BACTERIA IMPLEMENTATION GROUP'S TOP FIVE MOST AND TOP FIVE LEAST IMPAIRED WATER BODIES

Final Report

May 31, 2017

H-GAC Water Resources

Galveston Bay Estuary Program

TCEQ

EPA United States Environmental Protection Agency

Project funded through grants from the U.S Environmental Protection Agency through the Texas Commission on Environmental Quality's Galveston Bay Estuary Program.

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Prepared by the Houston-Galveston Area Council in cooperation with the Texas Commission on Environmental Quality's Galveston Bay Estuary Program and U.S. Environmental Protection Agency.

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List of Acronyms

BIG	Bacteria Implementation Group
CAR	Corrective Action Report
CFU	Colony-Forming Unit of Bacteria
COH	City of Houston
CRP	Clean Rivers Program
EPA	Environmental Protection Agency
GPS	Global Positioning System
GBEP	Galveston Bay Estuary Program
H-GAC	Houston-Galveston Area Council
IDDE	Illicit Discharge Detection and Elimination
I-Plan	Implementation Plan
LDC	Load Duration Curve
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
NELAP	National Environmental Laboratory Accreditation Program
OSSF	Onsite Sewage Facility
QAPP	Quality Assurance Project Plan
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
Top2/Least2	Top 2 Most Impaired/Top 2 Least Impaired Lists
Top5/Least5	Top 5 Most Impaired/Top 5 Least Impaired Lists
Top10/Least10	Top 10 Most Impaired/Top 10 Least Impaired Lists
USGS	United States Geological Survey
WPP	Watershed Protection Plan
WWTF	Wastewater Treatment Facility

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Executive Summary

In an area without mountains or other distinctive topography, the meandering bayous, streams, and gulf coast shoreline are what distinguish the Houston-Galveston region from other parts of the country. Clean water is essential to the region's ability to leverage this natural resource to promote an enhanced quality of life for its residents.

Currently, nearly half of the stream miles in the Houston-Galveston region have bacteria levels higher than the state standard for contact recreation. The Bacteria Implementation Group (BIG) was developed to address elevated levels of bacteria in 102 bacteria-impaired stream segments in the region. The BIG is responsible for development and approval of an Implementation Plan that helps reduce bacteria concentrations in the BIG project area and ultimately remove bacteria-impaired streams from the state's list of impaired water bodies.

The BIG I-Plan supports Illicit Discharge Detection and Elimination (IDDE) and other targeted bacteria monitoring projects as a valuable implementation tool that can help reduce bacteria levels. The BIG's Top Five Most and Top Five Least Impaired Water Bodies (Top 5/Least 5) project was developed to support IDDE by performing targeted bacteria monitoring investigations in the most and least bacteria-impaired water bodies in the BIG project area.

The Top 5/Least 5 project followed a structured, three-tiered approach. Project tasks were split into three phases with each phase building on the last. The project flow chart summarizes the primary components included in each phase of the project. Results and observations found during Phase I and II of the project are detailed in the Preliminary Action Report and the Bacteria Source Identification Report, respectively. A summary of bacteria results from each phase of sampling is shown in Table 1.

Table 1. Summary of bacteria data collected throughout the project. Concentrations greater than 126 MPN/100mL are in exceedance of state water quality standards for *E.coli.*

Most Bacteria-Impaired Streams				
Little White Oak Bayou (1013A_01)	**No. of Samples**	**Minimum**	**Maximum**	**Mean**
Phase I *E.coli* (cfu/100mL)	25	0	TNTC[1]	8,888[2]
Phase II Dry Weather *E.coli* (MPN/100mL)	8	161	7,700	1,317
Phase II Wet Weather *E.coli* (MPN/100mL)	8	11,200	24,200	22,575
Rummel Creek (1014N_01)	**No. of Samples**	**Minimum**	**Maximum**	**Mean**
Phase I *E.coli* (cfu/100mL)	13	100	2,275	552
Phase II Dry Weather *E.coli* (MPN/100mL)	4	175	1,860	834
Phase II Wet Weather *E.coli* (MPN/100mL)	5	8,660	24,200	17,792
Least Bacteria-Impaired Streams				
Canal C-147 (1007A_01)	**No. of Samples**	**Minimum**	**Maximum**	**Mean**
Phase I *E.coli* (cfu/100mL)	21	0	TNTC[1]	2,306[2]
Phase II Dry Weather *E.coli* (MPN/100mL)	4	5	605	167
Phase II Wet Weather *E.coli* (MPN/100mL)	7	63	24,200	9,860
Upper Panther Branch (1008B_02)	**No. of Samples**	**Minimum**	**Maximum**	**Mean**
Phase I *E.coli* (cfu/100mL)	15	20	3,420	496
Phase II Dry Weather *E.coli* (MPN/100mL)	4	52	185	111
Phase II Wet Weather *E.coli* (MPN/100mL)	4	5,790	9,800	7,533

[1]Samples with greater than 200 bacteria colonies formed per dish using the Phase I methodology were reported as Too Numerous To Count (TNTC).

[2]For Phase I mean calculations, samples reported as TNTC were given an estimated 20,000 cfu/100mL value because that is the upper limit of reliable bacteria concentrations measurable using Phase I methodology. Note that the reported mean concentrations are likely an underestimate due to this assumption.

Monitoring results were shared with local jurisdictions so that actions could be taken to address the issues. Overall, results indicate that the primary source of bacteria in the most impaired streams were related to point sources of pollution while the least impaired streams are impacted more so by nonpoint sources. Actions taken by local jurisdictions include follow up investigations to identify potential leaks and illicit discharges, infrastructure repairs, increased wastewater treatment facility sampling, and development of action plans and educational efforts for local residents.

Focusing efforts on the most and least bacteria-impaired waterways increases the likelihood of identifying significant sources of bacteria impacting the region while working toward removing impaired streams from the states list of impaired water bodies. Coordinating targeted bacteria monitoring and investigations with local jurisdictions also improves cost effectiveness for cities and counties managing municipal separate storm water system (MS4) permits by reducing duplication of effort, improving efficiency of corrective action implementation, and avoiding potential permit violations. The BIG's Top 5/Least 5 project can be used as a model for IDDE program implementation and efficient management of water resources in a rapidly growing metropolitan area.

Introduction

In an area without mountains or other distinctive topography, the 16,000 miles of meandering bayous, streams, and gulf coast shoreline are what distinguishes the Houston-Galveston region from other parts of the country. Clean water is essential to the region's ability to leverage this natural resource to promote an enhanced quality of life for its residents, provide healthy habitats for a diverse population of fish and wildlife, and set a precedent for efficient management of water resources in a rapidly growing metropolitan area.

With regional population growth of several million projected by the year 2040, there will be a greater strain on sustaining the quality and quantity of surface waters for future generations. Incoming residents will require water for everyday activities, increasing water supply needs and producing larger volumes of domestic wastewater. New residents will also utilize available recreational opportunities, increasing the need to ensure local waterways meet state water quality standards for contact recreation uses.

Currently, nearly half of the stream miles in the Houston-Galveston region have bacteria levels higher than the state standard for contact recreation (H-GAC 2016 Basin Summary Report). That equates to over 6,500 miles of bayous, streams, and gulf coast shoreline that pose a risk to human health during recreational activities. High bacterial concentrations may cause gastrointestinal illness or skin infections in swimmers or others who come into direct contact with polluted waters. Additionally, high bacterial concentrations may impact other water quality issues, like reducing dissolved oxygen levels, leading to potential fish kills that negatively impact ecotourism and commercial fishing in the region.

Several water quality and watershed management projects have been implemented over the years to address the ongoing bacteria problem in the region. These initiatives include development of Watershed Protection Plans (WPPs), Total Maximum Daily Loads (TMDLs), and Implementation Plans (I-Plans) to reduce bacteria levels through the implementation of best management practices (BMPs). One of the more robust efforts includes I-Plan development by the Bacteria Implementation Group (BIG), a partnership of government, business, and community leaders, that address elevated levels of bacteria in 102 bacteria-impaired stream segments in the Houston-Galveston Region. The BIG's Top Five Most and Top Five Least Impaired Water Bodies (Top 5/Least 5) project was developed to support the BIG's efforts in reducing bacteria concentrations in the most and least bacteria-impaired waterways in the BIG project area using a targeted monitoring approach.

The Houston-Galveston Area Council (H-GAC) is the Regional Council of Governments for the Gulf Coast State Planning Region and has been actively involved in regional water quality planning and public outreach activities since the 1970s. H-GAC is designated as the lead agency responsible for administration of the BIG's Top 5/Least 5 project. Funding was provided through grants from the U.S. Environmental Protection Agency (EPA) through the Texas Commission on Environmental Quality's (TCEQ) Galveston Bay Estuary Program (GBEP) and is intended to support the Non-point Source and Point Source action plans of The Galveston Bay Plan.

Project Significance and Background

The Texas Commission on Environmental Quality (TCEQ) continually assesses water quality conditions for stream segments in the State through established quarterly monitoring programs like the Texas Clean Rivers Program. The TCEQ uses data collected through this effort to develop state water quality standards and to maintain a list of stream segments that do not meet those standards. This list of impaired waterways is updated every two years and published in the Texas Integrated Report. Bacteria impairments continue to be the most pervasive water quality issue in the Houston-Galveston region.

The BIG was formed in 2008 to develop and approve an I-Plan that addresses elevated bacteria levels in 72 bacteria-impaired stream segments in the region. Since its inception, support for the BIG has continued to grow and now includes a project area covering a total of 102 bacteria-impaired stream segments (Figure 1). Success for the BIG will be achieved when waters assessed by the state in the BIG project area are no longer considered impaired for bacteria and contact recreation standards are met.

As part of this effort, the BIG developed a list of Top 10 Most Impaired and Top 10 Least Impaired streams to evaluate waterways with the highest bacteria concentrations above the state standard and waterways closest to meeting state water quality standards, respectively (Figures 2 and 3). Additionally, The BIG I-Plan supports Illicit Discharge Detection and Elimination (IDDE) and other targeted bacteria monitoring projects as a valuable implementation tool that can help reduce bacteria levels. The BIG's Top 5/Least 5 project was developed to support IDDE by performing targeted bacteria monitoring investigations in the most and least bacteria-impaired water bodies identified in the BIG project area.

Although the Clean Rivers Program provides data necessary to assess and monitor overall surface water quality conditions for stream segments throughout the state, it does not provide the information necessary to identify specific bacteria sources impacting those streams. Targeted bacteria monitoring and IDDE programs allow for expanded sampling of streams at outfall locations, tributaries, and surface waters in order to identify illicit discharges or other bacteria sources and work toward eliminating them.

Focusing investigative efforts on the most and least bacteria-impaired waterways in the project area increases the likelihood of identifying significant sources of bacteria and illicit discharges impacting the region. Additionally, coordinating targeted bacteria monitoring with MS4 permittees and local jurisdictions will improve the efficiency of implementing corrective actions in areas that need it most. The BIG's Top 5/Least 5 project can be used by MS4 permit holders as a model for IDDE program implementation that can help save costs while supporting effective management of water resources in rapidly growing metropolitan areas. This report outlines the methodology used during each phase of the project and can be a guide for those interested in implementing similar coordinated IDDE programs in their area.

Figure 1. Map of BIG project area

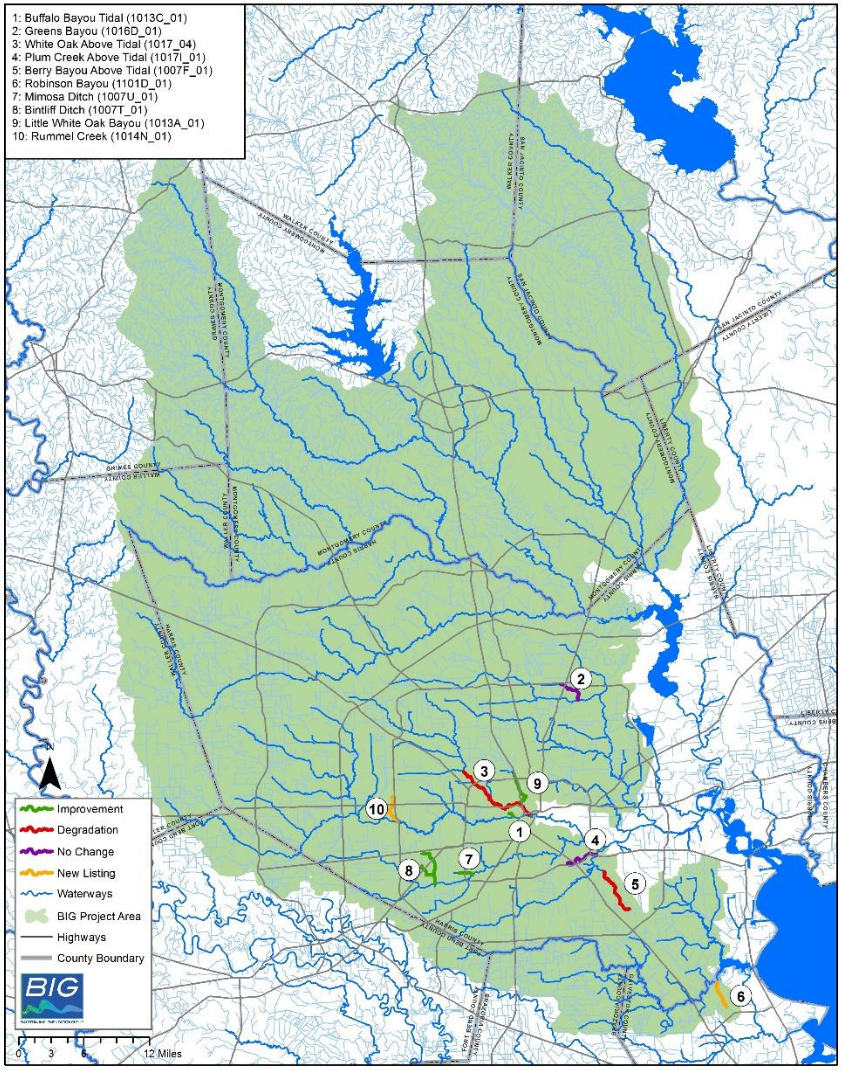

Figure 2. Top 10 Most Bacteria-Impaired streams from 2015

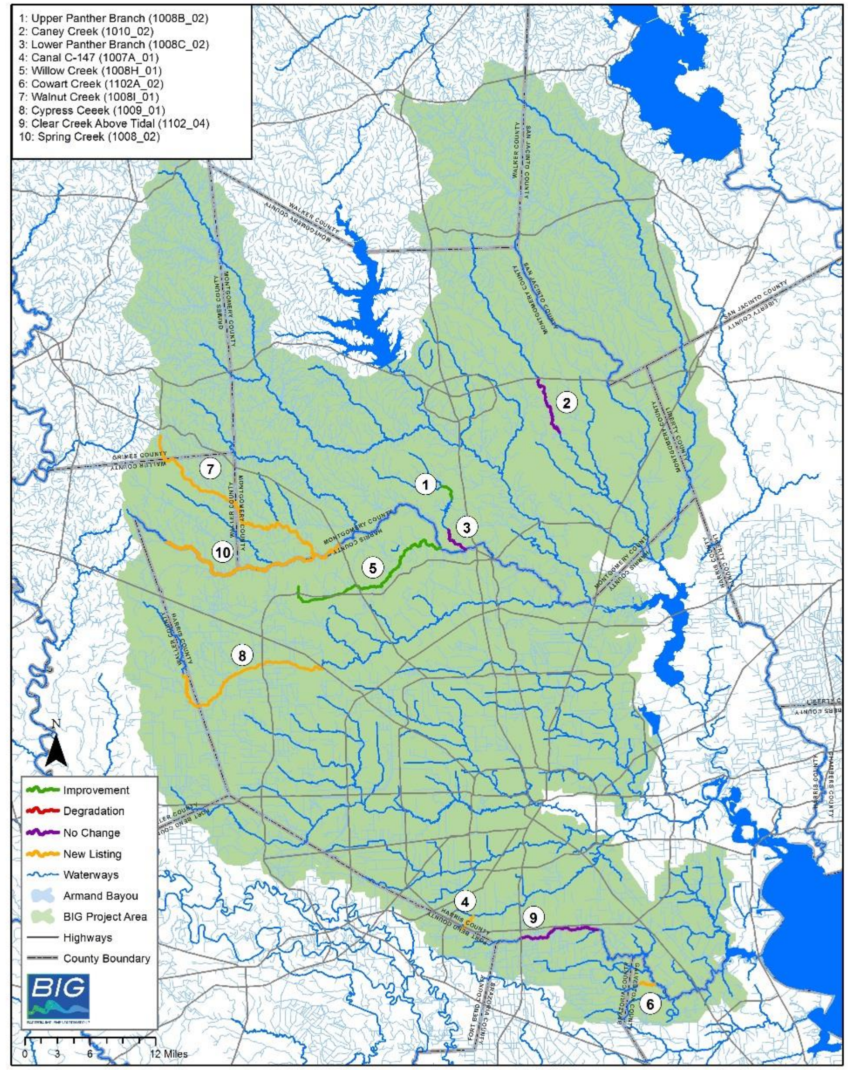

Figure 3. Top 10 Least Bacteria-Impaired streams from 2015

Methods

The Top 5/Least 5 project followed a structured, three-tiered approach. Project tasks were split into three phases with each phase building on the last. The acquisition, collection, and analysis of data followed standard approved methods outlined in the Quality Assurance Project Plan (QAPP) (Appendix A).

Phase I: Desk Review & Bacteria Screening

Phase I included initial desk review and analysis of existing data for the BIG's Top 10 Most and Top 10 Least Bacteria-Impaired (Top 10/Least 10) stream segments from 2015. Table 2 lists the data sources used and analyses performed during the desk review process.

Table 2. Phase I desk review analyses for BIG's Top 10/Least 10 streams segments from 2015.

Data Sources	Analyses Performed
TCEQ watershed areas	Review watershed size through map development
TCEQ stream segments	Review stream length through map development
Land use data	Review current land uses for each watershed assessed through map development
Wastewater outfall locations	Map location of wastewater outfalls for each watershed assessed
On-site sewage facility (OSSF) locations	Map location of OSSFs for each watershed assessed
Texas Clean Rivers Program water quality data	*E.coli* regression analysis for last 15 years of data; 7 year moving bacteria geometric mean plots; load duration curve analysis; days since last rain graphs
US Geological Survey flow gauge data	Load duration curve analysis
2014 Texas Integrated Report	Identify designated uses for each stream segment assessed; report current *E.coli* geometric mean value
Harris County Flood Warning System Website	Days since last rain graphs

A technical workgroup made up of representatives from local jurisdictions and water quality professionals provided feedback and guidance on which stream segments to investigate further based on the desk review analysis performed. Representatives from the following entities and jurisdictions participated in the workgroup:

- Bayou Preservation Association
- City of Houston Public Works and Engineering
- City of Houston Health Department
- Harris County Pollution Control Services Department
- Harris County Flood Control District
- Harris County Engineering Department
- City of Bellaire
- Galveston Bay Estuary Program
- Houston-Galveston Area Council
- Citizens Environmental Coalition
- San Jacinto River Authority

Multiple workgroup meetings were held to discuss the analyses performed and prioritize streams based on bacteria concentration, stream accessibility, designated uses, and level of interest expressed by the workgroup. Initial prioritization of the Top 10/Least 10 lists was discussed during a workgroup meeting in April 2016. The resulting Top 5/Least 5 prioritized stream segments were analyzed further and the watershed area was investigated through windshield surveys by H-GAC project staff. Windshield surveys included driving through watershed areas to observe and make note of potential bacteria sources located near the streams. The workgroup further prioritized the remaining stream segments down to a Top 2 Most Impaired and Top 2 Least Impaired (Top 2/Least 2) based on the additional analyses and information collected during the windshield surveys.

Table 3 lists the final Top 2/Least 2 streams that were selected for bacteria screening investigations. Bacteria screening involved intensive on-the-ground surveys where all outfalls were documented and water quality samples were collected from surface waters, tributaries, and discharging outfall locations. *E.coli* concentrations were measured using the Coliscan Easygel methodology outlined in the QAPP (Appendix A) to provide baseline data used to identify potential illicit discharges, hot spots, and areas of greatest concern for each of the streams investigated. Results and findings from the desk reviews, windshield surveys, and bacteria screening investigations are detailed in the Preliminary Action Report (Appendix B).

Table 3. Top 2 Most and Top 2 Least Impaired Water Bodies

Top 2 Most Impaired Water Bodies	Top 2 Least Impaired Water Bodies
Little White Oak Bayou (1013A_01)[1]	Upper Panther Branch (1008B_02)
Rummel Creek (1014N_01)	Canal C-147 (1007A_01)

[1]*Identification number included in parentheses represent TCEQ stream segment assessment unit.*

Phase II: Bacteria Source Identification

Bacteria screening results from Phase I were used as a precursor for the more targeted bacteria source identification surveys conducted for Phase II of the project. Phase II investigations focused on areas in the Top 2/Least 2 prioritized stream segments that had the highest bacteria screening concentrations and the greatest level of interest expressed by the technical workgroup and local jurisdictions. Sample collection during Phase II was intended to further refine source identification and aid in tracking sources of bacteria impairment to the greatest extent practicable. Bacteria source identification surveys included three main components:

1. Collection of wet weather and dry weather samples at each site.
2. Bacteria analysis at a National Environmental Laboratory Accreditation Program (NELAP) certified laboratory using more precise approved methods.
3. Collection of field water quality data including dissolved oxygen, temperature, specific conductance, pH, and other visual water quality parameters to supplement the bacteria data collected at each site.

Dry weather samples were collected following a minimum 72-hour antecedent dry period. Wet weather samples were collected during or immediately after a significant rain event (greater than 0.50 inches of rain) following a minimum 72-hour antecedent dry period. The Harris County Flood Warning System website was used to determine if a monitoring event qualified as either wet or dry weather. Methods used and a detailed account of results and findings from the Phase II surveys are included in the Bacteria Source Identification Report (Appendix C).

Phase III: Report Findings & Agency Action

All Phase I and Phase II results and findings were reported to local jurisdictions and MS4 permittees to assist them in the identification and further investigation of illicit discharges and significant sources of bacteria impacting the Top 2/Least 2 stream segments. Significant findings detected during the Phase I and Phase II investigations were reported through direct contact or through Houston's 311 Help & Information application.

Additional contact with local jurisdictions involved meetings, emails, and conference calls to discuss findings, provide recommendations, and track any corrective actions implemented based on the results and findings from Phase I and II investigations. Communication with the following jurisdictions and entities were included in this phase of the project.

- The City of Houston Public Works and Engineering
- City of Houston Health Department
- Harris County Pollution Control
- San Jacinto River Authority
- The Woodlands Township
- Montgomery County

Outreach and Education

An important component of this project was the dissemination of information to local jurisdictions and other stakeholders interested in the results and findings acquired through this effort. Presenting methodology, results, and lessons learned to the appropriate audience can assist in future project development for entities interested in pursuing similar IDDE program and bacteria source identification projects while highlighting the benefits of coordinating a targeted monitoring approach. Table 4 lists meetings, workshops, and publications where the BIG's Top 5/Least 5 project were presented.

Table 4. Summary of project outreach and education efforts

Date	Event/Promotional Item	Topic
April 20, 2016	Top 5/Least 5 Technical Workgroup	Desktop Review 1 Results: Prioritizing Top 10/Least 10 to Top 5/Least 5
May 10, 2016	Clean Rivers Program Basin Steering Committee Meeting	Project Overview and Timeline
May 26, 2016	Top 5/Least 5 Technical Workgroup	Desktop Review 2 Results: Prioritizing Top 5/Least 5 to Top 2/Least 2

Date	Event/Promotional Item	Topic
August 3, 2016	Houston-Galveston Area Council Texas Stream Team Quarterly Newsletter	Project launch featured in newsletter
August 4, 2016	Natural Resources Advisory Committee	Phase I Results
September 13, 2016	Top 5/Least 5 Technical Workgroup	Phase I Results
October 25, 2016	Bacteria Implementation Group Meeting	Phase I Results
February 28, 2017	Clean Rivers Program Basin Steering Committee	Phase II Results
March 20, 2017	Bacteria Implementation Group Stormwater Workgroup	Phase II Results and Lessons Learned
May 3, 2017	Houston-Galveston Area Council Texas Stream Team Quarterly Newsletter	Project wrap up featured in newsletter
May 15, 2017	Houston-Galveston Area Council's 2017 Basin Highlights Report	Project summary featured in report
May 23, 2017	Bacteria Implementation Group Meeting	Project Wrap Up, Agency Actions, and Lessons Learned

Results and Observations

Phase I: Desk Review & Bacteria Screening

The following figures illustrate the prioritization of stream segments by the technical workgroup beginning with the BIG's Top 10 Most and Top 10 Least Impaired lists from 2015. A detailed account of the analysis and review of these streams is included in the Preliminary Action Report (Appendix B).

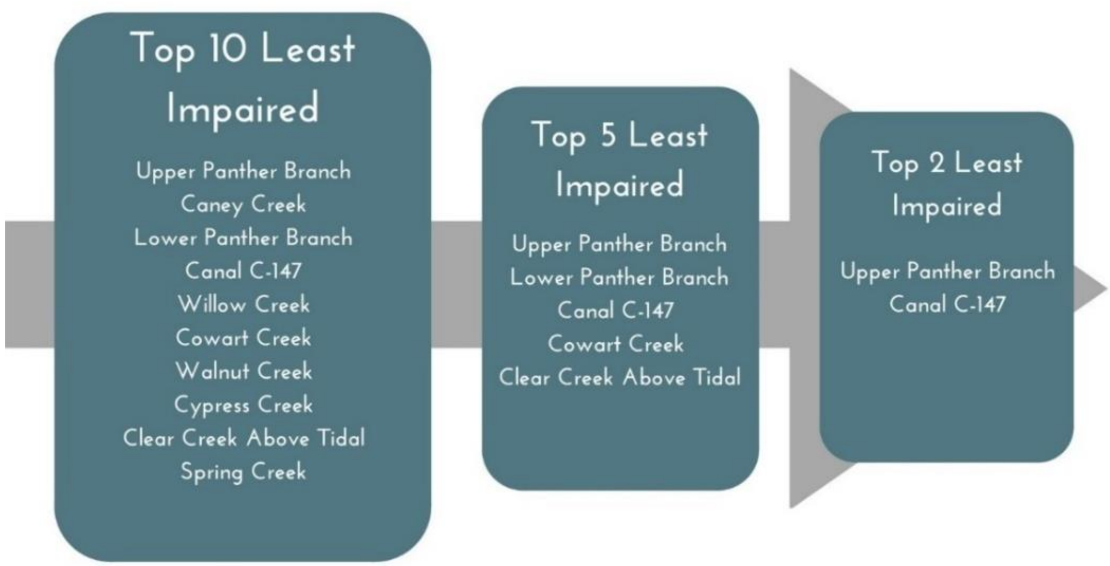

Figure 4. Prioritization of the least bacteria-impaired stream segments by the Technical Workgroup

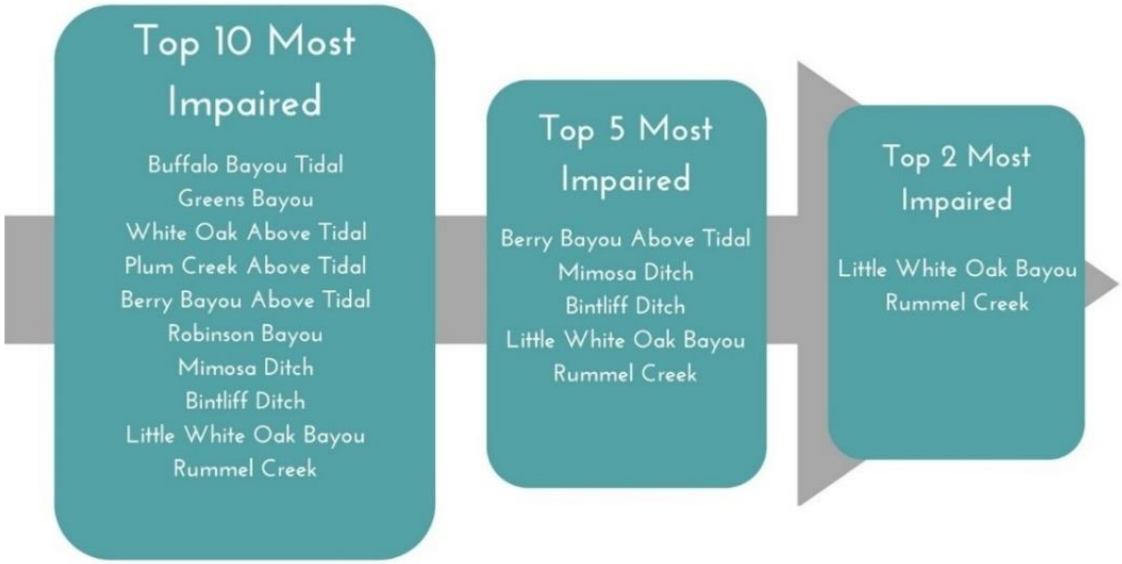

Figure 5. Prioritization of the most bacteria-impaired stream segments by the Technical Workgroup

The prioritized Top 2 Most Impaired and Top 2 Least Impaired stream segments were subject to intensive on the ground surveys where each water body was walked and all outfalls and tributaries were documented. Bacteria screening samples were collected from discharging outfalls, as well as from tributaries and surface waters. The following figures illustrate all Phase I sample locations for the four stream segments surveyed.

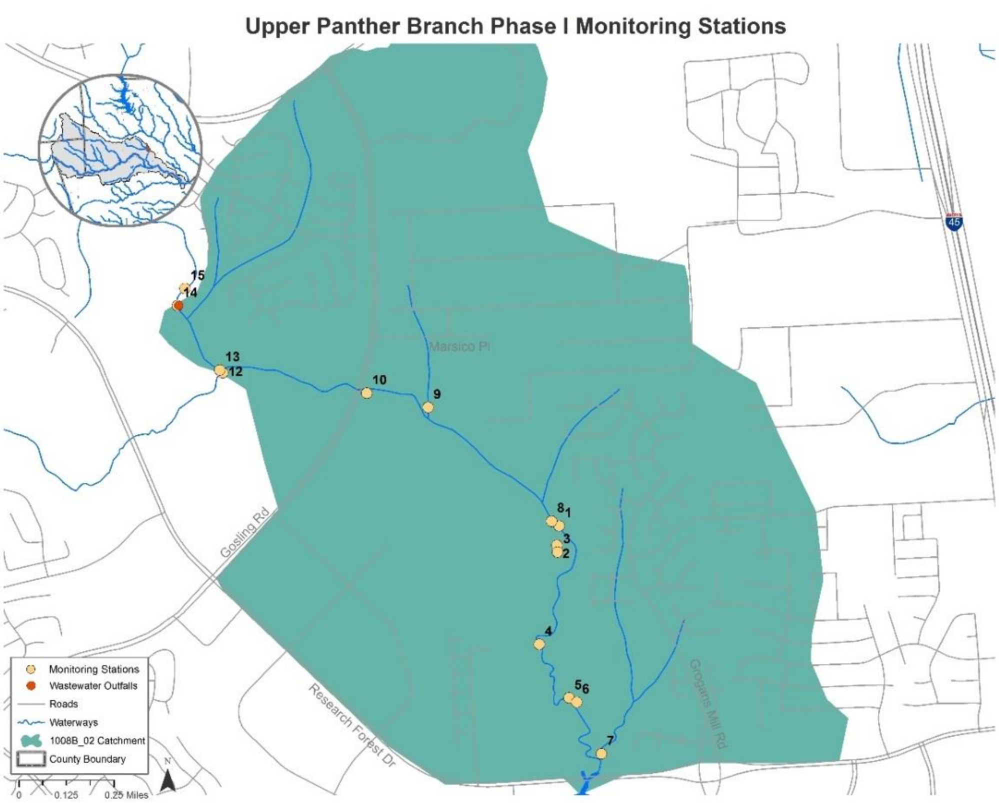

Figure 6. Phase I bacteria screening monitoring stations for Upper Panther Branch, Segment 1008B_02, from the Top 2 Least Impaired list.

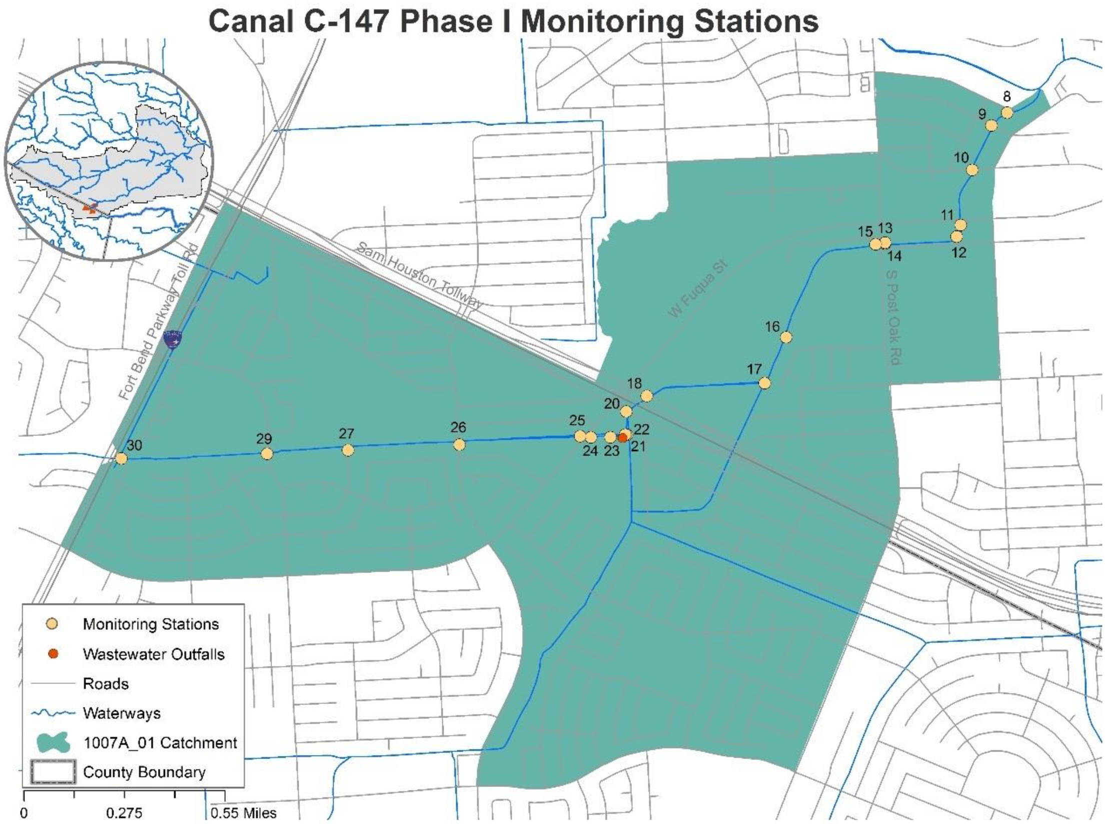

Figure 7. Phase I bacteria screening monitoring stations for Canal C-147, Segment 1007A_01, from the Top 2 Least Impaired list.

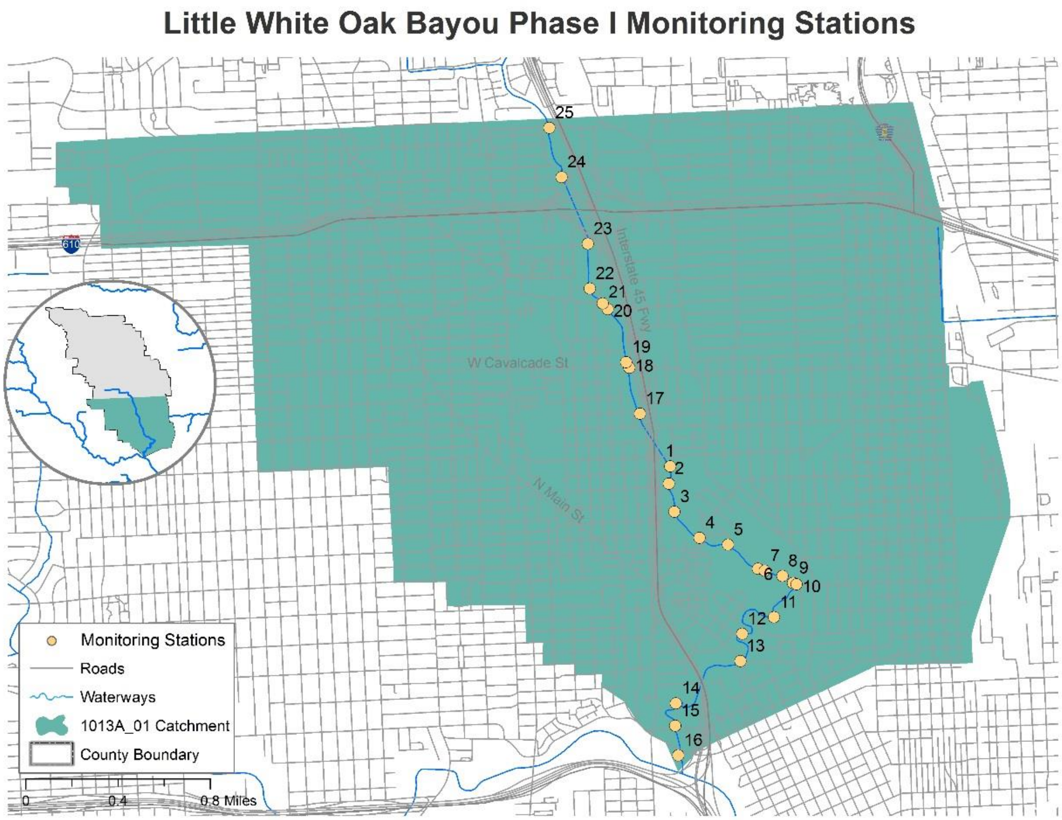

Figure 8. Phase I bacteria screening monitoring stations for Little White Oak Bayou, Segment 1013A_01, from the Top 2 Most Impaired list.

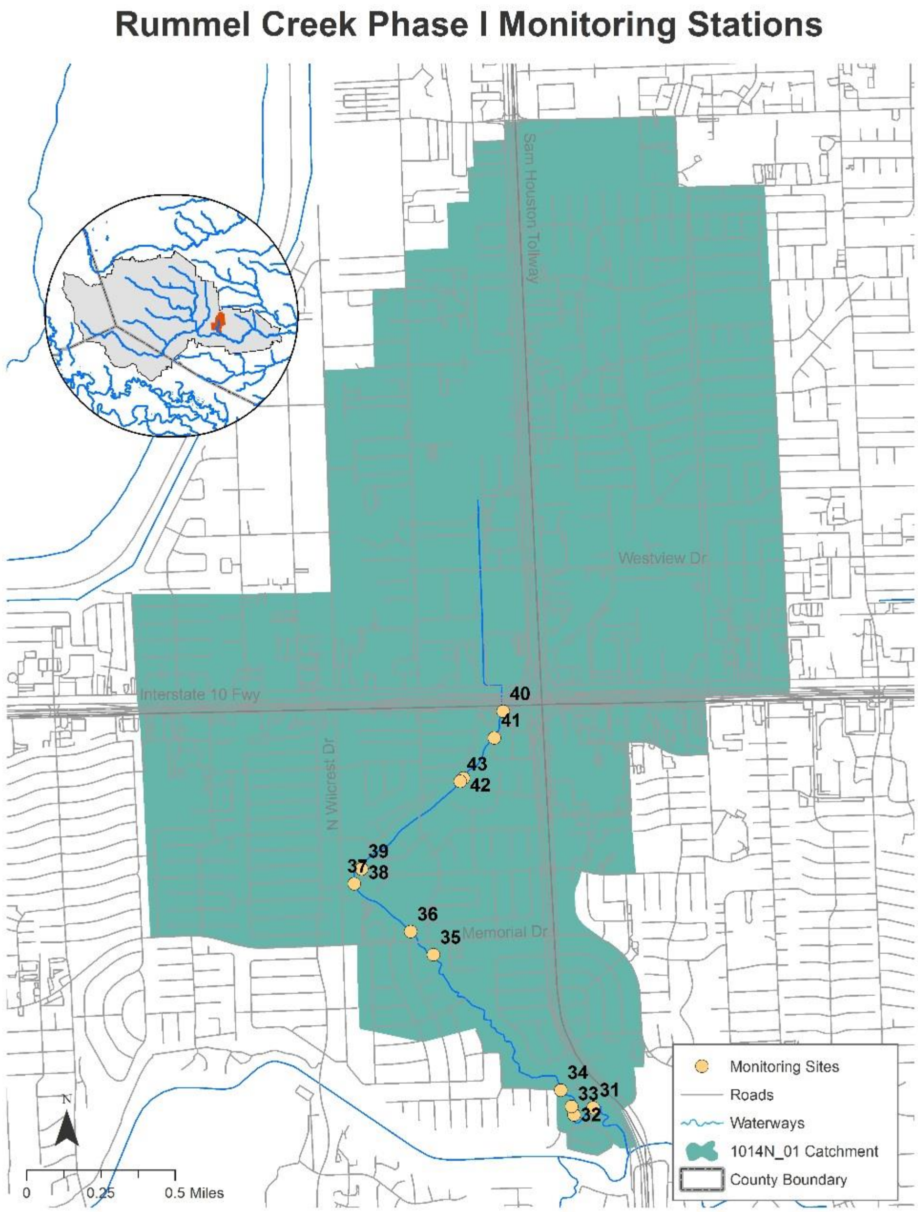

Figure 9. Phase I bacteria screening monitoring stations for Rummel Creek, Segment 1014N_01, from the Top 2 Most Impaired list.

Table 5 includes the *E.coli* concentrations measured using the Coliscan Easygel method for each sample collected during Phase I. Samples with greater than 200 colonies per dish were reported as Too Numerous To Count (TNTC). All samples with *E.coli* concentrations greater than 126 MPN/100mL are in exceedance of state water quality standards for bacteria. According to the bacteria screening results, the majority of samples collected during this phase were significantly greater than the standard with Little White Oak Bayou representing the stream segment with the most significant bacteria problem. Refer to the Preliminary Action Report (Appendix B) for additional results and findings from the Phase I bacteria screening surveys.

Table 5. Phase I bacteria screening results.

Upper Panther Branch																									
Station No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15										
***E.coli* (cfu/100mL)**	170	310	3420	140	100	580	60	50	1040	390	230	270	400	20	260										
Canal C-147																									
Station No.	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	25	26	27	29	30				
***E.coli* (cfu/100mL)**	800	230	290	200	180	TNTC	1770	190	510	TNTC	40	320	190	230	50	10	530	0	2130	230	520				
Little White Oak Bayou																									
Station No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
***E.coli* (cfu/100mL)**	575	700	450	250	1025	150	0	0	TNTC	TNTC	0	TNTC	TNTC	TNTC	TNTC	TNTC	10900	13300	7300	1350	6650	9450	4300	5800	TNTC
Rummel Creek																									
Station No.	31	32	33	34	35	36	37	38	39	40	41	42	43												
***E.coli* (cfu/100mL)**	125	225	775	252	425	2275	100	400	700	925	350	125	225												

Phase II: Bacteria Source Identification

Results and findings from the bacteria screening process were used as a precursor to Phase II assessments where only the stations with the highest bacteria screening concentrations from Phase I were subject to follow up bacteria source identification surveys. Additional information about the Phase II station selection process can be found in the Bacteria Source Identification Report (Appendix C). The following figures illustrate the monitoring stations sampled during the Phase II investigations. Sample numbers from Phase I were re-used for Phase II assessments to ensure facilitated tracking of sample locations.

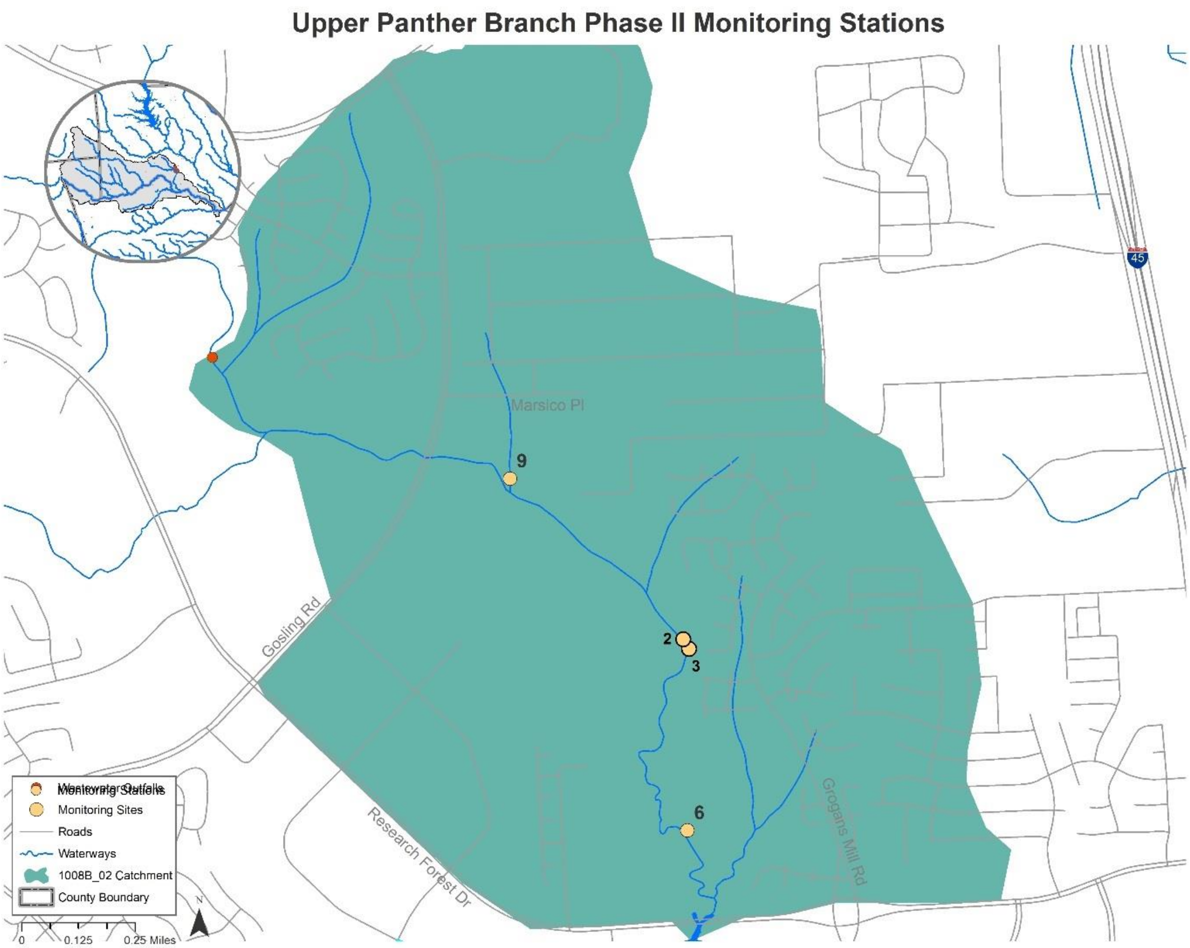

Figure 10. Phase II bacteria source identification monitoring stations for Upper Panther Branch, Segment 1008B_02, from the Top 2 Least Impaired list.

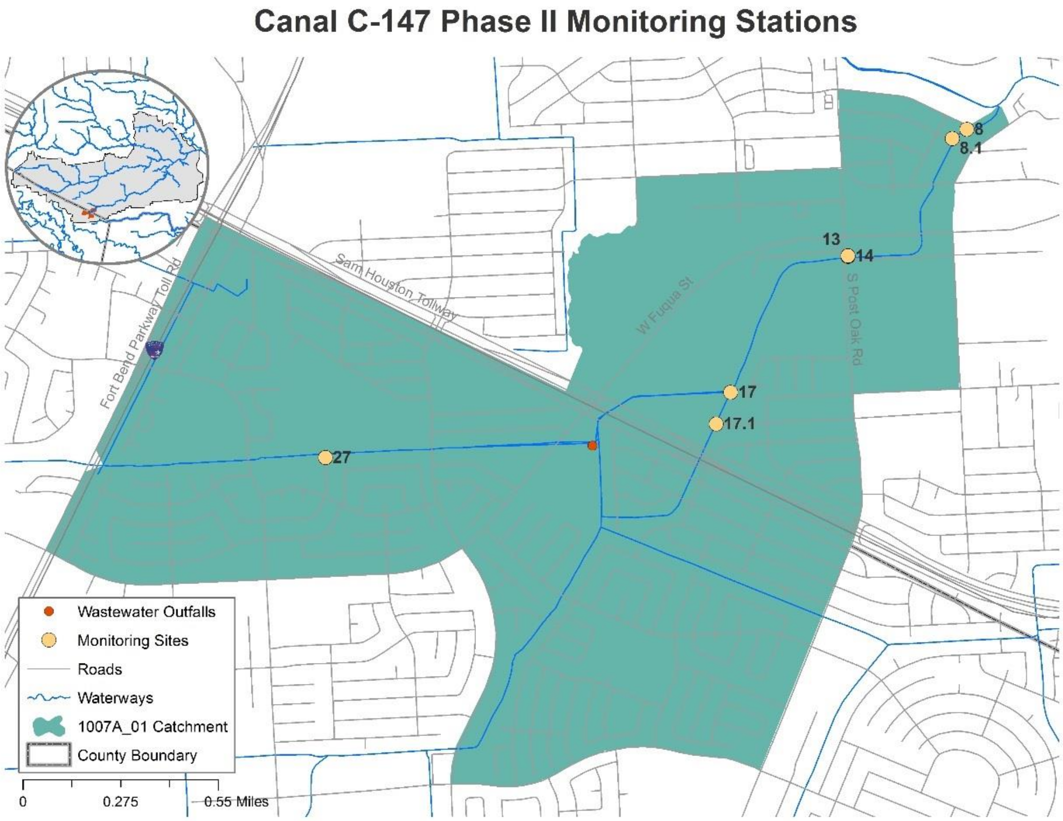

Figure 11. Phase II bacteria source identification monitoring stations for Canal C-147, Segment 1007A_01, from the Top 2 Least Impaired list.

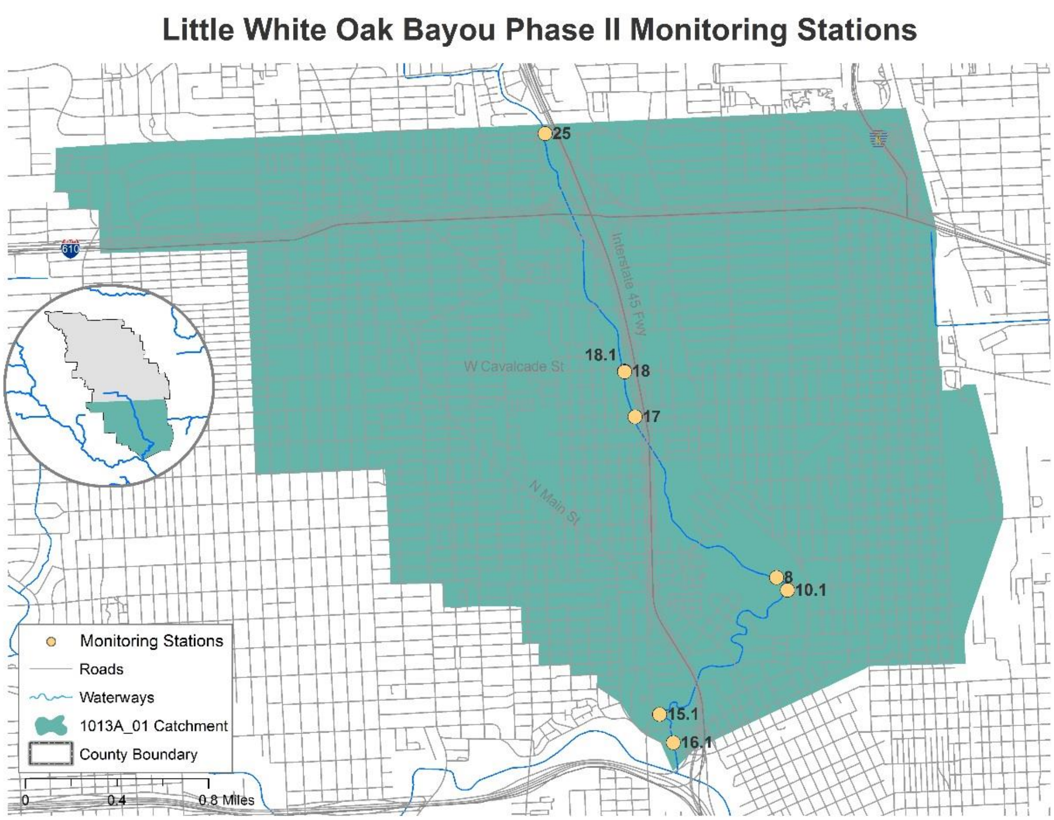

Figure 12. Phase II bacteria source identification for Little White Oak Bayou, Segment 1013A_01, from the Top 2 Most Impaired list.

