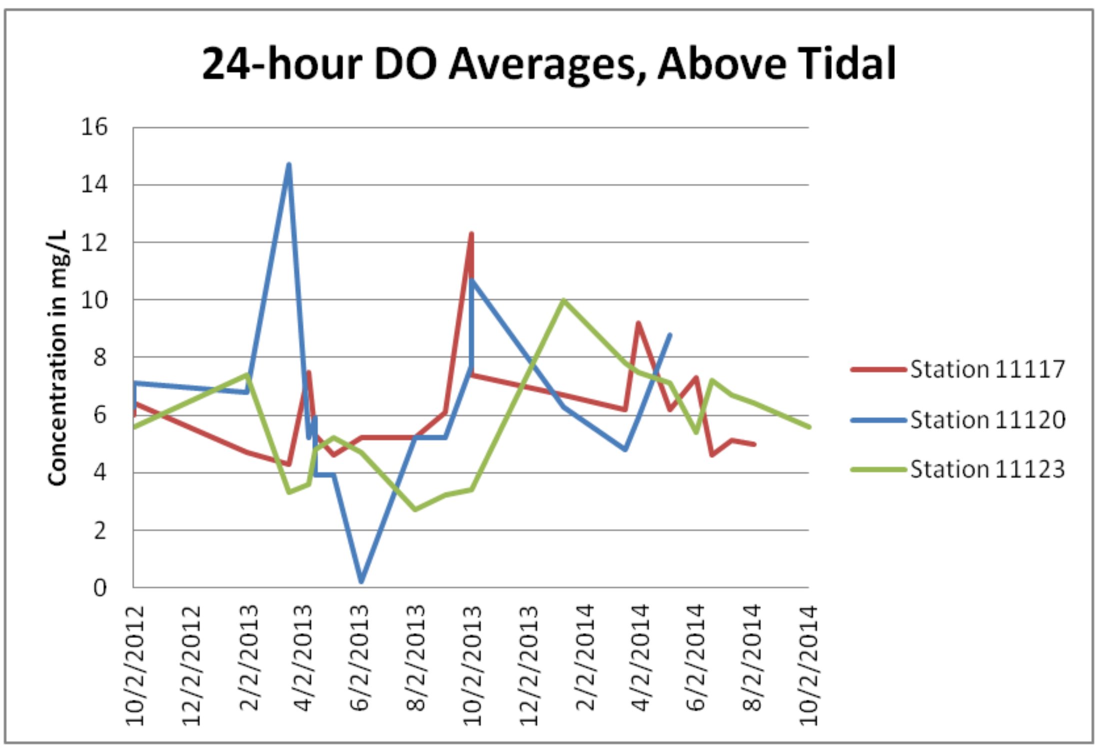


Figure 97 – 24-hour DO average values

Biological Monitoring

Prior to the 2012 IR, the Above Tidal segment had exhibited issues with supporting its aquatic communities. Previous data had suggested that the density and speciation of the macrobenthic communities was not sufficient to meet the segment's High Aquatic Use designation. When the project initiated in 2010, the data no longer indicated an impairment, but macrobenthic communities were still listed as a concern in the 2010 IR. During the project period, biological sampling was conducted twice a year for two years at station 11118 and 11120 to evaluate the current conditions of the monitoring. The results indicated that the Above Tidal segment was fully supporting its High Aquatic Use designation for both years, and in differing seasonal conditions. For both sites, and for both years, sampling was done once during the index period, and once during the critical period. In 2013 there was some potential issue with benthic macroinvertebrates being at the border of intermediate and high uses. However, in all cases, both stations were fully supporting. Reflecting this, the 2012 and 2014 IRs indicate no further impairment or concern (currently) for the Above Tidal segment. Table 16 summarizes the findings and comments for the biological monitoring effort.

Table 16 – Biological monitoring results summary

Biological Monitoring Results, 2013-2014		
Station 11118	**Supports High Aquatic Life Use?**	**Comments**
2013	Yes	Benthic macroinvertebrate results may approach intermediate use designation in the Critical period, but fully support the High use in the index period.
2014	Yes	None
Station 11120	**Supports High Aquatic Life Use?**	**Comments**
2013	Yes	Benthic macroinvertebrate and physical habitat parameters bordered on intermediate use designation in the Critical period, but fully support the High use in the index period.
2014	Yes	None

WWTF Effluent and SSO Analysis

As a potential source of human fecal bacteria, WWTFs and sanitary sewer collection systems are an important aspect of identifying and evaluating sources of water quality impacts. While well-maintained systems are often very effective at keeping bacteria out of waterways, even the best-run system will from time to time experience equipment malfunctions, broken infrastructure, or human error. WWTFs are required to report to the TCEQ on a regular basis regarding their effluent's compliance with permit limitations, and as to the occurrence of any SSOs.

TCEQ data for reported SSO and discharge monitoring reports (DMRs) were evaluated for a five year period (2009-2014) for all WWTFs in the watershed (Table 17). The SSO data indicated that approximately 3.8 million gallons of sewer overflow occurred in the five year period, with all but 6,000 gallons occurring in the Tidal segment. Five facilities reported SSOs: four in the Tidal, and one in the Above Tidal. However, 98% of the volume reported was from a single permit holder[72]. The primary reported cause of SSOs is excess rainfall, although equipment malfunction and line failure/blockages also contributed (see Figure 98). [73]

Table 17 – SSOs, 2009-2014

Number of permits with SSOs	**5**	
Tidal		*4*
Above Tidal		*1*

Segment/Permit	Number of SSOs	Total Volume (gallons)	Average Volume per SSO (gallons)
Tidal	**260**	**3,793,360**	**14,590**
City of Baytown (WQ0010395007)	*246*	*3,747,710*	*15,235*
Cedar Bayou Park UD (WQ0011713001)	*8*	*32,750*	*4,094*
Tower Terrace Plant (WQ0012478001)	*1*	*2,100*	*2,100*
Chambers CID #1 (WQ0014661001)	*5*	*10,800*	*2,160*
Above Tidal	**19**	**6,002**	**316**
City of Houston Cedar Bayou WWTP (WQ0010495112)	*19*	*6,002*	*316*
5-year Totals	**298**	**3,805,364**	**12,770**

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[72] The collection system for the City of Baytown's East Plant. It should be noted that these are 5-year totals. Based on the last three years of data, this permit has reported successively fewer SSOs, and is currently participating in the TCEQ's Sanitary Sewer Overflow Initiative (SSOI).

[73] The cause data is based on self-reported information from the permit holders. Actual causes may involve one or more factors (e.g. an SSO attributed to rainfall may also be due to inflow and infiltration issues in collection lines, or a lift station malfunction may be due to grease blockage).

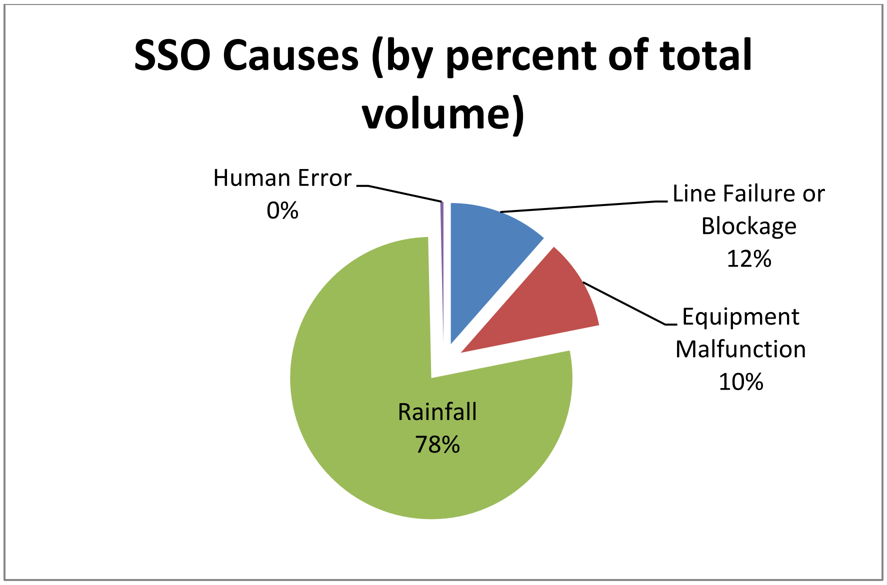

Figure 98 – SSO causes by percent of total volume

The DMR data was also evaluated for a seven year period. Twenty-nine facilities had DMR data on file with TCEQ, though only 11 had one or more forms of bacteriological data. However, these 11 plants represent the vast majority of the permitted flow. The bacteria data availability for these 11 facilities is shown in Table 18.

The primary concern in the review of the WWTF effluent data was the compliance with bacteria limits. Of specific interest were the City of Baytown's East and Northeast Plant in the Tidal segment, and the City of Houston and Chevron Phillips plants in the Above Tidal. These four plants, permitted for six, four, five, and four MGD respectively, make up over 90% of the permitted flow for facilities with bacteria data. In general, the data indicated that these four facilities were routinely meeting their limits. Of the other seven plants, two had data indicating failure to meet applicable limits based on both average and maximum values, while three others had maximum values in excess of the applicable limits. In general, this suggests that the WWTFs of the watershed in general are meeting their limits, although a few small facilities may have chronic issues to be addressed. The characterization of the bacteriological data is shown in Table 17. Values in red are in excess of applicable permit limits.

Table 18 – DMR bacteria data, 2007-2014

WWTF Name	Permit Number	Primary Flow Type	Bacteria Sampling Observations (number of samples/constituent sampled)	Average / Max Bacteria Values	Permitted Volume (MGD)
City of Baytown East Plant	TX0020117	Domestic	44 - Enterococci	4.60 / 31	6
Cedar Bayou Park UD	TX0068438	Domestic	7 - E. coli	353.86 / 2419	0.1
Luce Bayou PUD	TX0074870	Domestic	13 - E. coli	0.96 / 2	0.225
Monarch Utilities I , L.P.	TX0102091	Domestic	32 - E. coli 2 - Enterococci 18 - Fecal Coliform	130.88 / 2419.6 72.96 / 130.88 6.8 / 17	0.125
City of Houston	TX0103667	Domestic	23 - E. coli	7.48 / 120	5
Chemicals Incorporated	TX0118427	Industrial	31 - E. coli 10 - Fecal Coliform	39.92 / 649 4.4 / 20	0.2
City of Baytown Northeast	TX0126543	Domestic	6 - Enterococci	12.67 / 52	4
Chambers County ID 1	TX0128325	Domestic	19 - E. coli	3.24 / 13	0.24
Chevron Phillips Chem. Co. 5	TX0003948	Industrial	53 - Fecal Coliform	11.77 / 130	4
JSA Steel (USA) Inc.	TX0007706	Industrial	9 - Fecal Coliform	12.79 / 46.65	0.6
FCC Environmental	TX0126471	Industrial	8 - Fecal Coliform	51.28 / 375.16	0.1

Storm Flow Sampling

Ambient data tends to be skewed toward more average conditions, as sampling rarely occurs during a large storm event. However, the first flush of water from large storm events can carry high concentrations of bacteria and other contaminants of concern. During the project, two automatic sampling stations were installed to monitor the quality of stormwater flows in storms in which at least an inch of rain falls after a 72-hour antecedent dry period. The Tidal station was established on Carey Bayou, near the existing ambient monitoring station 21079. This station was chosen as it is representative of a storm flow tributary to the bayou that drains urban and suburban areas. The Above Tidal station was established at the northernmost existing ambient station. This station was chosen to represent the rural/agricultural and undeveloped land uses of the northern part of the watershed.

During 2014, five successful samples were collected from the Tidal station. Due to repeated vandalism, the northern station did not produce any usable samples[74].

The data from the southern sampler showed a divergent trend between nutrients and bacteria. Bacteria results were uniformly above the standard for both *E. coli* and Enterococcus, as high as several orders of magnitude for each constituent. While a general seasonal change can be observed in Figure 99, the sample set is too small to define this as a trend. Regardless, it can be observed that tributary conditions in developed areas can have high levels during storm events. Nutrients, however, had mixed results. Ammonia, total phosphorus and nitrate+nitrite levels were generally in the same or lower concentrations than ambient data. TKN, however, was elevated compared to ambient levels. TSS was also elevated, as would be expected in runoff events. The data from the five samples is summarized in Table 19.

Table 19 – Automated storm flow monitoring summary

Constituent	Unit	Standard/Screening Criteria	Max	Min	Mean	Geomean
Ammonia	mg/L	0.46 mg/L	0.60	0.10	0.29	*N/A*
E. coli	mpn/100ml	126 MPN/100mL	36,540	687	13,419	6,526
Enterococcus	mpn/100ml	35 MPN/100mL	46,110	218	23,783	10,732
Nitrate+Nitrite	mg/L	1.10 mg/L	0.30	0.02	0.11	*N/A*
TKN	mg/L	*N/A*	2.70	1.20	1.98	*N/A*
Total Phosphorus	mg/L	0.66 mg/L	0.61	0.22	0.42	*N/A*
TSS	mg/L	*N/A*	158.00	29.00	93.74	*N/A*

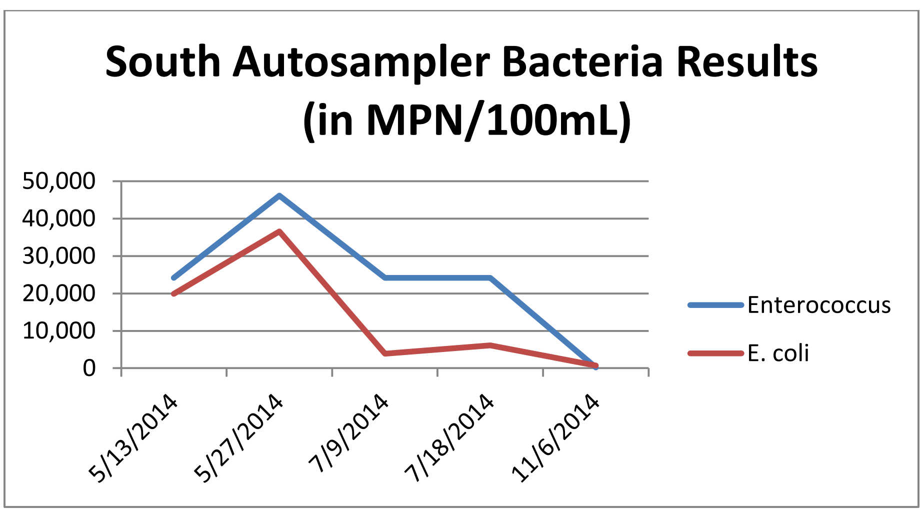

Figure 99 – South autosampler bacteria results

[74] The north sampler will continue to be operated during 2015.

WATER QUALITY SUMMARY

The results of the two-year monitoring effort reflect the changing conditions of the watershed and emphasize the importance of the Partnership's water quality goals. Bacteria continues to be a prominent impairment, especially in storm flow conditions in developed areas. Dissolved oxygen promises to be a more prominent issue, especially in the Above Tidal segment unless there is intervention in current trends. While SSOs may represent more of an acute, rather than chronic issue, the data indicates they remain an item to be addressed.

On the positive side, aquatic communities in the Above Tidal segment have rebounded from previous impairments and WWTFs are generally meeting their effluent permit limits.

Figure 100 – Monitoring site 11118

WATERSHED MODELING

The stakeholders rank bacteria as the primary pollutant of interest in the Water Quality Goals they adopted (see Section 2). The results of the bacteria source identification efforts (Section 4) indicated that there were multiple sources in the Cedar Bayou watershed, and that they represented a substantial overall contribution. Similarly, the results of the water quality analyses in this chapter indicated that bacteria remains an issue for the Tidal segment, and may present a future issue for the Above Tidal segment.

This WPP contains a selection of voluntary solutions designed to address that bacterial contamination, based on the sources identified. To guide the stakeholders' decisions on the necessary scale of the solutions, watershed models were employed to determine the relationship between the load produced by sources in the watershed and the impact it has on water quality. Due to differences in their character, a different model was used for each segment. The Soil and Water Assessment Tool (SWAT) was used for the Above Tidal Segment, and the Storm Water Management Model, version 5 (SWMM5) was used in the Tidal segment. The models establish the needed source load reductions based on this relationship. These needed reductions are then used to develop a scale for each set of solutions[75].

ABOVE TIDAL MODELING (SWAT)

SWAT was developed by AgriLife Research and the USDA Agricultural Research Service (USDA-ARS). The model is "a small watershed to river basin-scale model (used) to simulate the quality and quantity of surface and ground water and predict the environmental impact of land use…SWAT is widely used in assessing...non-point source pollution control and regional management in watersheds."[76] SWAT was used to model the processes that impact bacteria as they move from sources across the landscape into the waterways of the Above Tidal segment.

