2020 Basin Highlights Report

A Watershed Characterization of Little White Oak Bayou, Clear Creek Tidal, Clear Creek Above Tidal, Mustang Bayou, and Halls Bayou

INTRODUCTION

Whether it is swimming, shipping, fishing, industry, or tourism, water is integral to the way of life for the 6.5 million people living in the Houston-Galveston region. With over 16,000 miles of streams and shorelines, water is all around us. The water that flows through our ditches, creeks, streams, bayous, and rivers feed into one of the nation's most productive estuaries, Galveston Bay, before entering the Gulf of Mexico. These waters fuel our economy, bringing in billions of dollars and providing tens of thousands of jobs. Over 6.5 million people share these resources, and with another 3.8 million people expected to move to the region over the next 20 years, the strain put on these water resources will continue to rise.

The 2020 Basin Highlights Report provides watershed characterizations for several stream segments within the region. This report characterizes the Little White Oak Bayou (Segment 1013A), Clear Creek Tidal (Segment 1101), Clear Creek Above Tidal (Segment 1102), Mustang Bayou (Segment 2432A), and Halls Bayou (Segment 2432C) watersheds. The watershed characterizations identify:

- Specific water quality issues and trends;
- Sources of point and nonpoint source pollution;
- Current strategies and plans to reduce pollution within these watersheds; and
- Current and potential stakeholders within these watersheds.

H-GAC's CLEAN RIVERS PROGRAM

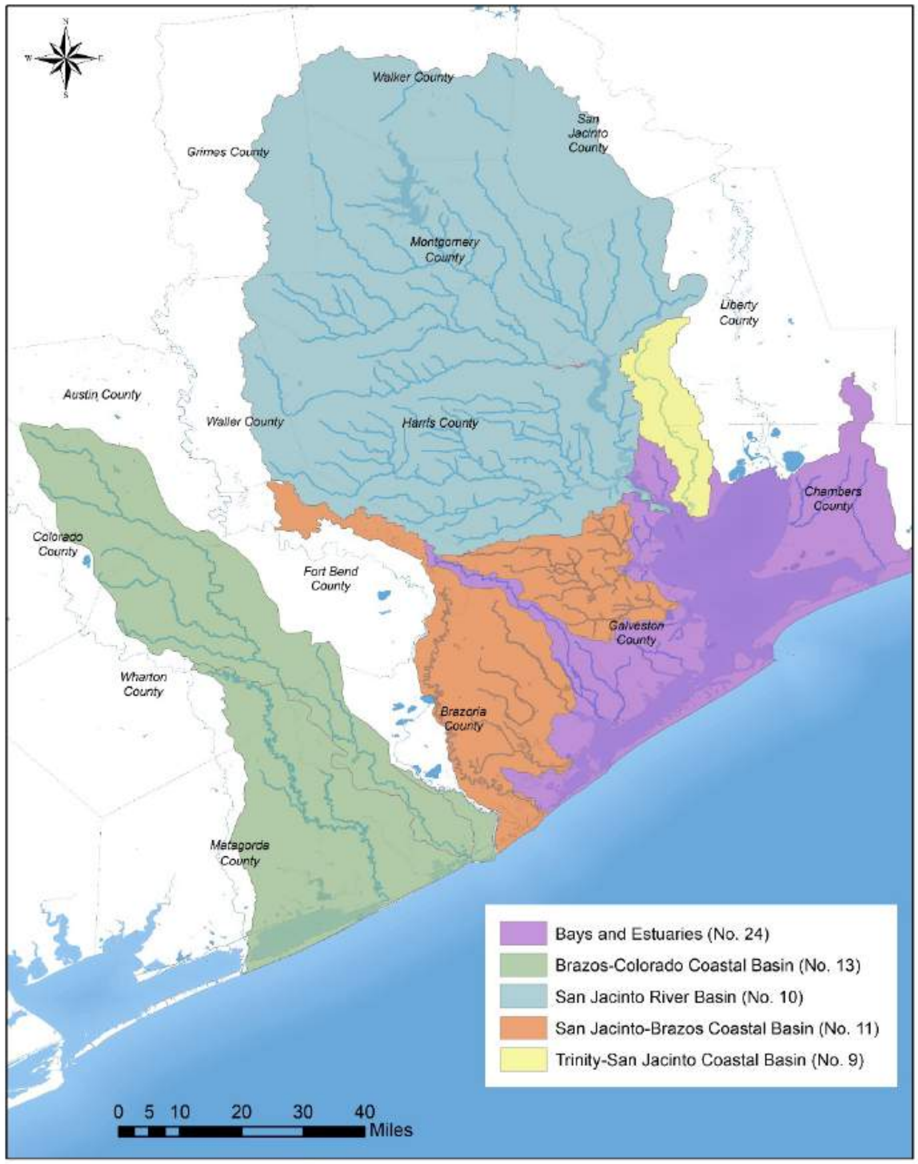
The Houston-Galveston Area Council's (H-GAC) Clean River Program is charged with conducting water quality monitoring and assessment to determine the health of water bodies throughout the region. H-GAC's Clean Rivers Program does this through a coordinated effort with local partners and the Texas Commission on Environmental Quality (TCEQ). In addition to analyzing monitoring data, H-GAC assesses factors and activities affecting water quality. Through an extensive public education and outreach program, H-GAC provides information on regional water quality and recommendations on what individuals, industry, and local governments can do to preserve and make improvements to local waterways. Data acquired through the Clean Rivers Program provides support for all watershed-based activities in the region.

COUNTIES AND BASINS

H-GAC's Clean Rivers Program uses a coordinated approach to water quality monitoring. H-GAC's extensive water quality monitoring activities cover one river and three coastal basins in all or a portion of 15 counties:

- Austin
- Brazoria
- Chambers
- Colorado
- Fort Bend
- Galveston
- Grimes
- Harris
- Liberty
- Matagorda
- Montgomery
- San Jacinto
- Walker
- Waller
- Wharton

H-GAC's Clean Rivers Program Basins



The four basins included in H-GAC's Clean Rivers Program study area are:

- San Jacinto River Basin
- Brazos-Colorado Coastal Basin
- San Jacinto Coastal Basin
- Trinity-San Jacinto Coastal Basin

The Bays and Estuaries are also included.

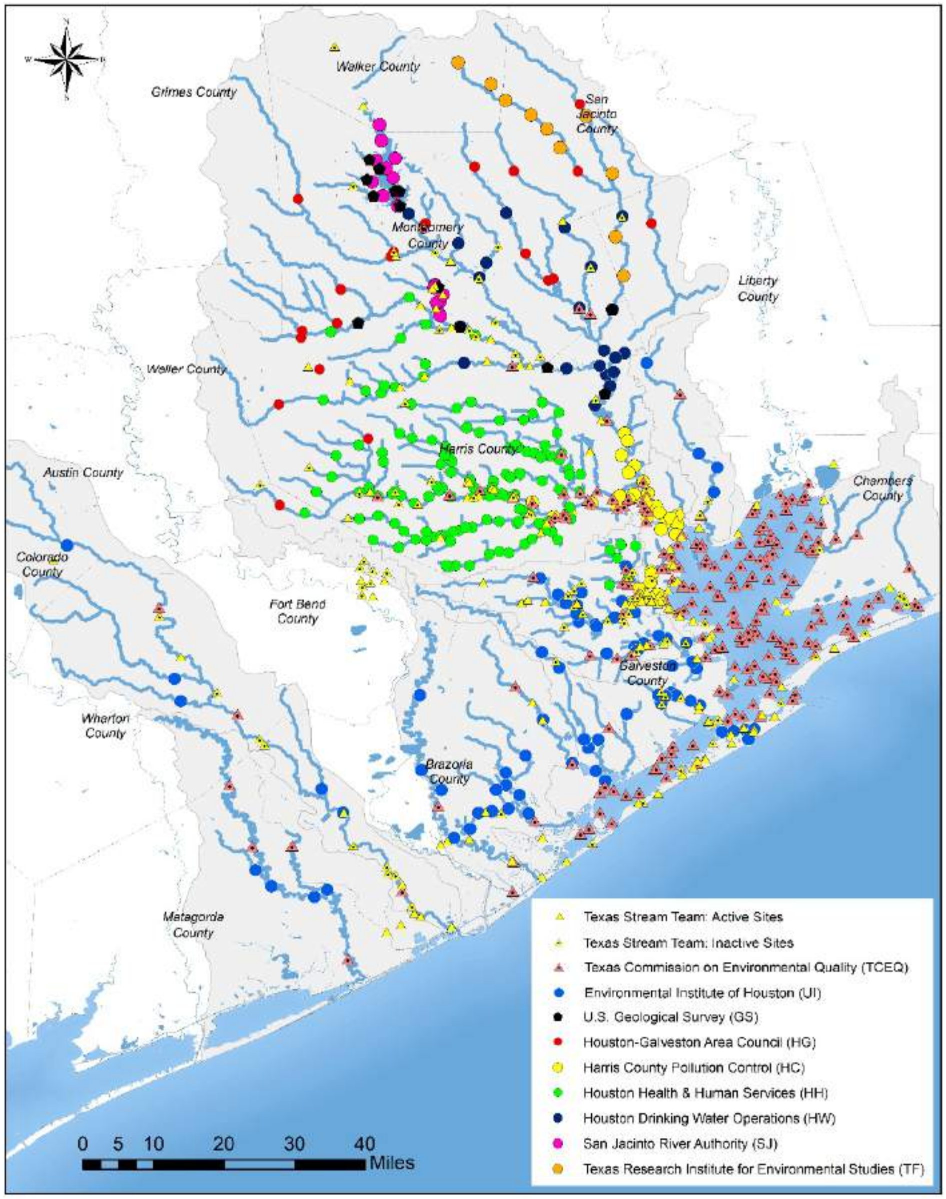
MONITORING PARTNERS AND CONTRACTORS

H-GAC's Clean Rivers Program monitoring includes more than 370 coordinated sampling sites and six regional partners.

These partners are:

- City of Houston Health Department
- City of Houston Drinking Water Operations
- Environmental Institute of Houston (EIH) | University of Houston-Clear Lake
- Harris County Pollution Control Services
- San Jacinto River Authority (SJRA) – Lake Conroe Division & The Woodlands Division
- Texas Research Institute for Environmental Studies | Sam Houston State University

Clean Rivers Program Monitoring Stations



Other agencies contributing data used by the Clean Rivers Program include:

- Texas Commission on Environmental Quality
- United States Geological Survey (flow gage data)

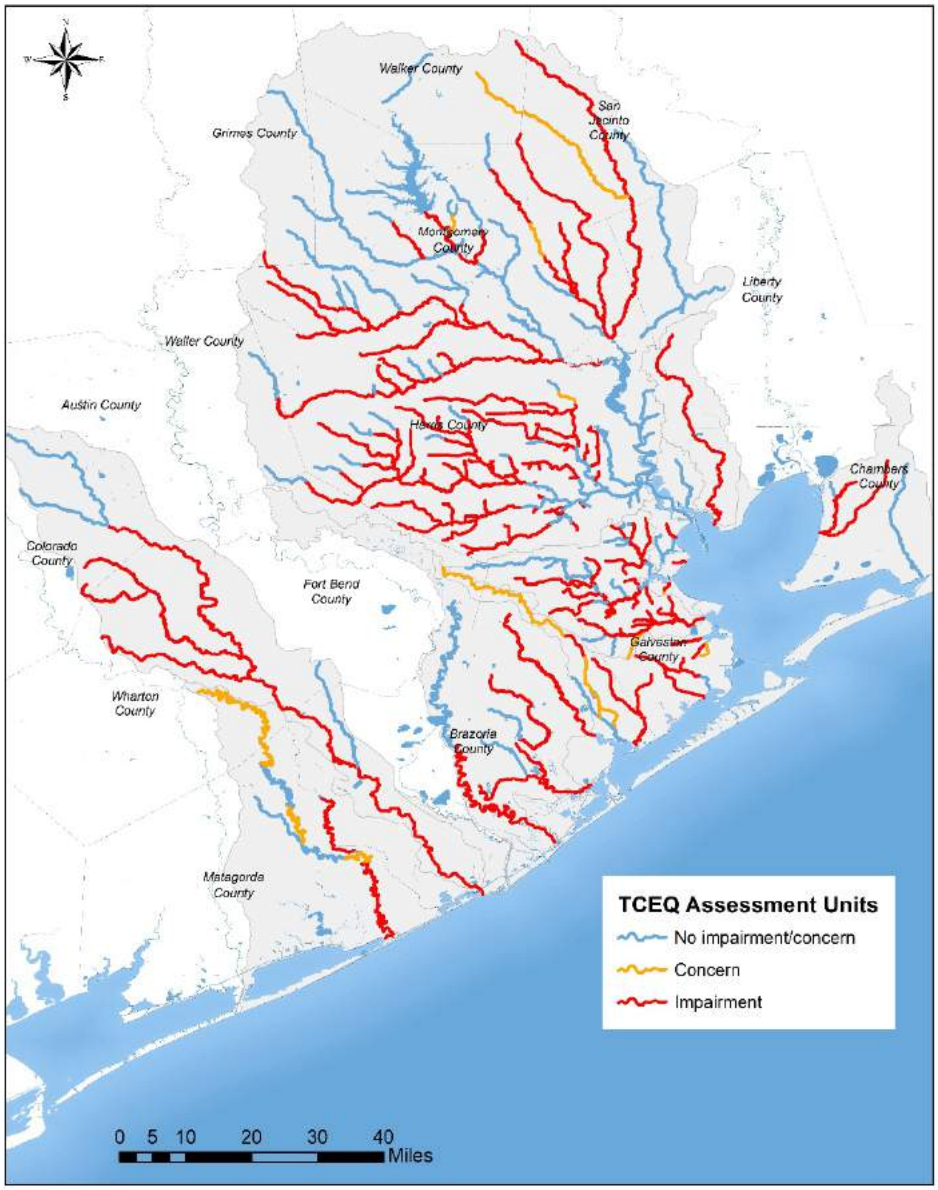
BACTERIA

42% of stream miles in our region are impaired due to elevated levels of bacteria

In the Houston-Galveston region, one of the most significant water quality issues faced is elevated levels of bacteria in our local waterways.

Bacteria concentrations are measured to ensure a water body is safe for recreation. Enterococci is collected in tidal waterways, while *E. coli* is collected in freshwater. Both are found in digestive tracts in people and animals and are used as indicators of the presence of sewage and pathogens (such as infectious bacteria, viruses, and protozoans). High bacterial concentrations may cause gastrointestinal illnesses or skin infections in swimmers or others who come into direct contact with the water.

Bacteria Impairments and Concerns



Sources of bacterial contamination include:

- untreated wastewater treatment facility (WWTF) releases;
- sanitary sewer overflows;
- failing on-site sewage facilities (septic systems); and
- fecal waste from livestock, pets, feral hogs, and other wildlife.

DISSOLVED OXYGEN

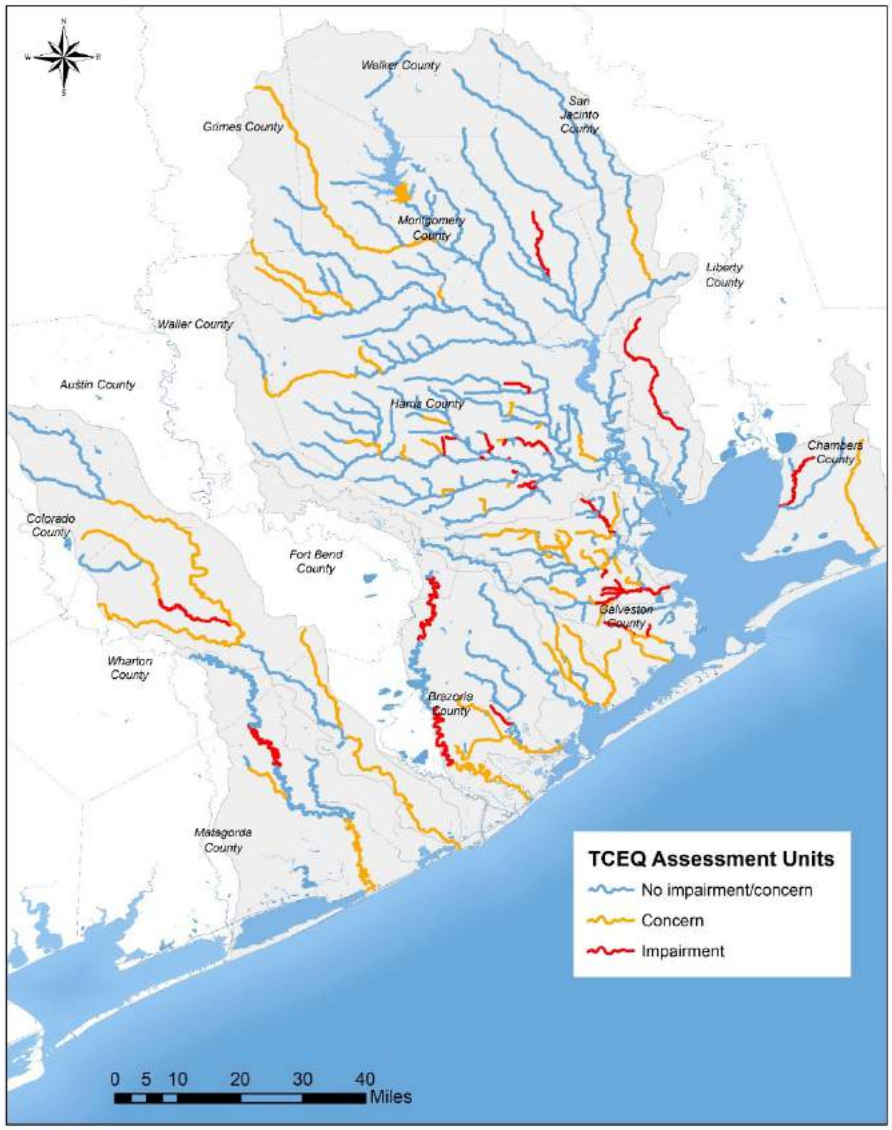
22% of stream miles in our region are impaired for
low levels of dissolved oxygen

Dissolved Oxygen (DO) levels are measured to ensure a water body can support aquatic life. As a general rule, higher levels of DO can support more abundant and diverse aquatic species. DO levels fluctuate naturally based on season and time of day; however, human activities can have a negative effect on DO concentrations in water bodies. Sudden or prolonged decreases in DO could result in fish kills.

DO levels can be negatively impacted by many factors, including:

- high concentrations of nutrients that cause algal blooms;
- sediment from construction sites;
- overgrazing of livestock;
- stream channel modification and development; and
- reduced riparian tree cover.

Dissolved Oxygen Impairments and Concerns



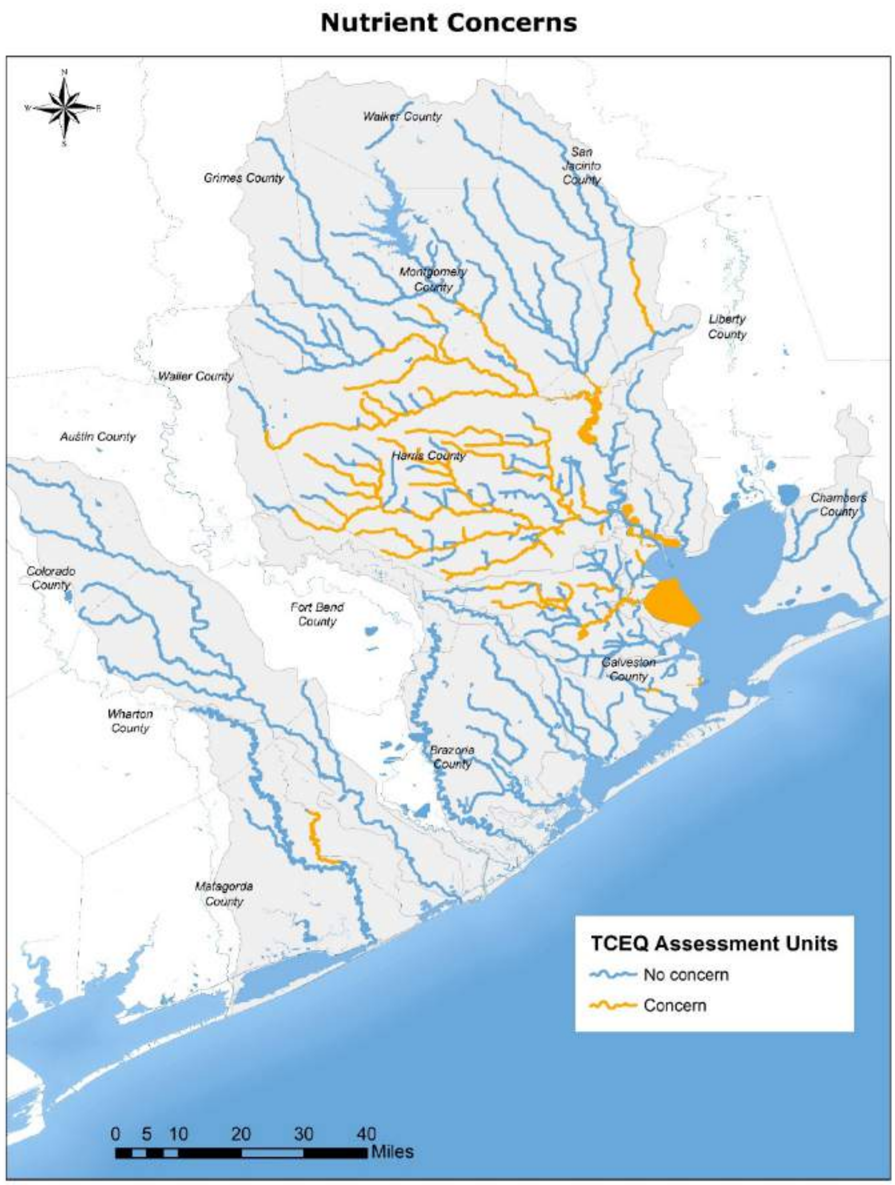
NUTRIENTS

35% of stream miles in the region exceed state screening levels for nutrients, such as nitrate, ammonia, and phosphorus

Nutrients, including phosphorus and nitrogen, occur naturally in surface waters. They are an important part of a healthy aquatic ecosystem. However, human activities can contribute excessive nutrients to water bodies. High concentrations of nutrients can result in algal blooms, which can depress DO levels and produce toxins that are harmful to humans and aquatic species.

Sources of nutrient pollution include:

- fertilizer runoff from lawns and agricultural fields;
- animal manure;
- sewage treatment plant discharges;
- stormwater runoff;
- and failing on-site sewage facilities, including septic systems.



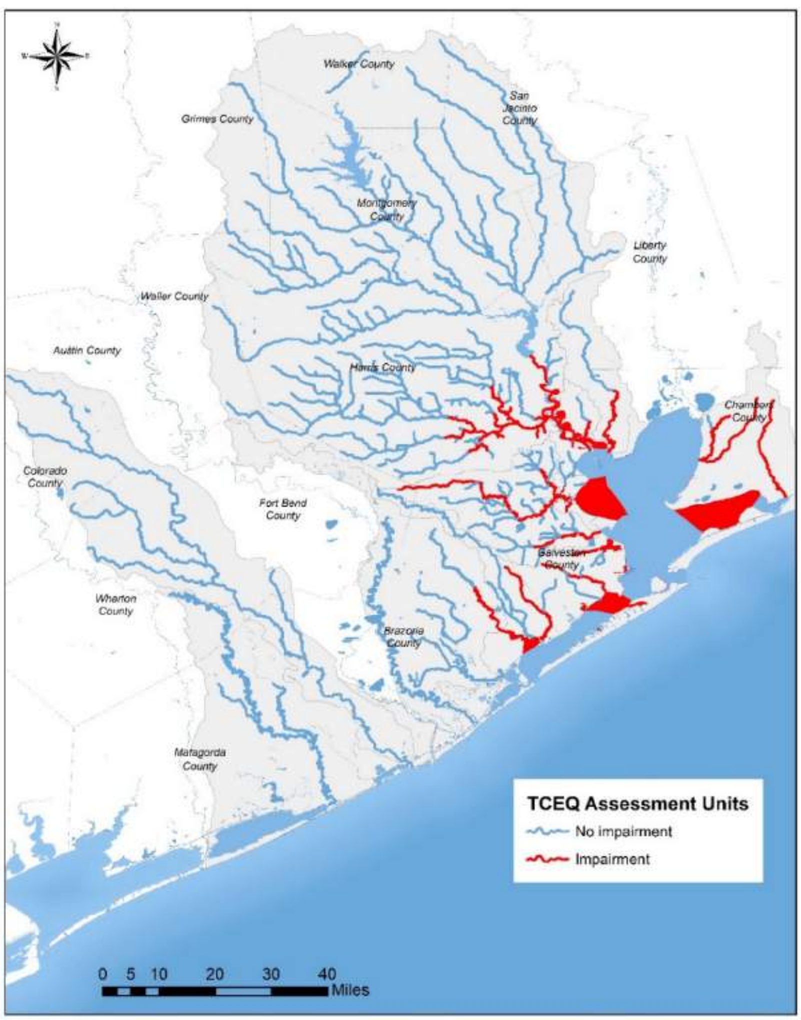
PCBs AND DIOXINS

6% of freshwater streams, 60% of tidal streams, and 75% of bays in our region are impaired for PCBs and Dioxin

PCBs, or polychlorinated biphenyls, and Dioxins are broad groups of synthetic organic compounds developed for industrial purposes or are by-products of industrial processes. PCBs and Dioxins are toxic and carcinogenic. PCBs and Dioxins are legacy pollutants, meaning they can remain in the environment long after they are introduced. Both accumulate in the fatty tissue of marine life, and humans can be exposed through consumption of contaminated fish and shellfish.

Clear Creek, which is characterized in this 2020 Basin Highlights Report, has a fish consumption advisory (ADV-37) issued by the Texas Department of State Health Services (TDSHS) due to elevated levels of PCBs. The consumption advisory recommends that people should not consume any species of fish from these waters.

PCBs and Dioxins Impairments



2020 REGIONAL WATER QUALITY SUMMARY

The numbers represent the percent of the total segment length that is impaired or of concern for each parameter. Cells without numbers (blanks) represent stream segments that are currently meeting state standards but may be improving or degrading for each parameter.

Basin	Watershed	Segment	DO	Bact	Chl-a	Nutr	PCB	Other*	Frogs
Trinity-San Jacinto Coastal	Cedar Bayou	0901		100			100		🐸
	Cedar Bayou Above Tidal	0902	100	100					🐸🐸🐸
San Jacinto River	Buffalo Bayou Above Tidal	1014	13.4	75.2		60.5			🐸🐸🐸
	Buffalo Bayou Tidal	1013	37.4	86.8	49.4	49.4			🐸🐸
	Caney Creek	1010	16.8	69.2					🐸🐸🐸
	Cypress Creek	1009	28.7	77.7	11.7	77.7		11.7	🐸🐸🐸
	East Fork San Jacinto River	1003		100					🐸🐸🐸
	Greens Bayou Above Tidal	1016	8.6	95.9	16.6	77.0			🐸🐸🐸
	Houston Ship Channel	1006	14.4	49.7	16.8	62.3	36.3	20.2	🐸🐸🐸
	Houston Ship Channel/Buffalo Bayou Tidal	1007	17.6	70.3	23.2	65.3	28.6	1.9	🐸🐸🐸
	Houston Ship Channel/San Jacinto River Tidal	1005					100		🐸🐸🐸
	Lake Conroe	1012	4.5						🐸🐸🐸🐸🐸
	Lake Creek	1015	70.8	12.1					🐸🐸🐸🐸
	Lake Houston	1002	20.9	7.0	27.4	48.3		0.1	🐸🐸🐸🐸
	Peach Creek	1011		100					🐸🐸🐸
	San Jacinto River Tidal	1001					36.5		🐸🐸🐸🐸
	Spring Creek	1008	23.3	64.6	1.2	37.4		3.6	🐸🐸🐸
	West Fork San Jacinto River	1004		27.9		25.8			🐸🐸🐸🐸
	Whiteoak Bayou Above Tidal	1017	11.7	87.0		79.5			🐸🐸
San Jacinto - Brazos Coastal	Armand Bayou Tidal	1113	61.4	73.7	40.6	16.9	23.7		🐸🐸🐸
	Bastrop Bayou Tidal	1105	44.8	68.7					🐸🐸🐸
	Chocolate Bayou Above Tidal	1108		100					🐸🐸🐸
	Chocolate Bayou Tidal	1107		100			100		🐸
	Clear Creek Above Tidal	1102	58.0	47.8		64.0	49.4	13.4	🐸🐸
	Clear Creek Tidal	1101	38.7	77.3	5.3	36.9	29.9		🐸🐸🐸
	Dickinson Bayou Above Tidal	1104	31.9	54.5					🐸🐸🐸
	Dickinson Bayou Tidal	1103	88.1	100	2.6		39.7		🐸🐸
	Old Brazos River Channel Tidal	1111			100				🐸🐸🐸🐸🐸
	Oyster Creek Above Tidal	1110	59.3	27.0				96.8	🐸🐸🐸
	Oyster Creek Tidal	1109	100	100					🐸🐸

Basin	Watershed	Segment	DO	Bact	Chl-a	Nutr	PCB	Other*	Frogs
Brazos-Colorado Coastal	Caney Creek Above Tidal	1305	28.4	55.0				14.4	🐸🐸🐸
	Caney Creek Tidal	1304	43.5	98.0	34.3	34.3			🐸🐸🐸
	San Bernard River Above Tidal	1302	61.5	71.1				7.3	🐸🐸🐸
	San Bernard River Tidal	1301	100	100					🐸🐸
Bays & Estuaries	Barbours Cut	2436				100	100		🐸🐸
	Bastrop Bay / Oyster Lake	2433							🐸🐸🐸🐸🐸
	Bayport Ship Channel	2438	100		100	100	100	100	🐸
	Black Duck Bay	2428			100	100	100		🐸🐸
	Burnett Bay	2430			85.9	100	100		🐸🐸
	Chocolate Bay	2432	45.6	65.0			38.7		🐸🐸🐸
	Christmas Bay	2434							🐸🐸🐸🐸🐸
	Clear Lake	2425		10.8	71.7	71.7	82.4	65.1	🐸🐸
	Drum Bay	2435							🐸🐸🐸🐸🐸
	East Bay	2423	30.0		100		100		🐸🐸
	Lower Galveston Bay	2439			100	61.7	100		🐸🐸
	Moses Lake	2431		47.5	15.8		43.8		🐸🐸🐸
	San Jacinto Bay	2427				100	100		🐸🐸
	Scott Bay	2429				100	100		🐸🐸
	Tabbs Bay	2426				34.9	61.5		🐸🐸🐸
	Texas City Ship Channel	2437			100	100	100		🐸🐸
	Trinity Bay	2422			100		100		🐸🐸
	Upper Galveston Bay	2421			89.5	100	100		🐸🐸
	West Bay	2424	11.5	9.3	8.2	2.3	88.5		🐸🐸🐸
	Gulf of Mexico	2501						100	🐸🐸

Chart Key

DO = Dissolved Oxygen Bact = Bacteria Chl-a = Chlorophyll-a Nutr = Nutrients PCB = PCB/Dioxins Other = See Below

🐸	Severe, multiple water quality impairment(s) or concern(s) exist in a majority of the waterbody
🐸🐸	Significant, multiple water quality impairment(s) or concern(s) exist in the waterbody
🐸🐸🐸	Water quality impairment(s) or concern(s) exist in a substantial portion of the waterbody
🐸🐸🐸🐸	Water quality impairment(s) or concern(s) exist in the waterbody
🐸🐸🐸🐸🐸	No significant water quality impairments or concerns exist in the waterbody

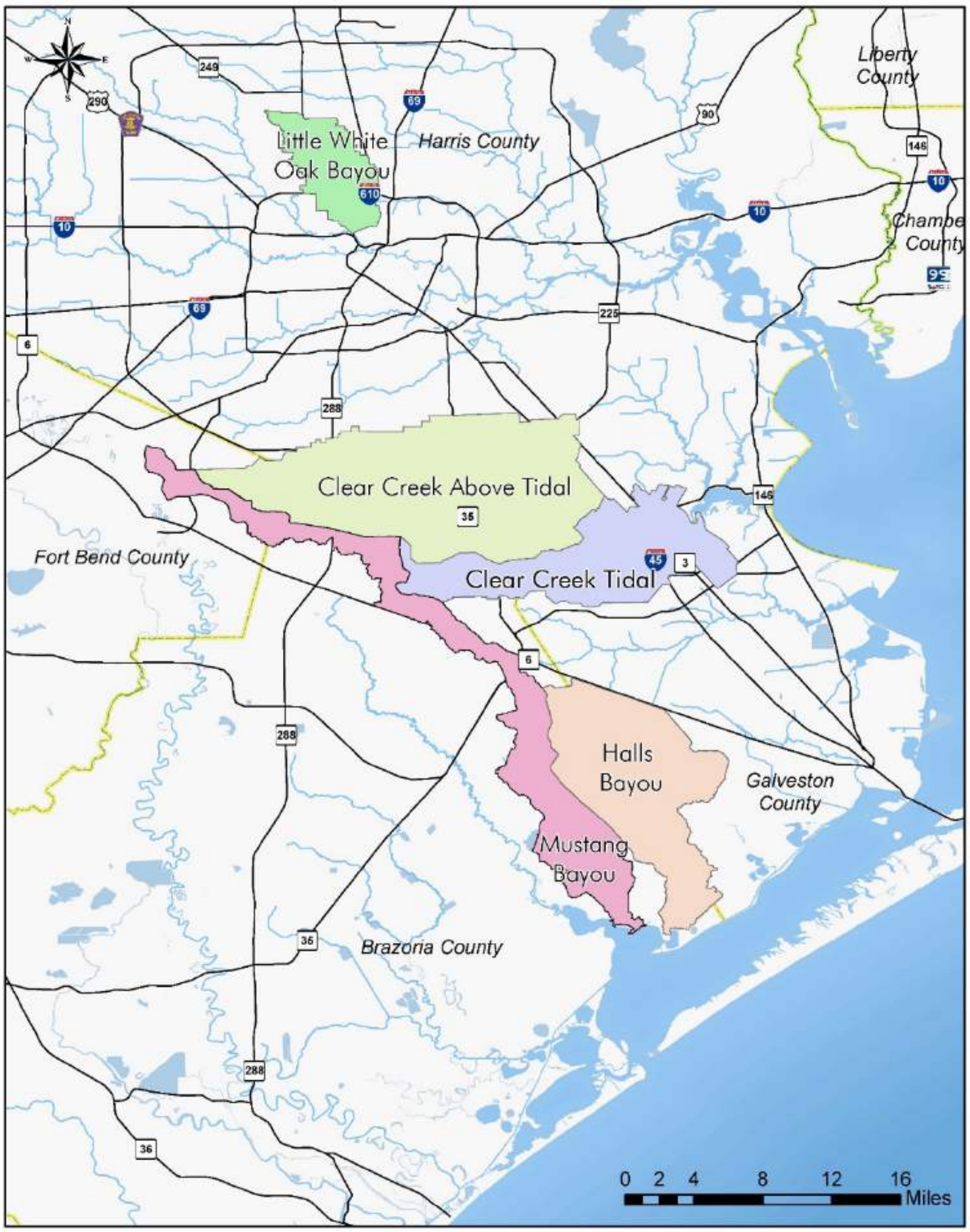
Improving Degrading

***Other** includes parameters such as metals in water, metals in sediment, impaired habitat, impaired benthic macroinvertebrates, impaired fish communities, sediment toxicity, fecal coliform, mercury in fish tissue, and fish contamination.

WATERSHED CHARACTERIZATIONS

The 2020 Basin Highlights Report characterizes select water bodies within the Houston-Galveston region. For this report, H-GAC has chosen to characterize the Little White Oak Bayou (1013A), Clear Creek Tidal (1101), Clear Creek Above Tidal (1102), Mustang Bayou (2432A), and Halls Bayou Tidal (2432C) watersheds. These watershed characterizations may be used to help prioritize monitoring efforts and in the development of watershed-based plans [such as Total Maximum Daily Loads (TMDLs) or watershed protection plans] to improve water quality.

Characterization Sites



Each watershed characterization will include the following sections:

- **Segment Description –** A description of the segment, assessment unit (AU) boundaries, and monitoring sites within each segment.

- **Hydrological Characteristics –** Streamflow variability, reservoir dynamics, seasonality of flow and typical flow trends.

- **Land Cover and Natural Characteristics –** A description of the land surrounding a segment, including developed lands, agricultural lands, forest/shrubs, barren land, open water, and wetlands.

- **Descriptions of Water Quality Issues –** Identification of the reason why the water body is listed as impaired and when it first appeared on the 303(d) List or why it is in an area of interest. This includes the number of samples, parameters of concern or impairment, assessment results, and the designated state water quality standard for comparison.

- **Potential Sources of Water Quality Issues** – Possible sources of water quality issues identified through land use and land cover, watershed surveys, and communications with stakeholders and staff from local and state agencies.

- **Potential Stakeholders** – Companies, agencies, organizations, or individuals that have a vested interest in the area.

- **Ongoing Projects** – Current or future projects within the segment.

- **Major Watershed Events** – Anticipated or known occurrences that have the potential to either positively or negatively affect water quality.

- **Recommendations for Improving Water Quality** – Proposed next steps based on the potential sources of impairment or concern.

For more information, including a list of acronyms, a glossary of water quality terminology, a technical primer, and information regarding the statistical methodology used for H-GAC's water quality analyses presented in this report, please refer to the appendices.

For more information on H-GAC's Clean Rivers Program, please visit
www.h-gac.com/community/water/rivers/default.aspx.

PREPARED IN COOPERATION WITH THE
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
The preparation of this report was financed through funding
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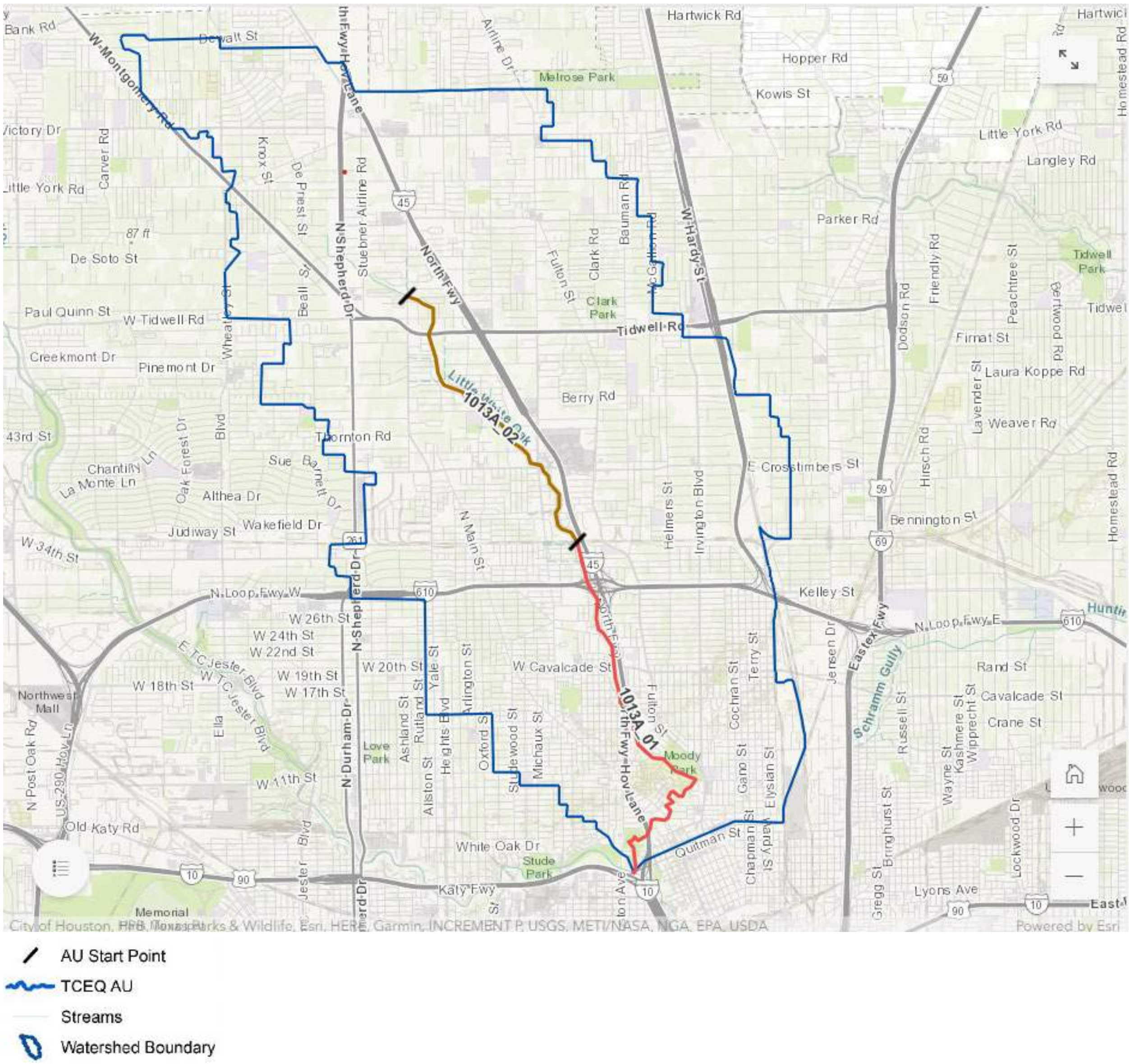
DETAILED WATERSHED CHARACTERIZATION
Little White Oak Bayou (1013A)

Figure 1- Little White Oak Bayou at White Oak Drive in North Houston (Monitoring Station 16648)

SEGMENT DESCRIPTION

Little White Oak Bayou (Segment 1013A) is a freshwater tributary to White Oak Bayou and is located north of downtown Houston. The segment description for Little White Oak Bayou describes the water body as spanning from the White Oak Bayou confluence to Yale Street in Harris County (Map 1). Little White Oak Bayou is composed of two assessment units (AUs) (Table 1).



Map 1 - Watershed map showing the extent of the drainage area of Segment 1013A (Little White Oak Bayou)

Table 1 - Assessment Units in Segment 1013A (Little White Oak Bayou)

Segment Name	Segment ID	AU	Description
Little White Oak Bayou	1013A	1013A_01	From the confluence with White Oak Bayou upstream to the railroad tracks north of IH 610.
Little White Oak Bayou	1013A	1013A_02	From the railroad tracks north of IH610 upstream to Yale Street

HYDROLOGICAL CHARACTERISTICS

The Little White Oak Bayou watershed receives flow from runoff only. There are no regulated wastewater treatment facilities the watershed. Harris County Flood Control District (HCFCD) has constructed several large detention basins along the waterway to receive and hold above-normal stormwater volumes. The detained stormwater slowly drains out of the detention basin as the flow and water surface elevation in the adjacent stream recedes. Some of these basins have an added benefit of helping reduce the sediment load washing down the stream while others were constructed to accommodate other uses, such as hike and bike trails, sports fields, wildlife habitat, etc. There are at least 10 such detention basins in this watershed.

There is one US Geological Survey (USGS) stream gage in this watershed at Trimble Street on the north edge of Hollywood Cemetery. USGS Gage 08074540 is a ”partial record” gage site, which means while this gage records gage height/water level at all times, the discharge is computed only during high flows. In 2005, the USGS and HCFCD determined flows in White Oak Bayou could affect the discharge measured at this gage. Both agencies agreed discharge measurements were only reliable at flows of > 100 cubic feet per second (cfs). Subsequently, no discharge measurements are calculated or published for flows < 100 cfs. Approximately 30-35 percent of the recorded flows between 2012 and 2019 were > 100 cfs.

LAND COVER AND NATURAL CHARACTERISTICS

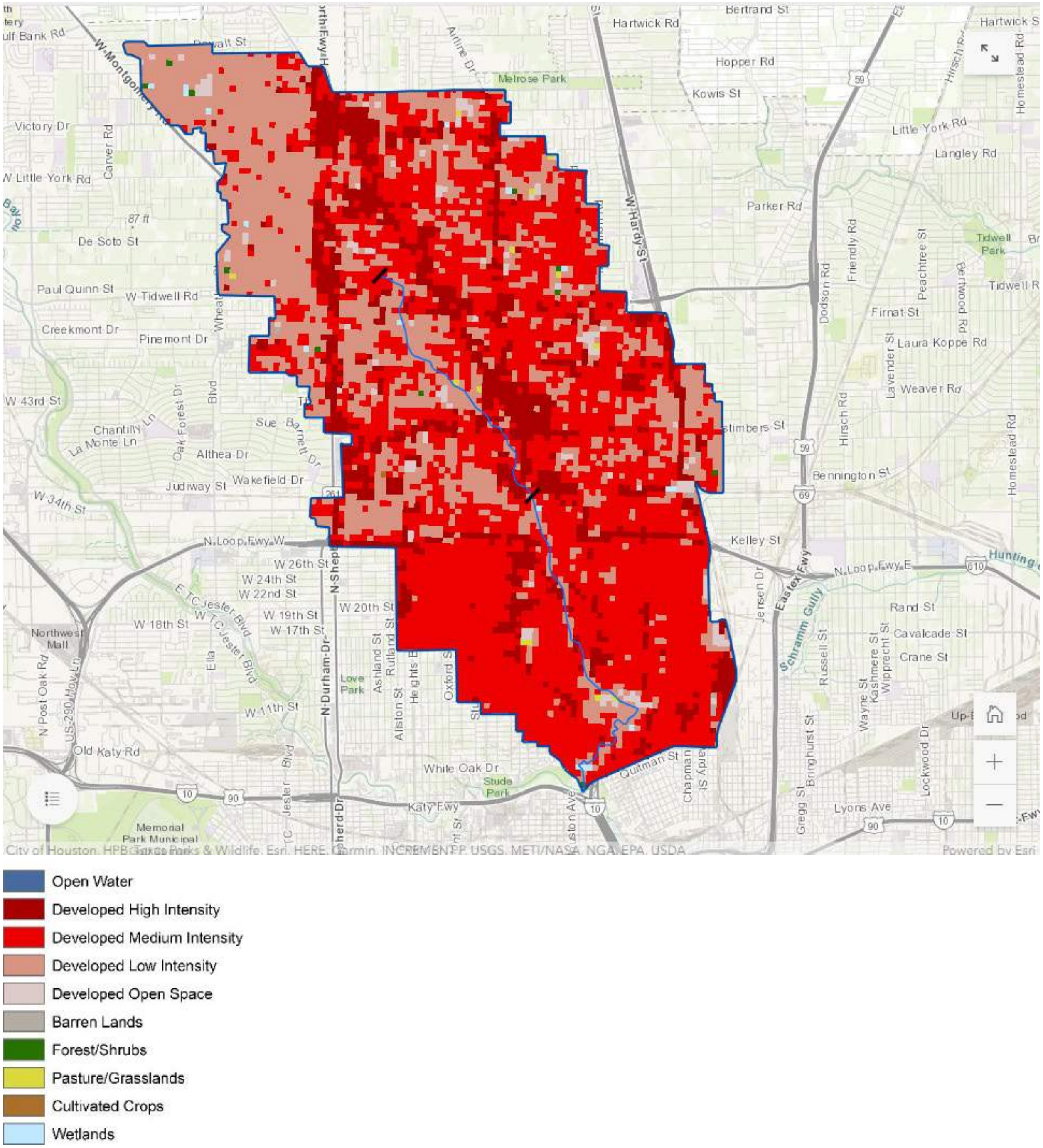
The Little White Oak Bayou watershed covers approximately 14,100 acres. The land cover (Table 2) consists almost entirely of developed land, which comprises 99.32 percent of the land cover. There has been very little change in the land cover between 2008 and 2018. The greatest changes were in lost open water, which could be explained by detention basins being dry, and lost forested/shrub acres. Barren lands had the greatest increase during this time period due to land clearing for more development.

Table 2 - Land Cover Comparison for Little White Oak Bayou, 2008 to 2018

Land Cover Class Name	Area Acres 2008	Area % 2008	Area Acres 2018	Area % 2018	% Change
Agriculture	35.03	0.25	27.95	0.20	-20.22
Barren Lands	0.89	0.01	11.98	0.09	1250.64
Developed	13961.53	99.05	13989.94	99.32	0.20
Forest/Shrubs	46.34	0.33	21.96	0.16	-52.61
Open Water	7.98	0.06	0.00	0.00	-100.00
Wetlands	43.23	0.31	33.94	0.24	-21.50
TOTAL	**14095.00**	**100.00**	**14085.76**	**100.00**	

More than 50 percent of the land cover is identified as medium intensity urban development. The high intensity urban development is primarily along the I-45 corridor and N. Shepherd Drive, which run north to south through the watershed, and Loop 610 North, which runs east to west in the watershed (Map 2). Low intensity development is scattered throughout the watershed, mostly in the northwest section.

Table 3 provides a description of the major land cover classes.



Map 2 - Land Cover in the Little White Oak Bayou watershed

Table 3 - Description of Land Cover classes

Map Key	Land Cover Class	Class Description
	Developed, High Intensity	Contains significant land area and is covered by impervious surfaces (i.e., concrete, asphalt, and other constructed materials). Vegetation, if present, occupies < 20 percent of the landscape. Impervious surfaces account for 80 to 100 percent of the total cover. This class includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas with a variety of land uses.
	Developed, Medium Intensity	Contains areas with a mixture of impervious surfaces and vegetation or other cover. Impervious surfaces account for 50 to 79 percent of total area. This class commonly includes multi- and single-family housing areas, especially in suburban neighborhoods, but may include all types of land use.
	Developed, Low Intensity	Contains areas with a mixture of impervious surfaces and substantial amounts of vegetation or other cover. Impervious surfaces account for 21 to 49 percent of total area. This class commonly includes single-family housing areas, especially in rural neighborhoods, but may include all types of land use.
	Developed, Open Space	Contains areas with a mixture of some impervious surfaces, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes. Impervious surfaces account for less than 20 percent of total land cover. This class commonly includes large-lot single family housing units, parks, and golf courses.
	Agriculture, Pasture/Grasslands	Contains both managed and unmanaged grasses, legumes, or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas can be subjective to intensive management, such as tilling, and utilized for grazing.
	Agriculture, Cultivated	Contains areas intensely managed for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
	Barren Land	Contains areas of gravel pits, bedrock, sand dunes, and other accumulations of earth material. Generally, vegetation accounts for less than 10 percent of total cover.
	Forest/Shrub	Includes two types of trees that cover greater than 20 percent of total vegetation cover. • *Forest*—areas dominated by all kinds of trees generally greater than 5 meters tall. • *Shrub*—areas dominated by shrubs generally less than 5 meters tall.
	Open Water	Include areas of open water, generally with less than 25 percent cover of vegetation or soil.
	Wetlands	Includes the area contains palustrine or estuarine vegetation that are periodically saturated or covered with water. Total vegetation coverage is greater than 20 percent.

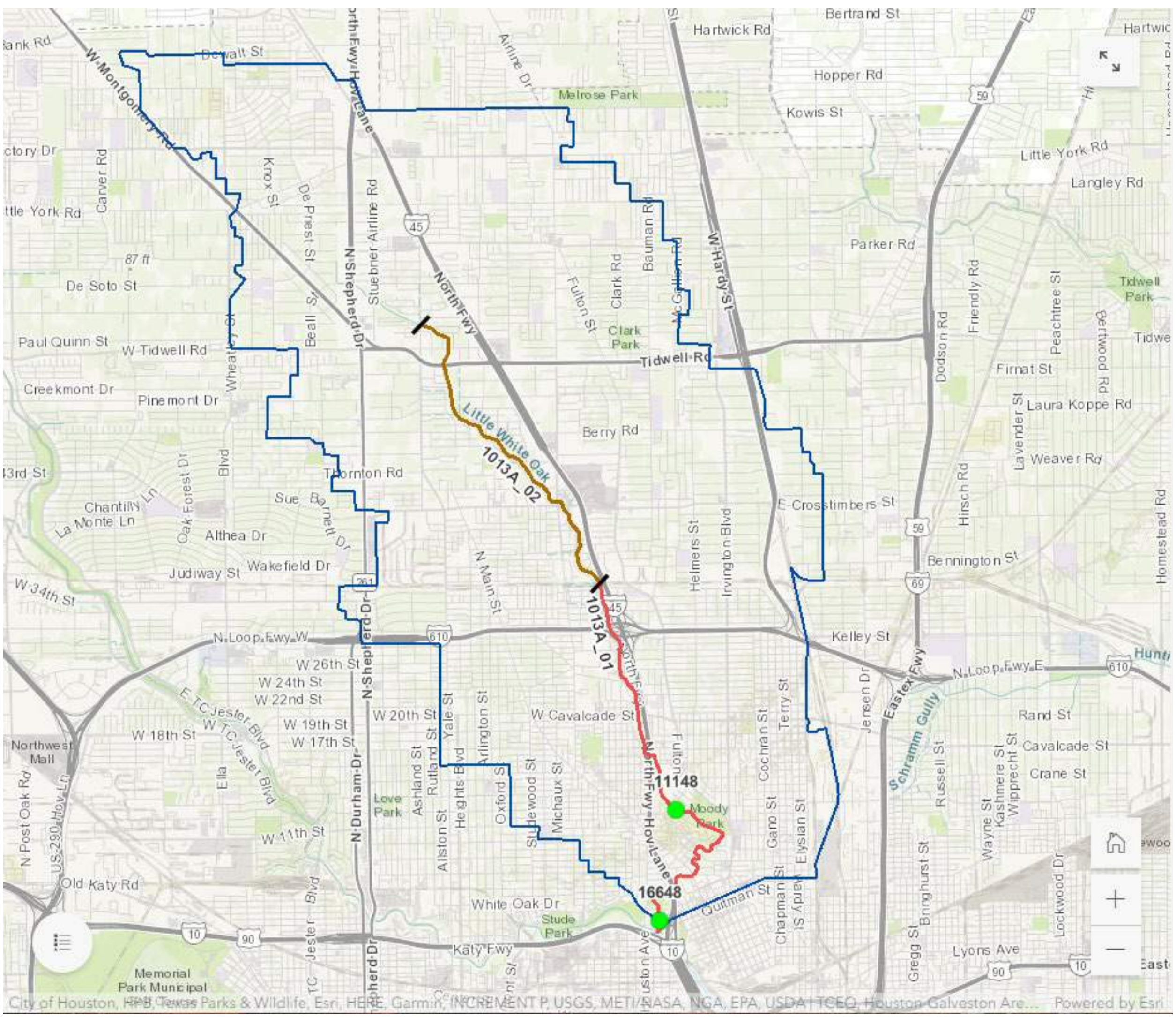
Source: National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) Land Cover Classifications https://coast.noaa.gov/digitalcoast/training/ccap-land-cover-classifications.html

DESCRIPTIONS OF WATER QUALITY ISSUES

Little White Oak Bayou has two designated assessment units (AUs). Both AUs are described as having perennial flows with the downstream reach (1013A_01) having an intermediate aquatic life use (ALU) designation. The upper reach (1013A_02), which is 100 percent concrete lined from the railroad tracks upstream to Yale Street, has a limited ALU designation.

There are two water monitoring stations within this segment, with both stations in the downstream AU. Field parameters, conventional parameters, and bacteria samples are collected at both sites six times per year by the City of Houston Health Department. Flow is obtained from a USGS flow gage (08074540) at the upper monitoring station (11148).

Map 3 shows the AUs and monitoring stations in Little White Oak Bayou.



Map 3 - Monitoring Stations in the Little White Oak watershed

Monitoring station locations, site descriptions and annual monitoring frequency are provided in Table 4.