Rummel Creek Phase II Monitoring Stations

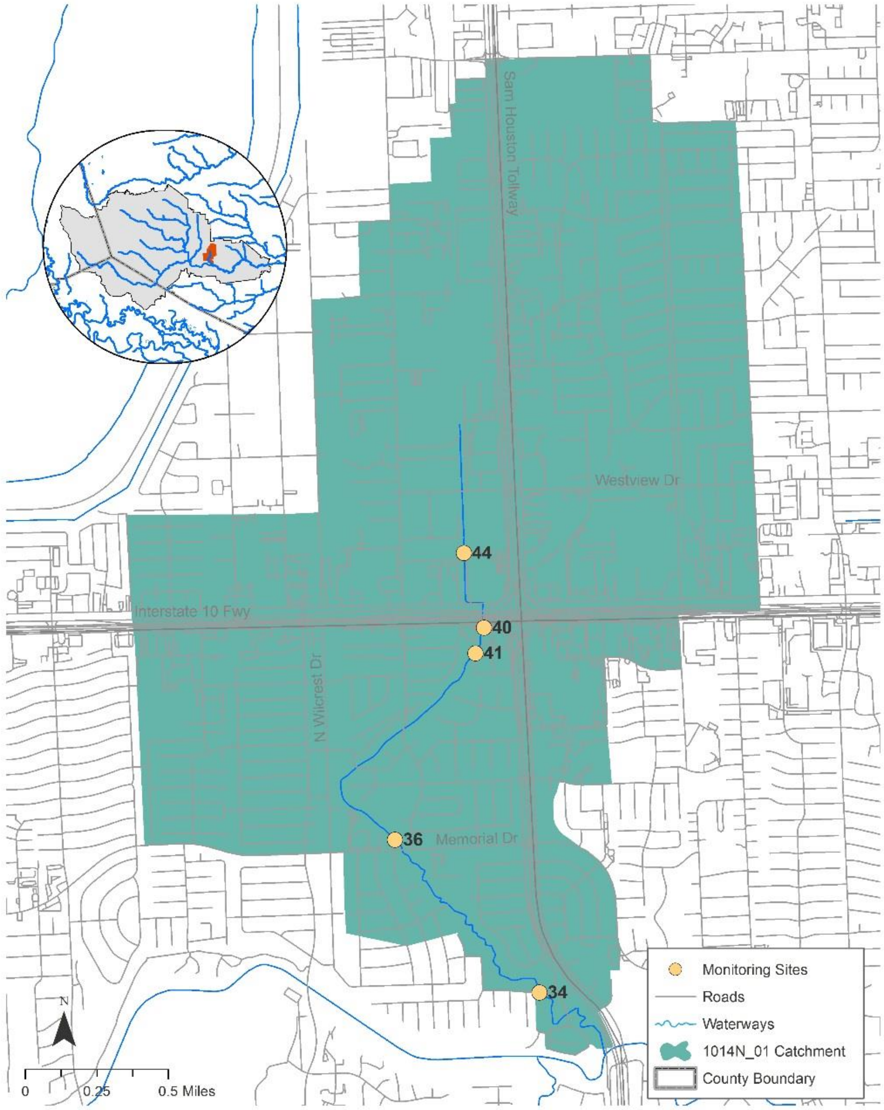

Figure 13. Phase II bacteria source identification monitoring stations for Rummel Creek, Segment 1014N_01, from the Top 2 Most Impaired list.

A NELAP certified laboratory was used for the *E.coli* analysis to provide more accurate and precise bacteria concentration data for the Phase II investigations. Figures 14-17 summarize the water quality data collected during Phase II dry and wet weather surveys.

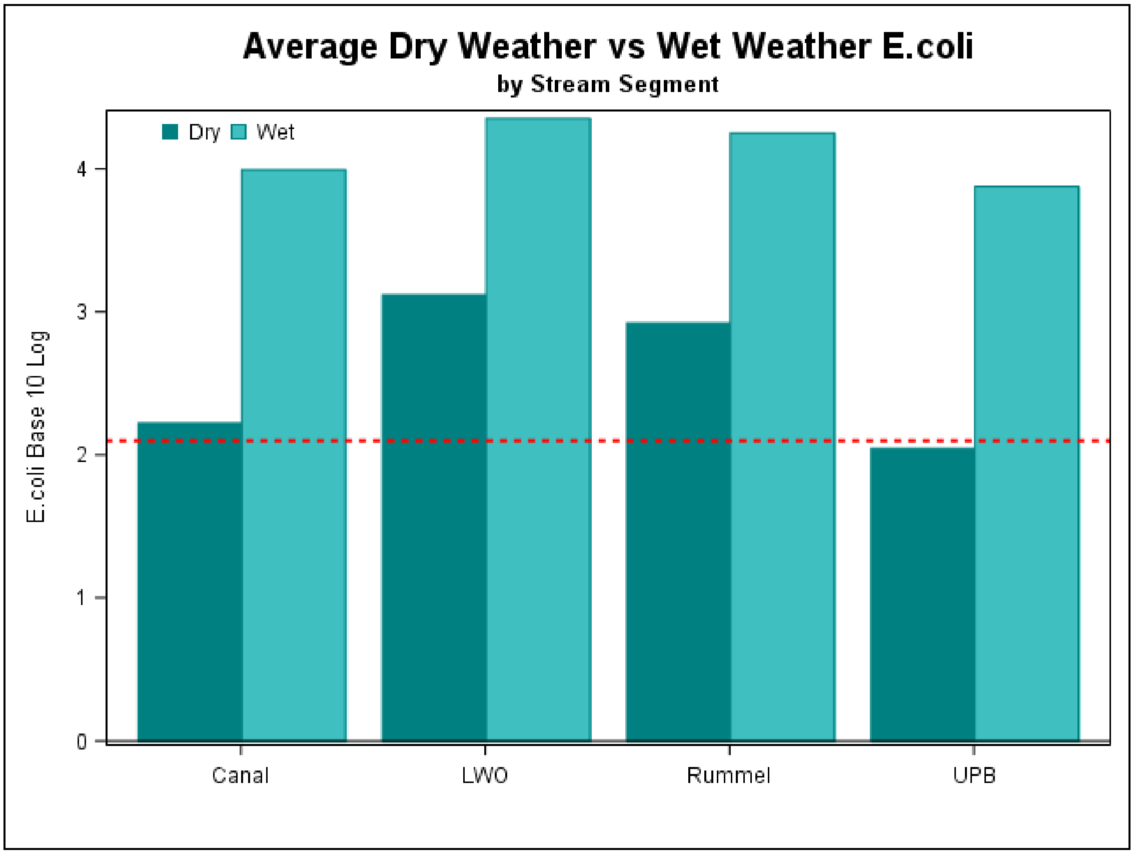

Figure 14. Average *E.coli* concentrations by stream segment for wet and dry weather surveys. Red dotted line represents the 126 MPN/100mL standard.

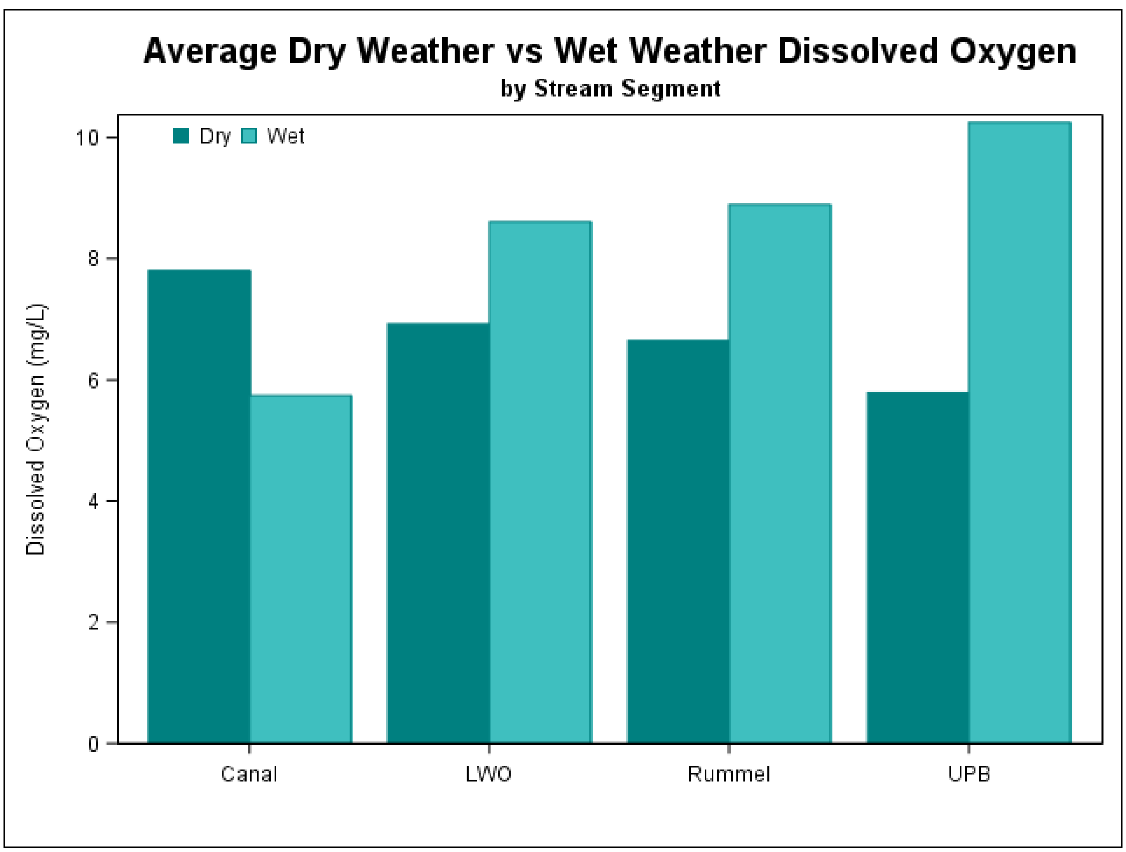

Figure 15. Average dissolved oxygen levels by stream segment for wet and dry weather surveys.

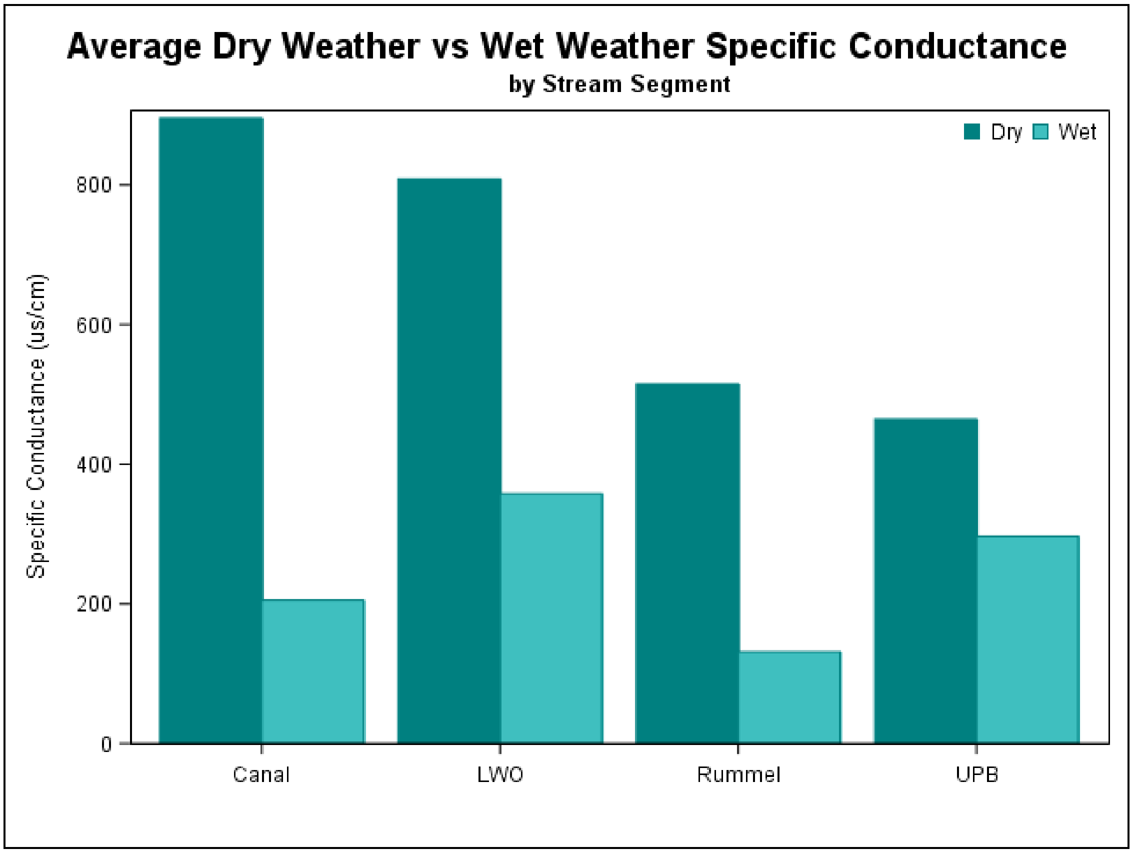

Figure 16. Average specific conductance by stream segment for wet and dry weather surveys.

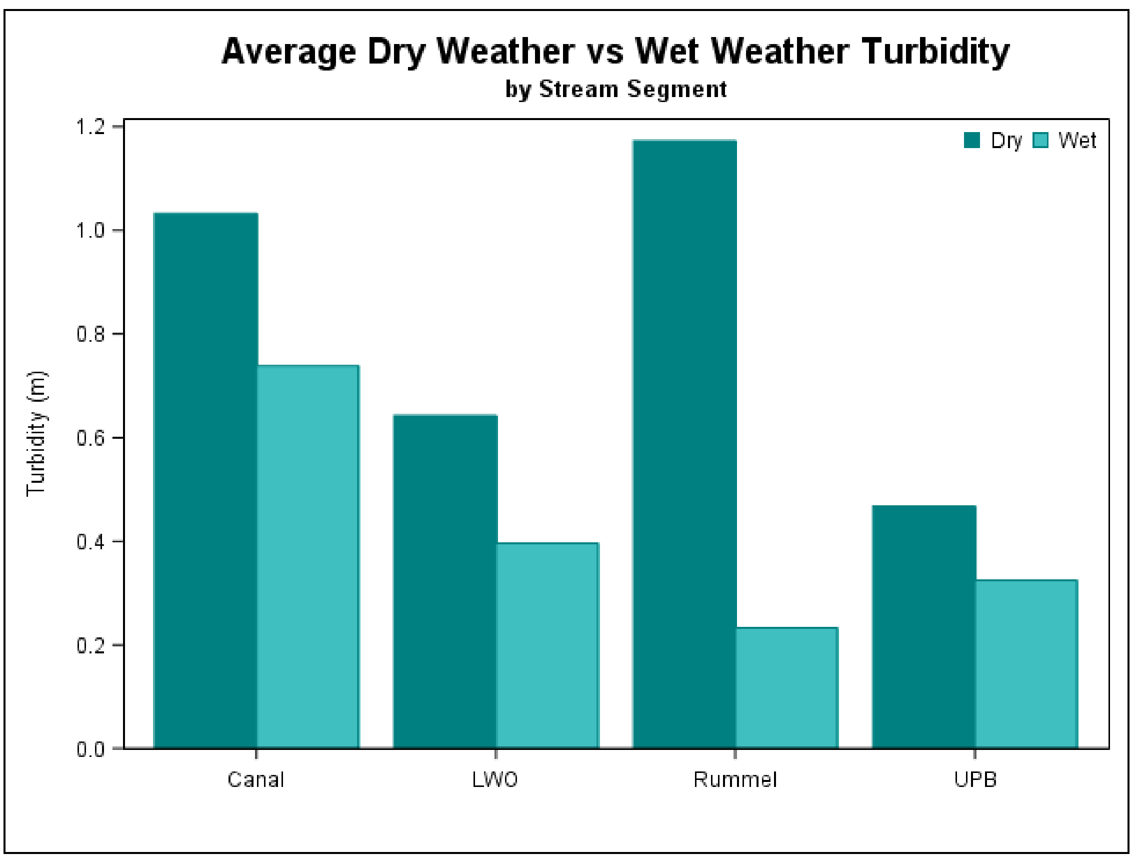

Figure 17. Average turbidity levels by stream segment for wet and dry weather surveys.

Overall, Phase II bacteria levels for the Top 2 Least Impaired segments, Upper Panther Branch and Canal C-147, were typically in compliance during dry weather conditions but were significantly greater during wet weather conditions. Phase II results for the Top 2 Most Impaired segments, Little White Oak Bayou and Rummel Creek, yielded the highest bacteria concentrations during both wet and dry weather conditions. Additionally, specific conductance was consistently higher during dry weather conditions compared to wet weather even though water clarity (turbidity level) was lower during wet weather events. This is likely because wastewater discharges and high evaporation rates during dry weather conditions increase the level of dissolved constituents in water resulting in higher conductivity and water clarity. After a significant rain event, the level of dissolved constituents decreases while suspended solids from sediment runoff increases, resulting in lower conductivity and water clarity.

Refer to the Bacteria Source Identification Report (Appendix C) for additional Phase II water quality data, detailed station descriptions for each stream segment, and recommendations to local jurisdictions for further investigation.

Phase III: Report Findings & Agency Action

Table 6 lists significant findings, responses, and actions taken by local jurisdictions to address bacteria sources and other issues or concerns. Communication with local jurisdictions has been ongoing and follow up investigations and corrective action implementation is expected to continue after completion of this project. H-GAC will not correct the issues, but will continue to work with local jurisdictions to reduce or eliminate pollutions sources found through this effort.

Table 6. Significant findings reported to local jurisdictions and actions taken.

Stream	Finding	Response	Action
Little White Oak Bayou (1013A_01)	City of Houston (COH) informed H-GAC of a faulty sewer system junction box located at Wrightwood Street that is a potential bacteria source to Little White Oak Bayou.	H-GAC staff met with COH Engineer at Wrightwood St bridge and observed what looked to be a faulty junction box adjacent to the Bayou. Toilet paper and strong sewage odor was evidence of recent overflow events. H-GAC field staff also submitted a 311 service request about this finding on 10/26/2016. Report: https://seeclickfix.com/issues/3024826	Communication with COH engineers and investigators about junction box repairs is ongoing. Some repairs have been made, including raising the box approximately 5 feet higher to reduce chances of overflows during flood events. Additional repairs are underway and investigative staff will continue to monitor the area once work has been completed.
Little White Oak Bayou (1013A_01)	Sample collected from station 8 during Phase I resulted in a 0 cfu/100mL bacteria concentration. This was suspect considering all bacteria concentrations measured around that storm drain location were significantly higher.	City of Houston was notified of the results through the Preliminary Action Report.	COH Storm Water Quality Enforcement investigated this site further through dye testing and visual inspection. A water leak was detected originating east of the storm drain but has not been linked to a specific source. No corrective actions have been implemented at this location.

Stream	Finding	Response	Action
Little White Oak Bayou (1013A_01)	An oily sheen and strong hydrocarbon/diesel odor was observed at Little White Oak Bayou at the Stokes St bridge during the dry weather Phase II investigation.	H-GAC field staff submitted a 311 service request about this finding on 10/17/2016. Report: http://seeclickfix.com/issues/3004815	COH closed the report and referred the problem to Harris County for further investigation. H-GAC has not received additional information about the status of this investigation.
Little White Oak Bayou (1013A_01)	The storm drain located at Hayes Road (station 10) was identified as one of the most significant bacteria contributors to Little White Oak during both Phase I and Phase II investigations.	City of Houston was notified of the results through the Preliminary Action Report and Source Identification Report.	COH Storm Water Quality Enforcement investigated this site further and detected copper leachate in addition to high bacteria concentrations. It was speculated the source is from old pipelines. No corrective actions have been implemented at this location.
Little White Oak Bayou (1013A_01)	A faulty manhole with evidence of recent overflows was detected during Phase I and Phase II investigations near station 17.	City of Houston was notified about the issue through the Preliminary Action Report, Source Identification Report, and at meetings with City of Houston investigative staff.	COH Storm Water Quality Enforcement investigators identified the manhole as an active line and reported the hole to the wastewater department for repairs.
Rummel Creek (1014N_01)	Results from the station 36 outfall near Rummel Creek Elementary showed consistently high bacteria concentrations during all site visits and was flagged as one of the more significant sources of bacteria to Rummel Creek.	City of Houston was notified about the issue through the Preliminary Action Report, Source Identification Report, and through communications at meetings with investigative staff.	COH Pollution Control conducted follow-up *E.coli* testing at this outfall and found bacteria levels are still significantly greater than the standard. COH Pollution Control and Public Works and Engineering working together to collect samples from surrounding manholes and perform leak testing to identify bacteria source. Investigation will continue through the summer.
Little White Oak Bayou (1013A_01), Canal C-147 (1007A_01), and Rummel Creek (1014N_01)	Three of the four stream segments investigated for this project were in Harris County.	Harris County Pollution Control was notified of the results through the Preliminary Action Report, Source Identification Report, and other outreach efforts.	Harris County Pollution Control Services has proposed increased sampling at three wastewater treatment facilities located upstream of Little White Oak Bayou and Rummel Creek. Sampling will be increased from annually to quarterly at The Park on White Oak and Duree Manor for Little White Oak Bayou, and at City of Houston-West District for Rummel Creek. Additionally, Pollution Control personnel speculate that bridge dwelling bat colonies over the stream segments may also be a potential bacteria contributor.

Stream	Finding	Response	Action
Canal C-147 (1007A_01)	High bacteria concentrations were detected at station 8 during the Phase I investigations.	City of Houston was notified through the Preliminary Action Report and at workgroup meetings.	COH Pollution Control investigated this outfall location and detected a potable water leak. The leak was fixed and all samples collected during Phase II were in compliance with state water quality standards for bacteria.
Canal C-147 (1007A_01)	Large storm drain on right side of Canal C-147 at Post Oak Blvd flagged as potential contributor of bacteria into the Canal based on Phase I and Phase II bacteria results.	City of Houston was notified about the issue through the Preliminary Action Report, Source Identification Report, and through communications at meetings with investigative staff.	COH Pollution Control suspects a potable water leak within first 150 feet of water line running parallel to stormwater line leading to outfall. Problem referred to Public Works and Engineering Department for repair. Bacteria source suspected to be from natural sources (ex. birds, nonpoint sources)
Canal C-147 (1007A_01)	During the Phase II investigation of Canal C-147 on 10/19/2016, a significant amount of trash, tires, and furniture were observed at the downstream end of the watershed in the neighborhoods adjacent to the waterway.	H-GAC field staff submitted a 311 service request about this finding on 10/19/2016. Report: http://seeclickfix.com/issues/3010911	COH closed the report on 11/10/2016 stating that the issue has been resolved.
Upper Panther Branch (1008B_02)	High chlorine concentrations were observed during Phase I and Phase II dry weather investigations at Upper Panther Branch.	H-GAC PM contacted staff at the San Jacinto River Authority (SJRA) Lake Conroe Division to inform them of this finding.	SJRA staff informed H-GAC that it is unlikely the high chlorine levels are coming from the WWTF because UV is the primary means of tertiary treatment. It was speculated that the chlorine source may be related to the use of bleach to clean equipment at the WWTF. Improper maintenance of residential pools may also be a source of chlorine into the stream. Additional investigation and resident education is recommended to address this issue.
Upper Panther Branch (1008B_02)	Upper Panther Branch was investigated and bacteria sources and chlorine detection was reported in both project reports.	The Woodlands Township was notified of the results through the Preliminary Action Report and Source Identification Report.	The Water Conservation Program at the Woodlands Township is interested in initiating an action plan to inform and educate residents about current water quality problems in their area. Education plan should promote proper pet waste disposal and swimming pool maintenance practices that limit negative impacts to nearby waterway.

Discussion

The BIG's Top Five Most and Top Five Least Impaired Water Bodies project provided a structured approach to addressing the region's bacteria impairment problem one stream at a time. With 102 bacteria-impaired stream segments in the BIG project area, focusing efforts on the Top 10 Most and Top 10 Least Impaired streams was an effective way to initiate investigations in areas that would make the greatest impact.

Investigating the most impaired stream segments can aid in identifying and eliminating some of the most significant bacteria sources and help reduce overall bacteria levels in the BIG project area. Targeting the least impaired streams can help local jurisdictions implement corrective actions that will help bring those streams into compliance with state water quality standards for bacteria. Additionally, having a third-party organization such as H-GAC perform the initial on-the-ground investigations allows local jurisdictions to spend more time and resources correcting problems rather than finding them. Coordinating targeted bacteria monitoring and investigations with local jurisdictions also improves cost effectiveness for cities and counties managing MS4 permits by reducing duplication of effort, improving efficiency of corrective action implementation, and avoiding potential permit violations.

The development of a Technical Workgroup comprised of key members from local jurisdictions being involved in project development early on also contributed to the success of the project. Workgroup meetings during Phase I of the project helped raise interest and develop working relationships with investigative and enforcement staff that would be involved in follow up investigations. However, due to reporting delays related to wet weather water quality monitoring during Phase II, reduced communication with the workgroup resulted in a lower interest level as the project approached completion. Future recommendations regarding the Technical Workgroup would be to set up most meetings after Phase I and II investigations have been completed to review results and develop an action plan rather than conducting all workgroup meetings during the desk review process in Phase I.

Overall, project results indicate that the most significant sources of bacteria impacting the Top 2 Most Impaired segments are dry weather discharges (illicit discharges, leaking or faulty collection systems and pipelines, etc.), whereas bacteria sources impacting the Top 2 Least Impaired segments are likely related to nonpoint sources of pollution. However, illicit discharges and leaking or faulty collection systems and pipelines were observed in all stream segments surveyed except Upper Panther Branch. The most significant concern found at Upper Panther Branch was the detection of elevated chlorine levels throughout the entire segment during all dry weather sampling events. Sanitary sewer overflows following significant rain events were also a major source of bacteria identified through this effort. Little White Oak Bayou is especially susceptible to bacteria contributions through sanitary sewer overflows due to aging wastewater collection systems and rapid growth in the area. Further investigation into the source of chlorine in Upper Panther Branch and actions to help reduce frequency of sanitary sewer overflows in Little White Oak Bayou are recommended.

Summary

Currently, nearly half of the stream miles in the Houston-Galveston region have bacteria levels higher than the state standard for contact recreation. I-Plan development and approval by the BIG addresses this issue in 102 bacteria-impaired stream segments in the region. The BIG'sTop 5/Least 5 project was developed to support the BIG's efforts in reducing bacteria concentrations in the most and least bacteria-impaired waterways in the BIG project area.

The Top 5/Least 5 project was split into three phases with each phase building on the last. Phase I included initial analysis and review of the BIG's Top 10 Most and Top 10 Least bacteria-impaired lists from the 2015 BIG annual report. A Technical Workgroup made up of water quality professionals and representatives from local jurisdictions provided input and asisted in prioritizing the Top 10 and Least 10 lists to a Top 2 and Least 2 list that was subject to further investigation. H-GAC staff was responsible for conducting intensive bacteria screening investigations on the Top 2 and Least 2 prioritized stream segments to provide baseline data and identify potential illicit discharges, hot spots, and areas of greatest concern for each of the streams investigated.

Phase II investigations focused on areas in the Top 2 and Least 2 prioritized stream segments that had the highest Phase I bacteria screening concentrations and the greatest level of interest expressed by the technical workgroup and local jurisdictions. Sample collection during Phase II was intended to further refine source identification and aid in tracking sources of bacteria impairment to the greatest extent practicable. Results and observations found during Phase I and II of the project are detailed in the Preliminary Action Report (Appendix B) and the Source Identification Report (Appendix C), respectively.

Overall, results indicate the most significant sources of bacteria impacting the Top 2 Most Impaired segments, Little White Oak Bayou and Rummel Creek, include dry weather discharges and sanitary sewer overflows whereas bacteria sources impacting the Top 2 Least Impaired segments, Canal C-147 and Upper Panther Branch, are likely related to nonpoint sources of pollution.

Phase III of the project included reporting investigative results to local jurisdictions and providing recommendations for further action. Actions taken by local jurisdictions include follow up investigations to identify potential leaks and illicit discharges, infrastructure repairs, increased wastewater treatment facility sampling, and development of action plans and education campaigns for local residents.

Focusing efforts on the most and least bacteria-impaired waterways increases the likelihood of identifying significant sources of bacteria and guiding local jurisdictions in implementing corrective actions in areas that need it most. This targeted approach helps reduce duplication of effort and provides a more efficient means of correcting pollution sources while assisting the BIG achieve its long-term goal of removing bacteria-impaired streams from the State's list of impaired water bodies. This report provides a detailed outline of project methods that can be used as a guide in implementing similar coordinated IDDE programs geared toward improving bacteria conditions in area waterways.

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http://videos.h-gac.com/CE/water/big/BIG-I-Plan-Full-Document.pdf

TCEQ Implementation Plan for Seventy-Two Total Maximum Daily Loads for Bacteria in the Houston-Galveston Region: Bacteria Implementation Group Implementation Plan Third Addendum.
http://www.h-gac.com/community/water/tmdl/BIG/documents/3Addendum52016.pdf

Appendix A: Quality Assurance Project Plan

A1 Approval Page

By signing this document, signatories acknowledge their respective organizations' awareness of and commitment to requirements contained in this Quality Assurance Project Plan (QAPP) in accordance with roles and responsibilities as described in Section A4 Project/Task Organization.

Texas Commission on Environmental Quality (TCEQ)

Office of Water
Water Quality Planning Division
Planning and Implementation Section

____

Sarah Bernhardt, Ph.D., Program Manager Date
Galveston Bay Estuary Program (GBEP)

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Lisa Marshall, Project Manager (PM) Date
GBEP

____

Michelle Krause, Quality Assurance Officer (QAO) Date
GBEP

Office of Compliance and Enforcement
Monitoring Division
Laboratory and Quality Assurance (QA) Section

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Sharon Coleman, TCEQ QA Manager Date

Houston-Galveston Area Council (H-GAC)

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Paniz Miesen, PM Date
H-GAC

____
Jean Wright, QAO Date
H-GAC

____
Bill Hoffman, Clean Rivers Program (CRP) Data Manager Date
H-GAC

____
Will Merrell, GIS Data Manager Date
H-GAC

Eastex Environmental Laboratory (Eastex)

____ Date: ________________
Pam Hickman
Eastex Lab Manager

____ Date: ________________
Daniel Bowen
Lab

A2 Table of Contents

List of Acronyms

BIG	Bacteria Implementation Group
C&E	Community and Environmental Planning
CAR	Corrective Action Report
COG	Council of Governments
CFU	Colony-Forming Unit of Bacteria
CRP	Clean Rivers Program
CSDGM	Content Standards for Digital Geospatial Metadata
DM	Data Manager
EPA	Environmental Protection Agency
FDC	Flow Duration Curve
FGDC	Federal Geographic Data Committee
GPS	Global Positioning System
GBEP	Galveston Bay Estuary Program
H-GAC	Houston-Galveston Area Council
IDDE	Illicit Discharge Detection and Elimination
I-Plan	Implementation Plan
LDC	Load Duration Curve
LU/LC	Land Use/Land Cover
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
NELAP	National Environmental Laboratory Accreditation Program
OSSF	Onsite Sewage Facility
PM	Project Manager
QA/QC	Quality Assurance/Quality Control
QAM	Quality Assurance Manual (or Manager)
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QAS	Quality Assurance Specialist
QMP	Quality Management Plan
SOP	Standard Operating Procedure
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TNI	The NELAC Institute
TNRIS	Texas Natural Resources Information System
Top2	Top 2 Most Impaired/Top 2 Least Impaired Lists
Top5	Top 5 Most Impaired/Top 5 Least Impaired Lists
Top10	Top 10 Most Impaired/Top 10 Least Impaired Lists
TSWQS	Texas Surface Water Quality Standards
USGS	United States Geological Survey
WWTF	Wastewater Treatment Facility

A3 Distribution List

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The H-GAC QAO will provide copies of this project plan and any amendments or revisions of this plan to each person on this distribution list and to each sub-tier participant other than TCEQ and EPA staff. The H-GAC QAO or PM will provide documentation of this transmittal to the TCEQ GBEP Project Manager within two weeks of QAPP approval. This documentation will be maintained as part of the H-GAC's quality assurance records and as part of the TCEQ project file.

The TCEQ GBEP Project Manager is responsible for providing copies of the project plan and any amendments or revisions of this plan to TCEQ and EPA staff. Copies must be provided within two weeks of QAPP approval, and documentation of this transmittal will be available for review and maintained as part of the TCEQ project file.

A4 Project/Task Organization

The following is a list of individuals and organizations participating in the project with their specific roles and responsibilities:

GBEP

Sarah Bernhardt, Ph.D.
GBEP Program Manager
The TCEQ GBEP Program Manager is responsible for supervising the TCEQ's GBEP Team. Oversees the development of QA guidance for the GBEP Team to ensure it is within pertinent frameworks of the TCEQ. Reviews and/or approves all GBEP projects, QA audit responses, QAPPs, agency Quality Management Plans (QMPs), corrective action reports (CARs), work plans, and contracts. Enforces corrective action where QA protocols are not met. Ensures GBEP personnel are fully trained.

Lisa Marshall
GBEP PM
The TCEQ GBEP PM is responsible for ensuring that the project delivers data of known quality and quantity on schedule to achieve project objectives. PM is the primary point of contact between the H-GAC and the TCEQ. Tracks and reviews deliverables to ensure that tasks in the work plan are completed as specified in the contract. Reviews and approves QAPPs and any amendments or revisions and ensures proper distribution of approved/revised QAPPs to TCEQ participants and the EPA. Responsible for verifying that the QAPP is followed by the H-GAC. Notifies the TCEQ GBEP and GBEP Program Manager of significant project nonconformances and corrective actions taken as documented in CARs and/or quarterly progress reports (QRPs).

Michelle Krause
GBEP QAO
GBEP reviews and approves QAPPs and any amendments or revisions. Responsible for verifying that the QAPP is followed by the H-GAC. Assists the GBEP Program Manager and GBEP PM on QA-related issues. Prepares and distributes annual audit plans. Conveys QA problems to appropriate TCEQ management. Monitors implementation of corrective actions. Coordinates and conducts audits. Ensures maintenance of QAPPs and audit records for the GBEP program.

HOUSTON-GALVESTON AREA COUNCIL (H-GAC)

Paniz Miesen
H-GAC PM
The H-GAC PM is responsible for ensuring that all tasks and other requirements in the contract are executed on time and with the quality assurance/quality control requirements as defined by the contract and in the project QAPP; assessing the quality of subcontractor/participant work; submitting accurate and timely deliverables to the TCEQ GBEP PM; and coordinating attendance at conference calls, trainings, meetings, and related project activities with the TCEQ. Responsible for verifying that the QAPP is distributed and followed by the H-GAC (including all subcontractors and/or sub-tier project participants). Coordinates C&E staff assigned to conduct the desk reviews, groundtruthing field activities, sampling, and data acquisition for this project.

Jean Wright
H-GAC QAO
Responsible for coordinating development and implementation of the H-GAC's QA program. Responsible for writing and maintaining QAPPs, annual updates, and amendments, and monitoring their implementation. Responsible for maintaining records of QAPP distribution, including appendices and amendments. Responsible for maintaining written records of sub-tier commitment to requirements specified in this QAPP. Responsible for identifying, receiving, and maintaining project quality assurance records. Responsible for compiling and submitting the QA report. Responsible for coordinating with the GBEP to resolve QA-related issues. Notifies the H-GAC PM and GBEP PM of particular circumstances which deviate from requirements in the QAPP and may adversely affect the quality of data. Coordinates the research and review of technical QA material and data related to water quality monitoring system design and analytical techniques. Conducts assessments of participating organizations during the life of the project as noted in Section C1. Coordinates and monitors nonconformances and corrective actions. Also implements or ensures implementation of corrective actions needed to resolve nonconformances noted during assessments.

Bill Hoffman
H-GAC Data Manager
Responsible for the acquisition, verification, and transfer of data to the H-GAC PM. Oversees data management for the project. Provides the point of contact for the H-GAC PM to resolve issues related to the data and assumes responsibility for the correction of any data errors. Coordinates with H-GAC GIS Data Manager on use of data for GIS analysis.

Will Merrell
H-GAC GIS Data Manager
Responsible for the GIS data acquisition, interpretation, and analysis as well as providing technical guidance needed for the preparation of the project QAPP. Will oversee all GIS data processing, GIS and/or GPS data review, data analysis, incorporation of data into Basin 11 database, and will make sure the minimum requirements/ objective/data are met. H-GAC GIS Data Manager will work with H-GAC PM to address any GIS issues or concerns.

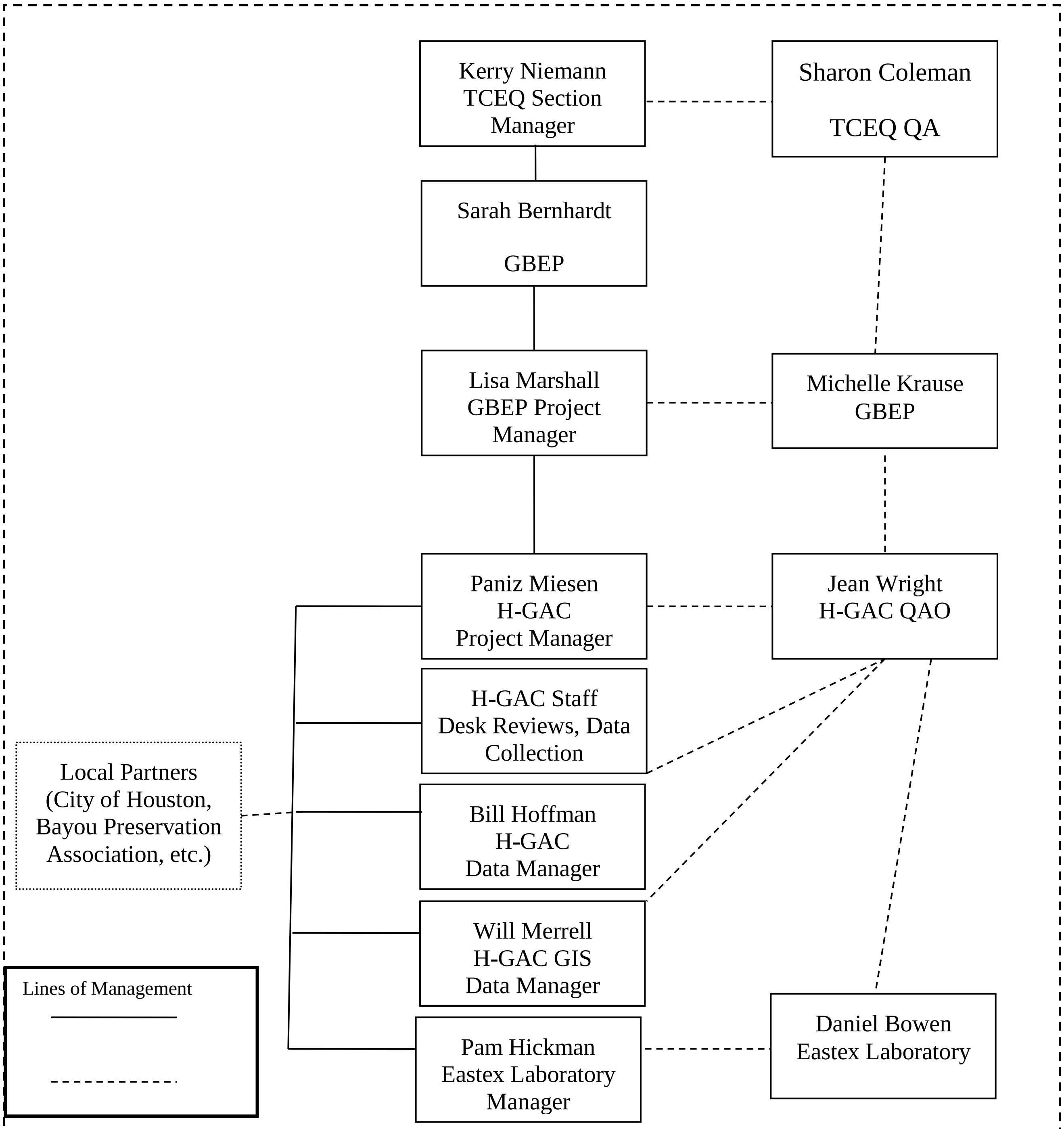
Eastex Environmental Laboratory (Eastex)

Pam Hickman
Laboratory Director - Eastex Environmental Laboratory (Contract Lab)
Responsible for producing quality analytical data for samples collected and submitted by H-GAC. Maintains verification of procedures establishing the level of quality. Responsible for sending data and COC forms to H-GAC within time specified in contract.

Daniel Bowen
Eastex Lab
Checks training, competency, and re-training of technicians. Performs verification and validation procedures to confirm quality data is issued to clients. Performs other QA/QC duties and checks associated with lab activities. Resolves out-of-control issues. Conducts internal lab audits.

Other Project Partners
Local governments, consultants, non-profits and other local and regional stakeholders (e.g. City of Houston Public Works, Bayou Preservation Association), particularly those involved in the Bacteria Implementation Group (BIG) may be invited to participate as part of a technical advisory work group. The work group will voluntarily assist the H-GAC project team with local knowledge of local conditions and may be asked to lend support in the field. Project partners will work alongside and not independent of H-GAC staff. Local partners will be determined during desk reviews and will be identified in reports.

Figure A4.1 Organization Chart



A5 Problem Definition/Background

The Bacteria Implementation Group (BIG) was formed in 2008, following the completed Total Maximum Daily Load (TMDL) study, to develop an implementation plan (I-Plan) that addresses the elevated levels of bacteria in 72 bacteria-impaired segments in the region. The BIG project area drains to Galveston Bay, where a sizeable area of the Bay's oyster producing waters are restricted to recreational harvest by the Texas Department of State Health Services due to elevated bacteria levels. Figure A5.1 presents the BIG project area map. Contact recreation is the primary impairment or concern identified in this BIG region and will be the focus of this project. The contact recreation standard uses indicator bacteria (*E. coli* and Enterococcus) as surrogates for the potential presence of human pathogens. Bacteria is known to come from a variety of sources (anthropogenic and wildlife) and is associated with land cover/land uses which include but are not limited to agriculture and urban development run-off and wastewater conveyance and treatment.

This project will address the Non-point Source and Point Source action plans of the Galveston Bay Plan, a Comprehensive Conservation Management Plan of the Galveston Bay Estuary Program. Illicit discharges were found by the BIG to be a potential source of bacteria impacting area streams. This project will identify potential bacteria discharges and seek to eliminate them by working with local jurisdictions.

The Houston-Galveston Area Council (H-GAC) is a Council of Governments (COG), the regional authority for the Gulf Coast State Planning Region, and has been actively involved in regional water quality planning and public outreach activities since the 1970's. H-GAC is a member of the BIG and has tracked bacteria levels to develop the Top Ten Most/Top Ten Least Impaired Lists (Top 10 Lists), "Most Wanted" (i.e. those impaired assessment units (AUs) with the highest geometric means relative to the state standards for bacteria) and "Most Likely to Succeed" (i.e. impaired AUs with the lowest geometric means relative to the state standards for bacteria). A project map that includes the Top 10 Lists can be found in Figure A5.1. Tables of the Top 10 Lists can be found in Appendix F.

H-GAC C&E staff will address ten targeted watersheds (five each from the Top 10 Lists) by prioritizing the watersheds through desk reviews, groundtruthing, identifying elevated sources of bacteria in the field through sample collection and analysis, and reporting those elevated bacteria sources to local jurisdictions where the sources were found. H-GAC will not correct the sources but will work with those jurisdictions to remove the sources. This project will demonstrate improved water quality and document the value of a prioritized watershed approach for correcting bacteria sources. Long-term AU water quality will be evaluated using CRP ambient monitoring not subject to this project. Results will be shared with BIG partners and other municipalities, particularly Municipal Separate Storm Sewer System (MS4) operators, through presentations and print material to encourage prioritization during Illicit Discharge Detection and Elimination (IDDE) programs.

The purpose of this QAPP is to clearly delineate H-GAC's QA policy, management, structure, and procedures which will be used to acquire the needed data from the identified sources and to complete the data analysis and land cover/land use comparisons. Data and results derived from this project will be used to increase understanding of water quality impairments and concerns and the source of those impairments or concerns. Results from this project may also be used by the TCEQ to address implementation of the Galveston Bay Plan and support future implementation projects to reduce bacteria to meet contact recreation standards in the Galveston Bay Watershed.

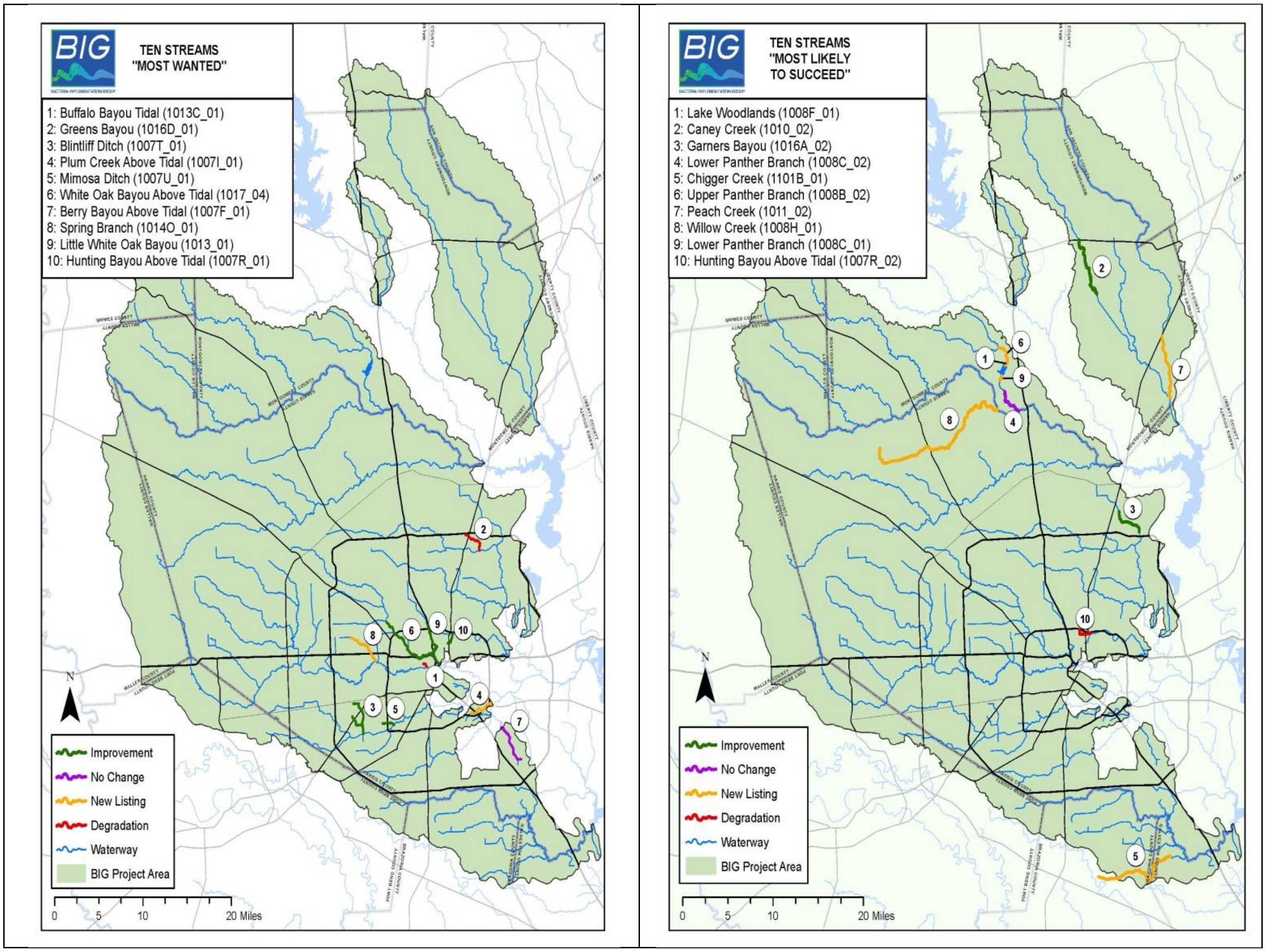


Figure A5.1 Project map depicting the BIG project area and Top Ten "Most Wanted" and Top Ten "Most Likely to Succeed" listed AUs.

A6 Project/Task Description

This project will use data collected through both direct and non-direct means. To simplify and monitor progress, this project has been split into three phases. Figure A6.1 delineates the three phases through a project flow chart and describes the tasks contained within. A project timeline has been provided with Figure A6.2. A more detailed and updated project work plan can be found in Appendix A.

Phase I

In Phase I of the project, H-GAC will conduct an initial desk review, Desk Review 1, of the Top 10 Lists to prioritize this list and pare it down to create a top five list for each top ten list. H-GAC will then conduct a more thorough desk review, Desk Review 2, to refine these lists one step further. The resulting prioritized list of two from each top 5 lists will then be subjected to ground truth analysis.

During Phase I, local project partners will be invited to participate in a technical work group to share their extensive knowledge of subject AUs. Local partners might be asked to participate alongside H-GAC in surveys of the selected AUs. The goal is to remove sources of bacteria in waterways and catchment areas which local partners might have jurisdiction. Developing trust and input by local partners will potentially facilitate future follow up actions to remove sources by these partners in Phase III of the project. Involvement of local partners will be detailed in project reports provided to the TCEQ.

During Desk Review 1, an assessment unit spreadsheet will be created which will contain at minimum, AU descriptions, monitoring station ID(s), location of monitoring stations, bacteria concentration (geometric mean), WWTF outfall locations, and stormwater outfall locations for the Top 10 lists. GIS will be used to capture aerial imagery for the AUs and conduct general geospatial analysis to determine accessibility. Previously collected quality assured ambient monitoring data from H-GAC and its partners (through CRP), TCEQ SWQM Program, and the U.S. Geological Survey (USGS) will be gathered during this part of Phase I. All data collected by TCEQ regional personnel are covered under the SWQM Program QAPP. The impaired watersheds will also be prioritized based on the I-Plan's recommendation under the Geographic Priority Framework for five criteria: Bacteria Level, Accessibility, Use Level, Implementation Opportunities, and Future Land Use Changes. If other criteria are determined as this project develops, those criteria will be written into the Final Report and made into a recommendation to the BIG for revision of the BIG I-Plan. The Top 10 Lists will be pared down to create preferential top five most and top five least (Top 5) lists for further review.

Under Desk Review 2, H-GAC will further refine the AU spreadsheet by defining the size of each AU catchment, completing AU bacteria trends using historical data beginning with January 1, 2003, and if sufficient data is available, complete load duration curves (LDCs) for the Top 5 Lists. GIS will be used to complete land use/land cover analysis (LU/LC), consider potential sources, and evaluate further the accessibility to AU and catch basin. Completed analysis should be able to prioritize the Top 5 Lists down to the top two most and top two least (Top 2) lists.

LDCs for the AUs will be calculated where feasible, should sufficient historic bacteria data and flow data be available. LDC and Flow Duration Curves (FDCs), a precursor in developing LDCs, will be calculated and plotted for bacteria in each selected AU. An LDC is a graphical illustration that shows the corresponding relationship between contaminant loadings and stream flow conditions in the AU. While sometimes considered as models, FDCs and LDCs are not in the truest sense models. Further they do not require calibration to measured data nor do they require validation to measured data, thus obviating these tasks of typical model development and coverage of these tasks by a QAPP. An LDC is a simple and effective first-step methodology to obtain data-based evaluations of the general relationship of concentrations to flow conditions, and allows for vary basic comparisons between LU/LC data.

LDCs assist in determining patterns in pollution loading (point sources, nonpoint sources, erosion, etc.) depending on the streamflow conditions. Based on the observed patterns, specific management measures can be implemented that target a particular kind of pollutant source. Another main advantage of the LDC method is that it can also be used to evaluate the current impairment by determining the percent of samples that exceed the standard.

The final step in Phase I will be to complete an AU Intensive Study by conducting ground truth analysis of the Top 2 Lists. Ground truth analysis will entail performing windshield surveys of the AU catchment area and waterway reconnaissance surveys where the AUs and tributaries are walked. Windshield and waterway reconnaissance will be conducted using established data collection forms and checklist developed by H-GAC. Example field data sheets and expected survey data collected can be found in Appendix C. Additionally, during the walks, bacteria screening samples will be collected at potential outfalls and suspected effluents to quickly establish areas of the AUs for follow-up monitoring during Phase II. Field staff will track the windshield survey and walks using GPS handheld devices to log the path traveled and collect waypoints for screening sample collection locations, additional outfall structure locations, potential sources, and other project relevant observations for follow-up during Phase II and Phase III. Photographs will also be taken to document observations.