Data on bacteria sources and observed values were combined with environmental data on elevation, rainfall, and many other factors, to develop a working simulation of the Above Tidal watershed. The simulation was then run in five year increments from 2015 through 2040, with 2025 designated as the target year for compliance[77].

The results of the SWAT modeling indicated that, although the Above Tidal watershed is not currently listed as having a bacterial impairment, current and future bacteria loads would require intervention to prevent a future listing and protect public health. The reductions needed vary from station to station,

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[75] The solutions themselves are described in Chapter 6. The method of scaling the solutions to the needed reductions is discussed later in this Section.

[76] http://swat.tamu.edu, as accessed on 3/9/2015.

[77] Results were generated for all subwatersheds for all time periods. However, to best mirror project needs for future compliance, emphasis was placed on the three monitoring stations at which long term monitoring will take place: 11123, 11120, and 11118. 11117 is also a long term monitoring station, but is used for the Tidal segment. It was included in this effort as an indicator of the Above Tidal watershed between 11118 and the segment boundary. Its reductions, however, will be included in the Tidal modeling results.

as the character of the watershed changes. Little reduction is needed in the upper part of the segment. However, as the waterway approaches the boundary with the Tidal segment, the reductions needed by 2025 generally increase.

The results summarized in Table 20 are cumulative, showing the impact of upstream areas (assuming no solutions are put into place).

Table 20 – SWAT modeling results

	21081				11123				11120			
	Instream Load[78]	Target Load[79]	Reduction Needed	Percent Reduction	Instream Load	Target Load	Reduction Needed	Percent Reduction	Instream Load	Target Load	Reduction Needed	Percent Reduction
2015	3.82E+11	3.70E+11	1.18E+10	3.08%	2.89E+11	4.84E+11	-1.94E+11	-67.12%	1.38E+12	1.12E+12	2.55E+11	18.52%
2020	3.81E+11	3.70E+11	1.03E+10	2.69%	2.90E+11	4.84E+11	-1.94E+11	-66.87%	1.40E+12	1.12E+12	2.76E+11	19.73%
2025	3.81E+11	3.70E+11	1.03E+10	2.69%	**2.90E+11**	**4.84E+11**	**-1.94E+11**	**-66.87%**	**1.41E+12**	**1.12E+12**	**2.87E+11**	**20.33%**
2030	3.81E+11	3.70E+11	1.03E+10	2.69%	2.94E+11	4.84E+11	-1.90E+11	-64.63%	1.42E+12	1.12E+12	2.93E+11	20.69%
2035	3.81E+11	3.70E+11	1.03E+10	2.69%	3.00E+11	4.84E+11	-1.83E+11	-61.07%	1.69E+12	1.12E+12	5.63E+11	33.38%
2040	3.81E+11	3.70E+11	1.03E+10	2.69%	3.04E+11	4.84E+11	-1.79E+11	-58.88%	2.71E+12	1.12E+12	1.59E+12	58.54%

	21080				11118				11117			
	Instream Load	Target Load	Reduction Needed	Percent Reduction	Instream Load	Target Load	Reduction Needed	Percent Reduction	Instream Load	Target Load	Reduction Needed	Percent Reduction
2015	5.75E+11	1.77E+11	3.99E+11	69.30%	4.43E+12	2.52E+12	1.91E+12	43.06%	9.54E+12	2.76E+12	6.78E+12	71.02%
2020	6.91E+11	1.77E+11	5.14E+11	74.42%	4.93E+12	2.52E+12	2.41E+12	48.84%	1.56E+13	2.76E+12	1.29E+13	82.31%
2025	1.02E+12	1.77E+11	8.41E+11	82.64%	**6.83E+12**	**2.52E+12**	**4.31E+12**	**63.08%**	1.96E+13	2.76E+12	1.68E+13	85.88%
2030	1.68E+12	1.77E+11	1.50E+12	89.49%	1.05E+13	2.52E+12	8.00E+12	76.03%	2.80E+13	2.76E+12	2.52E+13	90.13%
2035	2.75E+12	1.77E+11	2.58E+12	93.59%	1.67E+13	2.52E+12	1.41E+13	84.87%	2.82E+13	2.76E+12	2.54E+13	90.19%
2040	3.78E+12	1.77E+11	3.60E+12	95.32%	2.60E+13	2.52E+12	2.34E+13	90.28%	3.21E+13	2.76E+12	2.93E+13	91.39%

[78] Loads represent *E. coli* bacteria counts.

[79] Target load represents the instream load that corresponds to the 126 CFU/100mL standard.

To monitor compliance in the Above Tidal segment, three stations will continue to be sampled as part of TCEQ and H-GAC's Clean Rivers Program efforts. These stations are 11123 (end of subwatershed 2), 11120 (end of subwatershed 3), and 11118 (end of subwatershed 5, directly upstream of the Tidal boundary). The stakeholders chose to focus specifically on reductions needed to ensure compliance at these stations because they will be the future source of compliance data in the segment. Because no reduction is needed at station 11123[103], the focus of reductions was further narrowed to stations 11120 and 11118. The SWAT data was evaluated to predict a scenario in which reductions of loads upstream of 11120 brought it into compliance, and reductions in loads upstream of 11118, but downstream of 11120, brought it into compliance. Table 21 indicates the reductions needed in current conditions and in the 2025 target year to meet the standard for each of the long-term monitoring stations based on this scenario.

Table 21 – Reductions for Above Tidal long-term monitoring stations

Station	2015	2025
11123[80]	0.0%	0.0%
11120	18.5%	20.3%
11118	31.5%[81]	41.1%

[80] Reductions for 11123 in both Table 20 and Figure 104 are represented as 0. The actual modeled value is -67%, representing an ability of the waterway to assimilate additional pollutant. However, as the intent is to display reduction needs, and there is no need at this station, 0% is used.

[81] For the current year scenario, station 11118 meets the standard for nine months out of the year. However, during the three months it is not in compliance, an average 31.1% reduction is required. By 2025, however, the station requires reductions during most of the year. The 31.1% reduction is used as a conservative value here, to account for the highly variable conditions during the year which become less variable by 2025.

Tidal Modeling (SWMM5)

The Storm Water Management Model, version 5 (SWMM5) is "a dynamic hydrology-hydraulic water quality simulation model…used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas"[82]. SWMM5 was used to model the unique characteristics of the Tidal Segment, including the impact of tidal action, multiple outlets[83], and water withdrawals[84].

The SWMM5 model builds flow pathways that account for urban sheet flow, drainage channels and conveyances, water withdrawals by pumping, groundwater interaction, and waterway hydrology. Tidal action is calibrated using salinity values. Observed bacteria data is used to build the relationship between the model's land cover-based loading concentrations and actual instream conditions.

As with the Above Tidal modeling, SWMM5 modeled the reductions needed at each of the long-term monitoring stations at which compliance will be measured. Because the Tidal segment receives load from the Above Tidal segment, an assumption was made that the reductions would represent baseline conditions, not representative of reductions upstream. The stakeholders felt this should be acknowledged, as this is a conservative estimation. Therefore, all values represented here are reductions of source loads generated in the Tidal segment. Actual required reductions may be less, based on achievements in the Above Tidal segment. However, as the stakeholders had requested to evaluate each segment individually, this method was used. As part of the adaptive management processes, these reduction goals may be adjusted to reflect reductions achieved in the Above Tidal, if monitoring data suggests they are reducing the boundary condition concentrations in the Tidal segment. However, for the purpose of this WPP and to take into account the variability of tidal processes, the conservative assumption was used.

[82] http://www2.epa.gov/water-research/storm-water-management-model-swmm

[83] The Tidal portion of Cedar Bayou includes an additional inlet/outlet (the "cut") south of Roseland Park on the west shore of the bayou. The "cut" connects to the upper part of the Galveston Bay and was identified by the stakeholders as a source of concern regarding potential contamination from the Ship Channel and also the hydrologic impact thereof.

[84] The model accounts for water withdrawals from the NRG Cedar bayou generating facility, based on the last 10 years of pumping data. Because the pumping is shown to have an appreciable impact in the model, future changes in pumping may impact modeled results.

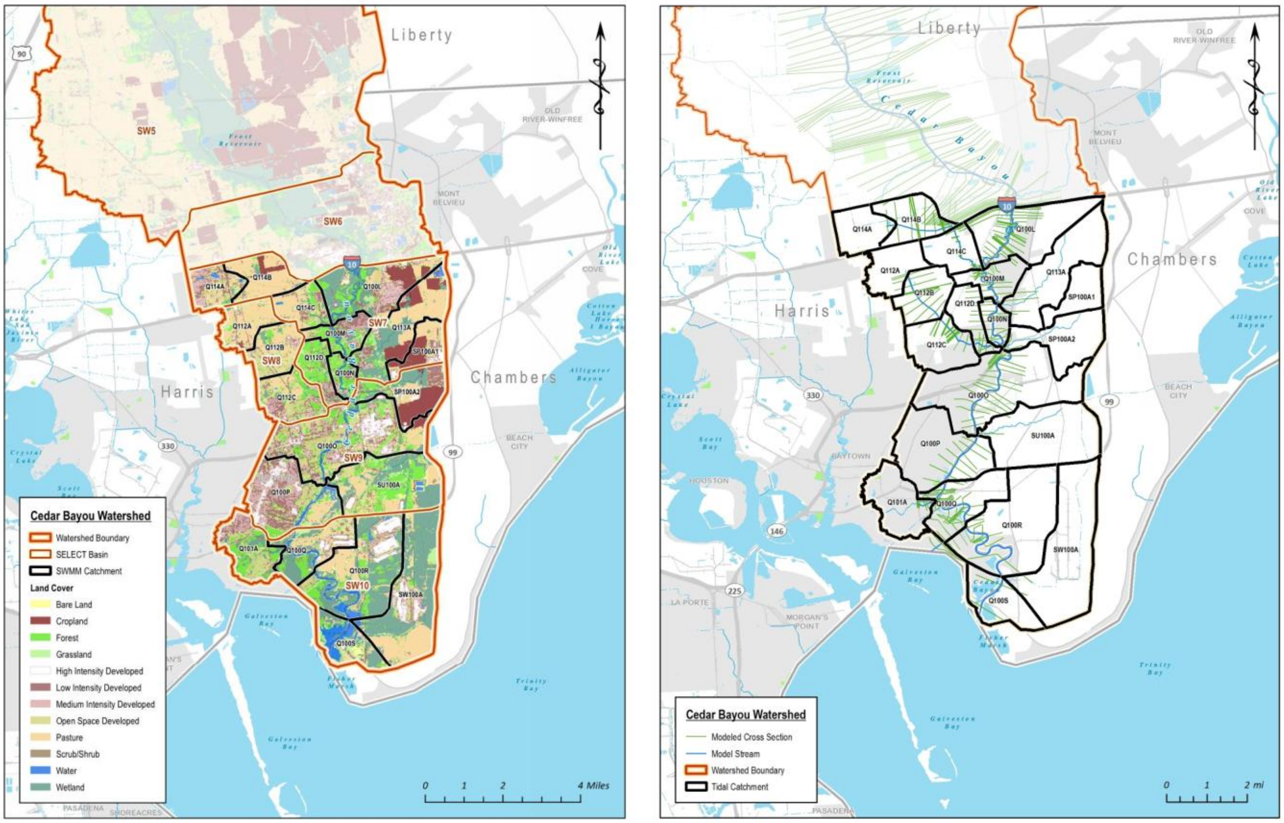


Figure 101 –Modeling the Tidal segment in SWMM5

The SWMM5 model broke the Tidal segment into many small subwatersheds (“catchments”). However, for the purpose of determining bacteria reduction needs, it specifically looked at the conglomeration of catchments upstream of each of the long-term monitoring stations (11111 and 11115)[85]. The model was calibrated to existing water quality monitoring data, including salinity as a conservative tracer. The impacts of the NRG Cedar Bayou generating station and the cut channel were also considered in this process, and found to be necessary to accurately predict flow and tidal processes. The potential impact of loadings from tidal flows entering the bayou was reflected in the boundary conditions. However, the concentration at the boundaries (other than that with the Above Tidal segment) was not found to be in excess of the standard.

Six scenarios were evaluated to identify reductions needed. These scenarios include two baseline conditions scenarios, which were generated, without any reductions applied, for both existing and future (2025) conditions. Alternative one was composed of two additional scenarios, in which all areas

[85] Station 11117 will also be monitored long-term. However, while this station is within the Tidal segment, an appreciable portion of its watershed lies in the Above Tidal segment, and was addressed in the SWAT modeling. For the purpose of this modeling effort, this station is considered part of boundary conditions, and the focus for compliance is based on 11111 and 11115.

in the segment met the standard at all times in current and future conditions. These two scenarios were considered the most conservative, as they represent a greater reduction than is needed to meet compliance. Alternative two was composed of the final two existing and future scenarios at which compliance was always met at the two target stations, 11115 and 11111. As these stations represent the areas of the watershed with among the higher loadings, the reductions required here are still sizeable to meet compliance.

The reductions required[86] for each of the target long term compliance stations are reflected in Table 22.

Table 22– Reductions for Tidal long-term monitoring stations

Station	2015	2025
11115	76%	77%
11111[87]	76%	77%

Figure 102 –Commercial traffic on Cedar Bayou Tidal

[86] The high level of reductions indicated for the Tidal segment is not wholly a reflection of the source load in the watershed itself. The modeling included the boundary conditions at the mouth and for the inflow from the cut channel south of Baytown. While these boundary conditions were not in excess of the standard, they do not leave much assimilative capacity for the waterway during high tide conditions.

[87] The modeled reductions needed to meet compliance at 11115 also brought station 11111 into compliance. For that reason, the reduction level is used for both stations.

Watershed Modeling Summary

The results of the watershed modeling efforts for the two segments indicate the likelihood that bacteria sources will continue to exceed Texas' WQS for contact recreation through the 2025 target year and beyond. While some sources (agricultural land uses, wildlife in undeveloped land uses) may decline in the modeled period, the overall load from all sources is expected to increase without intervention. The reductions generated are generally conservative values, especially in the Tidal segment where potential upstream Above Tidal reductions were purposefully not considered. Successfully addressing this water quality challenge will require the implementation of solutions scaled to equal the reductions identified in the models.

Target Reduction Goals and Scaling Bacteria Solutions

The watershed models established the overall bacterial reductions necessary to meet compliance. However, bacterial contamination in the Cedar Bayou Watershed results from a number of different sources in both segments. In watershed planning, the matching of solutions to needed reductions can be approached from several different perspectives. For example, a watershed may decide to meet its entire reduction need by addressing a single prominent source, or addressing all sources simultaneously, or addressing the sources in successive, phased approach over time. An endless combination of possible reduction scenarios exist.

For the Cedar Bayou watershed, the stakeholders chose to address all sources other than deer and other sources of wildlife unable to be quantified in the model, as discussed in Section 4. No feasible solutions existed within the scope of the voluntary efforts of the WPP (management of deer and other wildlife populations is handled by TPWD). Additionally, the model results indicated deer were a generally negligible source. Additionally, the stakeholders decided to pursue reductions from those sources proportional to the respective contributions from each source in 2025[88]. 2025 was chosen as the target year because it represents the timeframe the stakeholders felt was reasonable to plan activities for, and the period of time in which regional growth projections are most accurate.

A variety of solutions were identified and developed to address each source's required reductions (Section 6). To guide the scaling and implementation of the solutions selected by the stakeholders to meet the necessary reductions, representative, quantifiable units were developed for each source. The final results of this effort are: 1) defined reduction goals, by source, for the section of each segment related to each of the target long-term monitoring stations; and 2) an estimation of the number of

[88] i.e., the reduction from a given source would be proportionate to its contribution to the total load for that segment. Therefore, if source X accounted for 10% of the total 2025 load in the Tidal segment, solutions addressing source X will account for 10% of the needed reductions.

representative units for each source that need to be addressed to meet its portion of the reduction need.

Methodology

The methodology for determining the target reduction loads and scaling the bacteria solutions is based on four steps:

1) Identify needed bacteria (source) load reductions – *The source load reductions for the watershed segments were developed as part of the SWAT/SWMM5 watershed modeling efforts.*
2) Identify load reductions by source – *The proportion of the load reduction to be addressed through solutions was determined by each source's relative contribution to the overall 2025 load.*
3) Identify representative units for each source – *A representative unit was developed for each source, representing a quantifiable single unit load. For example, the representative unit for the source category "dogs" is a single dog*[89]*.*
4) Determine representative units to be addressed – *The number of units to be addressed by solutions is obtained by dividing the total reduction needed for that source (from Step 2) by the load per representative unit. To generate target reduction goals for this WPP, the stakeholders agreed to a methodology based on relative source contribution. The stakeholders chose to base their target reduction goals for each source on the relative contribution from that source.*

Target Reduction Goals

Steps one and two deal with the development of reduction amounts for each source within each section. The stakeholders decided to initially require reductions from each source according to its relative contribution to the total load in each section. The target reduction goals represent the daily bacteria load that needs to be addressed by each section, and is further defined by the portions that will come from each source. The target reduction goals are summarized in Tables 23 (Above Tidal station 11120), 24 (Above Tidal station 11118), and 25 (Tidal). It is important to note that the reduction goals for the Tidal segment do not assume that reductions were made in the Above Tidal. Improvements in the Above Tidal watershed load may reduce the scale of implementation needed in the Tidal segment.