Table 4 - Monitoring Stations in the Little White Oak Bayou watershed

Station ID	Segment ID	Site Description	SE	CE	24-hour DO	Flow	Field	Conv	Bacteria
16648	1013A	LITTLE WHITE OAK BAYOU AT WHITE OAK DRIVE IN NORTH HOUSTON	HG	HH	-	-	6	6	6
11148	1013A	LITTLE WHITE OAK BAYOU AT TRIMBLE STREET/NORTH EDGE OF HOLLYWOOD CEMETERY IN HOUSTON	HG	HH	-	6	6	6	6

SE = Submitting Entity
CE = Collecting Entity
HG = Houston-Galveston Area Council
HH = Houston Health & Human Services

Bacteria Impairments

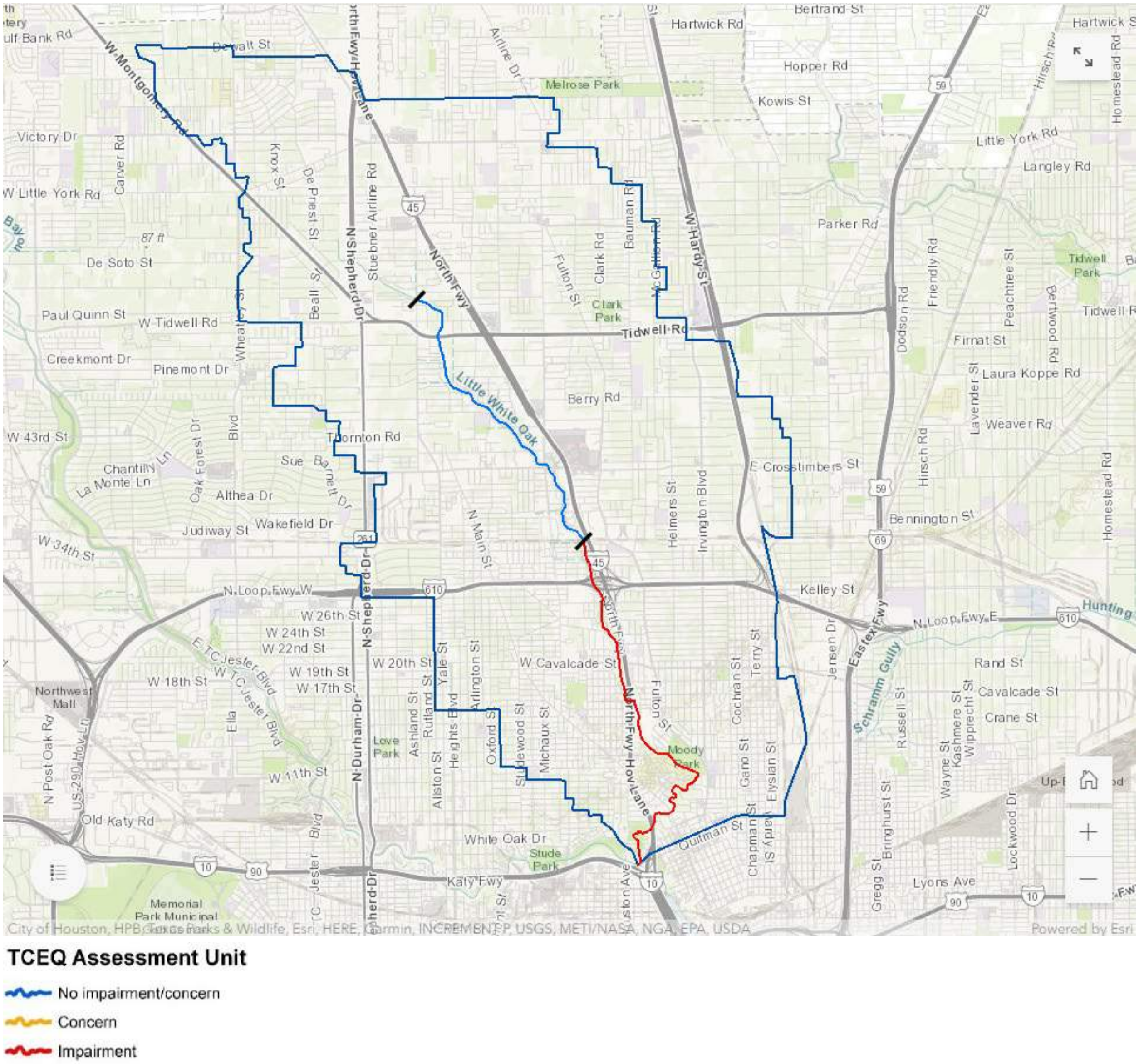
The 2018 Texas Integrated Report lists this unclassified segment as impaired with high bacteria concentrations. Therefore, contact recreation standards are not being met. Table 5 shows a comparison between the TCEQ's most recently EPA-approved assessment (the 2018 Integrated Report) and H-GAC's analysis of more recent water quality data. The assessment in the 2018 Integrated Report is based upon data collected from 2009 through 2016, while H-GAC's analysis used bacteria data from 2012 through 2019. Both evaluations are based on the geometric means from seven years of bacteria data. H-GAC's analysis indicates the geometric mean is still elevated and is not improving over time. See Appendix A-5 for a detailed discussion of the methodology used in H-GAC's data analysis.

Table 5 - Comparison of 2018 IR Bacteria Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

AU_ID	Parameter	Level of Support	Category	Geometric Mean of Bacteria Samples (2018 IR, 2009 – 2016)	Geometric Mean of Bacteria Samples (H-GAC Analysis, 2012 – 2019)
1013A_01	*E. coli*	NS	4a	1865	1941

NS = Not Supporting

AU 1013A_01 is listed as impaired for bacteria in the 2018 Integrated Report (Map 4). This AU is listed as category 4a, indicating that a Total Maximum Daily Load (TMDL) was completed. No monitoring data is available for the upstream AU (1013A_02).



Map 4 - Bacteria Impairments and Concerns in Little White Oak Bayou

To examine trends in the data, H-GAC plotted the bacteria grab sample results collected between 2004 and 2019 (Figure 2).

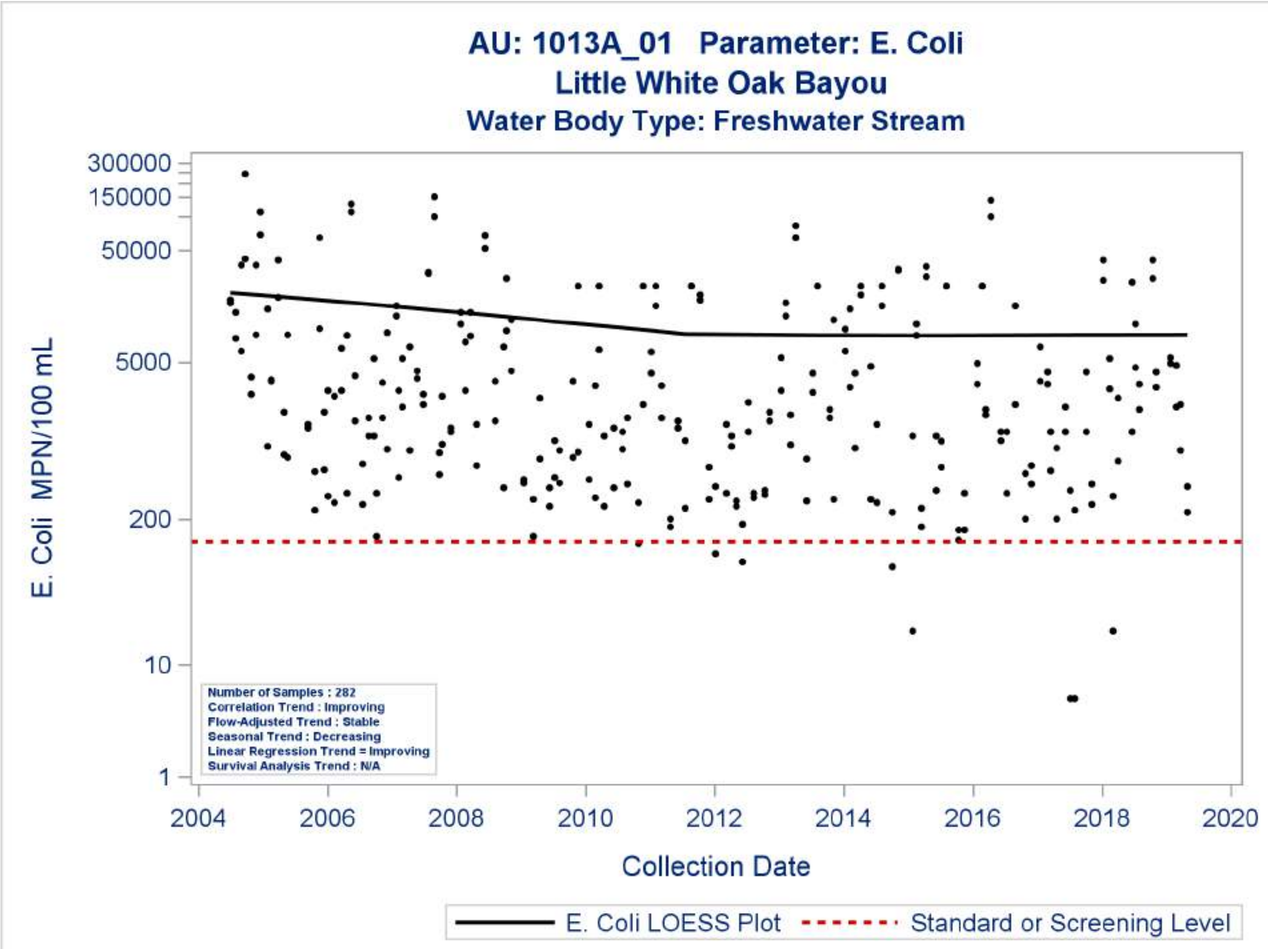


Figure 2 - Grab E. coli sample results of all samples collected from Little White Oak Bayou (2004 - 2019)

Between 2004 and 2011, the trend for grab sample results showed a decline due to fewer single samples being measured at extremely high concentrations of bacteria. While this trend is statistically significant, there is not much evidence of continuing improvement in the watershed. Since 2012, the trend is no longer significantly improving nor deteriorating. The red, dashed line shown in Figure 2 illustrates the *E. coli* geometric mean standard of 126 per 100 mL. In late 2010, individual grabs samples were measured below the geometric mean standard for the first time since 2004. However, the geometric mean remains well above the standard and has remained relatively stable since 2012, as shown in Figure 3.

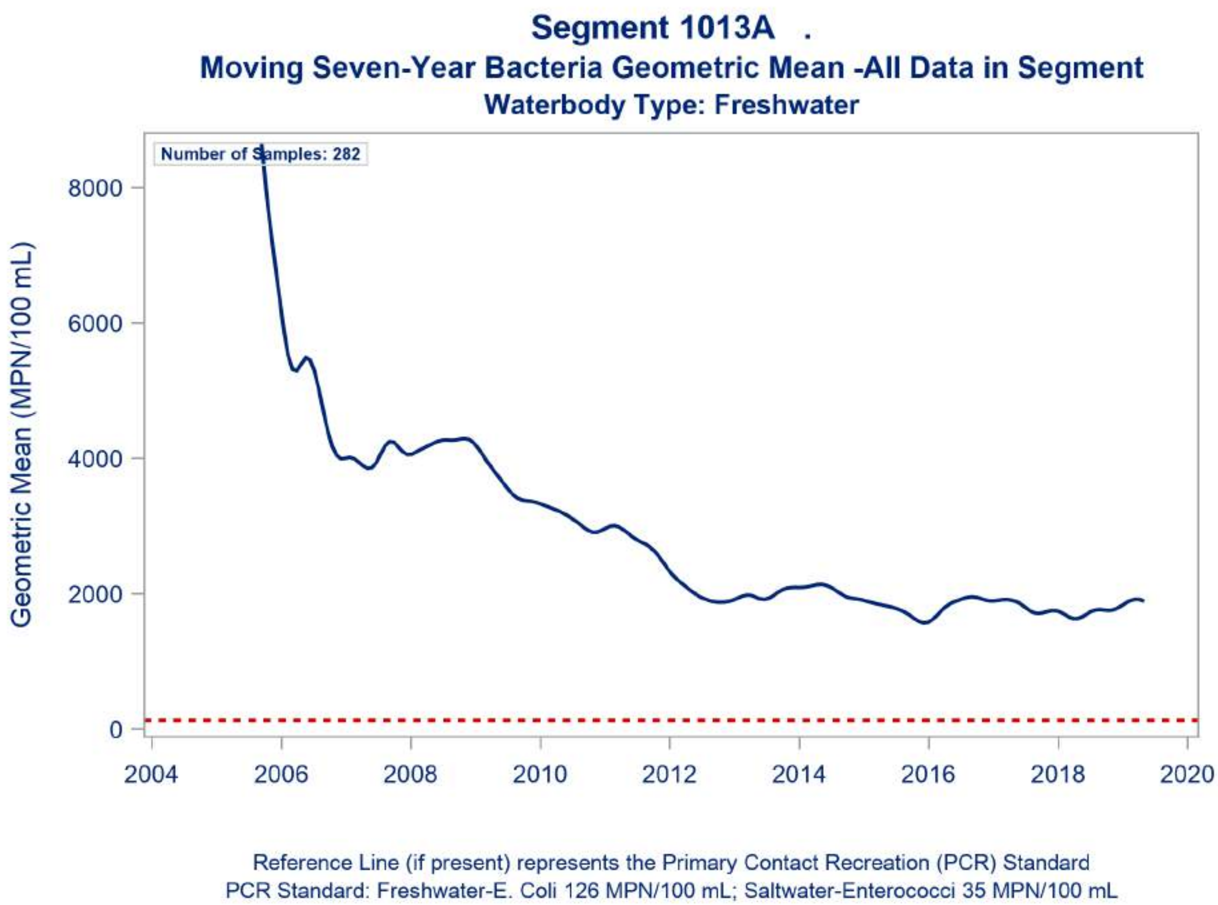


Figure 3 - Moving Seven-Year Bacteria Geometric Mean for Little White Oak Bayou

Dissolved Oxygen Impairments

The 24-hour dissolved oxygen (DO) average standard and the 24-hour minimum DO standard are not supported on Segment 1013A (Map 5) and there is a concern that the macrobenthic community is impaired. Depressed DO may limit species diversity and number of individual organisms able to survive in the benthic community.

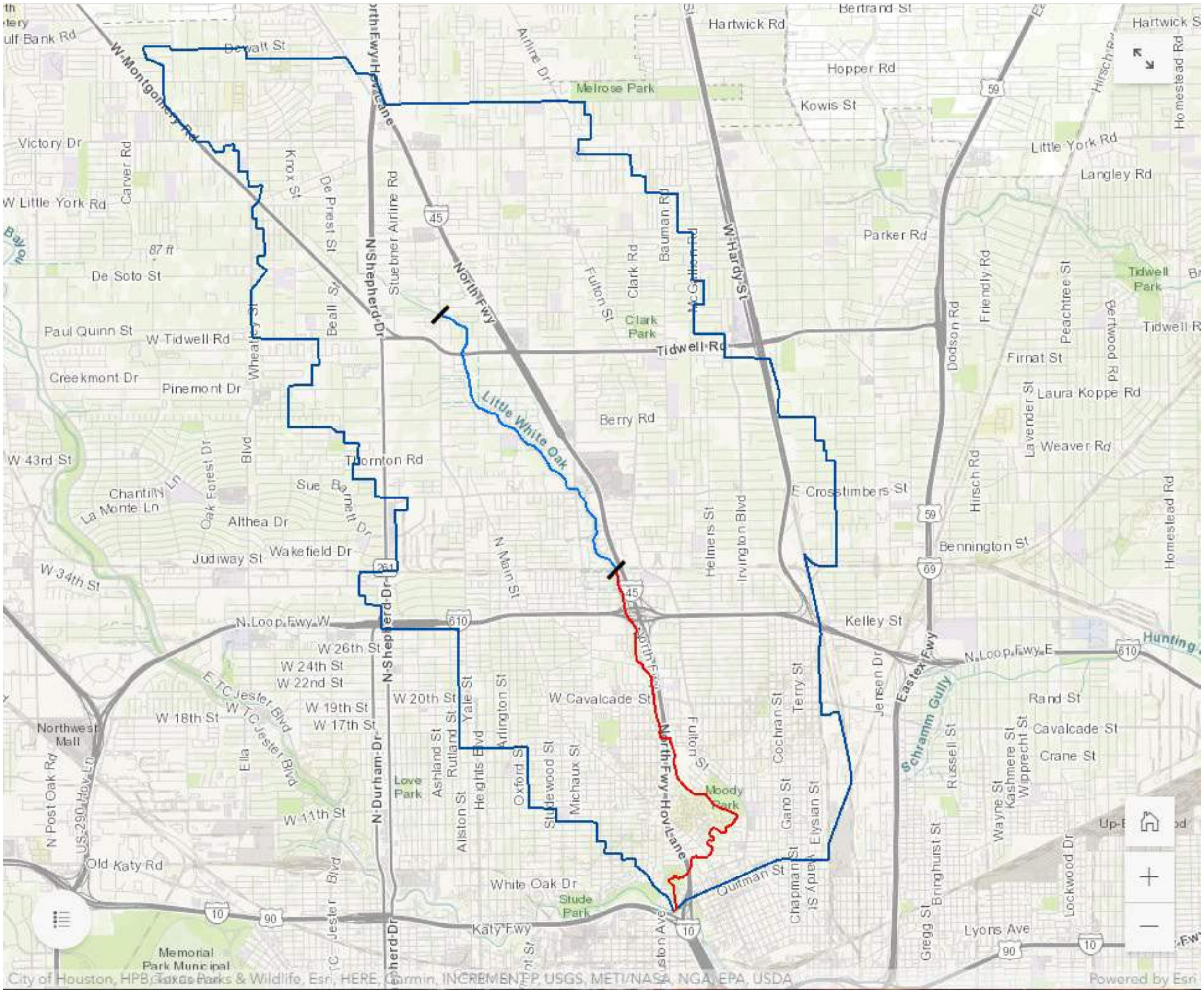
The 24-hour DO data collected from Little White Oak Bayou (1013A_01) shows the downstream portion of the waterway failed to meet the 24-hour average standard and the 24-hour minimum assigned to that AU (Table 6). The waterbody is assigned an intermediate ALU. This designation requires at least 4.0 mg/L for the 24-hour average and no individual measurements below 3.0 mg/L during the same 24-hour period. Data shows the measurements were below the assigned standards 40 percent and 60 percent of the time respectively (Table 6). This impairment is a carry-forward from the previous assessment. The first of two scheduled biological monitoring events was conducted on Little White Oak Bayou at Trimble Street (Monitoring Station ID 11148) on June 28, 2017. While a second event would be necessary for biological reassessment of the segment, H-GAC and the contractor performing the monitoring have chosen not to conduct a second sampling event at this time. This decision was made based upon the outcome of the first sampling event as well as concerns for the physical safety of the field crew.

There has been no 24-hour DO data collected from the upstream AU (1013_02), so this assessment unit has not been evaluated.

Table 6 - Comparison of 2018 IR Dissolved Oxygen Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

AU_ID	Parameter	Level of Support	Category	Percentage of Samples Exceeding Standard (2018 IR, 2009 – 2016)	Percentage of Samples Exceeding Standard (H-GAC Analysis, 2012 – 2019)
1013A_01	DO 24-hour Avg	NS	5c	40	0
1013A_01	DO 24-hour Min	NS	5c	60	0

NS = Not Supporting



TCEQ Assessment Unit

- No impairment/concern
- Concern
- Impairment

Map 5 – Dissolved Oxygen Impairments and Concerns in the Little White Oak Bayou watershed

Figure 4 shows the results of all DO grab samples collected at in AU 1013A_01 between 2004 and 2019. Data from this period shows an improving trend, with the vast majority of monitoring data since 2016 indicating DO levels above the standard. This indicates improving water quality in this AU.

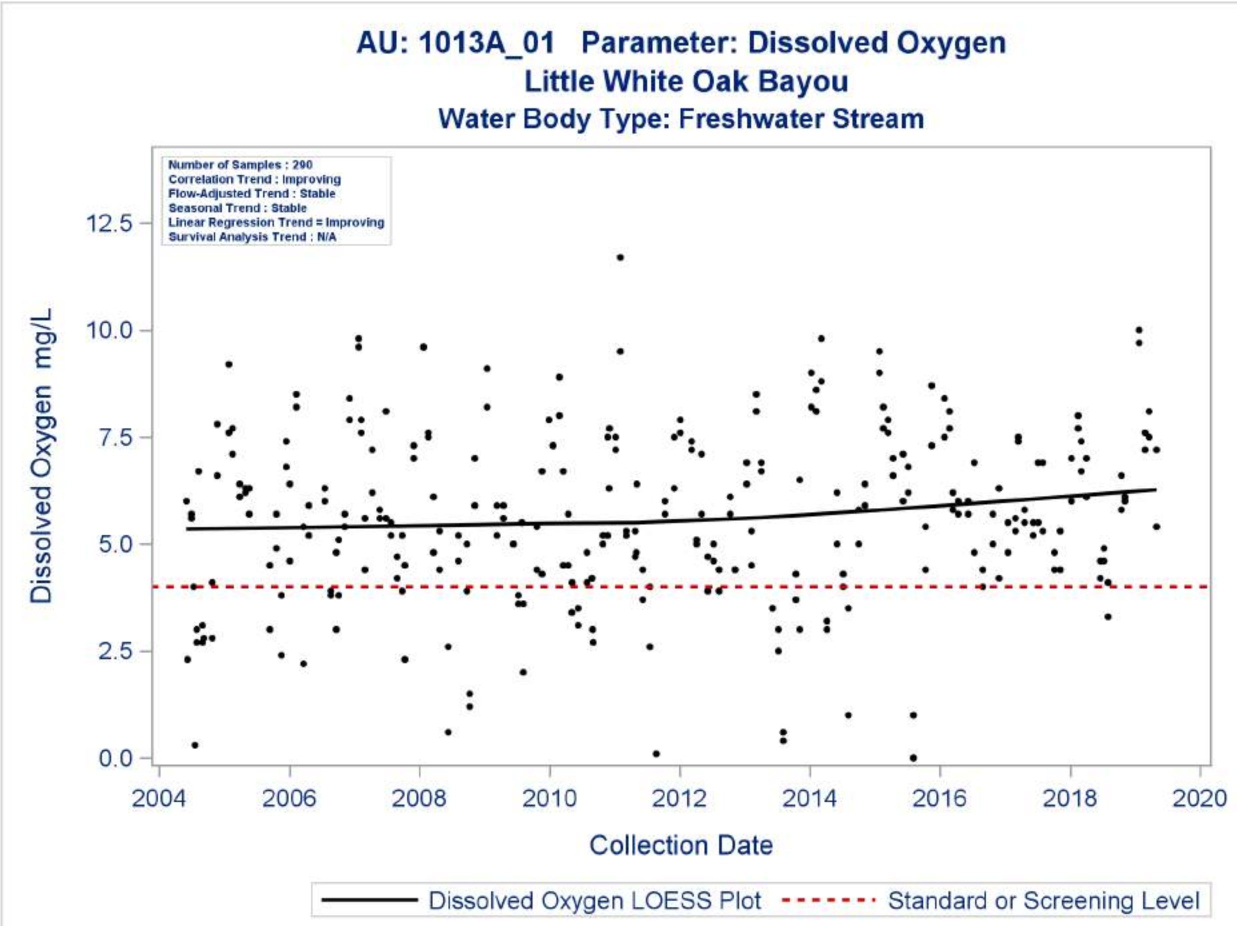


Figure 4 – All Dissolved Oxygen grab samples collected from Little White Oak Bayou (1013A_01) over time (2004 – 2019)

Nutrient Concerns

All ammonia, nitrate, and total phosphorus samples collected in Little White Oak Bayou (1013A_01) showed no concerns for exceeding the established nutrient screening criteria for that waterway (Table 7).

Table 7 - Comparison of 2018 IR Water Quality Data (2009 - 2016) and H-GAC's Analysis of Water Quality Data (2012 - 2019)

AU_ID	Parameter	Level of Support	Category	Percentage of Samples Exceeding Screening Criteria (2018 IR, 2009 – 2016)	Percentage of Samples Exceeding Screening Criteria (H-GAC Analysis, 2012 – 2019)
1013A_01	Ammonia	NC	-	4	4
1013A_01	Nitrate	NC	-	0	0
1013A_01	Total Phosphorus	NC	-	0	0.76

NC = No Concern

POTENTIAL SOURCES OF WATER QUALITY ISSUES

Potential sources of bacteria in the Little White Oak Bayou watershed include sanitary sewer overflows and nonpoint sources.

Sanitary Sewer Overflows

Although there are no regulated wastewater treatment facilities within the watershed, the area is almost entirely serviced by centralized sewer. As the transmission lines of these wastewater collection systems age, they are prone to failure, resulting in sanitary sewer overflows.

Based on sampling conducted as part of H-GAC's special study "Top Five/Least Five" Project, at least one sanitary sewer overflow source, a failing junction box, was identified and reported to the City of Houston for repair.

On-Site Sewage Facilities

On-Site Sewage Facilities are found primarily in the upper reach of the watershed but can be found scattered throughout. Only 6 of these on-site facilities have been permitted and installed in this watershed since 1989. There are an unknown number of on-site facilities that were installed prior to permitting requirements as well as prior to sanitary sewer services being provided to some areas of the watershed. Because of the age of the systems present, and the likelihood that they are conventional septic systems instead of aerobic systems, they are prone to failure.

Other Nonpoint Sources

Other potential sources of pollution in this watershed include runoff during storm events. Runoff from junk yards and small paddocks/lots supporting a few animals are found scattered throughout the watershed. Chickens are also raised by a large number of homeowners throughout the watershed, with a maximum of 30 per household allowed by the City of Houston. Although rare in such an urbanized area, feral hogs have access to the area through the riparian corridor. Conditions created by the paddocks for chickens may create areas that are attractive to and conducive for infiltration by feral hogs.

POTENTIAL STAKEHOLDERS

Potential stakeholders include:

- City of Houston Public Works
- City of Houston Health Department
- City of Houston Parks and Recreation Department
- Harris County Pollution Control Services
- Harris County Flood Control District
- Houston Parks Board
- Environmental and Conservancy Organizations, such as Bayou Preservation Association
- Community Groups, such as the White Oak Bayou Association
- TCEQ Region 12
- The Bacteria Implementation Group (BIG) Members
- Houston City Council Members (specifically District H)
- Greater Northside Management District
- Citizen Groups, such as the Texas Master Naturalists
- Homeowner Associations
- Industry

ONGOING PROJECTS

The annual *River, Lakes, Bays 'N Bayous Trash Bash* has a clean-up site at Moody Park which is immediately downstream of the Clean Rivers Program monitoring site at Trimble Street. Every year, hundreds of volunteers fill several dumpsters with trash collected from the stream, the banks and shoreline trees. Unfortunately, due to the close proximity to major highways and roadways, large amounts of litter and trash are carried by stormwater directly to areas adjacent to the bayou. It takes only a few rain events with medium to high flows for the area to be inundated with litter and trash. Unfortunately, due to closures and social-distancing requirements related to the COVID-19 pandemic, the *Rivers, Lakes, Bays 'N Bayous Trash Bash* was cancelled for 2020.

MAJOR WATERSHED EVENTS

Little White Oak Bayou was one of 10 waterbodies included in the “Top Five/Least Five” special study conducted by H-GAC from March 2016 through February 2017. Targeted monitoring was conducted to identify and eliminate sources of bacteria pollution. Four dry weather flows were identified as having high levels of bacteria. All four sources were turned over to the City of Houston for further investigation and remediation. Three of the four sources were remediated. The fourth source was from a failing junction box which is part of the sanitary sewer collection system. It was placed on a list of major city projects that will include significant engineering and reconstruction to eliminate.

AU 1013A_01 is listed in the 2018 Integrated Report as having depressed DO. To determine compliance with aquatic life use designations, TCEQ requires a minimum of two biological monitoring events be conducted, with one event completed during the index period and one event during the critical period. One biological monitoring event was conducted on Little White Oak Bayou at Trimble Street on June 28, 2017, during the index period. A second event, which would have been conducted during the critical period, was not collected due to safety concerns of the field crew and confirmation of impairments/concerns during the first event. Results from H-GAC’s subcontractor suggested the designated ALU rating of intermediate for nekton was not supported during their investigation. The subcontractor’s results suggest that the intermediate ALU rating was met for the microbenthic community, physical habitat and 24-hour DO during the index period. However, since two events are required by TCEQ to determine compliance, a final determination could not be made.

RECOMMENDATIONS FOR IMPROVING WATER QUALITY

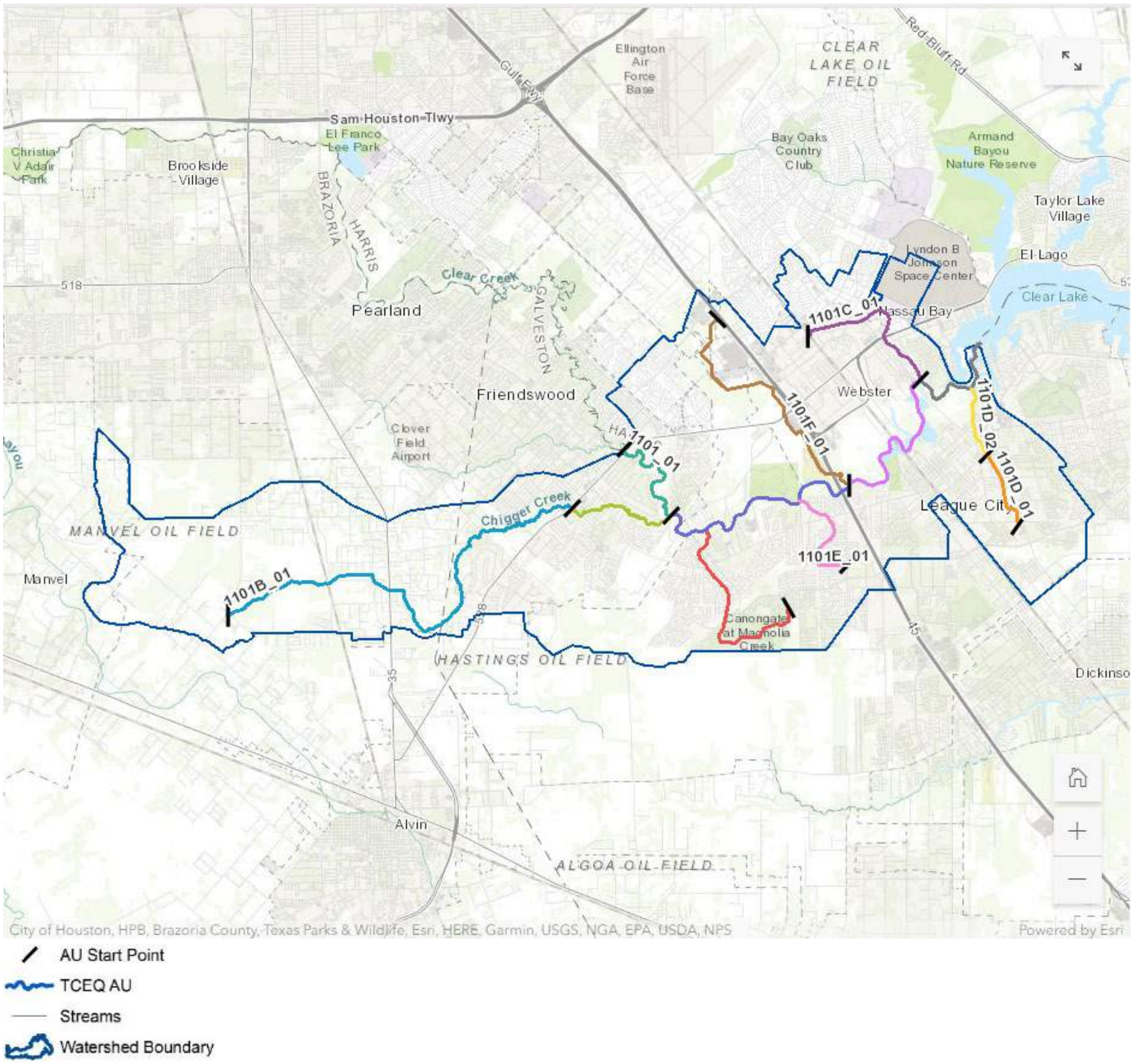
- Address bacteria and various other concerns through stakeholder involvement and best management practices
- Continue to analyze sanitary sewer overflow data from regulated dischargers and present results to TCEQ, wastewater permittees, local governments/utility districts, and stakeholders
- Support programs to assist homeowners with on-site sewage facilities, particularly those pre-dating permitting requirements, to connect to centralized sewer collection systems
- Continue collecting water quality data and expand monitoring efforts to support actions associated with the Total Maximum Daily Load program
- Pursue new local partners to collect additional data to help better isolate problem areas
- Support programs to educate homeowners on proper management of animal wastes, including those from pets and livestock
- Support programs to responsibly eliminate feral hog populations in the watershed
- Consult stakeholders to identify illegal dumping sites and improve signage and/or cameras, if needed

DETAILED WATERSHED CHARACTERIZATION
Clear Creek Tidal (1101)

Figure 5 - Clear Creek Tidal at State Highway 3 Near Webster (Monitoring Station 11446)

SEGMENT DESCRIPTION

Clear Creek Tidal (Segment 1101) is a tidal stream described as extending from the Clear Lake confluence at a point 3.2 km (2.0 mi) downstream of El Camino Real in Galveston/Harris County to a point 100 m (110 yards) upstream of FM 528 in Galveston/Harris County (Map 1). The 2018 Texas Integrated Report identifies four Assessment Units (AUs) in segment 1101 (Table 1).



Map 6 - Clear Creek Tidal (Segment 1101) Watershed

Table 8 - Assessment Unit descriptions for the Clear Creek Tidal watershed

Segment Name	Segment ID	AU	Description
Clear Creek Tidal	1101	1001_01	Upper segment boundary to Chigger Creek confluence
Clear Creek Tidal	1101	1001_02	Chigger Creel confluence to IH 45
Clear Creek Tidal	1101	1001_03	IH 45 to Cow Bayou confluence
Clear Creek Tidal	1101	1001_04	Cow Bayou confluence to confluence with Clear Lake

There are six additional unclassified segments in the watershed (Table 2).

Table 9 - Unclassified water bodies in the Clear Creek Tidal watershed

Segment Name	Segment ID	Description
Magnolia Creek	1101A	From the Clear Creek Tidal confluence upstream to 0.8 km (0.5 miles) upstream of the confluence with the second unnamed tributary.
Chigger Creek	1101B	From the confluence with Clear Creek Tidal to the Brazos River Authority Canal near CR 143 in Galveston County.
Cow Bayou	1101C	From the Clear Creek Tidal confluence to SH 3 in Galveston County.
Robinson Bayou	1101D	From confluence with Clear Creek to 0.33 miles upstream of Webster Street in Galveston County.
Unnamed Tributary of Clear Creek Tidal	1101E	From Clear Creek Tidal confluence to a point 3.2 km (2.0 miles) immediately downstream of I-45 in Galveston County.
Unnamed Tributary of Clear Creek Tidal	1101F	From Clear Creek Tidal confluence (immediately downstream of I-45 in Galveston County) to a point 7.8 km (4.8) miles upstream.

HYDROLOGICAL CHARACTERISTICS

Clear Creek forms the boundary between Galveston and Harris counties, with the Clear Creek Tidal segment draining into Clear Lake. It receives flow from runoff as well as receiving wastewater treatment facility effluent from five regulated outfalls scattered through the segment. With Clear Creek passing through highly developed residential and commercial areas of Friendswood, League City, and the Clear Lake region of Houston, the application of fertilizers to suburban lawns and landscaping may result in elevated nutrient and bacteria levels, as well as depressed dissolved oxygen (DO).

There are no US Geological Survey (USGS) flow gages on the tidal portion of Clear Creek.

LAND COVER AND NATURAL CHARACTERISTICS

Clear Creek Tidal stretches across the northern portion of Galveston County, into Brazoria County in the west and includes a portion of southern Harris County. It is densely urbanized in the eastern half of the segment with both high intensity and medium intensity development mixed. The Clear Creek Tidal watershed has experienced rapid growth of residential and commercial development over the past decade. Most of the higher intensity development is centered along the I-45 corridor in the eastern side of the watershed in the cities of Nassau Bay, Webster, Friendswood, and League City. The cities of League City and Friendswood sit on the south side of Clear Creek with Webster, parts of Friendswood and the part of Houston known as ”Clear Lake” sitting to the north of the creek. Major traffic corridors include FM 518 running east-west in Galveston County and NASA Road 1 and Bay Area Boulevard running east-west in southern Harris County. League City is the fastest growing city in Galveston County with Friendswood closely following. The majority of the high intensity development is served by wastewater treatment facilities, but some of the surrounding lower intensity development in the unincorporated areas rely on on-site sewage facilities.

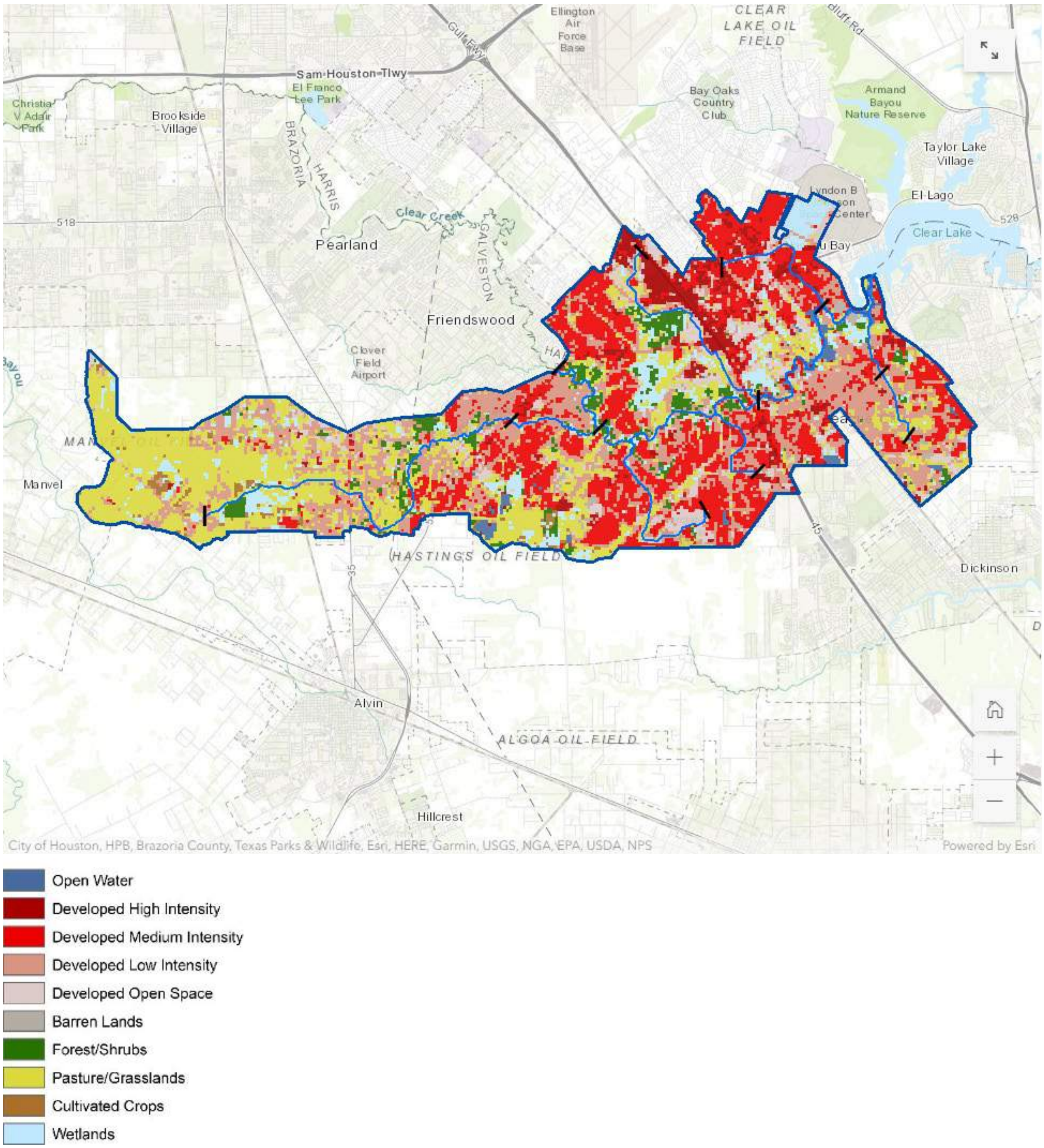
There are a few plots of undeveloped grassland and cultivated fields present, particularly in the western and southern parts of the watershed. Pasture/grasslands are predominantly found in the western portion of the watershed and drain to Chigger Creek which also flows through both medium and high intensity developments. Johnson Space Center is located in the very northeast section of the segment and its facility is surrounded by large fields of grass and wetlands.

The Clear Creek Tidal watershed covers approximately 37,645 acres, with 61.38 percent of the land being developed. Agricultural uses are the next largest category, at 25.13 percent, with the majority of the agricultural uses occurring in the western portion of the watershed (Table 3).

Table 10 - Land Cover Comparisons in the Clear Creek Tidal watershed, 2008 – 2018

Land Cover Class Name	Area Acres 2008	Area % 2008	Area Acres 2018	Area % 2018	% Change
Agriculture	8994.72	23.88	9459.83	25.13	5.17
Barren Lands	976.38	2.59	451.23	1.20	-53.79
Developed	22273.85	59.13	23105.43	61.38	3.73
Forest/Shrubs	1025.60	2.72	1622.43	4.31	58.19
Open Water	736.50	1.96	490.35	1.30	-33.42
Wetlands	3665.20	9.73	2516.22	6.68	-31.35
TOTAL	**37672.24**	**100.00**	**37645.49**	**100.00**	

Map 2 shows the land cover types in the Clear Creek Tidal watershed. Table 4 provides a description of these land cover types.



Map 7 - Land Cover in the Clear Creek Tidal watershed

Table 11 - Description of Land Cover Classes

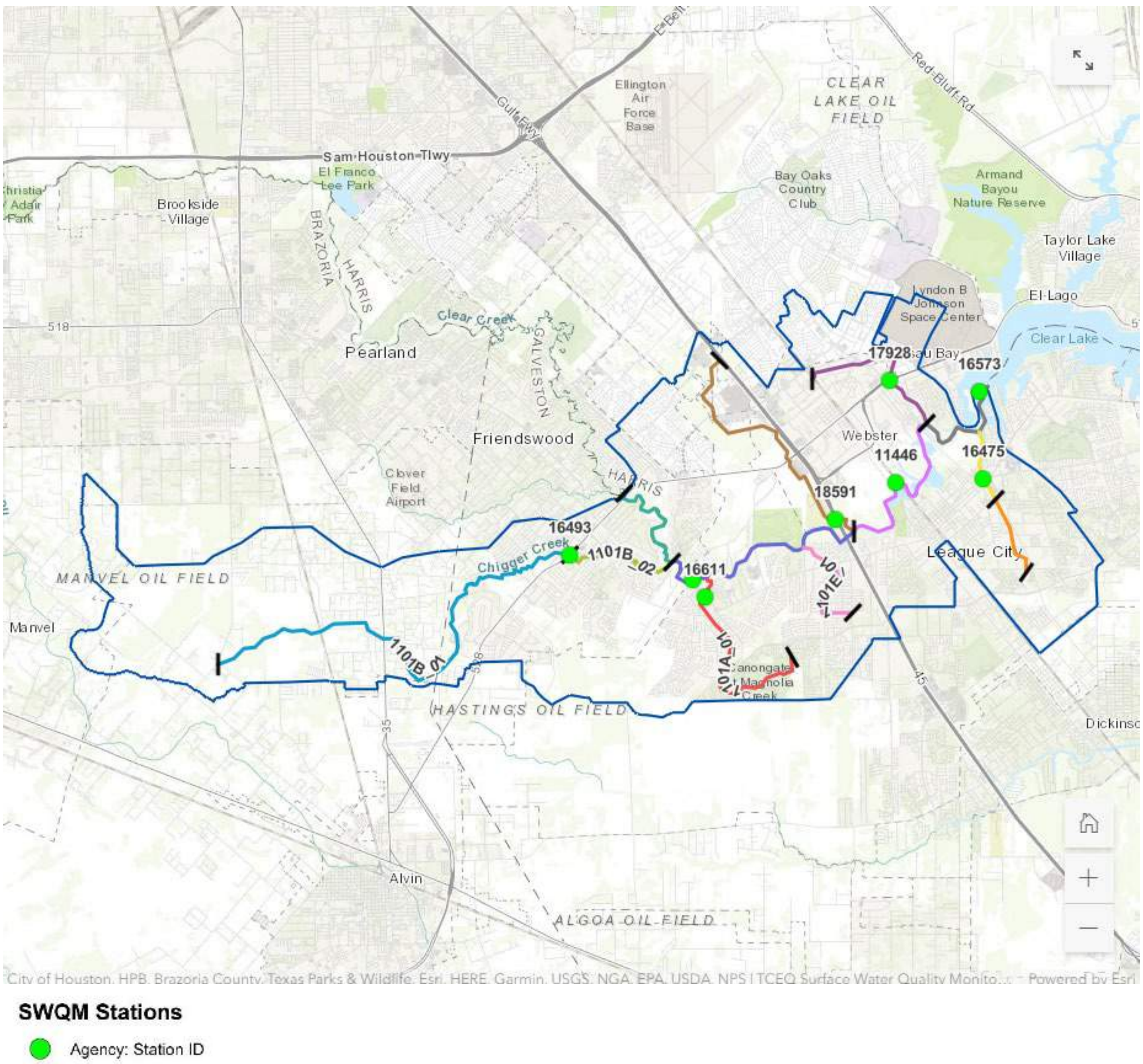
Map Key	Land Cover Class	Class Description
	Developed, High Intensity	Contains significant land area and is covered by impervious surfaces (i.e., concrete, asphalt, and other constructed materials). Vegetation, if present, occupies < 20 percent of the landscape. Impervious surfaces account for 80 to 100 percent of the total cover. This class includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas with a variety of land uses.
	Developed, Medium Intensity	Contains areas with a mixture of impervious surfaces and vegetation or other cover. Impervious surfaces account for 50 to 79 percent of total area. This class commonly includes multi- and single-family housing areas, especially in suburban neighborhoods, but may include all types of land use.
	Developed, Low Intensity	Contains areas with a mixture of impervious surfaces and substantial amounts of vegetation or other cover. Impervious surfaces account for 21 to 49 percent of total area. This class commonly includes single-family housing areas, especially in rural neighborhoods, but may include all types of land use.
	Developed, Open Space	Contains areas with a mixture of some impervious surfaces, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes. Impervious surfaces account for less than 20 percent of total land cover. This class commonly includes large-lot single family housing units, parks, and golf courses.
	Agriculture, Pasture/Grasslands	Contains both managed and unmanaged grasses, legumes, or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas can be subjective to intensive management, such as tilling, and utilized for grazing.
	Agriculture, Cultivated	Contains areas intensely managed for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
	Barren Land	Contains areas of gravel pits, bedrock, sand dunes, and other accumulations of earth material. Generally, vegetation accounts for less than 10 percent of total cover.
	Forest/Shrub	Includes two types of trees that cover greater than 20 percent of total vegetation cover. • *Forest*—areas dominated by all kinds of trees generally greater than 5 meters tall. • *Shrub*—areas dominated by shrubs generally less than 5 meters tall.
	Open Water	Include areas of open water, generally with less than 25 percent cover of vegetation or soil.
	Wetlands	Includes the area contains palustrine or estuarine vegetation that are periodically saturated or covered with water. Total vegetation coverage is greater than 20 percent.

Source: National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) Land Cover Classifications
https://coast.noaa.gov/digitalcoast/training/ccap-land-cover-classifications.html

DESCRIPTIONS OF WATER QUALITY ISSUES

The primary water quality issues for Clear Creek Tidal and its tributaries are elevated levels of bacteria and nutrients and low DO concerns in a few AUs.

H-GAC contracts with the University of Houston-Clear Lake Environmental Institute of Houston to collect samples from the upper segment area and the tributaries. Harris County Pollution Control Services samples the most downstream location because they access it by boat. TCEQ's field operations collects from one site at State Highway 3 in League City. Monitoring stations are shown in Map 3.



Map 8 - Monitoring Stations in the Clear Creek Tidal watershed

Monitoring station locations, site descriptions and annual monitoring frequency are provided in Table 5.

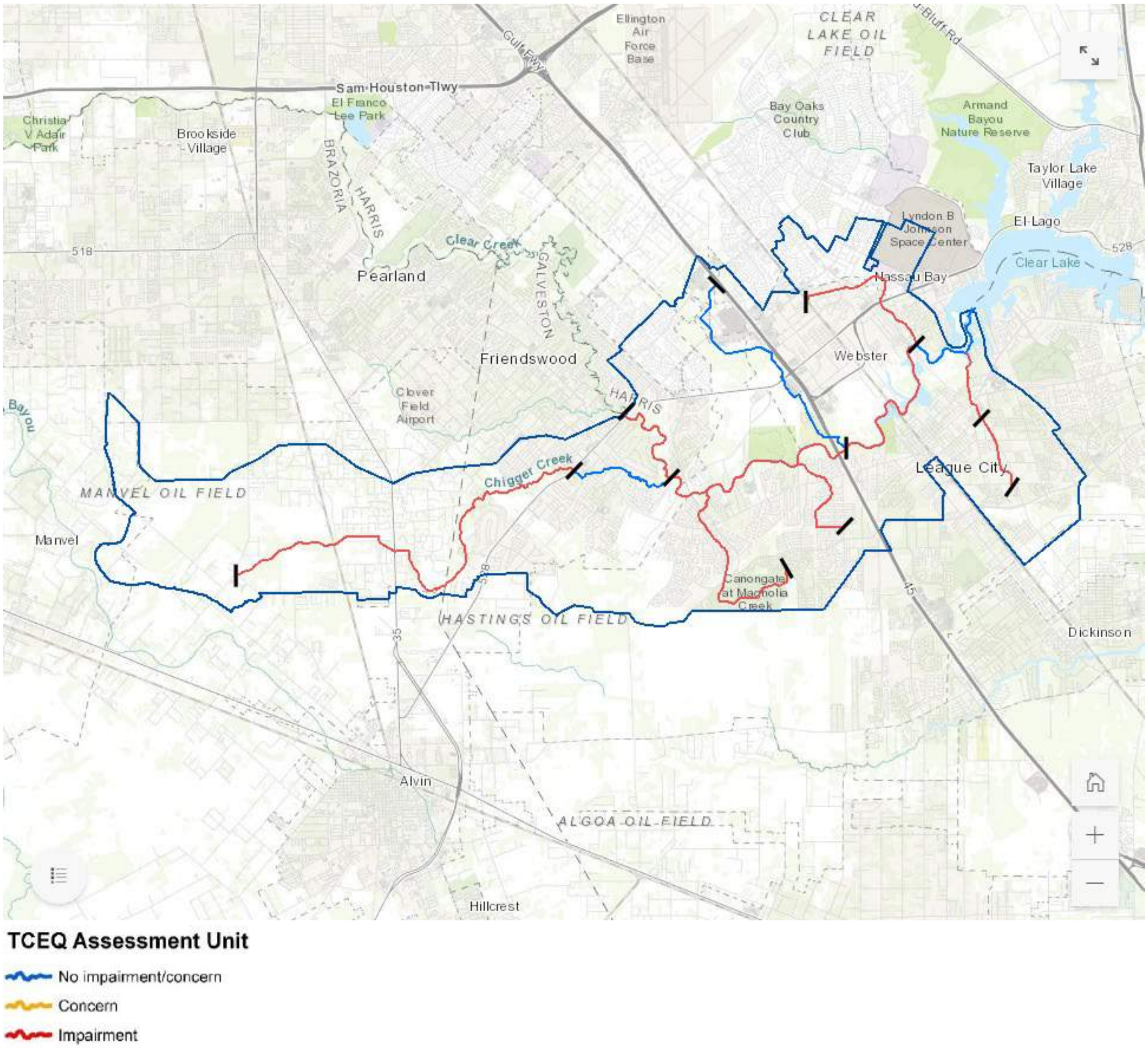
Table 12 - Monitoring Stations in the Clear Creek Tidal watershed

Station ID	Segment ID	Site Description	SE	CE	24-hour DO	Flow	Field	Conv	Bacteria
11446	1101	CLEAR CREEK TIDAL AT SH 3 NEAR WEBSTER	WC	FO	-	-	4	4	4
16573	1101	CLEAR CREEK TIDAL AT THE CONFLUENCE WITH CLEAR LAKE 30 M NORTH AND 266 M WEST OF DAVIS ROAD AT VEGA COURT IN LEAGUE CITY IN HARRIS COUNTY	HG	HC	-	-	6	6	6
16576	1101	CLEAR CREEK TIDAL AT BROOKDALE DR APPROX 0.1MI DOWNSTREAM OF GRISSOM ROAD IN COUNTRYSIDE PARK IN CANOE LAUNCHING AREA IN LEAGUE CITY	HG	UI	-	-	4	4	4
16611	1101A	MAGNOLIA CREEK AT W BAY AREA BLVD LEAGUE CITY APPROX 250 M UPSTREAM OF WWTP PERMIT WQ0010568-003	HG	UI	-	4	4	4	4
16493	1101B	CHIGGER CREEK AT FM 528 BRIDGE IN FRIENDSWOOD	HG	UI	-	4	4	4	4
17928	1101C	COW BAYOU AT NASA ROAD 1 IN WEBSTER 100 M EAST OF FM 270/EL CAMINO REAL	HG	UI	-	-	4	4	4
16475	1101D	ROBINSONS BAYOU AT FM 270 IN LEAGUE CITY	HG	UI	-	-	4	4	4
18591	1101F	UNNAMED TRIBUTARY OF CLEAR CREEK TIDAL IN FOREST PARK CEMETERY IMMEDIATELY UPSTREAM OF S FEEDER ROAD OF I-45/GULF FWY S OF NASA RD 1 IN WEBSTER	HG	UI	-	-	4	4	4

SE = Submitting Entity
CE = Collecting Entity HG = Houston-Galveston Area Council
HC = Harris County Pollution Control
UI = University of Houston Clear Lake / Environmental Institute of Houston
WC = Texas Commission on Environmental Quality
FO = TCEQ Regional Office

Bacteria Impairments and Concerns

As shown in Map 4, there are numerous impaired assessment units (AUs) in Clear Creek Tidal and its tributaries.



Map 9 - Bacteria Impairments and Concerns in the Clear Creek Tidal watershed

The 2018 Texas Integrated Report lists this classified segment as being impaired with high bacteria concentrations. Table 6 summarizes the results from TCEQ's most recently EPA-approved assessment (the 2018 Integrated Report), as well as results from H-GAC's analysis of more recent bacteria samples. The assessment in the 2018 Integrated Report is based on data collected from 2009 through 2016 while H-GAC's analysis used bacteria data from 2012 through 2019. Both evaluations are based on the geometric means from seven years of bacteria data. H-GAC's analysis indicates the geometric mean is still elevated and is not improving over time. See Appendix A-5 for a detailed discussion of the methodology used in H-GAC's data analysis.