During the initial waterway surveys, H-GAC will document pipe outfalls with dry weather effluent discharges. All outfalls emitting effluent during dry weather will be screened for bacteria by collecting samples for processing at H-GAC. H-GAC will follow Texas Stream Team (TST) protocols for collecting and analyzing screening bacteria samples as established in the TST procedures manual, chapter 4, and using Coliscan Easygel method. The excised portion of procedure manual specific to TST bacteria samples can be found in Appendix D. TST is a quality assured voluntary monitoring program managed by joint collaboration between the Meadows Center for Water and the Environment at Texas State University, the TCEQ, and EPA. H-GAC is the lead for TST activities in the region and staff is certified to train and audit TST volunteers. Samples will be handled within the required holding time as documented in the TST procedures manual. Bacteria screening will help prioritize areas within the AUs for further bacteria analysis during Phase II. A Preliminary Action Report documenting the results of Phase I will be created at the end of Phase I (See Appendix A, Project Work Plan).

Phase II

Bacteria samples and field parameters will be collected following the established policies and procedures of the CRP during Phase II. H-GAC is the CRP lead agency for the San Jacinto River Basin (Basin 10) and three associated coastal basins – the Trinity-San Jacinto (Basin 9), the San Jacinto-Brazos (Basin 11), and the Brazos-Colorado (Basin 13), which covers all of the BIG project area. Monitoring will be used to firmly establish bacteria concentrations found during bacteria screening and to further refine source identification and aid in tracking the source(s) of the impairment up the tributaries and ditches to the greatest extent practicable. H-GAC will monitor the prioritized AUs during wet weather and dry weather conditions by returning to suspected waypoints plotted during Phase I that exhibited elevated levels of bacteria.

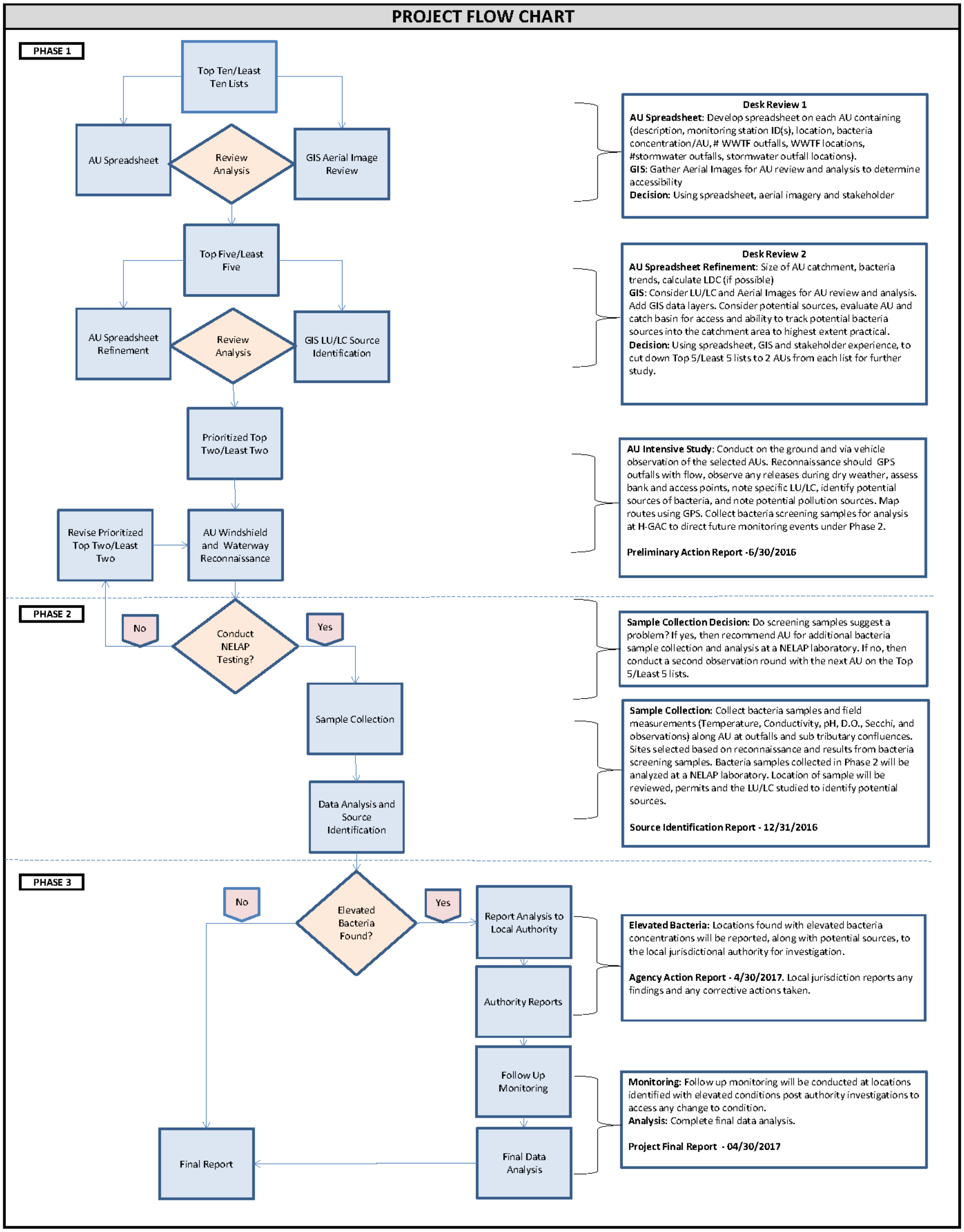


Figure A6.1 Project flow chart delineating phases and tasks.

All sampling and laboratory analysis methods are specified in H-GAC's Texas CRP FY 2016-2017 Regional Monitoring Activities Quality Assurance Project Plan (QAPP) as well as all past TCEQ approved QAPPs, revisions, and amendments. The collection and qualification of the Texas CRP data collected in the H-GAC region are addressed in the H-GAC's CRP QAPP found at http://www.h-gac.com/community/water/rivers/data/regional-quality-assurance-project-plan.aspx. All bacteria samples and conventional field parameters collected will follow this plan. Sample field data sheets can be found in Appendix C. Bacteria samples collected during Phase II will be analyzed at a NELAP certified laboratory and will be processed within the required holding time as noted in footnotes to Table A7.1b on page 22. Bacteria samples will be analyzed using IDEXX Colilert method.

The locations with high concentrations of bacteria will then be identified and plotted with GPS for use during Phase III. A Source Identification Report will document the results of Phase II (See Appendix A, Project Work Plan).

Phase III

In Phase III of the project, H-GAC will direct any project findings to the appropriate jurisdiction for further investigation. Additionally, any potential sources identified through the desk review and field ground truth analysis will be directed to local jurisdictions. H-GAC will not have any role in removing or remediating any bacteria source, determining the specific type of action needed or taken, nor providing project funding to local jurisdictions for implementing any identified action. H-GAC will not nor has the authority to require any action be taken by the local jurisdiction.

H-GAC will attempt to track implementation carried out by the local jurisdiction by documenting any remedial actions carried out to remove or modify the elevated effluent sources. Once sources have been reported as corrected, H-GAC will collect follow-up bacteria samples at locations where elevated bacteria concentrations were found to determine if the corrective action(s) resulted in improved water quality. All bacteria samples collected during Phase III will be analyzed at a NELAP certified laboratory. A final report will be created at the end of Phase III and will be used to document results from Phase III and summarized the entire project. (See Appendix A, Project Work Plan)

Data Collection, Acquisition, and Analysis

While much of the project addressed in this QAPP will require collection of direct measurements of data (i.e. windshield and water way reconnaissance, bacteria sample collection and analysis, and conventional parameters using a calibrated datasonde), this project will also require the acquisition of existing water quality data collected through other projects and the potential use of said data for purposes other than those for which the data were originally collected.

Non direct data will be gathered from the CRP program, TCEQ Field Ops, and the USGS who also collect or have collected ambient water quality data, including bacteria, through routine monitoring or during special studies. Only non-direct measured data collected after January 1, 2002 will be used in this project. The acquired data will include all bacteria data and associated field parameters collected with a calibrated datasonde. All acquired water quality data stored in SWQMIS was collected under approved QAPPs.

Routine ambient water quality data collected by CRP partners as well as the TCEQ are stored with other types of data in TCEQ's Surface Water Quality Monitoring Information System (SWQMIS) database. SWQMIS data are available from the TCEQ "Surface Water Quality Viewer" site (http://www.tceq.state.tx.us/gis/surface-water-quality-viewer). Data undergoes rigorous validation and verification processes outlined in applicable QAPPs.

H-GAC routinely acquires GIS data sets from reliable sources such as USGS, Texas Natural Resources Information System (TNRIS), TCEQ, US Census Bureau, COGs, and other local, regional, state, and federal organizations or governments. A complete list of files and sources is provided in Appendix 5 of H-GAC's C&E Data Management Plan (The Plan) found in Appendix B of this document. Using geospatial software, H-GAC's Community and Environmental Planning Department (C&E) develops, stores and/or maintains new created GIS data sets generated for this project. Data sets being used in this project include but are not limited to the following:

- 1996, 2001, 2006, 2011 and 2015 land cover/land use/aerial imagery data sets (exist in 5 year intervals only)
- 2016 CRP stream network and station datasets
- "H-GAC_15_County_Soils_2012_w_taxonomy" 2015 soils data layer
- elevation
- impervious/pervious cover
- EPA's Nitrogen and Phosphorus Data Access Tool (based on HUC 8's)
- USGS HUC 8 and USGS HUC 12 layers
- run-off curve number
- other databases as deemed necessary.

Bacteria trends will be assessed using a variety of parametric and non-parametric methods. If more than fifteen percent of the bacterial data in the analytical unit of interest are censored, survival analysis (SAS PROC LIFEREG) will be applied. H-GAC will use SAS General Linear Model (PROC GLM) to evaluate nominal variables and interactions between variables as appropriate. Discriminant analysis will be used to test correlations and classifications. Canonical correlation and Pearson/Spearman/Kendall correlation matrices may be included for reference.

H-GAC will control the Type I error rate by applying a significance level of 0.05 in all statistical tests. The applicable null hypothesis will be rejected if the p-value of the statistical test is below 0.0545. Where feasible, H-GAC will calculate the statistical power and Type II error rate for all tests. Data will be evaluated to ensure the assumptions of specific statistical tests are met. For parametric tests, data transformations will be employed as needed. If parametric tests are not appropriate due to the nature of the data, semi-parametric or nonparametric tests will be applied. No data will be disqualified on a statistical basis alone. Because all data that might be considered an "outlier" was confirmed as correct prior to inclusion in SWQMIS, outliers will not be removed but will be included in analysis using statistical tests that are insensitive to outliers.

Maps developed will be for illustrative purposes. Geospatial data utilized in maps may include land use, land cover, elevation, pervious/impervious cover, precipitation, soil type, run-off curve numbers, ecoregion, TCEQ monitoring station location, TCEQ permitted WWTF outfall, on-site sewage facilities (OSSFs), USGS gage location, city/county/state boundary, stream hydrology, reservoir, drought, road, watershed, municipal separate storm sewer system, urbanized area, basin, railroad, recreational area, area landmark, aerial photography. Park information may also be used to develop informative maps of the study area.

To assist with this project, H-GAC also maintains a centralized geospatial warehouse of both tabular (non-geographic) and spatial (geographic) datasets. Geographical Information System (GIS) staff in the C&E capture, manipulate, analyze, store and display spatially referenced data and associated metadata to support a wide variety of applications ranging from sites assessments, environmental planning, urban planning, and spatial analysis.

H-GAC will work to facilitate general education and outreach concerning IDDE and bacteria impairments across the watershed to raise the general awareness, but particularly with MS4s. H-GAC will also support watershed management, water quality issues, and options available to stakeholders to address water quality impairments during future watershed planning initiatives. The project, including any analysis, conclusions and recommendations, will be documented in a final report.

The Final Report will be written detailing the results of all data analysis, comparisons and correlation testing. A draft report will be due April 30, 2017. A final report will be due May 31, 2017 following receipt of TCEQ comments to the draft. Results from this project may be used by TCEQ for further implementation of the Galveston Bay Plan and help develop additional watershed action planning projects.

A project timeline can be found in Figure A6.2. The work to be performed and the products to be produced are described in detail in the project work plan (see Appendix A).

QAPP ANNUAL Revision

Until the work described is completed, this QAPP shall be revised as necessary and reissued annually on the anniversary date, or revised and reissued within 90 days of significant changes, whichever is sooner. The revision must be submitted to the TCEQ for approval 120-90 days before the last approved version expires. If the entire QAPP is current, valid, and accurately reflects the project goals and the organization's policy, the annual re-issuance may be done by certification that the plan is current. This can be accomplished by submitting a cover letter stating the status of the QAPP, including any amendments, and a copy of new, signed approval pages for the QAPP.

Amendments TO THE QAPP

Amendments to the QAPP may be necessary to reflect changes in project organization, tasks, schedules, objectives and methods; address nonconformances; improve operational efficiency; and/or accommodate unique or unanticipated circumstances. Requests for amendments are directed from the H-GAC's PM to the TCEQ GBEP PM in writing using the GBEP QAPP Amendment form (Appendix H). The GBEP PM will consult with the GBEP QAO to determine if the changes are substantive or eligible for the expedited amendment process. The changes are effective immediately upon approval by the H-GAC PM, the GBEP PM and QAO, and TCEQ QA Manager. Amendments to the QAPP and the reasons for the changes will be documented. Copies of the approved QAPP Amendment form will be distributed to all individuals on the QAPP distribution list by the H-GAC.

Amendments shall be reviewed, approved, and incorporated into a revised QAPP during the annual revision process or within 120 days of the initial approval in cases of significant changes.

Top 5/Least 5																						
		Quarter One			Quarter Two			Quarter Three			Quarter Four			Quarter One			Quarter Two			Quarter Three		
Task 1	Project Administration	Project Communication and Drafting PR			Project Communication and Drafting PR			Project Communication and Drafting PR			Project Communication and Drafting PR			Project Communication and Drafting PR			Project Communication and Drafting PR			Project Communication and Drafting PR		
	Paniz Miesen	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Todd Running	*	*	*	*	*	*	*	*	*	X	*	X	X	*	*	X	*	*	X	*	X
	Jeff Teabel	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Stephanie Beckford	*	*	*	X	*	*	X	*	*	X	*	*	X	*	*	X	*	*	X	*	X
	Virgie Hall	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	David Waller	*	*	*	X	*	*	X	*	*	X	*	*	X	*		X	*		X	*	X
Task 2	QAPP	Draft QAPP		QAPP Approval		QAPP Monitoring											QAPP Update		QAPP Monitoring			
	Paniz Miesen	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
	Jean Wright	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Bill Hoffman	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Thushara Ranatunga	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Task 3	Desk Review and Survey: Data Acquisition, Summarization and Analysis			Identify Existing Datasets				Acquire, Process, Create Databases, Process, Analyze Datasets														
	Paniz Miesen			X	X	X	X	X	X	X	X	X										
	Bill Hoffman			X	X	X	X	X	X	X	X	X										
	Thushara Ranatunga			X	X	X	X	X	X	X	X	X										
	Will Merrell			X	X	X	X	X	X	X	X	X										
	Rachel Fields			X	X	X	X	X	X	X	X	X										
Task 4	NELAP Bacteria Samples: Data Collection, Summarization and Analysis													Collect, Process, Analyze Bacteria Samples (NELAP)						Follow Up Sample Monitoring		
	Paniz Miesen											X	X	X	X	X	X	X	X	X	X	
	Bill Hoffman											X	X	X	X	X	X	X	X	X	X	
	Thushara Ranatunga											*	*	*	*	*	*	*	*	*	*	
	Will Merrell											X	X	X	X	X	X	X	X	X	X	
	Rachel Fields											X	X	X	X	X	X	X	X	X	X	
Task 5	Reporting and Outreach			Outreach: Local Jurisdictions, Watershed Stakeholder Groups, etc.																		
	Paniz Miesen			*	*	*	*	X	X	*	*	*	*	X	X	*	*	*	*	*	X	X
	Rachel Fields			*	*	*	*	X	X	*	*	*	*	X	X	*	*	*	*	*	X	X
Time Line		Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17
Results/Deliverables					Progress Report, FSRs			Progress Report, FSRs			Progress Report, FSRs			Progress Report, FSRs			Progress Report, FSRs			Progress Report, FSRs	Progress Report	Progress Report
			QAPP (draft)		Revised QAPP								Preliminary Action Report					QAPP Update (Draft)		Source Identification Report	Draft Final Report & Agency Action Report	Final Report

Figure A6.2 Project Timeline.

A7 Quality Objectives and Criteria

Existing data from other sources will be acquired and used as described in Section B9. Data will also be collected directly for this project.

The purpose of the water quality monitoring described in this QAPP is to collect bacteria samples in impaired AUs found in the BIG project area, identify potential sources of bacteria, work with local jurisdictions to remove or remediate sources of bacteria and observe improved water quality. H-GAC will have control over any data collected and observable information gathered, but does not have any control over how that information is received or acted upon by the local jurisdiction once notified.

This project is an example of systematic watershed monitoring, which is defined by sampling that is planned for a short duration (1 to 2 years) and is designed to: screen waters that would not normally be included in the routine monitoring program, monitor at sites to check the water quality situation, and investigate areas of potential concern. Due to the limitations regarding these data (e.g., not temporally representative, limited number of samples), the data will be used to determine whether any locations have values exceeding the TCEQ's water quality standards for bacteria.

Bacteria samples will be collected as screening samples during Phase I and follow-up laboratory samples used to confirm any elevated bacteria levels. Screening bacteria samples will be collected and analyzed following methods established by the TST. Follow-up bacteria samples, field parameters, and observations will be collected following procedures established under the CRP. Bacteria samples will be processed at a NELAP certified lab. The list of field parameters can be found in Table A7.1.

The measurement performance specifications to support the project objectives for a minimum data set are specified in Tables A7.1a and b below.

Ambient Water Reporting Limits (AWRLs)

AWRLs establish the reporting specification at or below which data for a parameter must be reported to be compared with freshwater screening criteria. AWRLs for field measurements as presented in Table A7.1a are considered not applicable (NA) and measurement performance will be consistent with SWQM guidance and standard measurement capability. The AWRLs specified in Table A7.1b are the program-defined reporting specifications for each analyte and yield data acceptable for TCEQ water quality assessment. The limit of quantitation (LOQ) is the minimum level, concentration, or quantity of a target variable (e.g., target analyte) that can be reported with a specified degree of confidence.

Table A7.1a - Field Measurement Performance Specifications for Routine Systematic and Biased Flow Monitoring Events

PARAMETER	UNITS	MATRIX	METHOD	PARA-METER CODE	AWRL	LOQ	LOQ CHECK STD %Rec	PRECISION (RPD of LCS/LCS dup)	BIAS (%Rec. of LCS)	Lab
Temperature	ºC	water	SM 2550 and TCEQ SOP, V1	00010	NA	NA	NA	NA	NA	Field
Specific Conductance	µS/cm	water	EPA 1201 and TCEQ SOP, V1	00094	NA	NA	NA	NA	NA	Field
pH	standard units	water	EPA 150.1 and TCEQ SOP, V1	00400	NA	NA	NA	NA	NA	Field

PARAMETER	UNITS	MATRIX	METHOD	PARA-METER CODE	AWRL	LOQ	LOQ CHECK STD %Rec	PRECISION (RPD of LCS/LCS dup)	BIAS (%Rec. of LCS)	Lab
DO	mg/L	water	SM 4500-O G. and TCEQ SOP, V1	00300	NA	NA	NA	NA	NA	Field
Transparency, Secchi Disc	meters	water	TCEQ SOP, V1	00078	NA	NA	NA	NA	NA	Field
Days since precipitation event	days	other	TCEQ SOP V1	72053	NA	NA	NA	NA	NA	Field
Wind Intensity (1=calm, 2=slight,3=mod, 4=strong)	No Unit	other	NA	89965	NA	NA	NA	NA	NA	Field
Present Weather (1=clear,2=ptcldy, 3=cldy,4=rain, 5=other)	No Unit	other	NA	89966	NA	NA	NA	NA	NA	Field
Water Color (1=brownish, 2=reddish,3=greenish,4=blackish, 5=clear,6=other)	No Unit	water	NA	89969	NA	NA	NA	NA	NA	Field
Water Odor (1=sewage,2=oily/ chemical,3=rotten egg,4=musky, 5=fishy,6=none, 7=other)	No Unit	water	NA	89971	NA	NA	NA	NA	NA	Field
Water clarity (1=excellent,2=good,3=fair,4=poor)	No Unit	water	NA	20424	NA	NA	NA	NA	NA	Field
Turbidity, observed (1=low,2=medium, 3=high)	No Unit	water	NA	88842	NA	NA	NA	NA	NA	Field
Algae Cover	No Unit	other	NA	NA	NA	NA	NA	NA	NA	Field
Primary contact, observed activity (# of people observed)	# of people observed	other	NA	89978	NA	NA	NA	NA	NA	Field
Evidence of primary contact recreation (1=observed, 0=not observed)	No Unit	other	NA	89979	NA	NA	NA	NA	NA	Field

References for Table A7.1a:

- United States Environmental Protection Agency (USEPA) "Methods for Chemical Analysis of Water and Wastes," Manual #EPA-600/4-79-020
- American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF), "Standard Methods for the Examination of Water and Wastewater," 20th Edition, (or most recent version)
- TCEQ SOP, V1 - TCEQ Surface Water Quality Monitoring Procedures Manual, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue, August 2012 or most recent editions (RG-415)

H-GAC does not anticipate this data being submitted to SWQMIS; however, all results will be provided to GBEP PM who will consult with TCEQ's Data Management Section. If deemed appropriate, the following requirements must be met in order to report results to the TCEQ SWQMIS:

- The laboratory's LOQ for each analyte must be at or below the AWRL as a matter of routine practice
- The laboratory must demonstrate its ability to quantitate at its LOQ for each analyte by running an LOQ check sample for each batch of samples analyzed.

Table A7.1b - Measurement Performance Specifications for Screening and Systematic Monitoring.

PARAMETER	UNITS	MATRIX	METHOD	PARA-METER CODE	AWRL	LOQ	LOQ CHECK STD %Rec	Log Difference of Duplicates	BIAS (%Rec. of LCS)	Lab
E. coli, , Colilert, IDEXX method MPN/mL	MPN/100 mL	water	Colilert-18[2]	31699	1	1	NA	0.5[1]	NA	Eastex
E. coli, Colilert, IDEXX, holding time	hours	other	NA	31704	NA	NA	NA	NA	NA	Eastex
E. coli, Coliscan Easygel	CFU/100mL	water	Coliscan Easygel[3]	NA	1	1	NA	1.0	NA	H-GAC
E. coli, Coliscan Easygel, holding time	hours	other	NA	NA	NA	NA	NA	NA	NA	H-GAC

1 It represents the maximum allowable difference between the logarithm of the sample result and the logarithm of the duplicate result. See Section B5.
2 *E.coli* samples analyzed by IDEXX Colilert-18 will always be processed as soon as possible and within 8 hours, but no more than 24 hours for non-regulatory samples.
3 Screening *E. coli* samples analyzed by Coliscan Easygel should always be processed as soon as possible and within 6 hours.

References for Table A7.1b:

- United States Environmental Protection Agency (USEPA) "Methods for Chemical Analysis of Water and Wastes," Manual #EPA-600/4-79-020
- American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF), "Standard Methods for the Examination of Water and Wastewater," 20th Edition or most recent version
- TCEQ SOP, V1 - TCEQ Surface Water Quality Monitoring Procedures Manual, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue, August 2012 or most recent editions (RG-415)

Precision

Precision is the degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves. It is a measure of agreement among replicate measurements of the same property, under prescribed similar conditions, and is an indication of random error.

Laboratory precision is assessed by comparing sample/duplicate pairs. Precision results are compared against measurement performance specifications and used during evaluation of analytical performance. Program-defined measurement performance specifications for precision are defined in Tables A7.1b.

Representativeness

No ambient monitoring will be conducted during this project. Each outfall that is sampled will be assessed on an individual basis.

Completeness

The completeness of the data is basically a relationship of how much of the data is available for use compared to the total potential data. Ideally, 100% of the data should be available. However, the possibility of unavailable data due to accidents, insufficient sample volume, broken or lost samples, etc. is to be expected. Therefore, it will be a general goal of the project(s) that 90% data completion is achieved.

Comparability

The only data comparisons conducted during this project will be between pre and post sampling of outfalls with flows. There will be no comparison with ambient data during this project.

Laboratory measurement quality control requirements, method sensitivity and acceptability criteria are provided in tables found in Section A7 and discussed in Section B5.

A8 Special Training/Certification

No special certifications are required to collect or evaluate water quality data for this project. However, all employees involved in this project will have the proper experience and educational credentials to understand the relevant issues and concepts. Plus, employees involved in each phase of the project have received additional training to be or already are proficient in using the equipment necessary to conduct field sampling under CRP, TST or to evaluate data using software required to complete each task.

- *SAS (Statistical Analysis Software) – college or vendor training to accomplish necessary water quality data analyses.*
- *GIS software – college or vendor trained and experienced in geospatial concepts and use of H-GAC GIS software.*
- *Map/Photo interpretation training and/or experience and understanding of cartographic concepts.*
- *Remote Sensing software – training and/or experience in remote sensing concepts and H-GAC software.*
- *Geospatial metadata – college or workshop training recommended.*
- *"A Guidance Manual for Identifying and Eliminating Illicit Connections to Municipal Separate Storm Sewer Systems (MS4)," prepared by the Galveston County Health District, Pollution Control Division, August 2002.*

Personnel conducting work associated with this project are deemed qualified to perform their work through educational credentials, specific job/task training, required demonstrations of competency, and internal and external assessments.

Laboratories are NELAP-accredited as required. Records of educational credentials, training, demonstrations of competency, assessments, and corrective actions are retained by project manager or designee and are available for review.

A9 Documents and Records

All GIS datasets generated by H-GAC have been fully documented as to original source, quality, and history per Federal Geographic Data Committee (FGDC) compliant metadata. Similarly, outside sources obtained and used by H-GAC will require FGDC-compliant metadata as provided by the source agency. Datasets without a known history and documented quality will be noted as provisional and used only when noted as such. Metadata will be completed for any modifications to outside sources, or integration of outside sources with agency datasets. Metadata formats possibly included html, xml, or txt.

The document and records that describe, specify, report, or certify activities, requirements, procedures, or results for this project are listed. H-GAC sends hard copies to off-site storage 2 years after the contract is closed. Otherwise, they are kept on-site for easy access.

Table A9.1a Project Documents and Records for H-GAC

The documents and records that describe, specify, report, or certify activities are listed In Table A9.1. All records are kept for a minimum of seven years after the end of the project.

Table A9.1 Project Documents and Records for H-GAC

Document/Record	Location	Retention*	Format
QAPPs, amendments and appendices	H-GAC	7 years	Paper/ Electronic
QAPP distribution documentation	H-GAC	7 years	Paper
Desk Review paperwork	H-GAC	7 years	Paper
Data Analysis - including SAS, GIS, LDC	H-GAC	7 years	Electronic
Field data sheets	H-GAC	7 years	Paper
Field instrument print outs	H-GAC	7 years	Electronic
Field staff training records	H-GAC	7 years	Paper
Field equipment calibration/maintenance logs	H-GAC	7 years	Paper
Chain of custody records	H-GAC	7 years	Paper
Field SOPs	H-GAC	7 years	Paper
Data Quality Review Checklist for Bacteria testing using Easygel	H-GAC	7 years	Paper
Corrective Action Documentation	H-GAC	7 years	Paper/Electronic

*Retention period in paper format/electronic format.

Table A9.1 Project Documents and Records for Eastex Lab

Document/Record	Location	Retention*	Format
QAPPs, amendments and appendices	H-GAC	7 years	Paper/ Electronic
Chain of custody records	Eastex and/or H-GAC	7 years	Paper
Laboratory QA Manuals	Eastex	7 years	Paper
Laboratory SOPs	Eastex	7 years	Paper
Laboratory data reports/results	Eastex	7 years	Paper
Laboratory staff training records	Eastex	7 years	Paper
Instrument printouts	Eastex and/or H-GAC	7 years	Paper
Laboratory equipment maintenance logs	Eastex	7 years	Paper
Laboratory calibration records	Eastex	7 years	Paper
Corrective Action Documentation	Eastex and/or H-GAC	7 years	Paper

*Retention period in paper format/electronic format.

All H-GAC records, including notebooks, binders, and electronic files of technical staff, will be archived by H-GAC for at least seven years after the end of the project. Electronic data are stored on individual computers and on the network servers. The network servers are backed up nightly. After one week, data tapes are sent off-site to an electronic storage warehouse where they are held for 8 weeks. At the end of that 8 week period, the tapes are sent back to H-GAC to be re-used to back-up the servers again and the cycle begins again. In the event of a catastrophic systems failure, the tapes can be used to restore the lost data. Data generated on the day of the failure may be lost, but can be reproduced from raw data in most cases.

The TCEQ may elect to take possession of records at the conclusion of the specified retention period.

Laboratory Test Reports

Test/data reports from the laboratory will document the test results clearly and accurately. Reporting of the data will follow standard formats and protocols for *TNI Volume 1 Module 2 Section 5.10* and include the information necessary for the interpretation and validation of data.

Eastex is the contract lab for H-GAC's monitoring program. The final lab data for H-GAC's program are submitted by Eastex directly to H-GAC's Data Manager. It is reformatted as needed and reviewed prior to use. Eastex lab reports include the following information.

1) The title "Test Report" or other identifying statement (the lab offers several report formats);
2) Name and address of laboratory, and phone number with name of contact person;
3) A unique identification number and the total number of pages, with all pages sequentially numbered;
4) Name and address of client;
5) Description and unambiguous identification of the sample(s) including the client identification code (i.e. station information);
6) Identification of results for any sample that did not meet sample acceptance requirements;
7) Date of receipt of sample, date and time of sample collection, sample matrix, and time of sample preparation and/or analysis if the required holding time for either activity is less than or equal to 48 hours (including holding time for SM9223-B);
8) Identification of the test method used plus its LOQ;
9) Reference to sampling procedure (grab or composite);
10) Any deviations from, additions to or exclusions from SOPs, and any conditions that may have affected the quality of results, and including the use and definitions of data qualifiers;
11) Measurements, examinations and derived results, supported by tables, graphs, sketches and photographs as appropriate, and any failures identified; identification of whether data are calculated on a dry weight or wet weight basis; identification of the reporting units such as µg/l or mg/kg;
12) Clear identification of all test data provided by outside sources, such as subcontracted laboratories, clients, etc.;
13) Clear identification of numerical results with values below the Reporting Limit, and
14) Identification of accreditation status per analysis.

If H-GAC receives any Eastex summary reports without all the above information, it is still available upon request.

Electronic Data

Should TCEQ wish to upload data from this project to SWQMIS, H-GAC will submit data to the GBEP/TCEQ in the event/result format specified in TCEQ's 2016 Data Management Reference Guide (DMRG) (https://www.tceq.texas.gov/assets/public/waterquality/dma/dmrg/dmrg_complete.pdf).

B1 Sampling Process Design

Data sample collection and analysis will be completed in all three phases of this project. Additionally, data will be acquired as non-direct measurements. All non-direct measurements will be discussed under B9.

Phase I

The basis for sample design is the BIG's Top Ten "Most Wanted" Streams and the Top Ten "Most Likely" Stream Lists where the bacteria concentration, ten AUs with highest concentration for "Most Wanted" and ten AUs with concentration just above standard, is used to rank the AUs for the BIG project area. The most recent ranking of the Top Ten Lists can be found in Appendix E. The rationale for using these two lists include:

- addressing a ranking from the BIG, therefore implementing an activity of the BIG I-Plan,
- AUs with the highest geometric mean concentration afford the opportunity to find and address bacteria sources, and
- AUs with the lowest concentration offer an opportunity to remove or remediate a source that might eventually take that AU off the state's impaired waters listing.

Starting from these two lists, H-GAC will complete two separate desk reviews to pare the lists down to two AUs from each of the Top Ten Lists. The project flow chart, Figure A6.1 on page 15, delineates this process, the three project phases and describes the tasks contained within.

Data will be collected from the Top2 List AUs through two methods: surveys and sample collection. H-GAC will conduct AU windshield and waterway surveys. Field data sheets have been created for conducting the reconnaissance and gathering observable data. The data sheets can be found in Appendix C. The purpose of the surveys is to identify outfalls with effluent discharges, observe physical characteristics of the waterway, bank habitat characteristics, confirm land cover uses within the AU catchment basin, and identify potential sources of pollution upstream of effluent discharges that have been identified with elevated levels of bacteria. The routes for the surveys will be tracked using GPS and interesting observation waypoints will be logged using GPS. The manual for the Garmin GPS units can be found in Appendix F. The forms and the information logged into GPS will then translated into GIS for each AU and catchment area for latter analysis. Photographs will also be taken to document observations.

During the waterway surveys H-GAC staff will also collect bacteria screening samples at outfalls exhibiting discharges during dry weather. The expectation is that only WWTFs should emit a discharge during dry weather. Sample locations will be identified using GPS and logged into the GPS for use in reporting and to potentially return to the location in later phases of the project. The screening samples will assist project staff in tracking potential sources back to their origin or to the furthest extent possible. Samples will then be taken to H-GAC and processed using TST procedures, Chapter 4, using Coliscan Easygel (Appendix D). Outfalls where samples were found to be elevated will then be confirmed during Phase II. Results from Phase I will be summarized in the Preliminary Action Report.

Phase II

During Phase II, H-GAC staff will return to outfall locations at least once during dry and wet weather conditions, using GPS data collected in Phase I, within the selected AUs that were found to have elevated levels of bacteria. During wet weather events, not all outfall locations will be monitored due to inaccessibility. Monitoring will be conducted during or immediately after a rainfall event that has created runoff, preferably preceded by a 72-hour antecedent dry period. Wet weather sampling events may also occur in the absence of a 72-hour antecedent dry period if trace rains with a total accumulation of less than 0.25 inches has occurred prior to sampling.

Bacteria samples and field measures using a calibrated datasonde will be taken at those locations. H-GAC will collect the samples following H-GAC's Texas CRP FY 2016-2017 Regional Monitoring Activities QAPP. Following appropriate sample and chain of custody procedures, the samples will be analyzed at Eastex Laboratory, a NELAP certified laboratory using procedures for IDEXX Colilert found in the CRP QAPP. Results from the processed samples and from surveys conducted in Phase II will be summarized in the Source Identification Report.

Phase III

Where elevated bacteria samples were found in Phase II, local jurisdictions will be alerted. Information passed along will include: locations of the samples taken, bacteria concentrations found, and potential bacteria sources identified. H-GAC will work with the local jurisdictions that were notified and document any actions taken by the local jurisdictions to remove or remediate sources of bacteria. Once actions have been taken, H-GAC will return to the location of the elevated samples to conduct follow-up bacteria sample collection to determine if the actions taken improved water quality. H-GAC will collect samples following H-GAC's Texas CRP FY 2016-2017 Regional Monitoring Activities QAPP. Following appropriate sample and chain of custody procedures, the samples will be analyzed at a NELAP certified laboratory using procedures found in the CRP QAPP.

B2 Sampling Methods

Field Sampling Procedures

Field sampling and data collection will be conducted according to procedures documented in the most current version of the *TCEQ SWQM Procedures, Volume 1*. Specifications outlined in Table B2.1 reflect additional requirements for sampling for the project and/or provide additional clarification.

Table B2.1 Sample Storage, Preservation and Handling Requirements for H-GAC Bacteria Samples.

Parameter	Matrix	Container	Preservation	Sample Volume	Holding Time
E. coli IDEXX Colilert	water	Sterile Plastic w/ sodium thiosulfate	Cool to <6°C but not frozen	120 mL	8 hours[1]
E. coli Coliscan Easygel	water	Sterile Plastic w/ sodium thiosulfate	Cool to <6°C but not frozen	120 mL	6 hours[2]

[1] *E.coli* samples analyzed by Colilert 18 should always be processed as soon as possible and within 8 hours, but no more than 24 hours.
[2] *E.coli* samples analyzed by Coliscan Easygel should always be processed as soon as possible and within 6 hours.

Sample Containers

Certificates from sample container manufacturers are maintained in a notebook by Eastex Lab as appropriate. Information about the various sample containers is described below.

All sample containers are provided to H-GAC by their contract lab, Eastex. The lab performs and tracks required QC procedures for all bottles purchased.

- Sterile, sealed, 120 mL plastic, disposable bottles with a sodium thiosulfate tablet added, are used for bacteriological samples.

Processes to Prevent Contamination

Procedures in the *TCEQ SWQM Procedures* outline the necessary steps to prevent contamination of samples, including direct collection into sample containers, when possible. Field QC samples (identified in Section B5) are collected to verify that contamination has not occurred.

Documentation of Field Sampling Activities

Field sampling activities are documented on field data sheets (see Appendix C). The following will be recorded for all visits:

- station ID
- sampling date
- sampling time
- sampling depth
- sample collector's name/signature
- values for all field parameters, including flow and flow severity
- detailed observational data, where appropriate, including:
  - water appearance
  - weather
  - biological activity
  - algal growth
  - unusual odors
  - pertinent observations related to water quality or stream uses (i.e., exceptionally poor water quality conditions; stream uses such as swimming, boating, fishing, irrigation pumps)
  - watershed or in stream activities (i.e., bridge construction, livestock watering upstream)
- missing parameters (i.e., when a scheduled parameter or group of parameters is not collected)

Recording Data

For the purposes of this section and subsequent sections, all field and laboratory personnel follow the basic rules for recording information as documented below:

- Legible writing in indelible ink with no modifications, write-overs or cross-outs.
- Correction of errors with a single line followed by an initial and date.
- Close-out on incomplete pages with an initialed and dated diagonal line.

Sampling Method Requirements or Sample Processing Design Deficiencies and Corrective Action

Examples of sampling method requirements or sample design deficiencies include but are not limited to such things as inadequate sample volume due to spillage or container leaks, failure to preserve samples appropriately, contamination of a sample bottle during collection, storage temperature and holding time exceedance, sampling at the wrong site, etc. Any deviations from the QAPP and appropriate sampling procedures may invalidate resulting data and may require corrective action. Corrective action may include for samples to be discarded and re-collected. It is the responsibility of the H-GAC PM, in consultation with the H-GAC QAO, to ensure that the actions and resolutions to problems are documented by completion of a corrective action report (CAR) and that records are maintained in accordance with this QAPP. In addition, these actions and resolutions will be conveyed to the GBEP PM in writing in the project progress reports.

The definition of and process for handling deficiencies and corrective action are defined in Section C1.

B3 Sample Handling and Custody

Sample Tracking

Proper sample handling and custody procedures ensure the custody and integrity of samples beginning at the time of sampling and continuing through transport, sample receipt, preparation, and analysis.

A sample is in custody if it is in actual physical possession or in a secured area that is restricted to authorized personnel. The Chain of Custody (COC) form is a record that documents the possession of the samples from the time of collection to receipt in the laboratory. The following information concerning the sample is recorded on the COC form (See Appendix C).

- date and time of collection,
- site identification,
- sample matrix, indicated by the test group code,
- number of containers and container type ID designation,
- preservative used or if the sample was filtered, indicated by test group code,
- analyses required, indicated by the test group code,
- name of collector,
- custody transfer signatures and dates and time of transfer,
- name of laboratory accepting the sample.

Sample Labeling

Samples from the field are labeled on the container with an indelible marker. Label information includes:

- site identification
- date of sampling
- time of sampling
- preservative added, if applicable

Sample Handling

After collection of samples is complete, sample containers are immediately stored in an ice chest for transport to the Eastex laboratory. Ice chests remain in the possession of the field technician or in the locked vehicle until being delivered to the lab. After submission to the Eastex laboratory, the samples remain in the log-in room until log-in is completed, then they are stored in the refrigeration unit or given to an analyst for immediate analysis. Only authorized laboratory personnel handle samples received by the laboratory. Eastex Environmental Laboratory Quality Manual (QM), most current version, addresses samples relinquished to the lab.

Sample Tracking Procedure Deficiencies and Corrective Action

All deficiencies associated with COC procedures and described in this QAPP are immediately reported to the H-GAC PM or QAO. These include such items as delays in transfer resulting in holding time violations; violations of sample preservation requirements; incomplete documentation, including signatures; possible tampering of samples; and broken or spilled samples. The H-GAC PM, in consultation with the GBEP PM and H-GAC QAO, will determine if the procedural violation may have compromised the validity of resulting data. Any failures that have reasonable potential to compromise data quality will invalidate data and the sampling event should be repeated, if feasible. The resolution of the situation will be reported to the GBEP PM in the project progress report. CARs will be prepared by the H-GAC personnel and summarized by the H-GAC PM for submittal to the GBEP PM for inclusion with project progress report.

The definition of and process for handling deficiencies and corrective action are defined in Section C1.

B4 Analytical Methods

The analytical methods, associated matrices, and performing laboratories are listed in Tables A7.1 a and b of Section A7. The procedures for laboratory analysis shall be in accordance with the most recently published edition of Standard Methods for the Examination of Water and Wastewater, the latest version of the TCEQ Surface Water Quality Monitoring (SWQM) Procedures, 40 CFR Part 136, or other reliable procedures acceptable to the TCEQ.

Laboratories analyzing bacteria data, except for screening bacteria tests, under this QAPP are compliant with the TNI Standards, at a minimum. Copies of laboratory quality assurance manual (QAM) and SOPs are available for review by the TCEQ, upon request.

Standards Traceability

All standards used in the field and laboratory are traceable to certified reference materials. Standards preparation is fully documented and maintained in a standards log book. Each documentation includes information concerning the standard identification, starting materials, including concentration, amount used and lot number; date prepared, expiration date and preparer's initials/signature. Reagent bottles are labeled to trace the reagent back to preparation. Tables A7.1a and b, Measurement Performance Specifications, list the methods to be used for field and laboratory analyses.

Deficiencies, Nonconformances and Corrective Action Related to Quality Control

Deficiencies are defined as unauthorized deviations from procedures documented in the QAPP or other applicable documents. Nonconformances are deficiencies which affect quantity and/or quality and render the data unacceptable or indeterminate. Deficiencies related to field and laboratory measurement systems include, but are not limited to, instrument malfunctions, blank contamination, and QC sample failures.

Deficiencies are documented in logbooks, field data sheets, etc. by field or laboratory staff and reported to the pertinent field or laboratory supervisor who will notify the H-GAC PM. A Corrective Action Report to document the deficiency is written for each deficiency.

The H-GAC PM, in consultation with the GBEP PM and H-GAC QAO (and other affected individuals/organizations), will determine whether the deficiency could affect data quality. If it is determined the item in question does not affect data quality and therefore is not a valid nonconformance, the CAR will be completed accordingly and closed. If it is determined a nonconformance does exist, the H-GAC Project Manager, in consultation with the GBEP PM and the H-GAC QAO, will determine the disposition of the nonconforming activity or item and necessary corrective action(s); results will be documented in the CAR (see Appendix E).

The definition of and process for handling deficiencies and corrective action are defined in Section C1.

B5 Quality Control

Sampling Quality Control Requirements and Acceptability Criteria

The minimum field QC requirements, and program-specific laboratory QC requirements, are outlined in SWQM Procedures.

Laboratory Measurement Quality Control Requirements and Acceptability Criteria

Batch
A batch is defined as environmental samples that are prepared and/or analyzed together with the same process and personnel, using the same lot(s) of reagents. A **preparation batch** is composed of one to 20 environmental samples of the same NELAP-defined matrix, meeting the above mentioned criteria and with a maximum time between the start of processing of the first and last sample in the batch to be 25 hours. An **analytical batch** is composed of prepared environmental samples (extract, digestates or concentrates) which are analyzed together as a group. An analytical batch can include prepared samples originating from various environmental matrices and can exceed 20 samples.

Method Specific QC requirements
QC samples, other than those specified in this section (i.e., sample duplicates, surrogates, internal standards, continuing calibration samples, interference check samples, positive control, negative control, and media blank), are analyzed as specified in the methods. The requirements for these samples, their acceptance criteria or instructions for establishing criteria, and corrective actions are method-specific.

Detailed laboratory QC requirements and corrective action procedures are contained within the individual laboratory SOPs. The minimum requirements to which all participants abide by are stated below.

Comparison Counting
For routine bacteriological samples, repeat counts on one or more positive samples are required, at least monthly. If possible, compare counts with an analyst who also performs the analysis. Replicate counts by the same analyst should agree within 5 percent, and those between analysts should agree within 10 percent. Record the results.

Laboratory Duplicates
A laboratory duplicate is an aliquot taken from the same container as an original sample under laboratory conditions and processed and analyzed independently. A laboratory control sample duplicate (LCSD) is prepared in the laboratory by splitting aliquots of an LCS. Both samples are carried through the entire preparation and analytical process. LCSDs are used to assess precision and are performed at a rate of one per batch.

For most parameters, except bacteria, precision is evaluated using the relative percent difference (RPD) between duplicate LCS results as defined by 100 times the difference (range) of each duplicate set, divided by the average value (mean) of the set. For duplicate results, X1 and X2, the RPD is calculated from the following equation:

$$RPD = |(X1 - X2)/\{(X1+X2)/2\} * 100|$$

For bacteriological parameters, precision is evaluated using the results from laboratory sample duplicates. Bacteriological duplicate are collected on a 10% frequency (or once per sampling run, whichever is more frequent). These duplicates will be collected in sufficient volume (200 mL or more) for analysis of the sample and its laboratory duplicate from the same container.

The base-10 logarithms of the results from the original sample and its duplicate are calculated. The absolute value of the difference between the two logarithms will be compared to the precision criterion in TableA7.1b. If the difference in logarithms is greater than the precision criterion, the data are not acceptable for use under this project and will not be reported to TCEQ. Results from all samples associated with that failed duplicate (usually a maximum of 10 samples) will be considered to have excessive analytical variability and will be qualified as not meeting project QC requirements.

The precision criterion in Table A7.1b for bacteriological duplicates applies to only samples with concentrations > 10 MPN/100 mL. Field splits are not collected for bacteriological analyses.

Method blank

A method blank is a sample of matrix similar to the batch of associated samples (when available) that is free from the analytes of interest and is processed simultaneously with and under the same conditions as the samples through all steps of the analytical procedures, and in which no target analytes or interferences are present at concentrations that impact the analytical results for sample analyses. The method blanks are performed at a rate of once per preparation batch. The method blank is used to document contamination from the analytical process. The analysis of method blanks should yield values less than the LOQ. For very high-level analyses, the blank value should be less than 5% of the lowest value of the batch, or corrective action will be implemented. Samples associated with a contaminated blank shall be evaluated as to the best corrective action for the samples (e.g., reprocessing or data qualifying codes). In all cases the corrective action shall be documented.

The method blank shall be analyzed at a minimum of one per preparation batch. In those instances for which no separate preparation method is used (example: volatiles in water) the batch shall be defined as environmental samples that are analyzed together with the same method and personnel, using the same lots of reagents, not to exceed the analysis of 20 environmental samples.

Field Blank

Field blanks are used to assess potential contamination from sample handling, airborne materials, equipment, media, and other sources. Field blanks are not required when using the IDEXX Colilert method but are required when using the Coliscan Easygel method to test for *E. coli* bacteria. A field blank usually consists of a sterile diluent sample that is taken to the site and poured into a properly labeled, sterile sample bottle during the first bacteria sampling of the day. The blank sample is collected in the same type of container, labeled as a field blank, and handled and analyzed along with all the bacteria samples collected on that day. The frequency of the bacteria field blank is one with every 10 samples or once a month if less than 10 samples are collected in a given 30 day period.

The analysis of field blanks should yield values lower than the LOQ. When target analyte concentrations are high, blank values should be lower than 5% of the lowest value of the batch.

Field blanks are associated with batches of field samples. In the event of a field blank failure, all applicable data associated with the field batch may need to be qualified as not meeting project QC requirements and may be rejected. Regardless, none of the bacteria results acquired from the Coliscan Easygel method will be reported to the TCEQ. These data include all samples collected on that day during that sample run and should not be confused with the laboratory analytical batch.

Deficiencies, Nonconformances and Corrective Action Related to Quality Control

Deficiencies are defined as unauthorized deviations from procedures documented in the QAPP or other applicable documents. Nonconformances are deficiencies that affect data quantity and/or quality and render the data unacceptable or indeterminate. Deficiencies related to QC include but are not limited to field and laboratory QC sample failures.

Deficiencies are documented in logbooks, field data sheets, etc., by field or laboratory staff and reported to the appropriate field or laboratory supervisor who will notify the H-GAC PM. The H-GAC PM will notify the GBEP QAO of the potential nonconformance. The H-GAC will initiate a CAR to document the deficiency.

The H-GAC PM, in consultation with H-GAC QAO (and other affected individuals/organizations), will determine if the deficiency constitutes a nonconformance. If it is determined the activity or item in question does not affect data quality and therefore is not a valid nonconformance, the CAR will be completed accordingly and the CAR closed. If it is determined a nonconformance does exist, the H-GAC PM in consultation with the H-GAC QAO will determine the disposition of the nonconforming activity or item and necessary corrective action(s); results will be documented by the H-GAC by completion of a CAR (see Appendix G).

CARs document: root cause(s); impact(s); specific corrective action(s) to address the deficiency; action(s) to prevent recurrence; individual(s) responsible for each action; the timetable for completion of each action; and, the means by which completion of each corrective action will be documented. CARs will be included with quarterly progress reports. In addition, significant conditions (i.e., situations which, if uncorrected, could have a serious effect on safety or on the validity or integrity of data) will be reported to TCEQ verbally and in writing.

B6 Instrument/Equipment Testing, Inspection and Maintenance

All sampling equipment testing and maintenance requirements are detailed in the *TCEQ SWQM Procedures, Volume 1*. Sampling equipment is inspected and tested upon receipt and is assured appropriate for use. Equipment records are kept on all field equipment and a supply of critical spare parts is maintained.

All laboratory tools, gauges, instrument, and equipment testing and maintenance requirements are contained within Eastex's laboratory QAM and SOPs and are available upon request. The QAM and SOPs apply to *E.coli* samples submitted to Eastex only.

B7 Instrument/Equipment Calibration and Frequency

Field equipment calibration requirements are contained in the *TCEQ Surface Water Quality Monitoring Procedures, Volume 1*. Post-calibration error limits and the disposition resulting from error are adhered to. Data not meeting post-error limit requirements invalidate associated data collected subsequent to the pre-calibration and should be disregarded. Refer to section C1 for description of corrective action reports.

Detailed laboratory calibrations are contained within the Eastex Laboratory QAM and SOPs and are available upon request. The incubator used to analyze Coliscan Easygel bacteria tests will have the unit thermometer checked against a National Institute of Standards Technology or NIST thermometer every ten batches or at least monthly.

B8 Inspection/Acceptance of Supplies and Consumables

All sampling equipment testing and maintenance requirements are detailed in the most recent version of *TCEQ SWQM Procedures, Volume 1*. Sampling equipment is inspected and tested upon receipt and is assured appropriate for use. Equipment records are kept on all field equipment and a supply of critical spare parts is maintained.

All laboratory tools, gauges, instrument, and equipment testing and maintenance requirements are contained within Eastex laboratory QAM and SOPs and available upon request. H-GAC PM or designee will retain all records related to Coliscan Easygel analyses.

B9 Non-Direct Measurements

Data of known and documented quality are integral to the success of this project, as these data could be used to support future decision-making. The establishment of data quality standards, and acknowledgement of conformity to quality standards, is therefore a high priority. Each of these datasets is validated by the responsible agency, usually when the datasets are updated. H-GAC accepts by reference the quality and validation/verification routines of these agencies. Metadata for each of the GIS datasets is stored within the feature class for the layer. Metadata for all other datasets are included in the database as a separate descriptive file that defines the source, download date, and nature of the dataset, and is stored in the same folder as the raw project dataset on the H-GAC server called G-drive. Data employed in this project may include, but are not limited to:

- water quality data from SWQMIS,
- flow data from the USGS,
- daily precipitation data from NOAA Climactic Data Center,
- monthly average wastewater discharge data from Discharge Monitoring Reports provided by TCEQ,
- wastewater permit data provided by TCEQ, and
- all GIS data and layers accumulated by H-GAC.

No data will be specifically collected nor submitted for inclusion in SWQMIS. Data collected by the TCEQ, the USGS, and the Texas CRP partners that meet the data quality objectives of this project may be useful in satisfying the data and informational needs for GBEP. The collection and qualification of the TCEQ and USGS data are addressed in the TCEQ SWQM QAPP (<www.tceq.state.tx.us/waterquality/monitoring/swqm_guides.html>). The collection and qualification of the Texas CRP data are addressed in the Texas CRP QAPPs (<www.tceq.texas.gov/waterquality/clean-rivers/qa/index.html>).