[89] The load associated with each representative unit is established by the same literature values used in the source modeling. Appendix A gives the full detail of the derivation and use of these representative units.

Table 23 – Target reduction goals by source, Above Tidal segment above station 11120

Bacteria Source	Relative Contribution, Current	Required Reduction, Current	Relative Contribution, 2025	Required Reduction, 2025
OSSFs	58.4%	9.13×10^{11}	59.46%	1.07E+12
WWTFs	0.1%	1.06×10^{9}	0.07%	1.20E+09
Urban Runoff	5.1%	8.04×10^{10}	5.08%	9.13E+10
Dogs	12.3%	1.93×10^{11}	12.40%	2.23E+11
Cattle	17.03%	2.66×10^{11}	16.27%	2.92E+11
Deer	0.15%	2.39×10^{9}	0.15%	2.63E+09
Feral Hogs	1.52%	2.38×10^{10}	1.46%	2.62E+10
Horses	0.61%	9.49×10^{9}	0.58%	1.04E+10
Sheep/Goats	4.76%	4.50×10^{9}	4.54%	8.16E+10
Total	100%	1.56×10^{12}	100%	1.80E+12

Table 24 – Target reduction goals by source, Above Tidal segment above station 11118

Bacteria Source	Relative Contribution, Current	Required Reduction, Current	Relative Contribution, 2025	Required Reduction, 2025
OSSFs	55.92%	9.13×10^{11}	63.68%	4.37×10^{12}
WWTFs	0.28%	1.06×10^{9}	0.18%	1.21×10^{10}
Urban Runoff	10.25%	8.04×10^{10}	9.55%	6.56×10^{11}
Dogs	11.68%	1.93×10^{11}	14.20%	9.75×10^{11}
Cattle	16.31%	2.66×10^{11}	9.23%	6.34×10^{11}
Deer	0.03%	2.39×10^{9}	0.02%	1.27×10^{9}
Feral Hogs	1.52%	2.38×10^{10}	0.87%	5.99×10^{10}
Horses	0.12%	9.49×10^{9}	0.07%	4.75×10^{9}
Sheep/Goats	3.89%	4.50×10^{9}	2.20%	1.51×10^{11}
Total	100%	1.56×10^{12}	63.68%	6.86×10^{12}

Table 25 – Target reduction goals by source, Tidal segment

Bacteria Source	Relative Contribution, Current	Required Reduction, Current[90]	Relative Contribution, 2025	Required Reduction, 2025
OSSFs	22.57%	2.98E+12	37.82%	5.71E+12
WWTFs	1.15%	1.51E+11	0.84%	1.27E+11
Urban Runoff	30.20%	3.99E+12	22.74%	3.43E+12
Dogs	41.58%	5.50E+12	36.47%	5.50E+12
Cattle	2.86%	3.78E+11	1.34%	2.02E+11
Deer	0.02%	3.11E+09	0.01%	1.83E+09
Feral Hogs	0.53%	7.01E+10	0.27%	4.14E+10
Horses	0.03%	4.43E+09	0.02%	2.35E+09
Sheep/Goats	1.06%	1.41E+11	0.49%	7.46E+10
Total	100%	1.32E+13	100%	1.51E+13

[90] The Tidal modeling was conducted for the marine bacteria indicator species. The reduction amounts presented in Table 23 are given in number of *E. coli* based on the ratio of the applicable standards (126 *E. coli* per 35 Enterococcus), which equates to a 3.6X scaling factor for Enterococcus values.

Representative Units

Steps three and four of the scaling methodology (page 132) deal with identifying and implementing representative units as a tool for scaling of solutions to meet the target reduction goals for each source.

The scaling methodology is based on the established target reduction goals (Tables 23-25), with the understanding that actual reductions generated from each source may differ based on changes in modeled values and opportunities that arise.

The load for the representative units for each of the sources were derived from literature values, as described in greater detail in Appendix A. Target reduction goals by representative units are described in both total load to be reduced and also number of representative units to be addressed, as summarized in Tables 26 (Above Tidal station 11120), 27 (Above Tidal station 11118), and 28 (Tidal).

Table 26 – Target reduction goals by representative units, Above Tidal segment above station 11120

Bacteria Source	Required Reduction, 2025	Representative Unit	Load per Representative Unit[91]	Representative Units to be Addressed[92]
OSSFs	1.07E+12	One malfunctioning OSSF	1.99×10^{11}	6
WWTFs	1.20E+09	One million gallons of effluent[93]	9.54×10^{9}	0.1
Urban Runoff	9.13E+10	One acre of urban land cover / One SSO	4.57×10^{8} / 1.2×10^{11}	200
Dogs	2.23E+11	One dog	1.25×10^{9}	179
Cattle	2.92E+11	One acre of active grazing land	5.70×10^{8}	514
Deer	2.63E+09	One deer	6.25×10^{7}	N/A
Feral Hogs	2.62E+10	One feral hog	2.23×10^{9}	12
Horses	1.04E+10	One horse	1.05×10^{8}	100
Sheep/Goats	8.16E+10	One sheep or goat	4.50×10^{9}	19

[91] Loads in charts 25-27 are given in number of *E. coli.*

[92] In the event the number of representative units to be addressed was not a whole number (i.e. 5.4), it was rounded up, with the exception of WWTF effluent, which would make an appreciable change in scale based on the representative unit.

[93] This refers to effluent not meeting the standard, based on the unit derived in Appendix A

Table 27 – Target reduction goals by representative units, Above Tidal segment above station 11118

Bacteria Source	Required Reduction, 2025	Representative Unit	Load per Representative Unit	Representative Units to be Addressed
OSSFs	4.37×10^{12}	One malfunctioning OSSF	1.99×10^{11}	22
WWTFs	1.21×10^{10}	One million gallons of effluent	9.54×10^{9}	2
Urban Runoff	6.56×10^{11}	One acre of urban land cover / One SSO	4.57×10^{8} / 1.2×10^{11}	1,436
Dogs	9.75×10^{11}	One dog	1.25×10^{9}	780
Cattle	6.34×10^{11}	One acre of active grazing land	5.70×10^{8}	1,113
Deer	1.27×10^{9}	One deer	6.25×10^{7}	N/A
Feral Hogs	5.99×10^{10}	One feral hog	2.23×10^{9}	27
Horses	4.75×10^{9}	One horse	1.05×10^{8}	46
Sheep/Goats	1.51×10^{11}	One sheep or goat	4.50×10^{9}	34

Table 28 – Target reduction goals by representative units, Tidal segment

Bacteria Source	Required Reduction, 2025	Representative Unit	Load per Representative Unit	Representative Units to be Addressed
OSSFs	2.05E+13	One malfunctioning OSSF	1.99×10^{11}	104 (135)
WWTFs	4.57E+11	One million gallons of effluent	9.54×10^{9}	48
Urban Runoff	1.24E+13	One acre of urban land cover / One SSO	4.57×10^{8} / 1.2×10^{11}	27,030 / 1,392
Dogs	1.98E+13	One dog	1.25×10^{9}	15,852
Cattle	7.28E+11	One acre of active grazing land	3.42×10^{8}	2,128
Deer	6.57E+09	One deer	6.25×10^{7}	N/A
Feral Hogs	1.49E+11	One feral hog	2.23×10^{9}	67
Horses	8.46E+09	One horse	1.05×10^{8}	81
Sheep/Goats	2.69E+11	One sheep or goat	4.50×10^{9}	60

The last step in the process was to ensure there were enough representative units in the watershed segment to be addressed in 2025. Tables 29 and 30 indicate the results of the analysis While the Above Tidal goals were able to be met within the available units, the Tidal segment experienced an issue with addressing adequate volumes of WWTF effluent and urban runoff. The deficit does not take into account potential reductions in the Above Tidal, or the impact of the education and outreach campaign. However, to plan conservatively, the stakeholders recommended making up the deficit by adding an additional number of OSSFs to the bacteria reduction target equivalent to the deficit load (Table 31). Therefore, 32 additional OSSFs were added to the Tidal segment's OSSF target, as indicated in parentheses in Table 28.

Table 29 – Review of available representative units, Above Tidal segment

Source Category	Available Units	*Needed above 11120*	*Needed above 11118*	Needed total	Sufficient Units
Failing OSSFs	2931	*5*	*22*	27	yes
Contaminated WWTF effluent flow in MGD	>0.1	*0*	*0.1*	0.1	yes
Urban acres	7518	*200*	*1435*	1635	yes
Dogs	10893	*178*	*780*	958	yes
Grazing Acres	33,690	*513*	*1112*	1626	yes
Deer	257	*42*	*20*	62	yes
Feral Hogs	286	*12*	*27*	39	yes
Horses	837	*99*	*45*	144	yes
Sheep/Goats	576	*18*	*34*	52	yes

Table 30 – Review of available representative units, Tidal segment

Source Category	Available Units	Needed	Sufficient Units
Failing OSSFs	675	103	yes
Contaminated WWTF effluent flow in MGD	<1	48	no
Urban acres	10,651	20901	no
Dogs	20,716	15852	yes
Grazing Acres	7,608	2128	yes
Deer	131	105	yes
Feral Hogs	70	67	yes
Horses	137	81	yes
Sheep/Goats	102	60	yes

Table 31 – Tidal segment load balancing

Total need	**Load value**
47 MGD WWTF effluent	4.48E+11
10250 Urban acres	6.06E+12
Total	***6.51E+12***
Potential surplus	**Load value**
Additional 32 OSSFs	6.37E+12
Reductions upstream	(unquantified)
Total	***(>) 6.37E+12***

Bacteria Solution Scaling Summary

The determination of the target number of representative units to be addressed, based on the modeled bacteria reduction goals is applied to the description of each of the stakeholder-selected solutions described in Section 6. Based on the variable nature of a watershed in transition, and the uncertainty of funding sources, these goals may shift within the overall reduction need. A source may be addressed in greater proportion than its share of the loading if it is relatively advantageous to do so. The stakeholders established these goals with the understanding that adaptive management, unforeseen opportunities, and other unpredictable factors may require their adjustment later on. Towards that end, the representative units were developed to assist in quantifying the scale of solutions addressing each source, as applied to each solution in Section 6.

Section 6 – Solutions

6 – SOLUTIONS

SOLUTIONS FOR WATER QUALITY ISSUES

Sources of pollution are widespread in the watershed, and are projected to increase by 2025. Without intervention, water quality will continue to degrade in both segments of Cedar Bayou. However, a number of potential solutions[94] 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 4 quantified the sources that contribute to water quality impairments, and Section 5 identified the bacteria reductions needed to meet the stakeholders' water quality goals. This Section will detail the voluntary solutions identified and prioritized by the stakeholders, and discuss the financial and technical resources needed to implement them. Section 7 will detail the timeline and milestones associated with implementation.

Figure 103 –A focus on local solutions

[94] 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. For the purpose of this WPP we refer to these efforts generally as "solutions". The stakeholders generally put an emphasis on outreach that avoided jargon and terms of art such as these.

Identifying Solutions

Stakeholder Goals for Selection

As indicated in Section 3, the stakeholders decided to highlight four principles in selecting and implementing solutions. They wanted decisions made at the local level; solutions to be voluntary, cost-effective, and to utilize existing resources and programs to the greatest extent possible; and they wanted to emphasize adapting their selections in the future as necessary to retain or increase effectiveness. These goals shaped the discussion of potential solutions and the ultimate selection and prioritization processes.

Identifying Potential Solutions

Stakeholders reviewed a wide range of potential solutions, starting with those identified in existing projects[95] and ongoing local efforts[96]. In addition to these recommendations, stakeholders had several opportunities to brainstorm on potential new efforts and devise or refine watershed-specific projects. The Work Groups collaborated with project staff to conduct the initial evaluation of potential solutions. The recommendations of the work groups were brought to the Partnership as a whole for comment and approval.

Because Cedar Bayou watershed has multiple categories of sources that contribute to fecal bacteria contamination, the stakeholders considered an array of solutions broad enough to address each source[97]. The end result of this process was a draft list of potential solutions, and an understanding of the intent to use adaptive management to add or remove solutions based on efficacy, funding levels, or changing conditions.

Solution Prioritization

After solutions were identified by the stakeholders, the work groups considered the priority of solutions within each bacteria source category. Specific consideration was given to the feasibility of the solution, the likely effectiveness of the solution, the resources needs of the solution, and the likelihood that the community would support the solution. This process relied heavily on feedback from watershed partners and local knowledge.

[95] Including previous WPPs and TMDL I-Plans conducted in other watersheds.
[96] Including planned or potential activities of local partners like the Galveston Bay Foundation, City of Baytown, et al.
[97] With the exception of deer, migratory birds, and other wildlife for which no feasible solutions were amenable to the stakeholders.

The Work Groups identified three tiers of projects:

- Tier one projects were the most desirable, or those already planned or being implemented.
- Tier two projects were those that were less desirable, but still worth pursuing if opportunities arose, funding sources changed, or due to adaptive management.
- Tier three projects were those projects that the stakeholders deemed low priority, unfeasible, undesirable, or unlike to be effective.

The work groups' recommended priorities were compiled and brought to the Partnership for review and comment. The Partnership made some adjustments to the priorities, but generally concurred with the work groups. The second and third tier solutions are summarized in Appendix B as potential solutions for future consideration. The solutions ranked as Tier one priorities were grouped by the source of pollution they addressed, with consideration of the resources[98], participants[99], and logistics needed to implement them. 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.

Figure 104 –Managing pet waste at the Baytown Dog Park

[98] Costs are given in current dollars.
[99] Throughout the Solutions sections, references to H-GAC as a participant should be considered to mean H-GAC in its role as facilitator of the WPP effort, or its successor if the role passes to another entity in the future. The exceptions are for those efforts like the H-GAC OSSF SEP that are specific to H-GAC itself.

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 for each source.

ON-SITE SEWAGE FACILITIES (OSSFS)

OSSFs make up an appreciable portion of the bacteria loading in each segment, and are therefore a priority source. The load reduction goals established in Section 5 require 28 failing OSSFs to be addressed in the Above Tidal segment, and 104 in the Tidal segment, to help meet water quality goals by 2025. 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.

The solutions identified by the stakeholders to address failing OSSFs are summarized as follows.

Figure 105 –Sewage from failed septic tank[101]

[100] The period represented herein for each solution is the timeframe within the initial 10-year implementation window. Many solutions will likely continue to be implemented as ongoing efforts or as needed to maintain water quality after that point.

[101] Image courtesy of http://www.conasaugariver.org

OSSF 1 - Identify OSSF locations

Purpose: Provide information to locate and prioritize failing systems for remediation

Description: As part of a grant project with TCEQ, H-GAC maintains and updates a regional database of OSSF locations for permitted systems, and assumed locations for unpermitted systems. Local authorized agents provide locations of new systems through H-GAC supplied GPS units. H-GAC and the authorized agents will continue to compile this information, and H-GAC will use it to identify areas where failing systems may be prominent.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; authorized agents	2015-2025	Bacteria, Nutrients (indirectly)	Existing, ongoing effort.

Technical and Financial Resources Needed	Estimated Costs and Funding
This is an ongoing effort as part of a CWA §604(b) grant with TCEQ, and efforts from the authorized agents. The resources involved are limited to: • A small portion of the staff time spent by H-GAC on the regional project, and; • Staff time incurred by the local authorized agents in acquiring and transmitting GPS data for new systems.	H-GAC/TCEQ • $800 per year, $8000 total. • Existing §604(b) funding. Authorized agents • $600 per year, $6,000 total • Existing salaries/ revenues.

Bacteria Reduction Capability

This solution is not expected to generate bacteria reductions directly. It provides information to facilitate remediation of failing OSSFs, through which reductions are generated.

OSSF 2 - Remediate Failing OSSFs

Purpose: Reduce bacteria and nutrient contributions from failing OSSFs.