Table 13 - Comparison of 2018 IR Bacteria Data (2009 – 2016) and H-GAC Analysis of Bacteria Data (2012 – 2019)

Waterbody	Seg ID	AU_ID	Parameter	Level of Support	Cat	Geometric Mean of Bacteria Samples (2018 IR, 2009 - 2016)	Geometric Mean of Bacteria Samples (H-GAC Analysis, 2012 - 2019)
Clear Creek Tidal	1101	1101_01	Enterococcus	NS	4a	**	**
		1101_02	Enterococcus	NS	4a	**	63
		1101_03	Enterococcus	NS	4a	92	81
		1101_04	Enterococcus	FS	-	21	19
Magnolia Creek	1101A	1101A_01	*E. coli*	NS	4a	416	502
Chigger Creek	1101B	1101B_01	*E. coli*	NS	4a	170	253
		1101B_02	Enterococcus	NA	-	*	*
Cow Bayou	1101C	1101C_01	Enterococcus	NS	4a	253	311
Robinson Bayou	1101D	1101D_01	Enterococcus	NS	4a	285	305
		1101D_02	Enterococcus	NS	4a	**	130
Unnamed Tributary of Clear Creek Tidal	1101E	1101E_01	Enterococcus	NS	4a	**	**
Unnamed Tributary of Clear Creek Tidal	1101F	1101F_01	*E. coli*	FS	-	50	51

FS = Fully Supporting
NS = Not Supporting
NA = Not Assessed
CN = Concern
NC = No Concern
*Insufficient Data available
**Not Calculated

Of the four assessment units (AUs) that make up the tidal portion of Clear Creek, only the most downstream AU (1101_04) is fully supportive of the contact recreation standard with an Enterococcus geometric mean of 21 Most Probable Number (MPN) per 100 mL. The geometric mean standard for Enterococcus is 35 MPN per 100 mL. The other three AUs have geometric mean values ranging from 63 to 95 MPN per 100 mL. Bacteria impairments in 1101_01, 1101_02, 1101D_02, and 1101E_01 are carried forward from the previous assessment. There was insufficient data during the assessment period for the most recent Integrated Report to assess these AUs. Figure 2 shows the bacteria results for the period of 2004 – 2019.

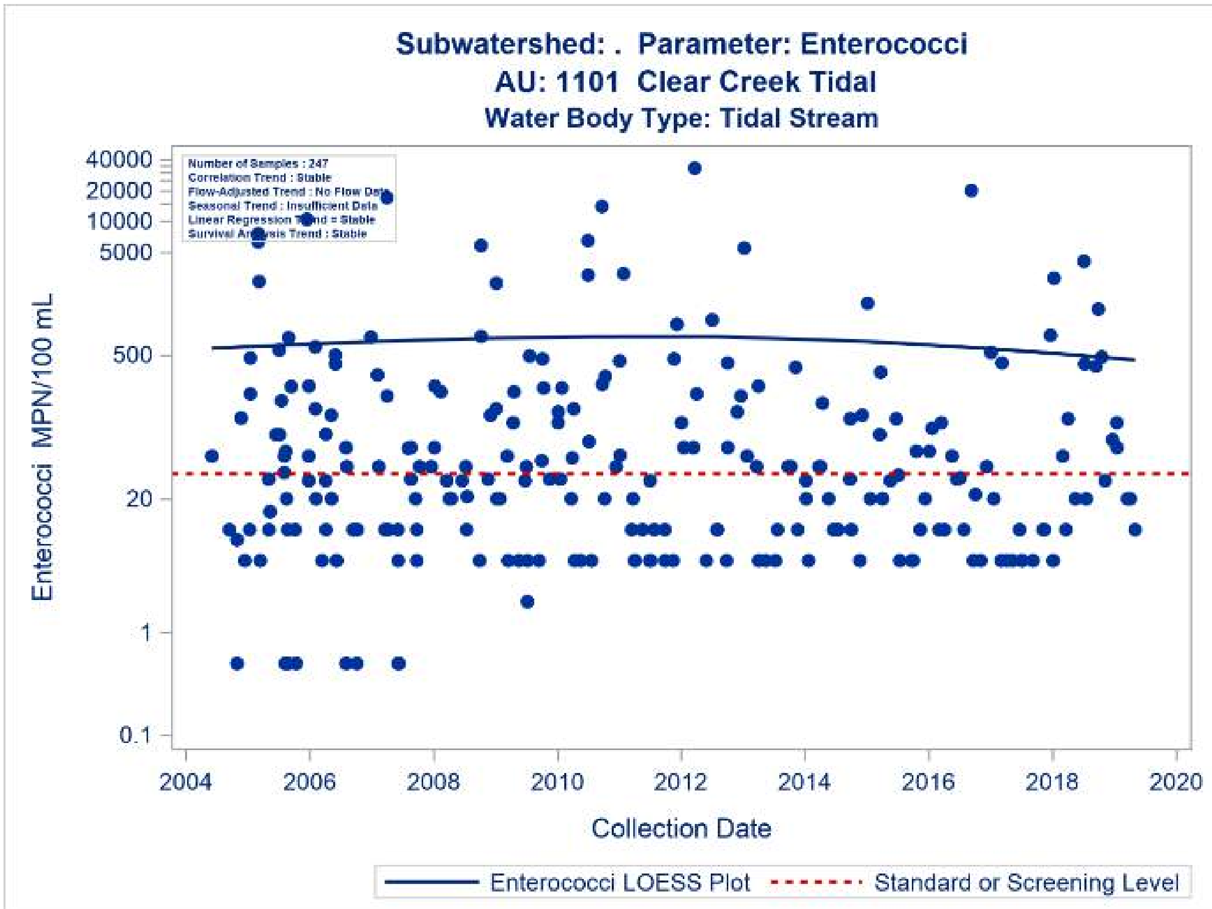


Figure 6 - All enterococcus bacteria sample results for Clear Creek Tidal (1101), 2004 - 2019

Five of the six unclassified segments do not support contact recreation standards.

Magnolia Creek (1101A) is impaired for non-support of the contact recreation standard. This freshwater stream has an *E. coli* geometric mean of 416 and 502 MPN/100 mL respectively between the Integrated Report and H-GAC's analysis. Figure 3 shows the *E. coli* results Magnolia Creek for the period of 2004 – 2019.

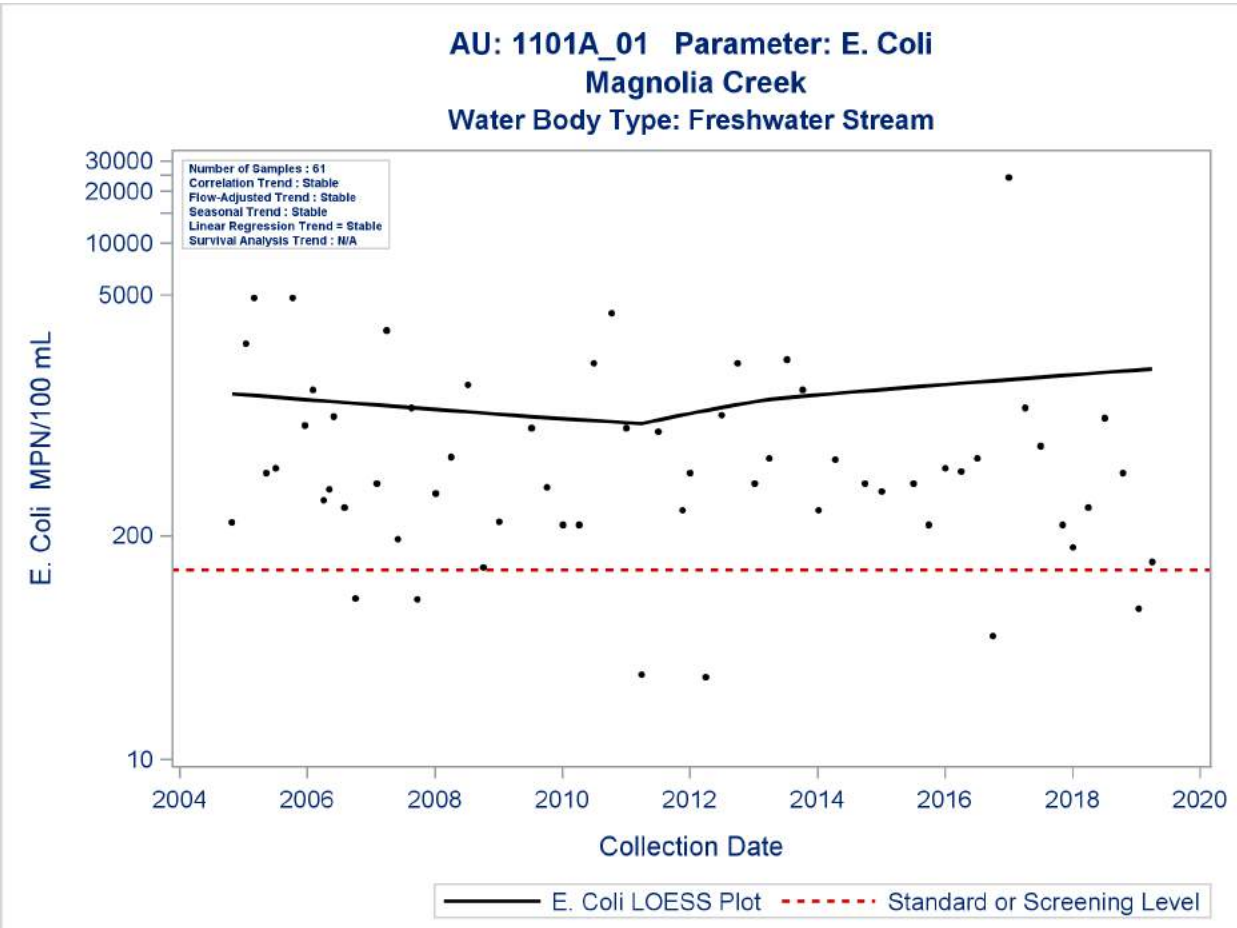


Figure 7 - E. coli results for Magnolia Creek (1101A_01), 2004 - 2019

Unclassified segment 1101B (Chigger Creek) has two AUs. The upstream AU is freshwater and is sampled for *E. coli* bacteria. The Integrated Report shows a geometric mean of 170 MPN/100 mL versus the freshwater standard of 126 MPN/100 mL. H-GAC's analysis of data from 2012 to 2019 shows an *E. coli* geometric mean of 253 MPN/100 mL. The downstream segment is tidal and is not currently monitored. The downstream AU is listed in the Integrated Report as NA (Not Assessed) as there is not sufficient data to perform an assessment. Figure 4 shows the *E. coli* results for Chigger Creek for the period of 2004 – 2019.

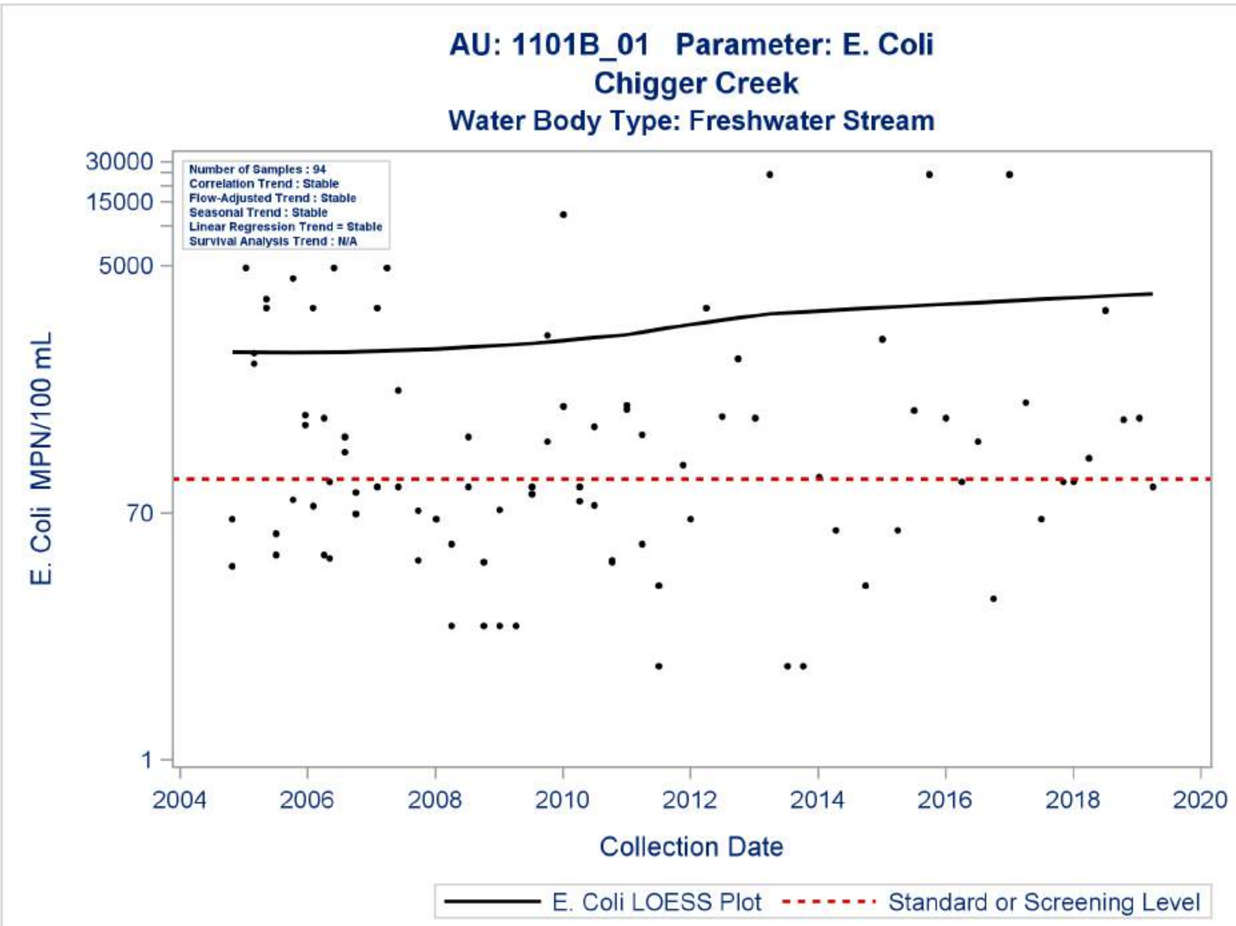


Figure 8 - E. coli results for Chigger Creek (1101B_01), 2004 - 2019

Cow Bayou (1101C) has an Enterococcus geometric mean of 253 (2018 Integrated Report) and 311 MPN/100 mL (H-GAC analysis) which greatly exceeds the 35 MPN/100 mL standard. The Enterococci results for this segment for the period of 2004 – 2019 are shown in Figure 5.

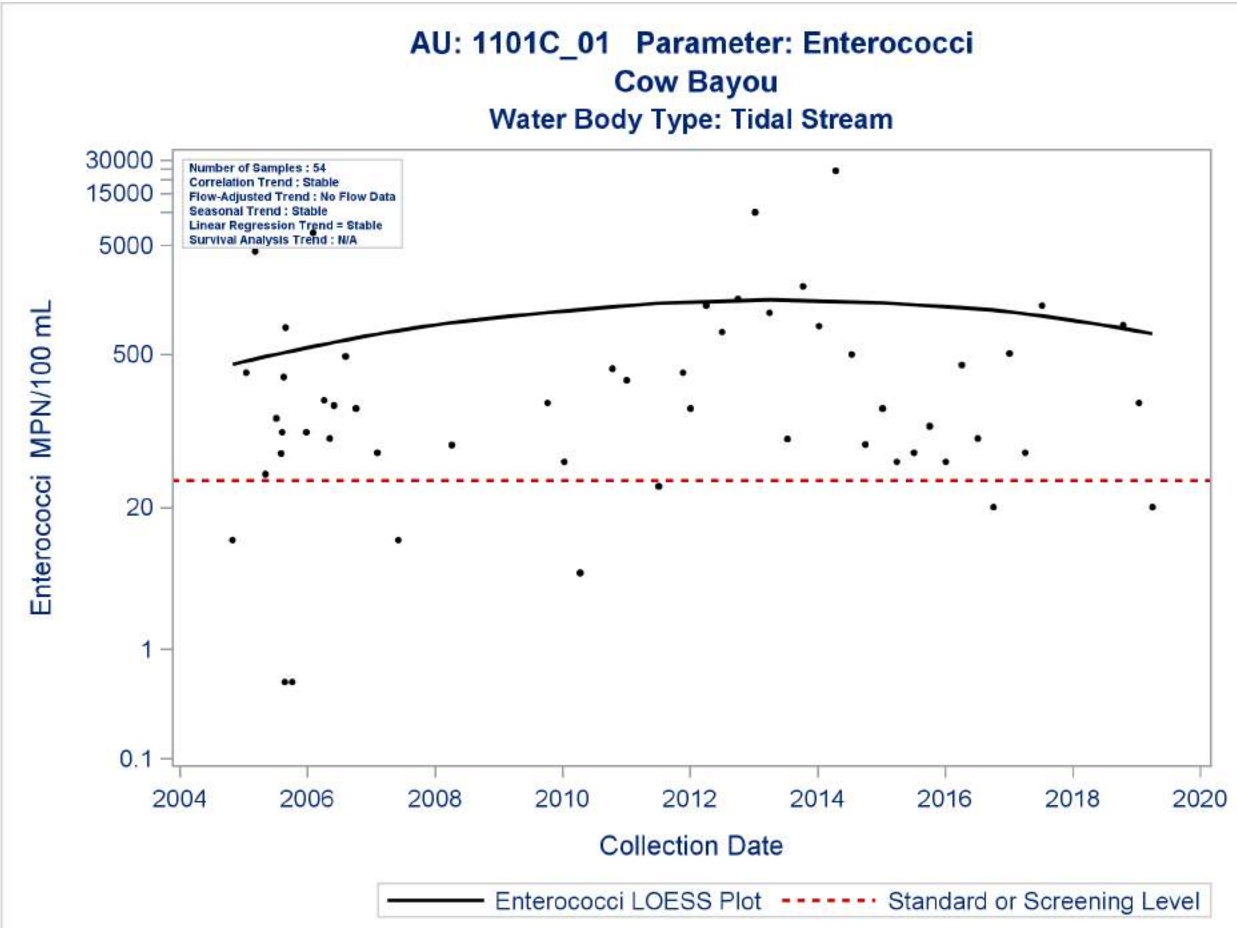


Figure 9 - Enterococci results for Cow Bayou (1101C), 2004 - 2019

The Enterococci geometric mean for Robinson Bayou's AU 1101D_01 was 285 in the 2008 Integrated Report and 305 in H-GAC's analysis of more recent data. There was not enough available data for an assessment of 1101D_02 in the IR.

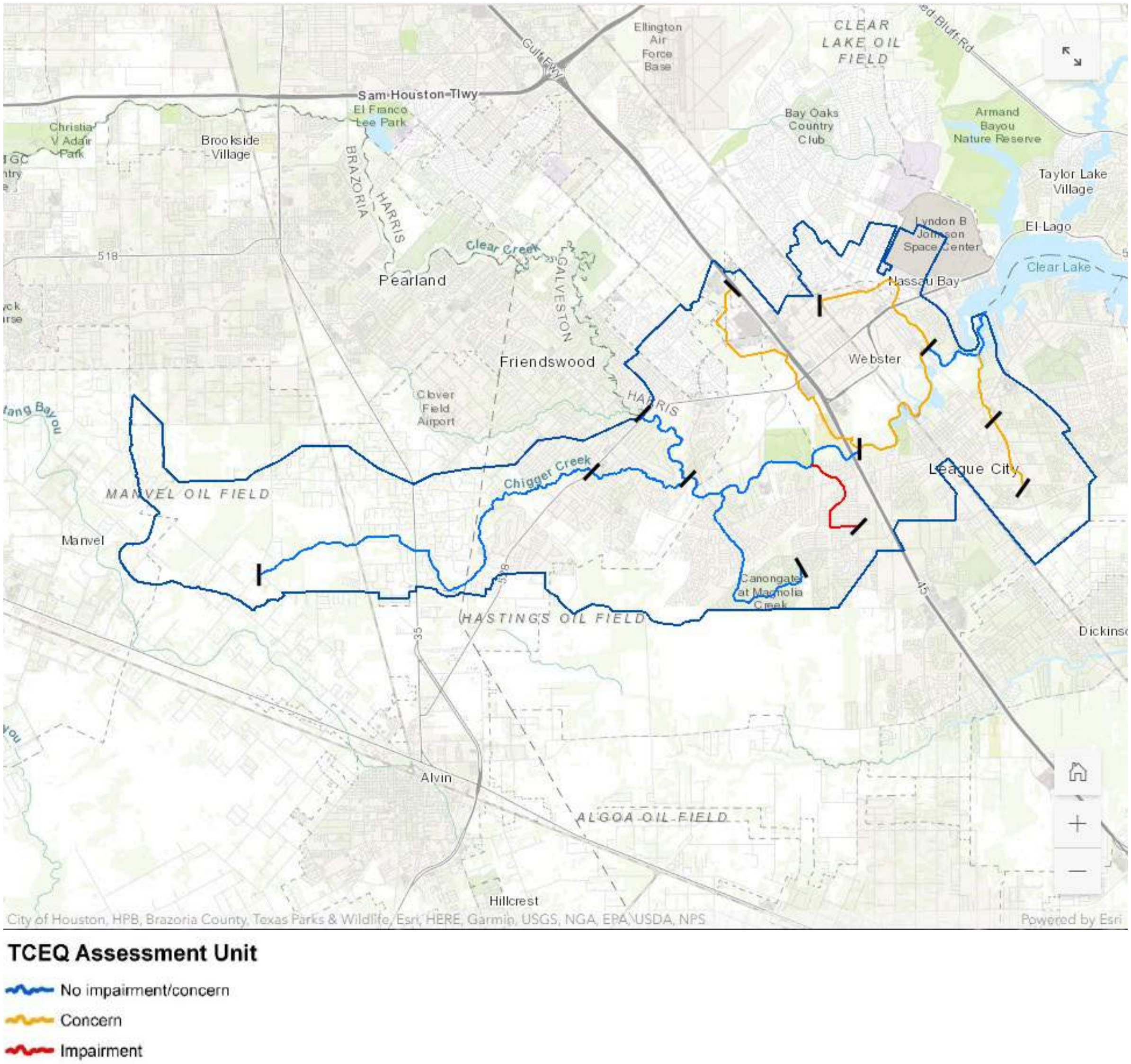
Unclassified segment 1101E (Newport Ditch) is not currently being sampled so there is no new data to demonstrate that bacteria concentrations have improved. When Newport Ditch was last monitored, its geometric mean was significantly higher than the standard so it is still considered non-supporting. Monitoring at this station was discontinued after repeated 24-hour DO monitoring indicated that measurements were consistent and reflective of true site conditions.

The unnamed tributary (1101F) that flows through the cemetery upstream of I-45 is supporting of the contact recreation standards with an *E. coli* geometric mean of 50 MPN/100 mL in the Integrated Report and 51 MPN/100 mL in H-GAC's analysis.

The impaired AUs within this segment are listed as category 4a, indicating that a Total Maximum Daily Load was completed to address the impairments and has been accepted by the EPA. The Bacteria Implementation Group (BIG) led the development of the Total Maximum Daily Load document for the Clear Creek watershed. The Total Maximum Daily Load was adopted by the TCEQ on September 10, 2008 and approved by the EPA on March 6, 2009.

Dissolved Oxygen Impairments and Concerns

There are four AUs in the Clear Creek Tidal segment showing concerns for screening levels based on DO grab samples results (Map 5), but 24-hour monitoring has not been conducted to determine whether the 24-hour average and minimum are less than the designated aquatic life use (ALU).



Map 10 - Dissolved Oxygen impairments and concerns in the Clear Creek Tidal watershed

The unnamed tributary upstream of I-45 (1101E), also known locally as Newport Ditch, is the only AU in the Clear Creek Tidal segment which does not support its high ALU designation. Seventy-five percent of all 24-hour averages were below 4.0 mg/L and 88 percent of 24-hour minimum DO measurements were less than 3.0 mg/L. Monitoring is not currently being conducted on this segment. This segment is categorized as 5c, indicating that additional information will be collected before a management strategy (such as a Total Maximum Daily Load) is scheduled.

Magnolia Creek (1101A) no longer has concerns for its DO values. Not only have the grab sample measurements improved but the 24-hour monitoring conducted during the past few years demonstrated the DO was fully supporting of the stream's high ALU. Figure 6 shows the DO results for Magnolia Creek for 2004 through 2019.

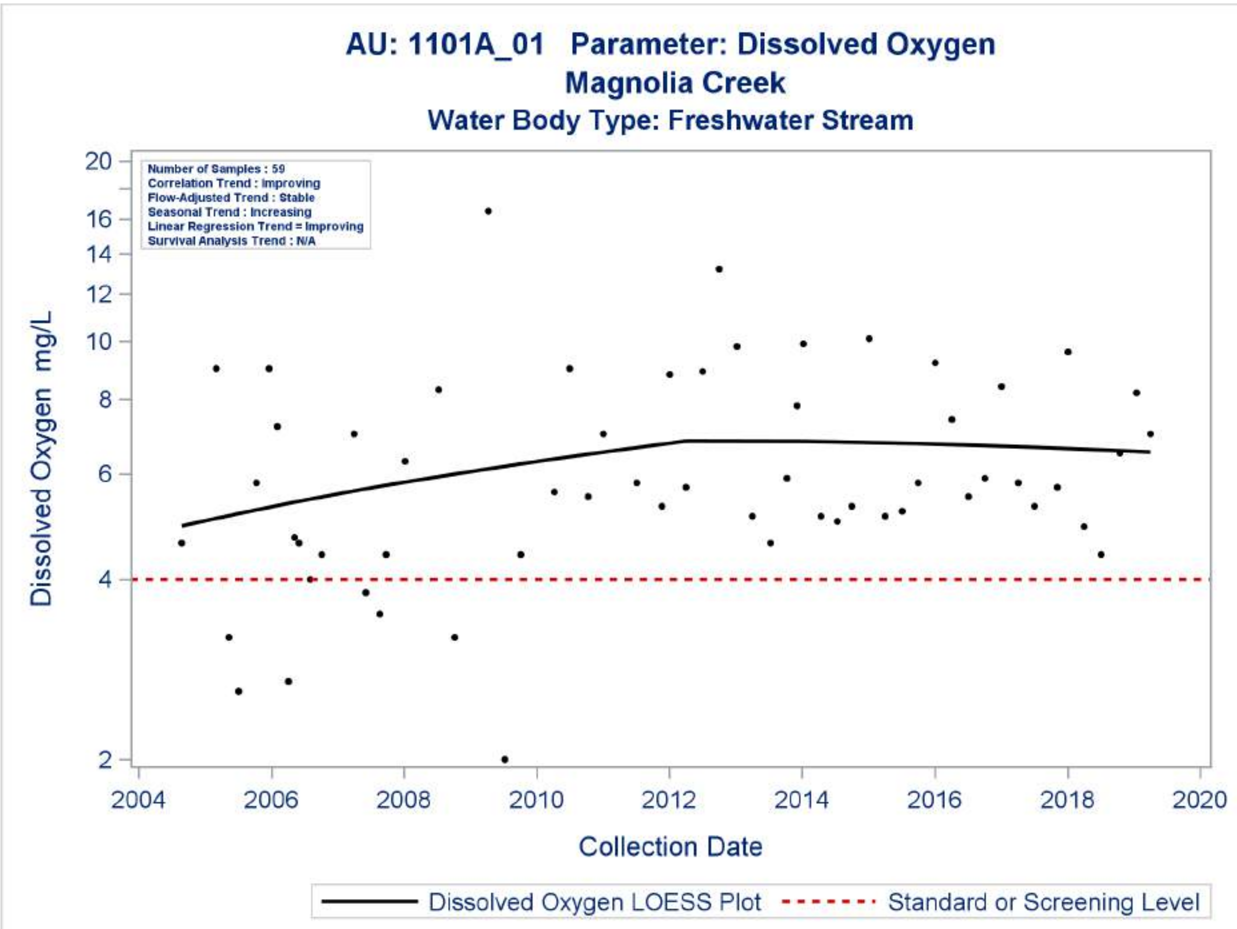


Figure 10 - Dissolved Oxygen grab sample results for Magnolia Creek (1101A_01, 2004 - 2019)

Table 7 shows the results of the analysis of DO samples for the Clear Creek Tidal watershed.

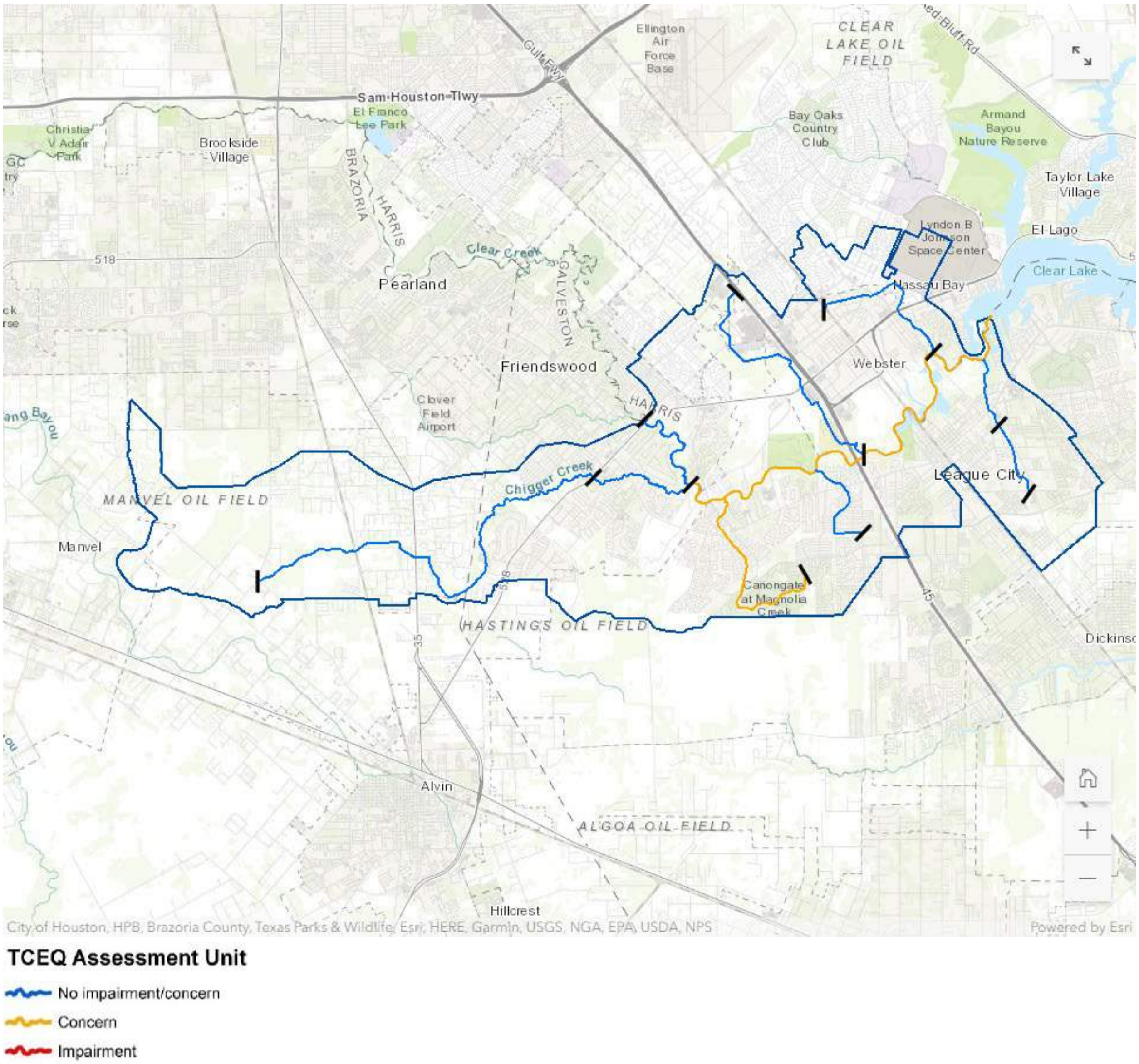
Table 14 - Comparison of 2018 IR Dissolved Oxygen Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

Waterbody	Seg ID	AU_ID	Parameter	Level of Support	Cat	Percentage of Samples Exceeding Standard (2018 IR, 2009 – 2016)	Percentage of Samples Exceeding Standard (H-GAC Analysis, 2012 - 2019)
Clear Creek Tidal	1101	1101_03	DO grab Minimum	FS	-	0	0
			DO Grab Screening Level	CS	-	14	12
		1101_04	DO grab Minimum	FS	-	0	0
			DO Grab Screening Level	NC	-	4	0
Magnolia Creek	1101A	1101A_01	Do grab Minimum	FS	-	0	0
			DO grab Screening Level	NC	-	0	0
Chigger Creek	1101B	1101B_01	DO grab Minimum	FS	-	6	7
			DO grab Screening Level	NC	-	6	7
Cow Bayou	1101C	1101C_01	DO grab Minimum	FS	-	8	4
			DO Grab Screening Level	CS	-	19	17
Robinson Creek	1101D	1101D_01	DO grab Minimum	FS	-	12	0
			DO grab Screening Level	CS	-	23	0
		1101D_02	DO grab Screening Level	CS	-	**	27
Unnamed Tributary	1101E	1101E_01	DO 24-hour Avg	NS	5c	75	71
			DO 24-hour Min	NS	5c	88	86
			DO grab Minimum	NA		100	100
			DO grab Screening Level	NA		100	100
Unnamed Tributary	1101F	1101F_01	DO grab	FS	-	7	4
			DO Grab Screening Level	CS	-	25	32

FS = Fully Supporting CS = Concern for Screening *Insufficient Data available
NS = Not Supporting NC = No Concern **Not Calculated
NA = Not Assessed

Nutrient Concerns

There are numerous concerns for nutrients in Clear Creek Tidal (1101) and Magnolia Creek (1101A). These segments with concerns are highlighted in Map 6.



Map 11 - Nutrient Concerns in the Clear Creek Tidal watershed

Table 8 shows the percentage of samples exceeding nutrient screening criteria. Results are shown for both the 2018 Integrated Report and H-GAC's analysis of data.

Table 15 - Comparison of 2018 IR Nitrate Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

Waterbody	Seg ID	AU_ID	Parameter	Level of Support	Percentage of Samples Exceeding Screening Criteria (2018 IR, 2009 – 2016)	Percentage of Samples Exceeding Screening Criteria (H-GAC Analysis, 2012 - 2019)
Clear Creek Tidal	1101	1101_02	Nitrate	CS	**	86
		1101_03	Nitrate	CS	57	58
		1101_04	Nitrate	CS	40	36
Magnolia Creek	1101A	1101A_01	Nitrate	CS	52	81

FS = Fully Supporting | CS = Concern for Screening | *Insufficient Data available
NS = Not Supporting | NC = No Concern | **Not Calculated

There is a concern for screening levels for nitrate in three AUs (1101_02, 1101_03, and 1101_04). In some AUs, the percentage of samples exceeding the screening level was greater than 50 percent. In H-GAC's analysis of data from 1101_02, 86 percent of results exceeded the screening level (Figure 7).

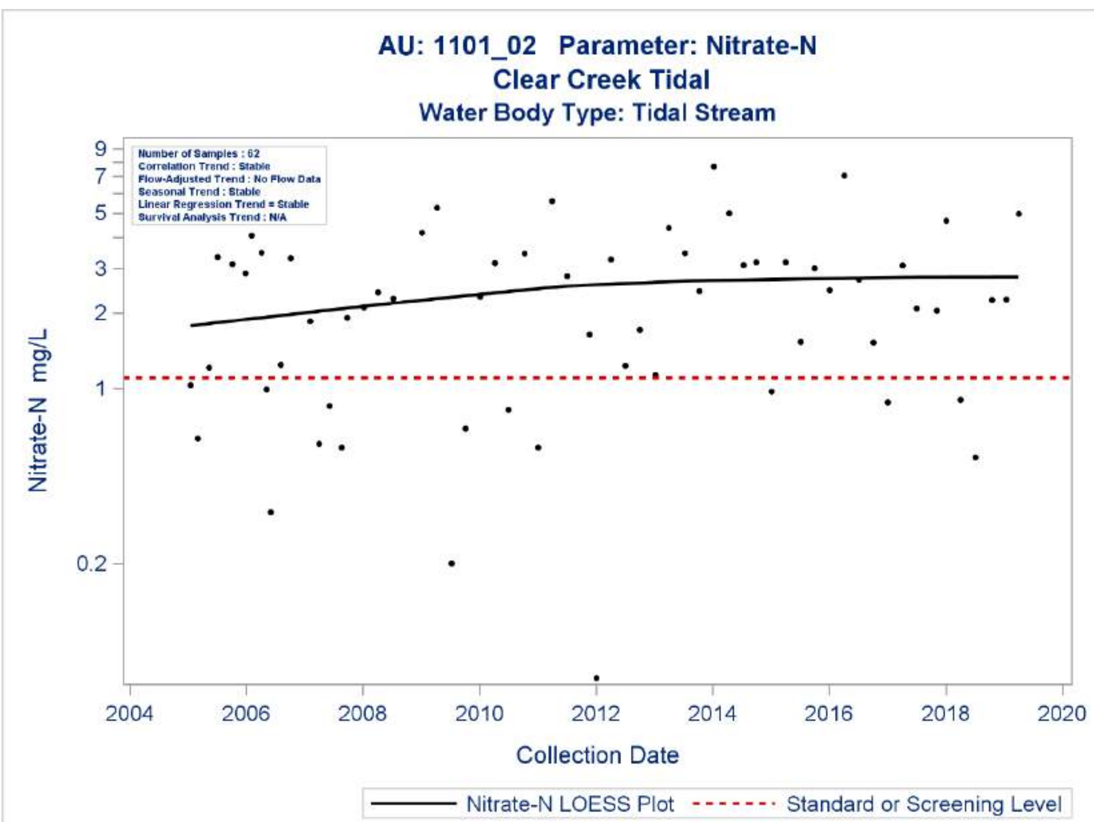


Figure 11 - Nitrate-N results for Clear Creek Tidal (AU 1101_02), 2004 - 2019

There is a concern for screening levels for nitrate for Magnolia Creek, with results showing a statistically significant increase beginning in 2013 (Figure 8). This marked increase in nitrate results may be the result of fertilizer application to landscaped areas within the watershed.

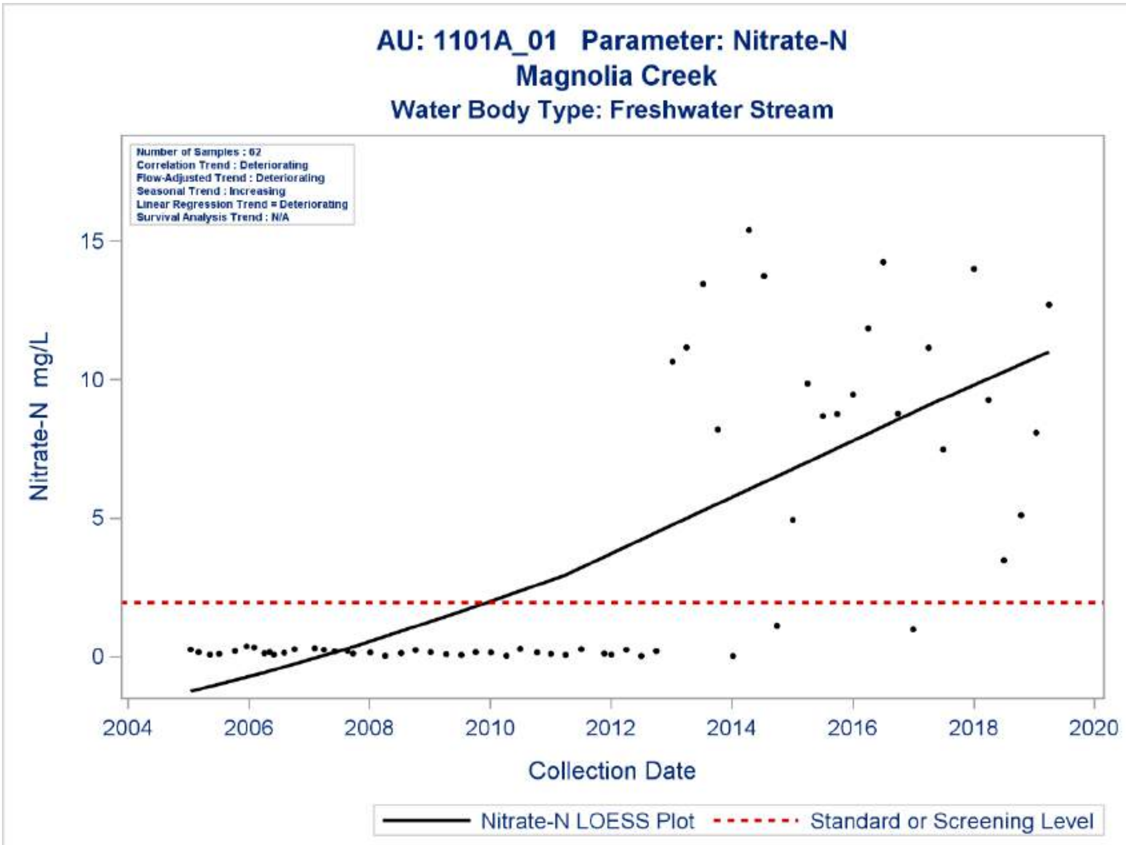


Figure 12 - Nitrate-N results for Magnolia Creek (1101A), 2004 - 2019)

No concerns were identified for ammonia in Clear Creek Tidal or any of the unclassified segments within the watershed (Table 9).

Table 16 - Comparison of 2018 IR Ammonia Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

Waterbody	Seg ID	AU_ID	Parameter	Level of Support	Percentage of Samples Exceeding Screening Criteria (2018 IR, 2009 – 2016)	Percentage of Samples Exceeding Standard (H-GAC Analysis, 2012 - 2019)
Clear Creek Tidal	1101	1101_03	Ammonia	NC	7	4
		1101_04	Ammonia	NC	6	2

FS = Fully Supporting CS = Concern for Screening *Insufficient Data available
NS = Not Supporting NC = No Concern **Not Calculated

Total Phosphorus was identified as a concern in three of Clear Creek's Tidal assessment units (Table 10). A concern for screening levels was also identified in Magnolia Creek. The results for total phosphorus in Magnolia Creek (Figure 9), particularly the timing of the increase in results, correlate well with the nitrate results (Figure 8). This indicates that these increases in nutrient levels may have a related cause.

Table 17 - Comparison of 2018 IR Total Phosphorus Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

Waterbody	Seg ID	AU_ID	Parameter	Level of Support	Percentage of Samples Exceeding Screening Criteria (2018 IR, 2009 – 2016)	Percentage of Samples Exceeding Standard (H-GAC Analysis, 2012 - 2019)
Clear Creek Tidal	1101	1101_02	Total Phosphorus	CS	**	68
		1101_03	Total Phosphorus	CS	46	43
		1101_04	Total Phosphorus	CS	31	24
Magnolia Creek	1101A	1101A_01	Total Phosphorus	CS	52	82

FS = Fully Supporting CS = Concern for Screening *Insufficient Data available
NS = Not Supporting NC = No Concern **Not Calculated

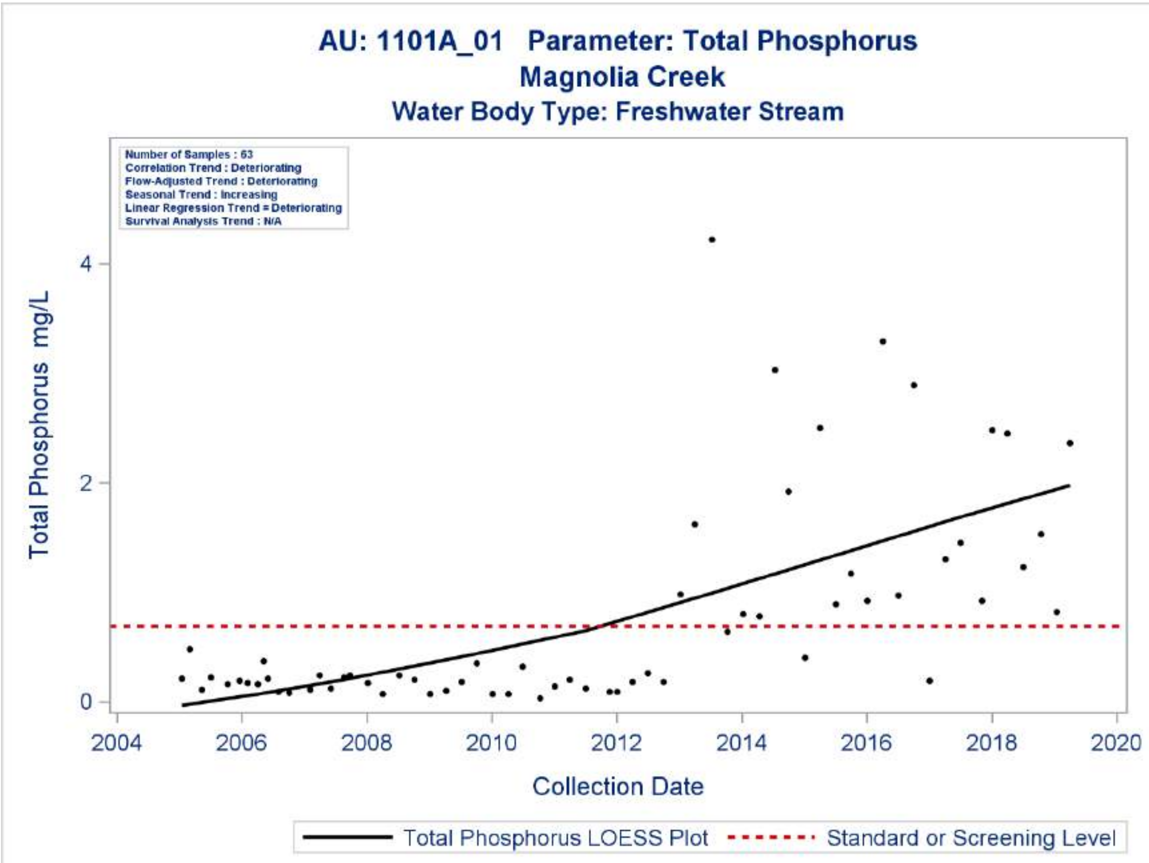


Figure 13 - Total Phosphorus results for Magnolia Creek (1101A_01), 2004 - 2019

A concern for screening level for chlorophyll was identified in the 2018 Integrated Report for AU 1101_04 (Table 11). There were insufficient data collected during the assessment period, so this impairment is a carry-forward from the previous assessment. No other Chlorophyll concerns were identified.

Table 18 - Comparison of 2018 IR Chlorophyll Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

Waterbody	Seg ID	AU_ID	Parameter	Level of Support	Percentage of Samples Exceeding Screening Criteria (2018 IR, 2009 – 2016)	Percentage of Samples Exceeding Standard (H-GAC Analysis, 2012 - 2019)
Clear Creek Tidal	1101	1101_03	Chlorophyll	NC	26	0
		1101_04	Chlorophyll	CS	*	50

FS = Fully Supporting
NS = Not Supporting
CS = Concern for Screening
NC = No Concern
*Insufficient Data available
**Not Calculated

Other Parameters of Interest

Figure 10 provides an illustration of how weather patterns have affected the chloride concentrations in AU 1101_03 of Clear Creek Tidal from 2004 to 2019. In 2008, Hurricane Ike pushed saltwater up into the bay and tributaries. Additionally, the greater Houston area experienced a drought from 2009 to 2012. The more recent years show a decreased concentration in chlorides due to the end of the drought and increased rainfall events related to super storms such as the “tax day flood.” Hurricane Harvey deposited more than 45 inches of rain in the League City, Friendswood, and Clear Lake area in August 2017.

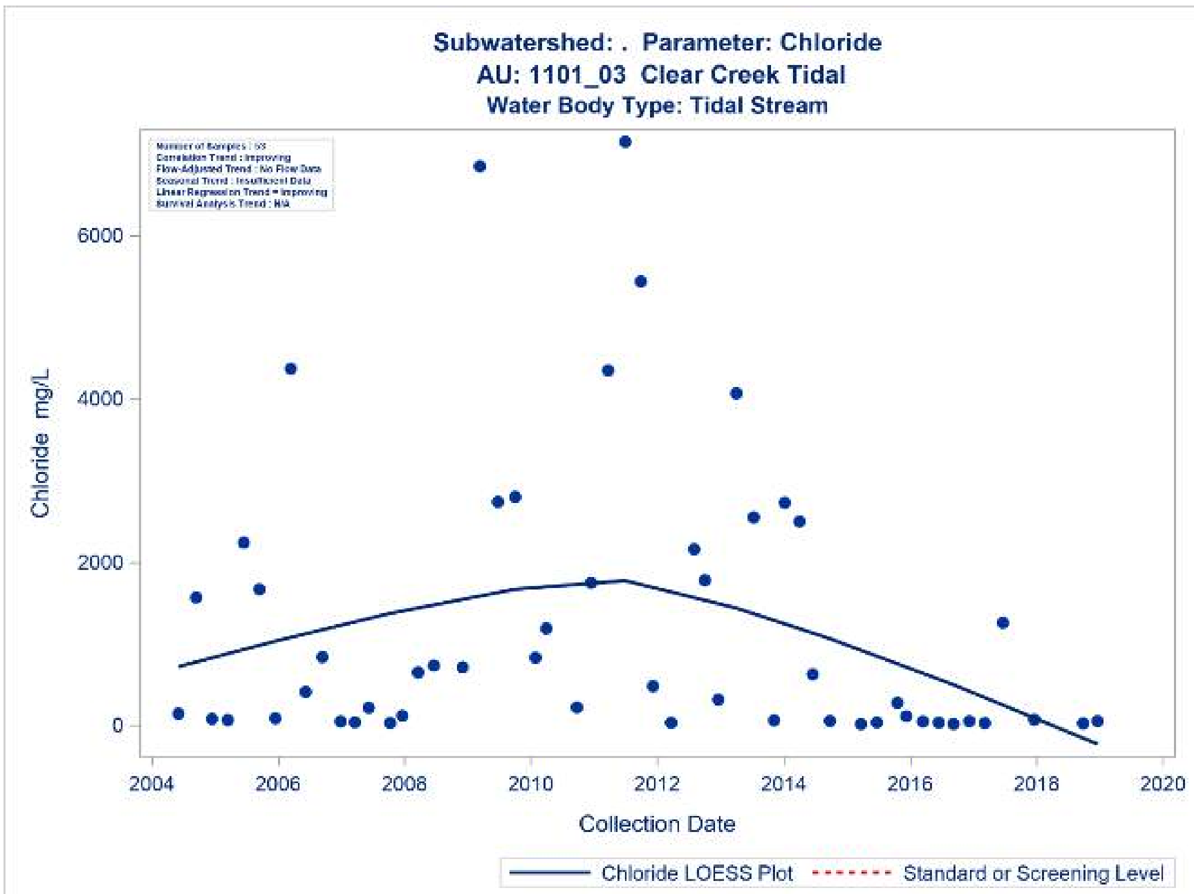
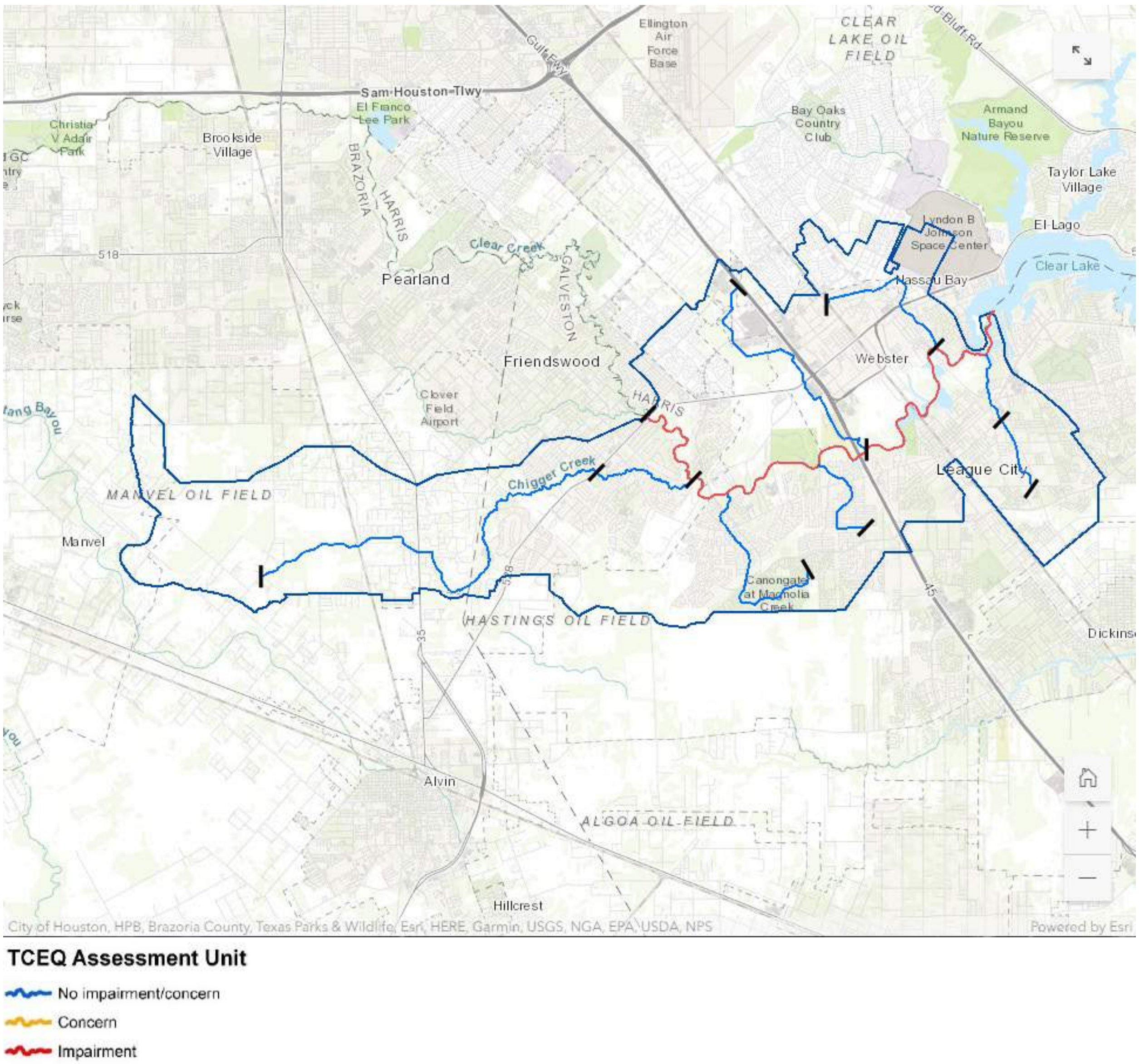


Figure 14 - Chloride concentrations of samples collected in Clear Creek Tidal segment (1101_03)

PCB and Dioxin Impairments

Clear Creek Tidal is listed as impaired for PCBs and Dioxins in fish tissue (Map 7). Fish samples collected from Clear Creek indicate the presence of PCBs at a concentration exceeding health assessment guidelines. A fish consumption advisory (ADV-37) issued by the Texas Department of State Health Services (TDSHS) on July 8, 2009 advises that people should not consume any species of fish from these waters.