The water quality data to be acquired for this project will include available ‘non-qualified,’ routine or special study, ambient, fixed station bacteria water quality data and associated field parameters in SWQMIS collected since January 1, 2002, from the BIG project area within the H-GAC region as well as associated field parameters.

The TCEQ’s SWQMIS is the largest and most complete repository for water quality data collected under accepted QAPP procedures in the State of Texas and was selected for that reason for these projects. Data will be downloaded from SWQMIS for each determination of correlation and analyses. The list of parameters includes bacteria results and field parameters only. Only data collected since January 1, 2002 will be used in this project. SWQMIS data are available from the TCEQ "Surface Water Quality Viewer" site (http://www.tceq.state.tx.us/ gis/surface-water-quality-viewer). This source of information will be specified in the Management Report/Final Report for this project.

For the parameter *E. coli*, since July 1, 2008, only analytical data generated by a NELAP accredited laboratory may be submitted to TCEQ for inclusion in SWQMIS. For field and bacteria data, only surface water data collected at a depth of 1 meter or less will be used. Only data without qualifier codes will be downloaded from SWQMIS for use in this project. The acquired data will include routine water quality data collected by TCEQ, CRP partners, and the USGS. Data will include only that which was collected after January 1, 2002.

Comparability of methods is based on TCEQ's CRP FY2016-2017 Guidance, Task 5. This document gives guidance for which method codes can be combined and which are considered comparable. The document also suggests methods on how to substitute or censor data reported below quantitation limits. All censored data methods will be evaluated before data is used in the final analysis and fully documented.

The H-GAC Community & Environmental Planning Department's Data Management Plan, August 2015 (The Plan) outlines how both tabular (non-geographic) and spatial (geographic) datasets are captured, manipulated, analyzed, stored, and displayed within the Geospatial/GIS environment as it relates to sharing of data, development of geospatial applications, cartography, and underlying GIS resources. The Plan can be found in Appendix B. H-GAC utilizes ESRI® ArcGIS 10 platform for all geospatial analysis and mapping needs. The ESRI® ArcGIS 10 platform includes integrated Python programming capabilities, which allows for the creation of programming scripts or batch programs to improve efficiency and documentation of processes. The Python programming language is an Open Source platform, and is freely distributable. H-GAC will first acquire the TCEQ GIS layer that has delineated watersheds for the selected AUs in the BIG project area for evaluations.

Only 'published' GIS data from recognized sources will be used to determine if there are correlations between watershed characteristics (land use/land cover) and the acquired ambient bacteria data. Land cover datasets have been compiled for the years 1996, 2001, 2006, 2011 and 2015.

During this project, GIS datasets may be or have already been acquired by H-GAC (See The Plan, Appendix B). The Plan outlines how both tabular (non-geographic) and spatial (geographic) datasets are captured, manipulated, analyzed, stored, and displayed within the Geospatial/Geographic Information Systems (GIS) environment as it relates to sharing of data, development of geospatial applications, cartography, and underlying GIS resources. The publishing of geospatial data by various organizations implies that the data is of known quality that it has been subject to review and approval by the publishing organization and has required metadata to prove its accuracy and completeness.

Additional geospatial data may be available from various local, regional, state, and federal organizations and may be used for cartographic purposes. Maps developed for reports will be for illustrative purposes. Geospatial data utilized in maps of the study area may include land use, precipitation, soil type, ecoregion, TCEQ monitoring location, TCEQ permitted outfall, gage location, city/county/state boundary, stream hydrology, reservoir, drought, road, watershed, municipal separate storm sewer system, urbanized area, basin, railroad, recreational area, area landmark, aerial photography, and park information. The above data come from the following reliable sources: USGS, TNRIS, TCEQ, US Census Bureau, COGs, and local governments. Geospatial data from these sources are accepted for developing project maps based on the reputability of these data sources and the lack of known comparable sources for these data. Geospatial data will be cited in reports.

B10 Data Management

The water quality data acquired for this project as well as data produced by this project will be maintained in a permanent SAS data table where it can be electronically and/or visually screened for errors. H-GAC Data Manager will create a metadata file once all data has been verified and validated from the original source to document datasets appropriateness for use. Bacteria data downloaded from TCEQ in pipe-delineated text will be stored, write protected in a project folder on the H-GAC data server. Data will be copied into secondary files of manipulation and analysis.

A description of the software and hardware to be used for GIS data, how data is converted or manipulated for use, how the metadata is documented, and stored is described in the C&E Data Management Plan located in Appendix B. Information about computer workstations and software supporting this project are also described in the C&E Data Management Plan located in Appendix B.

C1 Assessments and Response Actions

The following table presents types of assessments and response action applicable to this QAPP.

Table C1.1 Assessments and Response Actions

Assessment Activit y	**Approximate Schedule**	**Responsible Party**	**Scope**	**Response Requirements**
Status Monitoring Oversight, etc.	Continuous	H-GAC Project Manager, , GIS Data Manager or designee	Monitoring of the project status and records to ensure requirements are being fulfilled.	Report to the TCEQ in Progress Report. Ensure project requirements are being fulfilled.
GBEP QA Review and Contractor Review.	Annual	GBEP PM and/or Quality Assurance Officer	Monitoring of H-GAC's project status, Quality Assurance Program, and Project Deliverables.	Report to Management and Contractor for response and any corrective actions.

DEFICIENCIES AND CORRECTIVE ACTION

Deficiencies are any deviation from the QAPP and procedures referenced herein. It is the responsibility of the H-GAC PM, in consultation with the H-GAC QAO, to ensure that the actions and resolutions to the problems are documented and that records are maintained in accordance with this QAPP. In addition, these actions and resolutions will be conveyed to the GBEP PM in writing in the project progress reports and by completion of a corrective action report (CAR) (Appendix G).

Corrective Action Reports (CARs) should:

• identify the problem, nonconformity, or undesirable situation,
• identify immediate remedial actions if possible,
• identify the underlying cause(s) of the problem,
• identify whether the problem is likely to recur, or occur in other areas,
• evaluate the need for Corrective Action,
• use problem-solving techniques to verify causes, determine solution, and develop a CAR,
• identify personnel responsible for action,
• establish timelines and provide a schedule,
• document the corrective action in CARs.

Status of Corrective Action Reports (CARs) will be included with quarterly progress reports. In addition, significant conditions (i.e., situations which, if uncorrected, could have a serious effect on safety or on the validity or integrity of data) will be reported to the TCEQ immediately.

The H-GAC PM or QAO is responsible for implementing and tracking corrective action procedures as a result of audit findings. Records of audit findings and corrective actions are maintained by the H-GAC PM and/or QAO. Corrective action documentation will be submitted to the GBEP PM with the progress report.

If audit findings and corrective actions cannot be resolved, then the authority and responsibility for terminating work is specified in agreements or contracts between participating organizations.

C2 Reports to Management

Reports to H-GAC Project Management

The table below lists all the reports that are generated by H-GAC for this project. The reports are described in greater detail in the sections following the table. The final report will include a complete discussion regarding the analyses conducted, results of same analyses, the appropriate use and limitations of the data in terms of quality as well as all developed GIS datasets.

Table C2.1 QA Management Reports

Type of Report	**Frequency (daily, weekly, monthly, quarterly, etc.)**	**Projected Delivery Date(s)**	**Person(s) Responsible for Report Preparation**	**Report Recipients**
Project Updates	As needed	E-mails and conference calls	H-GAC PM	GBEP PM
Project Updates & Verbal Reports	Bi-weekly	Regularly scheduled staff meetings	H-GAC PM	H-GAC Water Resources Manager
TCEQ Quarterly Progress Report	Updates with Quarterly progress reports	15th day of the month following the end of the quarter. Monthly Progress Reports beginning June 2016.	H-GAC PM	H-GAC Water Resources Manager & GBEP PM
Preliminary Action Report	Updates with Quarterly progress reports	August 4, 2016	H-GAC PM	H-GAC Water Resources Manager & GBEP PM
Source Identification Report	Updates with Quarterly progress reports	March 2, 2017	H-GAC PM	H-GAC Water Resources Manager & GBEP PM
Draft Final Report	Updates with Quarterly progress reports	April 30, 2017	H-GAC PM	H-GAC Water Resources Manager & GBEP PM
Final Report with hard copies and digital copies. GIS shapefiles and Data files will be provided to the TCEQ & to the EPA upon request.	Following TCEQ Comment Period	May 31, 2017	H-GAC PM	H-GAC Water Resources Manager & GBEP PM

Reports to TCEQ Project Management

All reports detailed in this section are contract deliverables and are transferred to the TCEQ in accordance with contract requirements.

Progress Report –Summarizes the H-GAC's activities for each task; reports monitoring status, problems, delays, and status of corrective actions; and outlines the status of each task's deliverables. Submittal of progress reports will be at the frequency and format as identified in the contract or work order.

Reports by TCEQ Project Management

Contractor Evaluation - The H-GAC is evaluated in a Contractor Evaluation by the TCEQ annually for compliance with administrative and programmatic standards. Results of the evaluation are submitted to the TCEQ Support Services Division, Procurements and Contracts Section.

D1 Data Review, Verification, and Validation

Water quality data collected by the TCEQ, the USGS, and all CRP partners have been reviewed, verified, and validated according to the requirements of the respective programs prior to being loaded into SWQMIS. Only 'un-qualified' (unflagged), routine, ambient, fixed station water quality data currently stored in SWQMIS will be used in this project. All AU data for bacteria and field parameters will be evaluated for temporal extent, censored data, the availability of instantaneous flow and precipitation data. Sample collection methods and field measurement procedures have been monitored and audited by H-GAC staff since the mid 1990's. Laboratory analyses were performed using validated standard methods, and in many cases, by laboratories that had an acceptable quality system in place prior to the requirement that all laboratories submitted data obtain accreditation under NELAP by 2008. H-GAC believes data that has been collected as part of the routine sampling and produced by regional CRP partners and established laboratories, has met the review, verification, and validation requirements of CRP and meets the requirements of this project and all relevant DQOs. Comparable methods and limits of quantitation will be dealt with as required by CRP and described in the analysis of data for the Final Report referred to in section A6.

Only published geospatial data will be acquired for use in this project. Those organizations include, but are not limited to, the USGS, TNRIS, TCEQ, US Census Bureau, COGs, National Weather Service, and others. Each of the agencies generating Geospatial data have their own procedures for reviewing, verifying, and validating their data prior to being published. All published data will be considered adequately reviewed, verified, and validated. Any inconsistencies or inaccuracies found will be addressed with the publisher by H-GAC staff as they are identified and documented accordingly.

For datasets generated during this project, the data quality will be peer reviewed for logical consistency and coding errors as identified in appropriate standards. The GIS Data Manager, Water Quality Data Manager, PM or his designee will be responsible for overall validations and final approval of the data in accordance with project purpose and use of the data.

D2 Verification and Validation Methods

Data collected by the TCEQ, the USGS, and Texas CRP partners have been verified and validated according to the requirements of the respective programs prior to their use in this project. Data compilations created for this project will be electronically and/or visually screened for errors.

The H-GAC PM or GIS Data Manager will provide review and approval of the datasets before closure of the project. All data layers will be reviewed for FGDC-compliant metadata. GIS datasets lacking appropriate metadata will not be used in an analysis or delivered to outside agencies. Documentation of provisional datasets will be reviewed to verify references to the use and limitations of the data. The H-GAC PM or GIS Data Manager will review QC reports and peer reviews to ensure they are acceptable. The H-GAC PM or GIS Data Manager will also compare final datasets with original source information for consistency.

D3 Reconciliation with User Requirements

Data acquired for this project, and data collected by other organizations (e.g., USGS, TCEQ, etc.), will be analyzed and reconciled with project data quality requirements sufficient to produce the Management

Report/Final Report. Results of analysis may be used by the GBEP for implementation planning, future project planning and other water quality planning as appropriate.

The final data will be reviewed to ensure that it meets the requirements as described in section A6 of this QAPP. CARs will be initiated in cases where invalid or incorrect data have been detected. Any limitations on the use of the analyses presented in the Management Report/Final Report will be documented in the results and conclusion section of the report.

The data analysis, including LDCs, will be used to evaluate bacteria concentrations in AUs within the BIG project area. It will provide information pertaining to historical trends in water quality, trends in LU/LC change, relationship of pollutant loads to flow regimes, potential loading from areas within selected AUs, and the impacts of watershed processes on loads in selected AUs.

Once the final version of the LU/LC map is produced, the GBEP PM will review the product to determine if the results meet the quality objectives of this QAPP. If data quality indicators do not meet the project's requirements as outlined in this QAPP the revised dataset will be returned for revisions.

The LDC framework utilized for this project will be used to evaluate *E. coli* loading in relation to flow regimes in the BIG project area. These analyses will aid in targeting water quality planning recommendations to the most likely areas of *E. coli*.

The Final Report will be a document that describes data collection and analysis procedures, data analysis and results, and summarizes the data. The summaries will include charts, tables and graphical presentations, including LDCs, as well as proper citations, analyses and results. The final document will be provided to the TCEQ in both hard copy and electronic formats or a combination of each, along with data and GIS files as requested. Once the TCEQ gives document approval, the Final Report will be shared with the BIG stakeholders.

Appendix A: Work Plan/Scope of Work

Bacteria Implementation Group's Top Five Most and Top Five Least Impaired Water bodies

The BIG was formed in 2008 following the completed Total Maximum Daily Load (TMDL) study, to develop an implementation plan (I-Plan) to address the elevated levels of bacteria in 72 bacteria-impaired segments in the region. The BIG project area drains to Galveston Bay, where a sizeable area of the Bay's oyster producing waters are restricted to recreational harvest by the Texas Department of State Health Services due to elevated bacteria levels. This project will address the Non-point Source and Point Source action plans of the Galveston Bay Plan, a Comprehensive Conservation Management Plan of the Galveston Bay Estuary Program. Monitoring will be conducted to demonstrate water quality improvement.

The Performing Party as a member of the Bacteria Implementation Group (BIG) has tracked bacteria levels to develop the Top Ten Most/Top Ten Least Lists, "Most Wanted" (i.e. those streams with the highest geometric means relative to the state standards for bacteria) and "Most Likely to Succeed" (i.e. stream locations with the lowest geometric means relative to the state standards for bacteria) The Performing Party is seeking to address ten targeted watersheds (five from the Top Ten Most and five from the Top Ten Least) by prioritizing the watersheds through a desk review, identifying sources of bacteria in the field, and reporting those sources to local jurisdictions. The Performing Party will not correct the sources but will work with BIG partners to remove the sources. This project will demonstrate improved water quality and document the value of a prioritized watershed approach for correcting bacteria sources.

The Performing Party will conduct a desk review and ground truth analysis of ten impaired watersheds in the BIG project area to prioritize for wet and dry weather monitoring. Desk reviews will include previously collected ambient monitoring data gathered by The Performing Party and its partners through the quality assured State's CRP. Ten impaired watersheds will be prioritized based on the I-Plan's recommendation under the Geographic Priority Framework for five criteria: Bacteria Level, Accessibility, Use Level, Implementation Opportunities, and Future Land Use Changes. If other criteria are determined as this project develops, those criteria will be written into the Final Report and made into a recommendation to the BIG for revision of the BIG I-Plan.

Based on the prioritization, a subset of the 10 watersheds (due to the level of funding, a minimum of one to two watersheds from the Top Ten Most list and one to two from the Top Ten Least list) will be monitored during wet weather and dry weather conditions. Water quality monitoring will be used to further refine source identification and to aid in tracking the source(s) of the impairment to the greatest extent practicable. Once verified, the source(s) of the bacteria loading will be relayed to the appropriate jurisdiction for correction. Additionally, any potential sources identified through the desk review and field ground truth analysis will be directed to local jurisdictions. The Performing Party will track implementation of the corrective action and conduct additional monitoring of the original sites to determine if the corrective action results in improved water quality.

Project Tasks

Task 1: Project Administration

Objective: To effectively administer, coordinate, and monitor all work performed under this project including technical and financial supervision and preparation of status reports.

Subtask 1.1: Project Oversight - The Performing Party will provide technical and fiscal oversight of the staff and/or sub-grantee(s)/ subcontractor(s) to ensure Tasks and Deliverables are acceptable and completed as scheduled and within budget. With the TCEQ Project Manager's authorization, the Performing Party may secure the services of sub-grantee(s)/ subcontractor(s). Project oversight status will be provided to TCEQ with the Quarterly Progress Reports (QPRs)/Financial Status Reports (FSRs).

Subtask 1.2: QPRs/FSRs - The Performing Party will prepare electronic QPRs/FSRs for submission to TCEQ. QPRs/FSRs will document all activities performed and costs incurred quarterly and will be submitted by the 15th ofMarch, June, September, and December. For the final quarter of the Contract period, QPRs/FSRs are required to be submitted monthly.

The QPRs/FSRs are to include the following:

- status of deliverables for each task;
- brief narrative description in QPR format;
- expenses documented on FSR forms; and
- supply supporting financial documentation.

Subtask 1.3: Contract Communication - The Performing Party will participate in a post-award orientation meeting with TCEQ within 30 days of Contract execution and at minimum, annually thereafter. Performing Party will document the meetings through written meeting summary. The Performing Party will maintain regular telephone and/or email communication with the TCEQ Project Manager regarding the status and progress of the project. Matters that must be communicated to the TCEQ Project Manager include, but are not limited to:

- Notification within 7 days before the Performing Party has scheduled public meetings or events, initiation of construction, or other major task activities.
- Notification within 48 hours regarding events or circumstances that may require changes to the budget, scope of work, or schedule of deliverables.
- Meeting held within 30 days of Contract execution and annually, summary due 15 days after each meeting.

Task 1 Deliverables:

- QPRs;
- contract communication; and
- meeting summaries

Task 2: Quality Assurance

Objective: To refine, document, and implement data quality objectives (DQOs) and quality assurance/control (QA/QC) activities to ensure data of known and acceptable quality are generated through this project.

Subtask 2.1: QAPP - The Performing Party will create a Quality Assurance Project Plan (QAPP), sufficient for the needs of the data quality objectives of this Scope of Work. The Principle Investigator (PI) will submit a written draft QAPP within 60 days of contract execution for review and consideration of approval by the TCEQ Project Manager and in accordance with the EPA R-5 document guidelines. The draft QAPP will be revised to address comments received from the TCEQ and/or EPA. A final QAPP without highlights or strikeout text will be submitted for approval by the TCEQ. Collection of environmental data and processes associated with the collection of environmental data will not commence prior to approval of the QAPP.

Subtask 2.2: QAPP Annual Updates or Reissuances - The Performing Party will submit annual QAPP updates or reissuances no less than 90 days prior to the end of the effective period of the QAPP. The last approved version of a QAPP will remain in effect only for the specified approval period. Upon expiration of the approval period for a QAPP, all the work covered by the expired QAPP will cease until such time as a revised QAPP has been fully approved by TCEQ and, if necessary, EPA.

Subtask 2.3: QAPP Amendments - The Performing Party will review, approve, and incorporate all changes into a revised QAPP during the annual revision process, or will submit an amendment to the QAPP 90 days prior to the scheduled initiation of changes or additions to activities listed in the current QAPP. The Performing Party will document all changes to the QAPP and the reasons for the changes. The Performing Party will ensure the current QAPP is followed until an amended QAPP is signed/fully approved by TCEQ and, if necessary, EPA.

Subtask 2.4: Data Acquisition – The Performing Party with gather available datasets to conduct a desktop and on-the-ground analysis. Acquired data, including Geographic Information System (GIS) land use/land cover, CRP ambient monitoring, permit outfall, on-site sewage facility, and other available data will be reviewed to determine if the data was collected using common practices and standards for the date and time of the collection. The process for determining the quality of acquired data and acceptability for use must be detailed in the QAPP.

Subtask 2.5: Data Collection –
The Performing Party will conduct an initial desk review, Desk Review 1, of the Top 10 Lists to prioritize this list and pare it down to create a top five list for each top ten list. The Performing Party will then conduct a more thorough desk review, Desk Review 2, to refine these lists one step further. The resulting prioritized list of two from each top five lists will then be subjected to ground truth analysis. The survey design, field measures, and forms must be detailed in the QAPP.

The Performing Party, unless noted in the QAPP, will collect all samples for the project following procedures described in SWQM Procedures, Volume 1: Physical and Chemical Monitoring Methods. List of parameters for wet and dry weather sampling include: all CRP field parameters and *E. coli*. All samples will preferably follow a 72 hour antecedent dry period. Wet weather sampling events may also occur in the absence of a 72 hour antecedent dry period if trace rains with a total accumulation of less than 0.25 inches has occurred prior to sampling. Bacteria screening samples will be processed in house using the Coliscan Easygel method. Bacteria samples processed using IDEXX Colilert method will be processed at a NELAP accredited lab.

Unless authorized by the TCEQ, monitoring projects that include *E. coli* sampling are required to have samples processed by an accredited laboratory within an 8 hour time-frame for regulatory samples and 24 hour time-frame for non-regulatory samples.

Task 2 Deliverables:

- Draft and Final QAPP;
- QAPP Annual Updates;
- QAPP Amendments as needed; and
- Data Submittals

Task 3: Data Acquisition and Analysis - Desktop and Ground-Truth Analysis

Objective: To collect and analyze data in accordance with the approved QAPP. This task will incorporate the priority strategy identified in the *Bacteria Implementation Plan for Seventy- Two Total Maximum Daily Loads for Bacteria in the Houston-Galveston Region's* Geographic Priority Framework. The processes will include defining mini-watersheds for every outfall within Assessment Units (AUs) of interest and identify land cover throughout each watershed.

Subtask 3.1: Data Acquisition - The Performing Party will conduct desktop and on-the-ground analysis to refine the Top Ten Most and Top Ten Least lists to better direct wet and dry weather monitoring. Desktop analysis will use GIS land use/land cover data, ambient monitoring data, permit outfall data, on-site sewage facility system data and other available data for 10 watersheds from the Top Ten Most/Top Ten Least lists. Ground truth identification will include road – windshield surveys – and shoreline walks of accessible areas. Key stakeholders will be identified and asked to contribute to project planning, review of analysis and development of the prioritization strategy.

Subtask 3.2: Data Analysis - The Performing Party will analyze data and information collected in accordance with the QAPP under Task 2.1. The Performing Party will develop a Geospatial database using ESRI ArcGIS software to perform analysis of multiple data layers. Results will be used to further refine the watersheds and develop the prioritization strategy for wet and dry weather data collection under Task 4.0.

Subtask 3.3: Map Development - Results from Task 3.2 will be used to generate a map that will be used in the wet and dry weather data collection under task 4.0.

Subtask 3.4: Data Submittals - The Performing Party will review, verify, and validate water quality monitoring data before it is submitted to the TCEQ. The Performing Party will submit a semi-annual report of water quality data that is consistent with TCEQ formatting requirements for upload into the SWQMIS.

The Performing Party will submit data reports and presentations for review and approval at least two weeks prior to the scheduled public release.

Subtask 3.5: Data Acquisition and Analysis Report - The Performing Party will develop a report, Desk Review/Ground Truth Preliminary Action Report, detailing activities conducted under this task, including the development of a revised targeted watershed list.

Task 3 Deliverables:

- Desk Review/Ground Truth Preliminary Action Report;
- Geospatial Data Set; and
- Map Layer

Task 4: Data Collection and Analysis - Wet and Dry Weather Sampling and Analysis

Objective: To collect and analyze wet and dry weather samples that can be used to better identify sources of bacteria. Data will be used to generate an action report that will be delivered to local jurisdictions to follow up and remediate any sources. Follow up wet and dry weather sampling will be used to determine if corrective actions improved water quality.

Subtask 4.1: Data Collection - Wet Weather Sampling
The final number of wet weather monitoring sites will be based on results from Task 3. A minimum of 4 samples will be taken from each of the four Assessment Units (AUs), two AUs selected from each of the Top Five Most and Top Five Least watersheds identified in 3.0. List of parameters: all CRP field parameters and *E. coli*. All samples will preferably follow a 72 hour antecedent dry period. Wet weather sampling events may also occur in the absence of a 72 hour antecedent dry period if trace rains with a total accumulation of less than 0.25 inches has occurred prior to sampling. Bacteria screening samples will be processed in house using the Coliscan Easygel method. Bacteria samples processed using IDEXX Colilert method will be processed at a NELAP accredited lab. Additional samples will be collected during the last quarter of the project to monitor water quality benefits derived from corrective actions.

Subtask 4.2: Data Collection - Dry Weather Sampling
The final number of dry weather monitoring sites will be based on results from Task 3.0 and 4.1. A minimum of 20 samples will be taken from four AUs, two AUs selected from each Top Five Most and Top Five Least watersheds identified in 3.0. To assist with tracking illicit discharges to a source prior to collecting, the Performing Party will be prescreening bacteria using the Coliscan Easygel method. Bacteria samples processed using IDEXX Colilert method will be processed at a NELAP accredited lab. Water quality monitoring will focus on all CRP field parameters and *E. coli*.

Subtask 4.3: Data Analysis - The Performing Party will analyze data and information collected in accordance with the QAPP. All analysis will be processed in-house. Data will be processed using basic and advanced statistical analyses to determine trends and correlations.

Subtask 4.4: Data Submittals - The Performing Party will review, verify, and validate water quality monitoring data before it is submitted to the TCEQ. The Performing Party will submit a semi-annual report of water quality data that is consistent with TCEQ formatting requirements for upload into the SWQMIS. The Performing Party will submit data reports and presentations for review and approval at least two weeks prior to the scheduled public release.

Subtask 4.5: Data Collection and Analysis Report - The Performing Party will develop a Source Identification Report, detailing activities conducted under this task. Report will be delivered to local jurisdictions within the project area. Local jurisdictions will be encouraged to investigate any identified sources and to report on any action taken to address the identified source(s).

Task 4 Deliverables:

- Source Identification Report

Task 5: Reporting

Objective: To provide targeted outreach, education and training opportunities to local watershed stakeholders and produce a Final Report that summarizes all activities completed and conclusions reached during the project. The report will describe project activities, and identify and discuss the extent to which project goals and purposes have been achieved, and the amount of funds spent on the project. The report will emphasize successes, failures, lessons learned, and include specific water quality data demonstrating water quality improvements if applicable. The Final Report will summarize all the task reports in either the text or as appendices.

Subtask 5.1: Outreach, Education and Training - Select venues to conduct direct and meaningful outreach to target audiences, including the Performing Party's clean watershed initiative workshops. Selection of venues and presentations will include coordination with TCEQ. Additionally, general outreach and education concerning this project will be provided throughout the project period in conjunction with outreach efforts of the BIG and other community and environmental programs, including but not limited to: the Performing Party website, the Performing Party and partner meetings, and presentations to local governments, organizations and the public.

Subtask 5.2 Draft Final Report/Management Report -The Performing Party will provide a draft report that summarizes all activities completed and conclusions reached during the project. The report will describe project activities, and identify and discuss the extent to which project goals and purposes have been achieved, and the amount of funds actually spent on the project. The report will emphasize successes, failures, lessons learned, and will include specific water quality data demonstrating water quality improvements if applicable. The draft report will summarize all the Task Reports referencing and/or attaching them as web links or appendices. The report should be structured per the following outline:

Title;
Table of Contents;
Executive Summary;
Introduction;
Project Significance and Background;
Methods;
Results and Observations;
Discussion;
Summary;
References; and

Appendices

Subtask 5.3: Final Report/Management Report - The Performing Party will revise the draft report to address comments provided by the TCEQ Project Manager.

Task 5 Deliverables:

- Agency Action Report;
- Outreach and Education Report;
- Draft Final Report/Management Report;
- Address any comments; and
- Final Report/Management Report.

Delivery Schedule

Deliverable and associated sub-task	**Due Date(s)**
QPRs (1.2)	QPRs will document all activities performed quarterly and will be submitted by the 15th ofMarch, June, September, and December. For the final quarter of the Contract period, reimbursement forms are required to be submitted monthly.
Contract communication and meeting minutes (1.3)	Meeting held within 30 days of Contract execution and annually, minutes due 15 days after each meeting
Draft and Final QAPP (2.1)	Within 60 days of contract execution
Final QAPP (2.1)	Within 30 day following TCEQ review of the draft QAPP
QAPP Updates/Reissuance (2.2)	Annually
QAPP Amendments (2.3)	as needed
Data Submittals (2.5)	as needed
Desk Review/Ground Truth Preliminary Action Report (3.5) • Geospatial Data Set • Map Layer	8/4/2016
Source Identification Report • Wet Weather Data Collection (4.1) • Dry Weather Data Collection (4.2)	3/2/2017
Outreach and Education Report (5.1)	4/30/17
Draft Final Report (5.2)	4/30/17
Final Report (5.3)	5/31/17

Appendix B: Data Management Plan

Data Management Plan

July 2015

HOUSTON-GALVESTON AREA COUNCIL
Community & Environmental Planning Department

Prepared in cooperation with the
Texas Commission on Environmental Quality
under the authorization of the Texas Clean Rivers Act

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Introduction

The Data Management Plan (The Plan) outlines the standard policies and procedures for data management within the Community and Environmental Planning (C&E) Department. The Plan covers the management of both tabular (non-geographic) and spatial (geographic) datasets. Its primary purpose is to ensure the efficient access and maintenance of these datasets within the C&E Geospatial/Geographic Information Systems (GIS) environment.

GIS technology provides a systematic means to capture, manipulate, analyze, store and display spatially referenced data. GIS supports a wide variety of applications ranging from site assessments, environmental planning, urban planning, and spatial analysis to support organizational strategies. In general, GIS supports the overall departmental goals of guiding regional planning, enhancing the quality of the region's natural environment, and public education through outreach programs. The C&E GIS team supports various programs within the C&E department through data development, spatial analysis, geospatial applications development, cartography in support of departmental goals.

The Plan is considered a dynamic working document which responds to changing technology, funding, staffing, and project requirements. Consequently, the Plan is reviewed on an annual basis and amended as necessary.

Geospatial Services

The following section explains the geospatial services provided by the H-GAC C&E GIS team as it relates to the sharing of data, development of geospatial applications, cartography, and underlying GIS resources. The C&E GIS team is responsible for the development of data and sharing of many publicly viable datasets, developing geospatial applications, cartography, and coordination of maintenance of underlying geospatial hardware and software for C&E.

The C&E GIS team maintains a centralized geospatial warehouse (C&E SDE), an online mapping platform for web-based geospatial applications (Mapping Server), and an FTP download site (Data Clearinghouse). The C&E SDE utilizes ESRI's ArcSDE software running on a Microsoft SQLServer RDBMS. The mapping server uses ESRI's ArcGIS Server platform running on .NET. The Data Clearinghouse is an FTP server that provides C&E with storage space where it can post publicly available datasets for downloading. The C&E SDE, Mapping Server, and Data Clearinghouse platforms are installed by the H-GAC Data Services department (Data Services), with Data Services maintaining only the lower-level technology components such as the physical hardware, software installation, and low-level server and RDBMS functions.

All upgrades and maintenance is coordinated by the C&E GIS Manager. All geospatial content stored in the C&E SDE, the Data Clearinghouse, and Mapping Server, are the responsibility of the C&E GIS staff, which resides within the C&E Socio-Economic Modeling program. A detailed schematic of the geospatial technical architecture and how the various systems are interconnected can be found in the *System Architecture* section below.

Data Sharing
The C&E SDE serves as the primary internal repository for geospatial data, metadata, and other information relevant to the activities and goals of the C&E department. All GIS users within the C&E Socio-Economic Modeling program. and some users from other H-GAC departments are provided *Editor* or *Viewer* access to data in the C&E SDE. The majority of users outside the core C&E GIS team have only viewer access to data in the C&E SDE. Other specific users that maintain data in the C&E SDE have editor access to the datasets. H-GAC C&E staff without *Editor* or *Viewer* access to the C&E SDE server are able to access a copy of the geospatial data through a separate server that houses imported versions of the original GIS layers for project specific editing. This system ensures that the original formatting of geospatial data on the C&E SDE remains unchanged. All user access privileges are assigned by the C&E GIS Manager based upon business needs, GIS skills, and role within the organization. No users outside of the C&E department have editor level access to any GIS data in the C&E SDE, and in some instances there are datasets that are viewable by only C&E GIS users. Instructions for connecting to the C&E SDE are provided to authorized users.

Datasets determined to be viable for publication to the public are exported to the Data Clearinghouse website, thereby allowing the general public widespread access to this information via the internet. Members of the public may view metadata and download any of the datasets that are posted to the Data Clearinghouse. In some instances these datasets are used in web-based mapping applications and can be accessed online via the Mapping Server's services directory, or accessible via the Data Clearinghouse for downloading. All public C&E GIS data, applications, cartographic products, and the C&E map services directory can be accessed via our C&E GIS page athttp://www.h-gac.com/rds/gis-data/gis-datasets.aspx, and a screen shot of the website can be found in Appendix 7.

Geospatial Applications
The C&E department has made a strategic decision to incorporate internet-based mapping applications into its deliverables for many programs and projects. Before, the results of most projects consisted of a large-format map printed on a plotter up to 48"x36" in diameter. This form of cartography although still useful in many settings, did not allow programs to communicate results to the public or external organizations that had an interest in our analysis results. By taking results from C&E projects and coupling this with base map data and imagery, C&E has been able to share the results of projects to a far greater audience, and has created opportunities whereby map layers published on the C&E mapping server can be utilized in other organizations mapping applications.

Currently there are three platforms upon which C&E provides internet-based mapping solutions. The first platform is based on the Adobe Flex programming environment, and all mapping applications developed using this platform run inside standard internet browsers that support the Flash technology, such as Internet Explorer. This platform is intended to provide users with a graphics rich user interface whereby the map can be navigated, layers turned on/off, and information obtained on each feature. In some instances, features have links to additional resources such as photos of monitoring stations, external websites, and detailed reports. This mapping application environment allows the users to make full use of their computers internet browser window, and serves as a simple online GIS.

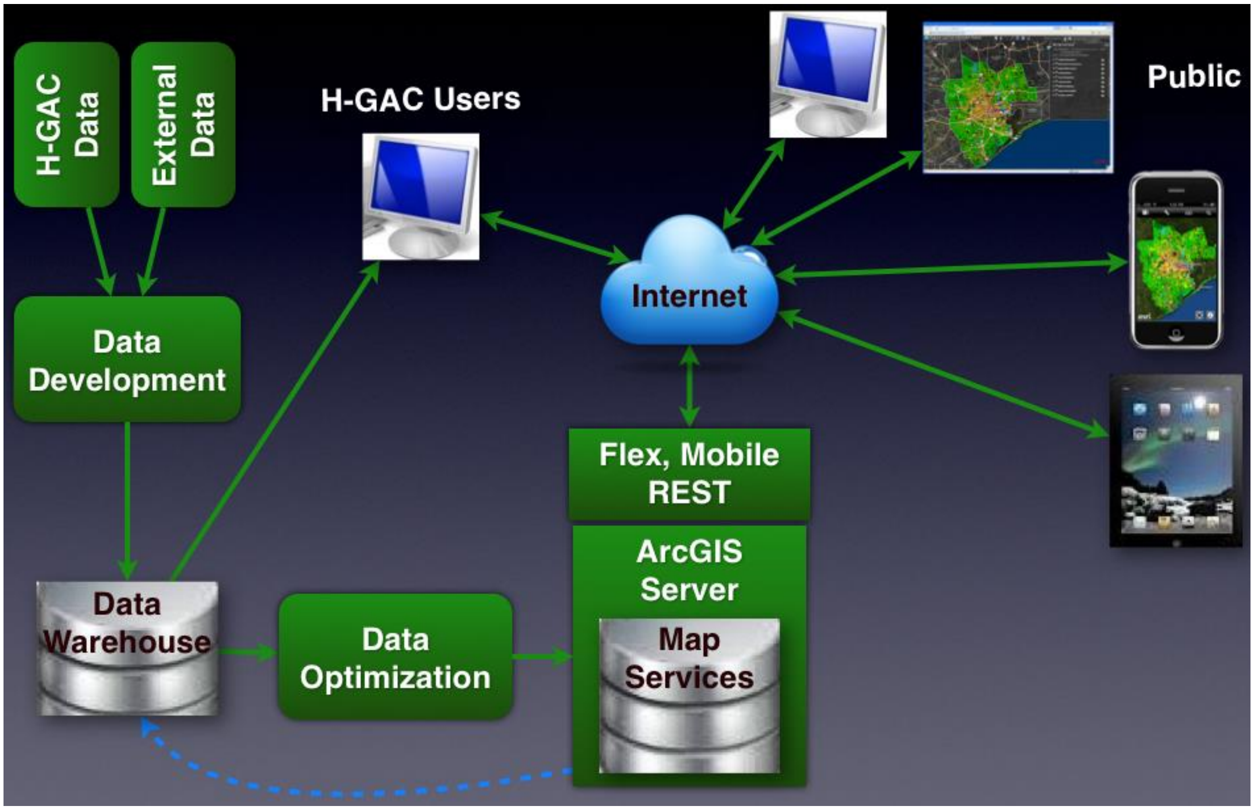
The second platform utilizes the capabilities of the ArcServer platform to allow users to directly access map layers published on the mapping server. This method of delivery is called 'streaming' and allows end users read-only access to individual map layers ad geoprocessing tools published on the server. Typical users of this method of deliver are other GIS users using desktop GIS, whereby they can connect directly to our ArcServer platform for read-only access and view our map layers. Other instances whereby users may utilize this method is where they are including our map layers in their own mapping applications.

The third and final platform involves developing applications for mobile devices or tablets. The C&E department has developed both native (installed) applications for the Apple iOS platform, as well as server-side scripted applications which utilize the free ESRI ArcGIS for Mobile Devices viewer app, which runs on iOS, Android, or Windows phone devices. In both instances, map layers used in these applications are delivered from the C&E ArcServer platform.
As previously mentioned, access to all the above forms of applications and data sharing methods can be accessed via our C&E GIS page at http://www.h-gac.com/go/cegis.

Mapping and Cartographic Products
The C&E department produces a variety of static cartographic maps for the region as a result of project activities and for general usage. To facilitate the sharing of these maps in an electronic format, C&E has implemented a Map Book as part of their C&E GIS page. Maps can be downloaded in multiple formats. The C&E Map Book can be accessed via our C&E GIS page at http://www.h-gac.com/go/cegis.

System Resources
System Architecture
The C&E department uses an integrated architecture to support the development, analysis, and dissemination of spatial information. The diagram below illustrates this system architecture at a high level. The goal of the overall system is to allow for a streamlined workflow to develop/maintain data, optimize the data for use in online applications, and the consumption of applications via multiple platforms.

Currently the C&E GIS platform supports sharing of geospatial data via the ArcServer mapping server platform. This allows end users internally or externally to consume map layers and geoprocessing tools via GIS desktop, mobile, tablet, or 3rd part applications.
In some instances, applications are configured with public feedback and volunteer GIS workflows that allow the C&E GIS team to obtain information for the public on various geographic features in the region. This public feedback loop allows C&E to investigate feedback and verify its validity prior to incorporating the information into the data warehouse.



Hardware
The configuration of the hardware used by staff that performs GIS and data Management work is a distributed network" This network consists of several PC's which are connected to central file servers. The department also uses a central web mapping server for online mapping applications. A complete listing of departmental hardware is found in Appendix 3.

Software
The C&E department relies upon the H-GAC Data Services department (Data Services) for all of its end user workstation configuration, installation, and maintenance. Each workstation for users comes with the Microsoft Office software package which includes Outlook (e-mail), Word (word processing), Excel (spreadsheets), PowerPoint (presentations), and in some instances Access (desktop database) should the user require desktop database capabilities. Each workstation is pre-configured and setup to operate within the H-GAC internal network, and has access to central servers for file storage. In some instances, certain personnel have addition non-standard software installed by Data Services as it is required for their responsibilities.

The C&E GIS staff utilizes ESRI's ArcGIS 10.1 platform for all geospatial analysis and mapping needs. In addition, as needed, the staff also utilizes the SAS software platform for further analysis and data development as deemed necessary. The ESRI ArcGIS 10.1 platform includes integrated Python programming capabilities, which allows for the creation of programming scripts or batch programs to improve efficiency and documentation of processes. The Python programming language is an Open Source platform, and is freely distributable.

The centralized SDE is also provided by ESRI, and provided for a centralized geospatial database where GIS staff can store geospatial data for either read-only or editable access by GIS users in the C&E department. The C&E GIS staff maintains access privileges to the SDE datasets, and assigns individual users to various SDE access groups to grant approved accessed to data in the SDE. The SDE is considered the central warehouse whereby GIS users can go to for geospatial data to use in their analysis or mapping projects.
The software products currently used to accomplish the department's data management objectives are listed in Appendix 4.

Programming Languages
Programming services will be provided on an as needed and resource available basis. All programming efforts will follow a standard procedure from needs assessment, program planning, development and testing, to refinement and documentation. The principal programming languages to be used in task automation and project customization will depend on the nature of the need and the current state of the technology. At this time, all web-based GIS applications are developed using the ESRI ArcGIS Server platform, and user interface components to that platform are developed using the Adobe Flex API. Automated data development and analysis workflows utilize the Python programming language and the SAS programming platform as needed.

Data
Department staff members will be consulted annually to determine priority needs for data management. Based on this consultation, specific data sets will be acquired or further developed for the various program areas represented in the department. The current list of department-specific data sets is shown in Appendix 5.

A separate database lists all datasets regularly obtained from external sources, contact information, as well as the frequency of the datasets availability, and its cost. This database is developed using Microsoft Access, and is available to the C&E GIS team for tracking when updates to dataset may be available.

Personnel
The Data Management staff will be responsible for the maintenance and development of the C&E SDE, mapping server, geospatial applications, C&E GIS page, and Data Clearinghouse. These data management responsibilities cover a wide range from original data creation, acquisition and integration, data archiving and distribution. Additional responsibilities include enhancing the geographic extent, feature attributes, and metadata of the datasets.

The C&E GIS team is comprised of 3 full-time GIS professionals, one of which is the GIS Manager, and 2 full-time GIS Analysts. The C&E GIS team supports all programs within the C&E department, which include Clean Rivers/Water Quality, Sustainability, Economic Development, Solid Waste, Ped/Bike, Socio-Economic Modeling, and special project. The C&E GIS team is part of the Socio-Economic Modeling program within C&E.
H-GAC's Data Services Department plays an indirect role in the implementation and maintenance of The Plan. The Data Services Department is responsible for managing the underlying hardware and network upon which C&E stores GIS data and implements GIS-based

applications.

Training
Training for all users of the system is a critical part of The Plan. C&E staff directly responsible for data management will attend conferences, seminars, and software/hardware training courses as needed. H-GAC users of the system will be trained and/or receive technical support by the C&E GIS Manger and other C&E subject matter experts.

Budget
Budgetary requirements to sustain data management efforts will be reviewed annually.

Data Maintenance, Manipulation, and Use

Quality Assurance/Quality Control
QA/QC is designed to standardize screening, documentation, entry, output, analysis, correction, and updating of data in the system. QA/QC will document those responsible for data and system maintenance.

Data Limitations
Prior to the integration of data within the C&E SDE and posting to the Data Clearinghouse, a review of the data set will be completed to determine predefined data limitations such as missing values, different sampling frequencies, multiple measurements, analytical uncertainty, censored or unavailable data, and duplicated data with existing data sets. After review of the data set, a report will be generated which records any errors detected and any corrections that may be necessary.

Data Development Protocol
The C&E GIS staff works to update existing dataset, acquire new data, and perform geospatial analysis in support of various C&E programs. All new data generated from the result of an analysis is a candidate to be stored not only in the SDE as a new dataset, but also as a layer with a mapping application should the need arise. All data development and analysis is done internally to C&E, and at times leverages outside resources such as consultants, other non-profits whom H-GAC is partnering with, as well as with other H-GAC departments to obtain necessary data. Two datasets that the C&E department uses regularly outside the C&E SDE are the Data Services StarMap road centerline dataset, and the Data Services aerial imagery database.

The C&E GIS staff uses a hybrid approach to conducting geospatial analysis. Much of the analysis being performed may need to be re-processed at a later date as new versions of datasets become available, or as inputs to the analysis models are updated themselves. Thus to minimize the time spend re-running analysis models, the C&E GIS staff utilizes the ESRI ArcGIS platform in conjunction with SAS and Python to develop repeatable and documented workflows. This approach saves more time than interactive methods whereby a user must remember the process to follow, and then execute each step in the analysis independently.

Documentation related to data management efforts such as system evolution, structure, and procedures for use will be compiled and made available for the end user. Documentation will be made available online and in hard copy format.

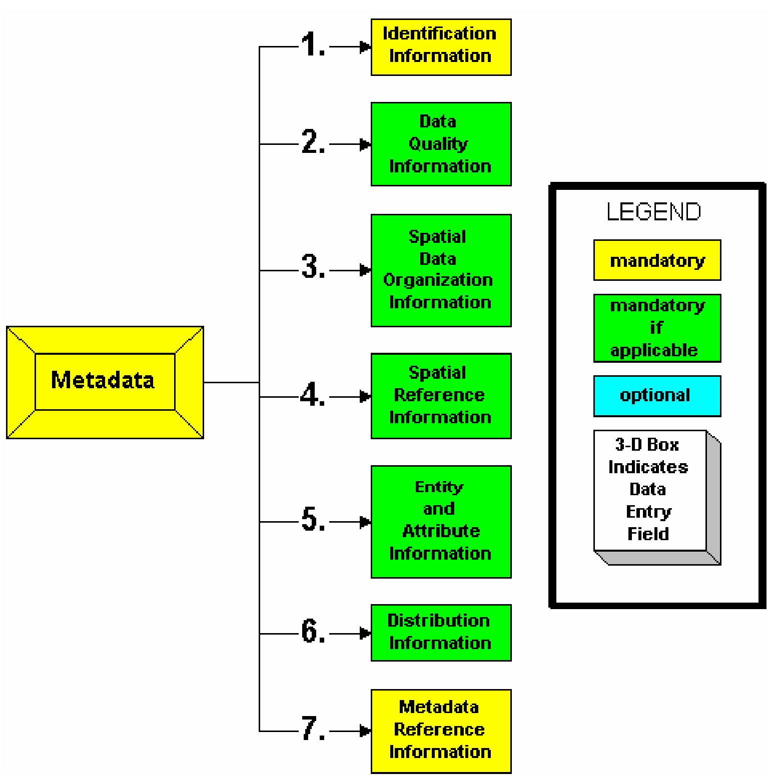
Data Input
Standard conventions for data input will be determined on a per project and or individual data set basis. To ensure Year 2000 Compliance, all data sets with date/time fields will include a four-digit year (YYYY). Either of the following formats will be used: International Standard Date notation where the date field is represented as MM/DD/YYYY (Month/Day/Year), or an ordinal format where the date field is represented as YYYYDDD.

Data Dictionary
A list of all C&E data available in either the C&E SDE or other tabular formats can be found in

Appendix 5. Metadata for each dataset in the C&E SDE is stored with the datasets, and can be viewed by GIS users via their GIS desktop software. Any data provided for public download via the Data Clearinghouse also has a metadata html page that can be viewed via internet browsers.

Metadata

Metadata is data about the original source, quality, content, history, condition, and other characteristics of geospatial data. All GIS datasets generated by H-GAC have been fully documented as per Federal Geographic Data Committee (FGDC) compliant metadata and follow Content Standards for Digital Geospatial Metadata (CSDGM) for all geospatial data. Similarly, outside sources obtained and used by H-GAC will require FGDC-compliant metadata as provided by the source agency. Datasets without a known history and documented quality will be noted as provisional and used only when noted as such. The diagram below illustrates elements of the CSDGM standards. This standard is applied to all Point, Line, Polygon, Raster, and Tabular data that are stored in the C&E SDE. The C&E GIS data manager and/or point of contact has the authorized access to edit/change the metadata when a new dataset is created or updated in the SDE. Metadata for each dataset in the C&E SDE is stored with the datasets, and can be viewed by GIS users via their GIS desktop software. Any data provided for public download via the Data Clearinghouse also has a metadata html page that can be viewed via internet browsers.



Data Conversion

Data to be imported into the C&E SDE from hard copy, digital or by manual data entry, will follow a uniform conversion protocol to comply with the structure of current data sets. The type of data being converted will determine the protocol. All data is stored in ESRI geodatabase format within the C&E SDE, and when posted to the Data Clearinghouse the data is stored in the ESRI File Geodatabase file format, unless there is a specific requirement to provide the data in another format such as Shapefile or GIS Coverage.

Coordinate Systems

The Texas Stateplane Coordinate System, North American Datum 1983 (NAD83) will be the standard for geographic data at H-GAC. This coordinate system is based on the Cartesian coordinate system, or rectangular coordinates. When receiving geographic data from other sources the data will be transformed into the Stateplane Coordinate System to ensure compatibility with current data sets.

When publishing mapping services for use in web-based GIS mapping applications, the Web Mercator Auxiliary Sphere projection is used for all Data Frame projections. However, the underlying GIS data within these mapping services still use the Texas Stateplane Coordinate System, North American Datum 1983 (NAD83) projection.

Data Validation

Data Quality Control

When data are received from any source, documentation will be created to include the source name, date received, format of data and a brief description of the contents. Data will be loaded onto the system from the media received and a review of the data will be made along with any corrections being made to the source documentation. An analysis will be made in order to determine the means of data entry into the system whether it is only a stand-alone database, a number of linked tables, or a geographic database. The data will be converted to the appropriate format for integration with the current system whether it is a conversion into MS Access, Excel, SAS, or ESRI ArcGIS. The data will be visually examined to determine its validity and accuracy. If the data is invalid it will be corrected (if possible) otherwise the data will be incorporated into the C&E SDE, and then if applicable, posted to the Data Clearinghouse and used in conjunction with existing data. A QA/QC report of all procedures and a detailed description of how the data was incorporated into the current system (from the date received to the date of integration) will be generated.

Equipment Quality Control

All printers, workstations, and server hardware and operating systems are maintained by the Data Services department, unless otherwise noted in Appendix 3.

Genealogy

Upon receipt of data from outside sources, all data will be screened for integrity and completeness. After the preliminary evaluation of the data, a log of the data source, type and completeness is created and maintained with the associated data. A description of the data and the responsible personnel are documented.

Migration/Transfer

A copy of every C&E generated GIS dataset will be housed in the C&E SDE which C&E GIS staff manage the contents and structure of datasets. The underlying hardware and network connections for the C&E SDE are maintained by the Data Services Department. Datasets that are of public interest will be placed in the Data Clearinghouse for public access. Transfer from the

C&E SDE to the Data Clearinghouse will occur on an as needed basis following department QA/QC measures and is handled by the C&E GIS team.

Data Security & Access

Data placed on the Data Clearinghouse will be available to those with Internet browsing and/or FTP capability. Data requests for non-public data from other agencies and the general public will be evaluated on an individual basis. When the data requests are received, a preliminary evaluation of the deliverable will be determined and a timeline and cost if applicable will be provided to the requesting agency or individual.

GIS and tabular data will be secure through directory permissions. H-GAC will employ Firewall or Proxy Server Technology to filter and severely restrict access to internal networks and database systems. Virus protection will be implemented to ensure system and data integrity.

Archives/Backup

Each week the C&E GIS team runs a schedule backup program to store a copy of all C&E SDE datasets on a portable hard drive with resides in a secure location within the H-GAC office. In addition, Data Services backs up and archives C&E SDE data and server configuration at regular intervals.. A backup will be performed daily and the tapes will be maintained for 8 weeks before they will be recycled. Every six month, a complete system backup will be performed and the tapes will be archived and kept for five years off-site for security.

Disaster Recovery

In the event of a disaster, the C&E department will have access to all C&E SDE data which is stored on the portable hard drive. The C&E GIS team will restore or provide needed data to GIS users from this portable hard drive until such as time that Data Services can restore the C&E SDE onto either a new server or a temporary server.

Appendices

Appendix 1 Data Source Information Sheet

Data Title:

Source Agency:
Contact:
Title:
Address
Phone:

Data Description:
Data source:
Date created:
Accuracy:
Media:
Data items:

Description of data:

Format (specify what software)
Map:
Tabular:
Image:
Text:

Retrieval Procedure:

Command(s):

Appendix 2 Data Log Sheet

Date received: ____

Report Prepared by: ____

Source Name and Phone: ____

Format: ____

Media: ____

Check the following steps to determine the validity of the data:

1. What is the extent of the geographic area? __________________________
____

2. Structure (Circle One) Vector Raster

3. Scale? ____

4. Projection and Datum? ____

1. Do any of the key fields have missing values? If so which parameters have missing values? Yes ___ No ___
____
____
____

2. Any known duplicate records? Yes ___ No ___

Appendix 3 Hardware

FTP Server

Windows 2000 Server

Mapping Application Servers

Production Server (NTCEIS01)

Model:	HP Proliant BL460c G6 Blade
CPU:	Quad-Core Intel Xeon X5560 (2.80 GHz, 8M Cache)
Memory:	8GB
Hard Drive:	300GB
OS:	Windows 2008
Internet Address:	204.65.99.189
Domain URL:	http://arcgis02.h-gac.com
Serial #:	USE936RV4S
Purchased:	January 2010

Development/Backup Server (NTIS04)

Model:	HP Proliant DL 380 G3
CPU:	Single Intel Xeon 2800
Memory:	1GB
Hard Drive:	C = 16 GB, D=66 GB
OS:	Windows 2000 SP 4
Internet Address:	204.65.99.240
Domain URL:	http://arcgis.h-gac.com
Serial #:	D313LDN1L122
Purchased:	April 2003

Printers & Plotters

HP1055CM Plotter - Used by C&E staff for large format printing of maps and schematics.
HP2500CM and LaserJet 4M Printers. C&E maintains both printers.