Description: H-GAC will work with local authorized agents and OSSF owners to remediate failing systems through 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. In the City of Baytown, OSSF owners in annexed areas will be required to connect to sanitary sewer within two years of annexation. In remediation efforts, priority will be given to failing systems in close proximity to the waterway.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; authorized agents; homeowners	2015-2025	Bacteria, Nutrients	Expansion of existing efforts (e.g. H-GAC OSSF SEP, residential maintenance)

Technical and Financial Resources Needed

The remediation of failing OSSFs will require information regarding OSSF locations and likely failing systems. Data on locations will come from H-GAC's regional database local authorized agents, who will also provide violation information as appropriate. Actual remediation conducted by H-GAC or the authorized agents will be conducted through a contractor. Connection to sanitary sewer in annexed areas of Baytown will be undertaken by the residents' contractors.

Financial resources required include H-GAC staff time to manage remediation contracts and funding for the remediation. The funding sources identified are CWA §319(h) grants; H-GAC OSSF SEP (for remediation); authorized agent internal funding; and homeowner contributions.

Estimated Costs

Estimated costs

- Average cost of $7,000 to repair, replace, or abandon and connect to sanitary.
- Total cost of $1,148,000 for 164 systems.

Bacteria Reduction Capability

Remediating or abandoning 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 2025.

OSSF 3 – OSSF Education

Purpose: Increase awareness of OSSF maintenance with residents and increase chance of identifying failing OSSFs at point of sale in real estate transactions.

Description: H-GAC will work with local authorized agents and AgriLife Extension to provide education and outreach seminars for residents and real estate inspectors using established education programs (A&M - residential OSSF education; H-GAC real estate inspector training). The seminars will be held at least twice each in the initial 10-year implementation phase.

The homeowner education provided by AgriLife Extension teaches homeowners the basics of OSSF ownership and maintenance. The H-GAC real estate inspector course, accredited through the Texas Real Estate Commission, provides inspectors with training to identify failing systems during home inspections.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; authorized agents; AgriLife Extension	2015-2025	Bacteria, Nutrients	Expansion of existing efforts

Technical and Financial Resources Needed	Estimated Costs
The educational seminars are existing programs. No additional development is required. Financial resources are limited to staff time for the respective agencies, travel, and program materials. Identified funding sources include CWA §319(h grants for H-GAC and AgriLife Extension, and internal funding for the authorized agents.	Estimated costs • Average of $600 per seminar in travel, materials, and staff time • Total cost of $2,400 for 4 seminars.

Bacteria Reduction Capability

This activity does not directly reduce bacteria, but contributes to a comprehensive education and outreach program.

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

WWTFs in the watershed are generally able to meet their bacteria limits, although some exceedances occur from time to time. The primary issue with sanitary sewer systems, especially in the Tidal segment, is SSOs in the collection system.

The aim of the efforts addressing SSOs is to remediate existing collection system issues, prevent future issues, and educate the public on actions they can take to help prevent SSOs. Based on established roles in dealing with SSOs, the infrastructure work will largely fall to the local utilities, primarily the City of Baytown. During the development of this project, many of the recommendations, including Baytown's participation in the TCEQ's Sanitary Sewer Overflow Initiative (SSOI) started to be implemented. The solutions identified by the stakeholders to address SSOs are summarized as follows.

WWTF/SSO 1 – Participate in the SSOI

Purpose: To increase focus and resources expended by utilities to reduce SSOs.

Description: The TCEQ's SSOI program allows publically owned wastewater utilities to avoid penalties associated with SSOs (under certain circumstances). The intent is to focus funds that may have been spent on penalties on improvements to reduce SSOs. The utility completes a signed agreement/plan with TCEQ which stipulates how they will meet the defined SSO reduction goals. More information about the SSOI can be found on TCEQ's website at https://www.tceq.texas.gov/field/ssoinitiative.

Responsible Parties	Period	Contaminant Addressed	Status
City of Baytown; other public utilities; TCEQ	2013-2023[102]	Bacteria, Nutrients	Existing effort; potential to expand

Technical and Financial Resources Needed	Estimated Costs
The primary target for participation in the SSOI is the City of Baytown, who accounts for the majority of SSOs in the watershed. Baytown entered into the SSOI in 2013. It is expected at least one more utility will join the SSOI by 2025. The City uses existing staff resources and contractors as appropriate. No additional technical resources are needed. Financial resources for addressing the Baytown SSOs come directly from the City's funds.	Estimated costs • Average of $6,000 per year for the first year, and $3,000 a year after that. • Total cost of $33,000 for the 10 year period.

Bacteria Reduction Capability
This activity does not directly reduce bacteria, but facilitates other activities (including remediation of collection systems).

[102] The City of Baytown's SSOI agreement was completed in 2013 for a 10 year period.

WWTF/SSO 2 – Reduce Collection System SSOs

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

Description: The City of Baytown, as part of their SSOI participation, has pledged to conduct a series of activities between 2013 and 2023 to reduce SSOs, including: preventative maintenance, infrastructure inspections, rehabilitation, infrastructure upgrades, ensuring adequate backup power infrastructure for lift stations, and education. The City also conducts a private sewer line inspection program to ensure resident's connections to the public system are sound. Work has already been implemented on many of these activities.

Responsible Parties	Period	Contaminant Addressed	Status
City of Baytown; other public utilities; residents	2013-2023[103]	Bacteria, Nutrients	Existing effort

Technical and Financial Resources Needed

The primary current responsibility for remediating SSOs lies with the City of Baytown, who is already addressing the problem in the framework of their SSOI participation. The City uses existing staff resources and contractors as appropriate. No additional technical resources are needed.

Financial resources for remediating SSOs are borne by the City of Baytown, and other utilities or WWTFs directly. 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

City of Baytown

- Approximately $1,000,000 on SSO rehabilitation per year.
- $10,000,000 in total.
- Costs may vary based on what portion of the system is addressed within the watershed.

Residential

- Average of $4,000 for connection line replacement/major repair.

Bacteria Reduction Capability

This activity is expected to reduce SSO activity at chronic locations dramatically. However, the City's infrastructure is aging and the stresses of new growth may have unanticipated future impacts.

[103] The City of Baytown's SSOI agreement was completed in 2013 for a 10 year period.

WWTF/SSO 3 – Reduce Fats, Oils and Grease

Purpose: To reduce fats, oils, and grease (FOG) related SSOs.

Description: FOG can be a major factor in SSOs, leading to clogged lines and damaged infrastructure. Education and outreach, in combination with grease trap inspection programs, in urban areas, are the primary tools for addressing FOG issues. This solution includes a multi-faceted FOG education program, through H-GAC, the Galveston Bay Foundation (GBF), Harris County, and the City of Baytown. The efforts will be coordinated as appropriate. The education programs are a mix of social media, direct contact with stakeholders, printed and electronic materials, and grease collection sites. In addition, the City of Baytown has instituted a grease trap inspection program, as noted in their SSOI, to reduce grease contributions from commercial establishments.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; City of Baytown; GBF; grease trap permittees.	2015-2025	Bacteria, Nutrients	Existing and expanded efforts

Technical and Financial Resources Needed	Estimated Costs
FOG programs and related materials already exist, as promoted by H-GAC and GBF (More information about the “Cease the Grease” can be seen at GBF’s website, http://galvbay.org/ceasethegrease/). The City of Baytown has agreed to participate in FOG education as part of its SSOI agreement. No additional program development is needed, although additional elements may be developed. Baytown’s grease trap inspection program is likewise already in effect. Financial resources for conducting education and outreach covers staff time and materials produced by the various agencies. Sources of funding are primarily General Land Office and 319(h) grants at present, with an expectation of a mix of Clean Water Act grant program funding and private funding through GBF and potential future donors (e.g. The Houston Endowment, etc.) Resources for grease trap inspection are funded by the City of Baytown and grease trap permittees.	FOG Education[104] • $60,000 for project development (currently acquired) • $10,000 a year (GBF); $5,000 (H-GAC and Baytown) for ongoing education • $160,000 total. Grease Trap Inspection • Costs for grease trap inspection in Baytown are routine costs for the City and permittees, not costs specific to this project.

Bacteria Reduction Capability

This activity is expected to have an indirect impact on bacteria reduction, by raising awareness and oversight on FOG contributions to SSOs. It is expected to contribute to the comprehensive education/outreach campaign for this WPP implementation. However, grease trap inspections may have a more direct impact that is unable to be adequately quantified.

[104] The costs here represent regional costs, not costs specific to the watershed. These include a $55,752 grant from GLO to GBF in 2015, and estimates of H-GAC staff time. Ongoing costs are an estimate of staff time and related activities and materials for GBF/H-GAC/City of Baytown.

Urban Runoff

Stormwater flows from urban areas can contribute greatly to contamination in Cedar Bayou. The solutions identified by the stakeholders are intended to address one or more of the combined impacts of SSOs (addressed in the previous section), feral domestic animals, urban wildlife and other non-domestic animals, construction, and other human sources that contribute to urban stormwater.

Figure 106 –Stormwater drain with marker

The primary means for addressing these sources in most of the urban areas of the watershed are the existing or new Municipal Separate Storm Sewer System (MS4) permits through the Texas Commission on Environmental Quality's General Permit (TXR040000). The new permits address bacteria in impaired waterways, and the Storm Water Management Plans (SWMPs) for each entity must address ways to assess bacterial sources in their storm water and delineate a program to address them[105]. While the efforts of this WPP will not be directed to meet these regulatory requirements for watershed permittees[106], the MS4s' activities are likely to impact bacteria and nutrient levels in Cedar Bayou, especially in the Tidal segment. As many of these MS4 bacteria elements are not yet implemented, the potential impact is not currently able to be quantified.

In addition to MS4 permit activities, the stakeholders recommended several additional solutions, including promoting low impact development (LID) in new and redeveloped areas, limiting impacts of development in riparian areas, education and outreach about FOG and residential lawn maintenance, and spay/neuter programs to reduce feral pet populations.

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

[106] No funding other than that of 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 Runoff 1 – Implement MS4 Permit Requirements

Purpose: To reduce contamination from MS4 areas

Description: There are three MS4 permittees in the Tidal segment: City of Baytown; Chambers County; and the Joint Task Force (representing Harris County, City of Houston, Harris County Flood Control District, and TXDOT). The Chambers County permit also covers an area in the lower Above Tidal segment. The permittees are bound to meet a series of minimum control measures that include identifying bacteria sources, and devising best practices to address them. In addition, the permits require a broad range of activities to address sources of other contaminants of concern, such as sediment and nutrients.

Responsible Parties	Period	Contaminant Addressed	Status
City of Baytown; Joint Task Force; Chambers County	2015-2025	Bacteria, Nutrients, Sediment	Existing and expanded efforts

Technical and Financial Resources Needed	Estimated Costs
Technical and financial resources related to this solution are specific to the components of each entity's SWMP. Because this is a permit-driven process, the costs associated with the permit implementation are borne by the permittees.	Costs of the MS4 permit activities are outside the scope of this WPP. Because the new permits have not been fully implemented, and cover areas in excess of the watershed, the costs for the watershed area cannot be accurately quantified. They are, however, likely significant contributions given the large watershed populations they address.

Bacteria Reduction Capability

This activity is the summation of several programs with multiple elements impacting bacteria. No comprehensive data exists on the number and type of elements actively implemented, or their impact on contaminants. It is expected that these MS4 activities will have an appreciable impact on sources within urban areas. The City of Baytown alone will spend approximately $1.37 million dollars in implementing its SWMP in 2015. However, until activities begin to be fully implemented and evaluated, the sum impact of the permits is not able to be quantified.

Urban Runoff 2 – Promote Low impact Development and Protect Riparian Areas

Purpose: To reduce contamination from stormwater flows through on-site mitigation and reducing sheet flow in urban riparian areas.

Description: This solution has two separate aspects: promoting low impact development in new and redeveloped areas (above and beyond existing mitigation/detention requirements); and maintaining a Watershed Protection Ordinance (WPO) in the City of Baytown.

LID will be promoted through dissemination of existing materials and discussions with developers and local governments by H-GAC. The intent is to promote the benefit of LID and related developmental practice for new development and redevelopment. The goal is to reduce storm flows from new development. Priority areas include new residential and commercial development in northern Baytown, along the I-10 corridor, and along the Highway 146 corridor; and industrial development in the Tidal Segment.

The City of Baytown's WPO sets requirements and restrictions on development within 200 feet of shorelines in the City. Requirements of the WPO include impact studies on proposed development in the protected zone and a 75-foot wide, vegetated buffer strip along public waterways. More information about the WPO can be found at http://goo.gl/bIiWEP. One of the purposes of the WPO is to reduce contaminated runoff from reaching the waterways. The City has enforced this ordinance during the development of this WPP.

Responsible Parties	Period	Contaminant Addressed	Status
City of Baytown; H-GAC; Developers	2015-2020 for LID, 2011-2025 for WPO	Bacteria, Nutrients, Sediment	Existing and expanded efforts

Technical and Financial Resources Needed

LID education and outreach materials already exist in a number of formats. H-GAC is actively involved in evaluating LID on a regional basis. Materials specific to the watershed may be developed as needs arise. Identified funding sources include H-GAC funds and 319(h) grant funding.

The Baytown WPO is current in place Resources for its continued enforcement are variable based on the number of development projects initiated in the WPO area in a given year, but are generally based on City staff time. The funding source is City revenue.

Estimated Costs

LID Promotion
- $300 per year in materials,
- $1,000 in H-GAC staff time for promotion activities.
- Total of $6,500

WPO
- Variable based on applications.

Bacteria Reduction Capability

This activity is expected to have an indirect impact on bacteria, nutrients and sediment by shaping growth.

Urban Runoff 3 – Resident Education

Purpose: To reduce storm flow contamination from residential activities

Description: H-GAC, in coordination with local partners, will offer events/workshops on FOG and residential lawn maintenance. Events will be focused on the urban areas of the Tidal watershed, but may be expanded to areas in the Above Tidal if interest exists. The workshops will highlight benefits of reducing FOG inputs (less repairs on residential pipes, reduced SSOs) and of water-friendly lawn maintenance (less fertilizer needed, less mowing needed, better water quality). All activities will be implemented such that they are supplementary to existing education efforts under the MS4 permits.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; GBF; City of Baytown; Joint Task Force	2015-2025, every two years	Bacteria, Nutrients, Sediment	Existing and expanded efforts

Technical and Financial Resources Needed	Estimated Costs
Residential education materials and programs for FOG and lawn maintenance already exist, including efforts by the City of Baytown, the Joint Task Force, GBF, and other local stakeholders. H-GAC will work with these entities to tailor existing materials to meet the needs of the watershed using in-house design and outreach staff. Potential funding for this effort has been identified as part of H-GAC CRP funds (for regional outreach development elements) and proposed 319(h) grant activities. It is anticipated that much of the effort will be completed in coordination with the other participants whose staff time and efforts will be a mix of internal revenue and grants (e.g. GBF has a grant from the GLO for the Cease The Grease program, as detailed in the WWTF/SSO solutions section previously). Cost estimates are based on general salary costs and estimated materials, travel, and related costs.	Educational Seminars • FOG – see WWTF/SSO Solution 3 • Residential Lawn Care - $2,100/event, $10,500 total.

Bacteria Reduction Capability

This activity is expected to have an indirect impact on bacteria reduction, by raising awareness and oversight on FOG and lawn waste. It is expected to contribute to a comprehensive education/outreach program.

Urban Runoff 4 – Addressing Feral Domestic Animals

Purpose: To reduce feral domestic animal populations through spay/neuter programs for pets.

Description: Unwanted pet offspring often find their way to the streets in urban areas, where feral populations establish. Addressing a single pet can potentially avoid a large number of future generations of progeny. H-GAC will coordinate with the City of Baytown and an area spay and neuter clinic or program (e.g. Houston Human Society, SNAP of Pasadena, et al.) to hold spay and neuter events in the watershed. Priority areas are the City of Baytown's urban areas in the watershed. One event will be held every two years or more frequently as funding and interest allows. H-GAC will also work with partners to publicize free or reduced-cost spay/neuter programs in the area to residents of the watershed.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; City of Baytown; SNAP or other program; residents	2015-2025, every two years	Bacteria, Nutrients	New effort

Technical and Financial Resources Needed	Estimated Costs
Several spay/neuter clinics exist in the area with reduced cost/free programs and established outreach. Other entities in the area (City of Houston, et al.) have held events featuring mobile clinics that H-GAC would seek to emulate. 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. Funding for the events has been proposed for a combination of H-GAC local funds and 319(h) grant funds, in addition to any contributions received from other interested partners. Funding for the events would cover staff time in preparation, travel costs, and outreach materials. 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.	Spay/Neuter Education • $2,100/event • $10,500 total Spay/Neuter • Estimated at $50-$150 per animal.