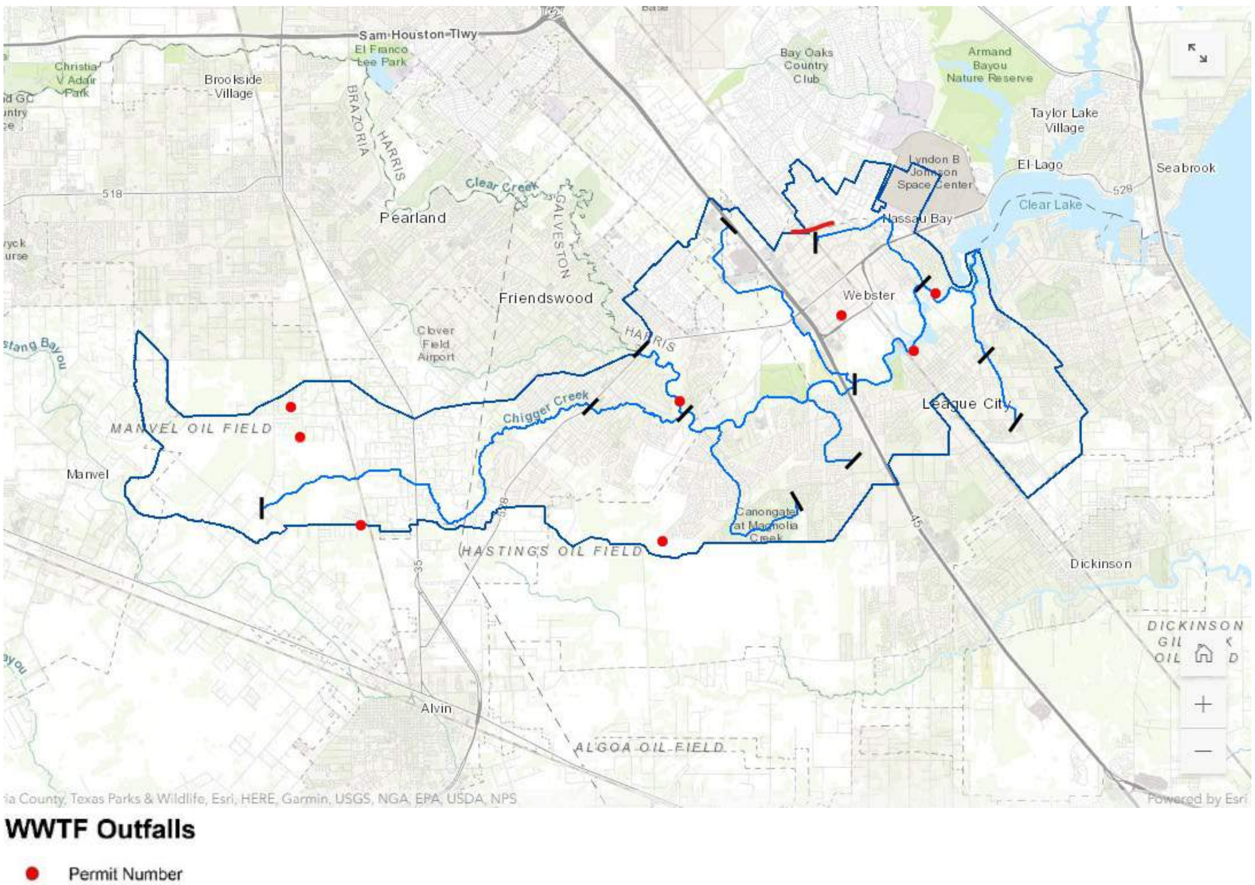
Map 12 - PCBs and Dioxin Impairments in the Clear Creek Tidal watershed

POTENTIAL SOURCES OF WATER QUALITY ISSUES

Potential sources of fecal indicator bacteria in the Clear Creek Tidal watershed include wastewater treatment facility effluent, sanitary sewer overflows, failing on-site sewage facilities, and other nonpoint sources.

Wastewater Treatment Facilities

There are five regulated wastewater treatment facilities in the Clear Creek Tidal watershed, some with multiple outfalls (Map 8). All of the facilities within this watershed are large, with permitted flows ranging from 3.30 Million Gallons per Day (MGD) up to 12.0 MGD.



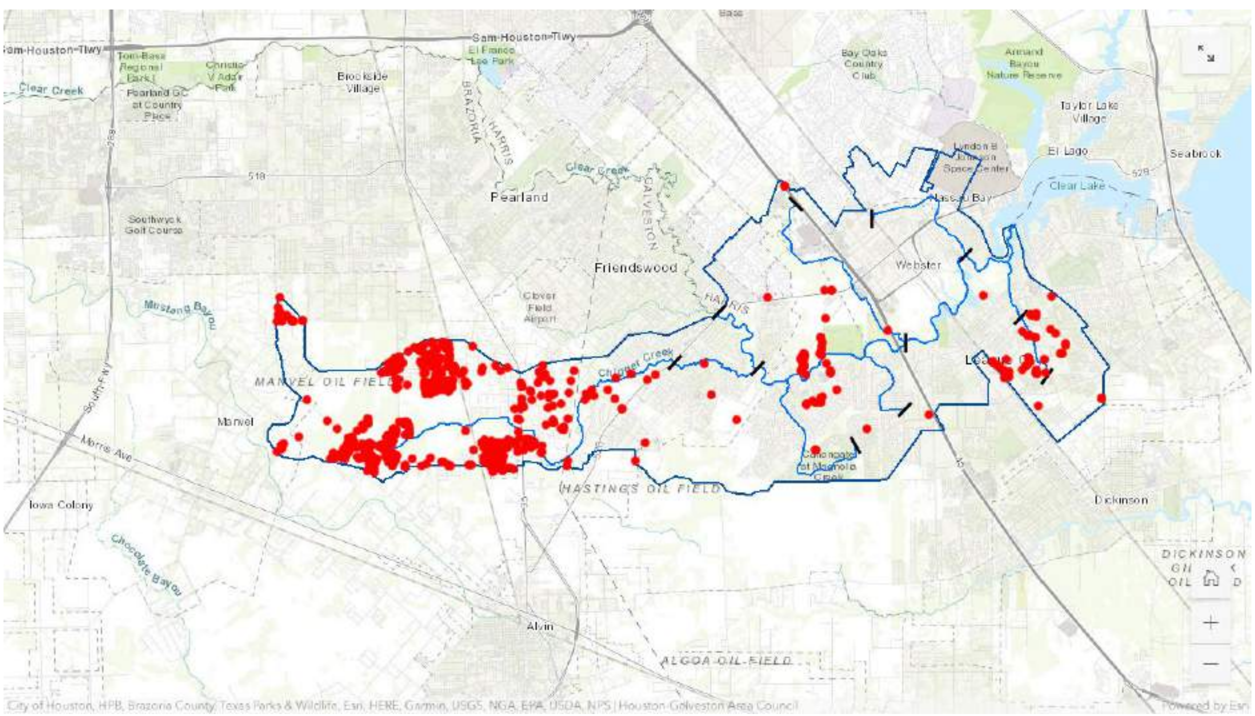
Map 13 - Permitted wastewater treatment facilities in the Clear Creek Tidal watershed

Sanitary Sewer Overflows

Although there are not many wastewater treatment facilities within the watershed, the facilities that are present service a sizeable portion of the watershed. Issues such as inflow and infiltration, mechanical failure, and improper disposal of fats, oils, and grease can result in sanitary sewer overflows at manholes and lift stations throughout the sanitary sewer collection system. Additionally, as the transmission lines of these wastewater collection systems age, they are prone to failure.

On-Site Sewage Facilities

There are 599 permitted on-site sewage facilities in the Clear Creek Tidal watershed (Map 9). The majority of these systems are in the less developed western part of the watershed. Much of this portion of the watershed remains pasture/grassland, and centralized sewer service, such as a wastewater treatment facility and collection system, are not an available option. In addition to these permitted systems, there are likely numerous unpermitted systems that were installed prior to the requirement that systems require a permit.



On-Site Sewage Facilities

TCEQ Assessment Unit

Map 14 - Permitted on-site sewage facilities in the Clear Creek Tidal watershed

Other Nonpoint Sources

Landscaping related to residential developments, golf courses, etc., may be an important source of elevated bacteria and nutrients within certain areas of the watershed, particularly Magnolia Creek. Pet waste may be a significant contributor to bacteria levels, particularly in the heavily populated areas of the watershed. Hobby farms, supporting a small number of animals, are also common in the upper reach of Chigger and Robinson Creeks which would be another potential source of bacteria and nutrients.

POTENTIAL STAKEHOLDERS

Potential stakeholders include:

- City of Friendswood
- City of League City
- City of Nassau Bay
- City of Webster
- Galveston Bay Foundation
- Galveston County
- Gulf Coast Waste Disposal Authority
- Harris County Commissioner Precinct 1
- Harris County Commissioner Precinct 2
- TCEQ Region 12 Office
- TCEQ Galveston Bay Estuary Program
- Texas Community Watershed Partners
- Texas State Soil and Water Conservation Board
- The Bacteria Implementation Group (BIG) Members
- Environmental and Conservancy Groups
- Citizen Groups, such as the Texas Master Naturalists
- Community Groups
- Homeowner Associations
- Drainage Districts
- Utility Districts
- Industry

ONGOING PROJECTS

H-GAC has been tasked by the TCEQ to implement a basin-wide approach for addressing bacterial impairments for the San Jacinto-Brazos Coastal Basin which includes Clear Creek. Development for the basin-wide Total Maximum Daily Load began in September 2015 and resulted in a final Basin 11 Summary Report that summarized basin characteristics, water quality impairments, potential bacteria sources, and recommendations for bacterial reduction. This segment is also part of the geographic area for the Bacteria Implementation Group (BIG) Total Maximum Daily Load.

H-GAC will develop a watershed protection plan for Clear Creek. This project is scheduled to begin in September 2020.

RECOMMENDATIONS FOR IMPROVING WATER QUALITY

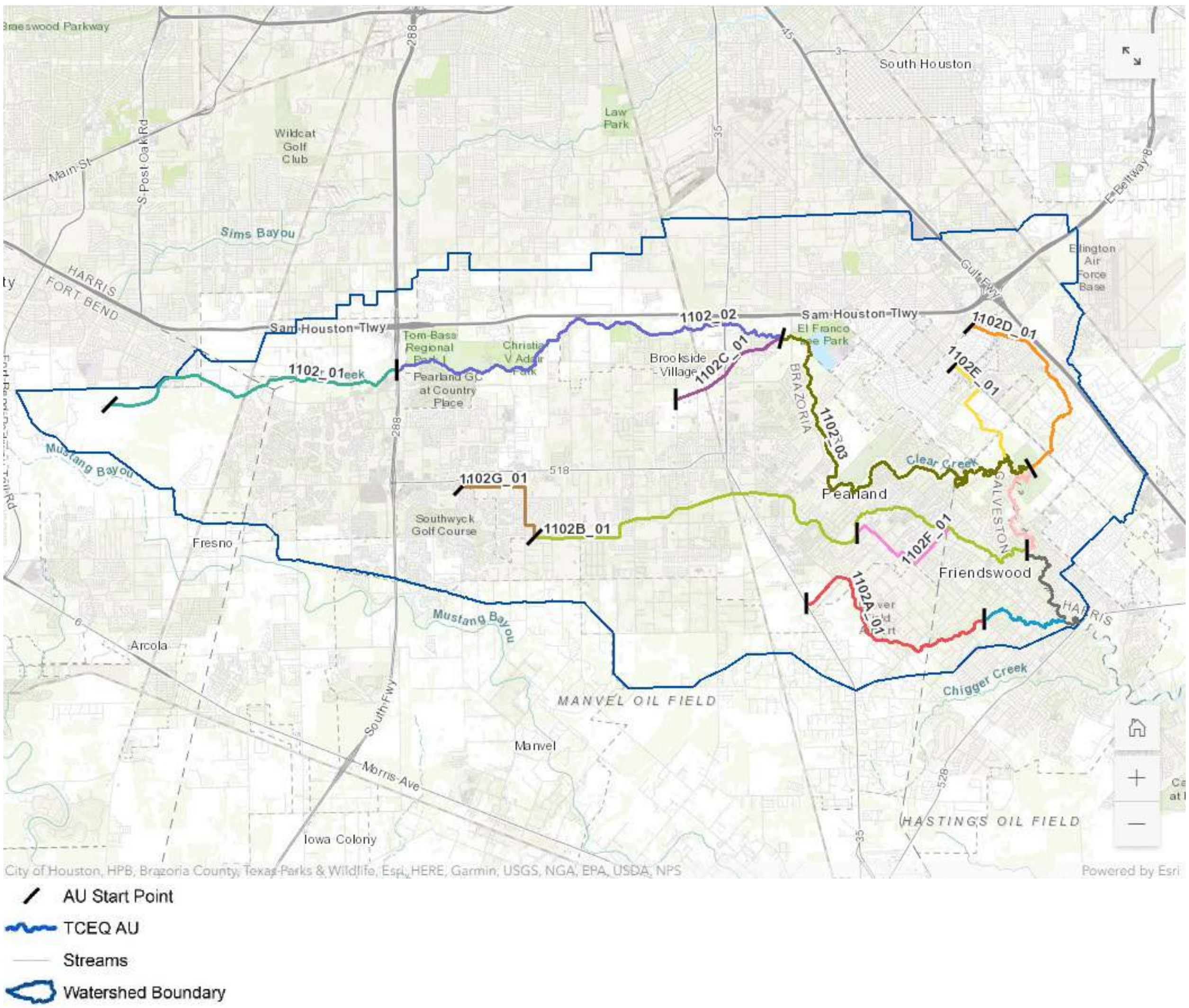
- Address bacteria and various other concerns through stakeholder involvement and best management practices
- Continue to work with the BIG to implement recommendations for bacteria reduction
- Continue to analyze Discharge Monitoring Report data and present results to TCEQ, wastewater permittees, local governments/utility districts, and stakeholders
- Improve compliance and enforcement of existing stormwater quality permits and improve stormwater controls in new developments
- Support public education programs to inform business and homeowners on appropriate disposal of fats, oil, and grease
- Support programs that oversee the maintenance, repair, and replacement of on-site sewage facilities
- Continue collecting water quality data and expand monitoring efforts to support actions associated with the Total Maximum Daily Load program and future watershed protection plan development
- Pursue new local partners to collect additional data to help better isolate problem areas
- Expand volunteer monitoring with Texas Stream Team in areas without professional monitoring
- Implement YardWise and Watersmart landscape practices
- Create and implement Water Quality Management Plans for individual agricultural properties
- Support public education on pet waste disposal
- Consult stakeholders to identify illegal dumping sites and improve signage and/or cameras, if needed

DETAILED WATERSHED CHARACTERIZATION
Clear Creek Above Tidal (1102)

Figure 1 - Clear Creek Above Tidal in the Pearland area

SEGMENT DESCRIPTION

Clear Creek Above Tidal (Segment 1102) is a classified freshwater stream described as extending from a point 100 meters (110 yards) upstream of FM 528 in Galveston/Harris County to Rouen Road in Fort Bend County. This watershed is located in the San Jacinto-Brazos Coastal Basin (Basin 11). Clear Creek forms the county line between Harris and Galveston counties and Harris and Brazoria counties. The Clear Creek Above Tidal watershed is shown in Map 1.



Map 1 - Clear Creek Above Tidal (Segment 1102) watershed map

The 2018 Texas Integrated Report describes five Assessment Units (AUs) in segment 1102 (Table 1).

Table 1 - Assessment Units in the Clear Creek Above Tidal segment (1102)

Segment Name	Segment ID	AU	Description
Clear Creek Above Tidal	1102	1102_01	Upper segment boundary (Rouen Road) to SH 288
Clear Creek Above Tidal	1102	1102_02	SH 288 to Hickory Slough confluence
Clear Creek Above Tidal	1102	1102_03	Hickory Slough confluence to Turkey Creek confluence
Clear Creek Above Tidal	1102	1102_04	Turkey Creek confluence to Mary's Creek confluence
Clear Creek Above Tidal	1102	1102_05	Mary's Creek confluence to lower segment boundary

There are seven additional unclassified water bodies or sub-watersheds in the segment. Those unclassified water bodies are listed in Table 2.

Table 2 - Unclassified segments in the Clear Creek Above Tidal watershed

Segment Name	Segment ID	Description
Cowart Creek	1102A	From the Clear Creek Above Tidal confluence in Galveston County to Texas State Highway 35 in Brazoria County
Mary's Creek / North Fork Mary's Creek	1102B	Perennial stream from the confluence with Clear Creek Above Tidal to the confluence with North and South Fork Mary's Creek near FM 1128, approximately 5 km (3.1 miles) southwest of Pearland. Includes perennial portion of North Fork Mary's Creek to the confluence with an unnamed tributary approximately 1.98 miles upstream of FM 1128.
Hickory Slough	1102C	From the Clear Creek Above Tidal confluence to a point 0.69 km (0.43 miles) upstream of Mykawa Road.
Turkey Creek	1102D	From the Clear Creek Above Tidal confluence to a point 0.98 km (0.61 miles) upstream of Scarsdale Boulevard.
Mud Gully	1102E	From confluence with Clear Creek Above Tidal to a point 0.80 km (0.49 miles) downstream of Hughes Road.
Mary's Creek Bypass	1102F	From the Mary's Creek confluence northeast of FM 518 to a point (0.96 km (0.60 miles) upstream to the Mary's Creek confluence (northwest of County Road 126).
Unnamed Tributary of Mary's Creek	1102G	From the Mary's Creek confluence 1.3 km (0.84 miles) west of FM 1128 to a point 1.2 km (0.75 miles) upstream to the confluence of an unnamed tributary.

HYDROLOGICAL CHARACTERISTICS

Clear Creek Above Tidal is a freshwater stream in the southern portion of Houston. Historically, the area has been primarily rural, but has undergone tremendous growth in recent years, particularly in the FM 518 and SH 288 corridor, that has resulted in an increased amount of development.

Clear Creel Above Tidal originates in the eastern portion of Fort Bend County and flows east to become the boundary of Harris and Brazoria counties. The segment continues, becoming the boundary of Harris and Galveston counties, before entering the tidal portion of Clear Creek.

Besides receiving flow from surface runoff, this waterway receives effluent from 13 regulated wastewater treatment facility outfalls scattered throughout the segment.

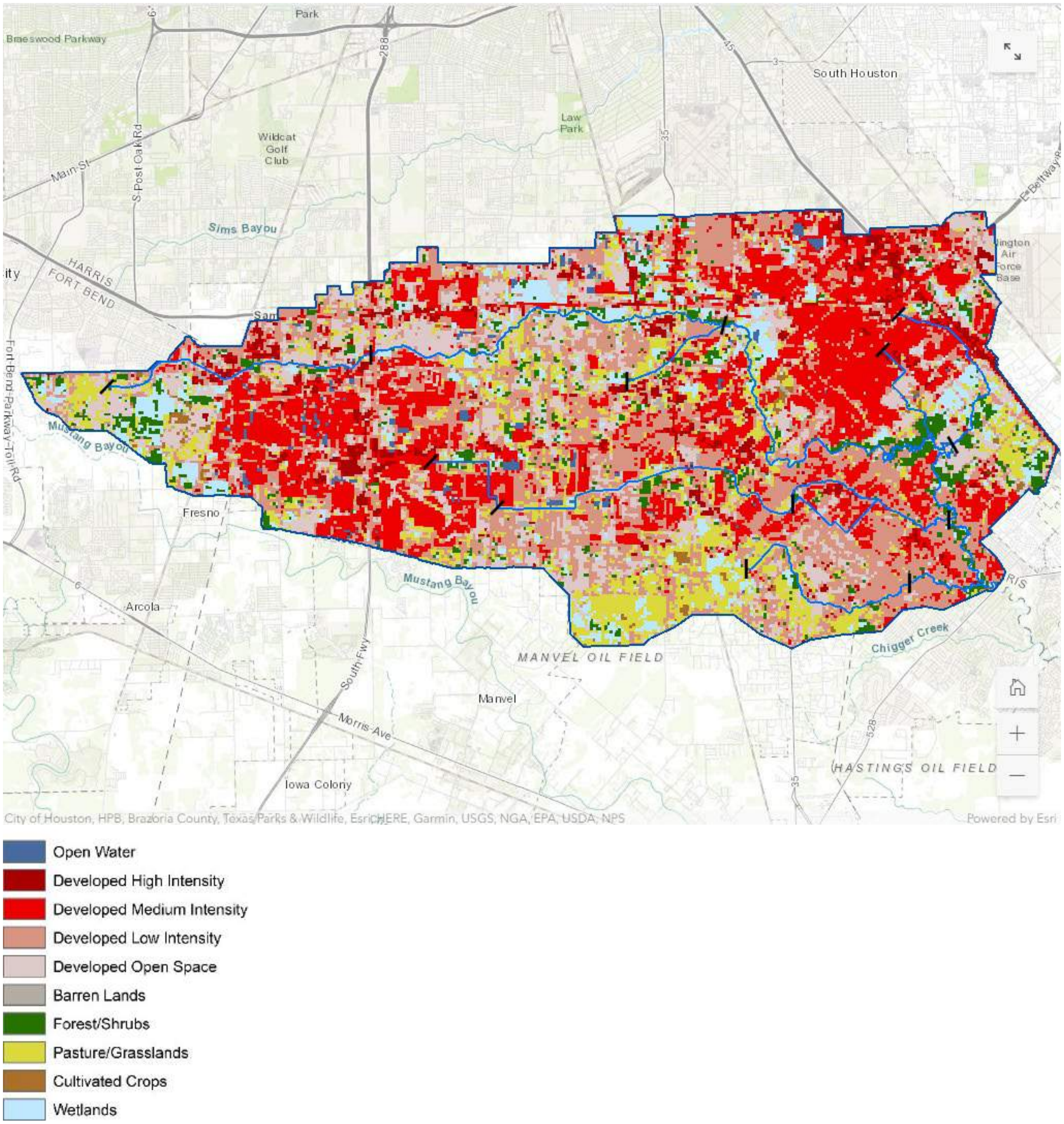
LAND COVER AND NATURAL CHARACTERISTICS

The Clear Creek Above Tidal watershed covers approximately 73,290 acres. Developed lands are dispersed throughout the watershed and compose 73.21 percent of the land cover. Agriculture, made up of cultivated crops and pasture/grassland, is the next largest land cover category, at 13.44 percent. High intensity developments have increased exponentially along the State Highway 288 corridor which run north-south through the west side of Pearland. Nearly 3,000 acres of land has been converted to development in the watershed between 2008 and 2018 (Table 3).

Table 3 - Land Cover Comparisons 2008 – 2018

Land Cover Class Name	Area Acres 2008	Area % 2008	Area Acres 2018	Area % 2018	% Change
Agriculture	12469.71	17.02	9846.83	13.44	-21.03
Barren Lands	1479.70	2.02	593.96	0.81	-59.86
Developed	50805.16	69.33	53643.67	73.21	5.59
Forest/Shrubs	1503.66	2.05	3600.39	4.91	-63.97
Open Water	1076.10	1.47	701.43	0.96	-34.82
Wetlands	5941.42	8.11	4883.12	6.66	-17.81
TOTAL	**73275.74**	**100.00**	**73269.40**	**100.00**	

Map 2 shows the distribution of land cover types in the Clear Creek Above Tidal watershed. Table 4 provides a description of these land cover types.



Map 2 - Land Cover in the Clear Creek Above Tidal watershed

Table 4 - Descriptions of Land Cover Classes

Map Key	Land Cover Class	Class Description
	Developed, High Intensity	Contains significant land area and is covered by impervious surfaces (i.e., concrete, asphalt, and other constructed materials). Vegetation, if present, occupies < 20 percent of the landscape. Impervious surfaces account for 80 to 100 percent of the total cover. This class includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas with a variety of land uses.
	Developed, Medium Intensity	Contains areas with a mixture of impervious surfaces and vegetation or other cover. Impervious surfaces account for 50 to 79 percent of total area. This class commonly includes multi- and single-family housing areas, especially in suburban neighborhoods, but may include all types of land use.
	Developed, Low Intensity	Contains areas with a mixture of impervious surfaces and substantial amounts of vegetation or other cover. Impervious surfaces account for 21 to 49 percent of total area. This class commonly includes single-family housing areas, especially in rural neighborhoods, but may include all types of land use.
	Developed, Open Space	Contains areas with a mixture of some impervious surfaces, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes. Impervious surfaces account for less than 20 percent of total land cover. This class commonly includes large-lot single family housing units, parks, and golf courses.
	Agriculture, Pasture/Grasslands	Contains both managed and unmanaged grasses, legumes, or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas can be subjective to intensive management, such as tilling, and utilized for grazing.
	Agriculture, Cultivated	Contains areas intensely managed for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
	Barren Land	Contains areas of gravel pits, bedrock, sand dunes, and other accumulations of earth material. Generally, vegetation accounts for less than 10 percent of total cover.
	Forest/Shrub	Includes two types of trees that cover greater than 20 percent of total vegetation cover. • *Forest*—areas dominated by all kinds of trees generally greater than 5 meters tall. • *Shrub*—areas dominated by shrubs generally less than 5 meters tall.
	Open Water	Include areas of open water, generally with less than 25 percent cover of vegetation or soil.
	Wetlands	Includes the area contains palustrine or estuarine vegetation that are periodically saturated or covered with water. Total vegetation coverage is greater than 20 percent.

Source: National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) Land Cover Classifications
https://coast.noaa.gov/digitalcoast/training/ccap-land-cover-classifications.html

With more impervious cover, the lower AUs in the segment are now showing higher instantaneous flows compared to previous years, especially during rain events (Figures 2 and 3).

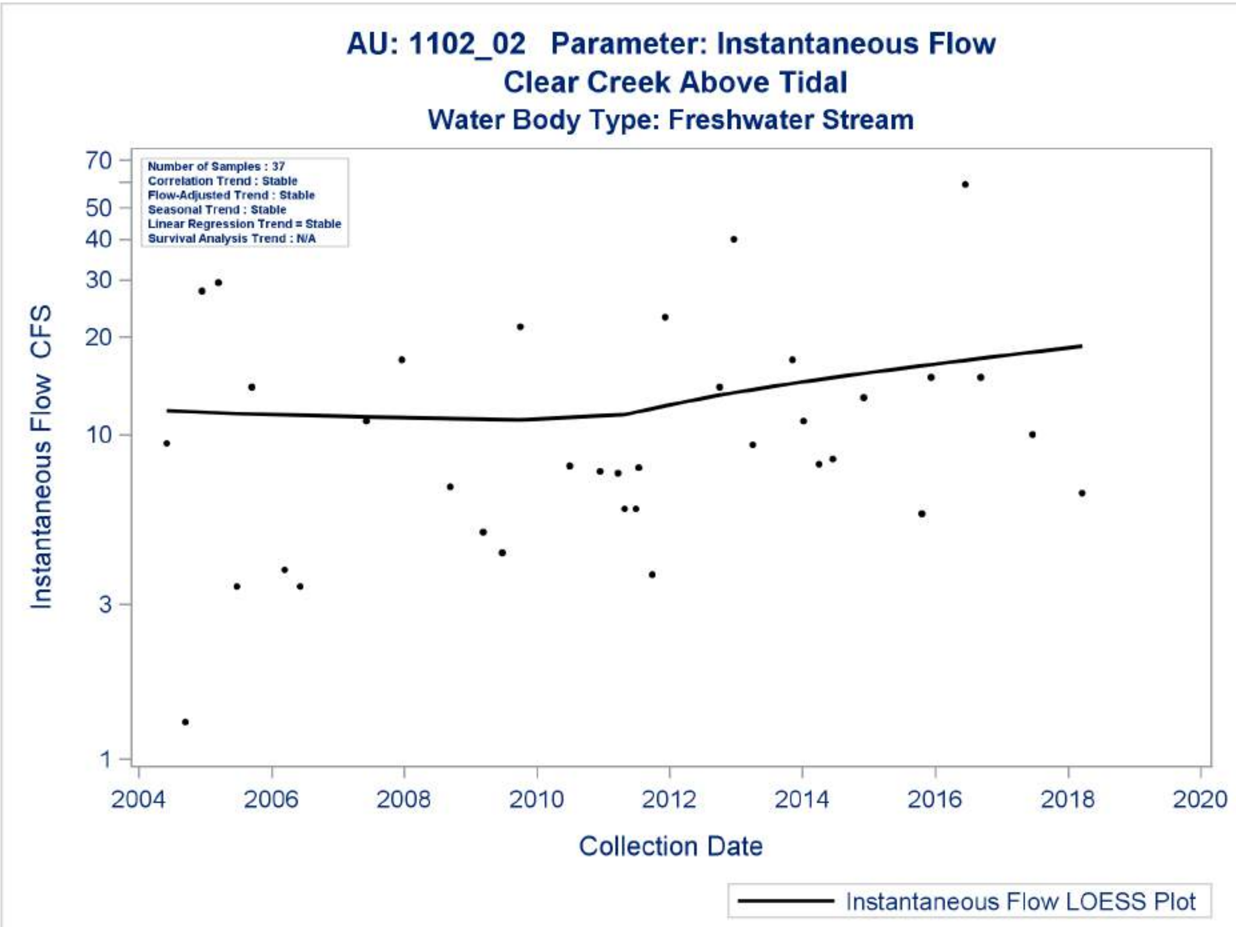


Figure 2 - Instantaneous flow at Clear Creek Above Tidal AU 1102_02

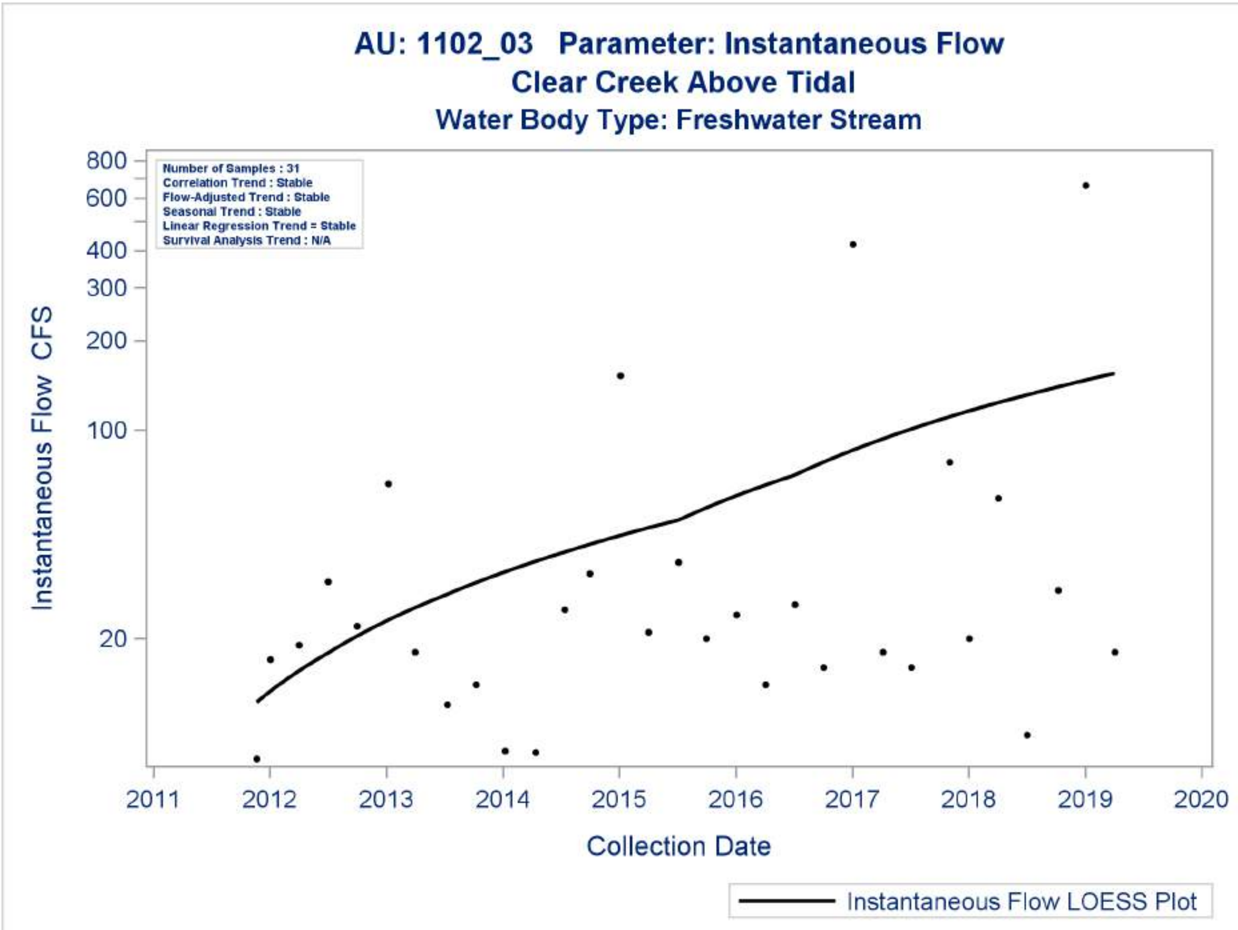
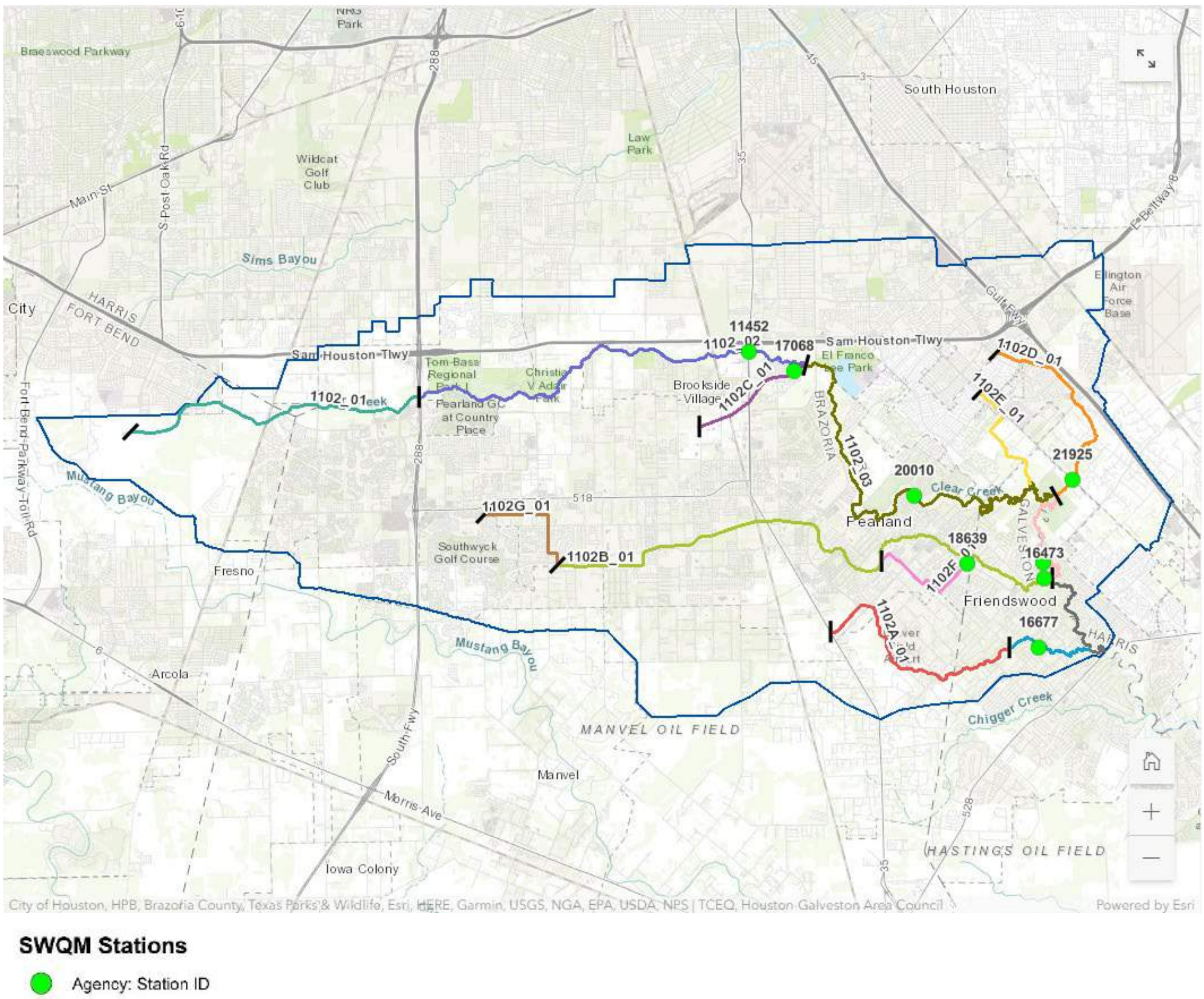


Figure 3 - Instantaneous flow at Clear Creek Above Tidal AU 1102_03

DESCRIPTIONS OF WATER QUALITY ISSUES

The primary water quality issues for Clear Creek Above Tidal and its tributaries are elevated levels of bacteria and nutrients and low DO and loss of habitat concerns in a few AUs. PCBs have been identified in fish tissue samples, leading to the issuance of a fish consumption advisory for Clear Creek.

Monitoring stations and assessment units for the Clear Creek Above Tidal watershed are shown in Map 3. Monitoring station locations, site descriptions and annual monitoring frequency are provided in Table 5.



Map 3 - Monitoring Stations in the Clear Creek Above Tidal watershed

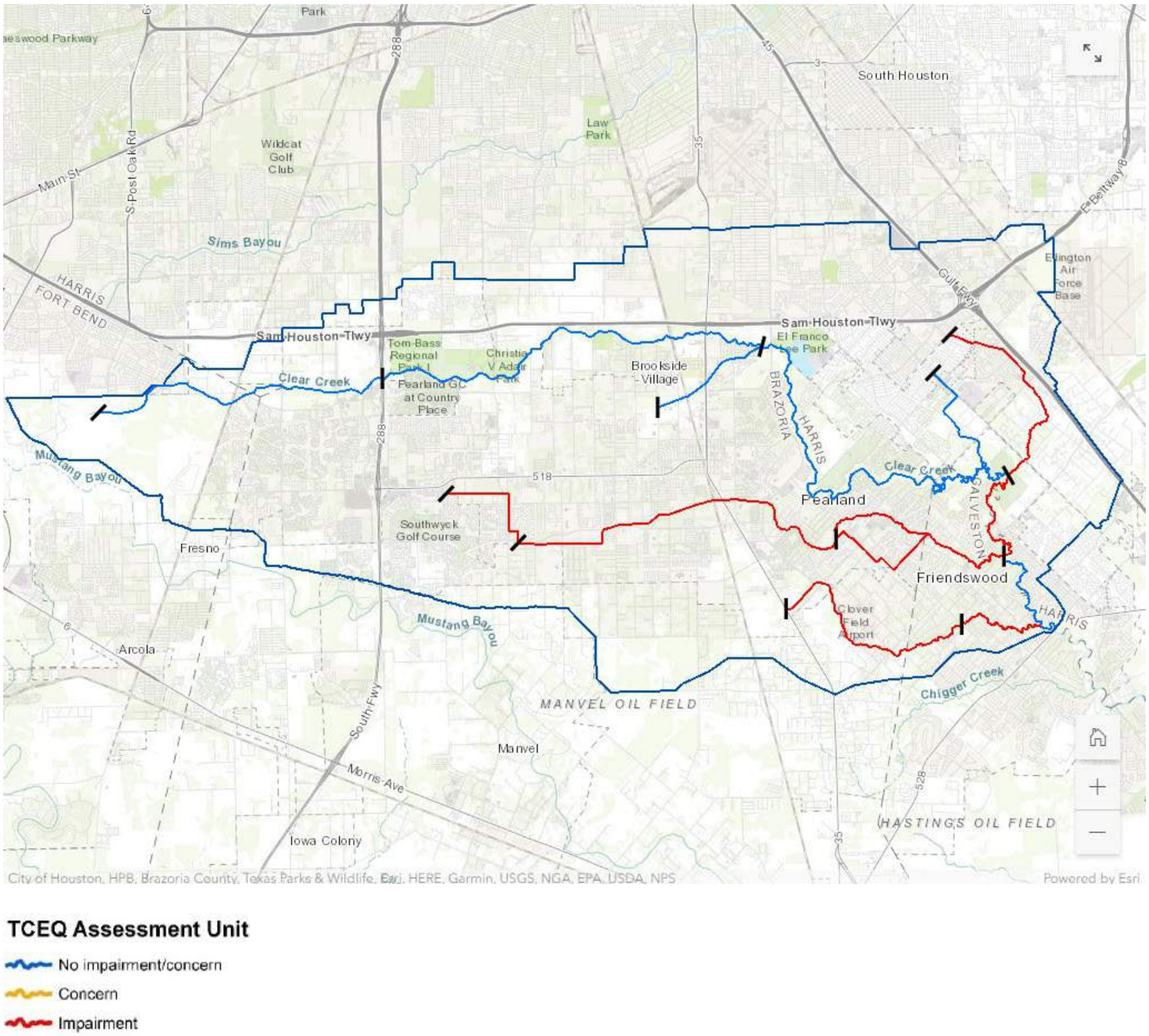
Table 5 - Monitoring Stations in the Clear Creek Above Tidal watershed

Station ID	Segment ID	Site Description	SE	CE	24-hour DO	Flow	Field	Conv	Bacteria
11450	1102	CLEAR CREEK AT FM2351 / CHOATE RD NEAR FRIENDSWOOD	WC	FO	-	-	4	4	4
11452	1102	CLEAR CREEK AT TELEPHONE RD SH35 IN SOUTH HOUSTON	WC	FO	-	4	4	4	4
20010	1102	CLEAR CREEK ABOVE TIDAL AT YOST ROAD TERMINUS IN PEARLAND IN BRAZORIA COUNTY	HG	HG	-	4	4	4	4
16677	1102A	COWART CREEK 9 METERS UPSTREAM FROM CASTLEWOOD DRIVE BRIDGE IN FRIENDSWOOD	HG	HG	-	4	4	4	4
16473	1102B	MARYS CREEK AT MARYS CROSSING IN NORTH FRIENDSWOOD	HG	HG	-	4	4	4	4
17068	1102C	HICKORY SLOUGH AT ROBINSON DRIVE IN PEARLAND	HG	HG	-	4	4	4	4
21925	1102D	TURKEY CREEK AT BEAMER ROAD 1.5 KM SOUTHEAST OF FM 1959/DIXIE FARM ROAD IN FRIENDSWOOD	HG	HG	-	4	4	4	4
18639	1102F	MARYS CREEK BYPASS AT EAST BROADWAY ST/FM 518 WEST OF SUNSET MEADOWS DR IN PEARLAND	HG	HG	-	4	4	4	4

The most upstream AU on Clear Creek Above Tidal (AU 1102_01) has a data gap between the end of 2005 to 2008. Samples collection resumed in 2008 but was once again discontinued later that year. Because of this gap in data, there are no discernable trends in this AU. While there are five AUs on the main body of water, only three of those AUs are currently being monitored.

Bacteria Impairments and Concerns

There are 13 classified and unclassified AUs in the Clear Creek Above Tidal watershed. Seven of the 13 do not support the contact recreation standard for freshwater streams (Map 4).



Map 4 - Bacteria Impairments and Concerns in the Clear Creek Above Tidal watershed

Two other AUs (1102_02 and 1102_03) are very close to being non-supporting with *E. coli* bacteria geometric means of 126 and 123 MPN/100 mL as listed in the 2018 Texas Integrated Report (IR). However, H-GAC analysis of more recent bacteria data (collected between 2012 and 2019) show both AUs are non-supportive, with geometric means of 173 and 191 MPN/100 mL respectively. There is no or insufficient data collected for AUs 1102_01 and 1102_05.

Cowart Creek (1102A), Turkey Creek (1102D), Mary's Creek Bypass (1102F), and the Unnamed Tributary of Mary's Creek (1102G) had insufficient data during the assessment period to assess. The Non-Support level of support for this AU is a carry-forward from the previous assessment.

The comparison of Integrated Report data to data analysis conducted by H-GAC is presented in Table 6.

Table 6 - Comparison of 2018 IR Bacteria Data (2009 – 2016) and H-GAC Analysis of Bacteria Data (2012 – 2019)

Waterbody	Seg ID	AU_ID	Parameter	Level of Support	Cat	Geometric Mean of Bacteria Samples (2018 IR, 2009 – 2016)	Geometric Mean of Bacteria Samples (H-GAC Analysis, 2012 - 2019)
Clear Creek Above Tidal	1102	1102_02	*E. coli*	FS	-	126	173
		1102_03	*E. coli*	FS	-	123	191
		1102_04	*E. coli*	NS	4a	224	256
Cowart Creek	1102A	1102A_01	*E. coli*	NS	4a	NA*	132
		1102A_02	*E. coli*	NS	4a	284	209
Mary's Creek / North Fork Mary's Creek	1102B	1102B_01	*E. coli*	NS	4a	300	495
Hickory Slough	1102C	1102C_01	*E. coli*	NC	-	78	99
Turkey Creek	1102D	1102D_01	*E. coli*	NS	4a	NA*	297
Mary's Creek Bypass	1102F	1102F_01	*E. coli*	NS	4a	31*	593
Unnamed Tributary of Mary's Creel	1102G	1102G_01	*E. coli*	NS	4a	NA	423

FS = Fully Supporting CN = Concern CS = Concern for Screening Level **Not Calculated
NS = Not Supporting NC = No Concern NA = Not Assessed *Insufficient Data available

Figure 4 illustrates the moving seven-year bacteria geometric mean when all bacteria data from all AUs are combined. There is no trend found in the combined results.

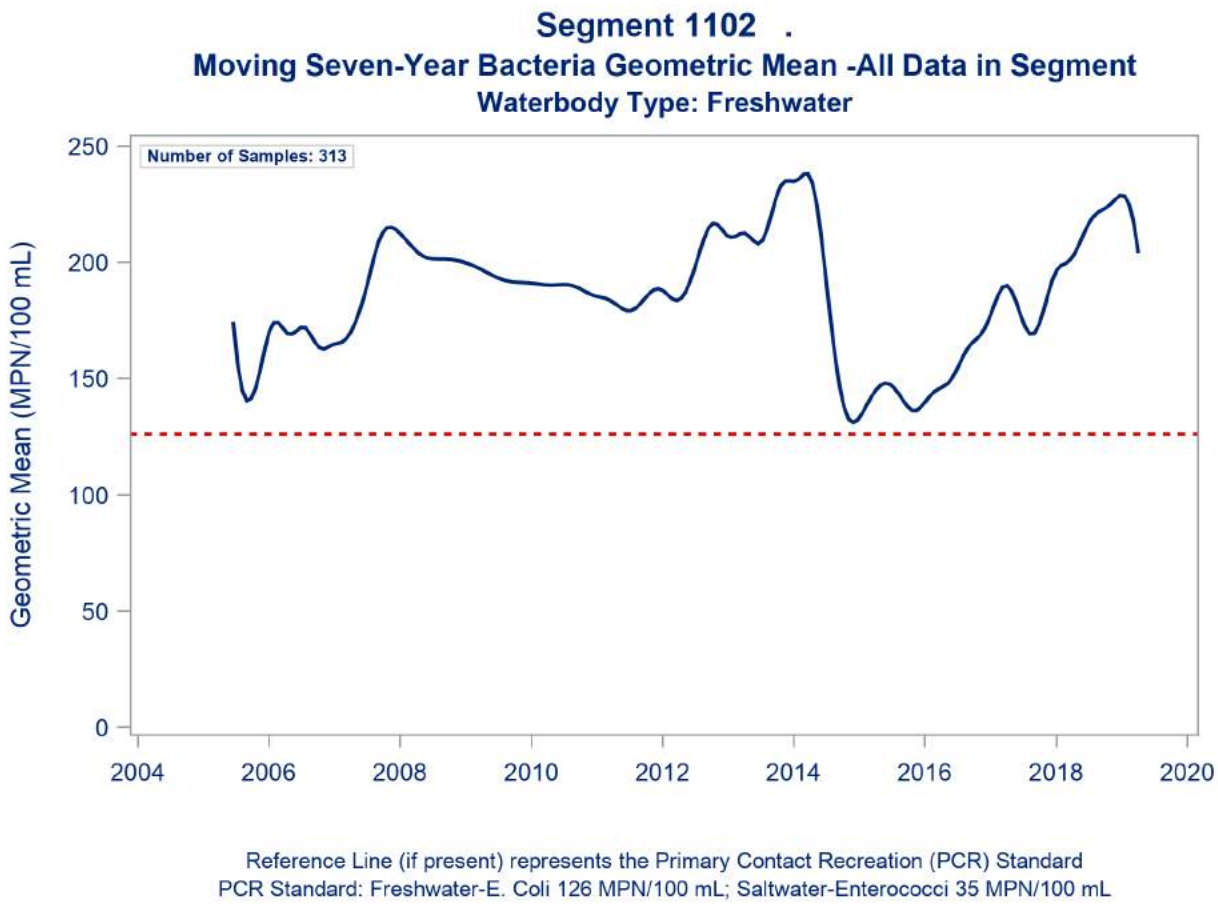


Figure 4 - Moving Seven-Year Bacteria geometric mean for all data collected throughout segment (1102)

However, if the data from only 1102A (Cowart Creek) is analyzed, there is a significant downward trend where the geometric mean shows improvement over time (Figure 5).

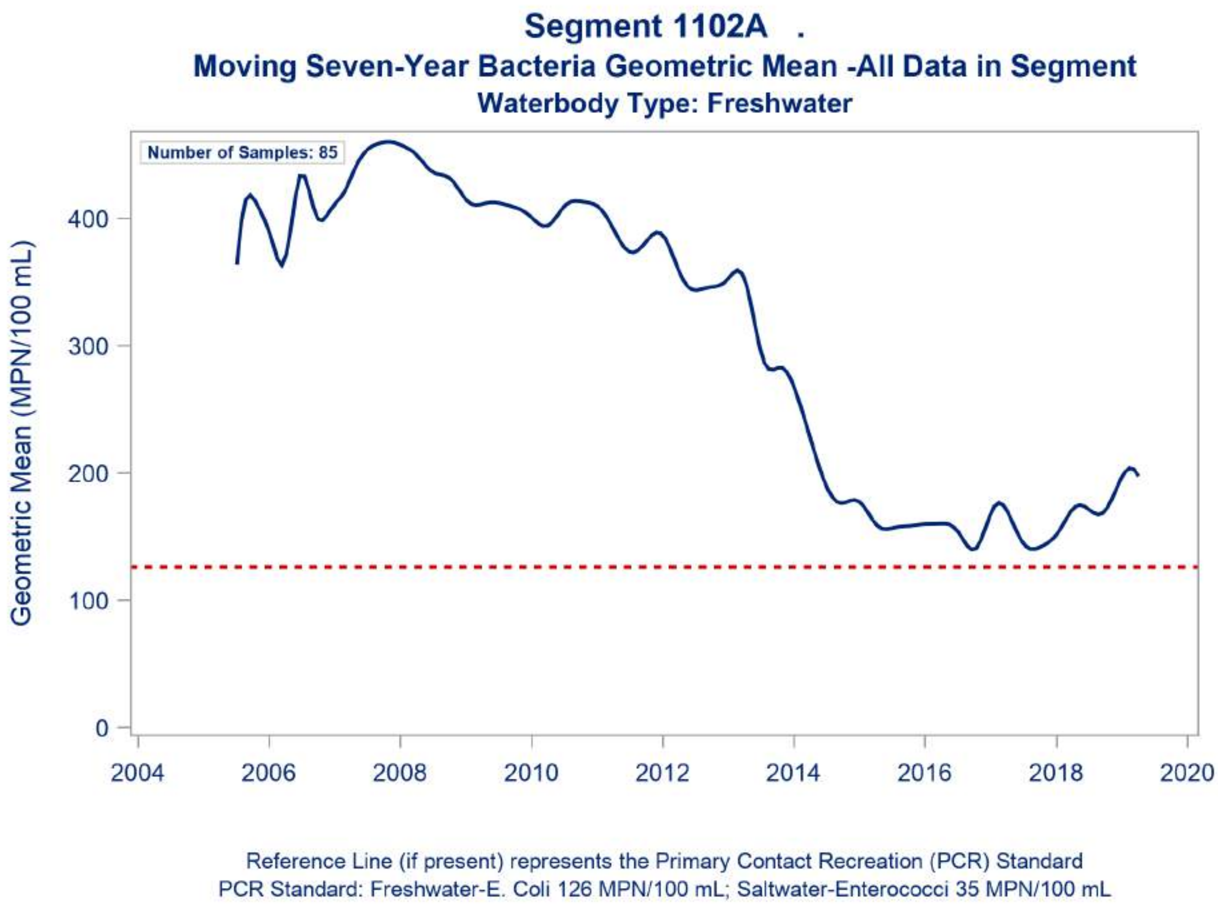


Figure 5 - Moving Seven-Year Bacteria geometric mean for all data collected at Cowart Creek (1102A)

Conversely, data from Mary's Creek/North Fork Mary's Creek (1102B), illustrates the opposite trend, with a sharp increase in *E. coli* results in recent years (Figure 6).