Global Positioning System (GPS) Units

The C&E Department possesses two GPS units.

Scanning Equipment

HP Scanjet 7400c. The CEP Department owns one network-accessible HP scanner.

Fax Equipment

Brother Intellifax 4750e. The C&E Department owns one fax machine.

Portable Storage Devices

Lacie 300GB external hard drive (USB, Firewire)

Appendix 4 Software

Office Productivity Software

Microsoft Office Pro (2007) - Word, Excel, Access, PowerPoint, publisher, InfoPath and Outlook.
Internet Explorer (ver 7) – Primary Development Tool

Graphics and Desktop Publishing

Macromedia Fireworks 4
Adobe Illustrator (ver 8.01) – Graphics
Adobe Photoshop (ver 5.0) – Graphics
Corel Draw (ver 7.0) - Graphics
Quark Express (ver 5.0) - Desktop Publishing.
Paintshop Pro (ver 4.12)
Camtasia Studio (ver 7.0) – Screen capture and video tutorial production

Programming

Visual Basic (ver 6.0) – Web Mapping Development Tool.
MS Active Server Pages (ver 2.0) – Web Database Development Tool.
Adobe Flex Builder (ver 4.0) – Web-based GIS application development tool
SAS (ver 9.3) – Data development and analytics.

Geographic Information Systems (GIS)

ESRI ArcGIS (ver 10.1, SP1) – Computer mapping and database manipulation capable of using ArcView, ArcInfo, and ArcEditor licenses as needed.
ESRI ArcGIS Server (ver 10, SP3) – Internet Mapping Application Server.
ESRI ArcSDE (ver 10.1, SP1) – Spatial data warehouse.

Data Management

Access (2007, 2010) - Relational Database.
SQL Server(2000) - Relational Database.

Operating Systems

Windows XP - PC working environment/Operating System
Windows 7 - PC working environment/Operating System
Windows 2003 & 2008 - Server Operating Systems

Appendix 5 Data List

C&E Spatial Data Warehouse (SDE) Datasets

Dataset Name	Type
AustCAD_Parcels_Coverage_2005	Polygon
AustCAD_Parcels_Coverage_2005_pts	Point
AustCAD_Parcels_Coverage_2006	Polygon
AustCAD_Parcels_Coverage_2006_pts	Point
AustCAD_Parcels_Coverage_2007	Polygon
AustCAD_Parcels_Coverage_2007_pts	Point
AustCAD_Parcels_Coverage_2008	Polygon
AustCAD_Parcels_Coverage_2008_Pts	Point
Austin_County	Polygon
AUSTIN_COUNTY_PARCEL_INFO_2005	Table
AUSTIN_COUNTY_PARCEL_INFO_2006	Table
AUSTIN_COUNTY_PARCEL_INFO_2007	Table
Austin_County_Parcel_Info_2008	Table
Austin_County_Parcel_Values_2006	Table
Austin_County_Parcel_Values_2007	Table
Austin_County_Parcel_Values_2008	Table
BrazCAD_Parcels_Coverage_2005	Polygon
BrazCAD_Parcels_Coverage_2005_pts	Point
BrazCAD_Parcels_Coverage_2006	Polygon
BrazCAD_Parcels_Coverage_2006_pts	Point
BrazCAD_Parcels_Coverage_2007	Polygon
BrazCAD_Parcels_Coverage_2007_pts	Point
BrazCAD_Parcels_Coverage_2008	Polygon
BrazCAD_Parcels_Coverage_2008_Pts	Point
Brazoria_County	Polygon
BRAZORIA_COUNTY_PARCEL_INFO_2005	Table
BRAZORIA_COUNTY_PARCEL_INFO_2006	Table
BRAZORIA_COUNTY_PARCEL_INFO_2007	Table
Brazoria_County_Parcel_Info_2008	Table
Brazoria_County_Parcel_Values_2005	Table
Brazoria_County_Parcel_Values_2006	Table
Brazoria_County_Parcel_Values_2007	Table
Brazoria_County_Parcel_Values_2008	Table
Brazoria_County_Political	Polygon
Chambers_County	Polygon
Chambers_County_Political	Polygon
Clean_Rivers_Public_Feedback	Point
Clean_Rivers_Public_Feedback__ATTACH	Table
Colorado_County	Polygon
CRP_Project_Areas	Polygon
FBendCAD_Parcels_Coverage_2005	Polygon

Dataset Name	Type
FBendCAD_Parcels_Coverage_2005_pts	Point
FBendCAD_Parcels_Coverage_2006	Polygon
FBendCAD_Parcels_Coverage_2006_pts	Point
FBendCAD_Parcels_Coverage_2007	Polygon
FBendCAD_Parcels_Coverage_2007_pts	Point
FBendCAD_Parcels_Coverage_2008	Polygon
FBendCAD_Parcels_Coverage_2008_Pts	Point
Fort_Bend_County	Polygon
Fort_Bend_County_Parcel_Info_2006	Table
Fort_Bend_County_Parcel_Info_2007	Table
Fort_Bend_County_Parcel_Info_2008	Table
Fort_Bend_County_Parcel_Values_2006	Table
Fort_Bend_County_Parcel_Values_2007	Table
Fort_Bend_County_Parcel_Values_2008	Table
GalvCAD_Parcels_Coverage_2005	Polygon
GalvCAD_Parcels_Coverage_2005_pts	Point
GalvCAD_Parcels_Coverage_2006	Polygon
GalvCAD_Parcels_Coverage_2006_pts	Point
GalvCAD_Parcels_Coverage_2007	Polygon
GalvCAD_Parcels_Coverage_2007_Pts	Point
GalvCAD_Parcels_Coverage_2008	Polygon
GalvCAD_Parcels_Coverage_2008_Pts	Point
Galveston_Bay_Estuary_Program_Watersheds	Polygon
Galveston_County	Polygon
GALVESTON_COUNTY_PARCEL_INFO_2005	Table
GALVESTON_COUNTY_PARCEL_INFO_2007	Table
Galveston_County_Parcel_Info_2008	Table
Galveston_County_Parcel_Values_2005	Table
Galveston_County_Parcel_Values_2007	Table
Galveston_County_Parcel_Values_2008	Table
Galveston_County_Political	Polygon
Grimes_County	Polygon
Gulf_Of_Mexico	Polygon
Harris_County	Polygon
Harris_County_FCD_Sub_Watersheds	Polygon
Harris_County_FCD_Watersheds	Polygon
HARRIS_COUNTY_PARCEL_INFO_2005	Table
HARRIS_COUNTY_PARCEL_INFO_2006	Table
HARRIS_COUNTY_PARCEL_INFO_2007	Table
Harris_County_Parcel_Info_2008	Table
Harris_County_Parcel_Values_2005	Table
Harris_County_Parcel_Values_2006	Table
Harris_County_Parcel_Values_2007	Table

Harris_County_Parcel_Values_2008	Table
Dataset Name	**Type**
Harris_County_Zones_58	Polygon
HCAD_Parcels_Coverage_2000	Polygon
HCAD_Parcels_Coverage_2000_pts	Point
HCAD_Parcels_Coverage_2003	Polygon
HCAD_Parcels_Coverage_2003_pts	Point
HCAD_Parcels_Coverage_2005	Polygon
HCAD_Parcels_Coverage_2005_pts	Point
HCAD_Parcels_Coverage_2006	Polygon
HCAD_Parcels_Coverage_2006_pts	Point
HCAD_Parcels_Coverage_2007	Polygon
HCAD_Parcels_Coverage_2007_Pts	Point
HCAD_Parcels_Coverage_2008	Polygon
HCAD_Parcels_Coverage_2008_Pts	Point
HGAC_13_County_Airports	Point
HGAC_13_County_Airports_ParcelIDs	Table
HGAC_13_County_BlockGroups_1990	Polygon
HGAC_13_County_BlockGroups_2000	Polygon
HGAC_13_County_BlockGroups_2010	Polygon
HGAC_13_County_Blocks_2000	Polygon
HGAC_13_County_Blocks_2010	Polygon
HGAC_13_County_Brownfield_Sites	Point
HGAC_13_County_Bus_Routes	Polyline
HGAC_13_County_Bus_Stops	Point
HGAC_13_County_Census_PL_Data_2010_Block_Groups	Table
HGAC_13_County_Census_PL_Data_2010_Blocks	Table
HGAC_13_County_Census_PL_Data_2010_Counties	Table
HGAC_13_County_Census_PL_Data_2010_Places	Table
HGAC_13_County_Census_PL_Data_2010_School_Districts	Table
HGAC_13_County_Census_PL_Data_2010_Tracts	Table
HGAC_13_County_Census_Places_2000	Polygon
HGAC_13_County_Census_Places_2000_Clipped	Polygon
HGAC_13_County_Census_Places_2000_Pts	Point
HGAC_13_County_Census_Places_2010	Polygon
HGAC_13_County_Census_Places_2010_Clipped	Polygon
HGAC_13_County_Census_Places_2010_Pts	Point
HGAC_13_County_Census_Urban_Areas_1990	Polygon
HGAC_13_County_Census_Urban_Areas_2000	Polygon
HGAC_13_County_Census_Urban_Areas_2009	Polygon
HGAC_13_County_Census_Urban_Areas_2010	Polygon
HGAC_13_County_Census_Zip_Codes_2010	Polygon
HGAC_13_County_City_Boundaries	Polygon
HGAC_13_County_City_Boundaries_Clipped	Polygon

HGAC_13_County_City_Ordinance_Areas	Polygon
HGAC_13_County_Closed_Landfill_Inventory	Point
Dataset Name	**Type**
HGAC_13_County_Landfill_Areas	Polygon
HGAC_13_County_Landfill_Areas_Historical	Polygon
HGAC_13_County_Landfills	Point
HGAC_13_County_Landfills_Historical	Point
HGAC_13_COUNTY_COASTAL_VIGNETTE	Raster
HGAC_13_County_Coastline	Polygon
HGAC_13_County_Coastline_Boundary	Polygon
HGAC_13_County_CRP_DO_Stations	Point
HGAC_13_County_CRP_Monitoring_Stations_2008	Point
HGAC_13_County_CRP_Monitoring_Stations_2010	Point
HGAC_13_County_CRP_Monitoring_Stations_2011	Point
HGAC_13_County_CRP_Monitoring_Stations_2012	Point
HGAC_13_County_CRP_Monitoring_Stations_2013	Point
HGAC_13_County_CRP_Monitoring_Stations_2014	Point
HGAC_13_County_CRP_Monitoring_Stations_2015	Point
HGAC_13_County_CRP_Monitoring_Stations_2016	Point
HGAC_13_County_CRP_Monitoring_Stations_Historical	Point
HGAC_13_County_Dams	Point
HGAC_13_County_Districts	Polygon
HGAC_13_County_Election_Precincts_2010	Polygon
HGAC_13_County_Farmland	Polygon
HGAC_13_County_Federal_Aid_Roads	Polyline
HGAC_13_County_G1M	Polygon
HGAC_13_County_G3M	Polygon
HGAC_13_County_G5M	Polygon
HGAC_13_County_Grocery_Stores	Point
HGAC_13_County_Libraries	Point
HGAC_13_County_Libraries_Parcel_Xref	Table
HGAC_13_County_Major_Rivers	Polyline
HGAC_13_County_Major_Roads	Polyline
HGAC_13_County_Metropolitan_Statistical_Area	Polygon
HGAC_13_County_OSSF_Permits	Point
HGAC_13_County_Parks	Point
HGAC_13_County_Parks_Awards	Table
HGAC_13_County_Parks_Features	Table
HGAC_13_County_Parks_Parcels	Table
HGAC_13_County_Pipelines	Polyline
HGAC_13_County_Plats	Polygon
HGAC_13_County_Political	Polygon
HGAC_13_County_Political_Boundary	Polygon
HGAC_13_County_Railroads	Polyline

HGAC_13_County_Raster_Extent	Polygon
HGAC_13_County_Recycle_Centers	Point
HGAC_13_County_School_Districts_Census_2010	Polygon
Dataset Name	**Type**
HGAC_13_County_School_Districts_TEA_2010	Polygon
HGAC_13_County_Service_Area_Boundaries	Polygon
HGAC_13_County_Soils	Polygon
HGAC_13_County_State_Parks	Polygon
HGAC_13_County_Superfund_NPL_Sites	Polygon
HGAC_13_County_Superfund_NPL_Sites_Pts	Point
HGAC_13_County_TIRZs	Polygon
HGAC_13_County_Tracts_1990	Polygon
HGAC_13_County_Tracts_2000	Polygon
HGAC_13_County_Tracts_2010	Polygon
HGAC_13_County_Transit_Centers_Parks_and_Rides	Point
HGAC_13_County_Water	Polygon
HGAC_13_County_Water_Detailed	Polygon
HGAC_13_County_Watershed_Project_Monitoring_Sites	Point
HGAC_13_County_Zip_Codes_2000	Polygon
HGAC_13_County_Zip_Codes_2002	Polygon
HGAC_13_County_Zip_Codes_2005	Polygon
HGAC_15_County_Aquifer_Recharge_Zones	Polygon
HGAC_15_County_Basins	Polygon
HGAC_15_County_Bio_Monitoring_Sites	Point
HGAC_15_County_Census_Zip_Codes_2010	Polygon
HGAC_15_County_City_Boundaries	Polygon
HGAC_15_County_City_Boundaries_Clipped	Polygon
HGAC_15_County_Coastline	Polygon
HGAC_15_County_Coastline_Boundary	Polygon
HGAC_15_County_Contours_2_Feet	Polyline
HGAC_15_County_Contours_5_Feet	Polyline
HGAC_15_COUNTY_CRP_Impairments	Table
HGAC_15_County_CRP_Lakes	Polygon
HGAC_15_County_CRP_Stream_End_Points	Point
HGAC_15_County_CRP_Streams	Polyline
HGAC_15_County_DEM_10m	Raster
HGAC_15_County_Hillshade	Raster
HGAC_15_County_Major_Rivers	Polyline
HGAC_15_County_Major_Roads	Polyline
HGAC_15_County_Political	Polygon
HGAC_15_County_Political_Boundary	Polygon
HGAC_15_County_School_Districts_TEA_2010	Polygon
HGAC_15_County_Soils	Polygon
HGAC_15_County_Wastewater_Outfalls	Point

HGAC_15_County_Wastewater_Outfalls_Historical	Point
HGAC_15_County_Wastewater_Outfalls_Info	Table
HGAC_15_County_Water	Polygon
HGAC_15_County_Watershed_Insets	Polygon
Dataset Name	**Type**
HGAC_15_County_Watershed_Signs	Point
HGAC_15_County_Watersheds	Polygon
HGAC_15_County_Zip_Codes_2000	Polygon
HGAC_15_County_Zip_Codes_2002	Polygon
HGAC_8_County_Bikeway_Needs	Polyline
HGAC_8_County_Bikeways	Polyline
HGAC_8_County_BlockGroups_2000	Polygon
HGAC_8_County_BlockGroups_2010	Polygon
HGAC_8_County_Blocks_2000	Polygon
HGAC_8_County_Blocks_2010	Polygon
HGAC_8_County_Census_Places_2000	Polygon
HGAC_8_County_Census_Places_2000_Clipped	Polygon
HGAC_8_County_Census_Places_2000_Pts	Polygon
HGAC_8_County_Census_Places_2010	Polygon
HGAC_8_County_Census_Places_2010_Clipped	Polygon
HGAC_8_County_Census_Places_2010_Pts	Polygon
HGAC_8_County_Census_Urban_Areas_2000	Polygon
HGAC_8_County_Census_Urban_Areas_2009	Polygon
HGAC_8_County_Census_Urban_Areas_2010	Polygon
HGAC_8_County_Census_Zip_Codes_2010	Polygon
HGAC_8_County_City_Boundaries	Polygon
HGAC_8_County_City_Boundaries_Clipped	Polygon
HGAC_8_County_City_Ordinance_Areas	Polygon
HGAC_8_COUNTY_COASTAL_VIGNETTE	Raster
HGAC_8_County_Coastal_Vignette_50_25	Polygon
HGAC_8_County_Coastline	Polygon
HGAC_8_County_Coastline_Boundary	Polygon
HGAC_8_County_Comprehensive_Plan_2010_pts	Point
HGAC_8_County_Eco_Types	Polygon
HGAC_8_County_Forecast_Cities_h	Table
HGAC_8_County_Forecast_Cities_v	Table
HGAC_8_County_Forecast_Counties_h	Table
HGAC_8_County_Forecast_Counties_v	Table
HGAC_8_County_Forecast_G025M_h	Table
HGAC_8_County_Forecast_G1_h	Table
HGAC_8_County_Forecast_G10K_h	Table
HGAC_8_County_Forecast_G10K_v	Table
HGAC_8_County_Forecast_G1M_h	Table
HGAC_8_County_Forecast_G1M_v	Table

HGAC_8_COUNTY_FORECAST_LU_G1_H	Table
HGAC_8_County_Forecast_RAZ_h	Table
HGAC_8_County_Forecast_RAZ_v	Table
HGAC_8_County_Forecast_Region_v	Table
HGAC_8_County_Forecast_TAZ_h_2003	Table
Dataset Name	**Type**
HGAC_8_County_Forecast_TAZ_v_2003	Table
HGAC_8_County_Forecast_Tracts_h	Table
HGAC_8_County_Forecast_Tracts_v	Table
HGAC_8_County_Forecast_Zip_Codes_h	Table
HGAC_8_County_Forecast_Zip_Codes_v	Table
HGAC_8_County_G025M	Polygon
HGAC_8_County_G1	Polygon
HGAC_8_County_G10	Polygon
HGAC_8_County_G1M	Polygon
HGAC_8_County_Livable_Centers	Point
HGAC_8_County_Livable_Centers_Areas	Polygon
HGAC_8_County_Major_Rivers	Polyline
HGAC_8_County_Major_Roads	Polyline
HGAC_8_County_PedBike_Improvement_Areas	Polyline
HGAC_8_County_PedBike_Improvement_Locations	Polyline
HGAC_8_County_Pedestrian_Pathways	Polyline
HGAC_8_County_Political	Polygon
HGAC_8_County_Political_Boundary	Polygon
HGAC_8_County_Railroads	Polyline
HGAC_8_County_Raster_Extent	Polygon
HGAC_8_County_RAZ	Polygon
HGAC_8_County_School_Districts_TEA_2010	Polygon
HGAC_8_County_Soils	Polygon
HGAC_8_County_TAZ_2003	Polygon
HGAC_8_County_Tracts_1970	Polygon
HGAC_8_County_Tracts_1980	Polygon
HGAC_8_County_Tracts_2000	Polygon
HGAC_8_County_Tracts_2010	Polygon
HGAC_8_County_Water	Polygon
HGAC_8_County_Water_Detailed	Polygon
HGAC_8_County_Zip_Codes_2000	Polygon
HGAC_8_County_Zip_Codes_2002	Polygon
HGAC_8_County_Zip_Codes_2005	Polygon
HGAC_8_County_Zoning_2010_pts	Point
HGAC_Bastrop_Bayou_Sub_Watersheds	Polygon
HGAC_CRP_Watersheds	Polygon
HGAC_LAND_COVER_10_CLASS_2008	Polygon
HGAC_LAND_COVER_10_CLASS_ROADS_2008	Raster

HGAC_LAND_COVER_3X3_MODE_FILTERED_2008	Raster
HGAC_LAND_COVER_MERGED_6_CLASS_2008	Raster
HGAC_Other_CRP_Monitoring_Stations	Point
HGAC_Sea_Level_Rise_10Ft	Polygon
HGAC_Sea_Level_Rise_15Ft	Polygon
HGAC_Sea_Level_Rise_1Ft	Polygon
Dataset Name	**Type**
HGAC_Sea_Level_Rise_20Ft	Polygon
HGAC_Sea_Level_Rise_25Ft	Polygon
HGAC_Sea_Level_Rise_30Ft	Polygon
HGAC_Sea_Level_Rise_35Ft	Polygon
HGAC_Sea_Level_Rise_3Ft	Polygon
HGAC_Sea_Level_Rise_5Ft	Polygon
HGAC_Sea_Level_Rise_All_Levels	Polygon
HGAC_Sea_Level_Rise_Current_Sea_Level	Polygon
Hurricane_Dolly_Observations	Point
Hurricane_Dolly_Track	Polyline
Hurricane_Ike_High_Water_Measurements	Point
Hurricane_Ike_Observations	Point
HURRICANE_IKE_SALT_BURN_GULF_COAST	Raster
Hurricane_Ike_Storm_Surge_Model_i48_gl2	Polygon
HURRICANE_IKE_STORM_SURGE_MODEL_I48_GL2_RASTER	Raster
Hurricane_Ike_Track	Polyline
Land_Cover_1992_19_Class_NLCD	Raster
Land_Cover_1992_19_Class_NLCD_Corrected	Raster
Land_Cover_1996_22_Class_NOAA	Raster
Land_Cover_2001_15_Class_NLCD	Raster
Land_Cover_2001_15_Class_NLCD_Corrected	Raster
Land_Cover_2001_22_Class_NOAA	Raster
Land_Cover_2005_22_Class_NOAA	Raster
Land_Cover_2006_15_Class_NLCD	Raster
Land_Cover_2011_15_Class_NOAA	Raster
Land_Cover_2011_22_Class_NOAA	Raster
Land_Cover_Change_1992_to_2011_9_Class	Raster
LibCAD_Parcels_Coverage_2007	Polygon
LibCAD_Parcels_Coverage_2007_pts	Point
LibCAD_Parcels_Coverage_2008	Polygon
LibCAD_Parcels_Coverage_2008_Pts	Point
Liberty_County	Polygon
LIBERTY_COUNTY_PARCEL_INFO_2007	Table
Liberty_County_Parcel_Info_2008	Table
Liberty_County_Parcel_Values_2007	Table
Liberty_County_Parcel_Values_2008	Table
Matagorda_County	Polygon

Matagorda_County_Political	Polygon
METRO_LRT_Lines	Polyline
METRO_LRT_Stations	Point
Model_Buildings	Point
Model_Buildings_Rural	Point
Model_Buildings_Uses	Point
Model_Buildings_Uses_Rural	Table
Dataset Name	**Type**
Model_Parcels	Table
Model_Parcels_Acct_Nums	Polygon
Model_Parcels_Acct_Nums_Rural	Table
Model_Parcels_Addresses	Table
Model_Parcels_Addresses_Rural	Table
Model_Parcels_Features	Table
Model_Parcels_Features_Rural	Table
Model_Parcels_Forecast	Table
Model_Parcels_Removed_Merged	Table
Model_Parcels_Rural	Polygon
MontCAD_Parcels_Coverage_2005	Polygon
MontCAD_Parcels_Coverage_2005_pts	Point
MontCAD_Parcels_Coverage_2006	Polygon
MontCAD_Parcels_Coverage_2006_pts	Point
MontCAD_Parcels_Coverage_2007	Polygon
MontCAD_Parcels_Coverage_2007_pts	Point
MontCAD_Parcels_Coverage_2008	Polygon
MontCAD_Parcels_Coverage_2008_Pts	Point
Montgomery_County	Polygon
MONTGOMERY_COUNTY_PARCEL_INFO_2006	Table
MONTGOMERY_COUNTY_PARCEL_INFO_2007	Table
Montgomery_County_Parcel_Info_2008	Table
Montgomery_County_Parcel_Values_2006	Table
Montgomery_County_Parcel_Values_2007	Table
Montgomery_County_Parcel_Values_2008	Table
Montgomery_County_Zones_4	Polygon
NLCD_IMPERVIOUSNESS_2001	Raster
NLCD_IMPERVIOUSNESS_2006	Raster
NLCD_IMPERVIOUSNESS_CHANGE_2006	Raster
NLCD_TREE_CANOPY_2001	Raster
NOAA_Surge_MOM_Galveston_Bay	Polygon
NOAA_Surge_MOM_Matagorda_Bay	Polygon
San_Jacinto_County	Polygon
SEM_User_Input_Point	Point
SEM_User_Input_Polygon	Polygon
SEM_User_Input_Polyline	Polyline

Texas_113th_Congressional_Districts	Polygon
Texas_Census_BlockGroups_1990	Polygon
Texas_Census_BlockGroups_2000	Polygon
Texas_Census_BlockGroups_2010	Polygon
Texas_Census_Blocks_2000	Polygon
Texas_Census_Blocks_2010	Polygon
Texas_Census_School_Districts_2010	Polygon
Texas_Census_Tracts_1990	Polygon
Dataset Name	**Type**
Texas_Census_Tracts_2000	Polygon
Texas_Census_Tracts_2010	Polygon
Texas_Census_Urban_Areas_2009	Polygon
Texas_Coastal_Bathymetry	Point
Texas_Coastal_Vignette_50_25	Polygon
Texas_Coastline	Polygon
Texas_COG_Boundaries	Polygon
Texas_Counties_Coastline	Polygon
Texas_Counties_Political	Polygon
Texas_Highways	Polyline
Texas_Impairment_Streams_2008	Polyline
Texas_Impairment_Waterbodies_2008	Polygon
Texas_Major_Rivers	Polyline
Texas_Map_Extent	Polygon
Texas_State_House_Districts_2012	Polygon
Texas_State_Senate_Districts_2012	Polygon
Texas_Stream_Team_Monitoring_Sites	Point
Texas_Zip_Codes_2005	Polygon
The_Woodlands_Pathways	Polyline
TMDL_Project_Areas	Polygon
TMDL_Project_Areas_Mask	Polygon
TMDL_Watersheds	Polygon
US_State_Boundaries	Polygon
USFWS_Wetlands_2009	Polygon
USFWS_Wetlands_2010	Polygon
USFWS_Wetlands_2011	Polygon
USFWS_Wetlands_2012	Polygon
USGS_HUC_10_Watersheds	Polygon
USGS_HUC_12_Sub_Watersheds	Polygon
USGS_HUC_6_Basins	Polygon
USGS_HUC_8_Sub_Basins	Polygon
USGS_River_Basins	Polygon
USGS_Stream_Gauges_2009	Point
USGS_Stream_Gauges_2010	Point
USGS_Stream_Gauges_2012	Point

USGS_Sub_Watershed_Study_Areas	Polygon
WalkCAD_Parcels_Coverage_2005	Polygon
WalkCAD_Parcels_Coverage_2005_pts	Point
WalkCAD_Parcels_Coverage_2006	Polygon
WalkCAD_Parcels_Coverage_2006_pts	Point
WalkCAD_Parcels_Coverage_2007	Polygon
WalkCAD_Parcels_Coverage_2007_pts	Point
WalkCAD_Parcels_Coverage_2008	Polygon
WalkCAD_Parcels_Coverage_2008_Pts	Point
Dataset Name	**Type**
Walker_County	Polygon
WALKER_COUNTY_PARCEL_INFO_2005	Table
WALKER_COUNTY_PARCEL_INFO_2006	Table
WALKER_COUNTY_PARCEL_INFO_2007	Table
Walker_County_Parcel_Info_2008	Table
Walker_County_Parcel_Values_2005	Table
Walker_County_Parcel_Values_2006	Table
Walker_County_Parcel_Values_2007	Table
Walker_County_Parcel_Values_2008	Table
WallCAD_Parcels_Coverage_2007	Polygon
WallCAD_Parcels_Coverage_2007_Pts	Point
WallCAD_Parcels_Coverage_2008	Polygon
WallCAD_Parcels_Coverage_2008_Pts	Point
Waller_County	Polygon
WALLER_COUNTY_PARCEL_INFO_2007	Table
Waller_County_Parcel_Info_2008	Table
Waller_County_Parcel_Values_2007	Table
Waller_County_Parcel_Values_2008	Table
Wharton_County	Polygon
World_Country_Boundaries	Polygon

C&E Non-Spatial Data

Ambient SWQM
Wastewater Self-reporting Data
Parcel-Based Land Use, Attributes, and Valuation (9 counties)
Census Data

Appendix 6 Data Dictionary

Data Dictionary **Houston-Galveston Area Council** **Community and Environmental Planning Department**

Thematic Layer Name		
Feature Class		
Topology		
Table Name		
Data Source		
Report Prepared by		
Phone	Fax	E-Mail

Attribute Table

Variable	Begin Column	Item Name	Alternate Name	Item Definition

Data History

Source Agency
Originating Date
Originating Scale

Status Information

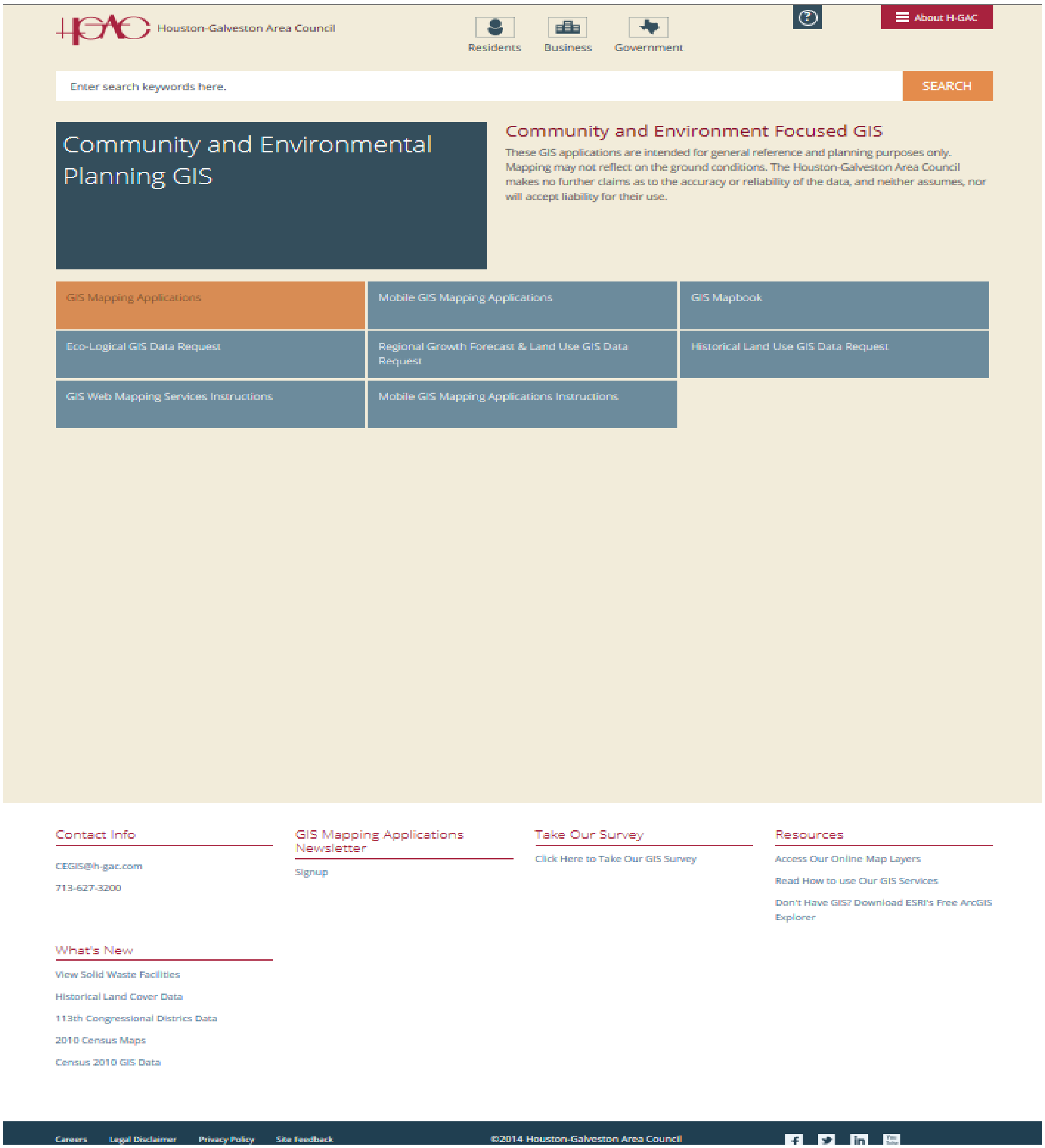
Percentage Complete
Planned Completion Date
Geographic Extent
Planned Enhancements
Known problems or limitations

Maintenance Information

Maintaining Office/Division/Section
Contact Name
Contact Telephone Number
Type of updates performed
Frequency of Updates

Data Format Information
Data Format
Software/Version
Number of features/records
Total File Size
Projection
Geographic Projection:
Spheroid:
Zone:
Datum:
Units:
Fips Zone:
Quadrant:
X Shift:
Y Shift:
1st Standard Parallel:
2nd Standard Parallel:
Central Meridian:
Lat. of Projection Origin:
False Easting:
False Northing:
Additional Documentation
Quality Assurance Quality Control
Attribute Reports Available
Additional Documentation Available

Appendix 6 H-GAC C&E GIS Website & Data Clearinghouse



Appendix C: Field Data & Chain of Custody Sheets

H-GAC – Illicit Flow Monitoring Data Sheet

Date: _______/_______/_______ Outfall Location: ____________________

Time (military):______________ Survey Conducted by:____________________

Material of outfall pipe	1 – concrete; 2 – PVC; 3 – metal; 4 - other		Latitude & Longitude	
Describe 'Other' pipe material			# of Days Since Last Significant Rainfall	
Inner Diameter of Pipe	Inches		Rainfall accumulation in last 3 days (inches)	
Depth of Water flowing from outfall pipe	Inches		Primary Contact, # of People Observed (1-10, >10)	
Chlorine Residual	PPM		Evidence of Primary Contact (1- Observed, 0 - Not Observed)	

Secchi Depth (disk or tube)	Observed Turbidity	Water Clarity	Water Color	Water Odor	Algae Cover in/on surface of pipe	Present Weather	Wind Intensity
meters	1 – low 2 – medium 3 – high	1 – excellent 2 – good 3 – fair 4 – poor	1 – brownish 2 – reddish 3 – greenish 4 – blackish 5 – clear 6 – other	1 – sewage 2 – oily/chemical 3 – rotten egg 4 – musky 5 – fishy 6 – none 7 – other	1 – absent 2 – rare (<25%) 3 – common (26-50%) 4 – abundant (51-75%) 5 – dominant (>75%)	1 – clear 2 – partly cloudy 3 – cloudy 4 – raining 5 – other	1 – calm 2 – slight 3 –moderate 4 – strong

Water Temperature	°C		pH	standard units	
Specific Conductance	µS/cm		Dissolved Oxygen	mg/L	
Comments or Observation					

Surveyor SN:____________________ Sonde SN:____________________

BACTERIA ANALYSIS

Containers	Preservatives	Analyses Requested
1 x 100 mL Sterile Plastic	Iced	Bacteria: *E. coli*
		Yes / No

Set-Up
Date:____________________Time:______________Analyst:____________

Reading
Date:____________________Time:______________Analyst:____________

INCUBATION	Period (28-31 hrs)		Temperature (33+/-3°C) Start / End		
SAMPLE 1	Sample Size (mL)		Dilution Factor (100/sample size)		
Colonies Counted		X dilution factor =	Results = Colonies/100 mL		
SAMPLE 2	Sample Size (mL)		Dilution Factor (100/sample size)		
Colonies Counted		X dilution factor =	Results = Colonies/100 mL		
FIELD BLANK	*E.coli* colony growth	(Check One)	Yes	No	
DATA QUALITY REVIEW	Checklist completed	(Check One)	Yes	No	

Updated: November 4, 2015

DATA QUALITY REVIEW CHECKLIST for BACTERIA TESTING using EASYGEL

	Yes / No	Comments
Monitor is trained & certified		
Is the media expired		
Incubation temperature is 33°C (+/-3°C)		
Incubation time is 28-31 hours		
Data Form is complete		
Optimal colony number is achieved (<200)		
Dilution factor calculation is correct		
Colony Growth on Field Blanks		

Analyst: ______________________ Date: ______________________ Time: ______________________

Updated: November 4, 2015

EASTEX ENVIRONMENTAL LAB, INC.

P.O. Box 1089 — Coldspring, TX 77331 — (936) 653-3249 * (800) 525-0508
P.O. Box 631375 — Nacogdoches, TX 75963-1375 — (936) 569-8879 * FAX (936) 569-8951

Company:	Bill to: H-GAC Attn: Jean Wright
Address:	Address: P.O. Box 22777, Houston, TX 77227-2777
	Phone: 713-627-3200 Email: jean.wright@h-gac.com
Attn:	Remarks:
Phone#:	
Fax#: Email:	
P.O. #	
Sampler's Name (print)	Sampler's Signature
Project Number	Project Name:

ANALYSIS REQUESTED

Sample ID	Spec. Cond (µS)	Date	Time	C or G	DO	pH	Cl_2	Flow	Temp	Matrix	Containers Tot #	Containers Size	Containers Type	Containers Pres	*E. coli* & Entero. (100mL, $Na_2S_2O_3$)	Entero. (100mL, $Na_2S_2O_3$)	TSS (1000mL)	NH_3, T PO_4, NO_2 +NO_3 (1000mL, H_2SO_4)	TKN (500mL, H_2SO_4)	Cl, SO_4 (500mL)					
				G																					
				G																					
				G																					
				G																					
				G																					
				G																					
				G																					
				G																					

Relinquished By:	Date	Time	Received By:	Date	Time	Received Iced: YES / NO
Relinquished By:	Date	Time	Received By:	Date	Time	Received Iced: YES / NO
Relinquished By:	Date	Time	Received By and/or Checked in By:	Date	Time	Received Iced: YES / NO
LAB USE ONLY Sample Condition Acceptable: YES / NO		Temp °C	Logged In By:	Date	Time	
Alternate Check In:	Date	Time				

Chain of Custody Sheet

Appendix D: Texas Stream Team
Bacteria SOP for EASYGEL Method

4.0 *E. coli* Monitoring and Analysis Procedures

Training Requirements

Texas Stream Team supports certification programs in both the "core" field parameters covered in the first part of the Texas Stream Team Water Quality Monitoring Manual and bacteriological monitoring protocols for *Escherichia coli (E. coli)* bacteria. In addition to the "core" volunteer monitoring certification training, volunteer certification in bacteriological monitoring includes:

- bacteriological information background and sample collection procedures
- media storage and preparation
- proper dilution, plating, and incubation procedures
- colony enumeration
- proper documentation and safety procedures

In order to ensure the highest confidence levels among data users, Texas Stream Team recommends that bacteriological monitors attend an annual bacteriological QC session during which they are updated and evaluated on monitoring techniques and enumeration of bacterial colonies.

Scope and Application

Texas Stream Team monitors will perform bacteria tests on streams, lakes, swimming beaches, and springs. The primary reasons for bacteria testing are determination of ambient conditions. Tests results may also be used to identify potential contamination from broken or leaking septic tanks and sewer lines, wastewater treatment plants, animal-holding operations and other point and nonpoint sources. Bacteriological monitors will develop sampling strategies to suit their objectives and budget, and sampling frequency will vary accordingly.

Results of the tests are evaluated against State of Texas contact recreation standards. If test results indicate contamination, Texas Stream Team advises the monitor to repeat and verify the initial results. If repeated high counts are found at a site over an extended period of time, the information will also be communicated to the appropriate local and state authorities.

Summary of Method

Coliscan Easygel is a method used to test for *E. coli* and general coliform bacteria. Dr. Jonathan Roth developed the technology for Micrology Laboratories, LLC. Easygel is not an agar, but is a pectin-gel. Easygel comes in a sterilized, two-piece unit, including a bottle of liquid medium and a petri dish treated with a special formulation.

With this method, a .5 to 5 mL of sample of water is collected using a sterile pipette and introduced into a 10 mL bottle of sterile liquid medium. The prepared medium is then plated on a treated petri dish, and incubated at a temperature of 33°C for 28 hours. Commercially available incubators, such as the Hovabator, are recommended. Incubator temperature is maintained and verified with the thermometer included with the incubator. Monitors will conduct field blank quality control analysis for ten percent of sampling events or once a month if less than 10 samplings are done in a month.

Upon incubation, the general coliforms and *E. coli* produce enzymes that react with color reagents in the media to produce pink to red colonies (general coliforms) or dark blue colonies *(E. coli)*. Two samples from each monitoring site are analyzed, and a mean value is reported.

Range and Accuracy

The Coliscan Easygel test can detect as little as one bacterial colony per sample, and can be used to identify up to 200 colonies per sample. Concentrations exceeding 200 colonies per

sample are recorded as too numerous to count (TNTC). A black and a white grid, which is the same size as the petri dishes, is provided to assist monitors in counting *E. coli* colonies.

Accuracy of Coliscan Easygel is based on the reasonable performance of properly stored, pre-treated sterile plates, media, and pipettes. Extensive evaluation of the Coliscan Easygel method was conducted by Alabama Water Watch, Alabama Department of Fisheries, and Auburn University from February to September 1998 to confirm the accuracy of the Coliscan Easygel method. The results indicated that this method is a reliable and valid tool for the detection of fecal contamination through a variety of concentrations.

In December 1999, Coliscan Easygel was approved by the U.S. Environmnetal Protection Agency (EPA) Region 4 for use in the bacteriological monitoring of surface waters as part of the program developed by the Alabama Water Watch under the direction of Dr. William G. Deutsch of the Department of Fisheries of Auburn University. As a result of this program and other studies, Coliscan Easygel has become the preferred method for bacteriological monitoring in volunteer water quality monitoring programs throughout the United States.

Supplies and Equipment

Necessary Items

The items needed to conduct bacteriological monitoring using the Coliscan Easygel method include:

- sterile bacteriological bottles
- Whirl-Pak™ or Whirl-Pak Thio-Bags™
- sterile Easygel medium
- pre-treated petri dishes
- sterile pipettes
- sterile diluent
- an incubator
- gloves
- bleach or isopropyl alcohol
- sealable plastic bags

Easygel proprietary items like media and pre-treated petri dishes can be ordered directly from Micrology Laboratories at (888) EASY-GEL or micrologylabs.com. Other equipment and supplies, including sterile diluent, can be purchased from a variety of sources like grocery and laboratory supplies stores. See the monitoring supplies section of the Texas Stream Team website for additional information.

Sample Media Storage and Disposal

When Coliscan Easygel reagents are received, the production date (if known) or arrival date, and the expiration date should be written on the box of media and petri dishes. Media bottles should be kept frozen until ready for use, allowing for a shelf life of up to one year. Thawed media is usable for up to two weeks when stored at room temperature. Medium can be refrozen but repeated freezing and thawing should be avoided. Pre-treated petri dishes should be stored at room temperature which also allows for a shelf life of one year. To dispose of expired media, pour a teaspoon of bleach into the bottle, cap the bottle, shake well, place the bottle in a sealable plastic bag, and dispose of it in household trash.

Quality Control

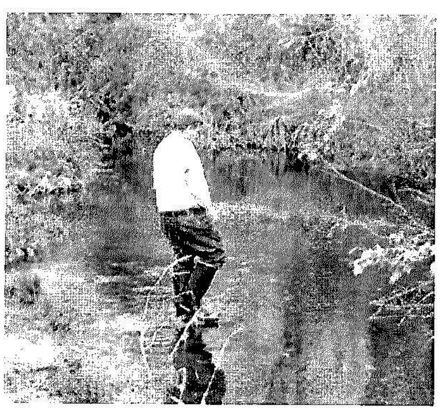
Analyzing samples for *E. coli* can introduce challenges in ensuring that contamination does not occur during sample collection and processing. It is important that all Texas Stream Team monitors use the same methods and procedures so that samples within and between streams can be compared to each other, and understanding the importance of quality assurance and quality control practices is crucial to generating credible environmental information. Quality assurance is the system used to make sure that all data collection activities are managed in a way that collected information meets the intended use of the project. Some examples of quality assurance measures include: the consistent Texas Stream Team training program, the use of consistent methods, written procedures, establishing data quality objectives, maintenance of records, and specifying the chain of custody procedures. Quality control procedures reassure that samples are being collected and documented in a consistent and accurate manner at all sites by all monitors. Examples of quality control include: double rinsing of nonsterile equipment prior to use, checking reagents for expiration dates, using data quality objectives to assess data validity, calibrating meters within 24 hours of use, and collecting field blanks on a routine basis. Together, quality assurance and quality control serve volunteer water quality monitors by bringing enhanced data credibility and use.

Cross Contamination

Efforts should be made to avoid contaminating sample containers, hands, tabletops, or any other surface or object. Do not touch bacterial colonies. The dishes should be taped shut and kept out of reach of children, pets, and curious wildlife. A disinfectant should be used to clean tabletops or other areas that colonized plates have touched. Monitors should wash hands before and after handling the plates.

Field Blank

Field blanks are used to assess potential contamination from sample handling, airborne materials, equipment, media, and other sources. A field blank usually consists of a sterile diluent sample of 1 mL that is taken to the site and poured into a properly labeled sample container during the first bacteria sampling event of that day. The blank sample is collected in the same type of container, labeled as a field blank, and handled and analyzed along with all the bacteria samples collected on that day. It is used to identify errors or contamination in sample collection and analysis. The frequency of a bacteria field blank is one with every 10 samples. If less than 10 samples are collected in a month, include at least one field blank for any month bacteria samples are collected. Report the results of the field blank on your data form. There should be no *E. coli* colony growth on the field blank samples. If *E. coli* growth occurs on the blank, discard all data collected on that day. Document the results on the data sheet and consult with your trainer.



4.1 Sample Collection Procedures

1.0 Sample Site Location

Establishing sampling site locations should follow procedures outlined in *Section 2.00 Choosing a Monitoring Location.* In streams, rivers, and lakes, care should be taken to collect the bacteriological sample at an undisturbed location.

1.1 Sample Containers

Collect bacteriological samples in sterile bacteriological bottles or Whirlpak bags.

Never pre-rinse the sample container. For Whirl-Pak bags, squeeze out the top one inch of water from the bag and whirl the bag to seal. The sealed bag must retain at least 50 mL of sample but leave a small pocket of air. This airspace will help mix the sample when it is shaken just before making dilutions and membrane filtration. During every tenth sampling event (or a minimum of once per month), prepare one additional sample container and petri dish for a quality control field blank. If your sample site is downstream of a wastewater treatment plant outfall, the effluent might contain chlorine disinfectant that could debilitate bacteria. At these sites, Texas Stream Team recommends that monitors use the Whirl-Pak Thio-Bag™. These bags contain 10 mg tablets of sodium thiosulphate to neutralize free chlorine in the sample.

1.2 Sample Labeling

Label each sample container with the station number, site name, date, and time collected.

If it is appropriate to process a field blank sample, this container will have the previously mentioned information plus a "field blank" label.

1.3 Collecting Samples

When submerging the sample container, take care to avoid contamination by surface scums. The surface film is enriched with particles and bacteria not representative of the water mass. Also be careful not to collect sediment from the bottom of stream or lake. The correct procedure for collecting samples is demonstrated during trainings. When it is appropriate, remember to collect the field blank using the sterile diluent prior to conducting routine sampling at your site. This involves transferring the sterile diluent from its original container to the routine sampling container while at your monitoring location.

In flowing streams, dip the open sample container to a depth of 0.3 m (1 ft), or roughly half the depth, in very shallow streams. Avoid contact with the sediment. With the open end facing upstream, push the mouth of the bag upstream at this depth until full. Always hold the mouth of the sample container upstream of the sampler, sampling apparatus, and any disturbed sediments.

In reservoirs and coastal waters, dip the sample container to a depth of 0.3 m (1 ft). At this depth, push the mouth of the sample container away from the boat, dock, shore, sampler, and any disturbed sediment.

When collecting samples from a bucket of water, collect the bacteria sample before other monitoring activities occur. Pour water into the bacteriological sample container. Never immerse water sample containers in the bucket. This could introduce contamination.

1.4 Sample Preservation and Hold Times

Place sample(s) on ice immediately after collection. Bacteriological samples must transported, processed (diluted and plated), and placed in incubator within 6 hours of sample collection. Do not report samples that are not processed within the time limit. Record the hold time on the Texas Stream Team *E. coli* data sheet.

4.2 Analyzing *E. coli* Using Coliscan Easygel Pour Plate Method

2.0 Preparation

Prepare media for a minimum of two samples for each site. Bottles of media should be removed from the freezer in time to ensure that they have reached room temperature (typically 2-3 hours) before use.

Prepare two petri dishes per sample. During every tenth sampling event (or once per month minimally), prepare one additional petri dish for a quality control field blank. Label the top of each petri dish with:

- site name
- date
- volume of sample
- time the sample is poured into the petri dish

The field blank consists of a sterile diluent sample, and the sample container and petri dish will be labeled like the other samples and will also include "field blank" next to the site name.

2.1 Drawing Proper Sample Size

Shake the sample container vigorously, and then carefully open it without touching the lip of the bag. Leave the pipette in the sterile wrapper until ready to draw the sample. Unwrap the pipette from the bulb end and avoid contacting the tip with anything except the sample water. Submerge the bottom half of the pipette into the sample container and squeeze the bulb to expel the air. Draw the appropriate sample size (1 mL, 3 mL, or 5 mL) into the pipette by releasing the bulb slowly. Squeeze out any sample water in excess of the desired volume. Deposit the sample into the Easygel media bottle, cap, and swirl gently. Record the sample size in the *E. coli* section of the Texas Stream Team data sheet. Draw a 1 mL aliquot for field blanks.

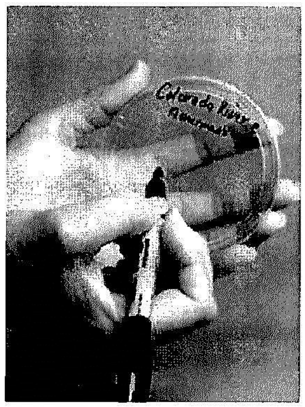
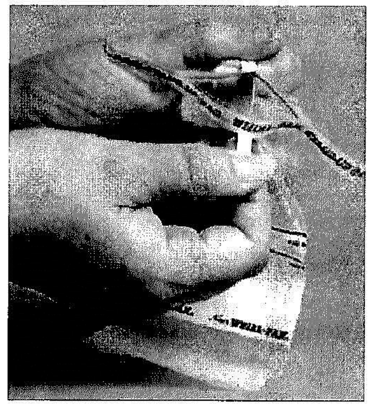


Figure A



FigureB

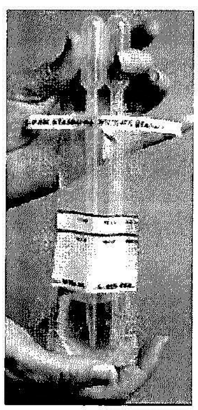


Figure C

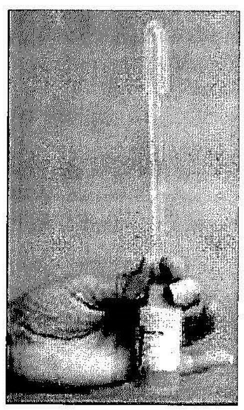


Figure D

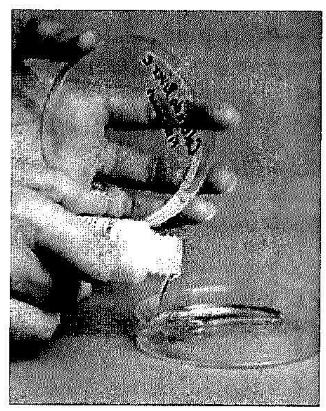


Figure E

- **Figure A** depicts a monitor holding a Whirlpak bag.
- **Figure B** portrays a monitor labeling a petri dish with the appropriate monitoring information .
- **Figure C** shows a monitor using a 5 mL pipette to remove a sample from the Whirlpak bag.
- **Figure D** shows the monitor placing the stream sample into the Coliscan Easygel bottle media.
- **Figure E** shows a monitor pouring the media, which includes the stream sample, onto the petri dish.

NOTE: Once mixed with Easygel media, the prepared samples should be either be plated within 10 minutes, or kept on ice or in a refrigerator until plated.

2.2 Determining Sample Size

The ideal number of colonies resulting from a single prepared plate is 20 to 60, and not over 200. Since the number of resulting colonies is dependent on the sample size, it may be necessary to experiment with several sample volumes to determine the best probable sample size to achieve 20-60 colonies. Draw a 1 mL aliquot for field blanks.