Bacteria Reduction Capability

This activity is expected to reduce bacteria and nutrients originating by reducing future feral pet populations. The bacteria reduction potential of the program is variable based on the number of residents who take advantage of it. The bacteria value for each feral pet avoided is based on the loading value for an average dog in Appendix A

PET WASTE

Pet waste is a leading source of contamination in the Cedar Bayou watershed, particularly in the Tidal segment. As with the other categories of solutions, the stakeholders favored a voluntary approach to addressing pet waste, focusing on dogs. The general focus of the solutions is to influence pet owner behavior by providing amenities and tools to make dealing with their pet's waste more easily and widely accepted.

Figure 107 –Pet waste outreach campaign

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 watersheds of the Tidal segment. The solutions selected by the stakeholders are to install pet waste stations in high traffic public areas, develop new dog parks or dog-specific areas within parks, and to recommend the City of Baytown and other local governments consider a pet waste ordinance[107]. Education and outreach activities related to pet waste are described in Section 8.

[107] The stakeholder also accented the need for spay/neuter programs to reduce unwanted puppies who contribute to feral animal populations. This solution is included in the Urban Runoff source category.

Pet Waste 1 – Installing Pet Waste Stations

Purpose: To reduce pet waste from entering Cedar Bayou by encouraging pet owners to pick up after pets in public areas.

Description: Pet waste stations are a widely use, 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 10 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, including J.C. Holloway Park, Roseland Park, Barkuloo Park, WL Jenkins Park, Frank C Murdoch Park, and Lincoln Cedars Park in Baytown; Cedar Bayou Park, LT May Park, and Cedar Grove Park in Harris County (Precinct 2); and other areas developed in the future.

The installation of the stations would be coordinated with pet waste education.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; City of Baytown; Harris County Precinct 2	2015-2018, (installation). 2015-2025 (ongoing use)	Bacteria, Nutrients	New effort

Technical and Financial Resources Needed	Estimated Costs
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); installation and ongoing maintenance (staff time, provided by the receiving partner); and ongoing maintenance; 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 Galveston Bay Foundation, or funding from private endowments.	Pet Waste Stations • Equipment - \$150 per station, \$50 per year in bags. • Installation - \$200 in labor and materials. • Maintenance - \$300/year per station • Total Yearly 1st Year - \$4,000 installation, \$3,000 maintenance. • Total 5 year cost - \$21,000

Bacteria Reduction Capability

This number of dogs impacted by this solution will vary based on the location. An average of 20 dogs a day per station served was chosen based on stakeholder description of Baytown area parks, and accounting for lesser usage of northerly Precinct 2 parks. Assuming half of the dog's daily waste is served, full implementation of this solution would yield 200 dogs, or 100 representative units, addressed. This would represent a daily bacteria reduction of 1.25 X 10^{11}.

Pet Waste 2 – Expanding Dog Parks

Purpose: To provide additional areas for dog owners to bring dogs, in order 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 acquiring new parkland. Dog park areas already exist in the watershed (most prominently, the Baytown Bark Park area in W.L. Jenkins Park. However, with an estimated 31,609 dogs by 2025, there is ample opportunity to increase the number of areas and dogs served by these facilities in the watershed. The City of Baytown's Strategic Parks & Recreation Master Plan indicates a need for 2-3 dog parks by 2020, with an ultimate need of 4[108] by 2030. Roseland Park or other southern areas are indicated as potential next expansions (within 5 years), and a park on the eastern shore of Cedar Bayou is denoted as a future priority. 2010 survey results indicated that close to 30% of Baytown residents already used the dog park. Harris County Precinct 2 also operates several parks in the watershed which may be suitable for dog areas. Priority areas are based on highest potential use/traffic and population served.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; City of Baytown; Harris County Precinct 2; Chambers County	2015-2020 (new park in Baytown), 2015-2025 (other)	Bacteria, Nutrients	New/expanded effort

Technical and Financial Resources Needed	Estimated Costs
Technical resources needed are a mix of City/County Parks staff expertise and professional services contracts for the study, acquisition, design, construction, and related tasks needed to bring new parks online. Financial resources needed reflect the stages for which technical resources needed. Identified sources of funding include internal revenue of the partners, grants from 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.	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 are general benchmarks and may not be indicative of actual watershed area costs.

Bacteria Reduction Capability

This solution indirectly reduces waste, by sequestering it where it can be more easily addressed by owners and park staff.

[108] More information on this can be found at http://baytown.org/home/showdocument?id=1299.

Pet Waste 3 – Recommend Pet Waste Ordinance(s)

Purpose: To provide incentive for residents to properly dispose of dog waste.

Description: Pet waste ordinances that require proper disposal of pet wastes in public areas are common in medium to large sized cities. Pet waste impacts aesthetics, can spread pathogens, impacts water quality, and represents a potential cost for removal in high use public areas. The City of Baytown, which represents the majority of the dogs in the watershed, does not currently have a pet waste ordinance. This solution would request that the City of Baytown adopt a pet waste ordinance requiring disposal of pet waste excreted in public areas. Baytown is the focus of this solution as it is the only urban area in the waterway in which an appreciable amount of public land and dog-owning households are contained.

Responsible Parties	Period	Contaminant Addressed	Status
City of Baytown; H-GAC	2015-2020 (development), 2020-on (enforcement)	Bacteria, Nutrients	New effort

Technical and Financial Resources Needed	Estimated Costs
Technical resources needed for this solution would include supporting the legal and political logistics of devising, adopting, and implementing a pet waste ordinance for the City of Baytown. Additionally, ongoing enforcement would require training or education for enforcement personnel. This is expected to be within the capacity of City's existing staff. Model ordinances are available through H-GAC and examples of ordinances from similarly-sized cities are available through Municode (e.g., the City of Sugar Land, as summarized at http://www.sugarlandtx.gov/DocumentCenter/View/415) Financial resources are expected to entail staff time for developing the ordinance and its subsequent enforcement. Identified funding sources are internal City revenues, with support from H-GAC staff for development, if appropriate. H-GAC support is intended to be funded through 319(h) grants or H-GAC local funds. Development and funding for educational outreach about the new ordinance would also need to be considered. Revenue for the program may be supplemented by fines or fees associated with violations.	Costs of ordinance development will vary depending on the extent model resources are used, new ordinance language is developed, and administrative or political oversight is made.

Bacteria Reduction Capability

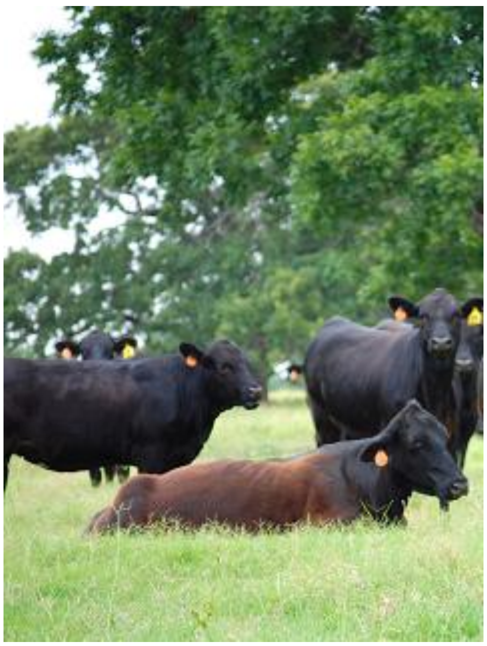
This solution's efficiency will vary based on enforcement/adoption by residents.

LIVESTOCK

Agricultural producers are spread throughout the watershed, with the majority of livestock being located in the Above Tidal segment. While modern agricultural practices are often efficient in reducing bacteria and nutrient load to waterways, bacteria loads from cattle, horses, and sheep and goats are still present in the watershed. The solutions identified by stakeholders to address livestock focus on expansion of 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.

Figure 108 –Cattle grazing.

The solutions selected by the stakeholders include promoting and implementing Water Quality Management Plans (WQMPs) and Conservation Plans on grazing acres, implementing other grazing management techniques through financial assistance and technical resources, and maintaining or promoting buffer areas in riparian corridors. These efforts will rely heavily on the established programs and resources of the TSSWCB, AgriLife Research and Extension, USDA NRCS, and other agricultural partners.



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. There are currently 5 WQMPs in the Cedar Bayou watershed, which cover 368 grazing acres, leaving ample opportunity for expansion of the program.

Based on agricultural census data and feedback from stakeholders: the average farm size in the watershed is 216 acres (based on the average farm size among the three counties in the watershed).

The number of WQMPs recommended to achieve the needed load reduction is 25 (The number of WQMPs per subwatershed is detailed in Table 32; the total accounts for rounding to whole numbers for each subwatershed, which requires a greater number of WQMPs than the 23 needed to meet requirements on a segment basis).

Priority for WQMPs and other projects will be given to management practices which most effectively control bacteria. Based on site-specific characteristics, plans will include one or more of the TSSWCB's approved practices[109]. Examples of these practices include but are not limited to filter strips, riparian buffers, prescribed grazing, and alternative shade and water.

Similarly, the USDA NRCS offers conservation planning services through its Conservation Technical Assistance program[110] and financial assistance through its Environmental Quality Incentive Program (EQIP) and related programs.

[109] More information on the WQMP program can be found at http://www.tsswcb.texas.gov/en/wqmp.
[110] 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/

	These services assist landowners to conserve resources and protect water quality by providing NRCS expertise and financial assistance.		
Responsible Parties	**Period**	**Contaminant Addressed**	**Status**
TSSWCB; SWCDs; USDA NRCS; agricultural producers/landowners	2015-2025	Bacteria, Nutrients, Sediment	New or expanded effort

Technical and Financial Resources Needed	**Estimated Costs**
Technical resources required by this solution are the expertise of TSSWCB and USDA NRCS staff involved with their respective programs. An additional WQMP technician is needed to implement WQMPs on a broad basis in the watershed area. Financial resources required for this solution vary based on the type and scope of plan implemented. WQMPs and NRCS conservation planning efforts can cover a wide variety of practices and acreages. Identified needs in the Cedar Bayou Watershed include the WQMP technician position, which is intended to be funded under a CWA §319(h) grant proposal from TSSWCB. Absent additional CWA §319(h) funds, existing staff can implement this solution, though at a much reduced scale. 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.	WQMPs • up to $15,000 per WQMP in financial incentives, total of $375,000[111] • Estimated $75,000 year for a WQMP Technician, total of $375,000 (half of cost). • Landowner share of costs is variable. NRCS Conservation Plans • Estimated at $2,000-$3,000 in NRCS staff time. • Resident share variable.

Bacteria Reduction Capability
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.

[111] 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. This equates to a need for 25 WQMPs (13 in the Above Tidal, and 12 in the Tidal). This was chosen as a conservative estimation of potential costs.

Table 32 – WQMPs by Subwatershed

Segment	Total WQMPs Needed	Subwatershed	WQMPs per Subwatershed
Above Tidal	13	SW1	2
		SW2	1
		SW3	3
		SW4	1
		SW5	5
		SW6	1
Tidal	12	SW7	4
		SW8	3
		SW9	2
		SW10	3

WILDLIFE AND FERAL HOGS

Wildlife and free-roaming non-domestic animals are often unavoidable sources of bacteria in a watershed, given the limited number of solutions available to address most sources. For the purpose of this WPP, the stakeholders considered solutions for deer and feral hogs. The solutions represented reflect the stakeholders' decision to not pursue reductions from deer due to a lack of feasible means to achieve them. However, the stakeholders did choose to address feral hogs because they have a greater bacteria load, are more destructive to other interests (including native species), and are the subject of existing management efforts in the region. Reduction from feral hogs is expected to derive directly from landowner efforts, as supported by partner agencies through information and technical services.

Figure 109 –Feral hogs in trap

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. The solutions selected for feral hog abatement include encouraging landowners and local governments to use existing technical services through AgriLife Extension and other partners, and holding feral hog education programs in the watershed.

Feral Hogs 1 – Technical Services for Hog Abatement

Purpose: To encourage residents to use existing technical services and resource programs to aid in reducing feral hogs.

Description: There are several existing programs that provide education and technical advice on feral hog abatement. Active programs in the area include the Texas Wildlife Service (TWS), AgriLife Extension; and the TSSWCB[112]. While the primary aim of existing programs is to educate (see Feral Hogs 2, below), technical support services or information resources are available on a limited basis through these programs.

- TWS[113] provides direct assistance to landowners with abatement projects through county-level technicians.
- AgriLife Extension Agents and staff can assist landowners by answering questions and providing recommendations, in addition to their seminars and informational resources.
- TSSWCB will provide technical assistance in priority watersheds as part of the Lone Star Healthy Streams (LSHS) Feral Hog Component.

Responsible Parties	Period	Contaminant Addressed	Status
Landowners; TWS; AgriLife Extension; TSSWCB	2015-2025	Bacteria, Nutrients	Expansion of existing effort

Technical and Financial Resources Needed	Estimated Costs
The technical resources needed for this solution are availability of recommendations, and technical support for landowners engaged in feral hog abatement. The technical resources of the existing programs are sufficient to meet this need, pending continued funding. Financial resources of this project include the staff time and related costs of the partner agencies, and the cost of implementing solutions borne by the landowners. Existing programs rely on either internal funding or 319(h) grant funds (e.g., the TSSWCB LSHS Feral Hog Component). Identified future funding sources include additional CWA §319(h) and programmatic funding.	Available funding varies by agency, and may be difficult to parse out of budgets. Most costs associated with providing information are able to be accomplished within existing positions. Direct on-site support costs will depend on the usage by landowners.

Bacteria Reduction Capability

This solution does not directly reduce bacteria; it provides support for landowner efforts to reduce feral hogs and thus bacteria contributions.

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[112] More information on the roles and responsibilities of various agencies can be found on p. 31 of the Lone Star Healthy Streams Feral Hog Manual, located at: http://lshs.tamu.edu/media/340450/feral_hogs.pdf

[113] TWS is cooperative program of the USDA Animal and Plant Health Inspection Service (APHIS) program

Feral Hogs 2 – Feral Hog Education and Outreach

Purpose: To educate residents on feral hogs and resources available to address them.

Description: A number of programs (including those described in Feral Hogs 1 above) offer educational components related to feral hog management.
This solution would implement two workshops of the AgriLife Extension Feral Hog Workshop, and promote other opportunities as available and appropriate. AgriLife Extension conducts Feral Hog Workshops to educate landowners on feral hogs and their control. A workshop was already held for the watershed area in June 2014, and additional workshops are proposed to be held twice in the implementation period.

Responsible Parties	Period	Contaminant Addressed	Status
AgriLife Extension; H-GAC	2015-2020 (1st workshop) 2020-2025 (2nd workshop)	Bacteria, Nutrients	Existing effort expanded to watershed

Technical and Financial Resources Needed	Estimated Costs
The technical resources for this effort are the AgriLife Extension staff expertise and information resources available under their existing 319(h)-funded workshop program. Funding resources are currently met by 319(h) grant programs and agency programmatic funding. Coordination in the watershed by H-GAC is also proposed to be met by a mix of 319(h) grant funding and H-GAC local funds.	The estimated staff cost of completing a workshop is $4,000-$5,000, for a total cost of $8,000-$10,000.

Bacteria Reduction Capability

This solution does not directly reduce bacteria; it provides support for landowner efforts to reduce feral hogs and thus bacteria contributions.

Riparian Corridors

The potential impact of many of the sources described previously is mitigated by the extent to which their bacteria can be transported into waterbodies. The condition of the riparian corridor can greatly impact the amount and timing of contaminated runoff's impact. Vegetated buffers in the riparian corridor can reduce the amount of bacteria, nutrients, and sediment entering the waterbody, as well as decreasing the volume and velocity of storm flows.

There are forested buffers in portions of the watershed's riparian corridor between highway 90 and I-10. Additionally, large industrial properties in the Tidal (especially the eastern shore) have ample vegetated area fronting the main stem of Cedar Bayou. Much of the upper watershed and aspects of the urban shoreline in the Tidal segment have opportunities for additional vegetated buffer areas.

The stakeholders prioritized maintaining riparian buffers wherever possible, and as a secondary priority, increasing buffers in previously developed areas. This solution touches on a variety of sources and land uses, and therefore can draw from a variety of existing programs.

Figure 110 –Vegetated buffer along Cedar Bayou Tidal

Riparian Corridors 1 – Riparian Buffers

Purpose: To reduce transmission of bacteria, nutrients and sediment to waterways by maintaining or implementing vegetated buffers in riparian corridors.

Description: Buffer areas in riparian corridors help to slow storm flow, filter pollutants, and reduce direct fecal deposition by livestock in waterways. This solution would promote riparian corridor protection to landowners and local governments via outreach, focusing on vegetated riparian buffers on public and private land.