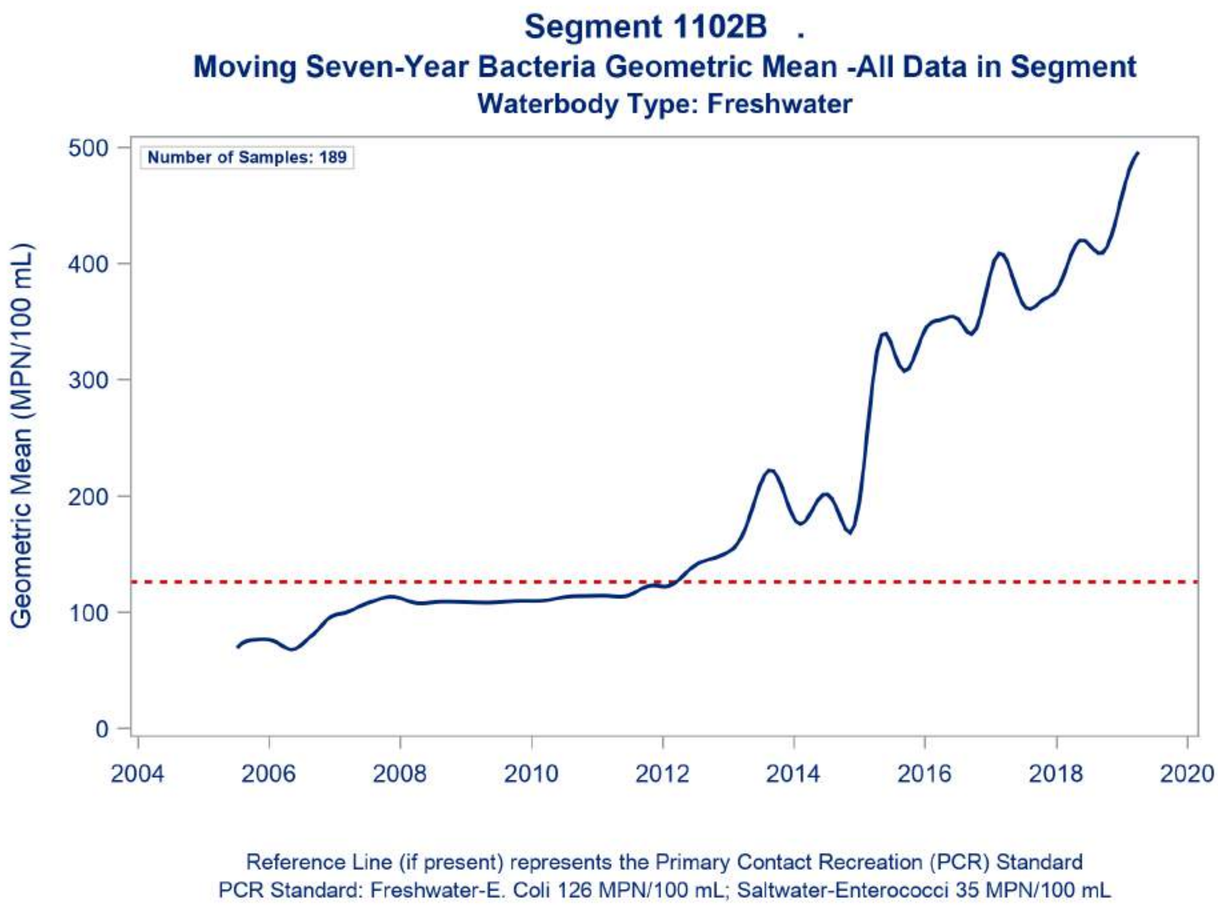
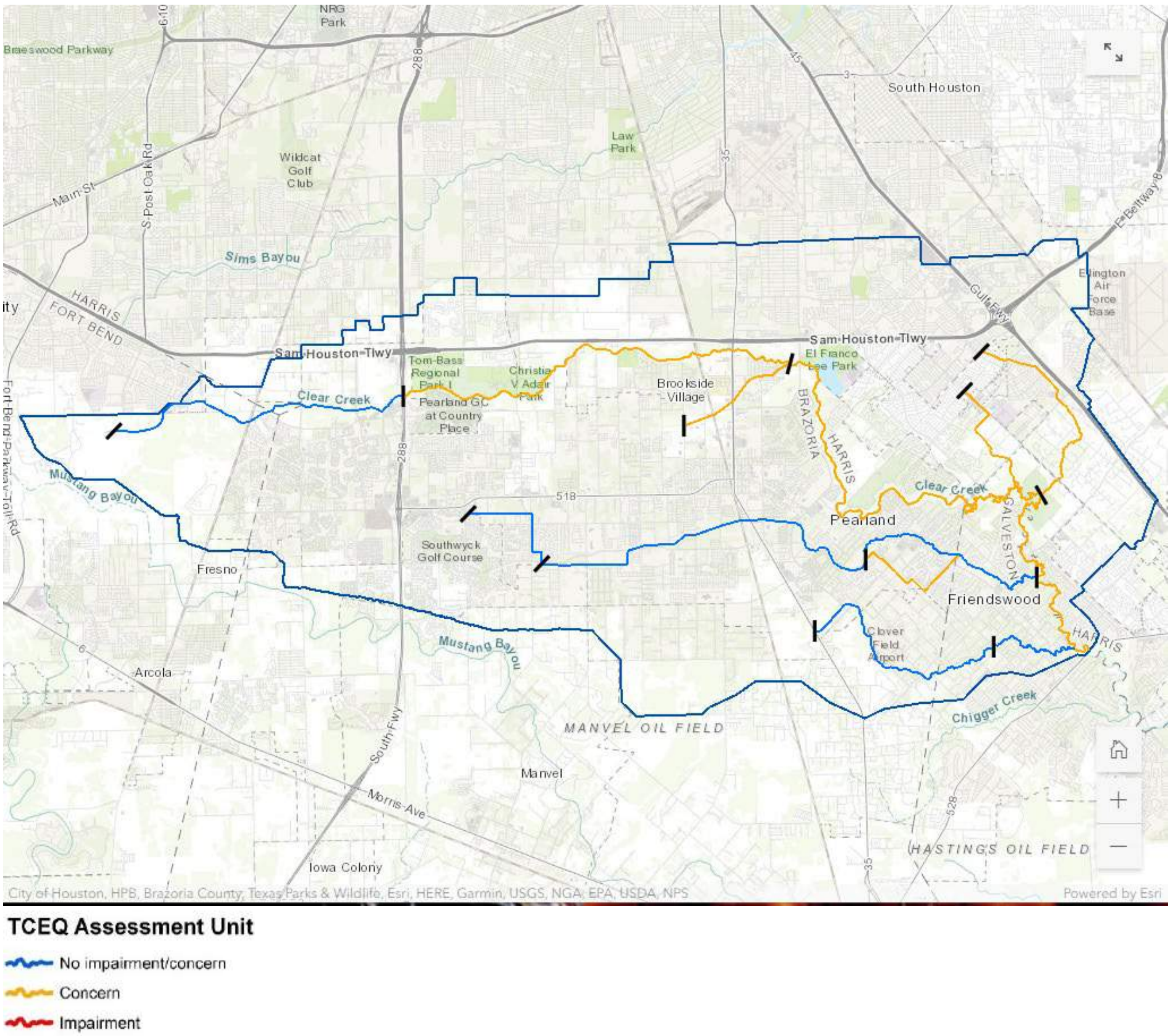


Figure 6 - Moving Seven-Year Bacteria geometric mean for all data collected at Mary's Creek (1102B)

Dissolved Oxygen Impairments and Concerns

Four of the five AUs designated on Clear Creek are identified as having concerns for the DO grab screening concentrations. Concerns also apply to Hickory Slough (1102C), Turkey Creek (1102D), Mud Gully (1102E), and Mary's Creek Bypass (1102F). Segments with concerns are shown in Map 5.



Map 5 - Dissolved Oxygen Impairments and Concerns for Clear Creek Above Tidal

Table 7 shows the assessment for DO in the Clear Creek Above Tidal watershed. Several segments (1102D, 1102E, and 1102F) did not have enough data to assess but were assigned an integrated level of support of concern for screening levels. This level of support is a carry-forward from the previous assessment.

Table 7 - Comparison of 2018 IR Dissolved Oxygen Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

Waterbody	Seg ID	AU_ID	Parameter	Level of Support	Percentage of Samples Exceeding Standard (2018 IR, 2009 – 2016)	Percentage of Samples Exceeding Standard (H-GAC Analysis, 2012 - 2019)
Clear Creek Above Tidal	1102	1102_02	DO Grab Minimum	CS	14	4
			DO Grab Screening Level	CS	28	20
		1102_03	DO Grab Minimum	FS	5	4
			DO Grab Screening Level	CS	19	14
		1102_04	DO Grab Minimum	FS	0	0
			DO Grab Screening Level	CS	18	15
		1102_05	DO Grab Screening Level	CS	NA	**
Cowart Creek	1102A	1102A_02	DO Grab Minimum	FS	0	0
			DO Grab Screening Level	NC	0	0
Mary's Creek / North Fork Mary's Creek	1102B	1102B_01	DO Grab Minimum	FS	0	0
			DO Grab Screening Level	NC	0	0
Hickory Slough	1102C	1102C_01	DO Grab Minimum	FS	5	4
			DO Grab Screening Level	CS	40	33
Turkey Creek	1102D	1102D_01	DO Grab Screening Level	CS	NA*	27
Mud Gully	1102E	1102E_01	DO Grab Screening Level	CS	NA*	**
Mary's Creek Bypass	1102F	1102F_01	DO Grab Minimum	NA	0	0
			DO Grab Screening Level	CS	NA*	9

FS = Fully Supporting CN = Concern CS = Concern for Screening Level **Not Calculated
NS = Not Supporting NC = No Concern *Insufficient Data available NA = Not Assessed

All classified and unclassified segments of Clear Creek except for three have a presumed high aquatic life use (ALU) designation. Site-specific standards are assigned for Cowart Creek and Mary's Creek / North Fork Mary's Creek. Both AUs in Cowart Creek are assigned a limited ALU and Mary's Creek/ North Fork Mary's Creek has an intermediate ALU designation. Cowart Creek is intermittent with perennial pools, while Mary's Creek has been highly channelized.

Figure 7 illustrates how DO concentrations have improved in Cowart Creek over time. Since 2007, the concentration of DO has not been measured below the screening level of 3.0. If DO continues to improve, this waterway may be on a track to support an intermediate or, possibly, a high ALU designation in the future.

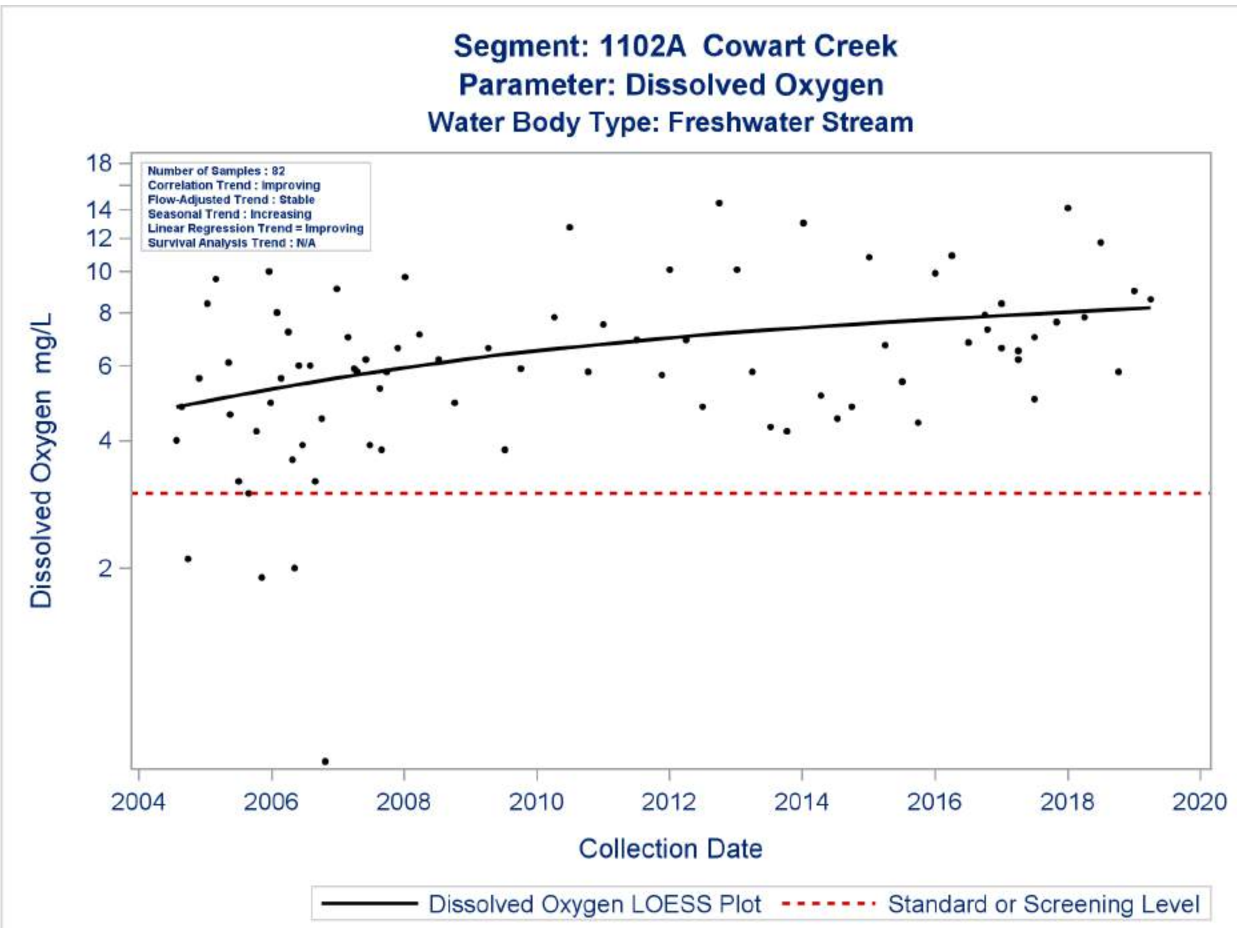
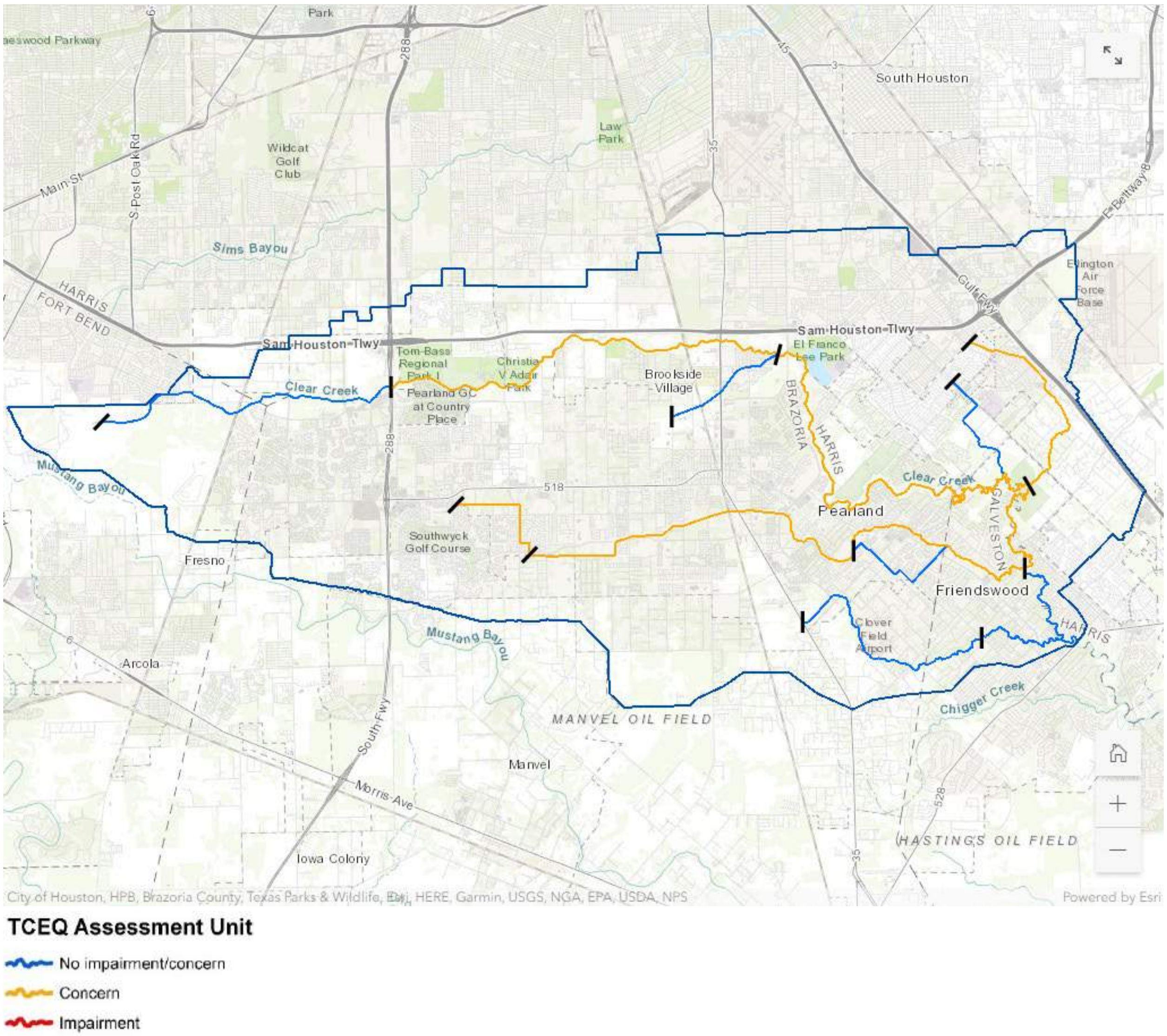


Figure 7 - Dissolved Oxygen results for Cowart Creek (1102A), 2004 - 2019

Nutrient Concerns

Eight out of 13 classified and unclassified segments have one or more concerns with nutrients (Map 7). There is no data for two of the segments – the most upstream AU (1102_01) and the most downstream AU (1102_05) on Clear Creek Above Tidal.



Map 7 - Nutrient Concerns in the Clear Creek Above Tidal watershed

Three AUs in Clear Creek Above Tidal have concerns for nitrate (Table 8). This includes AU 1102_05, which is a carry-forward from the previous assessment. There are also concerns for nitrate in Mary's Creek / North Fork Mary's Creek, Turkey Creek, Mud Gully, and Mary's Creek Bypass. The concerns for Turkey Creek and Mud Gully are also carry-forwards. There are no concerns for nitrate in Cowart Creek and Hickory Slough.

Table 8 - Comparison of 2018 IR Nitrate Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

Waterbody	Seg ID	AU_ID	Parameter	Level of Support	Percentage of Samples Exceeding Screening Criteria (2018 IR, 2009 - 2016)	Percentage of Samples Exceeding Screening Criteria (H-GAC Analysis, 2012 – 2019)
Clear Creek Above Tidal	1102	1102_03	Nitrate	CS	52	50
		1102_04	Nitrate	CS	75	65
		1102_05	Nitrate	CS	NA*	*
Cowart Creek	1102A	1102A_02	Nitrate	NC	*	*
Mary's Creek / North Fork Mary's Creek	1102B	1102B_01	Nitrate	CS	52	57
Hickory Slough	1102C	1102C_01	Nitrate	NC	0	0
Turkey Creek	1102D	1102D_01	Nitrate	CS	NA	64
Mud Gully	1102E	1102E_01	Nitrate	CS	NA	NA
Mary's Creek Bypass	1102F	1102F_01	Nitrate	CS	100	27

FS = Fully Supporting CS = Concern for Screening *Insufficient Data available
NS = Not Supporting NC = No Concern **Not Calculated

Concerns for ammonia have been identified in two AUs in Clear Creek Above Tidal and Turkey Creek (Table 9).

Table 9 - Comparison of 2018 IR Ammonia Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

Waterbody	Seg ID	AU_ID	Parameter	Level of Support	Percentage of Samples Exceeding Screening Criteria (2018 IR, 2009 - 2016)	Percentage of Samples Exceeding Screening Criteria (H-GAC Analysis, 2012 – 2019)
Clear Creek Above Tidal	1102	1102_02	Ammonia	CS	32	30
		1102_03	Ammonia	CS	38	32
		1102_04	Ammonia	NC	15	12
Cowart Creek	1102A	1102A_02	Ammonia	NC	18	28
Mary's Creek / North Fork Mary's Creek	1102B	1102B_01	Ammonia	NC	7	21
Hickory Slough	1102C	1102C_01	Ammonia	NC	5	4
Turkey Creek	1102D	1102D_01	Ammonia	CS	NA	45

FS = Fully Supporting CS = Concern for Screening *Insufficient Data available
NS = Not Supporting NC = No Concern **Not Calculated

Concerns for nutrient screening levels for total phosphorus were identified for 3 AUs in Clear Creek Tidal, Mary's Creek / North Fork Mary's Creek, Turkey Creek, and Mary's Creek Bypass (Table 10). There was insufficient data to assess Turkey Creek. The concern for screening levels for this segment is a carry-forward from the previous Integrated Report. There were no concerns for Total Phosphorus for Cowart Creek or Hickory Slough.

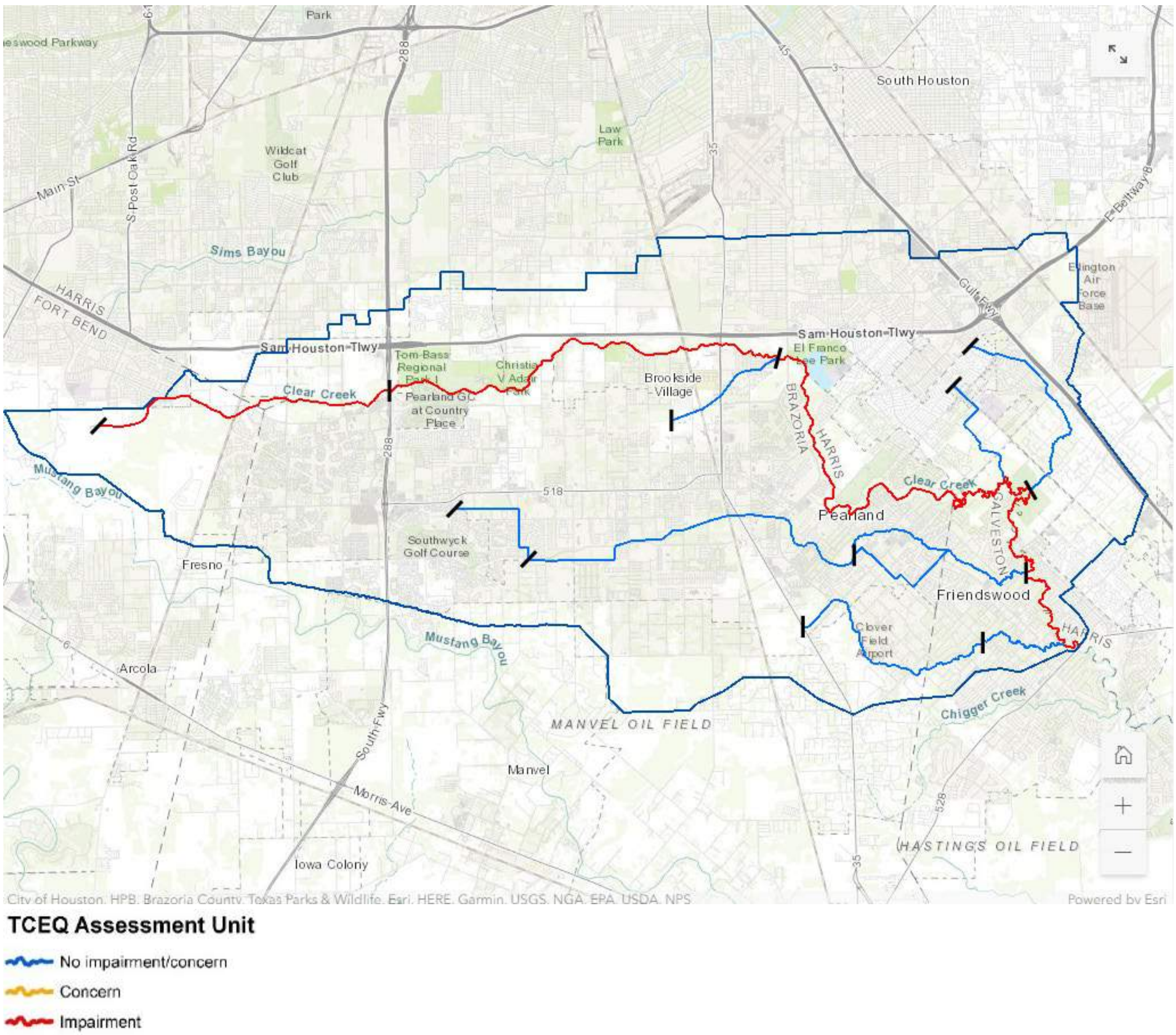
Table 10 - Comparison of 2018 IR Total Phosphorus Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

Waterbody	Seg ID	AU_ID	Parameter	Level of Support	Percentage of Samples Exceeding Screening Criteria (2018 IR, 2009 - 2016)	Percentage of Samples Exceeding Screening Criteria (H-GAC Analysis, 2012 – 2019)
Clear Creek Above Tidal	1102	1102_02	Total Phosphorus	CS	52	52
		1102_03	Total Phosphorus	CS	67	64
		1102_04	Total Phosphorus	CS	56	52
Cowart Creek	1102A	1102A_02	Total Phosphorus	NC	0	4
Mary's Creek / North Fork Mary's Creek	1102B	1102B_01	Total Phosphorus	CS	81	68
Hickory Slough	1102C	1102C_01	Total Phosphorus	NC	14	18
Turkey Creek	1102D	1102D_01	Total Phosphorus	CS	NA*	64
Mary's Creek Bypass	1102F	1102F_01	Total Phosphorus	CS	100	54

FS = Fully Supporting CS = Concern for Screening *Insufficient Data available
NS = Not Supporting NC = No Concern **Not Calculated

PCB and Dioxin Impairments

Clear Creek Above Tidal is listed as impaired for PCBs and Dioxins in fish tissue (Map 7). Fish samples collected from Clear Creek indicate the presence of PCBs at a concentration exceeding health assessment guidelines. A fish consumption advisory (ADV-37) issued by the Texas Department of State Health Services (TDSHS) on July 8, 2009 advises that people should not consume any species of fish from these waters.



Map 15 - PCBs and Dioxin Impairments in the Clear Creek Above Tidal watershed

Additional Parameters

Figure 8 shows how the chlorides and specific conductance decreased between 2004 and 2010 due to several brine water discharges being stopped through efforts of the Texas Railroad Commission well-plugging operation.

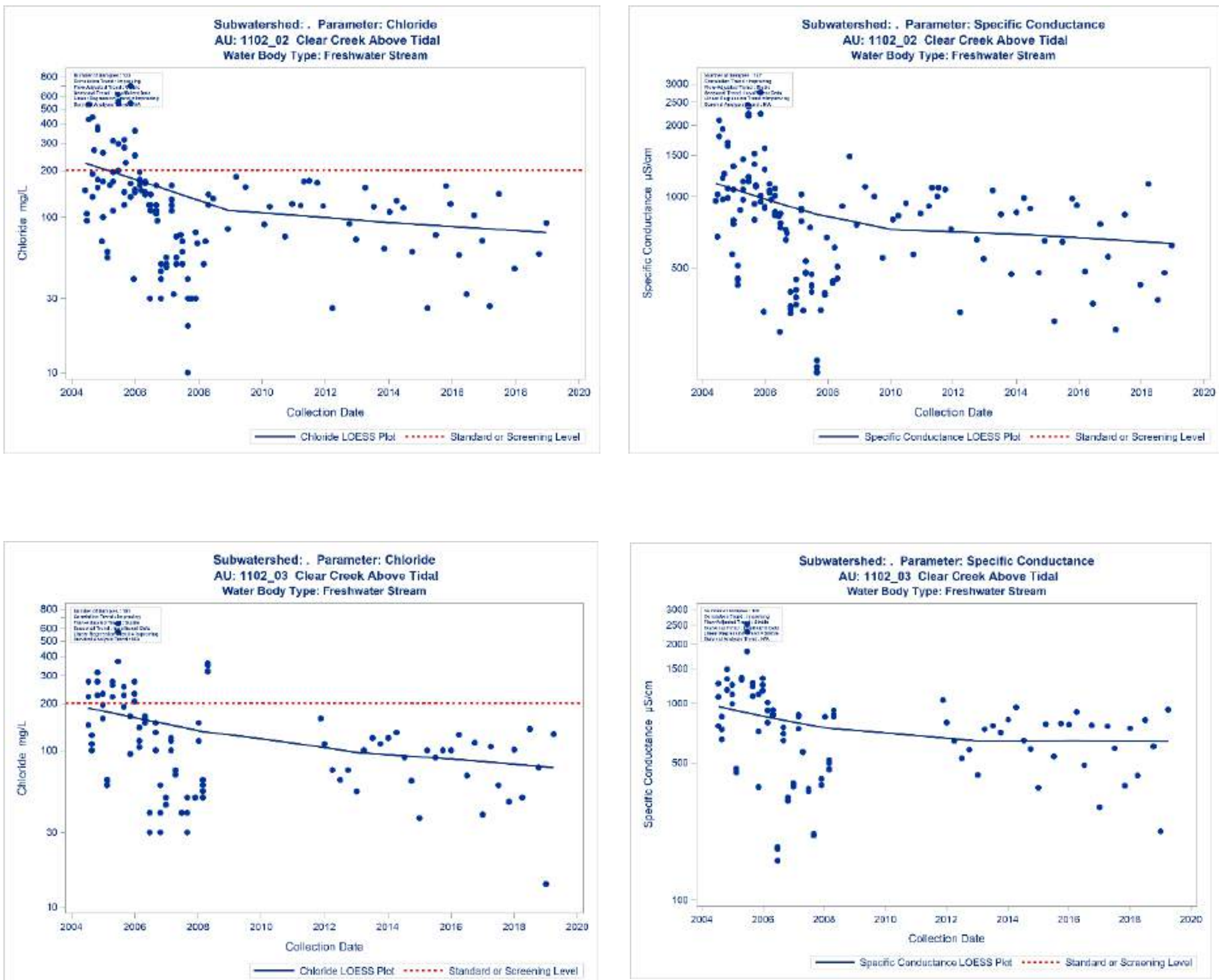


Figure 8 - Chloride and Specific Conductance graphs for the Clear Creek Tidal watershed, 2004 - 2019

With the conversion of more than 3,000 acres into medium and high intensity development, instantaneous flows throughout the watershed have increased. Figure 9 illustrates the increasing trends in Clear Creek Above Tidal.

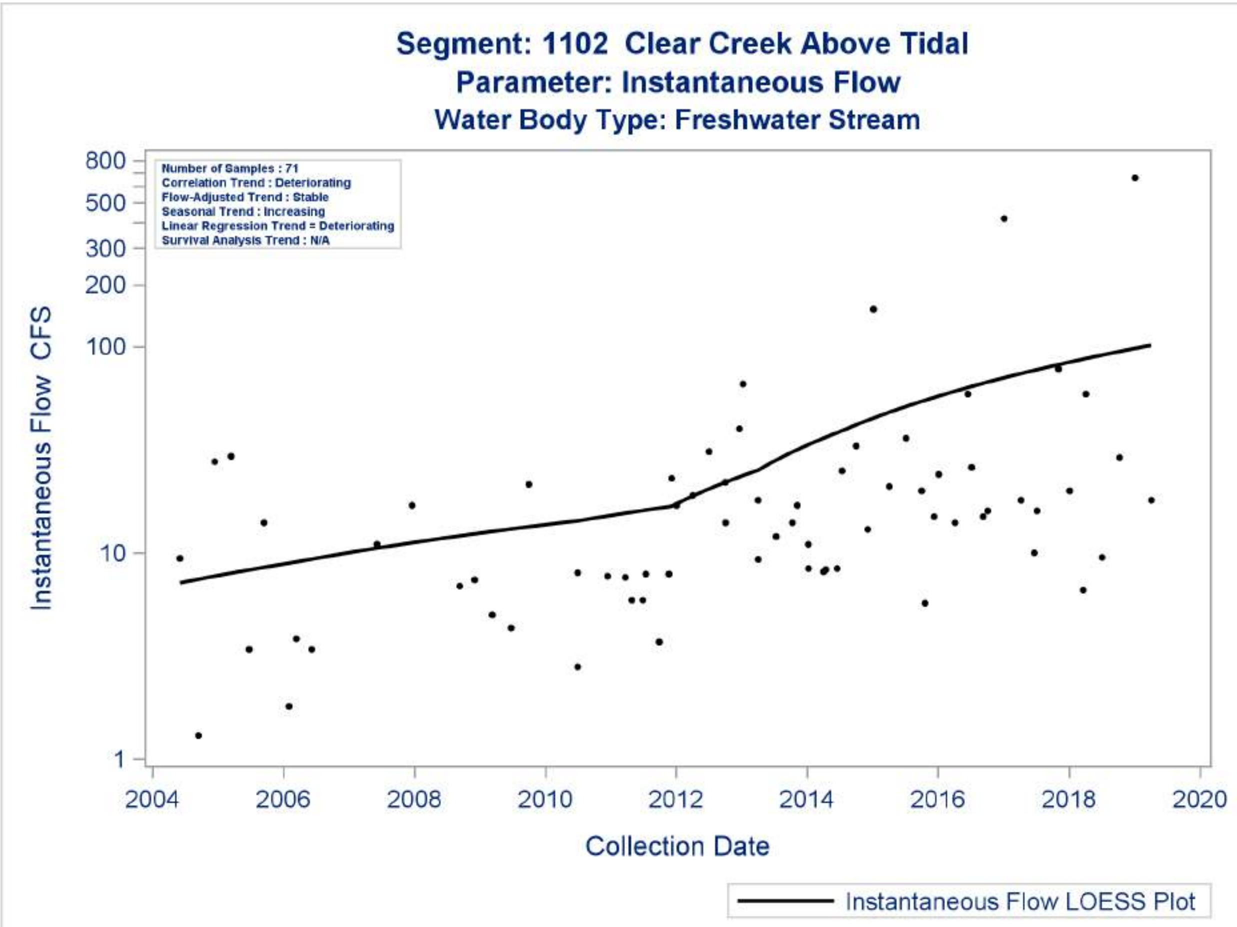


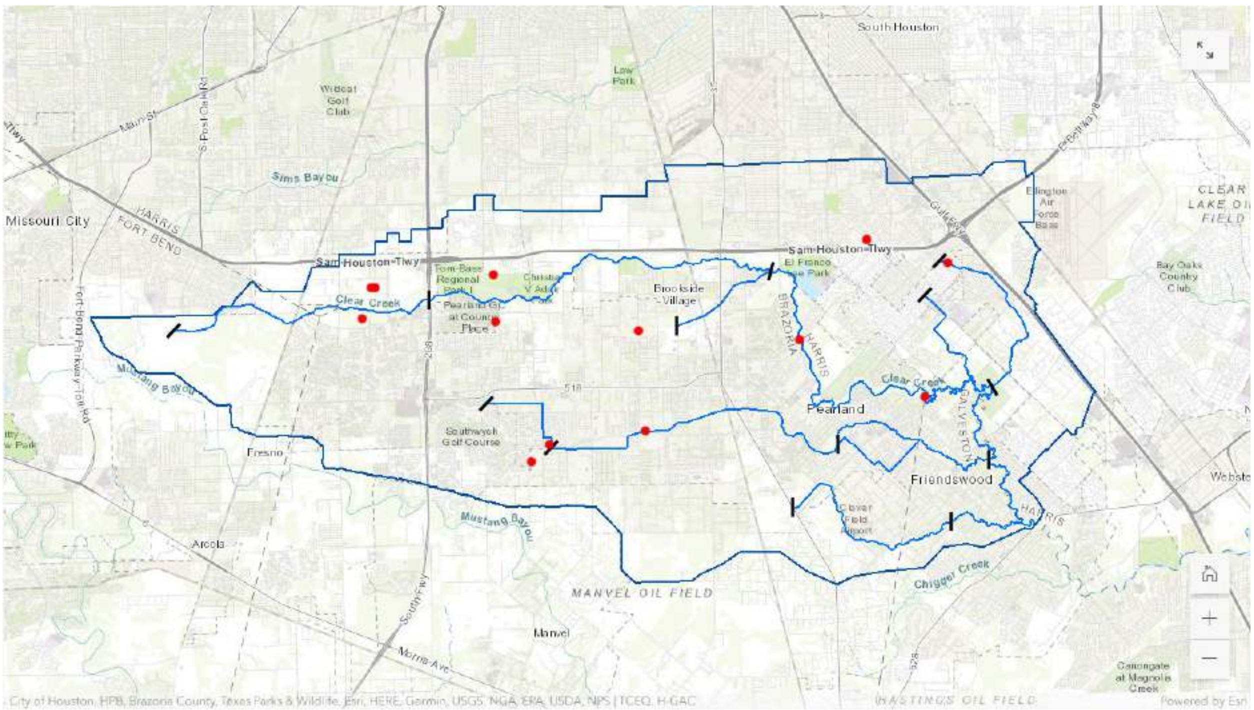
Figure 9 - Increasing instantaneous flow in 1102 (Clear Creek Above Tidal)

POTENTIAL SOURCES OF WATER QUALITY ISSUES

Potential sources of bacteria in Clear Creek Above Tidal include wastewater treatment facilities, sanitary sewer overflows, failing on-site sewage facilities, livestock, and other nonpoint sources.

Wastewater Treatment Facilities

There are 13 TCEQ regulated wastewater treatment facilities in the Clear Creek Above Tidal segment (Map 8). Four of these facilities are small (<0.1 MGD). However, three of the facilities are permitted for flows between 5 – 10 MGD.



WWTF Outfalls

● Permit Number

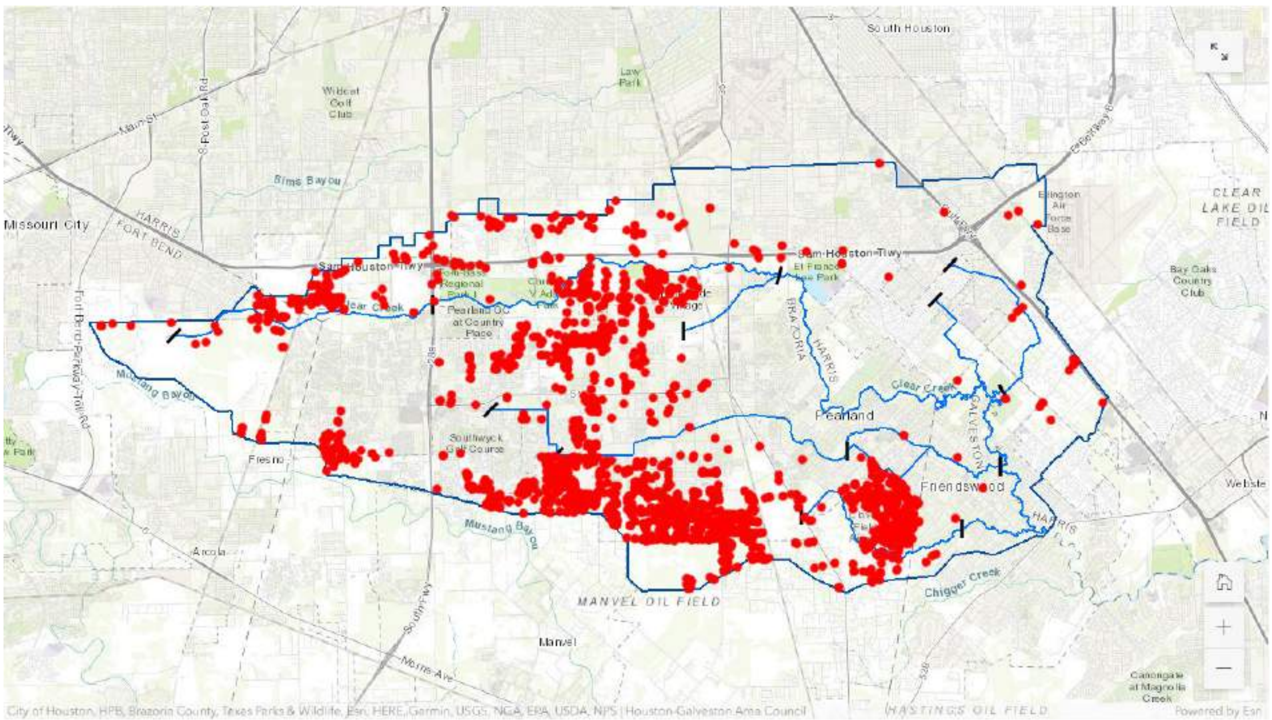
Map 8 - Permitted wastewater treatment facilities in the Clear Creek Above Tidal watershed

Sanitary Sewer Overflows

As with any sanitary sewer collection system, the potential overflows exist due to numerous reasons, such as inflow and infiltration, mechanical failure, and improper disposal of fats, oils, and grease, among other causes. These types of overflows result in the discharge of untreated sewage which may enter local water ways. These sanitary sewer overflows can be a major source of bacteria.

On-Site Sewage Facilities

For areas that are agricultural or pasture/grassland, on-site sewage facilities are still regularly in use as the primary method of waste treatment and disposal. The locations of these on-site facilities correlate well with the locations of pasture/grassland acreage in the watershed. There are currently 1,962 permitted on-site sewage facilities within the Clear Creek Above Tidal watershed (Map 9). In addition to these systems, there are numerous "grandfathered" systems installed prior to the requirement that on-site systems be permitted.



On-Site Sewage Facilities

TCEQ Assessment Unit

Map 9 - Permitted on-site sewage facilities in the Clear Creek Above Tidal watershed

Livestock and Other Animal Sources

Although there has been rapid development in this watershed, there are still areas with livestock. Animal wastes, as well as application of fertilizers, may contribute to bacteria and nutrient issues within the watershed. Additionally, feral hogs may be an issue is some of the less urbanized areas.

POTENTIAL STAKEHOLDERS

Potential stakeholders include:

- City of Brookside Village
- City of Friendswood
- City of Houston
- City of Pearland
- Brazoria County
- Galveston County
- Fort Bend County
- Harris County Commissioner Precinct 1
- Environmental and Conservancy Groups, such as local Keep Texas Beautiful Affiliates
- TCEQ Region 12 Office
- TCEQ Galveston Bay Estuary Program
- Texas State Soil and Water Conservation Board
- The Bacteria Implementation Group (BIG) Members
- Texas AgriLife Extension Offices
- Citizen Groups, such as the Texas Master Naturalists
- Community Groups
- Homeowner Associations
- Drainage Districts
- Utility Districts
- Industry

ONGOING PROJECTS

H-GAC has been tasked by the TCEQ to implement a basin-wide approach for addressing bacterial impairments for the San Jacinto-Brazos Coastal Basin which includes Clear Creek. Development for the basin-wide TMDL began in September of 2015 and resulted in a final Basin 11 Summary Report that summarized basin characteristics, water quality impairments, potential bacteria sources, and recommendations for bacterial reduction. This segment is also part of the geographic area for the Bacteria Implementation Group (BIG) Total Maximum Daily Load.

H-GAC will develop a watershed protection plan for Clear Creek. This project is scheduled to begin in September 2020.

RECOMMENDATIONS FOR IMPROVING WATER QUALITY

- Address bacteria and various other concerns through stakeholder involvement and best management practices
- Continue to work with the BIG to implement recommendations for bacteria reduction
- Continue to analyze Discharge Monitoring Report data and present results to TCEQ, wastewater permittees, local governments/utility districts, and stakeholders
- Improve compliance and enforcement of existing stormwater quality permits and improve stormwater controls in new developments
- Support public education programs to inform business and homeowners on appropriate disposal of fats, oil, and grease
- Support programs that oversee the maintenance, repair, and replacement of on-site sewage facilities
- Continue collecting water quality data and expand monitoring efforts to support actions associated with the TMDL program and future watershed protection plan development
- Pursue new local partners to collect additional data to help better isolate problem areas
- Expand volunteer monitoring with Texas Stream Team in areas without professional monitoring
- Implement YardWise and Watersmart landscape practices
- Create and implement Water Quality Management Plans for individual agricultural properties
- Support programs to responsibly eliminate feral hog populations in the watershed, particularly in the less urbanized areas in the western portion of the watershed
- Support public education on pet waste disposal
- Consult stakeholders to identify illegal dumping sites and improve signage and/or cameras, if needed

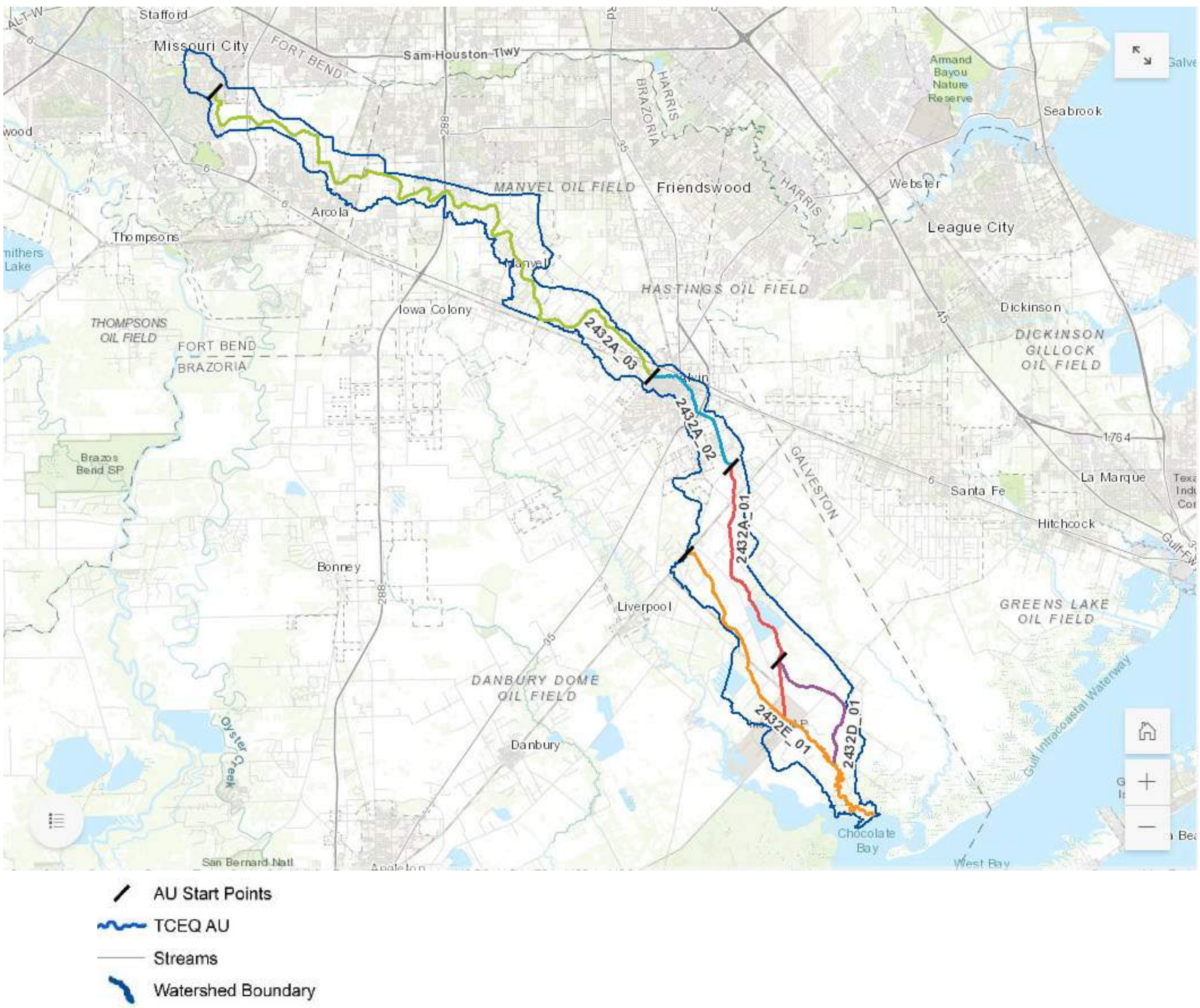
DETAILED WATERSHED CHARACTERIZATION
Mustang Bayou (2432A)

Figure 1 - Mustang Bayou (Segment 2432A), Monitoring Station 20011

SEGMENT DESCRIPTION

Mustang Bayou (Segment 2432A) is an unclassified freshwater stream in the Chocolate Bay (Segment 2432) watershed. This stream is approximately 42.7 miles long and flows southeast through Fort Bend and Brazoria counties, including the cities of Missouri City, Fresno, Pearland, Manvel, and Alvin. The headwaters are in the city limits of Missouri City in Fort Bend County, with the majority of the stream in Brazoria County. This segment has been heavily modified and channelized in parts. Mustang Bayou continues in a more southerly direction past Alvin until its confluence with New Bayou near FM 2004 (Map 1).

Persimmon Bayou (Segment 2432D) branches off Mustang Bayou and flows southward downstream for approximately 5.5 miles to a confluence with New Bayou. New Bayou (Segment 2432E) begins at Ditch C-1, a tributary to Chocolate Bayou, near County Road 169 and flows southeastward 15.8 miles southeast to its confluence with Chocolate Bay.



Map 1 - Watershed map showing Mustang Bayou (2432A), Persimmon Bayou (2432D), and New Bayou (2432E)

The assessment units (AUs) in Mustang Bayou, Persimmon Bayou, and New Bayou are described in Table 1.

Table 1 - Assessment Units for Mustang Bayou (2432A), Persimmon Bayou (2432D), and New Bayou (2432E)

Segment Name	Segment ID	AU	Description
Mustang Bayou	2432A	2432A_01	From the New Bayou confluence upstream to County Road 166
Mustang Bayou	2432A	2432A_02	From County Road 166 upstream to an unnamed tributary 0.3 km upstream of SH 35
Mustang Bayou	2432A	2432A_03	From an unnamed tributary 0.3 km upstream of SH 35 upstream to an unnamed tributary downstream of Cartwright Road
Persimmon Bayou	2432D	2432D_01	From the New Bayou confluence upstream to the confluence with Mustang Bayou
New Bayou	2432E	2432E_01	From the Chocolate Bay confluence 25.4 km (15.8 mi) to an unnamed tributary

HYDROLOGICAL CHARACTERISTICS

The Mustang Bayou watershed consists of flat terrain that is typical of a coastal plain. Due to this gentle sloping relief, Mustang, Persimmon, and New bayous are typically sluggish. The upper portions of the watershed are modified for agricultural uses and increasingly for residential and commercial developments. Agricultural production use, including rice farming, can be found in the lower reaches. Chemical production can also be found in the watershed, most focused in the lower reaches near New Bayou and Chocolate Bay.

The Gulf Coast Water Authority maintains pump stations on Mustang Bayou and adjacent waterbodies to supply up to 400,000 acre-feet of water per year for industrial, irrigation, and municipal purposes.

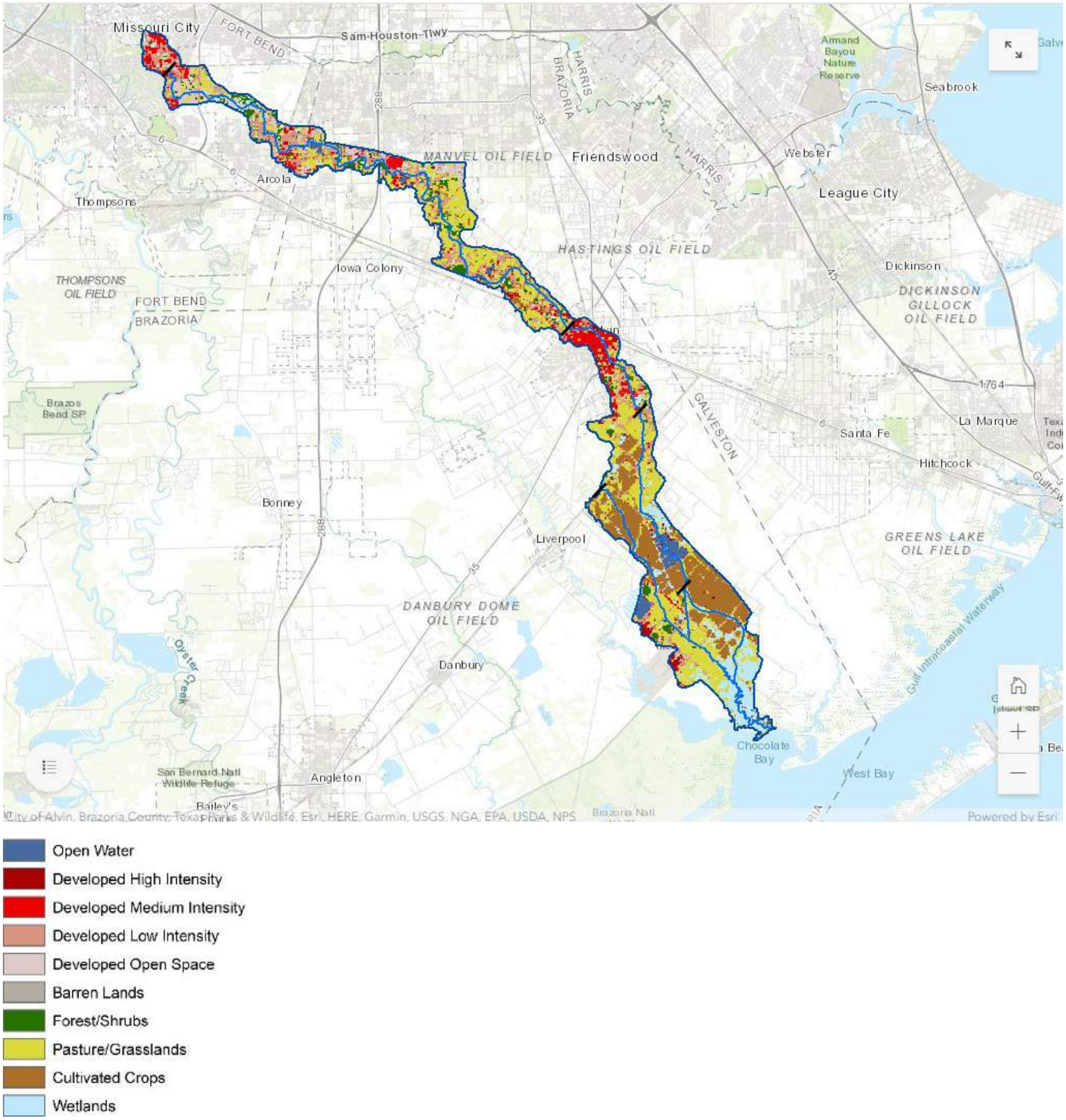
Mustang Bayou is channelized along most of its length, and in some places the channel was widened and instream and riparian vegetation was removed.

Average precipitation for the Mustang Bayou watershed is 46.8 inches per year, as measured at the weather gauge in Freeport, Texas. Average monthly precipitation ranges from 2.6 to 7.3 inches, with the least rainfall occurring during February and March. The summer months typically see the greatest rainfall due to tropical disturbances. September has the highest average rainfall, as that month corresponds with the height of the hurricane season.

Average monthly air temperature ranges from slightly above 54 ºF in the winter to slightly below 85 ºF in the summer months.

LAND COVER AND NATURAL CHARACTERISTICS

The Mustang Bayou watershed area is primarily used for agricultural purposes, with grassland and pastureland comprising the largest share. Agricultural lands make up 52.66 percent of the total watershed acreage. Most development is found in the upper watershed around the City of Alvin, and around the cities and towns between Alvin and Missouri City. In the lower part of the watershed near the coast, oil and gas production is common (Map 2). Table 2 provides a description of the different land cover categories. Table 3 lists the acreage and percentage of these different land cover categories that make up the watershed.



Map 2 - Land Cover map for Mustang Bayou

Table 2 - Description of Land Cover classes

Map Key	Land Cover Class	Class Description
	Developed, High Intensity	Contains significant land area and is covered by impervious surfaces (i.e., concrete, asphalt, and other constructed materials). Vegetation, if present, occupies < 20 percent of the landscape. Impervious surfaces account for 80 to 100 percent of the total cover. This class includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas with a variety of land uses.
	Developed, Medium Intensity	Contains areas with a mixture of impervious surfaces and vegetation or other cover. Impervious surfaces account for 50 to 79 percent of total area. This class commonly includes multi- and single-family housing areas, especially in suburban neighborhoods, but may include all types of land use.
	Developed, Low Intensity	Contains areas with a mixture of impervious surfaces and substantial amounts of vegetation or other cover. Impervious surfaces account for 21 to 49 percent of total area. This class commonly includes single-family housing areas, especially in rural neighborhoods, but may include all types of land use.
	Developed, Open Space	Contains areas with a mixture of some impervious surfaces, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes. Impervious surfaces account for less than 20 percent of total land cover. This class commonly includes large-lot single family housing units, parks, and golf courses.
	Agriculture, Pasture/Grasslands	Contains both managed and unmanaged grasses, legumes, or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas can be subjective to intensive management, such as tilling, and utilized for grazing.
	Agriculture, Cultivated	Contains areas intensely managed for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
	Barren Land	Contains areas of gravel pits, bedrock, sand dunes, and other accumulations of earth material. Generally, vegetation accounts for less than 10 percent of total cover.
	Forest/Shrub	Includes two types of trees that cover greater than 20 percent of total vegetation cover. • *Forest*—areas dominated by all kinds of trees generally greater than 5 meters tall. • *Shrub*—areas dominated by shrubs generally less than 5 meters tall.
	Open Water	Include areas of open water, generally with less than 25 percent cover of vegetation or soil.
	Wetlands	Includes the area contains palustrine or estuarine vegetation that are periodically saturated or covered with water. Total vegetation coverage is greater than 20 percent.