To establish a baseline for typical conditions, collect a 1 mL and a 5 mL sample volume during the first sampling event. If the 1 mL *E. coli* colony reading results in zero or only a few colonies, the sample volume should be to increased to 3 mL or 5 mL. Conversely, if the 5 mL sample results in more than 60 colonies, the sample size should be reduced to 1 mL or 3 mL during the next sampling event.

Environmental and precipitation variables will influence levels of bacteria. Urban creeks with low discharge often have abundant *E. coli* and other coliform growth, and the volunteer should begin sampling with 1 mL and 3 mL volumes. Pristine waters may require a 5 mL sample to achieve the preferred range of colonies.

2.3 Plating the Sample

Pour the prepared sample (the Easygel media mixed with the water sample) slowly into the petri dish. Gently swirl until there is a smooth coating of prepared sample across the bottom of the petri dish (but be careful not to splash over the side or on the lid). Set on a level surface and allow five to forty-five minutes for the media to gel. This will help ensure that the sample will be spread uniformly across the petri dish and help prevent shifting or pooling of the media after being placed in the incubator.

2.4 Incubation

Turn on the incubator far enough in advance to ensure the appropriate temperature is reached before loading petri dishes. Place petri dishes right-side up in the incubator and maintain a steady incubation temperature of 33°C. At this temperature, colonies should not be counted for a minimum of 28 hours. For optimum results, count and record colonies at 28 hours of incubation. No counts should be made after 31 hours. Record the incubation time and temperature on the *E. coli* section of the Texas Stream Team data sheet.

2.5 Counting *E. coli* Colonies

Count the number of individual and distinct dark purple and dark blue colonies.

Colonies which have the blue-green color are not considered to be either coliforms or *E. coli* and therefore should be ignored. Similarly, colonies which are white should also be ignored.

Record the number of *E. coli* colonies on the Texas Stream Team data sheet.

NOTE: Refer to the graphic inside the back cover for a color detail of the Easygel Colony Color Guide. Use the grid to assist in your *E. coli* count.

Field Blanks:

The frequency of a bacteria field blank is one with every 10 samples. If less than 10 samples are collected in a month, include at least one field blank for any month bacteria samples are collected. Follow routine handling, plating, and analysis procedures, and report the results on your data form.There should be no *E. coli* colony growth on the field blank samples. If *E. coli* growth occurs on the blank, discard all data collected on that day. Document the results on the data sheet and consult with your trainer. Trainers will work closely with monitors who have issues concerning field blank contamination to resolve the problem.

2.6 Data Reporting

Final results of the analysis for the two samples per site plus the field blank are reported on the Texas Stream Team data sheet as "colonies per 100 mL" of sample water. To arrive at that number you must first determine the dilution factor.

Dilution factor = 100 / sample size

For example, if you collected a sample size of 1 mL in the pipette and added this to the Easygel solution, your dilution factor is 100 / 1 or 100. Common dilution factors are:

.5 mL sample = dilution factor of 200
3 mL sample = dilution factor of 33.3
5 mL sample = dilution factor of 20

To determine the number of colonies per 100 mL, multiply the number of colonies counted times the dilution factor.

For example, if you counted 8 colonies and had a dilution factor of 33.3 (3 mL sample size), your final result is 8 times 33.3 or 266 *E. coli* colonies/100mL. For a count of 11 colonies times a dilution factor of 20 (5 mL sample size) your result is 220 *E. coli* colonies/100mL.

This information should be entered on the *E. coli* section of the Texas Stream Team data sheet to document the final results of each set of samples analyzed. Verify that the dilution factor calculation is correct and marked accordingly on the Quality Data Review Checklist.

INCUBATION: Period (hrs) ______ (28-31 hrs) Temp. (°C) ______ (33+/-3°C)
SAMPLE 1: Sample size ______ mL Dilution factor (100/sample size) ______
Colonies counted ______ x dilution factor ______ = ______ colonies/100 mL
SAMPLE 2: Sample size ______ mL Dilution factor (100/sample size) ______
Colonies counted ______ x dilution factor ______ = ______ colonies/100 mL
FIELD BLANK: *E. coli* colony growth (circle one) YES / NO
DATA QUALITY REVIEW: Checklist completed (circle one) YES / NO

2.8 Waste Disposal

To dispose of the used petri dishes, lift the lid and pour 5 ml (about 1 teaspoon) of straight bleach into each dish. Re-tape the lid, make sure the bleach has covered the entire dish, and allow to stand for a minimum of fifteen minutes. Place the dishes in a sealed plastic bag and place in normal household trash.

Periodically clean the inside of incubator with dilute bleach solution and allow it to air dry before the next use.

2.9 Data Review

The following Quality Data Review Checklist is used by the monitor, Texas Stream Team staff, and data user to verify that data are valid.

Data Quality Review Checklist

	Yes / No	Comments
Monitor is certified		
Is the media expired		
Incubation temperature is 33 ° C (+/- 3 ° C)		
Incubation time is 28 – 31 hours		
Data form is complete		
Optimal colony number is achieved (<200)		
Dilution factor calculation is correct		
Colony Growth on Field Blanks		

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Appendix E: BIG'S Top Ten Prioritized Lists

TOP TEN "MOST WANTED" STREAMS							
Rank	***Assessment Unit***	***Parameter***	***Relative Geomean (MPN/100 mL)***	***Geomean (MPN/100 mL)***	***AU Status***	***Assessment Unit Description***	***Watershed***
1	1013C_01	*E. coli*	39.86	5022	No Change	Unamed tributary located approximately 1.8 miles upstream of the Buffalo Bayou/White Oak Bayou confluence between IH-10 and Memorial Drive west of IH-45 in Harris County	Buffalo Bayou
2	1016D_01	*E. coli*	29.67	3738	No Change	Unamed tributary of Greens Bayou from the confluence with Greens Bayou, west of El Dorado Country Club to Lee Road, west of US Hwy 59 in Harris County	Greens Bayou
3	1017_04	*E. coli*	23.58	2971	Degraded	White Oak Bayou, Brickhouse Gully confluence to a point immediately upstream of the confluence of Little White Oak Bayou in Harris County	White Oak Bayou
4	1007I_01	*E. coli*	22.23	2801	No Change	Plum Creek f rom the Sims Bayou confluence to Telephone Road in Harris County	Sims Bayou
5	1007F_01	*E. coli*	19.59	2469	Degraded	Berry Bayou from a point 2.4 km (1.5 mi) upstream of the Sims Bayou confluence to SH 3	Sims Bayou
6	1101D_01	Enterococcus	19.01	665	Degraded New Listing	Robinson Bayou, from Clear Creek Tidal confluence to 0.05 km (0.03 mi) upstream of Hewitt Street	Clear Creek
7	1007U_01	*E. coli*	16.93	2133	Improved	Mimosa Ditch from the Brays Bayou confluence upstream 2.9 km (1.8 mi) to the Chimney Rock bridge crossing	Brays Bayou
8	1007T_01	*E. coli*	16.89	2128	Improved	Bintliff Ditch from the Brays Bayou confluence to 0.57 km (0.35 mi) upstream of the Fondren Road bridge crossing	Brays Bayou
9	1013A_01	*E. coli*	15.68	1975	Degraded	Little White Oak Bayou, from the White Oak Bayou confluence to Yale Street in Harris County	White Oak Bayou
10	1014N_01	*E. coli*	15.56	1960	Degraded New Listing	Rummel Creek, from the Buffalo Bayou Above Tidal confluence to 1.2 km (0.75 mi) upstream of IH-10	Buffalo Bayou

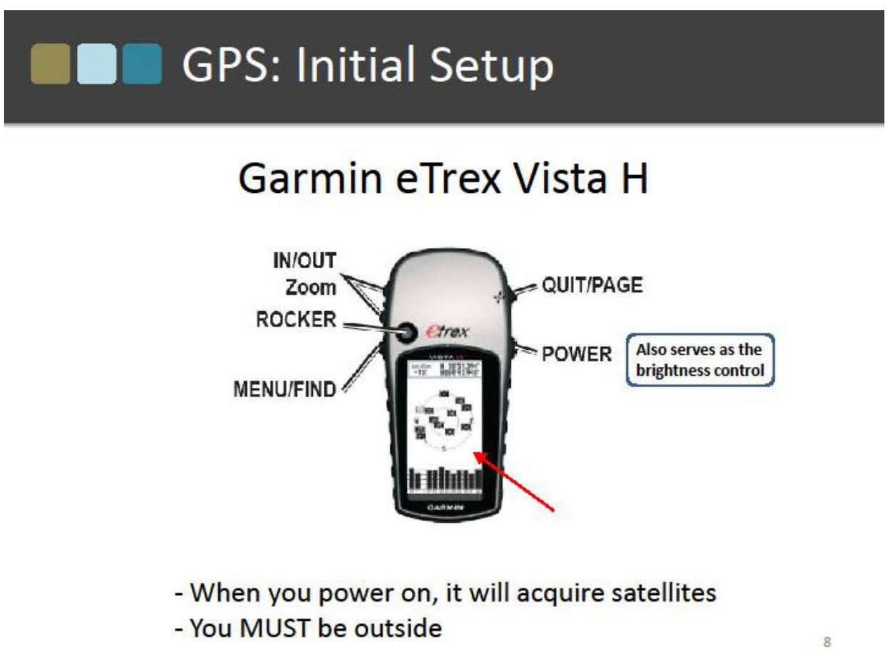
TOP 10 "MOST LIKELY TO SUCCEED" STREAMS

Rank	Assessment Unit	Parameter	Relative Geomean (MPN/100 mL)	Geomean (MPN/100 mL)	AU Status	Assessment Unit Description	Watershed
1	1008B_02	*E. Coli*	1.06	133	Improved	Upper Panther Branch, from a point 0.22 miles (0.35 km) upstream of the Bear Branch confluence to the confluence of Lake Woodlands	Cypress Creek
2	1010_02	*E. Coli*	1.18	148	No Change	Caney Creek, from FM 1097 to SH 105	Caney Creek
3	1113A_01	*E. Coli*	1.2	151	New Listing	Armand Bayou, from the upper segment boundary of Armand Bayou Tidal (point 0.8 km (0.5 miles) downstream of Genoa-Red Bluff Road) upstream to Beltway 8	Armand Bayou
4	1113_02	Enterococcus	1.22	43	New Listing	Armand Bayou, from the Horsepen Bayou confluence to the Big Island Slough confluence	Armand Bayou
5	1008C_02	*E. Coli*	1.24	156	No Change	Lower Panther Branch, from Saw Dust Road to the Lake Woodlands Dam	Panther Branch
6	1007A_01	*E. Coli*	1.25	157	Improved New Listing	Canal C-147, from the Sims Bayou confluence upstream to a point 0.71 km (0.44 mi) east of Beltway 8	Sims Bayou
7	1008C_01	*E. Coli*	1.27	160	Improved	Willow Creek, from the Spring Creek confluence to a point 0.48 km (0.3 mi) north of Juergen Rd	Spring Creek
8	1102A_02	*E. Coli*	1.28	161	Improved New Listing	Cowart Creek, confluence with Clear Creek to Sunset Drive	Clear Creek
9	1113C_01	*E. Coli*	1.29	163	Improved New Listing	Horsepen Bayou, from the Horsepen Bayou confluence to Reseda Drive	Armand Bayou
10	1008I_01	*E. Coli*	1.3	163	Improved New Listing	Walnut Creek, from the Spring Creek confluence to a point 41.1 km (25.5 mi) upstream	Spring Creek

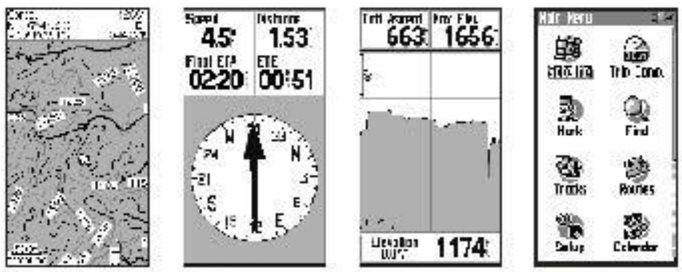
Appendix F: Garmin Product Manual

Garmin *eTrex* Vista H GPS Unit

- High-sensitivity
- 24 MB internal storage
- USB connection for electronic storage



GPS: Main Screens



GPS: Compass Calibration

*Before first use, calibrate the compass

From Main Menu,
Click:
'Setup'
Scroll down and click 'Calibration'

Click:
-'Compass'

Click:
-'Start'

10

GPS: Coordinate Units

Must change units to **DECIMAL DEGREES**

Main Menu

Click:
'Units'

Defaults to:
Degree Minutes Seconds
Click:
'Position Format'

Scroll:
Up one
Click:
'hddd.ddddd'

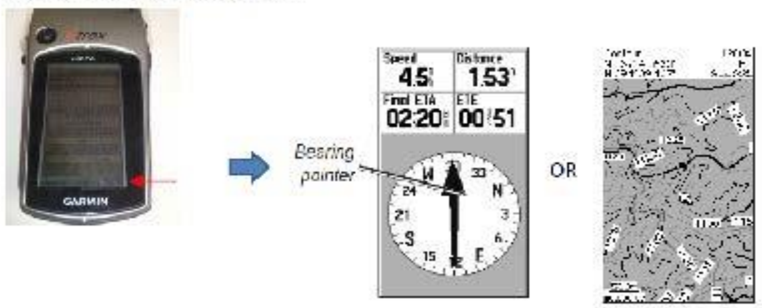
GPS: Saving a Waypoint

-From any of the main screens, **HOLD** the 'Rocker' button to create a Waypoint
-The 'Mark Waypoint' page will appear
-Change the name of the waypoint immediately by clicking the rocker when the 3-digit name is highlighted
 -Type in the desired Waypoint name
-Then click OK twice

It's that easy!

GPS: Locating the Waypoint

If you need to find a waypoint...



What's Next?

Using the coordinates gathered

-Mapsource Software

-http://www8.garmin.com/support/download_details.jsp?id=209

-Google Earth / Maps

What is the best method of providing the data to H-GAC?

-Database
-Spreadsheet
-Paper Records

Appendix G: Corrective Action Form

CORRECTIVE ACTION REPORT
QAPP DEVIATION and CORRECTIVE ACTION PLAN

Project Name	
Contract Number	
Lead Organization	
Lead Organization PM	
Lead Organization	
TCEQ GBEP PM	
TCEQ GBEP Manager	
TCEQ Lead QAS	

1. Identification of Deficiencies and Nonconformances
Deficiencies and nonconformances shall be identified and reported to TCEQ as required in the QAPP (see below). The Lead Organization's project manager, in conjunction with the Quality Assurance Officer, will complete the information on this form and send to the GBEP Project Manager with the progress report. The GBEP Project Manager is to **forward copies of corrective action reports to the GBEP PM, the GBEP QAO, and to the TCEQ Quality Assurance Specialist.** When appropriate, the report will be forwarded to the to the lead quality assurance staff to monitor the implementation of corrective action plans and to advise the appropriate project and program manager if the plans are not implemented in a timely manner. In the case of significant conditions, lead quality assurance staff shall also advise the appropriate Program Manager, Section Manager, and the quality assurance manager if corrective action plans are not implemented in a timely manner.

2. Planning and Implementing Corrective Actions
The Lead Organization shall document the following with regard to deficiencies and nonconformances and include the corrective plan of action for each.

A. List the deviation(s) from the QAPP.

B. For each deviation described above, describe each of the items in 1-6 for each deficiency.

1. root cause(s);
2. programmatic impact;
3. required corrective action(s), including action(s) needed to prevent recurrence;
4. means by which corrective action completion will be documented and verified;
5. timetable(s); and
6. individuals responsible.

Appendix H: GBEP QAPP Amendment Form

Amendment # _
to the Project Name
Quality Assurance Project Plan

USEPA QTRAK#____________

Funding Source: Check with GBEP PM and Specify State Funds or Grant Title
Federal Grant #XXXXXXXX-X

State USAS Grant # XXXXXX

Effective Date: Upon date of final signature

Questions concerning this quality assurance project plan should be directed to:

Lead Organization Project Manager Name
Title
Address *(Include physical address for package delivery)*
City, Texas Zip Code
(XXX) XXX-XXXX
email address

Note: Highlighted language should be replaced with appropriate text prior to submittal of the QAPP
***Language in italics** should be removed prior to submittal of the QAPP.*

Justification: *Summarize the reason(s) for amending the document and the change(s) that is being proposed. Examples of changes include: parameters, sampling or analytical procedures, and project organization.*

Summary of Changes: *List each section in which a change is proposed and provide a description of the change(s).*

Detail of Changes: *Include a copy of the changed section(s) (e.g., Table A7.1, Section A7, Section B1) in their entirety with changes indicated. New language should be underlined and highlighted. Removed language should be struck out and highlighted.*

Note: Be sure to address all sections that are impacted by the change. For example, if a new parameter has been added, then a new DQO table will need to be referenced and attached as well as a new holding time table, sample container information, etc.

Distribution: The Lead Organization QA Officer will provide copies of this amendment to each person on the distribution list and to each sub-tier participant other than TCEQ and EPA staff. The Lead Organization QA Officer will provide documentation of this transmittal to the GBEP PM within two weeks of QAPP approval. This documentation will be maintained as part of the Lead Organization's quality assurance records and as part of the GBEP project file.

The GBEP PM is responsible for providing copies of the project plan and any amendments or revisions of this plan to TCEQ and EPA staff other than the TCEQ QA Specialist. Copies must be provided within two weeks of QAPP approval, and documentation of this transmittal will be available for review and maintained as part of the GBEP project file.

Adherence Letters: The Lead Organization will secure written documentation from additional project participants (e.g., subcontractors, laboratories) stating the organization's awareness of and commitment to requirements contained in this quality assurance project plan amendment. The Lead Organization will maintain this documentation as part of the project's quality assurance records. This documentation will be available for review. Copies of this documentation will also be submitted as deliverables to the GBEP PM within 30 days of final TCEQ approval of the QAPP Amendment.

Approval: The changes are effective upon final approval of the amendment. These changes will be incorporated into the full QAPP document when the QAPP is updated. The TCEQ, the Lead Organization, and the Subcontractor Name *(as relevant)* acknowledge and accept these changes by signing this amendment.

____

Name, Lead Organization Project Manager Date

____

Name, Lead Organization Date

____

Name, Lead Organization /Subcontractor QA Role Date

(create a signatory line for each person from the Contracted or Subcontracted Entities that signed the original QAPP).

____

Name, TCEQ GBEP Project Manager Date

____

Name, TCEQ GBEP QA Coordinator Date

____

Name, TCEQ GBEP Program Manager Date

Appendix B: Preliminary Action Report

BACTERIA IMPLEMENTATION GROUP'S TOP FIVE MOST AND TOP FIVE LEAST IMPAIRED WATER BODIES

PRELIMINARY ACTION REPORT

August 4, 2016

Prepared by
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Project funded through grants from the U.S. Environmental Protection Agency through the Texas Commission on Environmental Quality's Galveston Bay Estuary Program

Table of Contents

1.0 Introduction

1.1 Background

The Bacteria Implementation Group (BIG), a partnership of government, business, and community leaders, was formed in 2008 following the completed Total Maximum Daily Load (TMDL) study. The BIG developed an implementation plan (I-Plan) that addresses elevated levels of bacteria in 72 bacteria-impaired segments in the Houston-Galveston region. The *BIG's Top Five Most and Top Five Least Impaired Water Bodies* project was developed as a result of the BIG's tracking of bacteria levels and development of the Top 10 Most/ Top 10 Least Impaired Water Bodies lists. The Top 10 Most Impaired Water Bodies are impaired assessment units (AUs) with the highest geometric means relative to the state standards for bacteria; and the Top 10 Least Impaired Water Bodies are impaired AUs with the lowest geometric means relative to the state standards for bacteria. See Figure 1. The purpose of *BIG's Top Five Most and Top Five Least Impaired Water Bodies* project is to investigate potential bacteria discharges in selected AUs from the Top 10/Least 10 lists to eliminate them by working with local jurisdictions in an effort to assist with Illicit Discharge Detection and Elimination (IDDE) in the BIG area. The ultimate goal of the project is to improve conditions enough to meet state water quality standards and remove listed stream segments from the state's list of bacteria-impaired waterways.

The BIG project area drains to Galveston Bay, where a sizeable area of the Bay's oyster producing waters are restricted to recreational harvest by the Texas Department of State Health Services due to elevated bacteria levels. However, contact recreation is the primary impairment or concern identified in the BIG region and will be the focus of this project. The contact recreation standard uses indicator bacteria (*E. coli* and Enterococcus) as surrogates for the potential presence of human pathogens. Bacteria is known to come from a variety of sources (anthropogenic and wildlife) and is associated with land cover/land uses which include but are not limited to agriculture and urban development run-off, wastewater conveyance and treatment, and illicit discharges.

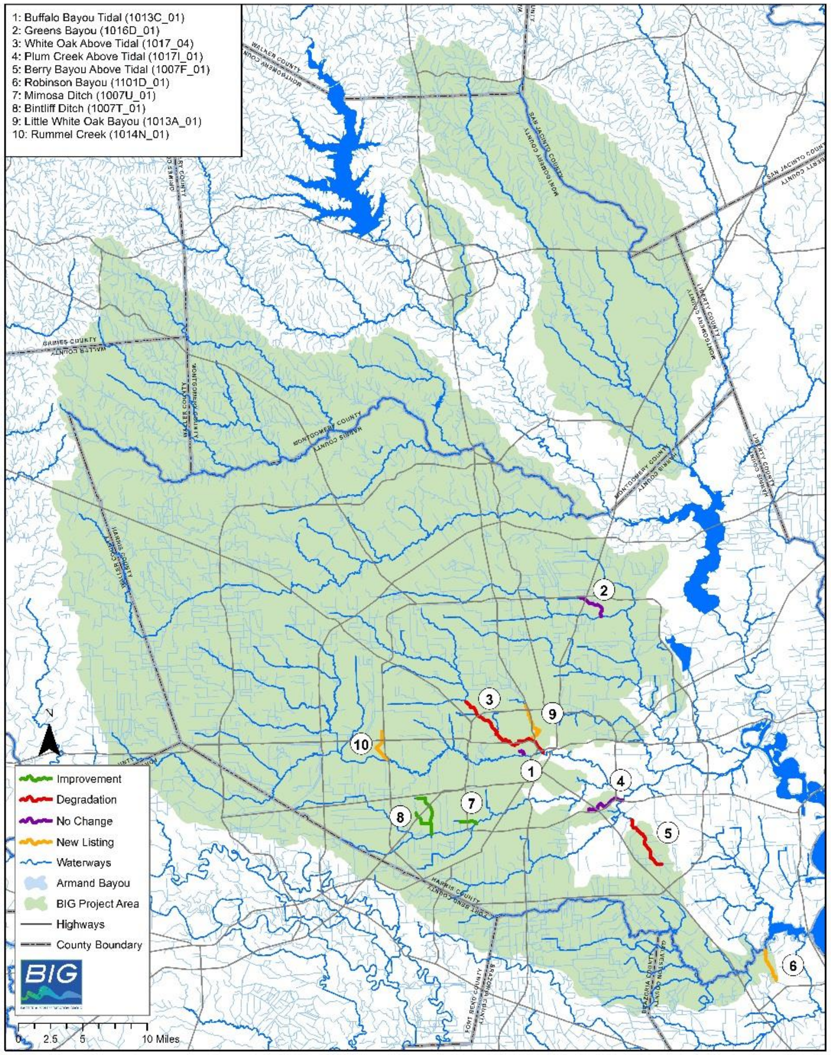
The Houston-Galveston Area Council (H-GAC) is the Regional Council of Governments for the Gulf Coast State Planning Region and has been actively involved in regional water quality planning and public outreach activities since the 1970s. H-GAC is designated as the lead agency responsible for administration of the *BIG's Top Five Most and Top Five Least Impaired Water Bodies* project. The project is funded through grants from the U.S. Environmental Protection Agency through the Texas Commission on Environmental Quality's (TCEQ) Galveston Bay Estuary Program (GBEP).

1.2 Project Description

H-GAC staff will address 10 targeted watersheds (five each from the Top 10/Least 10 lists) by prioritizing the watersheds through desk reviews, ground truthing, identifying elevated sources of bacteria in the field through sample collection and analysis, and reporting those elevated bacteria sources to appropriate local jurisdictions. H-GAC will not correct the sources but will work with those jurisdictions to remove and/or eliminate the sources.

Local project partners are participating in a technical workgroup to share their extensive knowledge of subject AUs during regular progress meetings held throughout the project period. The project has been split into three phases for simplicity. Figure 2 delineates the three phases through a project flow chart and describes the tasks contained within. This Preliminary Action Report summarizes results for Phase I tasks completed between April and July 2016.

BIG'S TOP TEN MOST IMPAIRED ASSESSMENT UNITS



BIG'S TOP TEN LEAST IMPAIRED ASSESSMENT UNITS

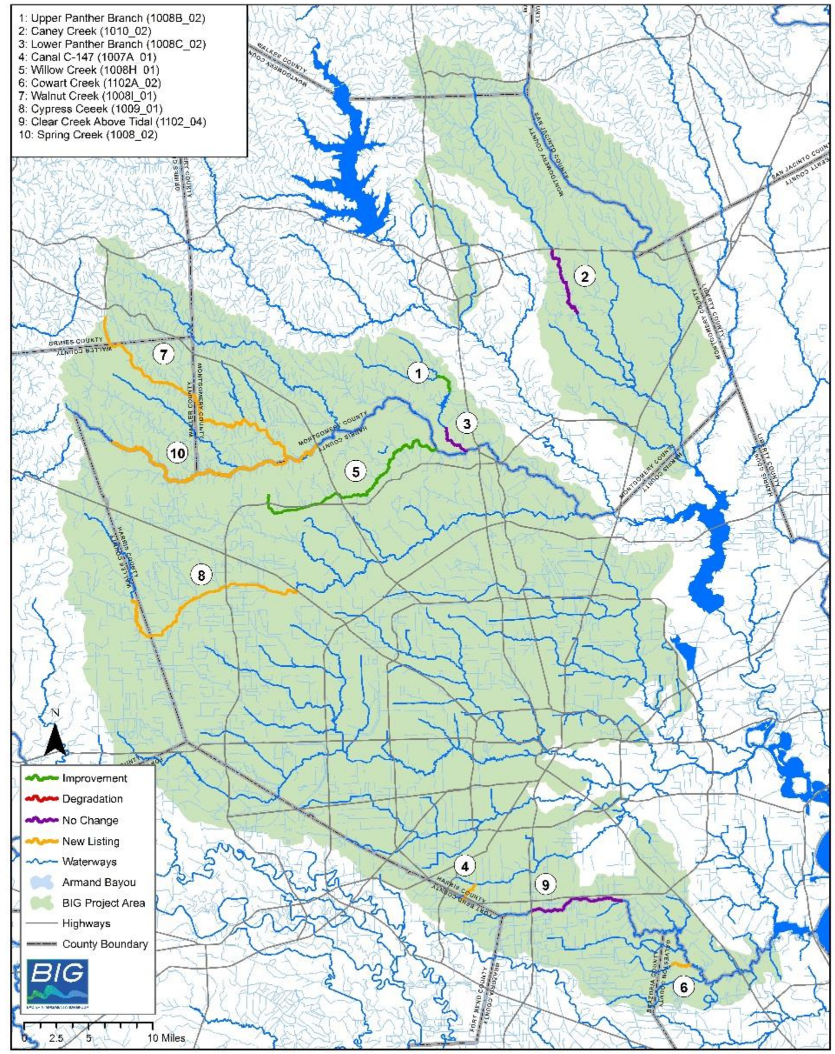


Figure 7. Bacteria Implementation Group's (BIG's) 2015 Top 10/Least 10 AU maps

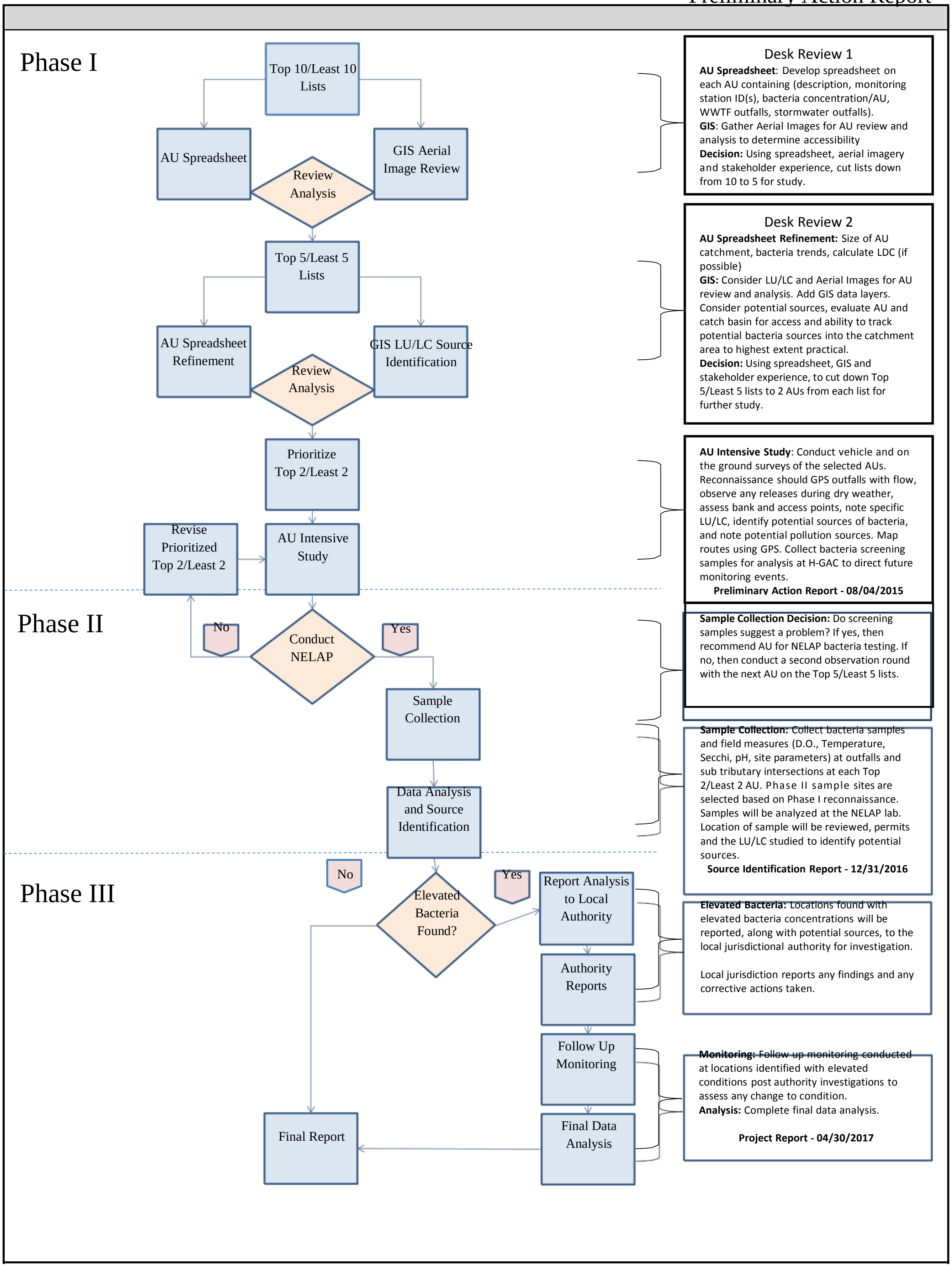


Figure 2. Project flow chart and timeline

2.0 Desk Review 1

During Desk Review 1, initial information about each AU on the BIG's Top 10/Least 10 lists were gathered through GIS map development and data analysis using SAS 9.3 statistical software. Desk Review 1 maps included information about the catchment area for each Top 10/Least 10 AU, as well as AU length, active monitoring stations, wastewater treatment facility (WWTF) outfalls, stormwater outfalls, and on-site sewage facilities (OSSFs). Desk Review 1 maps can be found in Appendix A.

An AU spreadsheet supplements the Top 10/Least 10 lists Desk Review 1 maps. The AU spreadsheet includes a description of each AU on the Top 10/Least 10 lists, along with designated uses, bacteria geometric mean concentrations, number of bacteria measurements used in analysis, as well as a description of active monitoring stations for each AU. Information from the Desk Review 1 AU spreadsheet can be found in the technical workgroup meeting presentation included in Appendix A.

Historical Clean Rivers Program (CRP) monitoring data ranging from January 2005 to present were used to develop moving seven-year bacteria geometric mean plots for each AU on the Top 10/Least 10 lists. The moving seven-year geometric mean plots for bacteria provide a visual interpretation of bacteria fluctuations over time for each AU being analyzed. Desk Review 1 moving-seven year bacteria geometric mean plots can be found in Appendix A.

All materials gathered during Desk Review 1 were presented at the technical workgroup meeting on April 20, 2016. Local partners and interested stakeholders participated and provided feedback about findings and shared additional knowledge and expertise about the Top 10AUs discussed. Based on Desk Review 1 results and discussions with the technical workgroup, the BIG's Top 10 AUs were cut down to the Top 5/Least 5 AUs with bacteria concentration, designated uses, accessibility, and level of interest being the primary criteria by which the lists were prioritized. Table 1 lists the final Top 5/Least 5 AUs that were selected. All materials presented at the meeting, as well as meeting summary notes, can be found in Appendix A.

Table 7. Top 5/Least 5 AU list after Phase I: Desk Review 1

Top Five Most Impaired AUs	Top Five Least Impaired AUs
Berry Bayou Above Tidal (Segment 1007F_01)	*Upper Panther Branch (Segment 1008B_02)*
Mimosa Ditch (Segment 1007U_01)	Lower Panther Branch (Segment 1008C_02)
Bintliff Ditch (Segment 1007T_01)	Canal C-147 (Segment 1007A_01)
Little White Oak Bayou (1013A_01)	Cowart Creek (Segment 1102A_02)
Rummel Creek (1014N_01)	Clear Creek Above Tidal (Segment 1102_04)

3.0 Desk Review 2

During Desk Review 2, the existing GIS maps from Desk Review 1 were further refined to include additional information about the prioritized Top 5/Least 5 AUs. In addition to the map layers included in Desk Review 1, a land use/land cover (LU/LC) layer was added to the Desk Review 2 maps to better identify potential bacteria sources within each AU on the Top 5/Least 5 lists. Potential bacteria sources were also identified on the Desk Review 2 maps with GPS coordinates included for each. Desk Review 2 maps can be found in Appendix B.

Further statistical analysis of historical CRP data was conducted for each AU on the Top 5/Least 5 lists during Desk Review 2. In addition to the moving seven-year bacteria geometric mean plots, a trend analysis was conducted for each AU to evaluate if bacteria conditions have been improving or getting worse over time. LDCs were also developed for AUs with available U.S. Geological Survey (USGS) flow data. A LDC is a graphical illustration that shows the corresponding relationship between contaminant loadings and stream flow conditions in a given area. Only two AUs on the Top 5/Least 5 lists had enough flow data available to generate LDCs, including Little White Oak Bayou and Cowart Creek. To better evaluate which stream segments tend to have high bacteria concentrations during dry weather conditions, bacteria versus days since last rain graphs were generated for the remaining AUs on the Top 5/Least 5 lists where LDCs were not feasible. Trend graphs, LDCs, and rain graphs generated during Desk Review 2 can be found in Appendix B.

All materials gathered during Desk Review 2 were presented at the technical workgroup meeting on May 26, 2016. The established workgroup participated and provided feedback on findings to assist in prioritizing the Top 5/Least 5 list down to a Top 2/Least 2 list for further assessment and ground truthing during the AU Intensive Study portion of Phase I. Based on Desk Review 2 results and discussions with the technical workgroup, the BIG's Top 5/Least 5 AUs were cut down to the Top 2/Least 2 AUs with bacteria conditions, designated uses, accessibility, and level of interest being the primary criteria by which the lists were prioritized. Table 2 lists the final Top 2/Least 2 AUs that were selected. All materials presented at the meeting, as well as meeting summary notes, can be found in Appendix B.

Table 2. Top 2/Least 2 AU list that was decided on after Phase I: Desk Review 2

Top Two Most Impaired AUs	Top Two Least Impaired AUs
Little White Oak Bayou (1013A_01)	*Upper Panther Branch (Segment 1008B_02)*
Rummel Creek (1014N_01)	Canal C-147 (Segment 1007A_01)

4.0 AU Intensive Study: Top 2 Most Impaired

4.1 Little White Oak Bayou

Little White Oak Bayou, Segment 1013A_01, is one of the most impaired water bodies within the BIG geographic area, with an *E.coli* geometric mean concentration of 1975 MPN/100mL compared to the state water quality standard of 126 MPN/100mL. Desk Review 1 and 2 findings show the primary LU/LC within the 7.9 square mile catchment area is residential. The total length of the waterway is approximately 3.9 miles with two active CRP monitoring stations: station 11148 at Little White Oak Bayou and Trimble Street; and station 16648 at Little White Oak Bayou and White Oak Drive. Designated uses for this segment include Aquatic Life Use, General Use, and Contact Recreation Use. Refer to Figure 3 for the watershed map of Little White Oak Bayou developed during Desk Review 2.

Statistical analysis of Little White Oak Bayou data revealed a gradual decrease in bacteria geometric mean concentrations since 2005 (Figure 4). However, *E.coli* concentrations remain significantly higher than the 126 MPN/100mL standard for the majority of samples collected during the assessment period (Figure 5). The LDC curve generated for station 11148 on Little White Oak Bayou revealed the majority of data points exceeding the state standard for *E.coli* during dry conditions, implying that dry weather discharges high in bacteria seem to be a common occurrence for this stream segment (Figure 6).

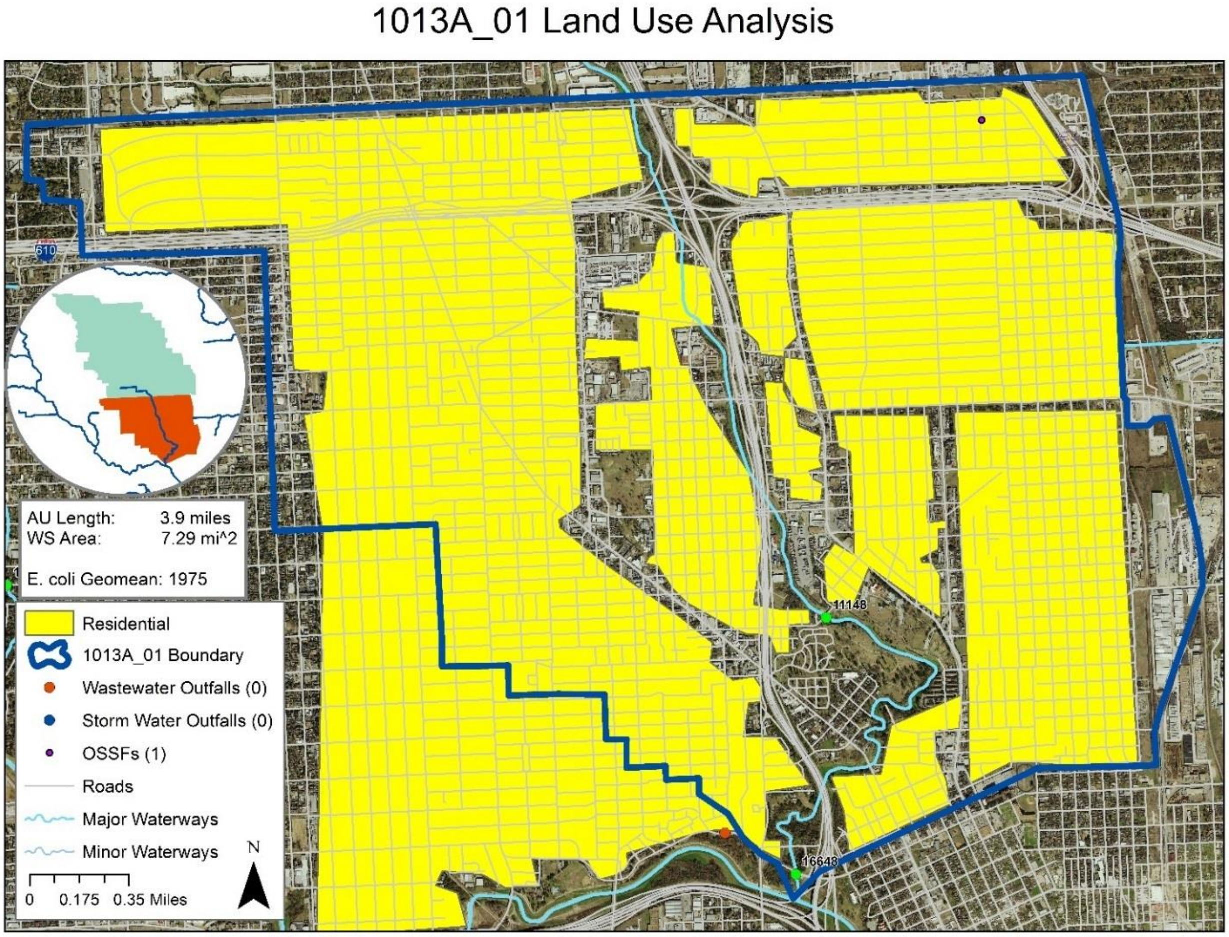


Figure 3. Desk Review 2 map for Little White Oak Bayou Segment 1013A_01

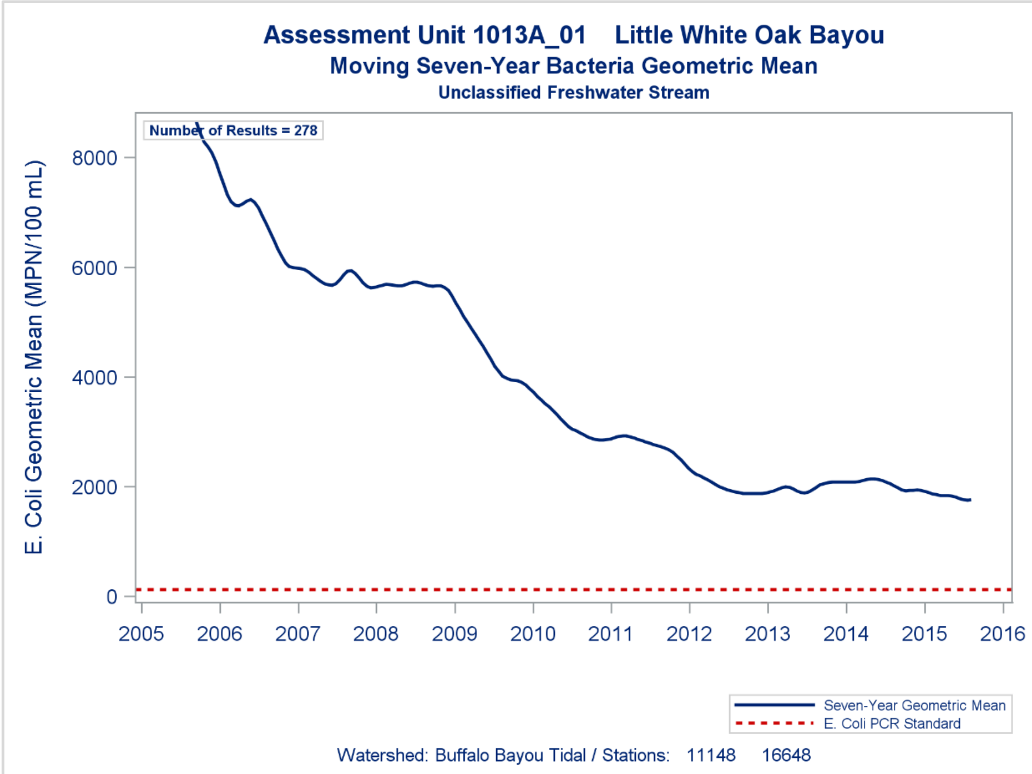


Figure 4. Moving seven-year E.coli geometric mean plot for Little White Oak Bayou

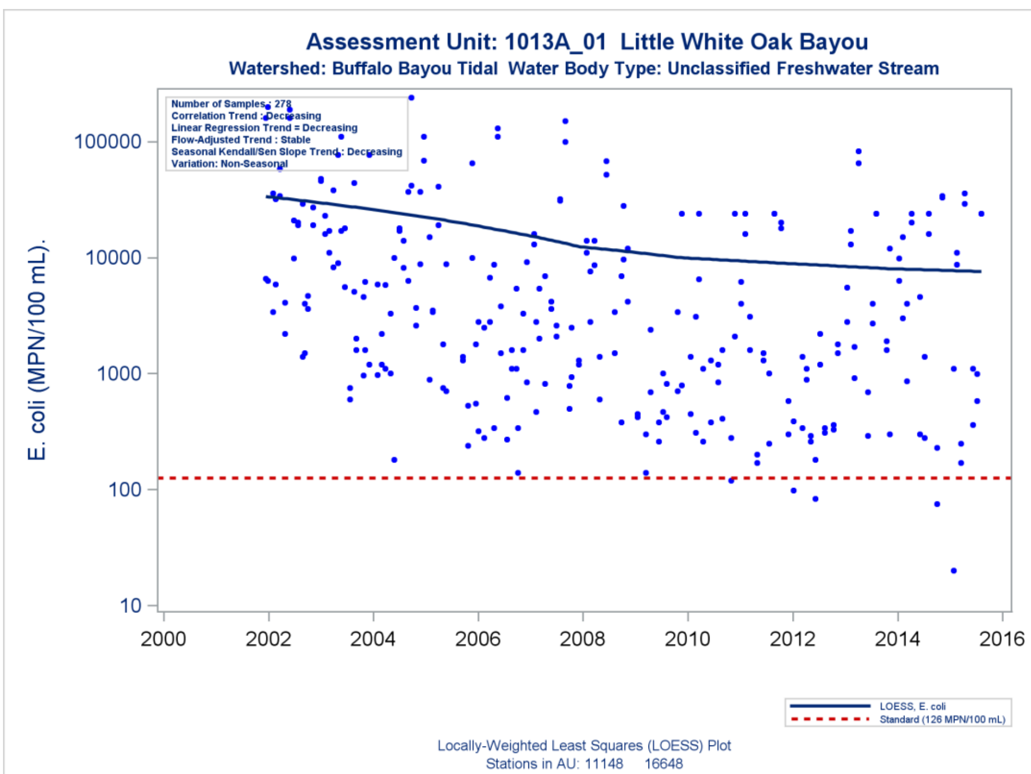


Figure 5. E.coli trend analysis for Little White Oak Bayou

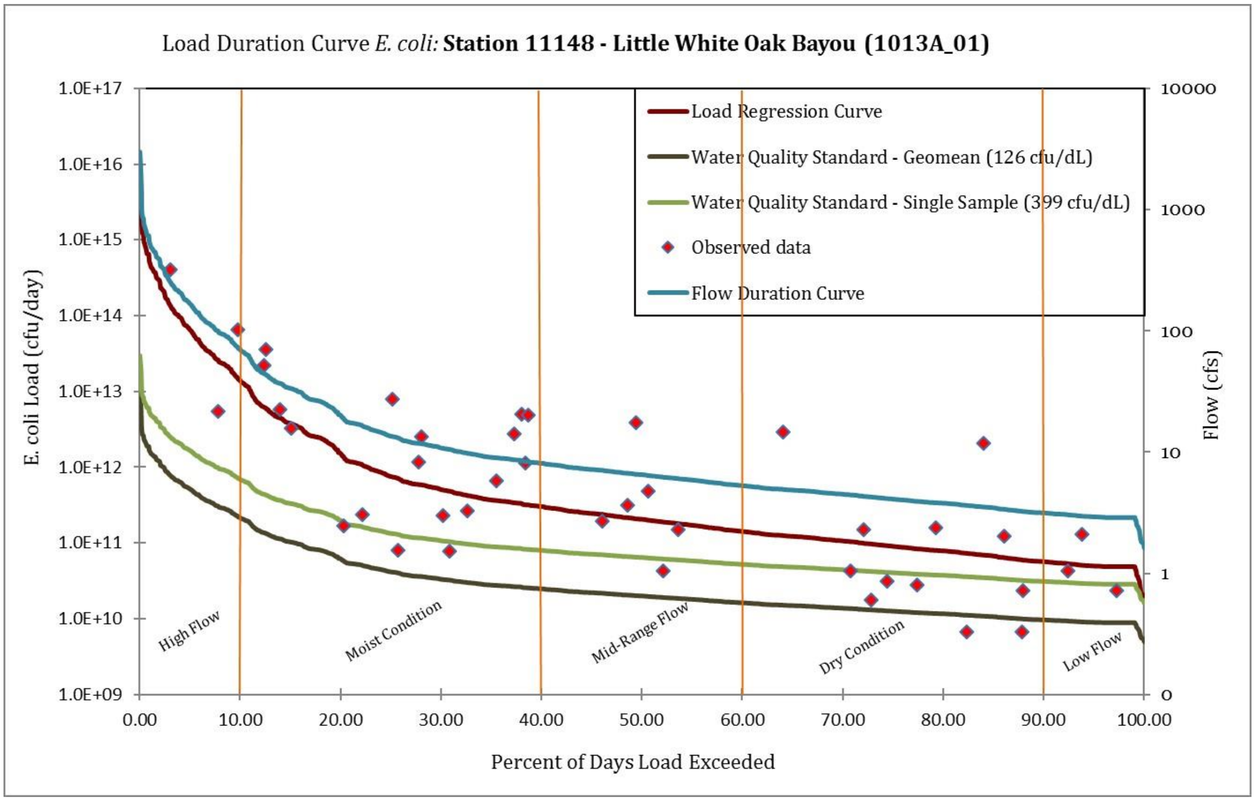


Figure 6. LDC for Little White Oak Bayou at station 11148

4.1.1 Windshield Survey

The windshield survey for Little White Oak Bayou was conducted on June 22, 2016. The waterway was investigated by vehicle, and points of access and potential bacteria sources were noted during the survey. Primary land use is residential throughout the catchment area with light commercial land uses present along the primary thoroughfares of Fulton Street, Main Street, and the I-45 and I-610 corridors. Although no potential bacteria sources were observed during the windshield survey, a significant amount of accumulated trash and litter was seen at bridge crossings and access points throughout the waterway. Refer to Figure C1 in Appendix C for a map of the windshield survey route.

4.1.2 Bacteria Screening

A total of 25 bacteria screening samples were collected along Little White Oak Bayou during the on-the -round surveys July 13, 18, and 20, 2016. Samples were collected at eight discharging outfalls (Figure 7) and one tributary, while the rest of the samples were surface water samples collected in an effort to better identify hot spots and trace bacteria sources back to their origin. It should be noted that a significant rain event occurred on July 19, 2016, making the samples collected on July 20, 2016, wet weather samples. Sample sites from July 20, 2016, will be re-visited during Phase II to collect dry weather samples for comparison.

Figure 7. Collecting sample from discharging outfall

Samples were analyzed using the Coliscan Easygel method to test for *E.coli* concentrations. The prepared water samples were plated on a treated petri dish and incubated at a temperature of 33°C for 28 hours. Upon incubation, *E.coli* within the samples produce enzymes that react with color reagents in the media to create dark blue colonies. The number of colonies present on each petri dish reflect the *E.coli* concentration for that sample (Figure 8). Samples with greater than 200 blue colonies are labeled as Too Numerous To Count (TNTC). Two dilutions were measured for each sample and the average concentration is reported in Table 3. Refer to Figure 9 for a station map illustrating the location and sample type for each sample collected during the Little White Oak Bayou survey, and to Figure 10 for a map illustrating the bacteria results for each sample collected. Additional information about sample locations and descriptions can be found in Table C1 in Appendix C.