Methods of implementing this solution include implementing buffers as part of voluntary WQMPs, EQIP, etc.; as part of partnerships with large industrial properties and local governments/public lands; utilizing conservation easements held by land trusts; and outreach and education for local landowners. Priorities for this solution are maintaining buffers in subwatersheds 5 and 6; expanding buffers in agricultural areas of the Above Tidal segment as part of WQMPs or other landowner partnerships; expanding riparian buffers in urban and industrial areas of the Tidal segment. Priorities for education and outreach are to work directly with landowners and local partners rather than large scale outreach to the general public.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; USDA NRCS; TSSWCB; local SWCDs; landowners/producers; local governments; industrial partners.	2015-2025	Bacteria, Nutrients, Sediment	New and expanded efforts

Technical and Financial Resources Needed	Estimated Costs
Technical resources needed for this solution include the existing programmatic resources and staff expertise of NRCS, TSSWCB, H-GAC, and other local partners. Financial resources needed for this solution include the staff resources and landowner contributions previously detailed for WQMPs and EQIP, as well as similar resources for other landowner efforts and partnerships. Additionally, the need for outreach and education to support these aims requires resources for H-GAC. This funding is proposed to come from a 319(h) grant.	Costs for WQMPs, EQIP, and similar land management projects are discussed in previous solutions. Costs for education and outreach vary based on the type.

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. This effort is intended to be supplementary to other source-specific solutions (as part of WQMPs, etc.) which are intended to directly meet the bacteria reduction goals.

ADDITIONAL SOLUTIONS

While the focus of the solution identification, prioritization, and evaluation process was to address bacterial contamination, stakeholders also identified solutions for other watershed issues (see page 49 for the original discussion of these concerns). Additionally, secondary bacteria solutions are listed in Appendix B for use as needed under an adaptive management framework.

Figure 111 – Community efforts: marsh restoration, trash reduction, and PCB signage

OTHER CONCERNS

The diverse group of stakeholders that took part in this WPP process reflected an equally wide number of interests and concerns in the watershed. Some of the concerns are outside the scope of the WPP (regulatory processes involving PCB and Dioxins), or are not directly related to the water quality goals.

However, the concerns and efforts of the community make up an important part of the overall efforts to improve Cedar Bayou. For those issues on which there was reasonable consensus, recommendations are included here to reflect efforts that are ongoing, or which may be employed in the future. Some issues (e.g., the potential impacts of dredging and hydrologic modification) did not have clear consensus by the stakeholders, and therefore the recommendations for these issues are limited to general emphasis on transparency for the continuing discussions.

Abandoned Boats – *Solutions recommended or ongoing to address abandoned vessels in the waterway (primarily Cedar Bayou Tidal).*

Solution	Description	Potential Impact(s)	Responsible Parties	Status
Remove abandoned vessels	Physically remove abandoned vessels.	Increase boater safety; Remove legacy pollutants	CBWP; GLO; GBF; CHART; Chambers County; CBF; et al.	Complete[114]
Ongoing patrol for vessels	Routine patrols by County Sherriff's office for new abandoned vessels.	Increase boater safety; Remove legacy pollutants	Harris County Sherriff's office (patrols); CBF (coordination)	Ongoing

Trash/Illegal Dumping – *Solutions concerning illegal dumping and trash reduction in areas adjacent to the Bayou.*

Solution	Description	Potential Impact(s)	Responsible Parties	Status
Adopt-a-Street	Routine trash reduction on streets adjacent to Cedar Bayou. This is currently done for one area by CBF, but could be expanded.	Trash reduction in Cedar Bayou.	Cedar Bayou Friends (current)	Ongoing, with the potential to expand.
Trash reduction event	One-day event to address trash along the area waterways (akin to Trash Bash, etc.)	Trash reduction in Cedar Bayou.	City of Baytown (potential	New effort[115]
Curtail illegal dumping	Enhance enforcement of illegal dumping adjacent to waterways through vigilance, cameras as appropriate, or other means.	Reduction of trash; bacteria reduction (dependant on trash)	Local governments; H-GAC Solid Waste Program[116]	Expansion of existing efforts.

[114] The 21 vessels were removed during the development of the WPP, with the exception of one barge on private land.
[115] The City of Baytown currently holds a yearly Trash Off trash collection event, but does not currently participate in the Rivers, Lakes, Bays and Bayous Trash Bash event held throughout the region.
[116] H-GAC currently works with local partners to loan remote cameras for use in deterring illegal dumping.

Landfills – *Solutions that address stakeholder concerns about the potential impact of landfill operations in the watershed.*

Solution	Description	Potential Impact(s)	Responsible Parties	Status
Gull abatement	Recommend to Waste Management that they consider additional measures to deter the large gull populations at the landfill at Cedar Bayou's mouth (the assessment of gull populations indicated that they were not likely an appreciable bacteria source at the mouth of Cedar Bayou. However stakeholder concern led to a discussion of potential BMPs to deter excess gull populations).	Bacteria /nutrient reduction	Waste Management	New

Habitat – *Solutions that address habitat loss and ecological systems function.*

Solution	Description	Potential Impact(s)	Responsible Parties	Status
Restore marsh areas	Restore marsh areas through partner efforts like the GBF's Marsh Mania program, NRG's Ecocenter's native grass nursery and donations program, and remediation efforts related to dredging projects.	Water quality improvement; storm resilience improvement; habitat improvement.	GBF; NRG; volunteers; GLO; GBEP	Ongoing

PCBs/Dioxins – *The solutions address the broader Bay-wide issue of PCB/Dioxins contamination of edible fish tissue. They are based on the stakeholders' water quality goals, which emphasize a support role for the Partnership rather than direct remediation efforts.*

Solution	Description	Potential Impact(s)	Responsible Parties	Status
Advisory signage	Post fish advisory signage at Roseland Park	Human health	GBF; City of Baytown	Complete
Support TMDL	Support the efforts of the Bay PCB /Dioxin TMDLs	Human Health	Partnership; TCEQ	Ongoing

Dredging/hydrological modification - *The ongoing maintenance and potential modification of the Tidal segment channel is a point of discussion for the stakeholders. While regulating dredging activities are outside of the scope of the WPP, the stakeholders prioritized communication between the parties involved in this issue as part of broader concerns for the segment's future.*

Solution	**Description**	**Potential Impact(s)**	**Responsible Parties**	**Status**
Promote communication	Promote transparency and communication between opposing parties regarding the dredging and proposed modification of the Tidal segment's maintained navigation channel. The purpose is to ensure correct information is disseminated to the public, and public feedback is considered.	Hydrologic	CBND; local community members	Ongoing

Solutions Summary

The solutions presented in this Section are intended to meet the bacteria reduction goals defined in Section 5, and also to impact other water quality concerns. They have been vetted by the stakeholders, and represent a locally-led decision-making process. However, the implementation process will involve ongoing evaluation of the effectiveness or feasibility of these solutions. With an emphasis on adaptive management, this WPP is designed to be a living document, and these solutions may be updated form time to time as need and opportunity require. To accomplish these goals, a locally-based watershed coordinator position will be funded to guide early implementation efforts.

Figure 112 – Cedar Bayou at Roseland Park

Section 7 –
Education and Outreach

7 – Education and Outreach

Raising Public Awareness

Maintaining and growing public support for the Partnership's implementation efforts requires robust education and outreach strategies. Successful implementation will rely strongly on the public's participation in watershed activities and changes in individual behavior. A successful education and outreach campaign is crucial to meeting these goals and the overall success of the WPP.

There is a wealth of existing education and outreach efforts ongoing in the watershed, and opportunities to expand, enhance and supplement those efforts based on the specific needs of this WPP. This Section details the existing and proposed education and outreach elements identified by the stakeholders, and the sources of bacteria or other concerns they address. Some components related to specific sources are discussed in more detail in Section 6, Solutions.

The overall philosophy behind the outreach and education campaign is to utilize existing resources, coordinate with ongoing efforts, and to intelligently target messages to key watershed groups based on their values and common experiences. The elements of this campaign may be varied in message, but serve the same overall goal. Except as noted in Section 6, these are intended as ongoing efforts.

Figure 113 – An early public outreach meet for the Partnership

General Project Outreach and Education

The Partnership will seek to raise general 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 general public, represent the watershed among regional and state organizations. Many of the efforts described as part of the general goals will also be used as vehicles for more individualized messages for the specific sources. The Partnership will work with local strategic partners, such as the Cedar Bayou Friends, to enhance existing general watershed awareness. A local watershed coordinator will be necessary to guide implementation, education and outreach efforts.

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:

- Continued facilitation by TSSWCB and H-GAC (or successor agencies)
- Periodic meetings of the Partnership (at least twice a year)
- Dissemination of information regarding WPP activities among stakeholders through email and newsletters
- Individual meetings with strategic partners to maintain commitments and coordinate efforts

Building the Brand

One of the initial goals of the Partnership was to build a presence in the watershed. While many of the stakeholders represent entities with an existing presence, the Partnership must be the visible representation of its specific goals in the eyes of the general public. To accomplish this goal, the Partnership must:

- Maintain a presence at local events and meetings that includes information on the Partnership, the WPP, and their goals.
- Maintaining and expanding the Texas Stream Team monitoring sites.
- Holding Texas Watershed Steward trainings as appropriate to increase public awareness
- Continue to maintain the project website and social media

Regional Coordination

The Partnership is one of many similar groups throughout the state and nation. The free flow of ideas within this community can benefit local projects and reduce costs. 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, and others
- Coordinate with regional projects that benefit the watershed, such as the PCB/Dioxin TMDLs for Galveston Bay, and GBF's Fats, Oils and Grease project.

Figure 114 – General watershed outreach at the Baytown Nurture Nature Festival (photo courtesy of Jerry Jones)

SOURCE-SPECIFIC OUTREACH AND EDUCATION

In addition to general project promotion, members of the Partnership will engage in new and existing education and outreach efforts that focus on one reducing specific sources of bacteria in the watershed. The goal of these efforts is to target behaviors or conditions with specific and relevant messages and education products. The emphasis will be on active engagement rather than passive information.

OSSFS

The proper maintenance of OSSFs in a watershed relies on thousands of individual owners rather than a centralized system. Therefore, public education and outreach activities are important tools in achieving reduction goals. As detailed in Section 6, the education and outreach elements for OSSFs include:

- Homeowner education through AgriLife Extension workshops
- Real estate inspector trainings through H-GAC[117]
- Harris County OSSF workshops for the OSSF service and regulatory communities
- Dissemination of OSSF location data through H-GAC's online database
- OSSF literature (pamphlets) for local events

WWTFS

There are no education and outreach elements aimed specifically at WWTFs, other than general coordination of the project. However, public education regarding SSOs and information on how to report spills and contact local utilities will benefit both this category and urban runoff. This goal is met through:

- Coordination with GBF's FOG educational outreach program, "Cease the Grease", including H-GAC's Cease the Grease game at local events.
- Promotion of GBF's Galveston Bay Action Network tool for utility contact identification for the public.

URBAN RUNOFF

The majority of outreach and education for urban areas is conducted as part of the TPDES MS4 stormwater permits by the City of Baytown, et al., as defined in their SWMPs. Supplemental outreach efforts include:

[117] In coordination with an ongoing Clean Water Act 604b grant from the TCEQ.

- Coordination with GBF's FOG educational outreach program, "Cease the Grease", including H-GAC's Cease the Grease game at local events.
- GBF's Rain Barrel Workshops.
- Promotion of spay and neuter programs to reduce feral animal populations.

Pet Waste

As with other nonpoint sources, pet waste management relies on the individual efforts of thousands of pet owners. The education and outreach elements designed to impact these behaviors include:

- Signage at pet waste stations to reinforce their use
- Dissemination of dog waste bags as part of ongoing H-GAC efforts and as part of GBF's Bag it for Your Bay initiative.
- Pamphlets at local events
- Promotion of spay and neuter programs to reduce feral animal populations.

Livestock

There are several successful agricultural education programs already at work in the watershed, including the efforts of AgriLife Extension and Research, TSSWCB, and USDA NRCS outlined in Section 6. The elements that will be applied in this watershed include:

- Promotion of available services and financial incentive programs to landowners (WQMPs, NRCS programs, etc.) by the agencies, through H-GAC "Growing Green" events in the watershed, and through literature at local events.
- Holding educational events for landowners, including AgriLife Research's riparian workshops

Feral Hogs

Feral hogs are the focus of many state-wide education efforts that promote hog management by landowners. The programs and outreach efforts that will be applied in this watershed include:

- Educating landowners through AgriLife Extension's feral hog workshops
- Promotion of existing resources like the Lone Star Healthy Stream feral hog manual in appropriate communications and venues
- Literature at local events

Figure 115 – Partners conducting outreach on pet waste, riparian ecology, and FOG

Outreach and Education for Other Concerns

The stakeholders identified additional education and outreach elements for watershed concerns not directly related to bacteria reduction. These efforts are partner programs that will assist in the overall goal of watershed health and public awareness.

PCBs and Dioxins

The stakeholders are taking a support role for this regional issue, and identified these elements to meet that goal:

- Install fish advisory signage at local public fishing access sites (currently through GBF).
- Include PCB/Dioxin literature (e.g. H-GAC's "Dioxin for Dinner?" pamphlet) in outreach resources at local events.

Trash and Dumping

Trash and dumping outreach is being conducted through:

- The City of Baytown's MS4 permit activities, and annual trash events.
- Promotion of trash reduction events by the Cedar Bayou Friends
- Connecting residents to proper authorities for dumping reports (and other environmental concerns) through GBF's Galveston Bay Action Network tool.

Habitat

Habitat concerns are being addressed through:

- The NRG Ecocenter, and it's grass restoration support

- The Baytown Eddie V Gray Wetlands Center's educational programs
- Public advocacy by the Cedar Bayou Friends and other local partners

Recreation

The importance of Cedar Bayou as a recreational venue is being promoted through:

- The City of Baytown's promotion of recreational activities at Roseland, Holloway, and other parks
- Paddling trips with environmental education messages by the Cedar Bayou Friends
- Water-based community events like the annual Christmas Boat Parade

Figure 116 – Cedar Bayou Friends paddling trip on Cedar Bayou Tidal

Section 8 – Implementation

8 – IMPLEMENTATION

IMPLEMENTATION

The solutions (Section 6) and education and outreach activities (Section 7) identified by the stakeholders represent a range of activities addressing different sources. They will be implemented by multiple partners over the course of a decade, and will require differing financial and technical resources. In order to aid in the logistics of implementation, this Section describes the general strategy for implementation, timelines for activities, and measurable milestones for gauging progress.

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 Cedar Bayou Watershed. As a result, the stakeholders recommended that a local Watershed Coordinator position be maintained in the watershed in addition to the technical and financial resources needed for implementation activities. The locally-based Watershed Coordinator will facilitate local implementation and outreach efforts, engage with individual stakeholders and groups, organize and coordinate regular updates for the Partnership. 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. The Watershed Coordinator also will work to secure external funding to facilitate implementation activities and coordinate with partner efforts.

An estimated $70,000 per year including travel expenses will be necessary for this position. Initial funding for the Watershed Coordinator will be incorporated into a CWA 319(h) grant proposal. Subsequently, with assistance from the Partnership, the position will work to identify other funding sources for future facilitation.

Implementation Strategy

The general strategy for implementation of this WPP's goals is based on four principles:

1) ***Make decisions locally*** – Decision-making for the implementation of efforts to improve water quality in Cedar Bayou should be a function of local stakeholders operating in good faith to represent local interests and priorities.
2) ***Promote/enhance implementation of existing, successful programs*** – There are a wide variety of existing programs or efforts for agricultural (Texas State Soil and Water Conservation Board WQMPs, Natural Resources Conservation Service's Environmental Quality Incentives Program [EQIP}, AgriLife Extension technical support programs, etc.), OSSFs (Regional Supplemental Environmental Projects, OSSF location database[s], etc.), urban runoff (MS4 TPDES permits, existing educational efforts), pet waste (spay and neuter programs, dog parks, etc.), wildlife (feral hog hunting and management programs, AgriLife Extension feral hog technical services and support, etc.), and wastewater treatment facilities (TCEQ's Sanitary Sewer Initiative, municipal Capital Improvement Plans, etc.). Use of existing programs that have been proven successful and viable helps reduce uncertainty, redundancy, and cost for local stakeholders.
3) ***Target cost-effective solutions at current primary sources*** – Stakeholders will focus implementation efforts on reducing redundancy through coordination or similar efforts (e.g., stormwater management under MS4 TPDES permits). They will also prioritize voluntary implementation efforts that address relatively significant sources with high probability of transmission to the waterway.
4) ***Monitor the impact of future change to proactively address emerging sources*** – Implementation efforts are phased to reflect the changing nature of the watershed. Current sources that can be addressed in the short term are prioritized for current implementation efforts. As land use and growth change the balance of sources, implementation efforts will shift to address the new priorities.