Source: National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) Land Cover Classifications
https://coast.noaa.gov/digitalcoast/training/ccap-land-cover-classifications.html

Table 3 - Land Cover comparisons for Mustang Bayou, 2008 - 2018

Land Cover Class Name	Area Acres 2008	Area % 2008	Area Acres 2018	Area % 2018	% Change
Agriculture	24803.28	56.46	23136.18	52.66	-6.72
Barren Lands	838.21	1.91	572.04	1.30	-31.75
Developed	11252.13	25.61	12673.05	28.84	12.63
Forest/Shrubs	574.81	1.31	2065.47	4.70	259.33
Open Water	556.81	1.27	1253.64	2.85	125.15
Wetlands	5905.47	13.44	4235.61	9.64	-28.28
TOTAL	**43930.70**	**100.00**	**43935.99**	**100.00**	

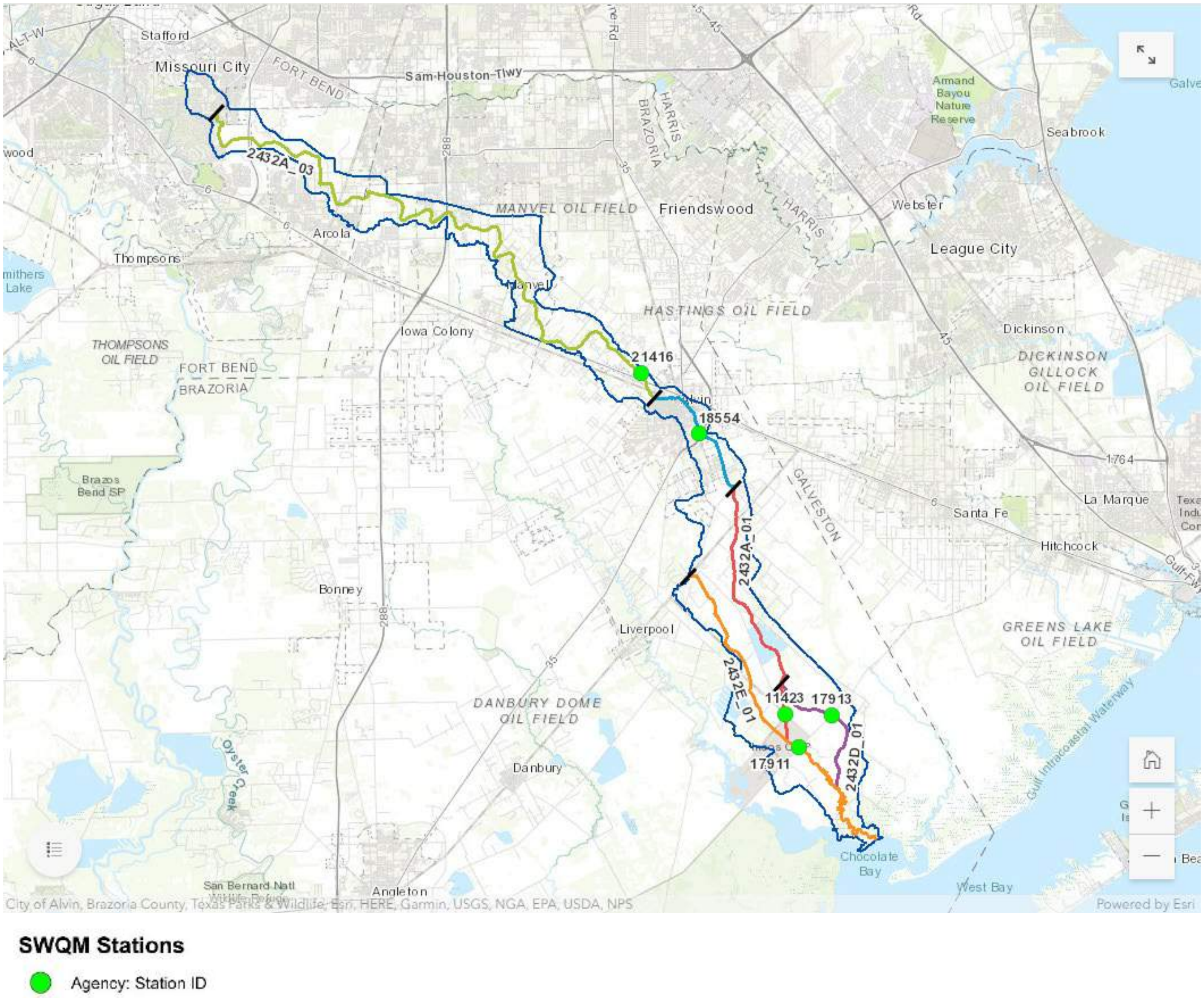
The Mustang Bayou watershed, including the area for Persimmon Bayou and New Bayou, contains approximately 43,936 acres. The most predominant land cover type is agricultural lands, comprising 52.66 percent of the acreage. Agricultural lands are composed of Cultivated Cropland and Pasture/Grasslands. The percentages of agricultural lands in Persimmon and New Bayous are higher than in Mustang Bayou, reflecting the smaller population in those areas.

Developed Lands (including High, Medium, and Low Intensity and Open Space) comprise 28.84 percent of the watershed. This reflects the development in the cities of Missouri City, Pearland, Manvel, Alvin, and Hillcrest Village. Also of note is an area of Developed High Intensity in New Bayou, which is due to a large industrial area adjacent to the bayou.

DESCRIPTIONS OF WATER QUALITY ISSUES

Routine ambient water quality data is collected at three stations on Mustang Bayou and at 1 station on Persimmon Bayou and one station on New Bayou (Map 3). These data are collected for the Clean Rivers Program by the Environmental Institute of Houston – Clear Lake.

As described in the 2018 Integrated Report, Mustang Bayou has an impairment in one AU (2432A_02) for not supporting its designated primary contact recreation use due to elevated bacteria. Concerns for near non-attainment of primary contact recreation are present in the other two AUs (2432A_01 and 2432A_03). There is a gap in the data collection between 2008 and 2012 that may be affecting the assessment.



Map 3 - Monitoring Stations in Mustang Bayou (2432A), Persimmon Bayou (2432D), and New Bayou (2432E)

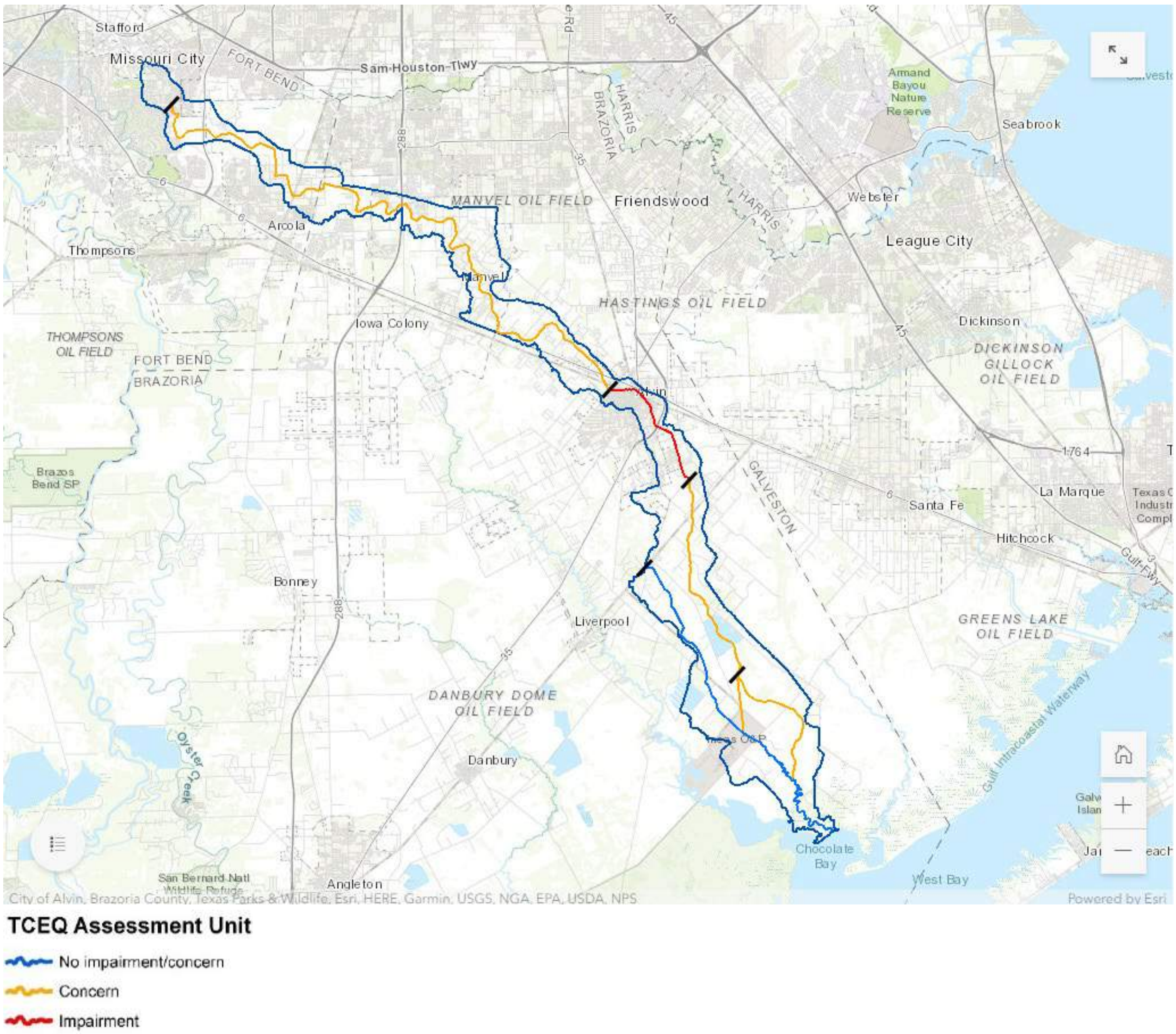
Monitoring station locations, site descriptions and annual monitoring frequency are provided in Table 4.

Table 4 - Monitoring Stations in Mustang Bayou (2432A), Persimmon Bayou (2432D), and New Bayou (2432E)

Station ID	Segment ID	Site Description	SE	CE	24-hour DO	Flow	Field	Conv	Bacteria
21416	2432A	MUSTANG BAYOU AT THE HEIGHTS-MANVEL ROAD / CARDINAL DRIVE BRIDGE NEAR ALVIN	HG	UI	-	4	4	4	4
18554	2432A	MUSTANG BAYOU IMMEDIATELY UPSTREAM OF EAST SOUTH STREET 85 METERS WEST OF SOUTHBOUND SH 35 IN ALVIN USGS ID 8077890	HG	UI	-	4	4	4	4
11423	2432A	MUSTANG BAYOU AT FM 2917 SOUTH OF ALVIN	HG	UI	-	4	4	4	4
17913	2432D	PERSIMMON BAYOU AT FM 2004 S/SW OF HITCHCOCK	HG	UI	-	-	4	4	4
17911	2432E	NEW BAYOU AT FM 2004 S/SW OF HITCHCOCK	HG	UI	-	-	4	4	4

Bacteria Impairments and Concerns

In the 2018 Integrated Report, AU 2432A_02 was identified as not supporting its designated contact recreation use (Map 4). This impairment was based on an *E. coli* geometric mean of 1,539.18 MPN/100 mL, which is over 12 times the primary contact recreation standard of 126 MPN/100 mL. A concern for near non-attainment of the primary contact recreation standard for bacteria was identified in AUs 2432A_01 of Mustang Bayou and AU 2432D_01 in Persimmon Bayou (Table 5)



Map 4 - Bacteria Impairments and Concerns in Mustang Bayou, Persimmon Bayou, and New Bayou

Table 5 - Comparison of Draft 2018 IR Bacteria Data (2009 – 2016) and H-GAC Analysis of Bacteria Data (2012 – 2019)

Waterbody	AU_ID	Parameter	Level of Support	Category	Geometric Mean of Bacteria Samples (2018 IR, 2009 - 2016)	Geometric Mean of Bacteria Samples (H-GAC Analysis, 2012 - 2019)
Mustang Bayou	2432A_01	*E. coli*	CN	-	463	222
Mustang Bayou	2432A_02	*E. coli*	NS	5c	1539	1194
Mustang Bayou	2432A_03	*E. coli*	CN	-	606	251
Persimmon Bayou	2432D_01	*E. coli*	CN	-	113	
New Bayou	2432E_01	*E. coli*	NC	-	116	

FS = Fully Supporting
NS = Nonsupport
**Not Calculated
NC = No Concern
CS = Screening Level Concern
NA = Not Accessed
CN = Use Concern

The concerns for AU 2432A_03 and 2432D_01 are carry-forwards from the previous Integrated Report, as there were insufficient data during the assessment period to perform an assessment.

Figure 2 shows the single grab *E. coli* results for Mustang Bayou for 2007 to 2019. There is a gap in the data from 2008 to 2012 where sampling was not conducted.

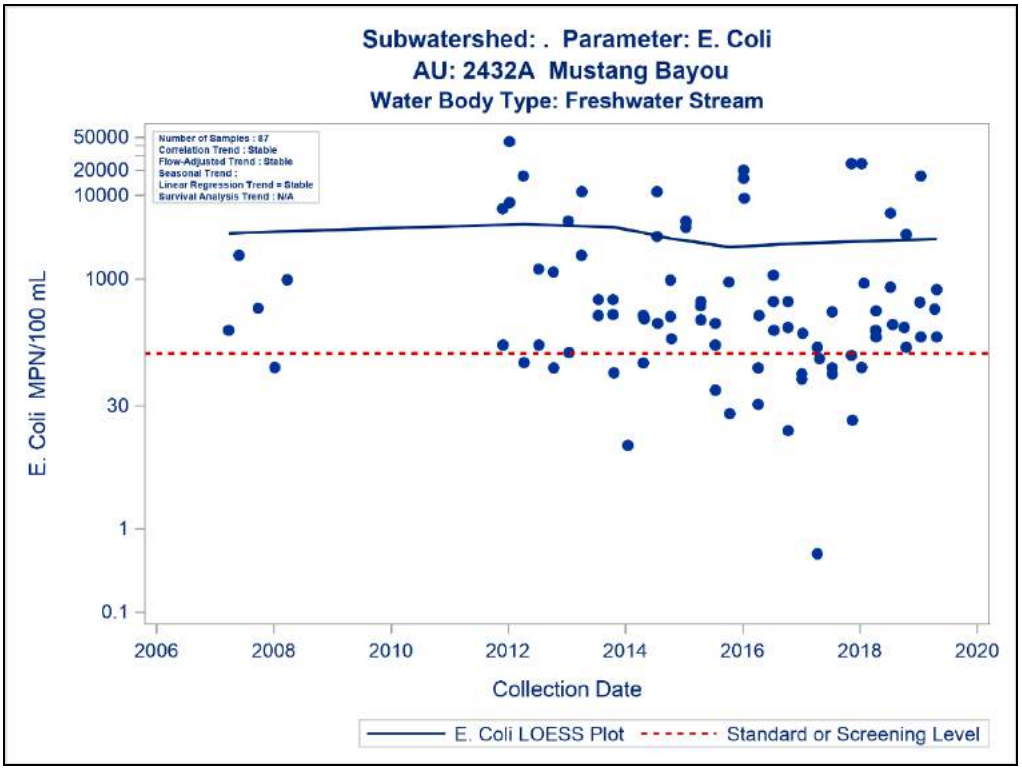
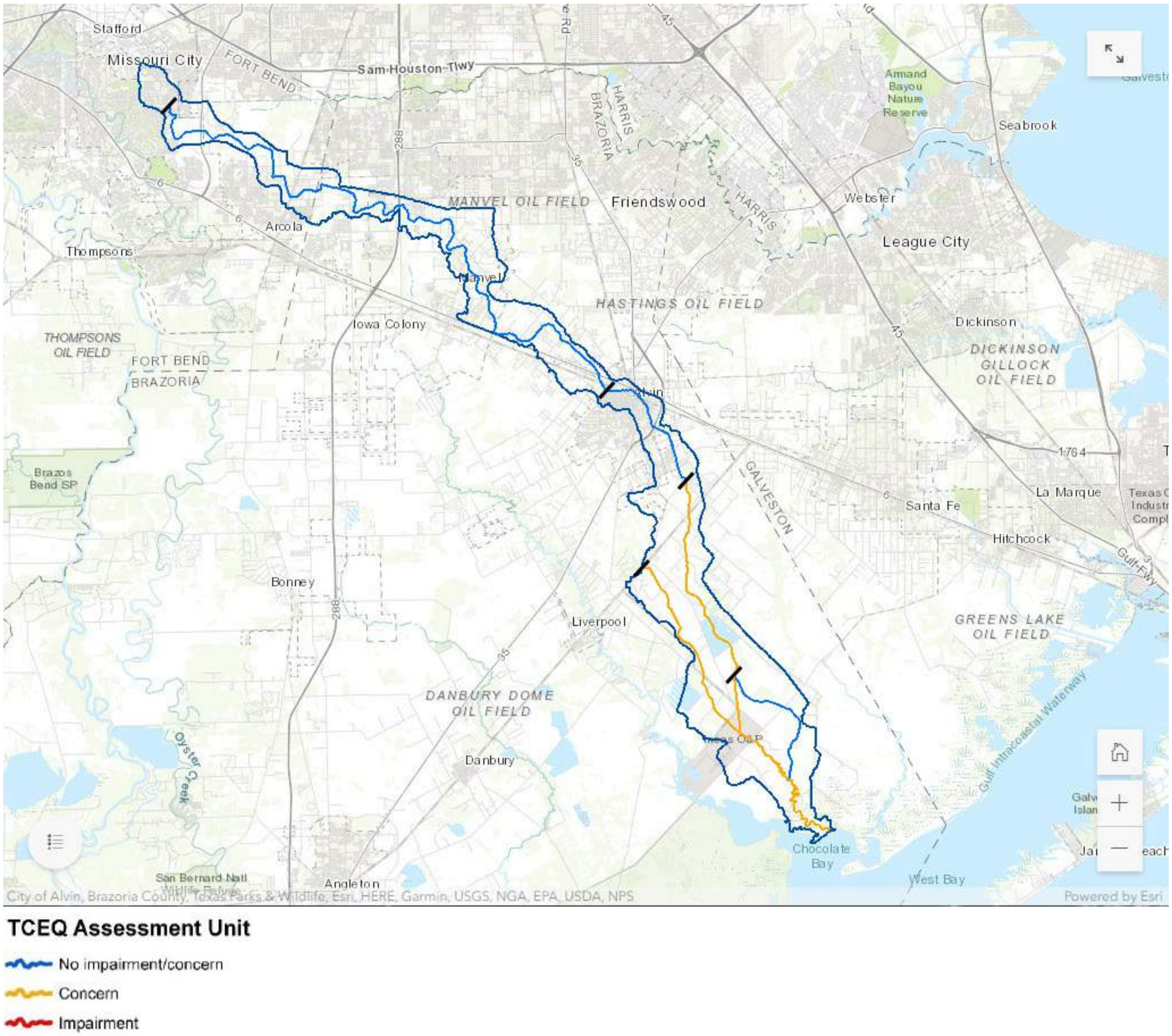


Figure 2 - E. coli results in Mustang Bayou, 2007 - 2019

Dissolved Oxygen Impairments and Concerns

In the 2018 Integrated Report, there is a concern for dissolved oxygen (DO) screening levels in AU 2432A_01 of Mustang Bayou and AU 2432E_01 of New Bayou (Map 5).



Map 5 - Dissolved Oxygen impairments and concerns in Mustang Bayou

Results from the 2018 Integrated Report assessment and H-GAC's analysis of DO results are shown in Table 6.

Table 6 – Comparison of 2018 IR Dissolved Oxygen Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

Waterbody	AU_ID	Parameter	Level of Support	Percentage of Samples Exceeding Standard (2018 IR, 2009 - 2016)	Percentage of Samples Exceeding Standard (H-GAC Analysis, 2012 - 2019)
Mustang Bayou	2432A_01	DO grab min	FS	0	10.71
		DO grab screening level	CS	42.86	53.57
	2432A_02	DO grab min	FS	0	0
		DO grab screening level	NC	0	3.57
	2432A_03	DO grab min	FS	0	0
		DO grab screening level	NC	8.33	9.09
Persimmon Bayou	2432D_01	DO grab min	FS	0	0
		DO grab screening level	NC	11.11	25
New Bayou	2432E_01	DO grab min	FS	0	0
		DO grab screening level	CS	23.08	28.57

FS = Fully Supporting NS = Nonsupport **Not Calculated
NC = No Concern CS = Screening Level Concern
NA = Not Accessed CN = Use Concern

Figure 3 shows the DO results (in mg/L) in Mustang Bayou (AU 2432A_01) from 2004 – 2019. It should be noted that there is a gap in the data, with no samples collected between 2006 and 2012. A decreasing trend is observed with the data; however, this trend could be skewed due to the gap in the data. Recent data points (post-2012) show a fairly even mix of sample results above and below the screening level. A concern for depressed DO was identified for this AU.

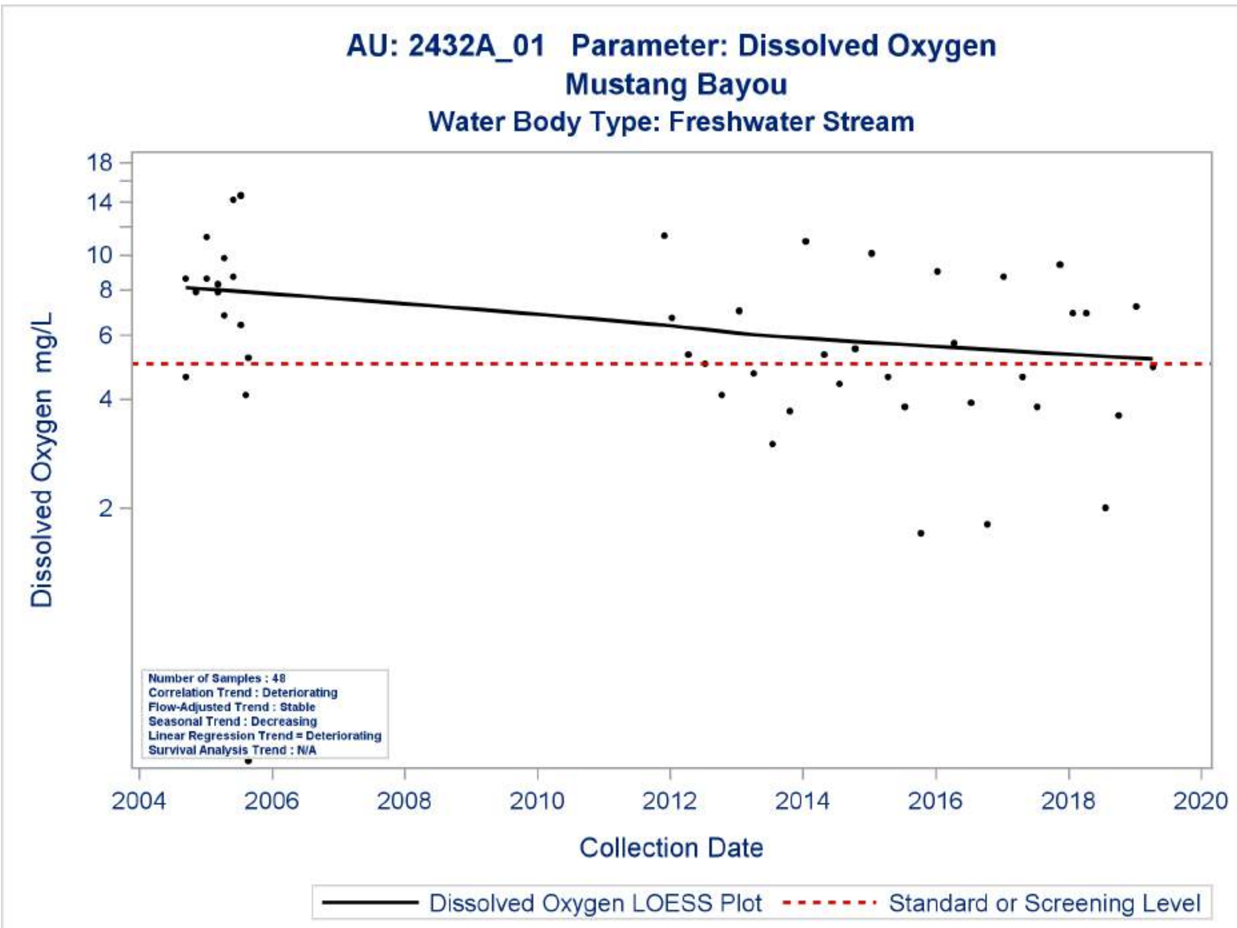


Figure 3 - Dissolved Oxygen results in AU 2432A_01, 2004 – 2019

Figure 4 shows DO grab results for AU 2432A_03. No concerns were identified for this AU. The majority of recent samples are above the screening level.

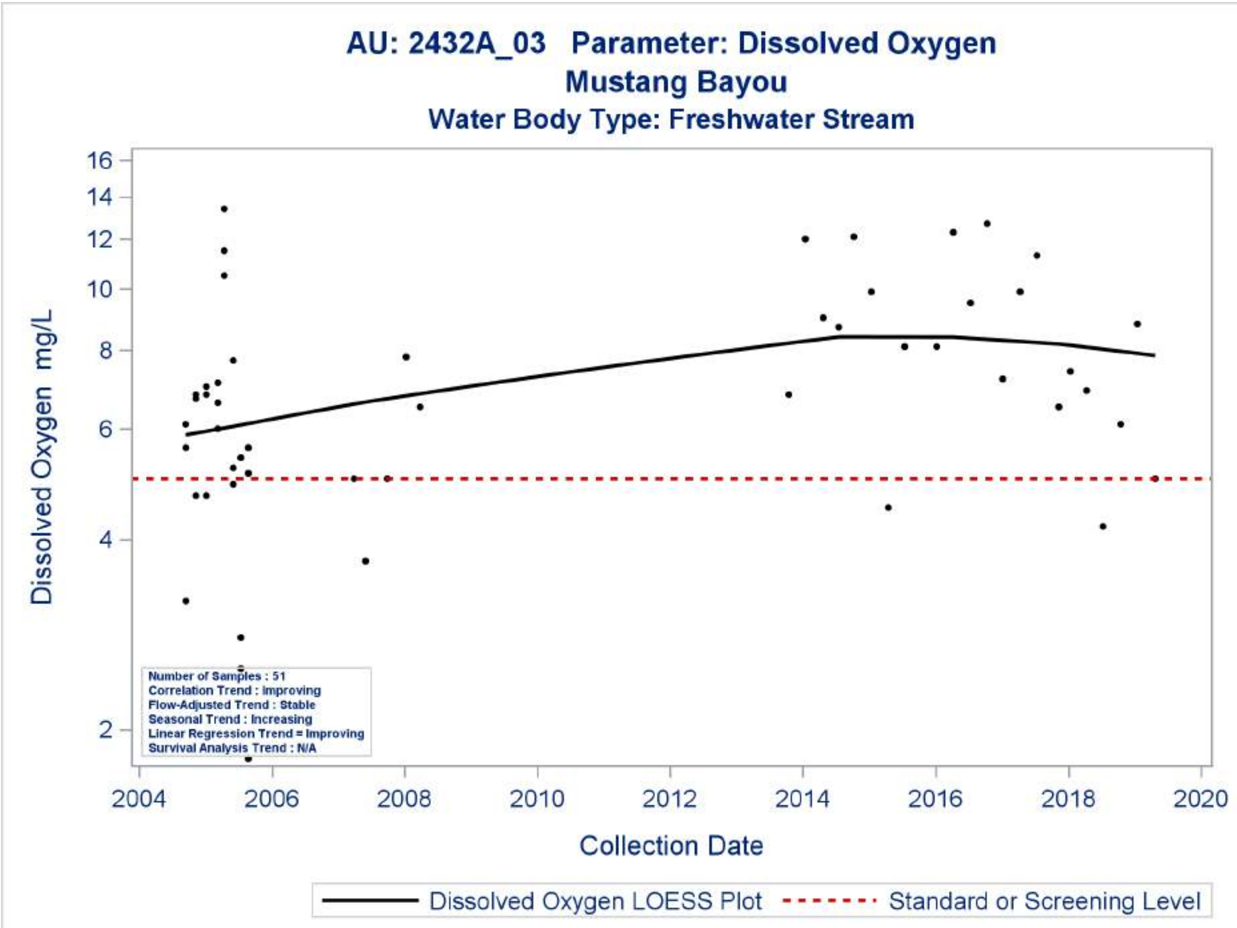


Figure 4 - Dissolved Oxygen results in AU 2432_03, 2004 - 2019

Nutrient Concerns

There are no nutrient concerns in Mustang, Persimmon, or New bayous. Figures 5 and 6 show nutrient parameter results in Mustang Bayou.

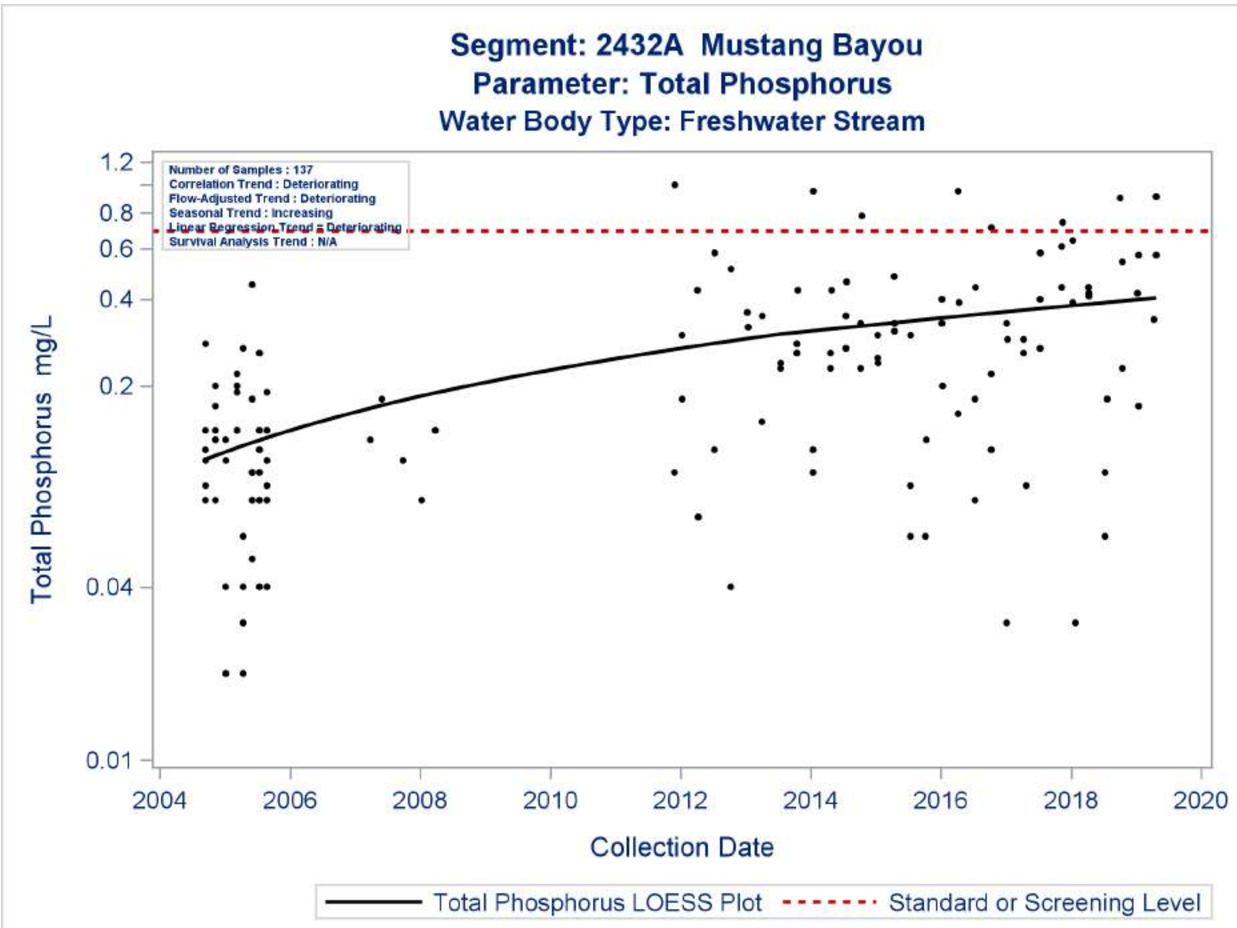


Figure 5 - Total Phosphorus grab sample results in Mustang Bayou, 2004 - 2019

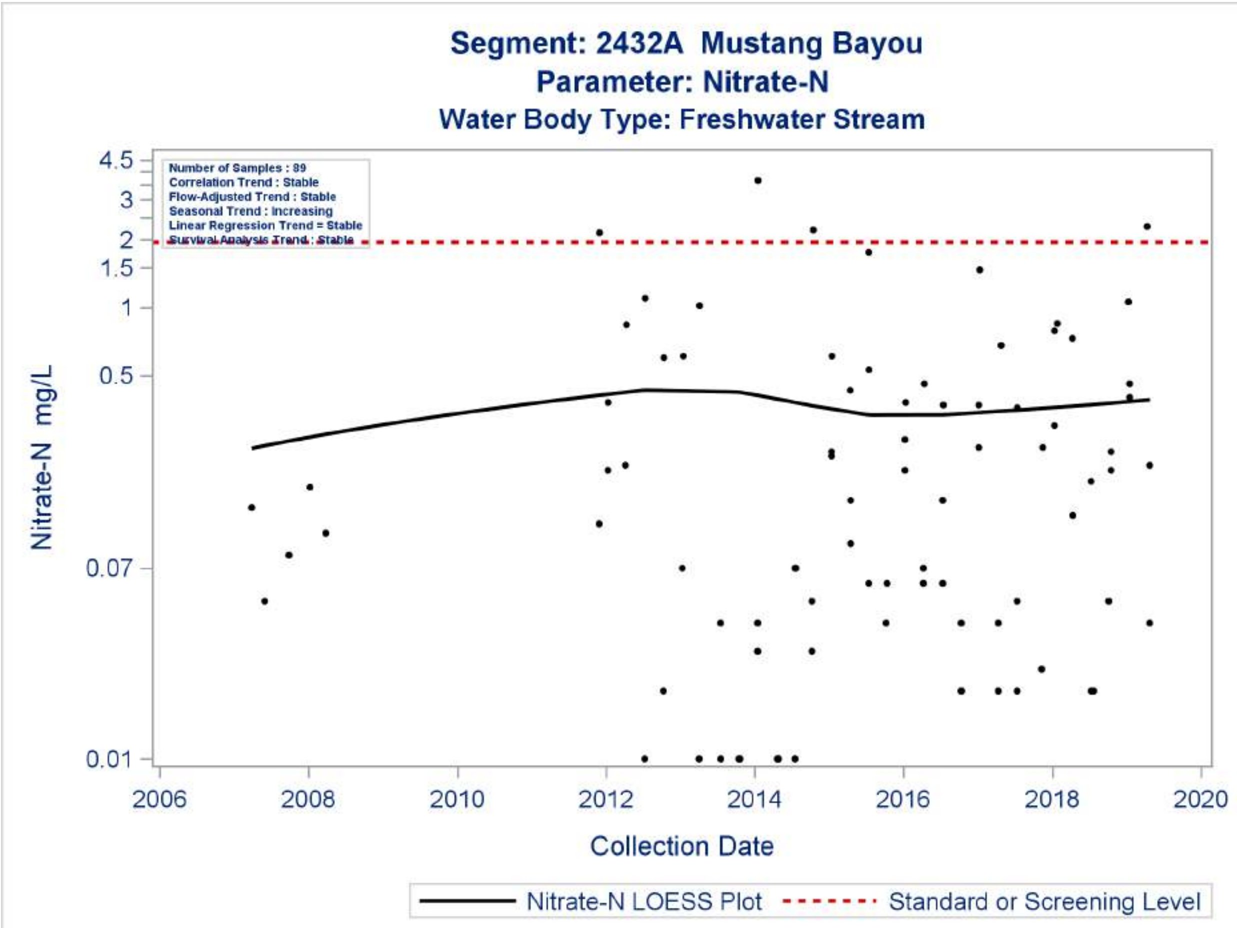


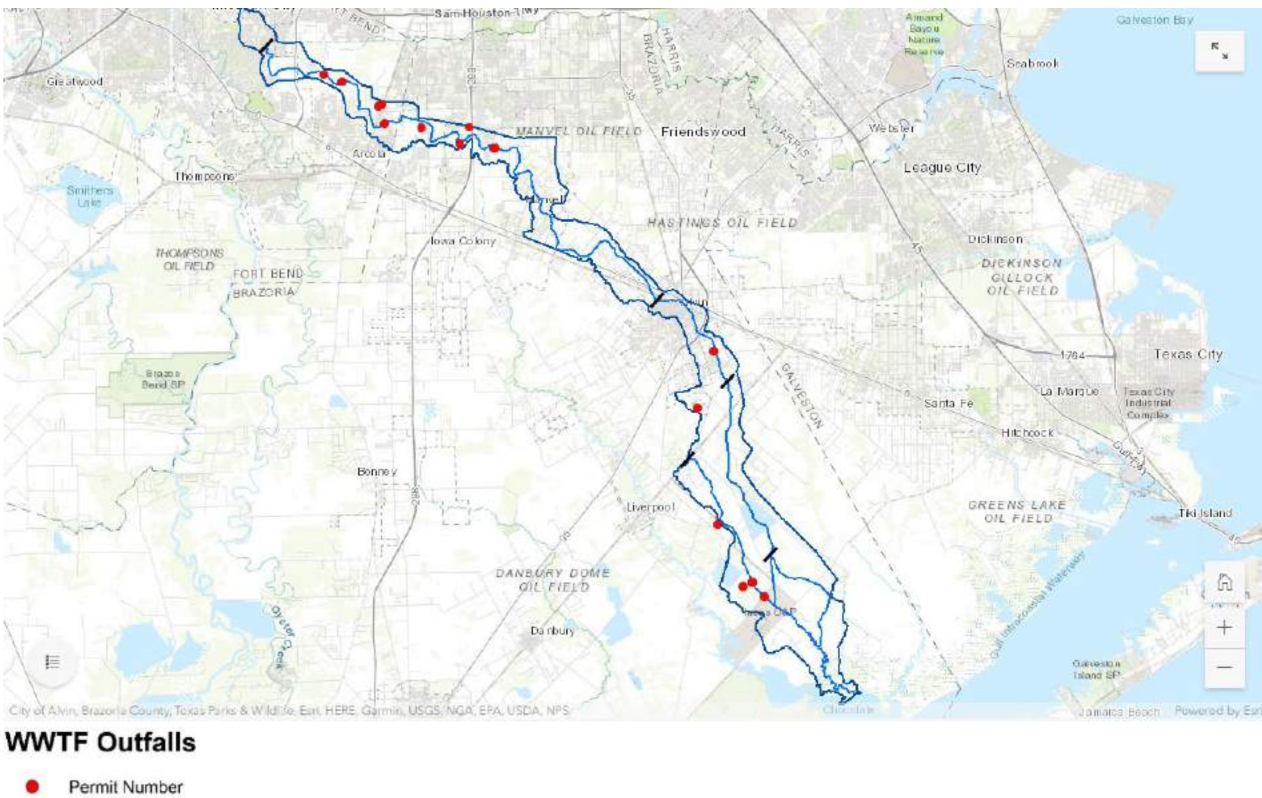
Figure 6 - Nitrate-N grab sample results in Mustang Bayou, 2012 - 2019

POTENTIAL SOURCES OF WATER QUALITY ISSUES

Potential sources of bacteria in Mustang Bayou include wastewater treatment facility effluent, sanitary sewer overflows, failing on-site sewage facilities, livestock, pets, wildlife, and other nonpoint sources.

Wastewater Treatment Facilities

There are 14 distinct wastewater permits, including 17 outfalls, in the watershed (Map 6). There are three industrial permits - two in New Bayou and one in Mustang Bayou. The industrial dischargers in New Bayou are not permitted to discharge bacteria in their effluent. All regulated wastewater treatment facilities within the watershed are relatively small, with the largest of the facilities having a permitted discharge of 0.8 MGD.



Map 6 - Permitted Wastewater Treatment Facilities in Mustang Bayou, Persimmon Bayou, and New Bayou

Sanitary Sewer Overflows

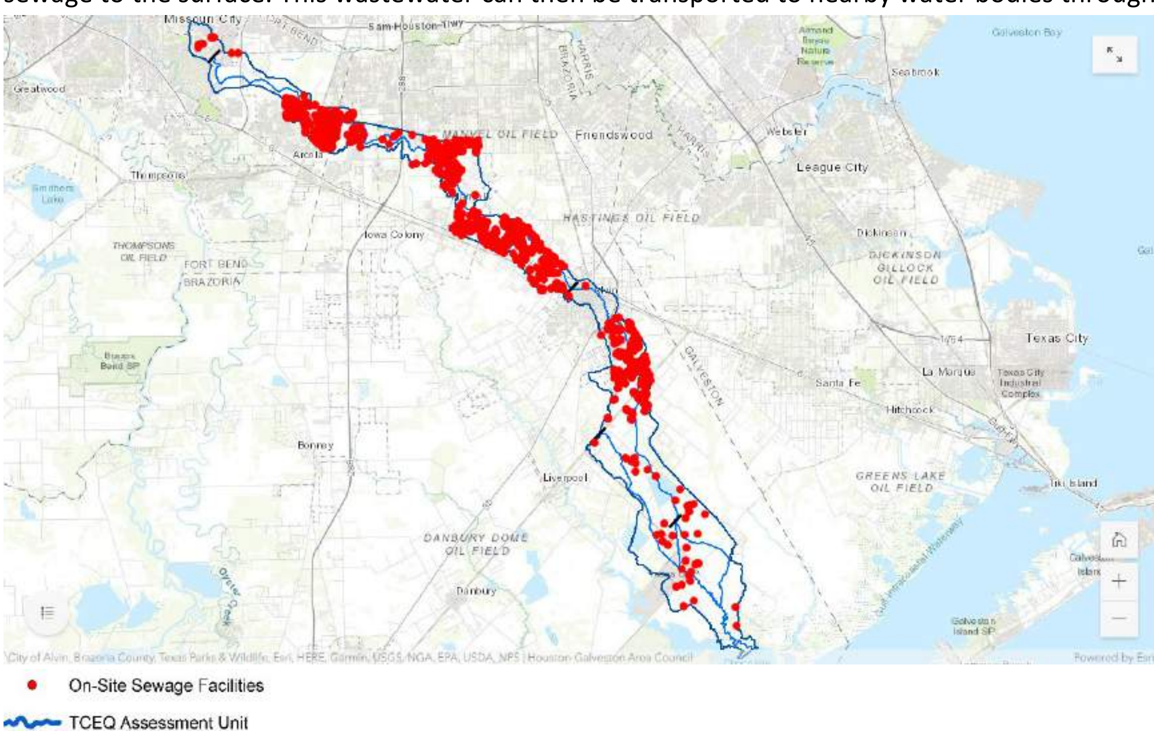
In areas served by centralized sanitary sewer, operational upsets and sanitary sewer overflows are potential sources of bacteria and nutrients within the waterways. Inflow and infiltration of stormwater, mechanical failures, and improper disposal of fats, oils, and grease can disrupt the proper operation of the collection system, resulting in overflows which can release untreated sewage to the waterways. These sanitary sewer overflows can be an appreciable source of bacteria and nutrients.

On-Site Sewage Facilities

Although there are numerous municipalities and utility districts with permitted wastewater treatment facilities, there are still large portions of the watershed without centralized sewage. For these areas, on-site sewage facilities are the primary method of wastewater treatment and disposal.

For Mustang Bayou, there are 1,261 permitted on-site sewage facilities (Map 7). However, this does not reflect the total number of systems within the watershed, as there was not a requirement to permit on-site systems installed prior to 1989. While many newer systems are under maintenance contracts, many of these older systems are not, and are more likely to fail due to improper usage or a lack of proper maintenance.

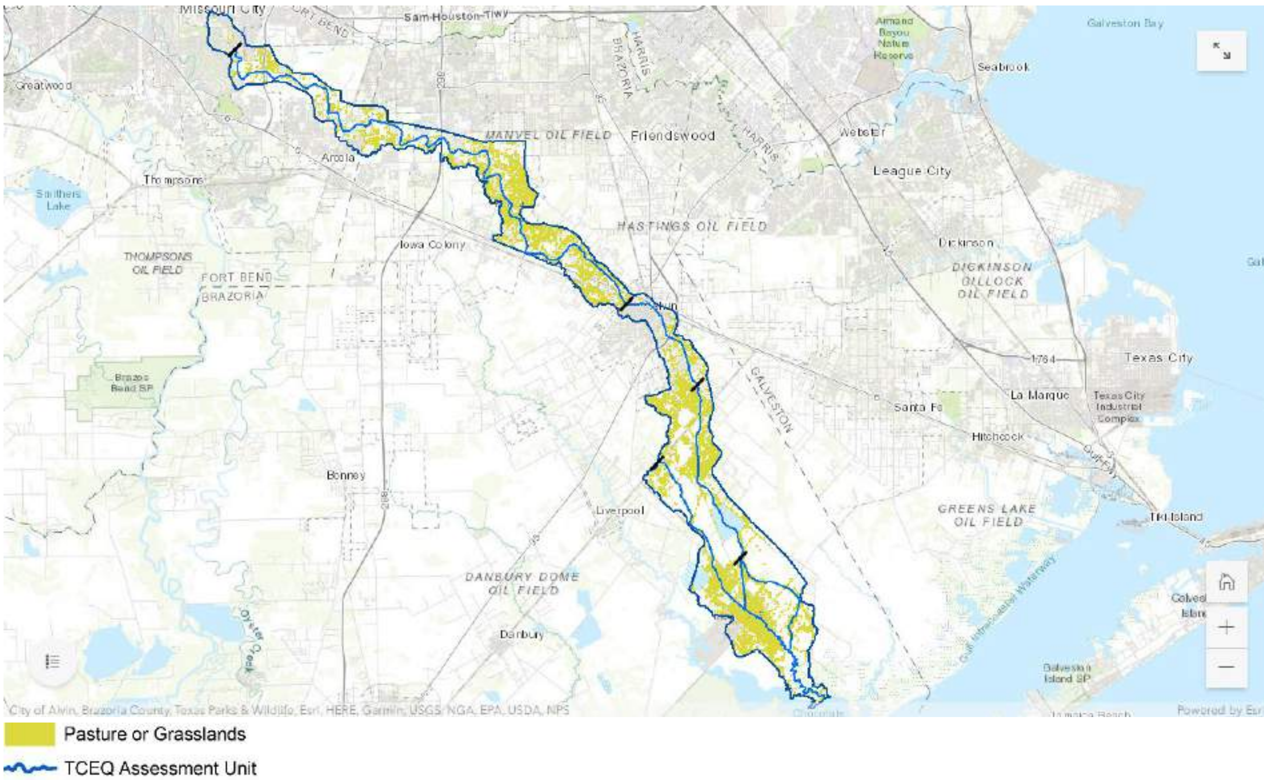
When properly sited and maintained, on-site systems provide a high level of treatment. However, if they system is not appropriate for the soil type (*i.e.*, a conventional system in clay soil) or has not been properly maintained, these systems can be prone to failure, resulting in the discharge of partially treated sewage to the surface. This wastewater can then be transported to nearby water bodies through runoff.



Map 7 - Permitted On-Site Sewage Facilities in Mustang Bayou, Persimmon Bayou, and New Bayou

Livestock and Other Animal Sources

Pasture and grassland make up a sizable portion of the Mustang Bayou watershed (Map 8), and much of this land is used for agricultural and livestock use. With this land use, animal wastes and fertilizer application can contribute to bacteria and nutrient concentrations in waterbodies. Due to the rural nature of the watershed, there are numerous areas that are suitable for feral hogs. Wastes from household pets (dogs and cats) are also a potential source of bacteria.



Map 8 – Pasture and Grassland Areas in Mustang Bayou

POTENTIAL STAKEHOLDERS

Potential stakeholders include:

- Cities of Missouri City, Fresno, Manvel, Alvin, and Hillcrest Village
- Environmental and Conservancy Organizations, such as local Keep Texas Beautiful Affiliates
- Citizen Groups, such as the Texas Master Naturalists
- Texas AgriLife Extension Offices
- Texas State Soil and Water Conservation Board
- Texas Parks and Wildlife
- Homeowner Associations
- Drainage Districts
- Utility Districts
- Industry

ONGOING PROJECTS

A Total Maximum Daily Load for bacteria is being developed.

RECOMMENDATIONS FOR IMPROVING WATER QUALITY

- Address bacteria and various other concerns through stakeholder involvement and best management practices
- Continue to analyze Discharge Monitoring Report data and present results to TCEQ, wastewater permittees, local governments/utility districts, and stakeholders
- Support public education programs to inform business and homeowners on appropriate disposal of fats, oil, and grease
- Support programs that oversee the maintenance, repair, and replacement of on-site sewage facilities
- Create and implement Water Quality Management Plans for individual agricultural properties
- Continue collecting water quality data and expand monitoring efforts to support actions associated with the Total Maximum Daily Load program
- Pursue new local partners to collect additional data to help better isolate problem areas
- Expand volunteer monitoring with Texas Stream Team in areas without professional monitoring
- Support programs to responsibly eliminate feral hog populations in the watershed
- Consult stakeholders to identify illegal dumping sites and improve signage and/or cameras, if needed

DETAILED WATERSHED CHARACTERIZATION
Halls Bayou Tidal (2432C)
Willow Bayou (2432B)

Figure 1 - Halls Bayou Tidal (Monitoring Station 11422) Source: EIH

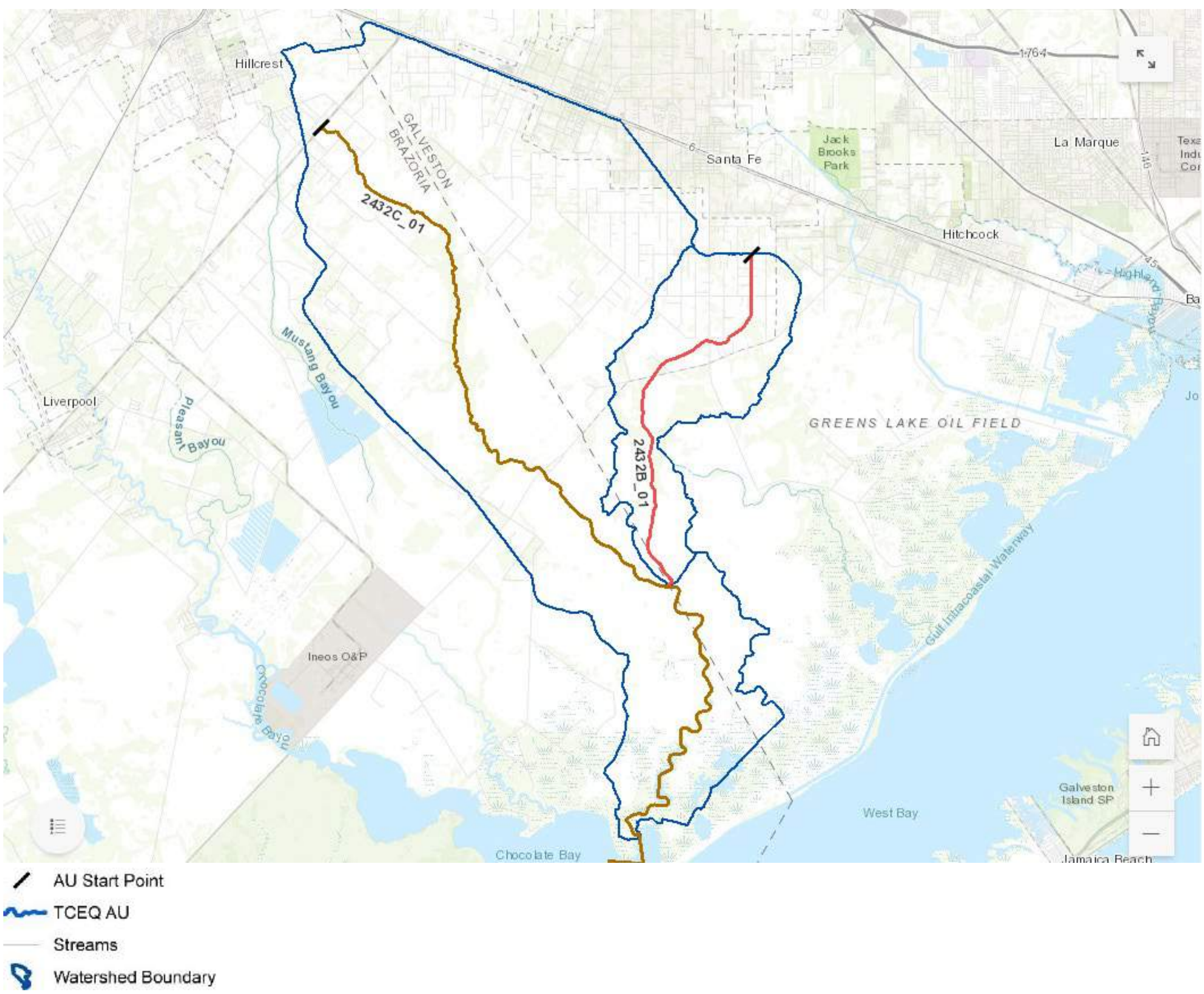
Figure 2 - Willow Bayou (Monitoring Station 18668) Source: EIH

SEGMENT DESCRIPTION

Located within the Chocolate Bay (Segment 2432) watershed, the Halls Bayou watershed (Map 1) is composed of Halls Bayou Tidal (Segment 2432C) and Willow Bayou (Segment 2432B). Halls Bayou Tidal is a 31.5 km (19.6 ml) long tidal stream that arises southeast of Alvin in Brazoria County and flows southeasterly, briefly entering Galveston County, runs parallel to the Galveston County line into Halls Lake, and then into Chocolate Bay, an embayment of West Galveston Bay.

Willow Bayou, a freshwater tributary to Halls Bayou Tidal, begins in Galveston County three miles southwest of Hitchcock in western Galveston County and flows 9.7 km (6 mi) to its confluence with Halls Bayou Tidal at the Brazoria County line.

Both segments consist of a single Assessment Unit (AU). Descriptions of the AUs are in Table 1.



Map 1 - Watershed map showing the extent of the drainage area of Halls Bayou Tidal (Segment 2432C) and Willow Bayou (Segment 2432B)

Table 1 - Assessment Unit Description for Halls Bayou Tidal and Willow Bayou

Segment Name	Segment ID	AU	Description
Halls Bayou Tidal	2432C	2432C_01	From the Chocolate Bay confluence upstream to a point 31.5 km (19.6 mi) upstream
Willow Bayou	2432B	2432B_01	From the Halls Bayou confluence to a point 9.7 km (6 mi) upstream

HYDROLOGICAL CHARACTERISTICS

Halls Bayou and its tributaries are typically sluggish due to the gentle sloping relief found on the coastal plain. Riparian vegetation is common along portions of the bayou.

Average precipitation for the watershed is 46.8 inches per year, with the monthly average ranging from 2.6 to 7.3 inches. Rainfall occurs throughout the year with February and March seeing the least amount of rainfall, while the summer months typically see the greatest rainfall due to tropical disturbances.

The Gulf Coast Water Authority maintains pump stations on Chocolate, Mustang, and Halls bayous to supply up to 400,000-acre-feet of water per year for industrial, irrigation, and municipal purposes.

LAND COVER AND NATURAL CHARACTERISTICS

The Halls Bayou watershed is primarily tall grass prairies and marsh wetlands, with forested riparian areas consisting of water-tolerant hardwoods and conifers. This habitat supports a diverse population of both freshwater and saltwater fish. With extensive beds of seagrass, particularly wild celery, the bayou provides habitat for numerous waterfowls in the winter.