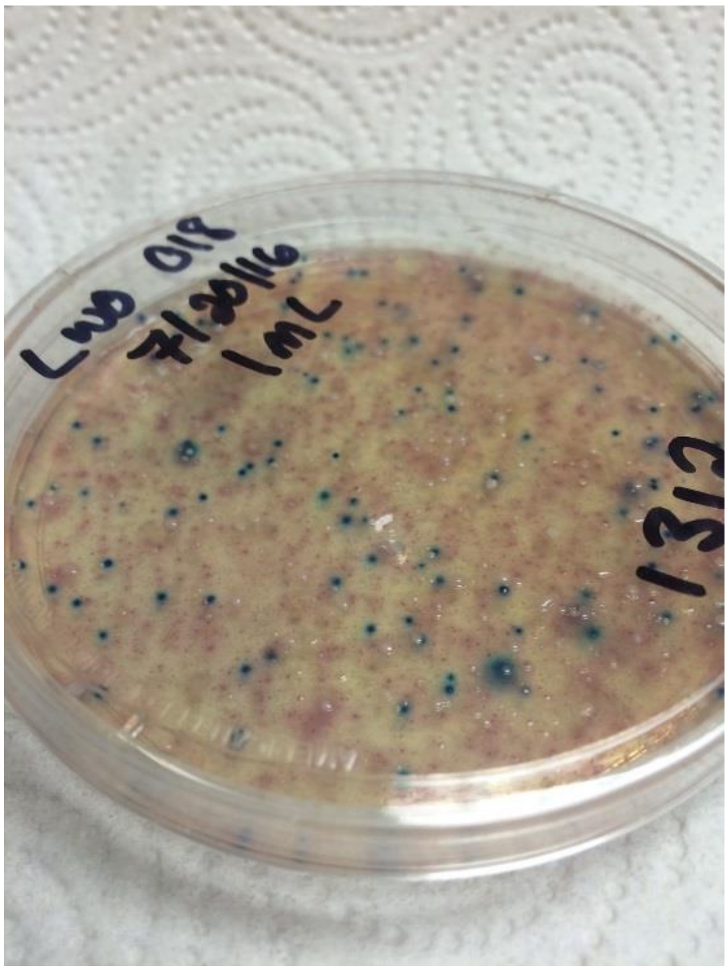


Figure 8. Coliscan Easygel E.coli colony count for Little White Oak Bayou sample 018

1013A_01 Little White Oak Bayou Bacteria Sample Sites

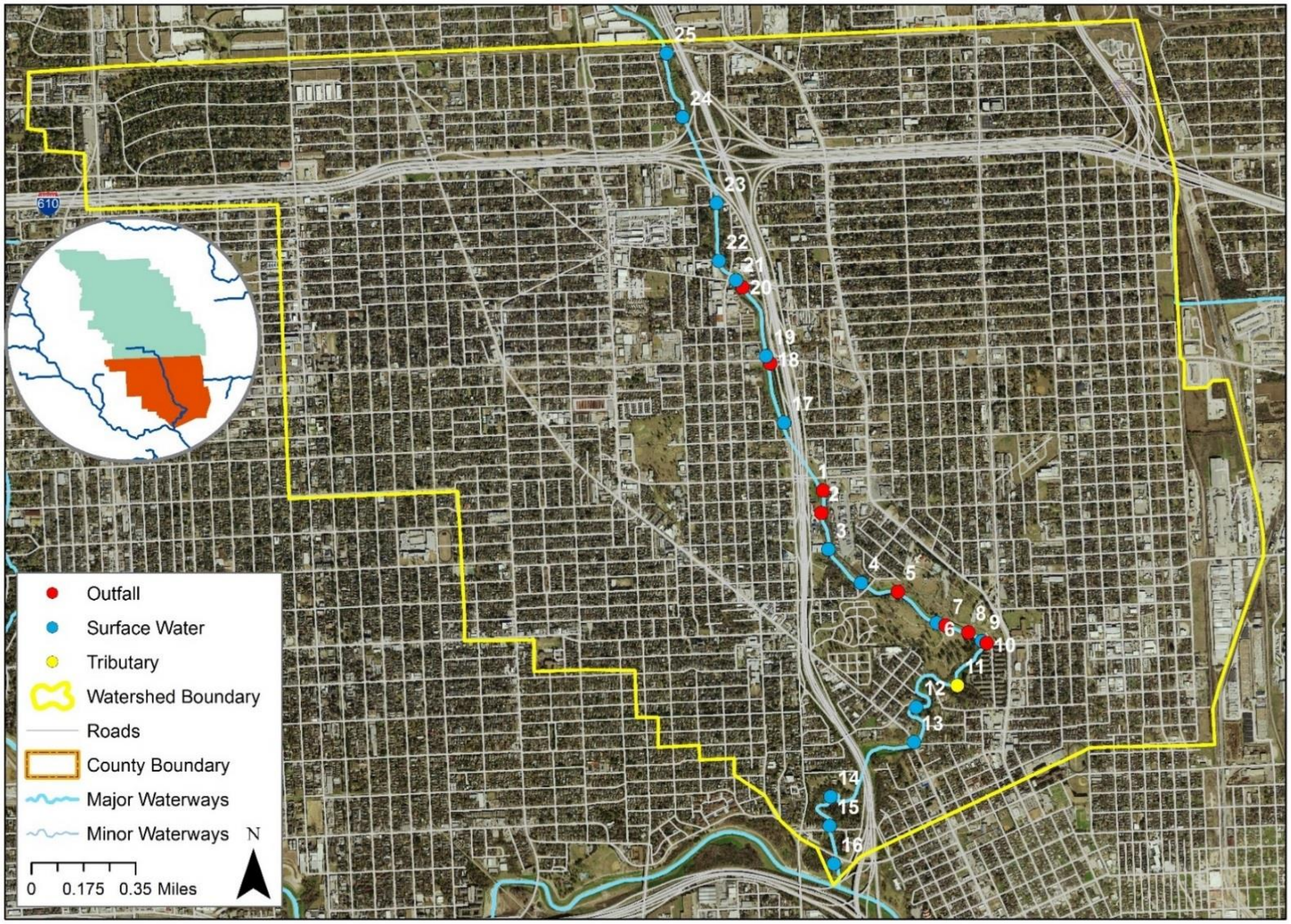


Figure 9. Station map for Little White Oak Bayou survey on July 13, 18, and 20, 2016

1013A_01 Little White Oak Bayou Bacteria Sample Counts

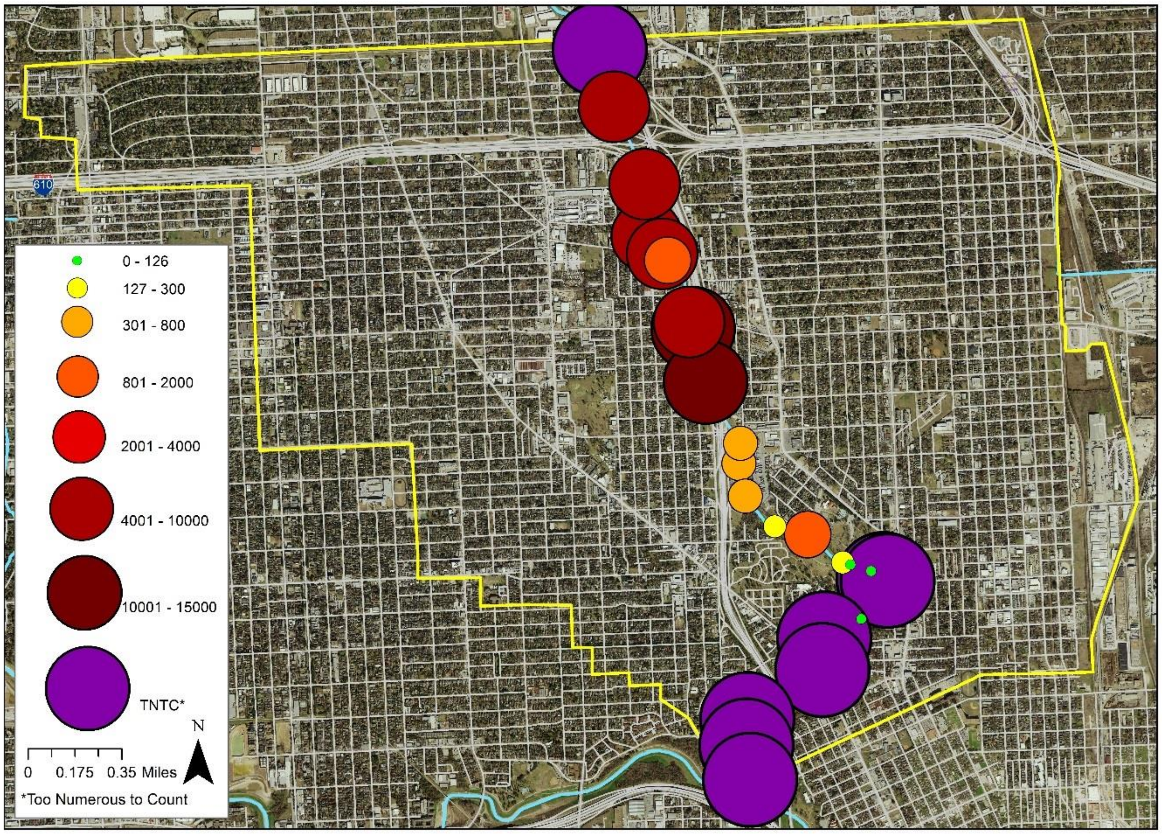


Figure 10. Bacteria screening results for Little White Oak Bayou surveys

4.1.3 Significant Findings

The most significant observation recorded during the Little White Oak Bayou survey was the litter and trash problem along the entire waterway. Portions of Little White Oak's banks were completely covered in trash and debris ranging from tires, shopping carts, plastics, Styrofoam, aluminum, and clothing. Trees along the lower portion of the waterway were covered in trash, likely from high flow conditions washing significant amounts of litter downstream that become trapped in branches and wrapped around tree trunks (Figures 11-14). However, even with the accumulated trash, there were abundant amounts of wildlife and aquatic organisms observed during the field surveys. Turtles and various bird species were common, many of which have made homes in the littered trees, shopping carts and tires. Alligator gar were also observed, primarily at the mouth of storm drains and outfall locations.

Table 3 lists all significant findings that require further investigation and follow-up sampling. The average *E.coli* count for the Little White Oak Bayou bacteria screening was approximately 3,974 cfu/100mL, which is likely a gross underestimation considering 32 percent of the samples were TNTC. Due to the extremely high concentrations found within this segment, samples collected with *E.coli* counts greater than 9,000 cfu/100mL were flagged as problem areas where further investigation is recommended. Three of the 25 samples collected had no bacteria colony forming units--two outfalls and one tributary. Further investigation is recommended for the non-detect sample locations to identify potential chlorine leaks or illicit discharges with high anti-bacterial agents.

Table 3. Summary of bacteria results and significant findings for Little White Oak Bayou

No.	Tier II ID	Tier II Type	Outfall Flow	Sample ID	Sample Type	*E. coli (cfu/100ml)*	Issue	Date Identified	Further Investigation	Latitude	Longitude
1	023	Outfall	Present	001	Outfall	575	N/A	7/13/2016	No	29.79758	-95.37048
2	025	Outfall	Present	002	Outfall	700	N/A	7/13/2016	No	29.79642	-95.37062
3	N/A	N/A	N/A	003	Surface Water	450	N/A	7/13/2016	No	29.79464	-95.37029
4	N/A	N/A	N/A	004	Surface Water	250	N/A	7/13/2016	No	29.79296	-95.36852
5	034	Outfall	Present	005	Outfall	1025	N/A	7/13/2016	No	29.79088	-95.36414
6	N/A	N/A	N/A	006	Surface Water	150	N/A	7/13/2016	No	29.79090	-95.36438
7	036	Outfall	Present	007	Outfall	0	No Bacteria	7/13/2016	Yes	29.79083	-95.36405
8	041	Outfall	Present	008	Outfall	0	No Bacteria	7/18/2016	Yes	29.79039	-95.36263
9	N/A	N/A	N/A	009	Surface Water	TNTC	High Bacteria	7/18/2016	Yes	29.78994	-95.36188
10	044	Outfall	Present	010	Outfall	TNTC	High Bacteria	7/18/2016	Yes	29.78984	-95.36163
11	048	Tributary	N/A	011	Surface Water	0	No Bacteria	7/18/2016	Yes	29.78782	-95.36334
12	N/A	N/A	N/A	012	Surface Water	TNTC	High Bacteria	7/18/2016	Yes	29.78683	-95.36567
13	N/A	N/A	N/A	013	Surface Water	TNTC	High Bacteria	7/18/2016	Yes	29.78513	-95.36585
14	N/A	N/A	N/A	014	Surface Water	TNTC	High Bacteria	7/18/2016	Yes	29.78260	-95.37060
15	050	Outfall	Present	015	Surface Water	TNTC	High Bacteria	7/18/2016	Yes	29.78119	-95.37070
16	N/A	N/A	N/A	016	Surface Water	TNTC	High Bacteria	7/18/2016	Yes	29.77933	-95.37054
17	N/A	N/A	N/A	017	Surface Water	10900	High Bacteria	7/20/2016	Yes	29.80087	-95.37254
18	053	Outfall	Present	018	Outfall	13300	High Bacteria	7/20/2016	Yes	29.80372	-95.37321
19	N/A	N/A	N/A	019	Surface Water	7300	N/A	7/20/2016	No	29.80414	-95.37343
20	055	Outfall	Present	020	Outfall	1350	N/A	7/20/2016	No	29.80751	-95.37463
21	N/A	Outfall	Absent	021	Surface Water	6650	N/A	7/20/2016	No	29.80787	-95.37498
22	N/A	Outfall	Absent	021	Surface Water	6650	N/A	7/20/2016	No	29.80787	-95.37498
23	N/A	Outfall	Absent	021	Surface Water	6650	N/A	7/20/2016	No	29.80787	-95.37498
24	056	Outfall	Absent	022	Surface Water	9450	High Bacteria	7/20/2016	Yes	29.80884	-95.37589
25	N/A	N/A	N/A	023	Surface Water	4300	N/A	7/20/2016	No	29.81165	-95.37593
26	058	Outfall	Absent	024	Surface Water	5800	N/A	7/20/2016	No	29.81596	-95.37775
27	N/A	N/A	N/A	025	Surface Water	TNTC	High Bacteria	7/20/2016	Yes	29.81901	-95.37845
28	035	Outfall	Absent	N/A	N/A	N/A	Screen Cover	7/13/2016	Yes	29.79082	-95.36403
29	040	Outfall	Absent	N/A	N/A	N/A	Screen Cover	7/18/2016	Yes	29.79043	-95.36283
30	052	Sewer Manhole	Absent	N/A	N/A	N/A	Damaged	7/20/2016	Yes	29.80126	-95.37309
31	N/A	Outfall	Absent	N/A	N/A	N/A	Suspicious Pipe	7/20/2016	Yes	29.80425	-95.37350
32	033	Outfall	Present	N/A	N/A	N/A	Screen Cover	7/13/2016	Yes	29.79246	-95.36655
33	047	Sewer Manhole	N/A	N/A	N/A	N/A	Open	7/18/2016	Yes	29.78791	-95.36320

Figure 11. Shopping cart and litter on water bank

Figure 12. Trash wrapped around tree trunks in lower portion of Little White Oak

Figure 14. Washed up trash trapped by tree branches

Other than the in-stream and outfall samples collected, additional findings that require further investigation include the following:

1) Three suspicious outfall pipes adjacent to the Moody Park area had metal screened covers attached to the ends. One of the three pipes had a small amount of discharge dripping from the outfall, but not enough for sample collection and bacteria screening. Locations for the screened outfalls can be found in Table 3 (Tier II ID 033, 035, and 040). Refer to Figures 15-17 for images of the three suspicious outfall pipes.


Figure 15. Outfall Tier II ID 035


Figure 16. Outfall Tier II ID 035


Figure 17. Outfall Tier II ID 040

2) Two sewer manholes require follow-up investigation. One manhole (Tier II ID 047) was found along the Bayou with an open lid likely from a recent sewer overflow. The smell of sewage inside the manhole could be detected from the bank. A second damaged manhole was found along the Bayou (Tier II ID 052). This manhole was about six feet tall with a large hole in the cement casing. Another hole was found in the ground by the sewer manhole. It was unclear if this was an active or abandoned manhole, but further investigation is recommended to ensure raw sewage does not discharge at the location. Refer to Table 3 for locations of each manhole, and to Figures 18-20 for images of each.


Figure 18. Outfall Tier II ID 047


Figure 19. Outfall Tier II ID 052


Figure 20. Outfall Tier II ID 052

3) A suspicious drain line from the Astro Inn's parking lot leads directly into Little White Oak Bayou on the right bank upstream of the West Cavalcade Street bridge. There was no discharge at the outfall at the time of sampling, but a surface water sample (019) was collected directly downstream of the pipe line resulting in an *E.coli* concentration of 7,300 cfu/100mL. Additional investigation is recommended to ensure this is not an illicit discharge. Refer to Table 3 (No. 31) for GPS coordinates and to Figure 21-23 for images of the drain line and parking lot.


Figure 21. Astro Inn Parking lot (No. 31)


Figure 22. Outfall No. 31


Figure 23. Outfall Tier No. 31

4.2 Rummel Creek

Rummel Creek, Segment 1014N_01, is one of the most impaired water bodies within the BIG geographic area, with an *E.coli* geometric mean concentration of 1960 MPN/100mL compared to the state water quality standard of 126 MPN/100mL. The stream length is approximately 3.04 miles with a catchment area of 4.62 square miles. There is one active CRP monitoring station located at Rummel Creek and Memorial Drive (station ID 11188). Primary LU/LC in the area is residential with some light commercial and industrial land uses present north of Beltway 8. Designated uses for this segment include Aquatic Life Use, General Use, and Contact Recreation Use. Potential bacteria sources identified during Desk Review 2 include dirt yards and a nursery located at the intersection of I-10 and Beltway 8(Figure 24).

Statistical analysis of Rummel Creek data revealed a gradual decrease in bacteria geometric mean concentrations since 2005 (Figure 25). However, *E.coli* concentrations remain significantly higher than the 126 MPN/100mL standard for the majority of samples collected during the assessment period (Figure 26). No LDC graphs were generated for Rummel Creek because flow data from USGS was unavailable for this segment. To assess the occurrence of high *E.coli* concentrations during dry weather conditions, an *E.coli* versus days since last rain graph was developed and showed data points exceeding the state water quality standard for bacteria more than 20 days after the last rain event (Figure 27).

4.2.1 Windshield Survey

The windshield survey for Rummel Creek was June 22, 2016. The waterway was investigated by vehicle, and points of access and potential pollution sources were noted. Primary land use is residential throughout the catchment area with commercial and industrial land uses present primarily north of Beltway 8 and at the intersection of I-10 and Beltway 8. Several industrial stormwater outfalls are adjacent to the I-10 corridor north of Beltway 8 before the stream goes underground. Nearby facilities include a hospital and various flooring distribution and furniture warehouses. A large plant nursery is on the southwest corner of the I-10 and Beltway 8 intersection adjacent to where Rummel Creek emerges from underground. A large discharging outfall appeared to be coming from the stormwater detention area adjacent to the nursery. A significant amount of vegetation was growing through the cement-lined channel adjacent to the nursery and stormwater detention outfall (Figure 28). Refer to Figure D1 in Appendix D for a map of the windshield survey route.

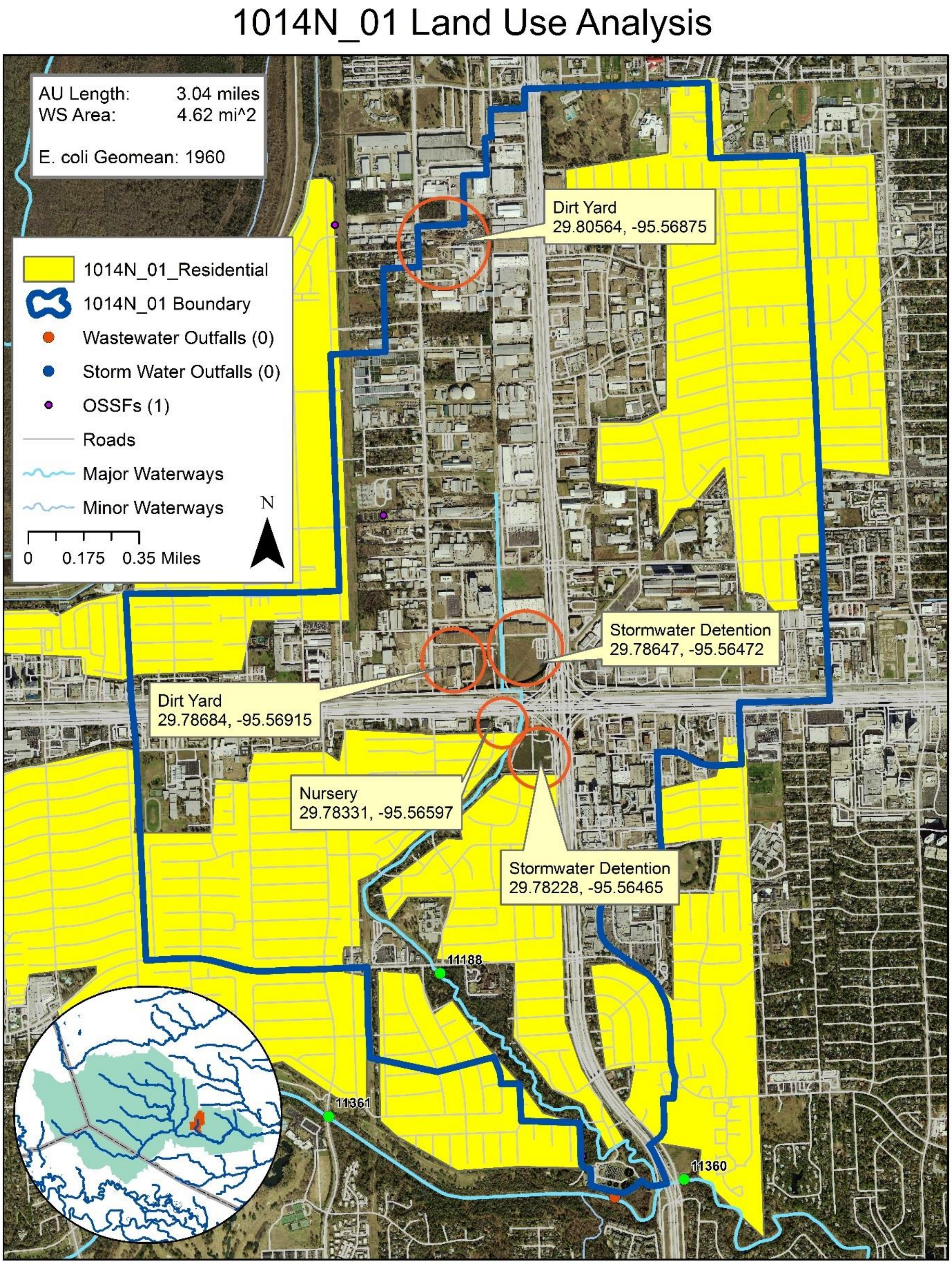


Figure 24. Desk Review 2 map for Rummel Creek, Segment 1014N_01

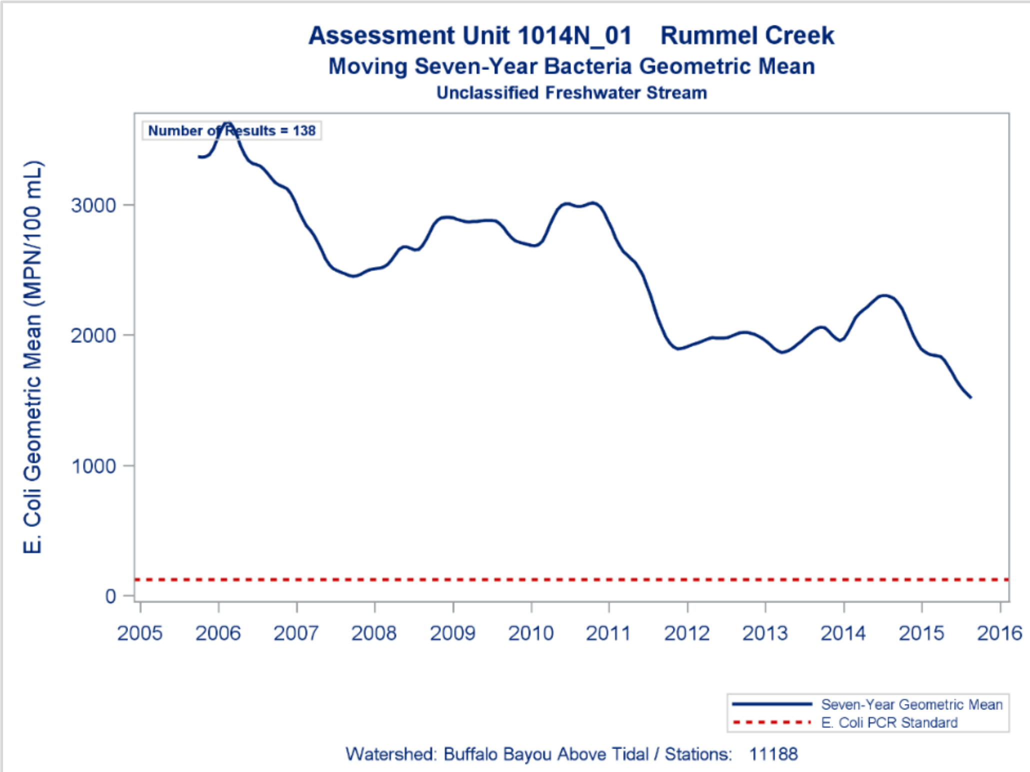


Figure 25. Moving seven-year E.coli geometric mean plot for Rummel Creek

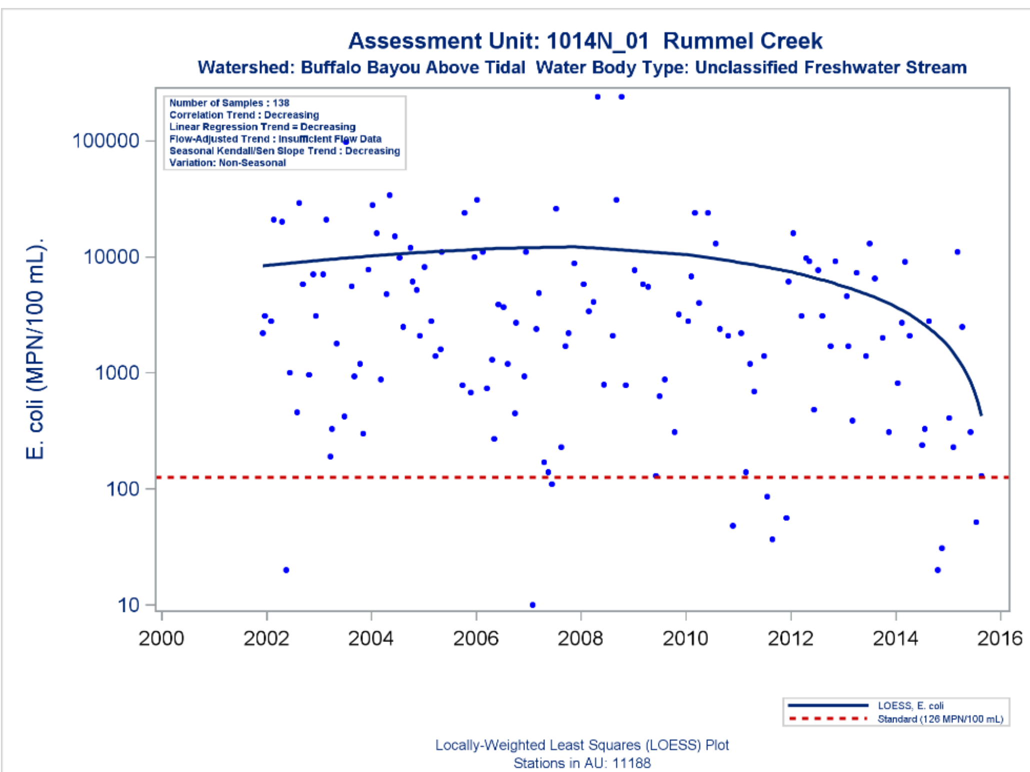


Figure 26. E.coli trend analysis for Rummel Creek

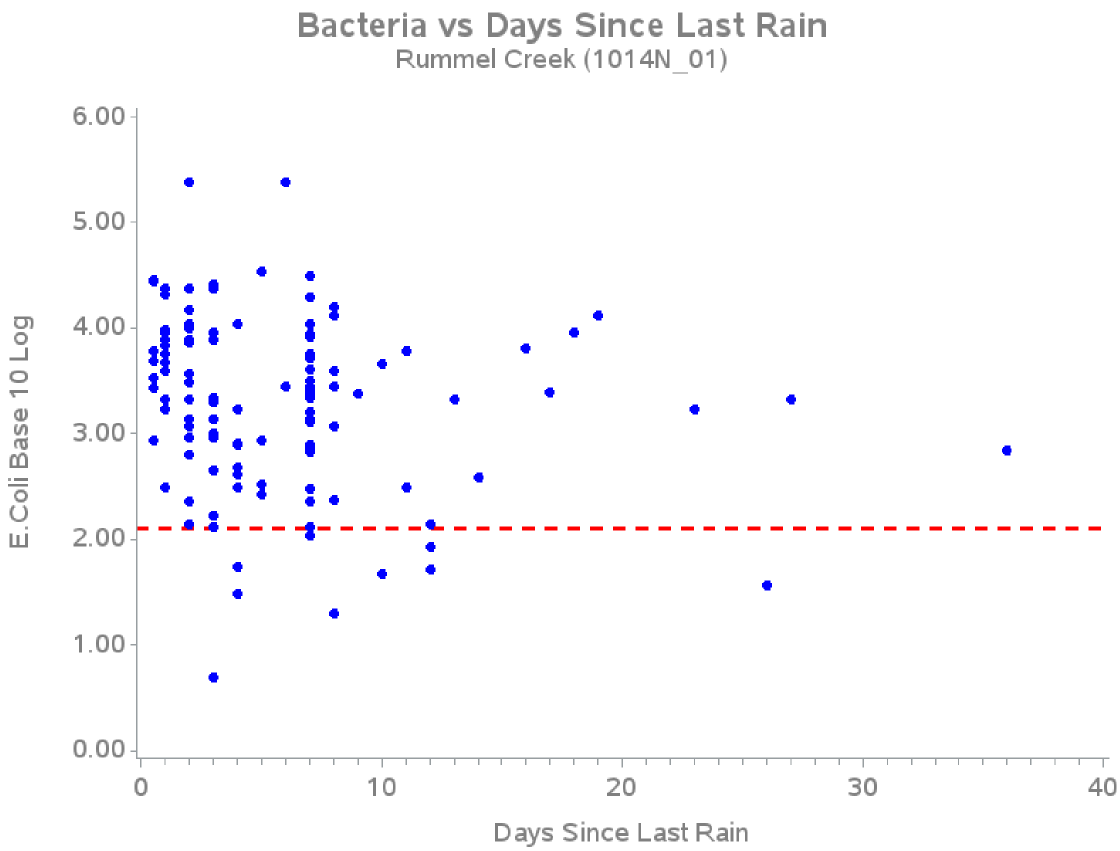


Figure 27. Bacteria versus days since last rain graph for Rummel Creek. Red dotted line represents the water quality standard for E.coli.

Figure 28. Stormwater detention outfall adjacent to plant nursery at southwest corner of I-10 and Beltway 8 intersection

4.2.2 Bacteria Screening

A total of 13 bacteria screening samples were collected along Rummel Creek during the on-the-ground survey July 11, 2016. Samples were collected at four discharging outfalls and two tributaries, while the rest of the samples were surface water samples collected in an effort to better identify hot spots and trace bacteria sources back to their origin.

Samples were analyzed using the Coliscan Easygel method to test for *E.coli* concentrations. Two dilutions were measured for each sample and the average concentration is reported in Table 4. Refer to Figure 29 for a station map illustrating the location and sample type for each sample collected during the Rummel Creek survey, and to Figure 30 for a map illustrating the bacteria results for each sample collected. Additional information about sample locations and descriptions can be found in Table D1 in Appendix D.

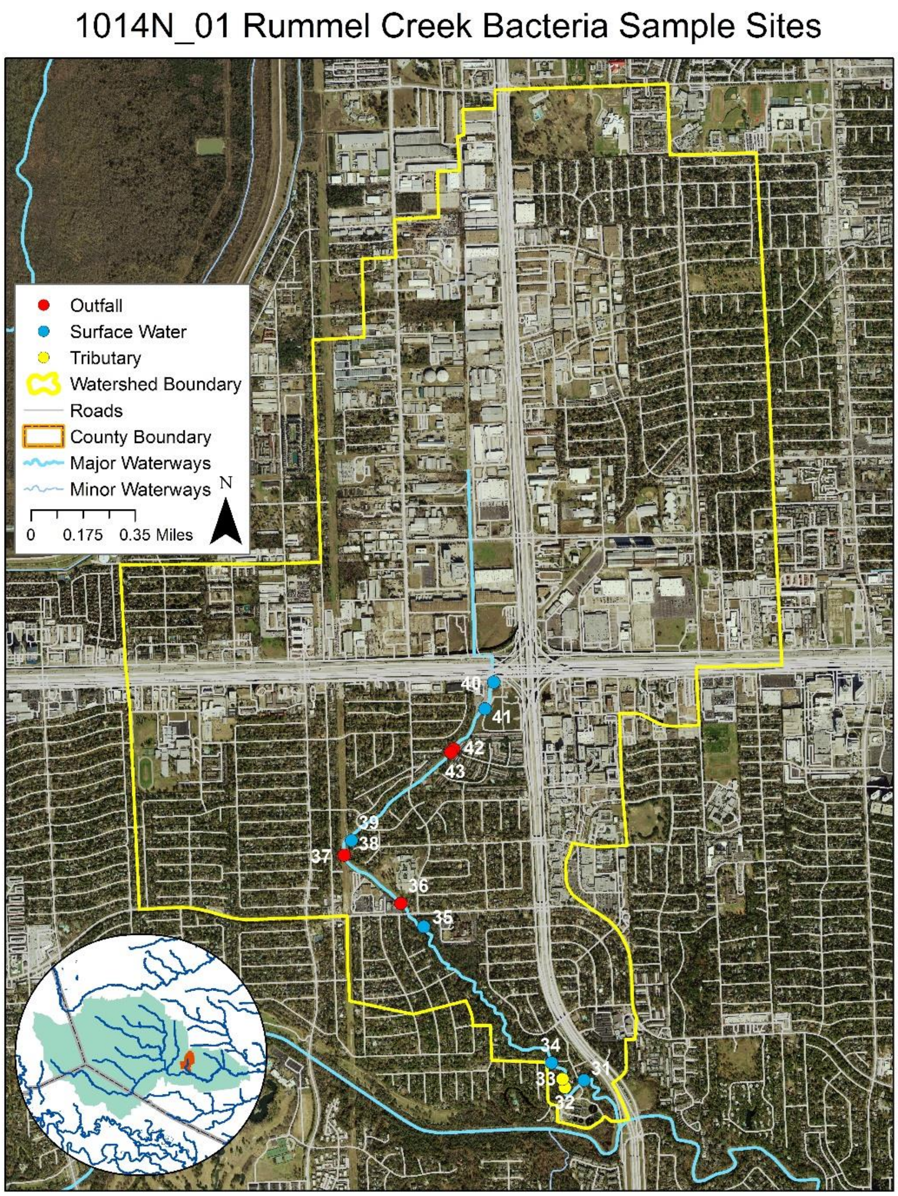


Figure 29. Station map for Rummel Creek survey July 11, 2016

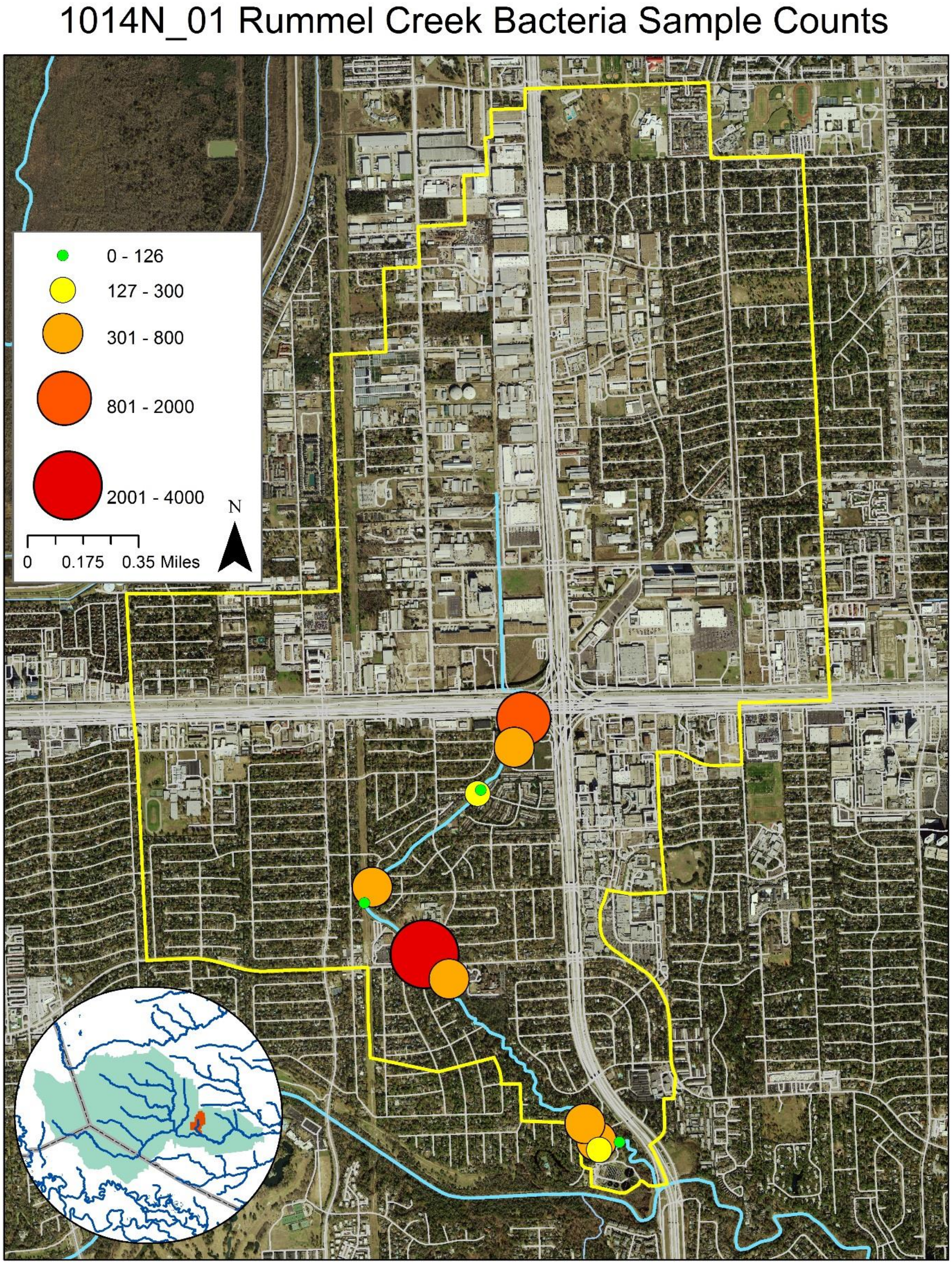


Figure 30. Bacteria screening results for Rummel Creek survey

Table 4. Summary of bacteria results and significant findings for Rummel Creek

No.	Tier II ID	Tier II Type	Outfall Flow	Sample ID	Sample Type	*E. coli (cfu/100ml)*	Issue	Date Identified	Further Investigation	Latitude	Longitude
1	N/A	N/A	N/A	031	Surface Water	125	N/A	7/11/2016	No	29.76429	-95.56070
2	002	Tributary	Absent	032	Surface Water	225	N/A	7/11/2016	No	29.76397	-95.56178
3	003	Tributary	Absent	033	Surface Water	775	High Bacteria	7/11/2016	Yes	29.76438	-95.56191
4	N/A	N/A	N/A	034	Surface Water	525	High Bacteria	7/11/2016	Yes	29.76519	-95.56248
5	N/A	N/A	N/A	035	Surface Water	425	N/A	7/11/2016	No	29.77200	-95.56940
6	006	Outfall	Present	036	Outfall	2275	High Bacteria	7/11/2016	Yes	29.77316	-95.57065
7	010	Outfall	Present	037	Outfall	100	N/A	7/11/2016	No	29.77559	-95.57374
8	N/A	N/A	N/A	038	Surface Water	400	N/A	7/11/2016	No	29.77630	-95.57330
9	N/A	N/A	N/A	039	Surface Water	700	High Bacteria	7/11/2016	Yes	29.77630	-95.57330
10	N/A	N/A	N/A	040	Surface Water	925	High Bacteria	7/11/2016	Yes	29.78381	-95.56509
11	N/A	N/A	N/A	041	Surface Water	350	N/A	7/11/2016	No	29.78252	-95.56563
12	021	Outfall	Present	042	Outfall	125	N/A	7/11/2016	No	29.78060	-95.56744
13	023	Outfall	Present	043	Outfall	225	N/A	7/11/2016	No	29.78044	-95.56762

4.2.3 Significant Findings

Table 4 lists all significant findings that require further investigation and follow-up sampling. The average *E.coli* count for the Rummel Creek bacteria screening was approximately 552 cfu/100mL. Samples collected with *E.coli* counts greater than 500 cfu/100mL were flagged as problem areas where further investigation is recommended.

Figure 31. Groundwater discharge and surface sheen at sample 033

Noteworthy findings include sample 033 collected at a bend in the stream segment where trash accumulation was observed and apparent groundwater discharge was present. A slight sheen was visible on the water surface at the same location disturbed by the groundwater movement in the otherwise stagnant water (Figure 31). Two dilapidated pipes were observed at sample location 034 where high bacteria levels were detected. One pipe was bored under the waterway (Figure 32) while the other crossed above the water at street level. A concrete slab was found on the floor of Rummel Creek just downstream of the Rummel Creek Road bridge (Figure 33). The concrete was impeding water flow and creating high algae accumulation on the upstream side of the slab. Samples were taken upstream and downstream of the concrete slab, and bacteria levels were higher upstream where water flow was slower (sample 039). Algae was common throughout the waterway but appeared particularly dense north of Memorial Drive near Rummel Creek Elementary School (Figures 34-35). The sample collected at this location (sample 036) had the highest bacteria concentration collected during the Rummel Creek survey.

Figure 32. Pipe and outfall near sample 034

Figure 33. Concrete slab downstream of Rummel Creek Road

Figure 34. Dense algal blooms near Rummel Creek Elementary School (sample 036)

Figure 35. Dense algal blooms near Rummel Creek Elementary School (sample 036)

5.0 AU Intensive Study: Top 2 Least Impaired

5.1 Canal C-147

Canal C-147, Segment 1007A_01, is one of the least impaired water bodies within the BIG geographic area. It is close to meeting state water quality standards for bacteria, with an *E.coli* geometric mean concentration of 157 MPN/100mL compared to the 126 MPN/100mL standard. The segment length is approximately 2.08 miles with a catchment area of 2.63 square miles. There is one active CRP monitoring station at the downstream end of Canal C-147 at Tiffany Drive (station ID 16656). Primary LU/LC identified during Desk Review 2 is residential. Designated uses for this segment include Aquatic Life Use, General Use, and Recreation Use. Potential bacteria sources identified during Desk Review 2 include the WWTF located south of Beltway 8, and Pine Island Sand and Gravel northwest of the WWTF (Figure 36).

Statistical analysis of Canal C-147 data revealed a gradual decrease in bacteria geometric mean concentrations since 2005 (Figure 37). However, *E.coli* concentrations remain higher than the 126 MPN/100mL standard for nearly half of the samples collected during the assessment period (Figure 38). No LDC graphs were generated for Canal C-147 because flow data from USGS was unavailable for this segment. Bacteria versus days since last rain graphs for Canal C-147 show few instances where data points exceed the state water quality standard for bacteria after 10 or more days of no rain, with the majority of high bacteria concentrations following significant rain events (Figure 39).

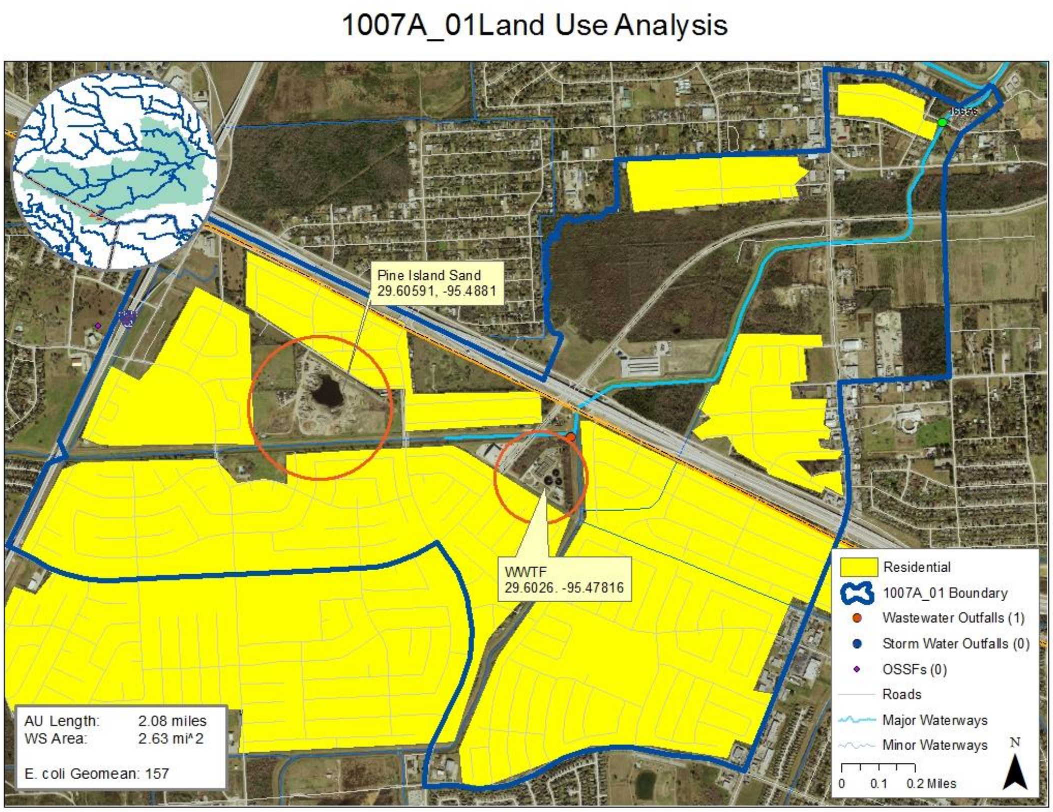


Figure 36. Desk Review 2 map for Canal C-147, Segment 1007A_01

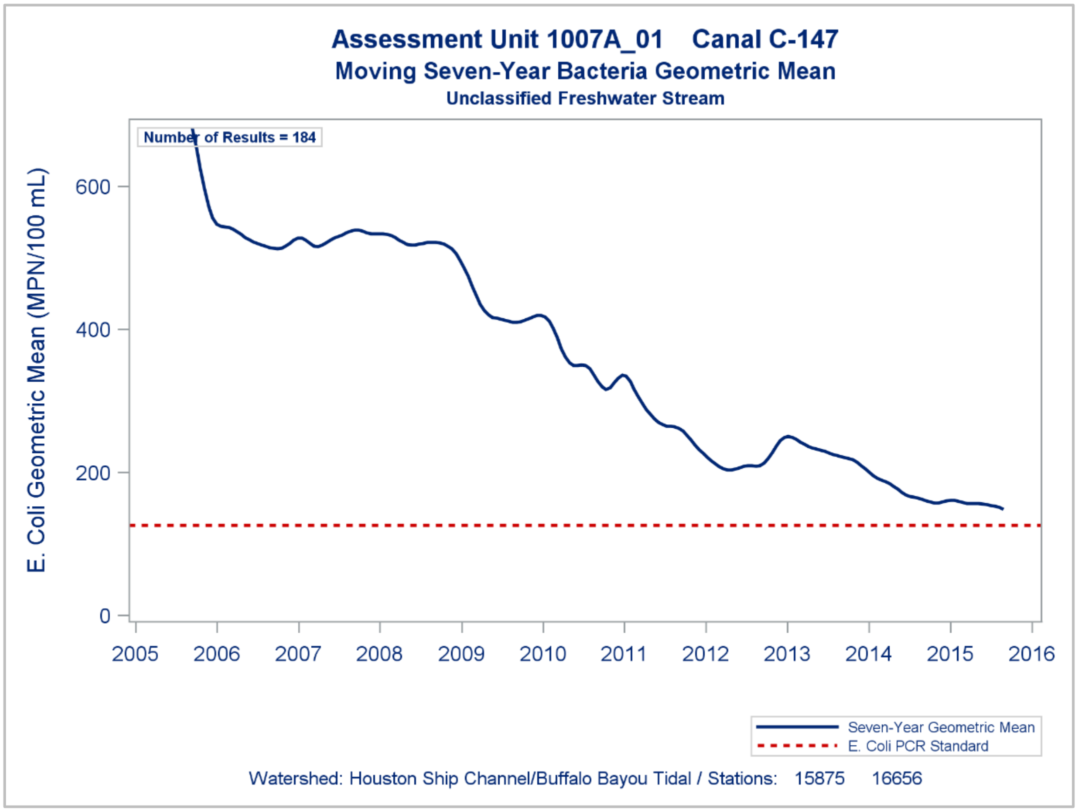


Figure 37. Moving seven-year E.coli geometric mean plot for Canal C-147

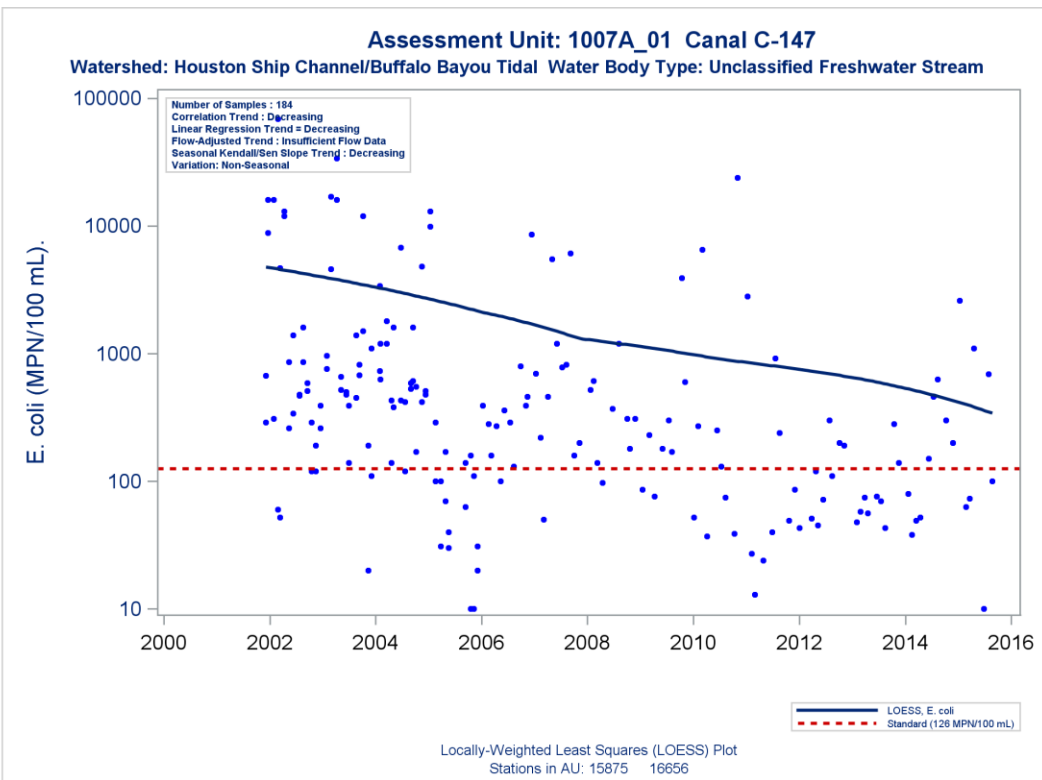


Figure 38. E.coli trend analysis for Canal C-147

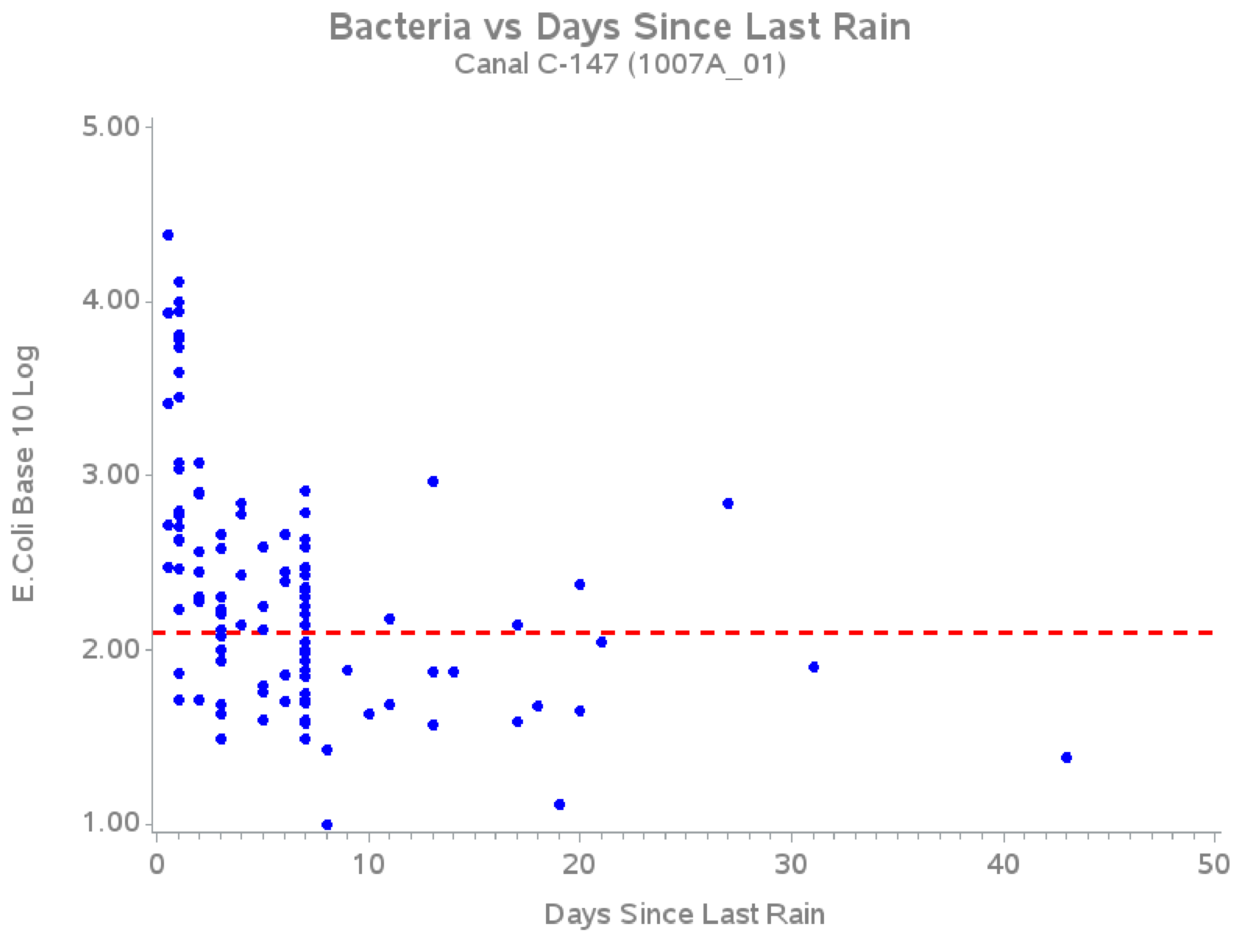


Figure 39. Bacteria versus days since last rain graph for Canal C-147. Red dotted line represents the water quality standard for E.coli.