Timelines for Implementation

Implementation of this WPP is intended to take place over a 10 year initial implementation timeframe (2015-2025) with some activities already underway.

Some of the solutions will be ongoing throughout this period, while others are intended for specific timeframes within that period. To guide the implementation process, timeline schedules were developed which take into account:

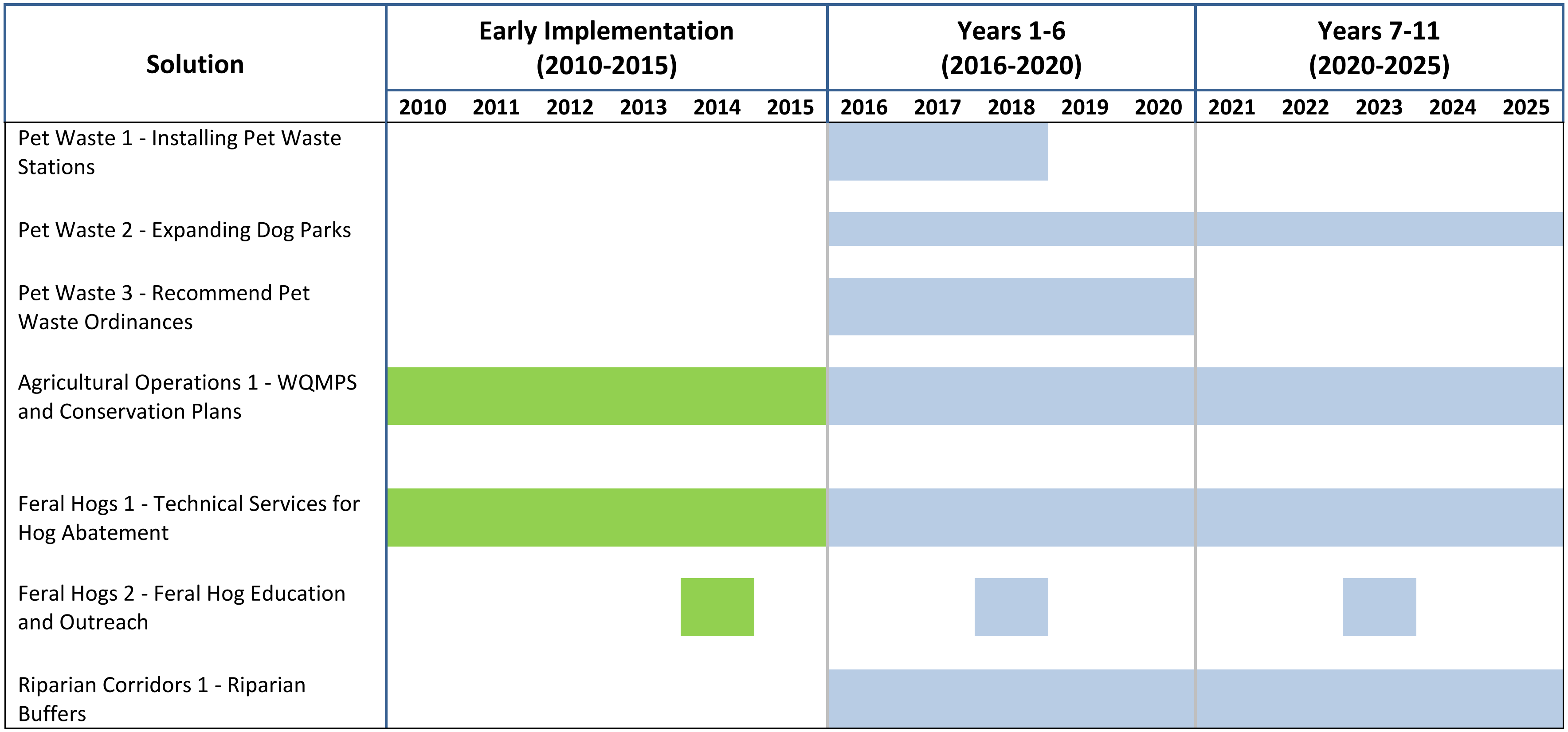
- stakeholder feedback on planned activities;
- change in relative prominence of sources over the time frame;
- estimates of manageable workload and logistics for new efforts; and
- proposed developmental changes in the watershed.

The timeline in Table 33 are intended to reflect the period in which each solution will be implemented. 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 and its intended implementation can be found in Section 6.

Figure 117 – Dog waste disposal bag dispensers

Table 33 – Implementation schedule

Solution	Early Implementation (2010-2015)						Years 1-6 (2016-2020)					Years 7-11 (2020-2025)				
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
OSSF 1 - Identify OSSF Locations																
OSSF 2 - Remediate Failing OSSFs																
OSSF 3 - OSSF Education (Homeowner Education)																
OSSF 3 - OSSF Education (Real Estate Inspector Training)																
WWTF/SSO 1 - Participate in the SSOI																
WWTF/SSO 2 - Reduce Collection System SSOs																
WWTF/SSO 3 - Reduce Fats Oils and Grease																
Urban Runoff 1 - Implement MS4 permit requirements																
Urban Runoff 2 - Promote Low Impact Development																
Urban Runoff 2 - Protect Riparian Buffers (Baytown WPO)																
Urban Runoff 3 - Resident Education																
Urban Runoff 4 - Addressing Feral Domestic Animals																


Solution
Early Implementation (2010-2015)
Years 1-6 (2016-2020)
Years 7-11 (2020-2025)
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
Pet Waste 1 - Installing Pet Waste Stations
Pet Waste 2 - Expanding Dog Parks
Pet Waste 3 - Recommend Pet Waste Ordinances
Agricultural Operations 1 - WQMPS and Conservation Plans
Feral Hogs 1 - Technical Services for Hog Abatement
Feral Hogs 2 - Feral Hog Education and Outreach
Riparian Corridors 1 - Riparian Buffers

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 34 represent measurable increments of the implementation process.

Table 34 – Interim milestones for measuring implementation progress

Solutions	Overall Implementation Goal	Milestone 1	Milestone 2	Milestone 3
OSSF 1 - Identify OSSF Locations	Continue to compile OSSF location data; review locations with Authorized Agents every 3 years to ensure accuracy.	**2016 -** Review OSSF locations with Authorized Agents	**2019 -** Review OSSF Locations with Authorized Agents	**2022 -** Review OSSF Locations with Authorized Agents
OSSF 2 - Remediate Failing OSSFs	Remediate failing OSSFs at a rate of 16 per year. Review priority areas with stakeholders periodically	**Yearly, 2016-2025 -** Remediate 16 OSSFs each year.	**2019** - Review Priority areas with stakeholders.	**2022** - Review Priority areas with stakeholders.
OSSF 3 - OSSF Education (Homeowner Education)	Hold one homeowner education event every 5 years.	**2017 -** Hold one homeowner education event	**2023 -** Hold one homeowner education event	
OSSF 3 - OSSF Education (Real Estate Inspector Training)	Hold one Real estate inspector training event every 5 years.	**2016 -** Hold one training event	**2022 -** Hold one training event	
WWTF/SSO 1 - Participate in the SSOI	Maintain City of Baytown participation; encourage other utilities to participate.	**2023** - Baytown completes original 10 year SSOI agreement.	**2023** - Baytown and TCEQ evaluate need for additional agreement term.	
WWTF/SSO 2 - Reduce Collection System SSOs	Reduce SSOs in urban areas; maintain or increase yearly spending on SSO reduction.	**Yearly, 2013-2023 -** City of Baytown spends at least $1,000,000 on sanitary line rehabilitation per year.	**2023** - Baytown evaluates the need for additional spending commitment based on WWTF/SSO 2.	

Solutions	Overall Implementation Goal	Milestone 1	Milestone 2	Milestone 3
WWTF/SSO 3 - Reduce Fats Oils and Grease	Reduce SSOs from FOG, through outreach and grease trap inspection program.	**Yearly, 2015-2025 -** City of Baytown inspects and enforces compliance on all grease trap permittees.	**Yearly, 2015-2025 -** At least one FOG education event, presentation, or outreach effort is made by H-GAC, GBF, Baytown, or other participating entity.	
Urban Runoff 1 - Implement MS4 permit requirements	MS4 permittees implement SWMPs; Annual reports reviewed every 3 years.	**2017 -** Review and summarize bacteria actions in Annual Reports from MS4 permittees	**2020 -** Partnership **r**eviews and summarizes bacteria actions in Annual Reports from MS4 permittees	**2023 -** Review and summarize bacteria actions in Annual Reports from MS4 permittees
Urban Runoff 2 - Protect Riparian Buffers (Baytown WPO)	Enforce the City of Baytown's WPO; Create one public green space in the Baytown riparian corridor.	**Yearly, 2015-2025 -** City of Baytown enforces compliance with its WPO.	**2015 -** The City of Baytown accepts an 11-acre piece of land bounding Cedar Bayou, to preserve as public space.	
Urban Runoff 3 - Resident Education	To hold events every two years educating residents on FOG and/or residential lawn care.	**Every other year, 2016-2024 -** Partnership holds an event or significant outreach activity regarding FOG or residential lawn care.		
Urban Runoff 4 - Addressing Feral Domestic Animals	Reduce feral animal populations by encouraging spay/neuter programs; mid-project update on animal populations.	**Every other year, 2017-2025** - Partnership holds an event or significant outreach activity regarding residential lawn care.	**2020 -** The Partnership completes a review of feral animal population estimates.	

Solutions	Overall Implementation Goal	Milestone 1	Milestone 2	Milestone 3
Pet Waste 1 - Installing Pet Waste Stations	Reduce pet waste by installing pet waste stations in public areas.	**2018 -** The Partnership has installed at least 10 pet waste stations.	**2022 -** The Partnership has reviewed new public spaces for additional installation opportunities.	
Pet Waste 2 - Expanding Dog Parks	Expand dog-specific areas in public parks to sequester pet waste.	**2020 -** The City of Baytown has installed one additional dog-specific area or park.	**2025 -** An additional dog-specific area or park is installed in the watershed.	
Pet Waste 3 - Recommend Pet Waste Ordinances	To encourage responsible pet waste disposal through pet waste ordinances.	**2020 -** At least one local government will have considered adoption of a pet waste ordinance.		
Agricultural Operations 1 - WQMPs and Conservation Plans	To voluntarily implement best management practices that address all potential agricultural-related sources of bacteria.	**2018 -** WQMP Technician position created and funded to assist in WQMP development in Cedar Bayou.	**2020 –** 12 WQMPs implemented (half of ultimate goal).	**2025 –** 13 additional WQMPs implemented (second half of ultimate goal).
Feral Hogs 1 - Technical Services for Hog Abatement	To utilize technical services and resources to reduce feral hog populations and damage.	**2020 -** Landowners may utilize services and resources for projects addressing estimated hog populations of at least 53 hogs.	**2025 -** Landowners may utilize services and resources for projects addressing estimated hog populations of at least 53 (additional) hogs.	
Feral Hogs 2 - Feral Hog Education and Outreach	To provide landowners with information on feral hog management through AgriLife Extension workshops.	**2020 -** At least one workshop will have been held between 2015-2020.	**2025 -** One additional workshop will have been held between 2020-2025.	

Solutions	Overall Implementation Goal	Milestone 1	Milestone 2	Milestone 3
Riparian Corridors 1 - Riparian Buffers	To reduce transmission of pollutants to waterways by maintaining or improving riparian buffer areas.	**2020 -** At least 75% of riparian buffer areas will be maintained in its current state.	**2025 -** At least 50% of riparian buffer areas will be maintained in its current state.	

Adaptive Management

WPPs are intended to be living documents used to guide implementation of the solutions developed by local stakeholders. To ensure that efforts remain effective and cost-effective, WPPs engage in a process of continual review and revision called ***adaptive management***.

The core tenets of adaptive management revolve around the dynamic nature of watersheds. As conditions change within the watershed, the practices and approach we use to address water quality issues must adapt. Additionally, logistical challenges in implementing solutions, and the relative effectiveness of the solutions should be considered in deciding on the future course of implementation efforts.

This WPP is based on the best available science and knowledge available at the time of its writing. However, the Partnership understands that it is likely that changes will be needed in the future to ensure the WPP continues to recommend effective, cost-efficient solutions scaled to the watershed's needs. 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 35.

Table 35 – Adaptive management milestones

Adaptive Management Process	
Component	**Description**
Formal WPP Reviews	At least every five years 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 end result of the review will be an amended WPP. Criteria for review will include but not be limited to: o Stakeholder feedback on implemented solutions and resources o Water quality data summary of segment conditions o Review of progress in meeting programmatic milestones o Progress in complimentary efforts (MS4 permits, etc)
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. This step assumes that the Plan continues to be facilitated by a central entity. If the Partnership elects to follow a more distributed model of effort in the future, this process may be modified.
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.

Section 9 – Evaluating Success

9 – EVALUATION

EVALUATING SUCCESS

Maintaining a successful implementation effort over the life of the WPP requires an active application of the adaptive management process discussed in Section 8. That adaptive management process will be based on established criteria for success.

Water quality monitoring will be continued in Cedar Bayou throughout implementation. This monitoring program will be the default source of data on which to measure compliance with water quality standards. The effectiveness of implementation efforts to achieve the stakeholders' Water Quality Goals will be the primary driver for evaluating success. However, in addition to water quality criteria, programmatic goals will also be used as indicators of success. Evaluation will be facilitated by a locally-based watershed coordinator.

Figure 118 – Monitoring water quality in Cedar Bayou

Monitoring Program

Long-term monitoring in Cedar Bayou will be conducted by H-GAC and TCEQ, through the CRP, by volunteers as part of the Texas Stream Team initiative, and by permitted discharges as part of their permit requirements (e.g. DMRs, SSO reporting data). Special studies may be used to supplement these ongoing data collection efforts if they are deemed necessary in the future. These monitoring data will be used in the adaptive management process of review and revision described in Section 8.

Clean Rivers Program/SWQMIS Data

The CRP maintains four long term water quality sampling sites in Cedar Bayou, two in each segment, which are sampled on a quarterly basis. Additionally, TCEQ monitors one site each segment. The current sites[118] monitored by H-GAC and TCEQ are:

- 11111, Cedar Bayou Tidal at Roseland Park (TCEQ)
- 11115, Cedar Bayou Tidal at Highway 146 (H-GAC)
- 11117, Cedar Bayou Tidal at I-10 (H-GAC)
- 11118, Cedar Bayou Above Tidal at FM 1942 (H-GAC)
- 11120, Cedar Bayou Above Tidal at US 90 (TCEQ)
- 11123, Cedar Bayou at FM 1960 (H-GAC)

These quality-assured data from these sampling efforts is the primary means for evaluating Cedar Bayou's compliance with water quality standards, and will serve as the ultimate indicator of watershed progress under this WPP. The ambient constituents sampled include conventional, bacteriological, flow, and field parameters similar to those sampled during the WPP development project (See Section 5). Special studies, including biological assessment and 24-hour DO, may be conducted by CRP and/or TCEQ if these programs deem it necessary.

Additional Ongoing monitoring 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 Bayou. These sources include:

- WWTF DMR – outfall discharge monitoring data from WWTFs in the watershed will be reviewed periodically to assess the changing impacts of increasing WWTF flows.
- WWTF SSOs – SSOs reported to TCEQ will be assessed periodically to evaluate progress in reducing this source.
- TPWD reports – reports from TPWD Spills and Kills team investigations will be used to determine potential areas of concern or change in sources.

[118] More information on the sites can be found at https://cms.lcra.org/schedule.aspx?basin=9&FY=2016. The site locations are also indicated in Figure 98, in Section 5 of this document.

- Texas Stream Team volunteers – Stream Team volunteers provide valuable basic sampling information at several locations in the watershed. Stream team data is not used for regulatory purposes or for determining a segment's compliance with standards. However, this 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.
- MS4 permit data – Data generated by various efforts under MS4 permits will be used as appropriate to evaluate utility specific information on a variety of water quality issues, from bacteria to trash reduction through stormwater management efforts.

Potential Future Monitoring Efforts

The stakeholders indentified several special studies that are not currently funded but that could be initiated if funding was identified. These studies include:

- Bacteria Source Tracking (BST) – BST is used to identify the origins of bacteria present in a waterbody. Identification is based on the presence of indicator bacteria strains specific to different animal types. However, BST has an appreciable amount of uncertainty and a relatively high cost. However, it can be used as a general decision-making tool to refocus implementation efforts if BST results do not match source load estimates. This effort would be of greatest use in the Tidal segment.
- PCB/Dioxin sampling – Impairments for PCBs and Dioxins in edible fish tissue are based on DSHS fish advisories for the Greater Galveston Bay. However, there is little data in Cedar Bayou to identify whether these substances are of concern in the water column and sediment of the bayou. Sampling for these substances can be costly and time intensive, but opportunities to coordinate with other efforts (dredge management, PCB/Dioxin TMDLs, etc) may exist in the future.