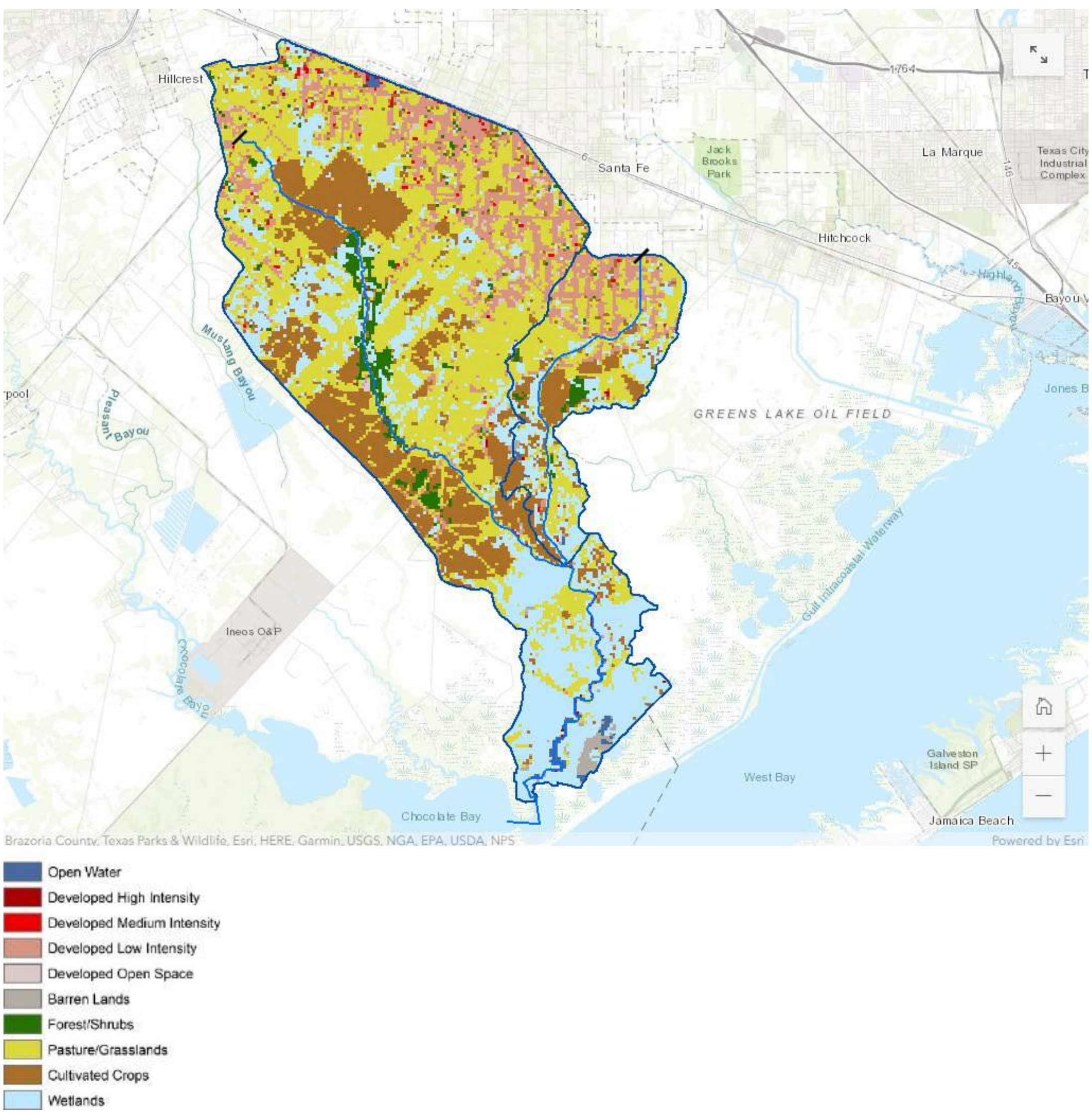
The entire Halls Bayou watershed, which includes both Halls Bayou Tidal and Willow Bayou, covers 44,146 acres.

Agriculture, including pasture/grassland and cultivated crops, is the predominant land cover type in the watershed, comprising 59.06 percent of the watershed in 2018 (Table 2). Wetlands comprise the next largest land cover category at 23.33 percent. Developed lands comprise 13.37 percent of land cover in 2018, a decrease from 19.54 percent in 2008. Forest/Shrubs, barren lands, and open water make up very small portions of the watershed area.

Table 2 - Land Cover Comparisons for Halls Bayou Tidal, 2008 to 2018

Land Cover Class Name	Area Acres 2008	Area % 2008	Area Acres 2018	Area % 2018	% Change
Agriculture	25341.75	57.29	26074.43	59.06	2.89
Barren Lands	310.94	0.70	378.99	0.86	21.89
Developed	8642.18	19.54	5900.36	13.37	-31.73
Forest/Shrubs	442.87	1.00	1224.63	2.77	176.52
Open Water	358.92	0.81	268.05	0.61	-25.32
Wetlands	9138.35	20.66	10299.83	23.33	12.71
TOTAL	**44235.01**	**100.00**	**44146.28**	**100.00**	

Map 2 shows the land cover types within the Halls Bayou watershed. The descriptions of these land cover types are found in Table 3.



Map 2 - Land cover within Halls Bayou Tidal and Willow Bayou

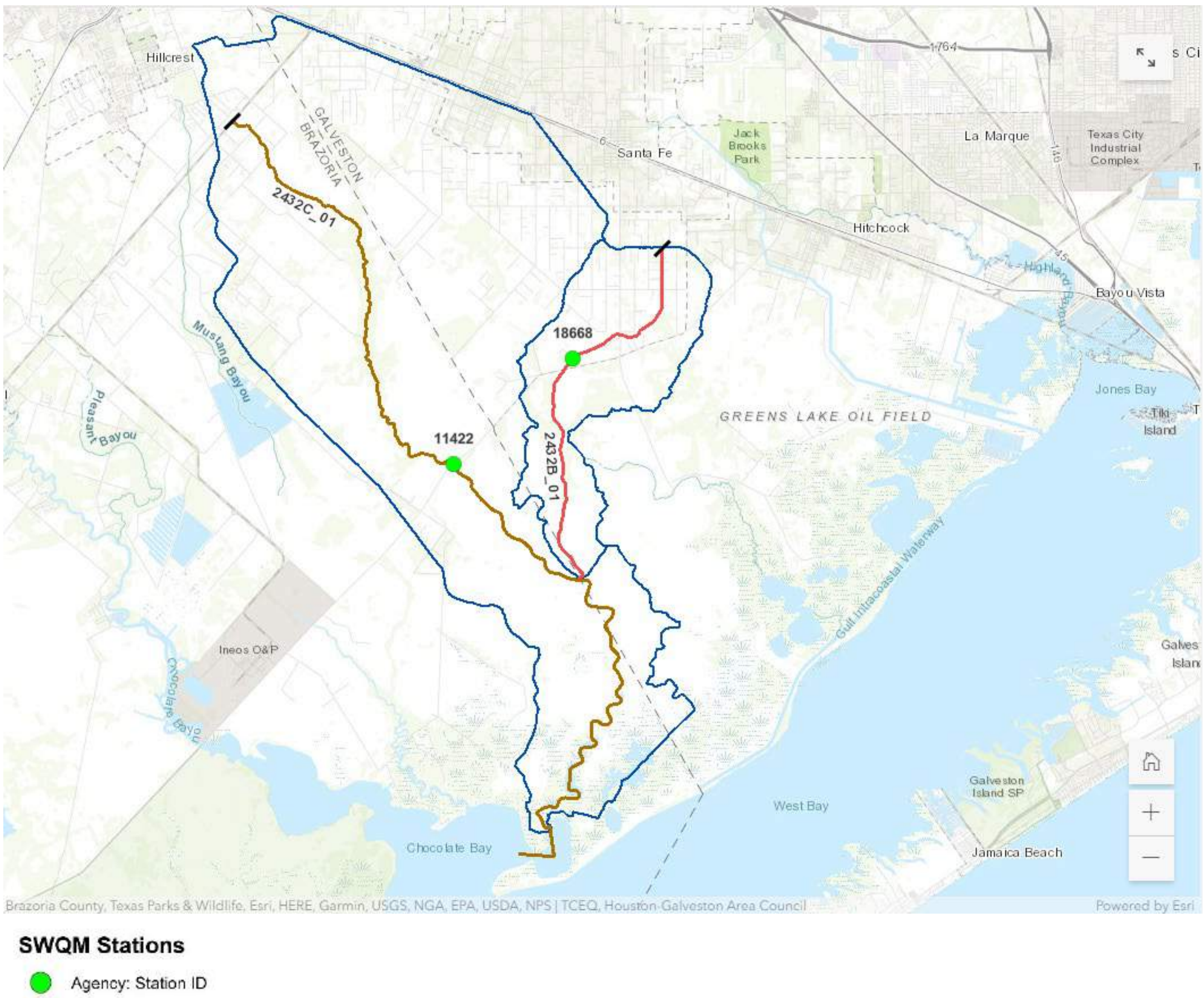
Table 3 - Description of land cover classes

Map Key	Land Cover Class	Class Description
	Developed, High Intensity	Contains significant land area and is covered by impervious surfaces (i.e., concrete, asphalt, and other constructed materials). Vegetation, if present, occupies < 20 percent of the landscape. Impervious surfaces account for 80 to 100 percent of the total cover. This class includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas with a variety of land uses.
	Developed, Medium Intensity	Contains areas with a mixture of impervious surfaces and vegetation or other cover. Impervious surfaces account for 50 to 79 percent of total area. This class commonly includes multi- and single-family housing areas, especially in suburban neighborhoods, but may include all types of land use.
	Developed, Low Intensity	Contains areas with a mixture of impervious surfaces and substantial amounts of vegetation or other cover. Impervious surfaces account for 21 to 49 percent of total area. This class commonly includes single-family housing areas, especially in rural neighborhoods, but may include all types of land use.
	Developed, Open Space	Contains areas with a mixture of some impervious surfaces, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes. Impervious surfaces account for less than 20 percent of total land cover. This class commonly includes large-lot single family housing units, parks, and golf courses.
	Agriculture, Pasture/Grasslands	Contains both managed and unmanaged grasses, legumes, or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas can be subjective to intensive management, such as tilling, and utilized for grazing.
	Agriculture, Cultivated	Contains areas intensely managed for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
	Barren Land	Contains areas of gravel pits, bedrock, sand dunes, and other accumulations of earth material. Generally, vegetation accounts for less than 10 percent of total cover.
	Forest/Shrub	Includes two types of trees that cover greater than 20 percent of total vegetation cover. • *Forest*—areas dominated by all kinds of trees generally greater than 5 meters tall. • *Shrub*—areas dominated by shrubs generally less than 5 meters tall.
	Open Water	Include areas of open water, generally with less than 25 percent cover of vegetation or soil.
	Wetlands	Includes the area contains palustrine or estuarine vegetation that are periodically saturated or covered with water. Total vegetation coverage is greater than 20 percent.

Source: National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) Land Cover Classifications https://coast.noaa.gov/digitalcoast/training/ccap-land-cover-classifications.html

DESCRIPTIONS OF WATER QUALITY ISSUES

Routine ambient water quality data is collected for Halls Bayou Tidal and Willow Bayou by the Environmental Institute of Houston – Clear Lake. The data for segment 2432C (Halls Bayou Tidal) are collected at monitoring station 11422, which is located at FM 2004 southwest of Santa Fe. Data for segment 2432B (Willow Bayou) are collected at station 18668 which is located at Baker Street (upstream of FM 2004) south of Santa Fe. Monitoring stations for this watershed are shown in Map 3.



Map 3 - Routine monitoring stations in Halls Bayou Tidal and Willow Bayou

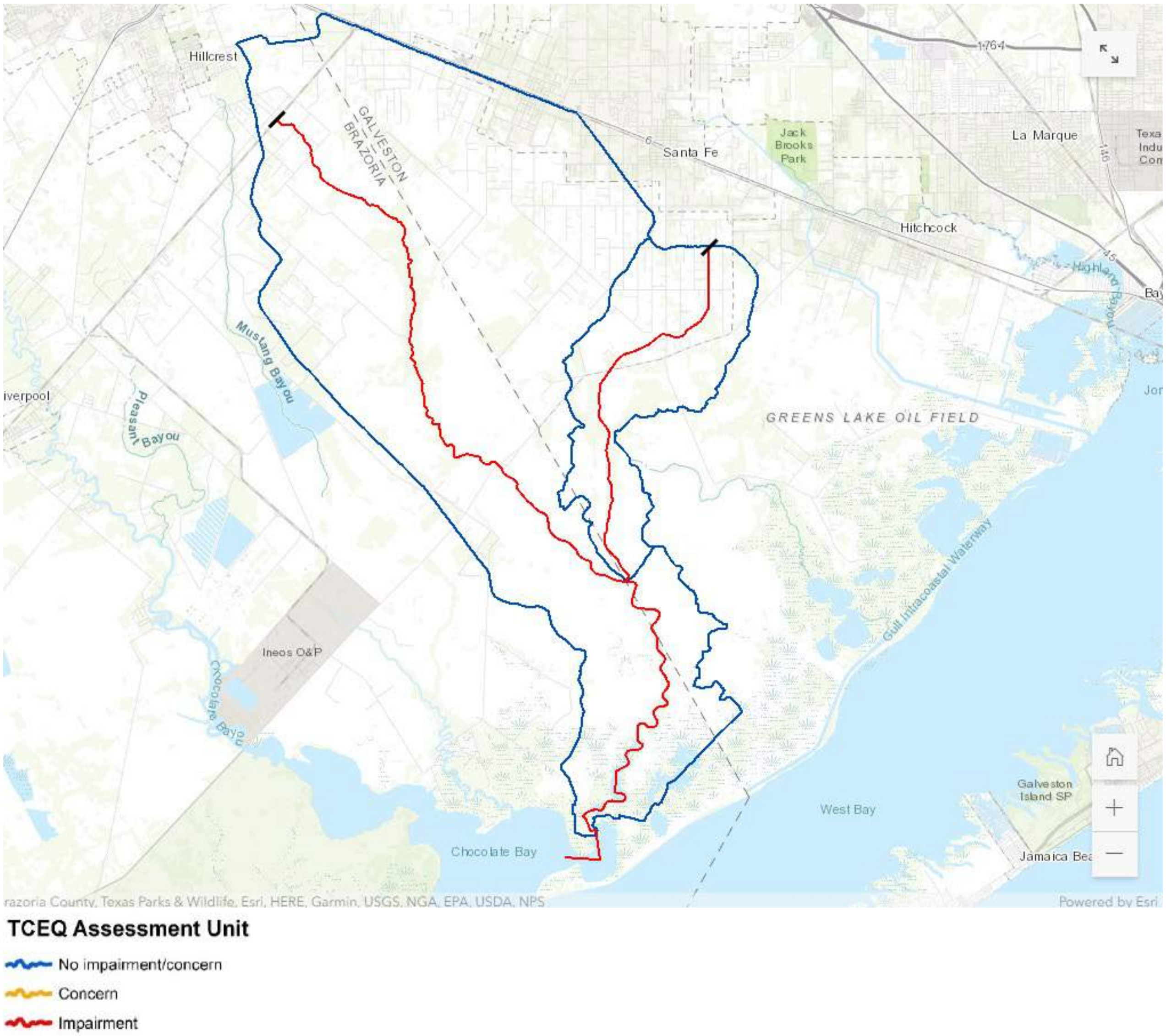
Monitoring station locations, site descriptions and annual monitoring frequency are provided in Table 4.

Table 4 - Monitoring Stations in Halls Bayou Tidal and Willow Bayou

Station ID	Segment ID	Site Description	SE	CE	24-hour DO	Flow	Field	Conv	Bacteria
11422	2432C	HALLS BAYOU AT FM 2004 SW OF ALTO LOMA	WC	FO	-	-	4	4	4
18668	2432B	WILLOW BAYOU AT BAKER ST 404 M UPSTREAM OF FM 2004 SOUTH OF SANTA FE IN GALVESOTN COUNTY	HG	UI	-	4	4	4	4

Bacteria Impairments and Concerns

TCEQ first identified bacteria impairments within the Halls Bayou Tidal watershed in 2012. A concern for bacteria was identified in Willow Bayou in 2014, with that water body first being recognized as impaired in the 2018 Integrated Report.



Map 4 - Bacteria Impairments in Halls Bayou Tidal and Willow Bayou

In the 2018 Integrated Report, Halls Bayou Tidal had an Enterococcus geometric mean of 149.95 MPN/100 mL, which is over four times the standard of 35 MPN/100 mL. During the same timeframe, Willow Bayou had a geometric mean of 342.68 MPN/100 mL for *E. coli*, which is approximately 2.7 times the standard of 126 MPN/100 mL.

A Total Maximum Daily Load for bacteria for Halls Bayou Tidal and Willow Bayou is under development.

Table 5 – Comparison of 2018 IR Bacteria Data (2009 – 2016 and H-GAC Analysis of Bacteria Data (2012 - 2019

Segment	AU_ID	Parameter	Level of Support	Category	Geometric Mean of Bacteria Samples (2018 IR, 2009 - 2016)	Geometric Mean of Bacteria Samples (H-GAC Analysis, 2012 - 2019)
Halls Bayou Tidal	2432C_01	Enterococcus	NS	5c	149.95	124.25
Willow Bayou	2432B_01	*E. coli*	NS	5c	342.68	122.33

FS = Fully Supporting NS = Nonsupport **Not Calculated
NC = No Concern CS = Screening Level Concern
NA = Not Accessed CN = Use Concern

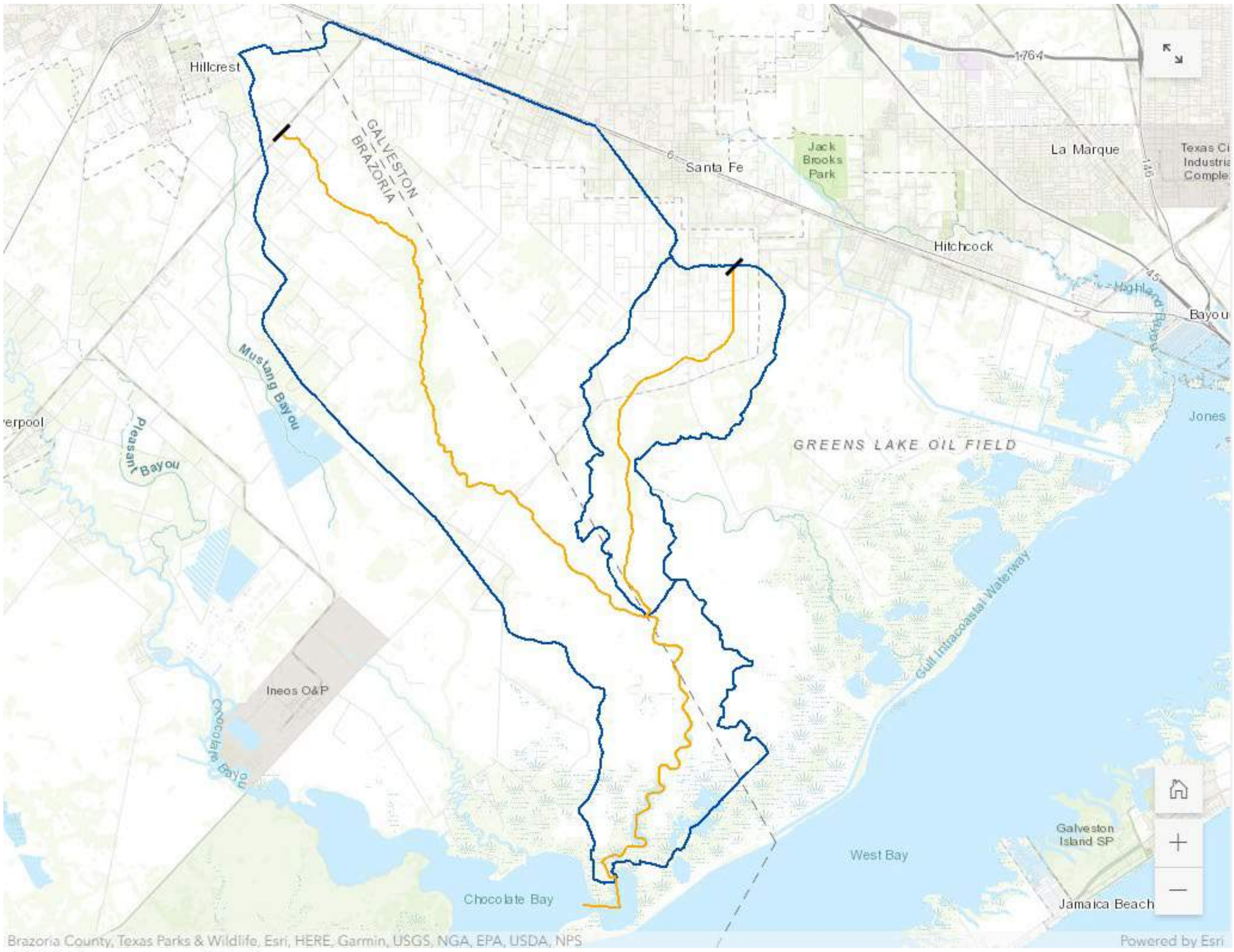
Dissolved Oxygen Impairments and Concerns

For Halls Bayou Tidal there is a concern for dissolved oxygen (DO) screening levels, with 25.86 percent of samples exceeding the screening level (Table 6). For Willow Bayou, there is a concern for DO screening levels, and a concern for near non-attainment based upon results of the grab samples. Concerns for DO are shown in Map 5.

Table 6 - Comparison of 2018 IR Dissolved Oxygen Data (2009 – 2016) and H-GAC Analysis of Water Quality Data (2012 – 2019)

Waterbody	AU_ID	Parameter	Level of Support	Percentage of Samples Exceeding Standard (2018 IR, 2009 – 2012))	Percentage of Samples Exceeding Standard (H-GAC Analysis, 2012 - 2019)
Halls Bayou Tidal	2432C_01	DO grab minimum	FS	5.17	4.08
		DO grab screening level	CS	25.86	22.45
Willow Bayou	2432B_01	DO grab minimum	CN	20	7.14
		DO grab screening level	CS	20	39.28

FS = Fully Supporting NS = Nonsupport **Not Calculated
NC = No Concern CS = Screening Level Concern
NA = Not Accessed CN = Use Concern



TCEQ Assessment Unit

- No impairment/concern
- Concern
- Impairment

Map 5 - Dissolved Oxygen Impairments in Halls Bayou Tidal

Nutrient Concerns

There are no nutrient concerns for ammonia-nitrogen, nitrate-nitrogen, total phosphorus, or chlorophyll-*a* for Halls Bayou Tidal or Willow Bayou identified in the 2018 Integrated Report.

Figure 3 shows results of grab samples for nitrate-N for Halls Bayou Tidal from 2004 – 2019. Numerous data points are reported at the limit of quantitation, so the result would be reported as a “less than” value (*i.e.,* <0.01 mg/L). The trend appears to be decreasing but is being influenced by the lower limit of quantitation used for analysis between 2013 and 2016, which is bringing the trend down.

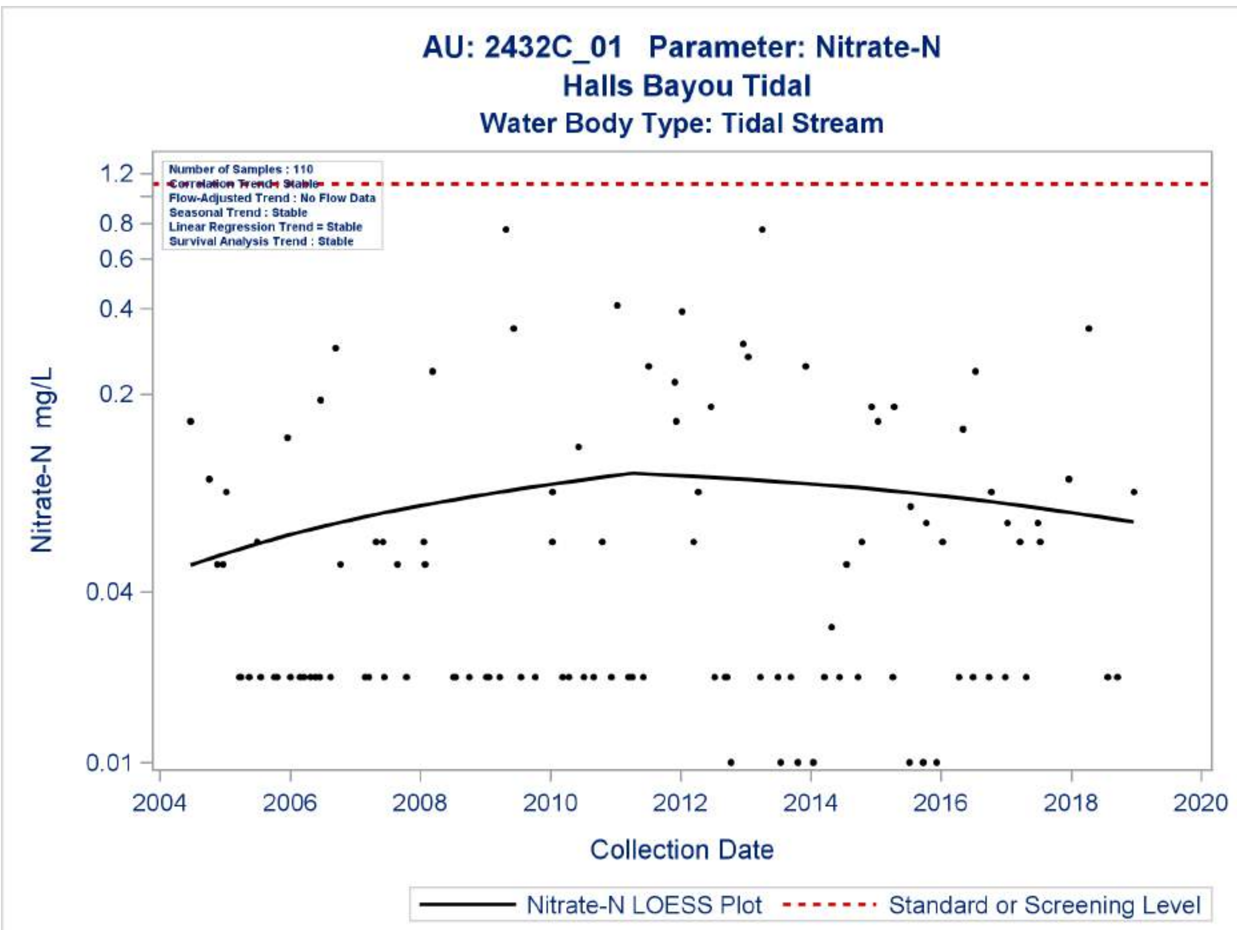


Figure 3 - Nitrate-N grab sample results for Halls Bayou Tidal, 2004 - 2019

Figure 4 shows grab sample results for total phosphorus for Willow Bayou from 2004 to 2019. An increasing trend is observed; however, most results still remain under the screening level.

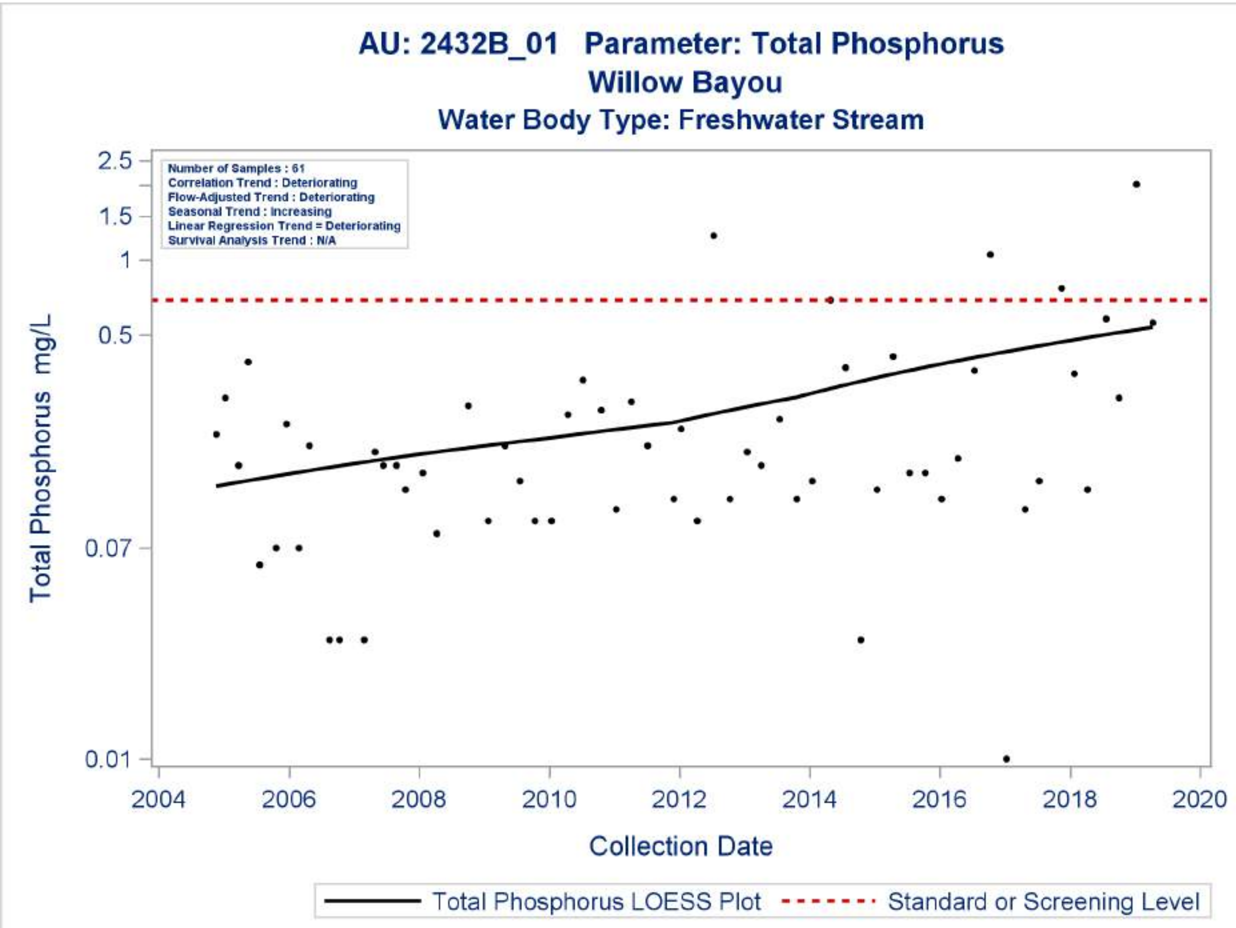


Figure 4 - Total Phosphorus grab sample results for Willow Bayou, 2004 - 2019

Additional Parameters

In reviewing data for Halls Bayou Tidal, a decrease in results for chloride (Figure 5), sulfate (Figure 6), and specific conductance (Figure 7) was noticed, beginning around 2014. The cause of these decreases is not known but may be related to flood and heavy rainfall events. Further examination may be warranted.

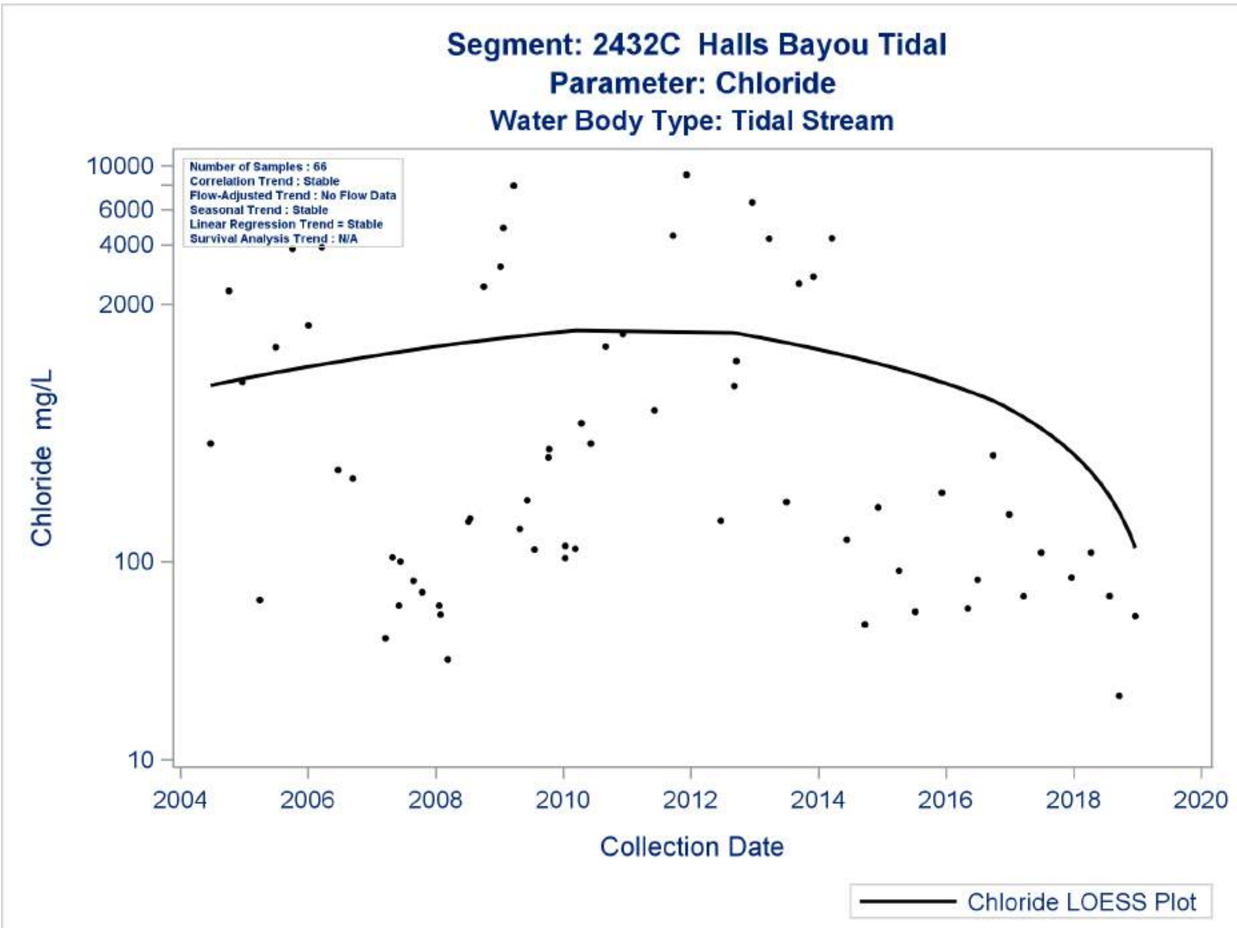


Figure 5 - Chloride grab sample results in Halls Bayou Tidal, 2004 – 2019

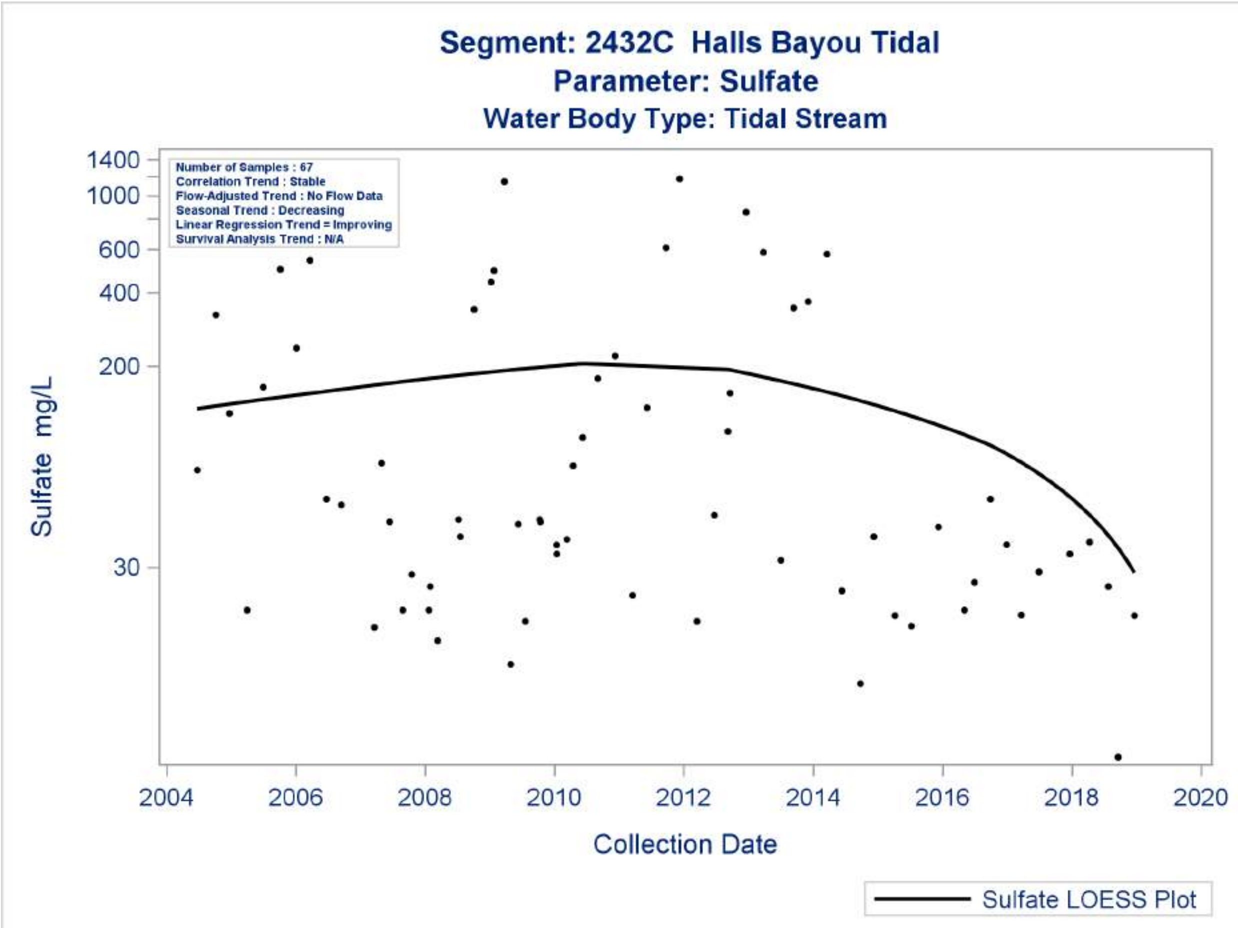


Figure 6 - Sulfate grab sample results in Halls Bayou Tidal, 2004 – 2019)

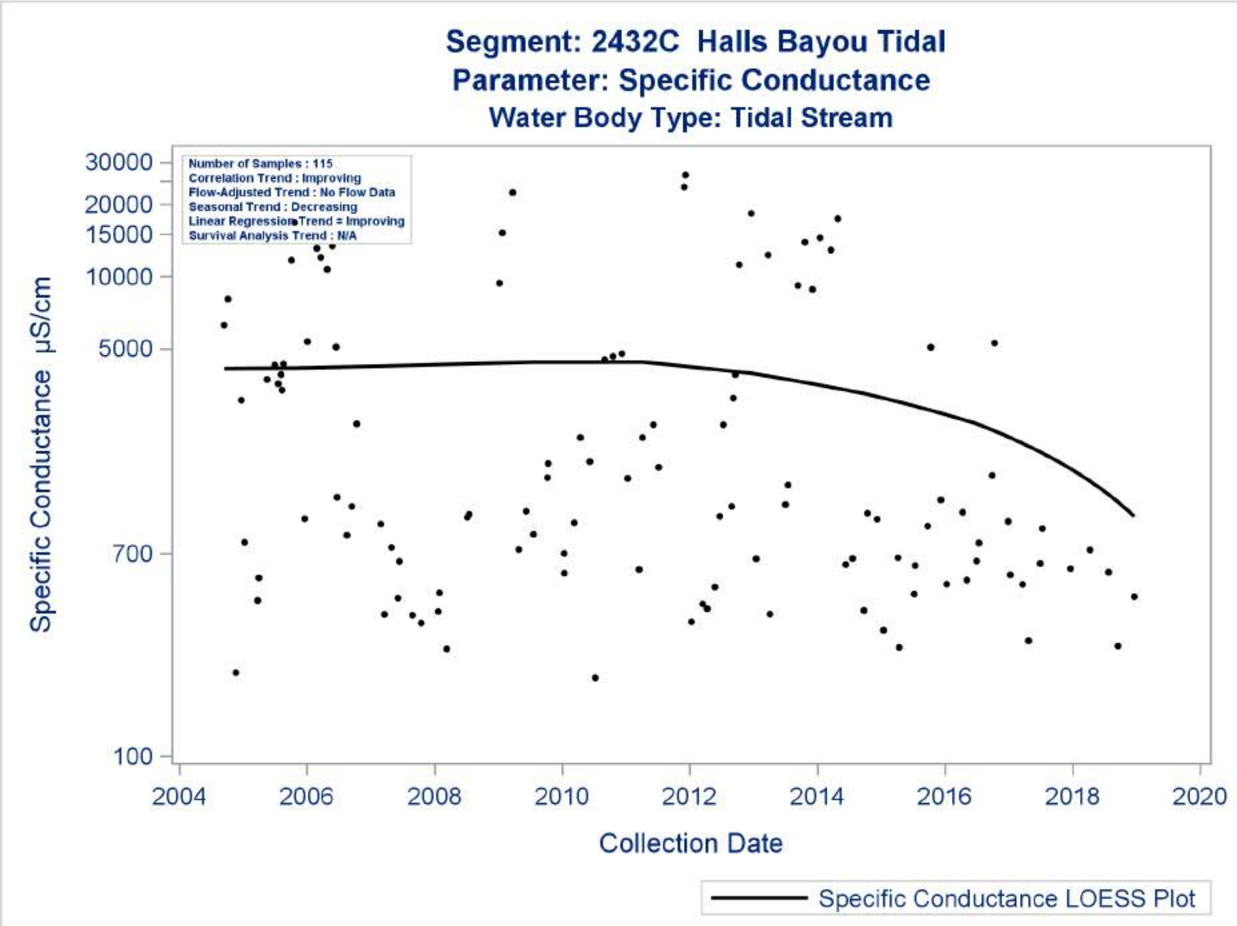
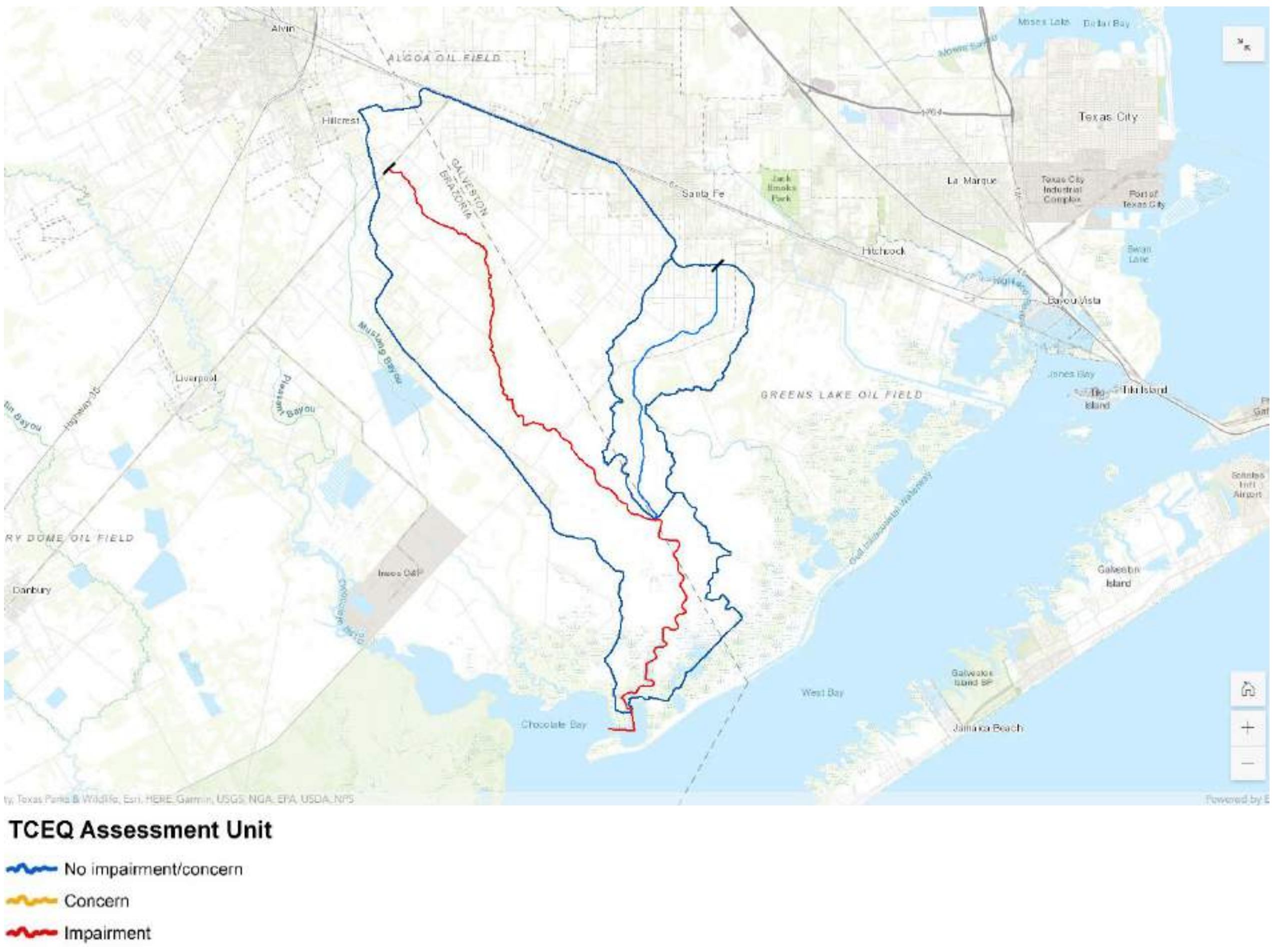


Figure 7 – Specific Conductance grab sample results in Halls Bayou Tidal, 2004 – 2019

PCB and Dioxin Impairments

Halls Bayou Tidal is listed as impaired for PCBs in fish tissue (Map 6). Fish samples collected from Clear Creek indicate the presence of PCBs at a concentration exceeding health assessment guidelines. A fish consumption advisory for the Galveston Bay Estuary (ADV-50) issued by the Texas Department of State Health Services (TDSHS) advises that people should not consume any species of fish from these waters.



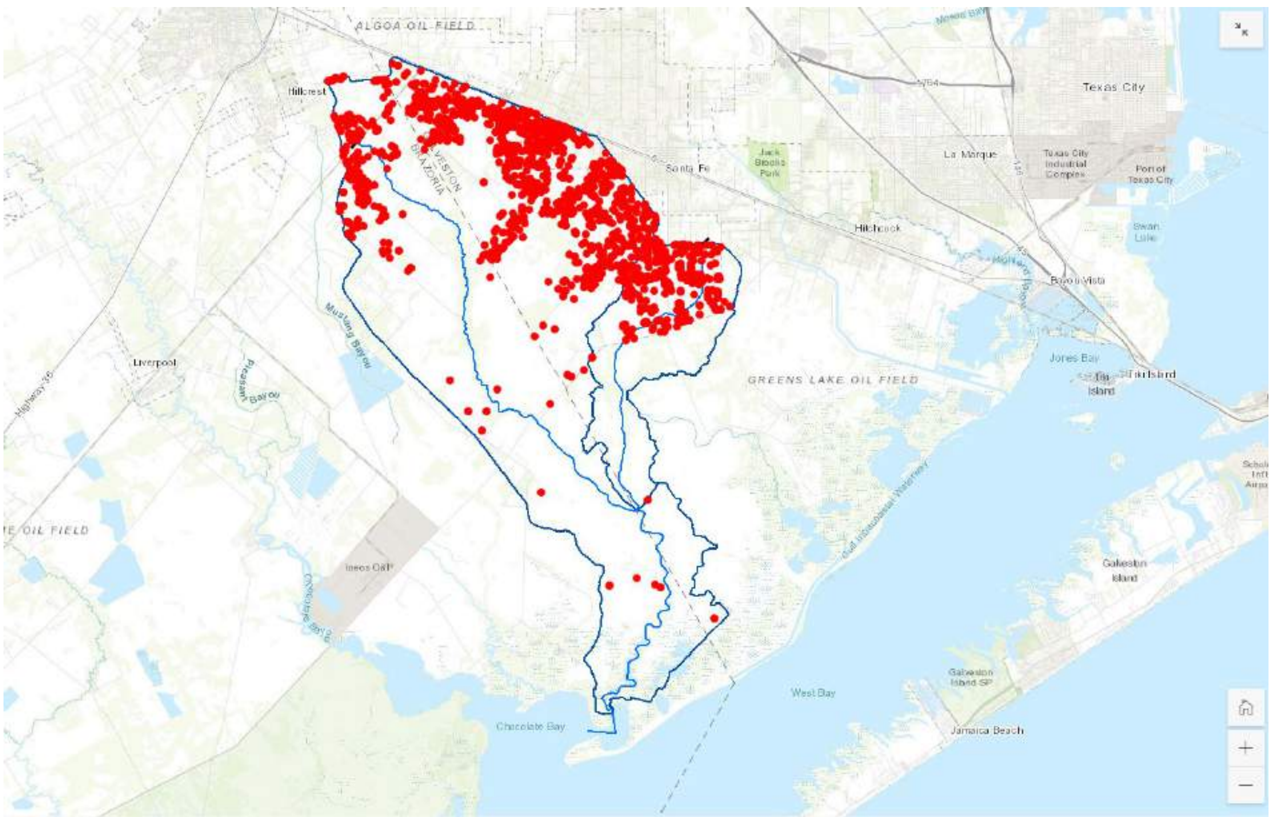
Map 6 - PCBs/Dioxin impairments in Halls Bayou Tidal

POTENTIAL SOURCES OF WATER QUALITY ISSUES

Potential sources of bacteria in Halls Bayou Tidal and Willow Bayou primarily include failing on-site sewage facilities, livestock, and other nonpoint sources.

On-Site Sewage Facilities

With limited development within the watershed, there are no permitted wastewater treatment facilities. Private on-site sewage facilities are the primary mode of sewage treatment and disposal within the area. There are 1,365 permitted on-site sewage facilities in the watershed (Map 7), and many more unpermitted systems. These unpermitted systems are considered to be “grandfathered” because they pre-date the requirement to be permitted (which became effective in 1989). Many of these unpermitted systems are of the conventional type, which may not be the most appropriate for the soil conditions.



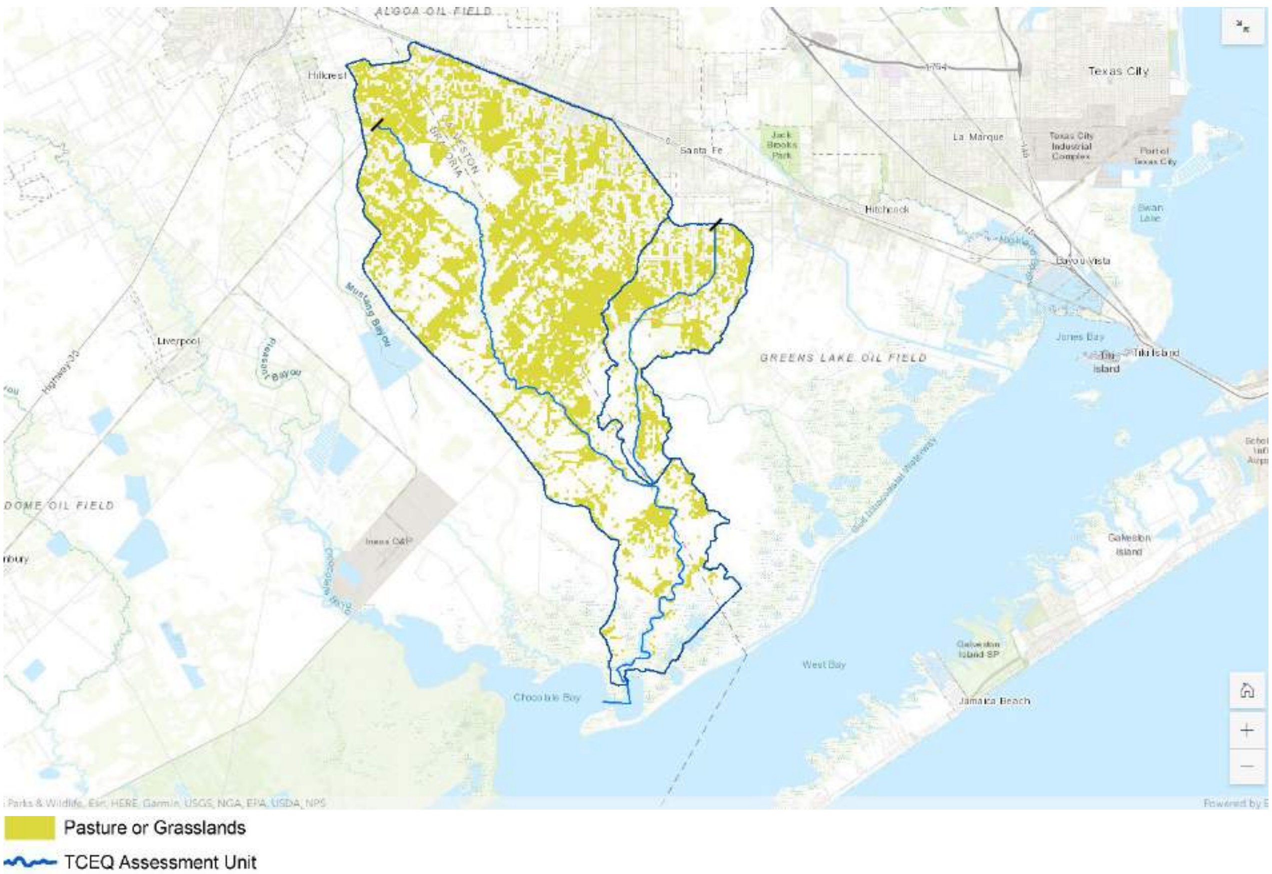
On-Site Sewage Facilities

TCEQ Assessment Unit

Map 7 - Permitted On-Site Sewage Facilities in the Halls Bayou Tidal and Willow Bayou watersheds

Livestock and Other Animal Sources

Much of the watershed land cover consists of cultivated crops, pasture, and grassland areas (Map 8). Agricultural activities and livestock are common in the watershed. These activities can impact water quality through animal wastes and the application of fertilizers. The land use and lack of development in the segment is also conducive for feral hogs. In the more populated areas, household pet waste may contribute to bacteria in the waterways.



Map 8 - Pasture and Grassland areas in the Halls Bayou Tidal and Willow Bayou watersheds

POTENTIAL STAKEHOLDERS

Potential stakeholders include:

- Brazoria County
- Galveston County
- Environmental and Conservancy Groups, such as local Keep Texas Beautiful Affiliates
- TCEQ Region 12 Office
- TCEQ Galveston Bay Estuary Program
- Texas State Soil and Water Conservation Board
- Texas AgriLife Extension Offices
- Citizen Groups, such as the Texas Master Naturalists
- Community Groups
- Homeowner Associations
- Drainage Districts
- Utility Districts

ONGOING PROJECTS

Total Maximum Daily Loads for bacteria are being developed for Halls Bayou Tidal (2432C) and Willow Bayou (2432B). Both water bodies fail to meet the standard for primary contact recreation and are listed as impaired in the 2018 Integrated Report.

RECOMMENDATIONS FOR IMPROVING WATER QUALITY

- Address bacteria and various other concerns through stakeholder involvement and best management practices
- Support programs that oversee the maintenance, repair, and replacement of on-site sewage facilities
- Create and implement Water Quality Management Plans for individual agricultural properties
- Continue collecting water quality data and expand monitoring efforts to support actions associated with the TMDL program
- Pursue new local partners to collect additional data to help better isolate problem areas
- Expand volunteer monitoring with Texas Stream Team in areas without professional monitoring
- Support programs to responsibly eliminate feral hog populations in the watershed
- Consult stakeholders to identify illegal dumping sites and improve signage and/or cameras, if needed

APPENDICES

APPENDIX A-1

ACRONYMS & ABBREVIATIONS

ALU	Aquatic Life Use
AU	Assessment Unit
BIG	Bacteria Implementation Group
CFS	Cubic feet per second
CFU	Colony-forming Unit
CMS	Coordinated Monitoring Schedule
CN	Concern for near-nonattainment
CS	Concern for screening levels
CWA	Clean Water Act
DO	Dissolved oxygen
EIH	Environmental Institute of Houston, University of Houston-Clear Lake
EPA	U.S. Environmental Protection Agency
FS	Fully-supporting designated use
HCFCD	Harris County Flood Control District
H-GAC	Houston-Galveston Area Council
I-Plan	Implementation Plan
IR	*Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d)*
km	kilometer
L	liter
LOESS	Locally-Weighted Least Squares Plot
LOQ	Limit of Quantitation
mg	milligram
mg/L	milligram per liter
MGD	Millions of gallons per day
mi	mile
mL	milliliter
MPN	Most Probably Number
MS4	Municipal Separate Storm Sewer System

NC	No concern
NCR	Non-contact recreation
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source pollution
NS	Nonsupport for designated use
OSSF	On-site sewage facility
PCB	Polychlorinated biphenyl
PCR	Primary contact recreation
QAPP	Quality Assurance Project Plan
RUAA	Recreational use attainment analysis
SAS	Statistical Analysis System
SEP	Supplemental Environmental Project
SJRA	San Jacinto River Authority
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids
TDSHS	Texas Department of State Health Services
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
TRIES	Texas Research Institute for Environmental Studies
TSS	Total suspended solids
TSSWCB	Texas State Soil and Water Conservation Board
TSWQS	Texas Surface Water Quality Standards
UAA	Use attainability analysis
USGS	U.S. Geological Survey
WPP	Watershed Protection Plan
WWTF	Wastewater treatment facility

APPENDIX A-2

GLOSSARY

A

Algae - Plants that lack true roots, stems and leaves. For the physical assessment described in this document, algae consist of nonvascular plants that attach to rocks and debris or float freely in the water. Such plants may be green, blue-green, or olive-green and slimy to the touch. They usually have a coarse filamentous structure.

Ambient - The existing water quality in a particular water body.

Ammonia-Nitrogen (NH_3^-) - Ammonia, naturally occurring in surface and wastewaters, is produced by the breakdown of compounds containing organic nitrogen.

Aquatic Life Use (ALU) – A designation assigned to an individual water body segment based upon the potential to support aquatic life.

Assessment Unit (AU) – The smallest geographic areas of a water body that can support a designated or site-specific use.

Attainable Use - A use that can be reasonably achieved by a water body in accordance with its physical, biological and chemical characteristics whether it is currently meeting that use or not. Guidelines for the determination and review of attainable uses are provided in the standards implementation procedures. The designated use, existing use, or presumed use of a water body may not necessarily be the attainable use.

B

Basin – Large geographic areas generally containing one or more watersheds.

Benthos - Aquatic bottom-dwelling organisms including worms, leeches, snails, flatworms, burrowing mayflies and clams.

Best Management Practices - Schedules of activities, maintenance procedures, and other management practices to prevent or reduce the pollution of water to the maximum extent practicable. Best management practices include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Bloom - The accelerated growth of algae and/or higher aquatic plants in a body of water. Bloom is often related to pollutants that increase the rate of growth.

C

Channelization - Straightening and deepening streams so water will move faster. A method of flood control that disturbs fish and wildlife habitats and can interfere with a water body's ability to assimilate waste.

Chloride (Cl^{-1}) - One of the major inorganic ions in water and wastewater. Concentrations can be increased by industrial processes. High chloride concentrations can affect metallic objects and growing plants.

Chlorophyll *a* - A photosynthetic pigment found in all green plants. The concentration of chlorophyll *a* is used to estimate phytoplankton biomass (all of the phytoplankton in a given area) in surface water.

Classified - Refers to a water body that is listed and described in Appendix A or Appendix C of the Texas Surface Water Quality Standards.

Coastal Basin – A collection of watersheds adjacent to the coastline that water flows through on its way to the ocean.

Conductivity - A measure of the carrying capacity for electrical current, in mhos/cm, of 1 cm^3 of water at 25°C. Dissolved substances in water dissociate into ions with the ability to conduct electrical current. Conductivity is a measure of how salty the water is. Salty water has high conductivity.

Contact Recreation - Recreational activities involving a significant risk of ingestion of water, including wading by children, swimming, water skiing, diving, and surfing. *See also* noncontact recreation.

Conventional Parameters - A list of basic parameters that require laboratory analyses. The parameters frequently include, but are not limited to, solids (TSS, TDS, VSS), nutrients (nitrogen and phosphorus compounds), chlorides, sulfates, hardness, and TOC.

Criteria - Water-quality conditions that are to be met to support and protect desired uses.

D

Designated Use - A use that is assigned to specific water bodies in Appendix A or in Appendix D of the Texas Surface Water Quality Standards. Typical uses that may be designated for specific water bodies include domestic water supply, categories of aquatic-life use, kinds of recreation, and aquifer protection.

Dioxin - A family of polychlorinated chemicals found in waste from the paper bleaching processes and the combustion of chlorinated compounds. It is considered carcinogenic and can disrupt the reproductive and immune systems in humans.

Dissolved Oxygen - The oxygen freely available in water. Dissolved oxygen is vital to fish and other aquatic life and for the prevention of odors. Traditionally, the level of dissolved oxygen has been accepted as the single most important indicator of a water body's ability to support desirable aquatic life.

Dissolved Oxygen (DO) Measurements, 24-hour – The measurement of dissolved oxygen over a 24-hour period using deployed, unattended, automated equipment preset to record and store field measurements over one 24-hour period. These measurements are used to assess Aquatic Life Use.

E

Effluent - Wastewater (treated or untreated) that flows out of a treatment plant or industrial outfall (point source) prior to entering a water body.

Enterococci - A subgroup of fecal streptococcal bacteria (mainly *Streptococcus faecalis* and *Streptococcus faecium*) found in the intestinal tracts and feces of warm-blooded animals. It is used as an indicator of the potential presence of pathogens.

Escherichia coli (E. coli) – *E. coli* is a member of the total coliform group of bacteria found in feces. It indicates fecal contamination and possible presence of enteric pathogens (viral, protozoan, and bacterial pathogens of the gastrointestinal route).

Estuary - Regions of interaction between rivers and near shore ocean waters, where tidal action and river flow create a mixing of fresh and salt water.

F

Fecal Coliform - A subset of the coliform bacteria group that is found in the intestinal tracts and feces of warm-blooded animals. Heat-tolerant bacteria from other sources can sometimes be included. It is used as an indicator of the potential presence of pathogens.

Field Parameters - A list of basic tests generally collected in the field using equipment and meters. The list also includes visual observations.

Fully Supporting – The water body meets Texas Surface Water Quality Standards (TSWQS) or supports its designated uses.

H

Habitat - The area in which an organism lives.

I

Impaired – A designation for an associated use (aquatic life, contact recreation, etc.) where a water quality standard is not attained.

Impoundment - A body of water confined by a dam, dike, floodgate, or other barrier.

Indicator Organism - An organism, species or community that indicates the presence of a certain environmental condition or conditions.

L

Limit of Quantitation (LOQ) – The lowest concentration of a substance that can be accurately measured under specific conditions.

LOESS Plot - A graph that shows the relationship of two variables (measurements or parameter values) made using a technique that calculates the slope of the plotted line at different time periods (locally weighted least-squares regression), producing a line that usually shows inflections (change points) rather than a straight line that best fits all points. LOESS is not really an acronym, and can be thought of as "LOcal regrESSion."

M

Macrobenthic Invertebrate - Aquatic bottom-dwelling fauna. Common types are flat worms, leeches, snails, and various insect species.

Monitoring – The process of sampling and analyzing water quality parameters over time.

Municipal Separate Storm Sewer System (MS4) – A conveyance (or system of conveyances) that is owned by a state, city, town, village, or other public entity that discharges to waters of the United States, is designed to collect or convey stormwater (e.g., storm drains, pipes, ditches), is not a combined sewer, and is not part of a sewage treatment plant or publicly owned treatment works.

N

Nekton - Free-swimming organisms (for example, fish, insects).

Nitrate-Nitrogen (NO_3-N) - A compound containing nitrogen that can exist as a dissolved solid in water. Excessive amounts can have harmful effects on humans and animals (>10 mg/L).

Nitrite-Nitrogen (NO_2-N) - An intermediate oxidation state in the nitrification process (ammonia, nitrite, and nitrate).

Noncontact Recreation - Aquatic recreational pursuits not involving a significant risk of water ingestion and limited body contact incidental to shoreline activity - including fishing, and commercial and recreational boating. *See also* contact recreation.

Nonpoint Source (NPS) Pollution - A pollution source that is not subject to regulation, that is diffuse and does not have a single point of origin, or is not introduced into a receiving stream from a specific outfall. NPS pollution typically results from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification.

Nutrient - Any substance used by living things to promote growth. The term is generally applied to nitrogen and phosphorus in water and wastewater, but is also applied to other essential and trace elements.

O

Outfall - A designated point of effluent discharge.

Oyster Waters - Waters producing edible species of clams, oysters, or mussels.

P

pH - The hydrogen-ion activity of water caused by the breakdown of water molecules and presence of dissolved acids and bases.

Phosphorus - A nutrient that is essential to the growth of organisms. It can be the nutrient that limits the primary productivity of water. In excessive amounts from wastewater, agricultural drainage, and certain industrial waste it also contributes to the eutrophication (the natural aging progression) of lakes and other water bodies.

Pollution - The alteration of the physical, thermal, chemical, or biological quality of, or the contamination of, any water that renders it harmful, detrimental, or injurious to humans, animal life, vegetation, property, or the public health, safety, or welfare. Pollution may impair the usefulness or the public enjoyment of the water for any lawful or reasonable purpose.

Point Source pollution - Any source of pollution that is subject to regulation and is permitted. An example of a point source is a permitted wastewater treatment facility effluent discharge.

Polychlorinated Biphenyls (PCBs) - A class of organic compounds used in dielectric fluids in transformers, capacitors, and coolants. PCBs are highly toxic and are associated with endocrine disruption and neural toxicity in humans.

Public Water Supply Use - A water body designated to provide water to a public water system.

Q

Quality Assurance Project Plan (QAPP) – A written document outlining the procedures a monitoring project will use to ensure the data it collects and analyzes meets project requirements.

R

Recreational Use Attainment Analysis (RUAA) – A Use Attainment Analysis designed to determine if contact recreation is an appropriate use of a water body.

Reservoir - Any natural or artificial holding area used to store, regulate, or control water.

River Basin - The land area drained by a river and its tributaries.

Routine Monitoring – Monitoring that is scheduled in advance without intentionally trying to target a certain environmental condition. Routine monitoring typically consists of field measurements, conventional chemical parameters, bacteria, and flow measurements.

Runoff - The part of precipitation or irrigation water that runs off land into streams and other surface water.

S

Screening Level – Established targets (instream concentrations) for parameters that establish targets that can be directly compared to monitoring data. Screening levels are derived from long-term monitoring data or published levels of concern.

Sediment - Particles and/or clumps of particles of sand, clay, silt, and plant or animal matter carried in water and deposited in reservoirs and slow-moving areas of streams and rivers.

Segment - A water body or portion of a water body that is individually defined and classified in the Texas Surface Water Quality Standards. A segment is intended to have relatively homogeneous chemical, physical, and hydrological characteristics. A segment provides a basic unit for assigning site-specific standards and for applying water quality management programs. Classified segments may include streams, rivers, bays, estuaries, wetlands, lakes, and reservoirs.

Sonde – A multi-parameter water quality monitoring device that calculates and records field parameters.

Standards - The designation of water bodies for desirable uses and the narrative and numerical criteria deemed necessary to protect those uses.

Stormwater - Rainfall runoff, snow-melt runoff, surface runoff, and drainage.

Subwatershed – Any of several drainage areas that flow to a specific location and collectively form a watershed.

Sulfate (SO_4^{-2}) - An ion derived from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Sulfates are widely distributed in nature.

SWQMIS – Surface Water Quality Monitoring Information System. A database that serves as a repository for surface water quality monitoring data for the state of Texas.

T

Texas Surface Water Quality Standards (TSWQS) – Standards that establish explicit goals for the water quality of streams, rivers, lakes, and bays throughout the state. The Standards are developed to maintain the quality of surface waters in Texas so that it supports public health and enjoyment and protects aquatic life, consistent with the sustainable economic development of the state. Water quality standards identify appropriate uses for the state's surface waters, including aquatic life, recreation, and sources of public water supply. The TSWQS are codified in Title 30, Chapter 307 of the Texas Administrative Code.

Tidal - Descriptive of coastal waters subject to the ebb and flow of tides. For purposes of standards applicability, tidal waters are saltwater. Classified tidal waters include all bays and estuaries with a segment number that begins with 24xx, all streams with the word tidal in the segment name, and the Gulf of Mexico.

Total Dissolved Solids - The amount of material (inorganic salts and small amounts of organic material) dissolved in water and commonly expressed as a concentration in terms of milligrams per liter.

Total Maximum Daily Load (TMDL) - The total amount of a substance that a water body can assimilate and still meet the Texas Surface Water Quality Standards.

Total Suspended Solids - The amount of organic and inorganic suspended particles in water.

Tributary - A stream or river that flows into a larger one.

U

Use Attainability Analysis (UAA) – A structured scientific assessment of the factors affecting a water body's attainment of specified uses.

W

Water body – Refers to any mass of water (lake, bay, river, creek, bayou, etc.).

Water Quality – The chemical, physical, and biological characteristics of water.

Watershed - The area of land from which precipitation drains to a single point. Watersheds are sometimes referred to as *drainage basins* or *drainage areas*.

APPENDIX A-3

LIST OF PARAMETERS

Table 1 - Water Quality Parameters by Type

FIELD PARAMETERS	CONVENTIONAL PARAMETERS	ORGANICS	BACTERIA
Dissolved Oxygen Flow pH Salinity Secchi Transparency Temperature	Ammonia-N Chloride Chlorophyll-*a* Nitrate-N Nitrite-N Total Phosphorus Sulfate Total Dissolved Solids Total Kjeldahl Nitrogen Total Suspended Solids	Dioxin PCBs	*Escherichia coli* (*E. coli*) Enterococci

Table 2 - Field Parameters

PARAMETER	POTENTIAL IMPACTS	POTENTIAL CAUSES
Dissolved Oxygen (DO)	The most important component for the survival of aquatic life is oxygen. DO is essentially the amount of oxygen available in water. Low DO will suffocate aquatic species, and a high amount of DO will reduce water odors.	Elevated levels of organic nutrients can cause an overabundance of bacteria and algae, which depletes oxygen from water. Human-caused increases in water temperature will also lower the capacity for water to hold oxygen.
Flow Instantaneous Flow Flow Severity	Flow conditions affect water quality. Aquatic species are adapted to specific in-stream flow patterns. Low flow events, associated with hot summer months, can severely alter a stream habitat. High flow events associated with heavy rain or melting snow can also disrupt an aquatic habitat.	Drought or heavy rain events can disrupt normal flow patterns. Impediments, such as fallen trees, beaver dams, or man-made dams can disrupt or alter in-stream flow.
pH	Aquatic organisms have evolved to live in a specific range of pH. Biological and chemical processes can be altered or affected if the pH drops or rises over certain thresholds. Fish species cannot survive if the pH drops below 4 or rises above 12.	Runoff from mining operations and discharges of industrial wastewater can alter the pH of a water body.
Salinity	Salinity is the measurement of conductive ions in the water. High levels of sodium sulfate and magnesium sulfate produce a laxative effect in drinking water. High levels of total dissolved solids can cause an unpleasant taste in potable water.	Weathering or erosion of rocks, salt mining, and salt water intrusions are sources of increased salinity.
Secchi Transparency	Secchi transparency is used to calculate the depth at which natural light can penetrate the water column. It also used as a measurement of eutrophication, the natural aging progression of a water body.	An abundance of algae and plants or excessive levels of Total Suspended Solids (TSS) will decrease the ability for light to transmit through the water column.
Temperature	The types of aquatic life that can survive in a waterbody are dependent upon the water temperature. Water temperature can affect levels of dissolved oxygen. Water with a high temperature has less capacity to hold oxygen. As the water temperature drops, cold-blooded animals, such as fish, can become more susceptible to pathogenic stress or shock, which can lead to infections or death.	Releases of water from reservoirs can contribute to drops in temperature. Temperatures will increase with the removal of flora from riparian areas or from the release of heated water from industrial activities.

Table 3 – Conventional Parameters

PARAMETER	POTENTIAL IMPACTS	POTENTIAL CAUSES
Ammonia-Nitrogen	Elevated levels of ammonia can injure or kill aquatic life, such as fish and invertebrates. In fish, even low concentrations of ammonia can damage sensitive tissues (such as gills), can deplete natural resistances to bacterial infections, and can hinder reproductive capacities and growth.	Ammonia occurs naturally as a by-product of protein metabolism and decomposition. Ammonia can also enter a water body from runoff of fertilizers, livestock waste, and from discharges of untreated sewage and industrial wastewater.
Chloride (Cl^{-1})	Although small amounts of chlorides are essential to proper cell function in plants and animals, large concentrations of chlorides can damage aquatic life physiology and hinder reproductive fertility and growth.	Chlorides occur naturally from the weathering and erosion of sedimentary rocks. Agricultural runoff, industrial wastewater, petroleum industrial activities, salt water intrusions, and effluent from wastewater treatment facilities are sources of chlorides.
Chlorophyll-*a*	Chlorophyll-*a* is a photosynthetic pigment found in green plants and is an indicator of the presence of algae in the water. It is used to monitor the trophic status of lakes or the primary productivity of ecosystems.	Elevated levels of nutrients could result in high concentrations of algal biomass.
Nitrogen Nitrate-(NO_3-N) Nitrite-(NO_2-N)	An abundance of nutrients can increase plant and algal growth. Bacteria use oxygen in the decomposition of plant matter, which can reduce dissolved oxygen. Nitrites are an intermediate form of Nitrogen that can cause brown blood disease in fish by preventing the transfer of oxygen by hemoglobin. Nitrites can also adversely affect human health, especially children under the age of 3.	Nutrient sources are usually found in runoff from fertilizers and livestock facilities. They are also present in the effluent of wastewater treatment facilities.
Phosphorus Total Phosphate-P	Most phosphorus compounds found in water are phosphates. Orthophosphate is consumed by aquatic plants and organisms and is considered the limiting factor for aquatic plant growth. High or excessive levels of orthophosphate results in higher yield in growth. Excessive plant growth can cause eutrophication, (the natural aging progression of a water body) which will decrease dissolved oxygen levels.	Phosphates occur naturally from the decomposition of organisms. Sources also include the weathering of rock material and runoff from fertilizers.
Sulfate (SO_4^{-2})	In the absence of oxygen and with a pH below 8, bacteria will reduce sulfate ions to sulfide ions. Sulfide ions will	Sulfate is derived from rocks and soils containing gypsum, iron sulfides, and organic compounds.

	cause serious and unpleasant odor problems. Sulfates in sediment can also alter soil composition and hinder or prevent growth of native plants.	Sulfur containing fossil fuels, heavy industrial activities, and some fertilizers are also potential sources for sulfates.
Total Suspended Solids (TSS)	An increase in the amount of total suspended solids (TSS) will decrease the ability for light to penetrate through the water column. This can decrease the productivity of aquatic plants. As excessive amounts of TSS settle and become sediment, benthic habitats can be altered or destroyed.	High erosion events, usually coinciding with the removal of riparian floral species and severe flow events will create excess levels of TSS. Unsound agricultural practices can also contribute to soil erosion into waterways.

Table 4 - Organic Parameters

PARAMETER	POTENTIAL IMPACTS	POTENTIAL CAUSES
Dioxin	Dioxin is a family of polychlorinated chemicals. It is carcinogenic and is detrimental to animal and human health.	Dioxin is present in the waste from the paper bleaching process and from the combustion of chlorinated compounds.
Polychlorinated biphenyls (PCB)	PCBs are acutely toxic, and can disrupt endocrine and neural processes in aquatic life and humans.	PCBs are found in dielectric fluids used in transformers, capacitors, and coolants.

Table 5 - Bacteria Parameters

PARAMETER	POTENTIAL IMPACTS	POTENTIAL CAUSES
Bacteria *Escherichia coli* (*E.coli*) Enterococci	*Escherichia coli* and Enterococci are bacterial indicator species for the presence of fecal matter, pathogenic bacteria, and viruses.	Malfunctioning or failing on-site sewage facilities, untreated domestic sewage, improper disposal of grease, and runoff from agricultural and livestock activities can cause an overabundance of bacteria and other pathogens.

APPENDIX A-4

WATER QUALITY TECHNICAL PRIMER

The Water Quality Technical Primer is provided as an overview of general water quality terminology. In combination with the Glossary, the Technical Primer provides background and defines terminologies and methodologies used to acquire, analyze, and report the data that is presented in the Basin Highlights Report.

THE FEDERAL CLEAN WATER ACT

The Clean Water Act establishes the basic structure for regulating pollutant discharges, pollutant loadings in water, and regulating surface water quality standards. The goal of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (33 U.S.C. §1251(a)).

Amendments to The Clean Water Act in 1977:

- Established the basic structure for regulating pollutant discharges into the waters of the United States;
- Gave the US Environmental Protection Agency (EPA) the authority to implement pollution control programs such as setting wastewater standards for industry;
- Maintained existing requirements to set water quality standards for all contaminants in surface waters;
- Made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions;
- Funded the construction of sewage treatment plants under the construction grants program; and
- Recognized the need for planning to address the critical problems posed by nonpoint source pollution.

Pollution

The Texas Administrative Code defines pollution as "the alteration of the physical, thermal, chemical, or biological quantity of, or the contamination of, any water in the state that renders the water harmful, detrimental, or injurious to humans, animal life, vegetation, or property or to public health, safety, or welfare, or impairs the usefulness or the public enjoyment of the water for any lawful or reasonable purpose."

There are two categories of pollution: Point Source and Nonpoint Source Pollution.

Point Source pollution is any source of pollution that is subject to regulation and is permitted. An example of a point source is a permitted wastewater treatment facility effluent discharge.

Nonpoint Source (NPS) pollution is any source that is not subject to regulation, that is diffuse and does not have a single point of origin, or is not introduced into a receiving stream from a specific outfall. NPS pollution typically results from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification.

TEXAS SURFACE WATER QUALITY STANDARDS

The **Texas Surface Water Quality Standards** (TSWQS) establish numerical and narrative goals to maintain the quality of streams, rivers, lakes, and bays throughout the state. Appendix A and Appendix D of the TSWQS establish the geographic boundaries and the appropriate standards for each body of water. The standards are developed to maintain the quality of surface waters. Standards ensure public health and enjoyment, protect aquatic life, and remain consistent with the sustainable economic development of the state. The Texas Commission on Environmental Quality (TCEQ) develops the TSWQS under the authorization of the U.S. Clean Water Act and Texas Water Code. The TSWQS are codified in Title 30, Chapter 307 of the Texas Administrative Code. The standards are approved by the EPA.

The TSWQS are designed to:

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

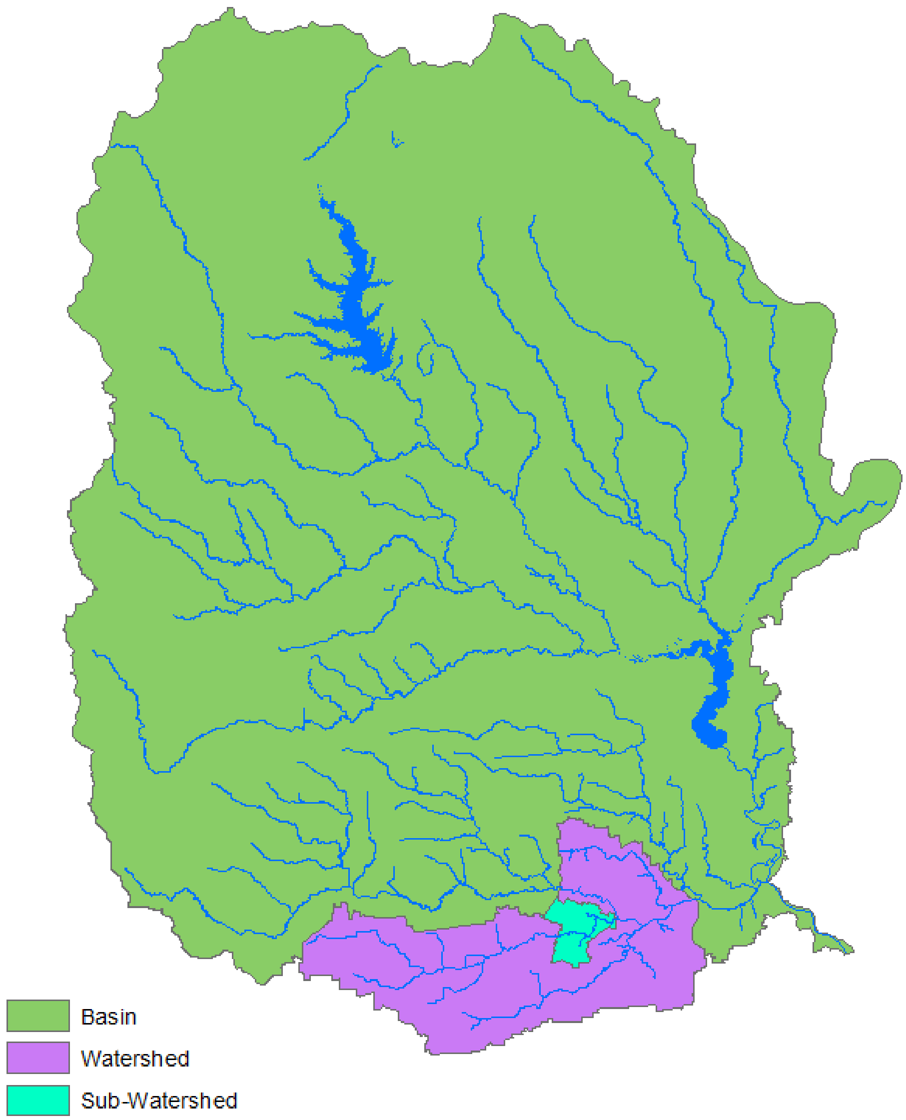
The criteria adopted and incorporated into the **standards** are the allowable concentrations of pollutants in State, Territory, and authorized Tribal waters and are developed for the protection of aquatic life and human health. Impairments occur when water quality conditions do not meet the assigned uses or criteria as defined in the TSWQS.

DRAINAGE AREAS – BASINS, WATERSHEDS, AND SUB-WATERSHEDS

A **watershed** is a defined geographic area that waterways flow through on the way to a common body of water. **Basins** are larger geographic areas generally containing one or more watersheds. A **river basin** is a collection of watersheds drained by a major river and tributaries. A **coastal basin** is a collection of watersheds adjacent to the coastline that water flows through on its way to the ocean. Typically, coastal basins are between and bound by two major river basins and a bay or other outlet to the ocean.

Watersheds can be broken down into even smaller drainage areas, which are referred to as **sub-watersheds**. For example, a sub-watershed could be defined as the drainage area of a small creek, stream, or portion of a stream that is part of the drainage area for a tributary, which is part of a major river drainage basin.

Figure 1 – General Map showing basin, watershed, and subwatershed levels

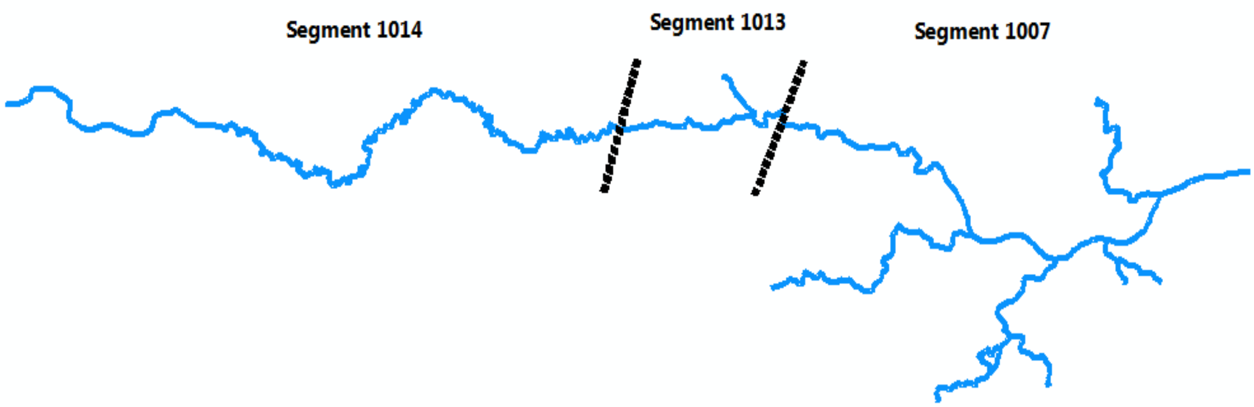


WATER BODIES, SEGMENTS, AND ASSESSMENT UNITS

The term **water body** is used to refer to any mass of water. A water body can be contained in a lake or a bay, or flow, such as a river, creek, or bayou. The TCEQ divides water bodies in the state into distinct **segments** that generally represent natural watersheds and are intended to have similar chemical, physical, and hydrological characteristics. Each segment is assigned a four-digit code. The first two digits identify the river basin, and the last two digits identify the segment. Segments can be either classified or unclassified.

Classified Segments

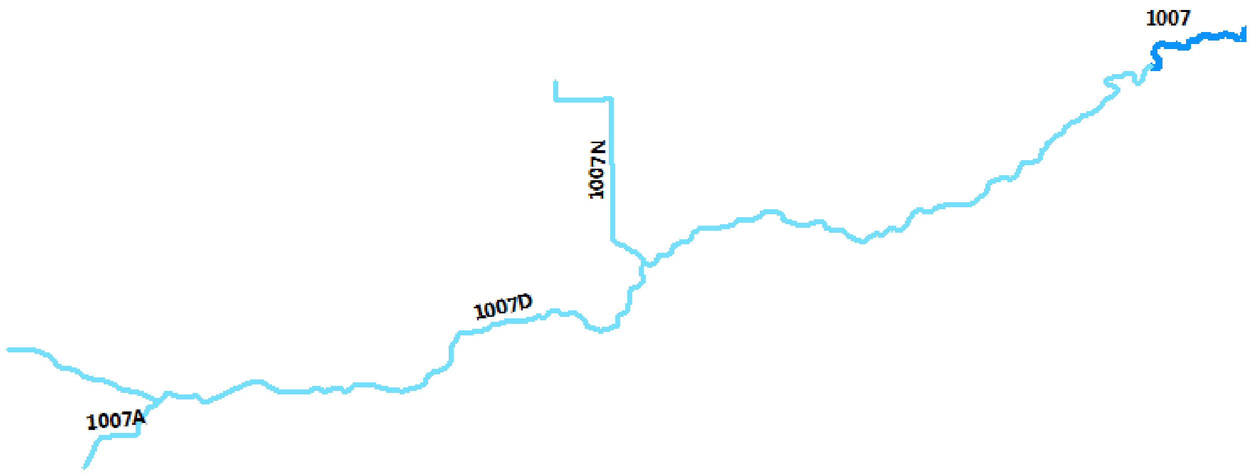
A **classified segment** is a water body (or portion of a water body) that is individually defined in the TSWQS. Typically, classified segments are major waterways. Site specific numerical criteria are developed to evaluate the uses and overall water quality of a classified segment. The parameters evaluated include bacteria, nutrients, and dissolved oxygen.



Site-specific numerical criteria are developed to evaluate the uses and water quality of classified segments. These uses include aquatic life use and recreational use (discussed later in the primer).

Unclassified Segments

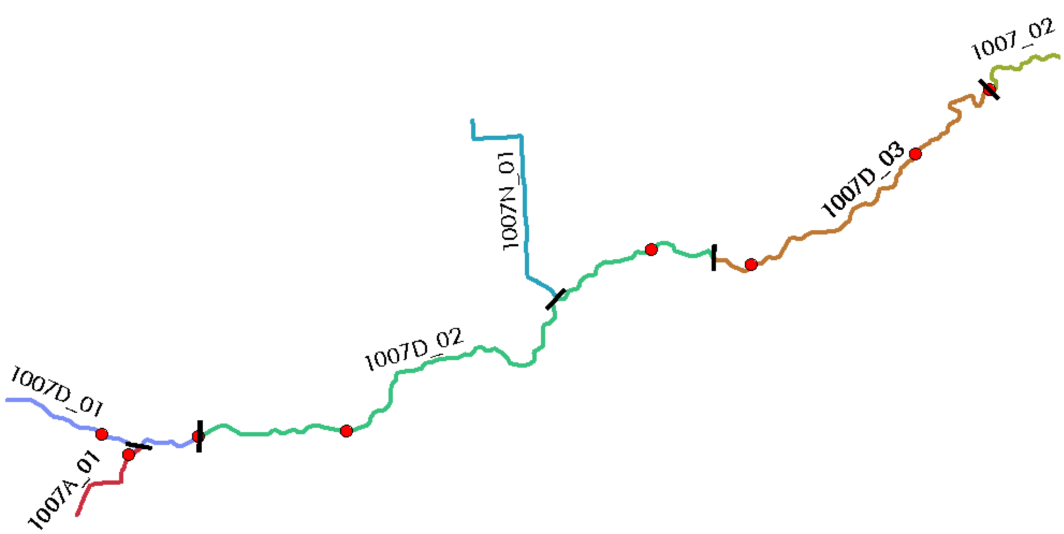
Unclassified segments are often tributaries of classified segments. These segments are usually assessed based on the criteria of the classified segment into which they flow. However, some unclassified segments have been assigned specific water quality standards in the TSWQS. Unclassified segments are assigned the same four-digit code as the classified segment and a letter that is specific to that waterway.



Assessment Units (AUs)

For assessment purposes, each segment is subdivided into hydrologically-distinct units, or **assessment units** (AUs). AUs are the smallest geographic areas of a water body that can support a designated or site-specific use. A segment may have one or multiple AUs, depending on water quality conditions or flow in different sections of the water body. Each AU has the same four or five-digit code as the segment followed by an AU identifier (e.g., _01, _02, etc.). If there are multiple AUs, the assessment units will generally be in sequential order (e.g., 1007D_01, 1007D_02, etc.). Each AU is evaluated separately as part of the assessment.

For example, Sims Bayou Above Tidal is divided into three AUs. The red dots represent monitoring stations. Monitoring stations have been placed on the downstream and upstream ends of each AU in 1007D. The smaller tributaries, 1007A and 1007N, have one monitoring station close to the confluence with the parent stream 1007D.



WATER QUALITY AND DESIGNATED USES

As defined in the TSWQS, a water body can be assigned specific uses including aquatic life, public water supply, and contact recreation use. Designated uses typically have corresponding numeric criteria listed in the TSWQS. General criteria apply across the entire state, but if sufficient information is available for a specific water body, the site-specific standards may be developed .

Aquatic Life Use

Aquatic life use (ALU) is determined by the amount of dissolved oxygen and the abundance and diversity of species. Aquatic life use consists of five categories: minimal, limited, intermediate, high, and exceptional. In Texas, water bodies not specifically listed in Appendix A or D of the TSWQS are presumed to have a high aquatic life use and corresponding dissolved oxygen criteria. This use is assessed using 24-hour dissolved oxygen data along with **nekton** and **macrobenthic invertebrate** community evaluations.

Public Water Supply Use

Public water supply use includes an evaluation of chloride, sulfates, and total dissolved solids in the water body. Criteria for these parameters are set so that public water supplies are capable of treating and delivering water of acceptable quality.

Recreational Use

Recreational use refers to how safely a water body can support activities that involve the possibility of ingesting or coming into contact with water. If activities are likely to result in ingestion of water (swimming, diving, tubing, surfing, wading by children), bacteria concentrations need to be lower. The TSWQS protects human health by setting numeric criteria in a water body relative to the types of recreational activity occurring on that water body. Fecal indicator bacteria levels are measured to determine risk. Criteria area expressed as the number of bacteria per 100 milliliters (mL) of water [in terms of colony-forming units (CFU), most probable number (MPN), or other applicable reporting measures]. The presence of fecal indicator bacteria in waters suggests that human and animal wastes may be reaching the assessed waters. In freshwater, the indicator organism is *Escherichia coli* (*E. coli*). Enterococci bacteria are the indicator for tidal water bodies.

There are four categories of recreational use, which are based on the type and frequency of recreation. Primary contact recreation refers to activities such as swimming, diving, and waterskiing. These activities are presumed to have a high likelihood of ingesting water. Secondary Contact Recreation refers to activities that have limited body contact, such as wading, fishing, and canoeing. If such activities are occurring frequently, the designation is Secondary Contact Recreation 1. If the activities are less frequent due to physical characteristics such as steep banks or limited public access, the designation is Secondary

Contact Recreation 2. A waterbody could be classified as supporting Noncontact Recreation if conditions are unsafe to engage in any activities in the water.

Primary contact recreation is the presumed recreational use in Texas water bodies unless there is evidence to show that the water body is not used for primary contact recreation. A Recreational Use Attainability Analysis (RUAA) is necessary to change the presumed use of a water body.

Table 1 – Recreational Use Categories for Freshwater

Category	Description	*E. coli* Geometric Mean Criterion (MPN/100 mL)	*E. coli* Single Grab Criterion (MPN/100 mL)
Primary Contact Recreation 1 (PCR1)	Activities that pose a significant risk of ingestion of water (e.g., swimming, wading by children, water skiing, diving, tubing, surfing, and the following whitewater activities: kayaking, canoeing, and rafting). Classified segments are designated for primary contact recreation 1 unless sufficient site-specific information demonstrates that elevated concentrations of FIB frequently occur due to sources of pollution that cannot be reasonably controlled by existing regulations; wildlife sources of bacteria are unavoidably high; there is limited aquatic recreational potential; or primary or secondary contact recreation is considered unsafe for other reasons such as ship and barge traffic.	126	399
Secondary Contact Recreation 1 (SCR1)	Activities that commonly occur but have limited body contact incidental to shoreline activity (e.g., wading by adults, fishing, canoeing, kayaking, rafting, and motor boating). These activities are presumed to pose a less significant risk of water ingestion than primary contact recreation.	630	NA
Secondary Contact Recreation 2 (SCR2)	Activities with limited body contact incidental to shoreline activity (e.g., fishing, canoeing, kayaking, rafting and motor boating) that are presumed to pose a less significant risk of water ingestion than secondary contact recreation 1. These activities occur less frequently than secondary contact recreation 1 due to physical characteristics of the water body or limited public access.	1,030	NA
Noncontact Recreation (NCR)	Activities that do not involve a significant risk of water ingestion, such as those with limited body contact incidental to shoreline activity, including birding, hiking, and biking. Noncontact recreation use may also be assigned where primary and secondary contact recreation activities should not occur because of unsafe conditions, such as ship and barge traffic.	2,060	NA

Table 2 – Recreational Use Categories for Saltwater

Category	Description	Enterococci Geometric Mean Criterion (MPN/100 mL)	Enterococcus Single Grab Criterion (MPN/100 mL)
Primary Contact Recreation 1 (PCR1)	Activities that pose a significant risk of ingestion of water (e.g., swimming, wading by children, water skiing, diving, tubing, surfing, and the following whitewater activities: kayaking, canoeing, and rafting). Classified segments are designated for primary contact recreation 1 unless sufficient site-specific information demonstrates that elevated concentrations of FIB frequently occur due to sources of pollution that cannot be reasonably controlled by existing regulations; wildlife sources of bacteria are unavoidably high; there is limited aquatic recreational potential; or primary or secondary contact recreation is considered unsafe for other reasons such as ship and barge traffic.	35	104
Secondary Contact Recreation 1 (SCR1)	A secondary contact recreation 1 use for tidal streams and rivers can be established on a site-specific basis if justified by a use-attainability analysis and the water body is not a coastal recreation water as defined by the Beaches Environmental Assessment and Coastal Health Act of 2000 (Beach Act).	175	NA
Noncontact Recreation (NCR)	A noncontact recreation use for tidal streams and rivers can be established on a site-specific basis if justified by the use-attainability analysis and the water body is not a coastal recreation water as defined by the Beach Act.	350	NA

WATER QUALITY MONITORING

Surface Water Quality Monitoring (SWQM) Program

TCEQ's Surface Water Quality Monitoring Program evaluates the physical, chemical, and biological characteristics to ensure that it is suitable for general or designated uses. Water quality is monitored and evaluated in relation to human health concerns, ecological conditions, and designated uses. Data collected under the SWQM program is utilized by the TCEQ to provide a basis for effective policies that promote the protection, restoration, and wise use of the state's surface water.

Surface water samples are collected for assessment purposes following the methodologies outlined in TCEQ's *Surface Water Quality Monitoring Procedures Volume 1: Physical and Chemical Monitoring*

Methods (TCEQ Publication RG-415) (colloquially referred to as “SWQM Procedures”). The guidelines outlined in the SWQM Procedures manual document the methods and the quality assurance procedures that must be used to demonstrate that data collected by monitoring personnel across the state are of a known and adequate quality. All data collected by H-GAC and its partners are collected following SWQM procedures.

Water quality data, including data collected under SWQM and the Clean Rivers Program, are stored in the **Surface Water Quality Monitoring Information System (SWQMIS)**. This database is used to enter, manage, track, and report on water quality-related data.

Coordinated Monitoring Schedule (CMS)

The Coordinated Monitoring Schedule (CMS) is the combined schedule for all surface water quality monitoring in Texas. Monitoring entities within a basin or region meet annually to establish and coordinate monitoring schedules as a way to ensure appropriate coverage, reduce duplication of effort, and better utilize available resources.

The CMS lists:

- monitoring stations
- collecting entities
- submitting entities
- monitoring type
- parameters
- monitoring frequency

The Coordinated Monitoring Schedule is available online at cms.lcra.org.

Quality Assurance Project Plan (QAPP)

H-GAC’s Clean Rivers Program **Quality Assurance Project Plan (QAPP)** describes H-GAC’s quality assurance policies, management structure, and procedures used to implement the quality assurance requirements for the Clean Rivers Program. These policies and procedures are necessary to verify and validate data collected for the Clean Rivers Program. The QAPP is reviewed and approved by TCEQ to help ensure that all data generated are of known and documented quality, deemed acceptable for their intended use and that the data have been collected and managed in such a way as to guarantee its reliability. Only quality-assured data may be used for water quality assessments or other regulatory purposes. H-GAC’s current and previous QAPP documents are available on H-GAC’s website at h-gac.com.

Monitoring Types

Monitoring activities may be divided into the following categories:

- Routine Monitoring
- Special-Study Monitoring
- Permit-Support Monitoring
- Systematic Monitoring

The type of monitoring conducted by the Clean Rivers Program is usually **routine**, meaning it is monitoring that is scheduled in advance without intentionally trying to target any certain environmental condition, with samples being collected regardless of the conditions encountered. Routine monitoring, at a minimum, includes field measurements [DO, pH, specific conductance, temperature], conventional chemical parameters (nutrients, chloride, sulfate), bacterial measurements (*E. coli* or enterococci), and flow measurements (if applicable for that water body). Please see the **List of Parameters** Appendix for a detailed description of each parameter.

Another monitoring type conducted by the Clean Rivers Program is biased monitoring (monitoring targeted to a season, time, or condition) measurements, such as **24-hour DO**. In this procedure a data **sonde** (a water quality monitoring device that calculates and records field parameters) is deployed to measure DO every 15 minutes for 24 hours. After the deployment period, the data is analyzed, and the 24-hour average and absolute minimum are calculated. The DO average and absolute minimum are used to assign an ALU category to a water body. For example, exceptional aquatic life use has a 24-hour average of 6.0 mg/L and an absolute minimum of 4.0 mg/L.

ASSESSMENT OF WATER QUALITY DATA

The provisions of sections 305(b) and 303(d) of the Clean Waters Act require the TCEQ to provide the *Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d)* (Integrated Report) to the EPA every two years. The report contains a list of water bodies evaluated, water bodies assessed by basin, impaired water bodies (303(d) List), water bodies of concern, water bodies either newly listed or removed from the 303(d) List, and other supporting information.

For the assessment, TCEQ evaluates data collected during a seven-year period. The timeframe is extended to 10 years (if needed) to attain the minimum number of data points needed for the assessment.

Each assessed water body is identified as:

- Fully Supporting: at least 10 data points (20 for bacteria) are available for an assessment, and the water body meets TSWQS or supports designated uses
- Of Concern: There are two levels of concern, CN and CS. CN means there is concern for near nonattainment of the TSWQS based on numeric criteria. A concern status of CN indicates that standards are not being met, but there is insufficient data to fully assess the water body. CS

means that there is a concern for water quality based on **screening levels**. Screening levels are used when there is not a defied standard (as with nutrients) and are derived from statistical distributions of statewide water quality monitoring data, with the 85th percentile for each applicable parameter is used as the screening level criteria.

- Impaired – Data indicates that the water body does not meet standards. Impaired waterbodies are placed on the 303(d) List.

When a water body is determined to be impaired, several things must happen:

- The water body must be listed on the 303(d) List;
- An evaluation must be undertaken to determine what is preventing the water body from supporting its designated use(s) or if the use(s) are appropriate;
- Steps must be taken to either remedy the problem, collect additional data, or evaluate which uses are appropriate for the water body. These steps may include additional monitoring, development of a Total Maximum Daily Load (TMDL) or Watershed Protection Plan (WPP), or a review of the water quality standards.

After assessment, water bodies are placed into one of five categories (with subcategories). These categories indicate the water quality status of the water body.

Table 3 – Categories on the 303(d) List

Category	Description
1	Attaining all water quality standards and no use is threatened.
2	Attaining some water quality standards and no use is threatened; and insufficient data and information are available to determine if the remaining uses are attained or threatened.
3	Insufficient data and information are available to determine if any water quality standard is attained.
4	Water quality standard is not supported or is threatened for one or more designated uses but does not require the development of a TMDL.
4a	TMDL has been completed and approved by EPA.
4b	Other pollution control requirements are reasonably expected to result in the attainment of the water quality standard in the near future.
4c	Nonsupport of the water quality standard is not caused by a pollutant.
5	The water body does not meet applicable water quality standards or is threatened for one or more designated uses by one or more pollutants.
5a	A TMDL is underway, scheduled, or will be scheduled.
5b	A review of the water quality standards for the water body will be conducted before a TMDL is scheduled.
5c	Additional data and information will be collected before a TMDL is scheduled.

If a previously assessed AU has insufficient data available during the assessment period for the most recent Integrated Report, this results in a carry-forward of the impairment listing from the previous report.

MANAGEMENT MEASURES FOR IMPAIRED WATER BODIES

If sufficient data is available to determine that a waterbody is impaired and does not meet standards, a management measure can be utilized to address the impairment.

- A **Total Maximum Daily Load (TMDL)** is a method used to determine the amount (load) of a pollutant an impaired waterbody can receive daily and still meet water quality standards and designated uses. After a load is calculated for the pollutant sources, an implementation plan (I-Plan) is drafted by the waterbody's stakeholders outlining management measures to be used to return the target pollutant to the calculated load. An I-Plan's management measures are usually voluntary actions but can, if recommended by stakeholders, include regulatory actions.
- A **Watershed Protection Plan (WPP)** is a community and stakeholder driven framework that uses a holistic/watershed approach to address potential sources of impaired waterways. The plan is developed with community involvement, and the measures to reduce pollutants are voluntary.
- A **Use Attainability Analysis (UAA)** determines if the natural characteristics of a water body cannot attain the currently designated uses and/or criteria. Natural characteristics include temperature, pH, DO, diversity of aquatic organisms, amount of streamflow, and physical conditions such as depth. If there is a consensus among stakeholders and resource agencies that a presumed or designated use may not be appropriate for a water body, a UAA may be conducted to determine the most appropriate use(s).
- A **Recreational Use Attainment Analysis (RUAA)** is used to determines if contact recreation use occurs in a waterbody. A waterway may have physical characteristics or limited public access that would not warrant a contact recreation use designation.

APPENDIX A-5

WATERSHED CHARACTERIZATION STATISTICAL METHODOLOGY

The identification of long- and short-term trends is important to many stakeholders, and these trends are important components of the Houston-Galveston Area Council's (H-GAC's) work, particularly in relation to the evaluation and revision of regional monitoring efforts and priorities. H-GAC staff used several methods of analyses to characterize surface water quality in the H-GAC region. Trend analysis can identify cases where the value of a water quality parameter is changing over time. Statistical tests are performed to distinguish statistically significant trends from random and seasonal variation. While it might seem reasonable to use *all* the data available for these analyses, as the amount of data increases the likelihood of finding a statistically significant but unimportant trend also increases. To minimize this, H-GAC performed trend analysis on the most recent 15 years (June 2004–May 2019) of Texas Commission on Environmental Quality (TCEQ)-validated data to highlight recent trends in water quality in the region. Data from the most recent 7 years (2012 – 2019) were used to compare assessment results and to calculate geometric means.

All data management and statistical analysis were performed using Statistical Analysis System (SAS) version 9.3. Complete details of data selection, preparation, and analysis can be found in the SAS code, which is available upon request.

Data Selection and Processing

For analyses in this report, H-GAC staff selected water quality data collected between June 1, 2004, and May 31, 2019 from data downloaded from the Surface Water Quality Monitoring Information System (SWQMIS) on October 7, 2019. SWQMIS is a database that serves as the repository for surface water quality data for the state of Texas. All data used for these analyses were collected under a TCEQ-approved Quality Assurance Project Plan (QAPP). Qualified data (data added to SWQMIS with qualifier codes that identify quality, sampling, or other problems that may render the data unsuitable) were excluded from the download. All data for all stations in the H-GAC Clean Rivers Program region (in general, basins 9, 10, 11, 13, and 24) were combined.

Variables in each data-set were transformed as appropriate, and new variables were created to facilitate analysis and graphical display of results. In some cases, data from two or more STORET (method) codes were combined because the results obtained from each method can be considered equivalent. Any data collected at a depth greater than 0.3 meters, or not collected under a routine ambient monitoring program, were deleted.

Censored data (data reported as < [parameter limit of quantitation (LOQ)] were transformed to a value of one-half the parameter LOQ associated with the data, with some important exceptions. Because nutrient quantitation limits have been lowered over time, the presence of data censored at many different LOQs in the same dataset poses several problems. If the data for a given parameter are censored at values well above a later, lower LOQ value, trend analysis could suggest a trend where no real water quality trend is present. There is no ideal solution to this problem. Editing the censored data alone would limit, but not eliminate, false trends. In cases where some of the data reflected use of a lower LOQ than the current H-GAC Clean Rivers Program LOQ, values were transformed to one-half of the H-GAC Clean Rivers Program to minimize the identification of trends caused by changing analytical methods. H-GAC does not believe the impact from this transformation is significant. The impact of this analysis would be most pronounced for parameter trends typically found at concentrations at or near the quantitation limit in that specific water body.

Parameters selected for analysis are listed in Table 1.

Table 1 - Parameter Codes and Parameters

Parameter Code	Parameter	Units
00061	Instantaneous Flow	cfs
00094	Specific Conductance	µmhos/cm @ 25ºC
00010	Temperature	ºC
00300	Dissolved Oxygen	mg/L
00078	Secchi Transparency	Meters
00400	pH	S.U.
31699	*E. coli*	MPN/100mL
31701	Enterococci	MPN/100mL
32211	Chlorophyll-*a*	µg/L
00665	Total Phosphorus	mg/L as P
00610	Ammonia-Nitrogen	mg/L as N
00630 00620	Nitrate+Nitrite* Nitrate	mg/L as N
00625	Total Kjeldahl Nitrogen	mg/L as N
00530	Total Suspended Solids	mg/L
00940	Chloride	mg/L as Cl
00945	Sulfate	mg/L as SO_4

*Nitrate+Nitrite was selected when available, but some labs have reported nitrate rather than nitrate+nitrite. These two parameters were considered equivalent for the purpose of analysis.

Data Selection for Trend Analysis

H-GAC staff performed segment-level trend analysis on a 15-year data series (if available) from all data in the segment. Trends were also evaluated at the assessment unit (AU) level, and graphs showing results from individual stations within each AU were produced for review.

Trend analysis methodology

The first stage of trend analysis looked for temporal patterns for both segments and AUs. To identify these patterns, nonparametric correlation analysis (Kendall's tau-*b*) of the parameter value with the sample collection date was used to identify correlations that were significant at $p < 0.05$. These potential trends were then evaluated with up to four other methods. Simple linear regression of the natural log of the parameter value on the time variable was performed for all data in the subset selected by H-GAC for trend analysis. Flow-adjusted trends were obtained through correlation of residuals from LOESS (locally-weighted least squares) regression in cases where instantaneous flow data were available. If there were no temporal gaps in the time-series (missing years, consistently missing seasons), seasonal Kendall/Sen Slope estimation/Theil regression was run. If more than 15 percent of the data were censored at the analytical limit of quantitation, survival analysis (Tobit analysis in SAS PROC LIFEREG) was performed.

Plots of selected statistically-significant trends were produced for segments and AUs in each of the watersheds selected for this report. Each graph includes an inset showing the results of multiple trend analyses. If the trend is described as Increasing or Decreasing the calculated p-value is below the threshold of 0.05 selected by H-GAC. Trends identified as Stable have a calculated p-value greater than 0.05. When evaluating the results of several trend analyses of a given parameter, H-GAC placed the most weight on the Kendall correlation because nonparametric methods are insensitive to outliers in the time series. However, if Kendall correlation differed from the results of seasonal trend analysis or flow-weighted analysis, the data were further evaluated. If no flow data were available, the flow-adjusted trend appears as Not Calculated (indicating no flow data is available) or Insufficient Data (indicating only one flow value exists and a correlation could not be calculated). If the seasonal Kendall/Sen Slope trend was not calculated due to gaps (missing seasons) in the time series, the seasonal Kendall trend appears as Not Calculated. Survival analysis was only applied in those cases where the amount of censored data could bias the results of the other methods. H-GAC set the threshold at 15 percent or more censored data. If fewer than 15 percent of the data were censored, survival analysis was not performed, and the trend appears as Not Applicable on graphs.

Trend analysis for the Regional Water Quality Summary

In 2015, H-GAC staff compiled a subset of stations in classified segments believed to be most representative of segment water quality by selecting one to three stations that were statistically *representative* of a given parameter in a given segment. Means and standard deviations of parameter values are calculated for each station, and those stations with means and standard deviations closest to the *overall* mean and standard deviation for the segment and parameter combination were selected. Preference was given to stations where stream flow was measured, and final selections were reviewed for reasonableness. In most cases, the station or stations at the most downstream location of the segment was the most statistically representative. Selection relied on SAS procedures PROC MEANS and PROC RANK. The same subset of stations has been used since 2015 to allow consistent comparisons across regional water quality summaries created for different years.

A conservative trend analysis was performed using seven years of recent data (June 1, 2012 – May 31, 2019) at the selected representative monitoring stations in the classified portion of each watershed to detect trends at the watershed level for the H-GAC Regional Water Quality Summary. Trends were identified by nonparametric correlation analysis and simple linear regression. Because nonparametric methods are less sensitive to extreme values in the data than parametric techniques like linear regression, trends that were suggested by linear regression analysis alone were not included in the chart.

Trends (for the "Frog Chart" analysis) were considered statistically significant if the p-value was below 0.05, which is the standard significance level used in most applications.

A Note on Statistical Significance
H-GAC feels that selecting all results with p-values ≤0.10 produces too many real, but unimportant, trends. In part, this is due to the large amount of data collected for our region – the more data one analyzes, the more likely it is that one will find a result – and identify a "trend" – that is statistically different from randomness ("no trend"). For example. 0.0545 rounds to 0.55, which in "arithmetic rounding' becomes 0.06 when expressed as one significant figure.

Moving Geometric Mean Plots

In addition to trend analysis, H-GAC created plots of seven-year geometric means for indicator bacteria for each segment. These are a type of moving- or rolling-average plot, and they are constructed by calculating the geometric mean of all data collected up to seven years before a given sample was collected and plotting it (on the y-axis) against the collection date (on the x axis) of the last sample in the series. A smoothed line (penalized B-spline) is fitted to the time series. One can assess the change in bacterial density over time from this sort of plot more easily than from a simple plot of density versus time. These plots are more meaningful for segments with historical bacteria data than for segments recently added to monitoring schedules (typically unclassified segments).

Watershed Characterizations

H-GAC used SAS to produce tables showing impairments and concerns for each AU, monitoring stations in each AU and segment, and a variety of other summary data to aid in the characterization of water quality issues in each watershed. In most cases, the source of the tabulated information was TCEQ (Integrated Reports and assessment results, the Coordinated Monitoring Schedule, station inventory reports, AU and segment GIS shapefiles).