Figure 119 – Cedar Bayou Stream Team Volunteers

Indicators of Success

Evaluating success in implementing a WPP requires that indicators of successful implementation must be identified and adopted. The indicators are used to measure the effectiveness of the implementation effort, in conjunction with the interim milestones presented in Section 8, which measure the pace of progress. In the case of Cedar Bayou, success must ultimately be evident in the water quality monitoring results. However, the Cedar Bayou Watershed is a dynamic area, experiencing rapid growth. In the interim years there may be periods in which water quality gains are countered by increasing sources due to new development. To ensure that progress can be evaluated against this background, programmatic metrics will also be used as indicators of successful progress. These indicators are based on the water quality goals identified by the stakeholders, and the available data sources by which to measure their effectiveness. The indicators are summarized in Table 36.

Compliance with Water Quality Standards

The primary goal of the Cedar Bayou WPP is to achieve and maintain compliance with state water quality standards in ambient conditions. A secondary goal is to ensure source reduction by meeting TPDES water quality permit limits. Therefore the primary indicators of success are:

- A fully supporting status for Cedar Bayou's segments on the Integrated Report related to all applicable uses, with specific focus on the contact recreation standard (bacteria) and aquatic life use standards (DO, etc.);
- positive or stable trends in the most current SWQMIS data from the CRP monitoring sites; and

- a positive or stable trend in WWTF compliance, as indicated in the DMRs.

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 a success.

Programmatic Achievement

While the ultimate success of the WPP will be evaluated against its impact on water quality, 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:

- Meeting the then-current interim milestones (Section 8);
- A stakeholder Partnership that continues to be active and engaged in implementation; and
- funding levels and technical resources sufficient to realize implementation goals.

Table 36 – 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 DRMs
Implement WPP	Solutions implemented	Interim milestones; MS4 Annual Reports; partner information
	Implementation funded	Funding sources identified and acquired.
	Maintain Partnership	At least annual meetings held

ACHIEVING SUCCESS

Although the water quality needs of Cedar Bayou may change over the course of implementation, success will continue to be measured by the core water quality goals of the Partnership. A strong focus on adaptive management must integrate feedback from monitoring and partners. Continual evaluation of the effectiveness of implementation efforts is a fundamental part of ensuring that effectiveness. While a variety of means will be utilized to measure the impact of various efforts, the overall success of this WPP will hinge greatly on the continued hard work and commitment of the Partnership.

Figure 120 – Local decision-making in action

Appendices

APPENDIX A – REPRESENTATIVE UNIT DEVELOPMENT

Bacteria Solution Scaling

To meet bacteria load reduction targets generated by the watershed models (Section 5), the Cedar Bayou stakeholders propose the implementation of a comprehensive selection of solutions (Section 6). For the WPP to be successful, solutions must be implemented on a scale significant enough to generate the required load reductions for each source.

For Cedar Bayou, the scaling methodology approved by the stakeholders relies on requiring reductions from the sources proportional to their contribution in 2025 (e.g. solutions for a source contributing 10% to the total load in 2025 will account for 10% of the total reduction load). To determine how much reduction a solution will generate towards a source's target goal, we must determine the amount of bacteria that solution will address. To do so, we establish a representative unit for each source.

A representative unit is an average, quantifiable component of each bacteria source. For example, the representative unit for dogs is a single dog, because its load is quantifiable and we can estimate the number of dogs addressed by a given solution. Determining the number of representative units of a bacteria source category whose waste needs to be addressed in order to achieve that category's bacteria reduction target involves simply dividing the required load reduction by the load of the representative unit.

For example, if a dog represents 10 units of hypothetical waste, and the required reduction is 1000 hypothetical waste units, then the waste from 100 dogs needs to be addressed to meet the required reduction (1000 total waste units divided by 10 waste units per dog=100 dogs). If a given solution (e.g. a dog waste station) is expected to address 10 dogs, then 10 instances of that solution would need to be implemented.

The following is a summary of the development of representative units for the Cedar Bayou Watershed.

Development of Representative Units

The representative units were based on the smallest easily segregated unit of a source. For some sources (dogs, cattle, sheep and goats, feral hogs, horses, OSSFs) this meant a single animal or device. For other sources, (urban runoff, WWTFs) the representative unit was based on a divisible unit that correlated to potential loading values in the models or in literature values. The developed units are shown in Table A1.

Table A1: Representative Units

Bacteria Source	Representative Unit
Cattle	One acre of active grazing land
Horses	One horse
Sheep and Goats	One sheep or one goat
Dogs	One dog
Feral Hogs	One feral hog
Deer	One deer[119]
OSSFs	One malfunctioning OSSF
Urban Runoff	One acre of urban land cover *or* One SSO[120]
WWTFs	One million gallons of effluent

The excretion or load generation rates for these units were then developed based on the literature values used for the SELECT modeling, as summarized in Table A2. Where literature values used in the project were not available (WWTFs, SSOs), data from the project was used with additional literature values to provide defensible load assumptions. For urban runoff, one representative unit is an acre of urban area. The average load related to this unit is represented by a general average for the watershed, but also specific averages for each subwatershed (Table A3). As with all other figures used, these values are assumed averages, which may differ from individual to individual, or event to event. However, these estimates are considered precise enough for the purpose of scaling solutions to load reductions targets.

[119] Deer are included in the representative units even though no reduction is planned to be achieved directly from addressing deer waste directly. However, some solutions (riparian buffer maintenance, etc.) may indirectly impact deer waste being transmitted to the waterways.

[120] SSOs were not individually modeled in the SELECT modeling; they were considered to be included in the urban runoff estimations based on literature values. However, solutions may deal directly with SSOs which are not relevant to acres of area, per se. in this instance, literature values for SSOs were adopted from EPA (http://water.epa.gov/polwaste/npdes/cso/upload/csossoRTC2004_AppendixH.pdf) which indicates the concentration for an SSO typical of the watershed (wet weather, which makes up at least 78% of Cedar Bayou SSOs) is 500,000 fecal coliform counts/100mL. With the 50% conversion to *E. coli,* this value becomes 250,000 CFU/100mL. The average SSO volume reported is 12,770 gallons based on the 5 year analysis reported in this WPP. Therefore, the load for a single SSO is 1.2X 10^{11}.

Table A2: Representative Unit Loads

Representative Unit	Daily Load per Unit (in *E. coli)*
One acre of active grazing land[121]	5.70 X 10^8 / 3.42 X 10^8
One horse	1.05 X 10^8
One sheep or one goat	4.50 X 10^9
One dog	1.25 X 10^9
One feral hog	2.23 X 10^9
One deer[122]	6.25 X 10^7
One malfunctioning OSSF	1.99 X 10^{11}
One acre of urban land cover	4.57 X 10^8 (see Table A3)
One SSO	1.20 X 10^{11}
One million gallons of effluent[123]	9.54 X 10^9

[121] The solutions to address cattle sources are based on acres of land in water quality management plans or other related activities. The load value for an acre of grazing land is derived from the loading estimates used for cattle. The densities of cattle per acre of grazing land were based on agricultural census data for each of the counties, which were then reviewed by the stakeholders and the Soil and Water Conservations Districts for each county. The revised figures were a stocking rate of 0.21 cows per care in the Above Tidal, and 0.12 cows per acre in the Tidal. The literature value for cattle loading is 1.35 X 10^9. Therefore, the loading rate per acre of grazing land in Table A2 is expressed as a proportional value to the stocking rate.

[122] Deer are included in the representative units even though no reduction is planned to be achieved directly from addressing deer. However, some solutions (riparian buffer maintenance, etc.) may indirectly impact deer waste indirectly.

[123] The exception to the literature value based methodology is WWTFs. Because the load from a WWTF is variable, the DMR data analysis in Section 5 was used to identify the average exceedances. For plants where either *E. coli* or Enterococcus limits were exceeded on the average, the range of average exceedance was between 1-3X the standard. 2X the standard was chosen as the average level of exceedance for insufficiently treated wastewater. Therefore, the load value of a million gallons of wastewater as a representative unit is equivalent to the load in excess of the permitted limit of 126 cfu/100mL or Enterococcus equivalent. The excess is derived from the average exceedance value minus the permitted limit (378–126 = 252). The resulting value per 100mL was applied to 1 million gallons (a standard unit of daily measurement for WWTFs) to find a daily load per 1 million gallons of insufficiently treated effluent. This is not intended to represent SSOs or untreated effluent, but rather, insufficiently treated effluent of the type demonstrated in the DRM data reviewed.

Table A3: Daily Urban Loads by Subwatershed

Subwatershed	Average Urban Load per Acre[124]
SW1	4.62E+08
SW2	5.22E+08
SW3	5.34E+08
SW4	3.63E+08
SW5	4.49E+08
SW6	6.26E+08
SW7	6.34E+08
SW8	3.67E+08
SW9	4.52E+08
SW10	4.71E+08
Average	4.88E+08
Tidal	*5.91E+08*
Above Tidal	*3.85E+08*

Application of Load Reductions based on Representative Units

The reduction target goals for each segment will be met by reducing sources in proportion to their contribution to loading, using the stakeholder selected solutions. To determine the impact of a solution, an assessment will be made of the number of representative units it will impact of each source (e.g., if a paved acre of urban land is turned into a dog park with a riparian buffer, it might impact 25 representative dogs and 1 acre of urban runoff). The potential impact of a solution is not necessarily 100% of the load from its representative unit. The following notes indicate how reductions will be assessed for solutions that do not remove 100% of the waste they address. Further information on the specific solutions is presented in Section 6.

Partial Removal - Reduction values are based on literature values regarding efficiency of related solutions are included as appropriate with the discussion of the specific solutions in Section 6. The reduction value of a solution will be based on the efficiency rate of the solution (See the specific entries for each solution in Section 6) multiplied by the number of representative units. Therefore, a land management practice expected to reduce 50% of the load from 200 head of cattle would be equivalent to reducing the load from 100 representative units.

[124] These values are dependent on the specific mix of developed and undeveloped areas, and the mix of developed types specific to each subwatershed's land cover. Therefore, these values will change over time. For the purpose of this effort, the 2025 values were used. The values should be updated in future revisions.

Similarly, if a solution reduces 100% of the waste for less than 100% of the time, it will be handled in the same manner. For example, if a dog park/pet waste stations handles one out of four fecal loads for 100 dogs, it will be considered equivalent to reducing the total load of 25 representative units (100/4=25).

Education and Outreach – Education events, unless otherwise noted in Section 6, are expected to be part of a larger comprehensive effort. Literature values indicate that a comprehensive education and outreach campaign will result in a 2% reduction in overall load (Abroms et al., 2008). This 2% is applied equally to all sources because no reasonable method could be found to parse out differential impacts on one source over another.

Complimentary Efforts – In addition to the efforts undertaken as part of this WPP (and as further detailed in Section 6), it is expected that other concurrent efforts will also reduce bacteria load. Some of these efforts or trends are unable to be completely quantified (market changes affecting agricultural production, etc.) while some are more definable. Specific efforts expected to have an appreciable impact on bacteria levels (as well as nutrients and DO) are:

- TPDES Stormwater Permits – One Phase 1 (Harris County/TXDOT) and several Phase II TPDES permits exist for MS4s in the watershed. As of the most recent permit round, bacteria source identification and remediation is a requirement to different degrees. As of the time of the writing of this WPP, it is unknown what impact the new permits will have. It is expected that existing efforts outlined in MS4 permits for the watershed will contribute greatly to bacteria reduction measures, especially in terms of education and outreach. Until specific measures are known, precise estimates of the impact of these permit requirements will not be known. Unless specifically called out in Section 6, it will be assumed all actions conducted under these permits to reduce bacteria that are education or outreach based are complementary to WPP efforts. All other efforts will be considered to be in excess of the WPP efforts until permit information or specific project data is available.
- Ongoing maintenance – Our estimates for some sources (OSSFs) do not assume that predicted failing systems will be replaced without intervention. However, it is expected that some will be replaced by residents, in excess of efforts by this project. Additionally, it is expected that some WWTF or MS4 issues may be corrected through standard maintenance without additional effort under stormwater permits or this WPP. In general, except as noted in Section 6, we do not assume any reductions from these sources under the reduction estimates for this WPP.

Special Cases – In some cases (as identified in Section 6 or as arise in the process of adaptive management in future revisions) specific reductions may be more accurately measured for a solution based on alternative measures. For example, the installation of a wet bottom retention structure for stormwater may be better estimated through influent and effluent paired monitoring. In the case more specific data for any solution is known, it will be used to generate reductions.

SSOs are a special case in terms of urban sources. The SSO value expressed in Table A2 is a daily value. However, because SSOs are not chronic sources, and do not represent continual daily loading, the scaling methodology cannot be adequately applied to them. The representative unit for urban sources, therefore, remains an acre of impervious cover. However, it is expected that SSO reductions will make up a sizeable portion of that load.

APPENDIX B – ADDITIONAL SOLUTIONS

The solutions presented in Section 6 represent the top tier of priority for the stakeholders. However, additional solutions were developed for consideration. These solutions are included with this WPP to enable the adaptive management process. All the solutions presented in Table B1 were approved by the stakeholders, and represent viable solutions for the watershed if higher priority solutions are not effective, or if opportunities arise.

Table B1 – Potential future solutions (second and third tier priorities)

Bacteria Source	Solution	Funding and Resources	Purpose	Priority Tier
Cattle, Agricultural, Wildlife	Use land management techniques to reduce nutrients and sediment (filter strips, cover crops, conservation tillage, prescribed grazing, contour plowing, etc.)	• Landowners • Financial incentive programs (EQIP, et al.) • Technical Assistance (AgriLife Extension, et al.) • WQMPs (TSSWCB)	• Reduce incidental bacteria, nutrients in storm flow from reaching waterways • Reduce sediment load	2
Cattle, Agricultural	Establish conservation easements	• Landowners • Local Governments • Land trusts	• Reduce runoff • Ensure riparian areas remain as buffers • Reduce future impervious cover in crucial areas	2
Feral Hogs	Assess populations/locations	• H-GAC or other appropriate academic or scientific body • Local stakeholders	• Further assess populations/ locations	2
WWTFs	Adopt or update asset management programs/proactive maintenance	• Utilities • Grant funding as available	• Reduce SSOs • Reduce future utility costs	2

WWTFs	Consolidate aging/undersized/ routine problem facilities with larger adjacent facilities	• Utilities • Grant/loan funding as available	• Reduce overflows and poor quality effluent	3
OSSFs	Increase enforcement	• Local/State Government	• Reduce failing systems	2
OSSFs	Connect properties with old/failing OSSFs to sanitary sewer	• Homeowner contribution (connection) • Local utility/ authorized agent (capital costs)	• Reduce old/failing OSSFs, prevent future failures	2
OSSFs	Enact local ordinances/requirements to have OSSFs inspected annually by licensed professional	• Property owner annual cost • Authorized agent staff time to enact ordinance	• Prevent failures and ensure proper maintenance	2
OSSFs	Require existing system inspections during property purchases	• Property owner, buyer • Authorized agent (for enacting requirements)	• Find/prevent existing failures at point of sale	2
Stormwater	Revise traditional drainage to incorporate more natural meanders/ wider channel (FGM approach by HCFCD)	• Harris County Flood Control District	• Increase filtration, reduce speed of flow	2
Stormwater, All Sources	Maintain or increase buffers in riparian areas	• Local government (ordinances and enforcement) • Partner agencies (conservation easements, public advocacy) • Private landowners (behavior change, donations, easements)	• Filter storm flows to reduce contamination	2

NA (Monitoring component)	Conduct bacteria source tracking	• H-GAC • Grants as available	• Further assess contribution of sources;	2
Stormwater	Install or retrofit wet-bottom detention	• Local government/ district capital funds • Grant funds as available (GBEP WSQ, etc.)	• Reduce bacterial contamination in storm flows • Improve drainage	2
Stormwater	Institute watershed protection regulations[125] (setbacks from water's edge, drainage requirements, etc.)	• Local Governments • Counties	• Reduce contamination from storm flow in developed areas	2
NA (Monitoring component)	Conduct bacteria source tracking	• H-GAC • Grants as available	• Further assess contribution of sources;	2
NA (Research component)	Further assess avian/bats populations and solutions	• H-GAC • TPWD • Local governments with bridges	• Identify where avian populations may be an appreciable source • Assess solution options	3

[125] It should be noted that this refers to ordinances in addition to the existing City of Baytown Watershed Protection Ordinance, which is a top tier priority.