5.1.1 Windshield Survey

The windshield survey for Canal C-147 was conducted on June 22, 2016. The waterway was investigated by vehicle, and points of access and potential pollution sources were noted. Primary land use is residential throughout the catchment area, with light commercial land uses present along the primary thoroughfares of West Fuqua Street and the Beltway 8 corridor. Illegal dumping of trash was common in the neighborhood at the downstream end of the canal adjacent to the CRP monitoring station. A significant amount of household trash, including mattresses, fencing, and furniture, was found in alleyways and ditches near the stream (Figures 40-42). Refer to Figure E1 in Appendix E for a map of the windshield survey route.

Figure 40. Illegal dumping

Figure 41. Illegal dumping

Figure 42. Illegal dumping

5.1.2 Bacteria Screening

A total of 21 bacteria screening samples were collected along Canal C-147 during the on the ground survey June 30, 2016. Samples were collected at eight discharging outfalls and three tributaries while the rest of the samples were surface water samples collected in an effort to track bacteria sources back to their origin.

Samples were analyzed using the Coliscan Easygel method to test for *E.coli* concentrations (Figure 43). Two dilutions were measured for each sample and the average concentration is reported in Table 5. Refer to Figure 44 for a station map illustrating the location and sample type for each sample collected during the Canal C-147 survey, and to Figure 45 for a map illustrating the bacteria results for each sample collected. Additional information about sample locations and descriptions can be found in Table E1 in Appendix E.

Figure 43. Plating Canal C-147 samples using Coliscan Easygel methodology

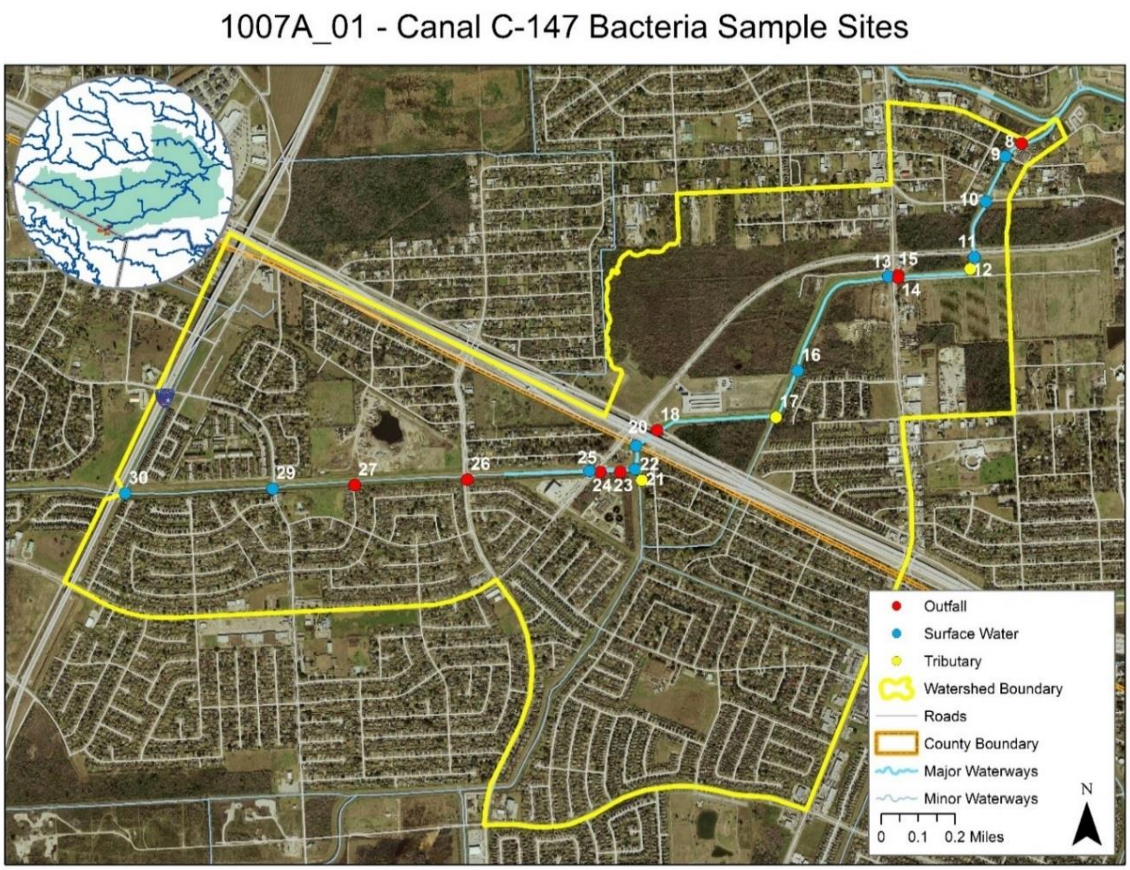


Figure 44. Station map for Canal C-147 survey June 30, 2016

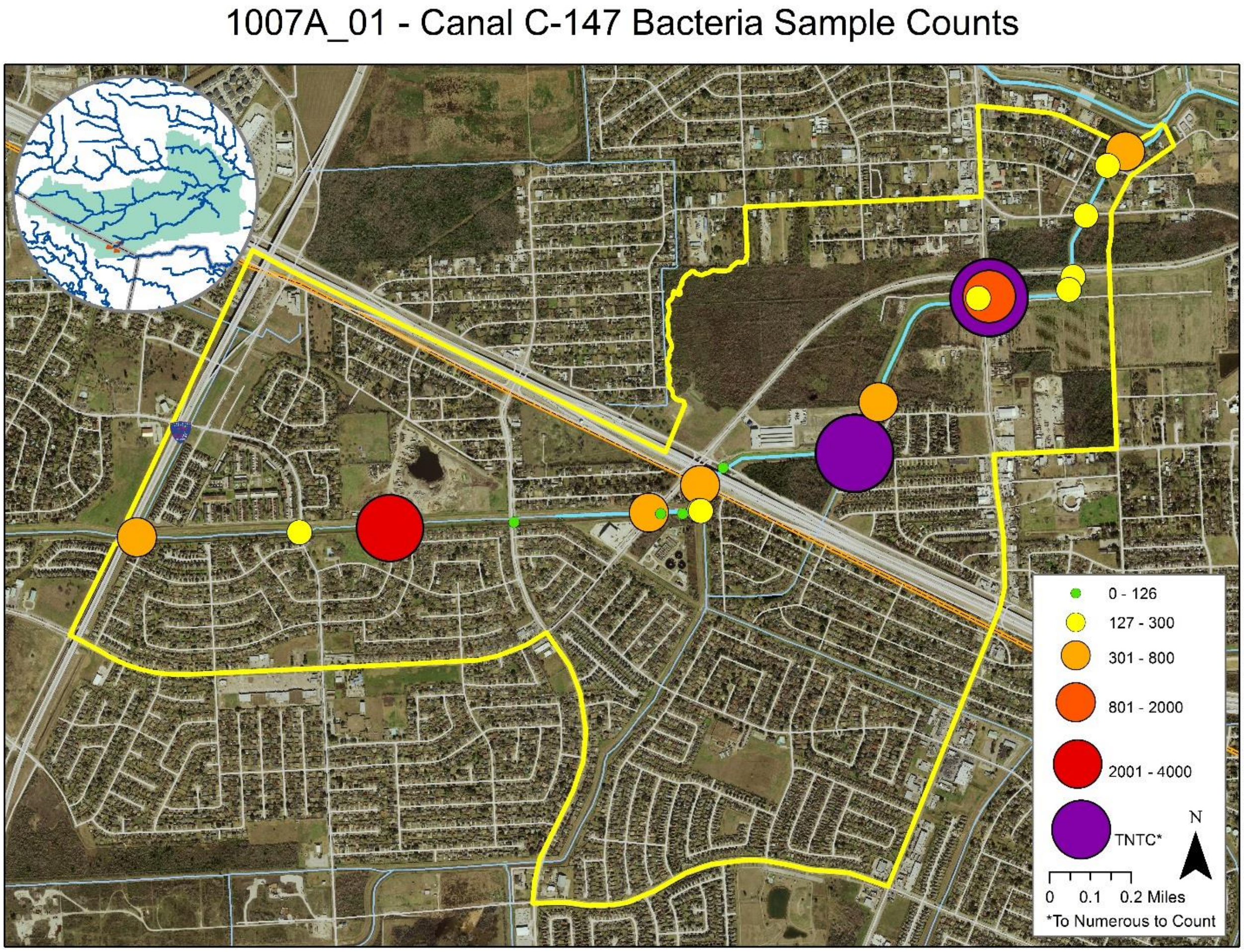


Figure 45. Bacteria screening results for Canal C-147 survey

5.1.3 Significant Finding

Table 5 lists all significant findings that require further investigation and follow up sampling. The average *E.coli* count for Canal C-147 bacteria screening was approximately 443 cfu/100mL which is likely a slight underestimation because about 10 percent of the samples were TNTC and were not incorporated into the overall average for the waterway. Samples collected with *E.coli* counts greater than 500 cfu/100mL were flagged as problem areas where further investigation is recommended. One outfall sample collected had no bacteria colony forming units detected during analysis. Further investigation is recommended for the non-detect sample to identify potential chlorine leaks or illicit discharges with high anti-bacterial agents.

Noteworthy findings include the high bacteria loading from an outfall (sample 008) directly downstream of the CRP monitoring station off Tiffany Drive (Figure 46). Discharges from this outfall would not be captured in routine CRP monitoring due to its location. Two large concrete storm drains directly downstream of the South Post Oak Road bridge (Figure 47-48) had high *E.coli* concentrations (samples 013 and 014). Another high bacteria source discharging into the canal was a small tributary north of Beltway 8, sample 021 (Figure 49).

Table 5. Summary of bacteria results and significant findings for Canal C-147

No.	Tier II ID	Tier II Type	Outfall Flow	Sample ID	Sample Type	*E. coli (cfu/100ml)*	Issue	Date Identified	Further Investigation	Latitude	Longitude
1	N/A	Outfall	Present	008	Outfall	800	High Bacteria	6/30/2016	Yes	29.61648	-95.45901
2	N/A	N/A	N/A	009	Surface Water	230	N/A	6/30/2016	No	29.61599	-95.45975
3	N/A	N/A	N/A	010	Surface Water	290	N/A	6/30/2016	No	29.61424	-95.46069
4	N/A	N/A	N/A	011	Surface Water	200	N/A	6/30/2016	No	29.61206	-95.46129
5	N/A	Tributary	Present	012	Surface Water	180	N/A	6/30/2016	No	29.61161	-95.46149
6	N/A	Outfall	Present	013	Outfall	TNTC	High Bacteria	6/30/2016	Yes	29.61142	-95.46475
7	N/A	Outfall	Present	014	Outfall	1770	High Bacteria	6/30/2016	Yes	29.61145	-95.46475
8	N/A	N/A	N/A	015	Surface Water	190	N/A	6/30/2016	No	29.61140	-95.46519
9	N/A	N/A	N/A	016	Surface Water	510	High Bacteria	6/30/2016	Yes	29.60781	-95.46939
10	N/A	Tributary	Present	017	Surface Water	TNTC	High Bacteria	6/30/2016	Yes	29.60601	-95.47043
11	N/A	Outfall	Present	018	Outfall	40	N/A	6/30/2016	No	29.60564	-95.47581
12	N/A	N/A	N/A	020	Surface Water	320	N/A	6/30/2016	No	29.60504	-95.47677
13	N/A	Tributary	Present	021	Surface Water	190	N/A	6/30/2016	No	29.60412	-95.47678
14	N/A	N/A	N/A	022	Surface Water	230	N/A	6/30/2016	No	29.60413	-95.47684
15	N/A	Outfall	Present	023	Outfall	50	N/A	6/30/2016	No	29.60404	-95.47752
16	N/A	Outfall	Present	024	Outfall	10	N/A	6/30/2016	No	29.60406	-95.47842
17	N/A	N/A	N/A	025	Surface Water	530	High Bacteria	6/30/2016	Yes	29.60412	-95.47890
18	N/A	Outfall	Present	026	Outfall	0	No Bacteria	6/30/2016	Yes	29.60392	-95.48441
19	N/A	Outfall	Present	027	Outfall	2130	High Bacteria	6/30/2016	Yes	29.60384	-95.48948
20	N/A	N/A	N/A	029	Surface Water	230	N/A	6/30/2016	No	29.60379	-95.49318
21	N/A	N/A	N/A	030	Surface Water	520	High Bacteria	6/30/2016	Yes	29.60378	-95.49982

Figure 46. Outfall with dry weather discharge downstream of CRP monitoring station (sample 008)

Figures 45 and 46. Storm drains downstream of the S. Post Oak Road bridge (samples 013 and 014)

Figure 47. Tributary north of Beltway 8 with high bacteria concentration (sample 021)

5.2 Upper Panther Branch

Upper Panther Branch, Segment 1008B_02, is one of the least impaired water bodies within the BIG geographic area. It is close to meeting state water quality standards for bacteria, with an *E.coli* geometric mean concentration of 133 MPN/100mL compared to the 126 MPN/100mL standard. The segment length is approximately 2.21 miles with a catchment area of 2.01 square miles. There are two active CRP monitoring stations: station 16632on Upper Panther Branch at Gosling Road; and station 16630 directly downstream of the WWTF. Primary LU/LC identified during Desk Review 2 is residential. Designated uses for this segment include Aquatic Life Use, Fish Consumption Use, General Use, and Recreation Use. Potential bacteria sources identified during Desk Review 2 include the WWTF off Research Forest Drive north of Gosling Road and a residential neighborhood east of Gosling with a concentration of OSSFs (Figure 48).

Statistical analysis of Upper Panther Branch data revealed a significant decrease in bacteria geometric mean concentrations in recent years (Figure 49). However, *E.coli* concentrations exceeding the 126 MPN/100mL standard are still frequent (Figure 50). No LDC graphs were generated for Upper Panther Branch because flow data from USGS was unavailable for this segment. Bacteria versus days since last rain graphs for this segment show few instances where data points exceed the state water quality standard for bacteria after 10 or more days of no rain, with the majority of high bacteria concentrations occurring immediately after significant rain events (Figure 51).

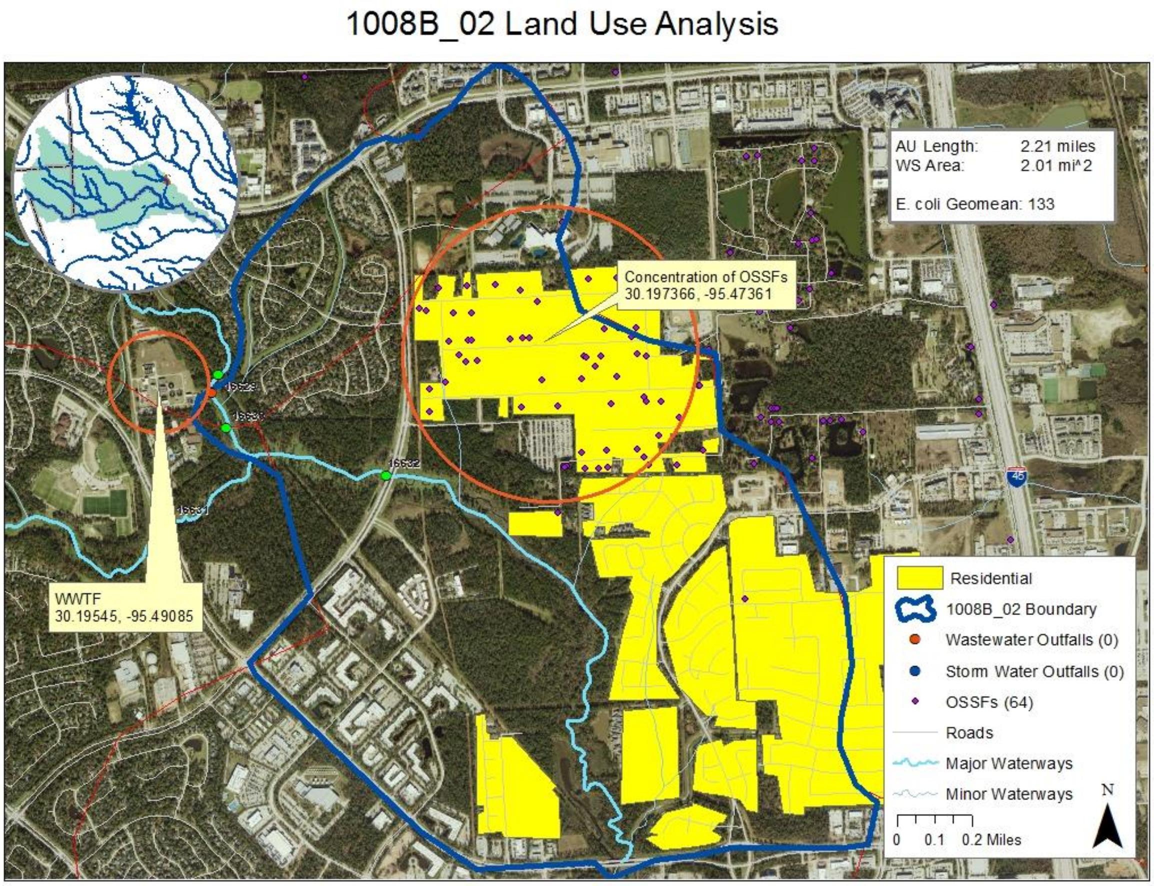


Figure 48. Desk Review 2 map for Upper Panther Branch, Segment 1008B_02

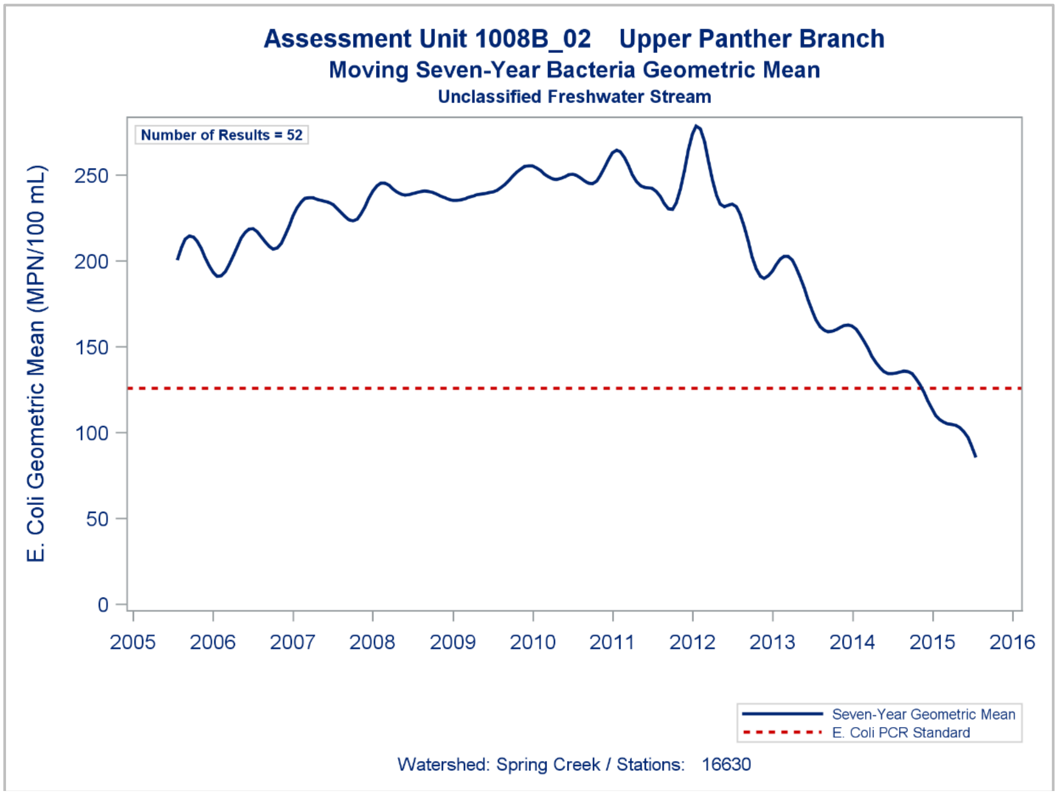


Figure 49. Moving seven-year E.coli geometric mean plot for Upper Panther Branch

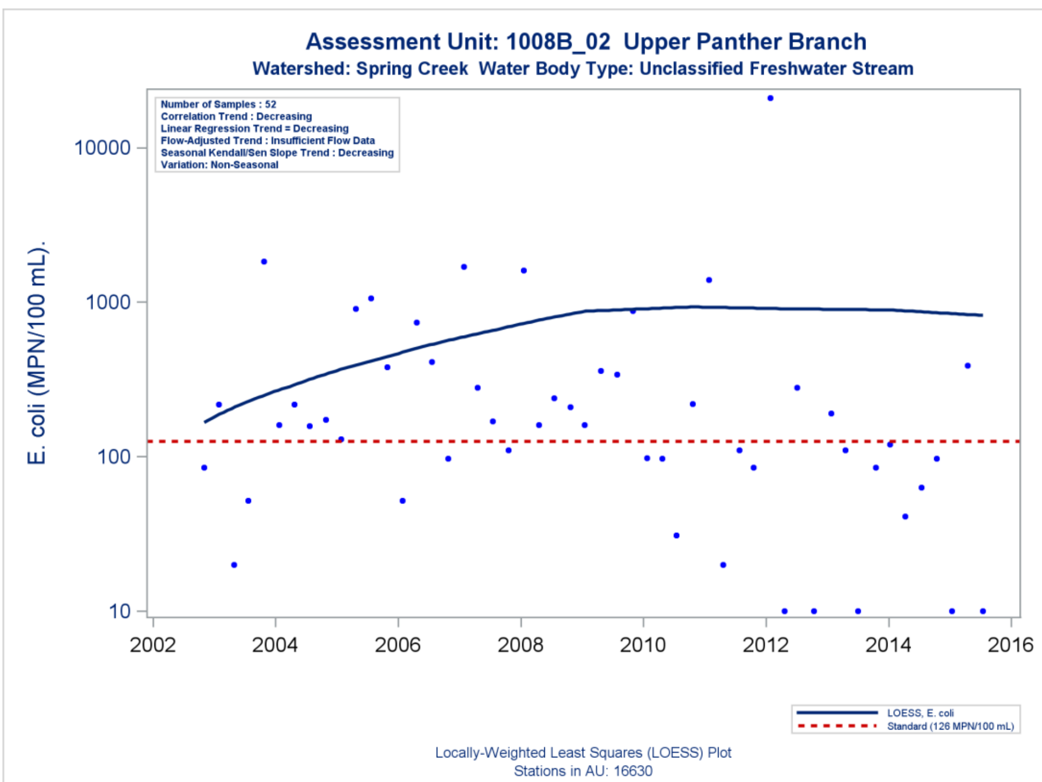


Figure 50. E.coli trend analysis for Upper Panther Branch

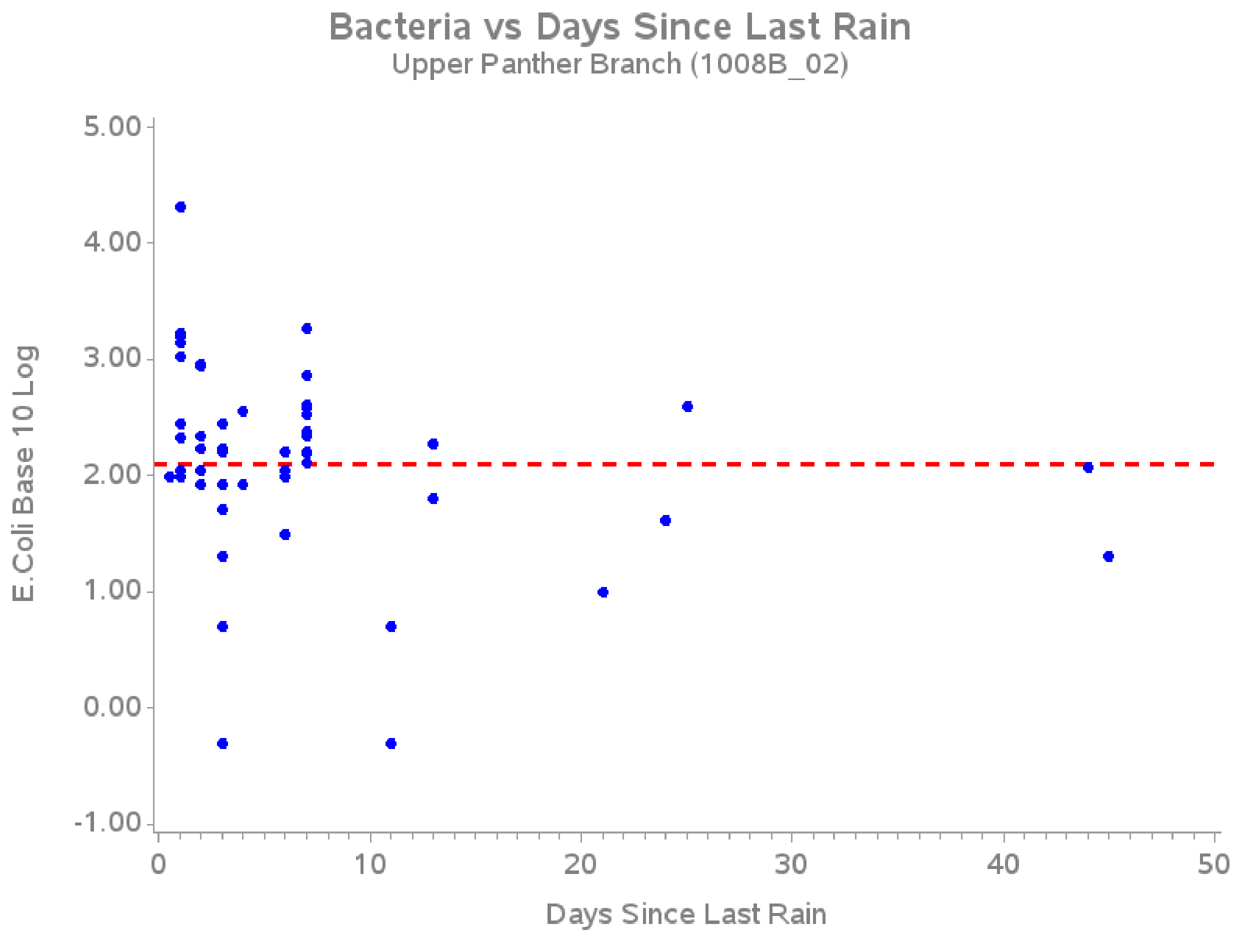


Figure 51. Bacteria versus days since last rain graph for Canal C-147. Red dotted line represents the water quality standard for E.coli

5.2.1 Windshield Survey

The windshield survey for Upper Panther Branch was on June 21, 2016. The waterway was investigated by vehicle, and points of access and potential pollution sources were noted. Primary land use is residential throughout the catchment area, with light commercial land uses present mainly along Research Forest Drive. Access points were difficult to locate by vehicle and would require a short trek through neighborhoods or hiking trails to reach the waterway (Figure 52). There were no potential bacteria sources observed during the windshield survey. Refer to Figure F1 in Appendix F for a map of the windshield survey route.

Figure 52. Hiking trail leading to Upper Panther Branch

5.2.2 Bacteria Screening
A total of 15 bacteria screening samples were collected along Upper Panther Branch during the on-the-ground survey on July 26 and 27, 2016. Samples were collected at nine discharging stormwater drainage tributaries and one discharging outfall, while the rest of the samples were surface water samples collected in an effort to track bacteria sources back to their origin.

Samples were analyzed using the Coliscan Easygel method to test for *E.coli* concentrations. Two dilutions were measured for each sample, and the average concentration is reported in Table 6. Refer to Figure 53 for a station map illustrating the location and sample type for each sample collected during the Upper Panther Branch survey, and to Figure 54 for a map illustrating the bacteria results for each sample collected. Additional information about sample locations and descriptions can be found in Table F1 in Appendix F.

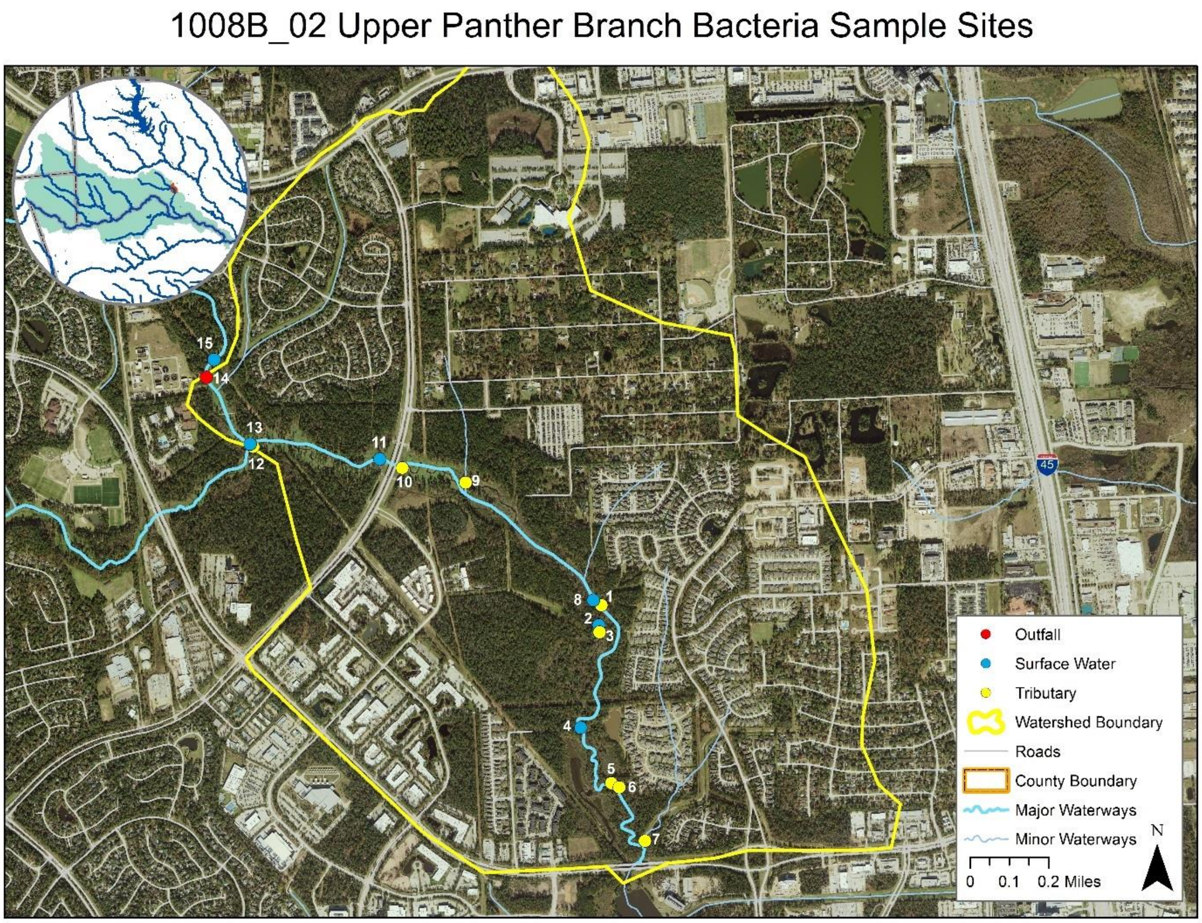


Figure 53. Station map for Upper Panther Branch survey July 26 and 27, 2016

1008B_02 Upper Panther Branch Bacteria Counts

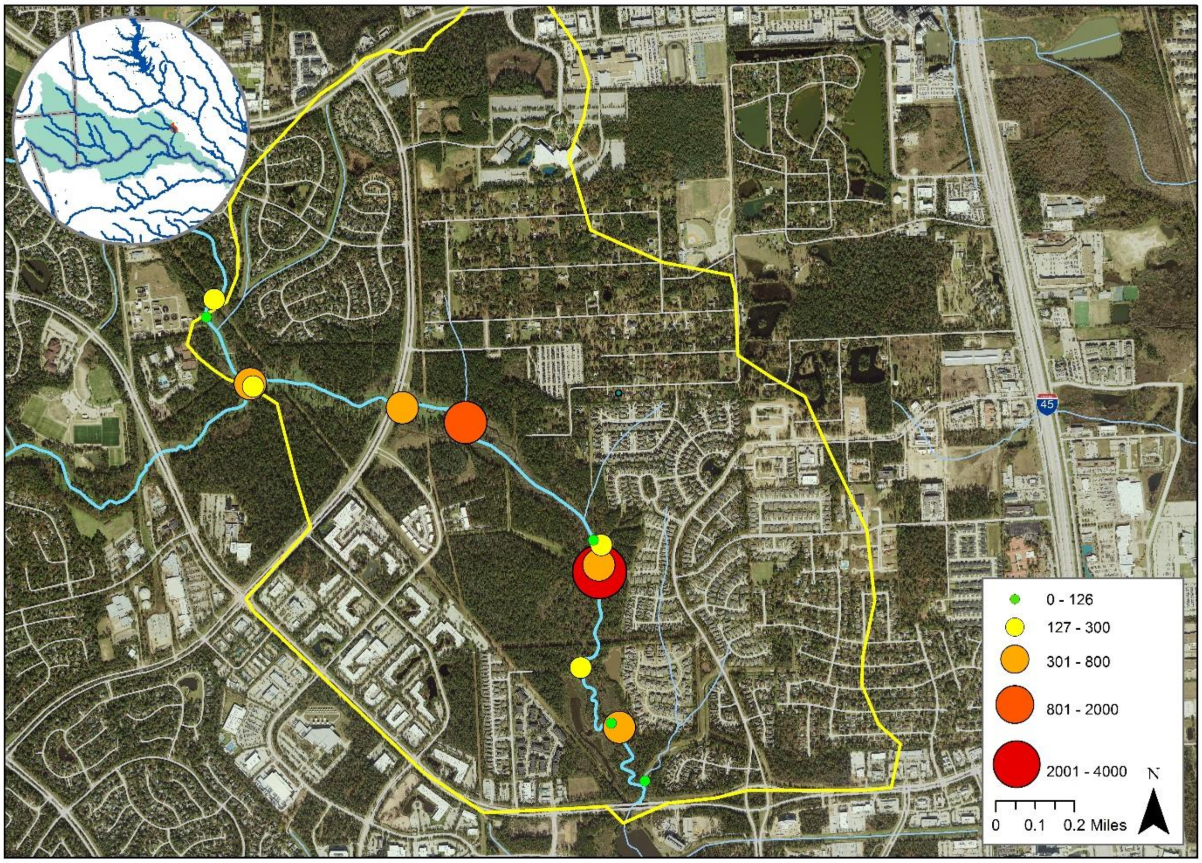


Figure 54. Bacteria screening results for Upper Panther Branch surveys

5.1.3 Significant Findings

The most significant observation recorded during the Upper Panther Branch surveys was the strong odor and presence of chlorine throughout the waterway. Chlorine test strips were used at the majority of sample locations to detect estimated chlorine levels. All chlorine test strips tested positive for chlorine with *at least* 1.0 mg/L present for every sample tested (Figure 55). Many of the stormwater drainage tributaries had lower levels of chlorine and higher bacteria concentrations compared to the main stem of Upper Panther Branch. Further investigation is recommended in order to identify where the chlorine was originating.

Figure 55. Chlorine test strip result for Upper Panther Branch sample 004

Table 6 lists all significant findings that require further investigation and follow-up sampling. The average *E.coli* count for Upper Panther Branch bacteria screening was approximately 496 cfu/100mL. Samples collected with *E.coli* counts greater than 500 cfu/100mL were flagged as problem areas where further investigation is recommended.

Noteworthy findings include the high bacteria loading from a stormwater drainage tributary (Tier II ID 065) originating from the subdivision off Grogans Mill Road (Figure 56). Homeowners were seen walking their dogs along the drainage tributaries in this area, making pet waste a potential contributor of bacteria at this location. Another stormwater drainage tributary (Tier II ID 072, sample 009) coming from the sporting facility on Marisco Place had high *E.coli* concentrations, l with the water sample having a strong petrochemical smell likely from surface runoff from the adjacent parking lot (Figure 57). Several of the tributaries feeding into Upper Panther Branch had a very distinct reddish tint (Figures 58-60). It was unclear if this was a result of impacts from different soil types or if there were other factors. However, there did not seem to be a correlation between bacteria concentration and red water at these sample locations.

Figure 56. Stormwater drainage tributary with high bacteria concentration (Tier II ID 065, sample 003)

Figure 57. Stormwater drainage tributary with high bacteria concentration (Tier II ID 072, sample 009)

Figures 58-60. Red tinted waters in the tributaries of Upper Panther Branch

Table 6. Summary of bacteria results and significant findings for Upper Panther Branch

No.	Tier II ID	Tier II Type	Outfall Flow	Sample ID	Sample Type	*E. coli (cfu/100ml)*	Issue	Date Identified	Further Investigation	Latitude	Longitude
1	062	Tributary	Present	001	Surface Water	170	N/A	7/26/2016	No	30.18642	-95.47234
2	063	Tributary	Present	002	Surface Water	310	N/A	7/26/2016	No	30.18568	-95.47247
3	065	Tributary	Present	003	Surface Water	3420	High Bacteria	7/26/2016	Yes	30.18542	-95.47245
4	067	N/A	N/A	004	Surface Water	140	N/A	7/26/2016	No	30.18191	-95.47338
5	068	Tributary	Present	005	Surface Water	100	N/A	7/26/2016	No	30.17983	-95.47214
6	069	Tributary	Present	006	Surface Water	580	High Bacteria	7/26/2016	Yes	30.17966	-95.47181
7	070	Tributary	Present	007	Surface Water	60	N/A	7/26/2016	No	30.17765	-95.47079
8	071	N/A	N/A	008	Surface Water	50	N/A	7/26/2016	No	30.18661	-95.47267
9	072	Tributary	Present	009	Surface Water	1040	High Bacteria	7/27/2016	Yes	30.19110	-95.47796
10	073	Tributary	Present	010	Surface Water	390	N/A	7/27/2016	No	30.19172	-95.48064
11	N/A	N/A	N/A	011	Surface Water	230	N/A	7/27/2016	No	30.19200	-95.48200
12	074	Tributary	Present	012	Surface Water	270	N/A	7/27/2016	No	30.19266	-95.48696
13	N/A	N/A	N/A	013	Surface Water	400	N/A	7/27/2016	No	30.19277	-95.48708
14	075	Outfall	Present	014	Outfall	20	N/A	7/27/2016	No	30.19528	-95.48886
15	N/A	N/A	N/A	015	Surface Water	260	N/A	7/27/2016	No	30.19593	-95.48851

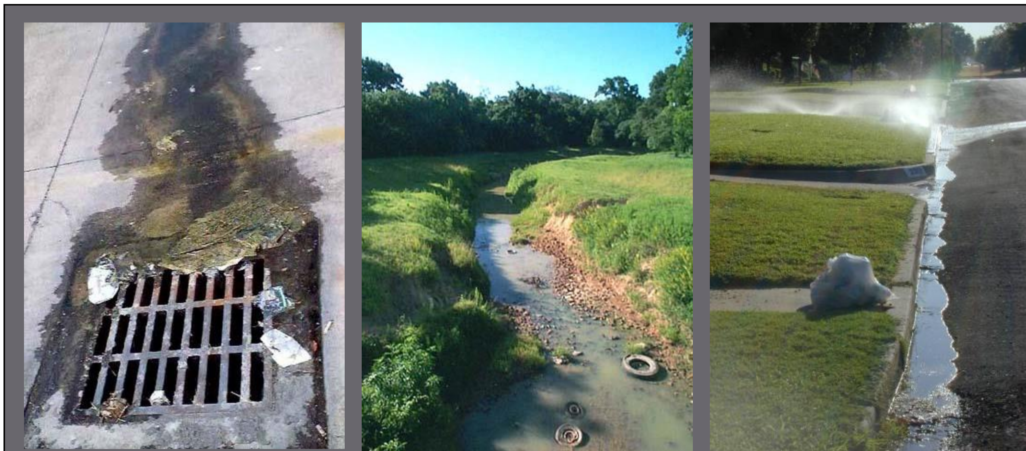
6.0 Conclusion

The *BIG's Top Five Most and Top Five Least Impaired Water Bodies* project was developed in an effort to demonstrate the value of a prioritized watershed approach for correcting bacteria sources in impaired water bodies within the BIG geographic area. The project began with a Top 10/Least 10 list of bacteria impaired water bodies developed by the BIG that was then prioritized and pared down to the Top 2/Least 2 lists through desk reviews and input from a technical workgroup. The resulting list of four AUs were then subject to further assessment and field investigation in order to identify potential bacteria sources. This Preliminary Action Report summarizes tasks completed during the first phase of the project, including Desk Review 1, Desk Review 2, windshield surveys, and field investigations for bacteria screening.

6.1. Next Steps

Phase II of the project will include professional water quality monitoring at the locations found to have high bacteria concentrations during the screening in Phase I. This report will help prioritize problem areas so Phase II investigations can be more focused to areas that present significant concerns. H-GAC staff will meet with the technical workgroup and local jurisdictions to discuss Phase I findings and plan where to focus efforts for the next phase of the project. Phase II sample results will then be reported to the appropriate jurisdictions for further investigation and implementation of corrective actions to reduce bacteria loadings into the surveyed AUs. Phase III of the project will include follow-up monitoring at locations where corrective actions were implemented to investigate the effectiveness of bacteria reduction practices.

Appendix A: Desk Review 1 Materials



TOP FIVE MOST AND TOP FIVE LEAST IMPAIRED WATER BODIES

Workgroup Meeting
April 20, 2016

Project Overview

- Phase I
  - Desk Review 1
  - Desk Review 2
  - AU Intensive Study
- Phase II
  - Sample Collection Decision
  - Sample Collection
- Phase III
  - Elevated Bacteria
  - Agency Action Report
  - Follow-up Monitoring
  - Analysis

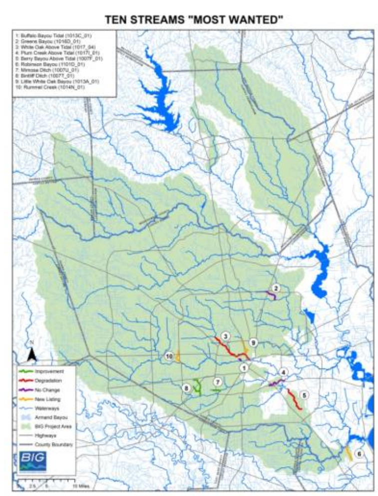
Phase I: Desk Review 1

- Review and analyze top 10 most wanted list
  - AU Spreadsheet
  - GIS Aerial Image Review

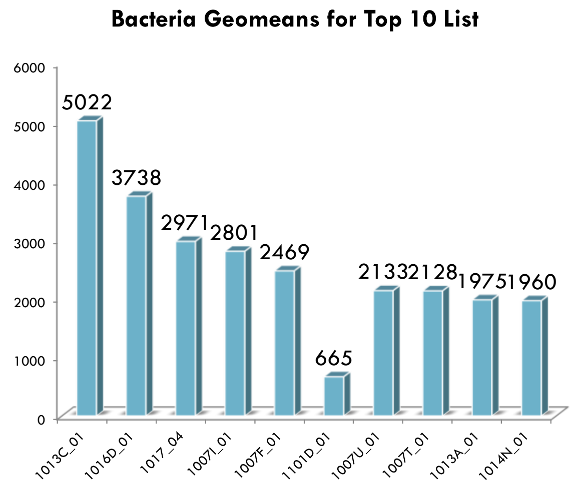
- Top 10 lists pared down to create preferential Top 5/Least 5 lists
  - BIG I-Plan Geographic Priority Framework:
    - Bacteria Level
    - Accessibility
    - Use Level
    - Implementation Opportunities
    - Future Land Use Changes

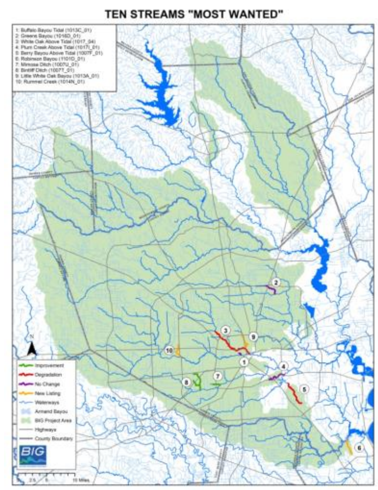
Top 10 Most Wanted

Rank	Assessment Unit	Use Level
1	Buffalo Bayou Tidal (1013C_01)	ALU; GU; RU
2	Greens Bayou (1016D_01)	ALU; GU; RU
3	White Oak Above Tidal (1017_04)	ALU; GU; RU
4	Plum Creek Above Tidal (1007I_01)	ALU; GU; RU
5	Berry Bayou Above Tidal (1007F_01)	ALU; GU; RU
6	Robinson Bayou (1101D_01)	ALU; GU; RU
7	Mimosa Ditch (1007U_01)	ALU; GU; RU
8	Bintliff Ditch (1007T_01)	ALU; GU; RU
9	Little White Oak Bayou (1013A_01)	ALU; GU; RU
10	Rummel Creek (1014N_01)	ALU; GU; RU

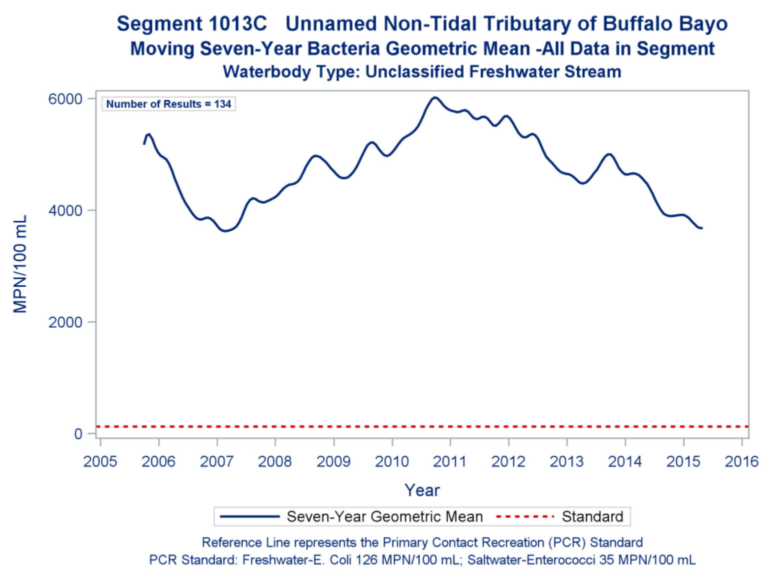


Top 10 Most Wanted



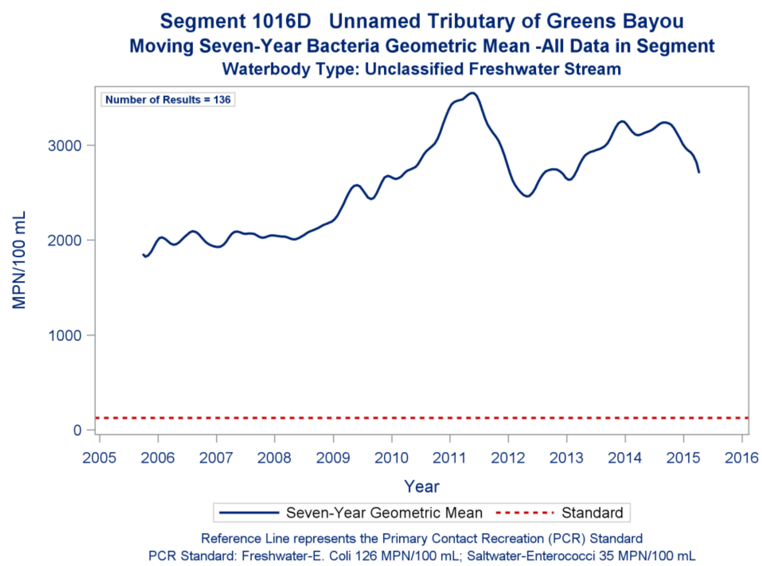


1. Buffalo Bayou Tidal



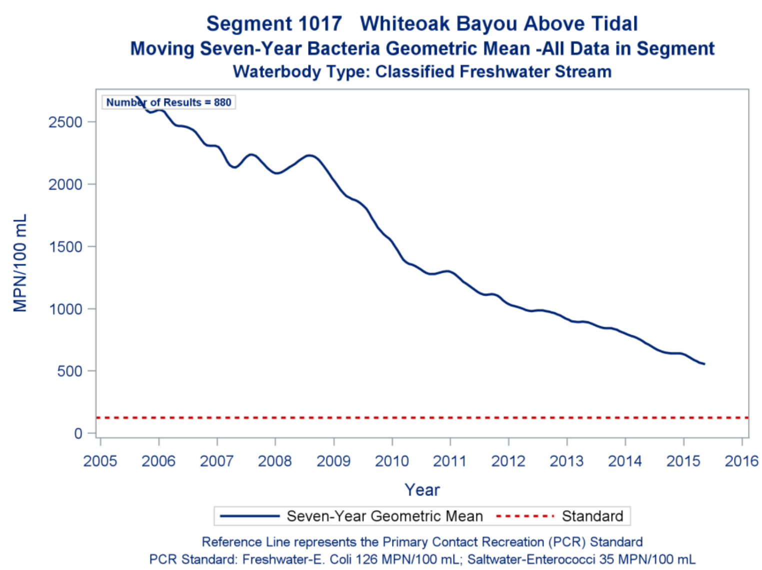
MOST WANTED

2. Greens Bayou

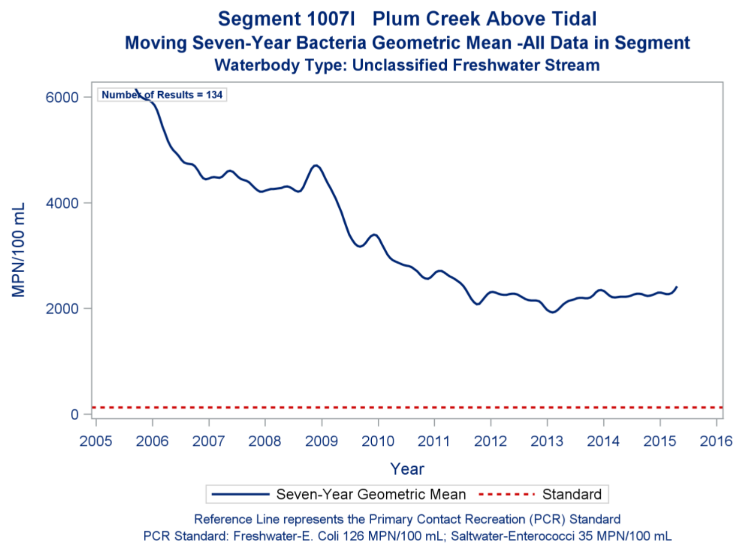


MOST WANTED

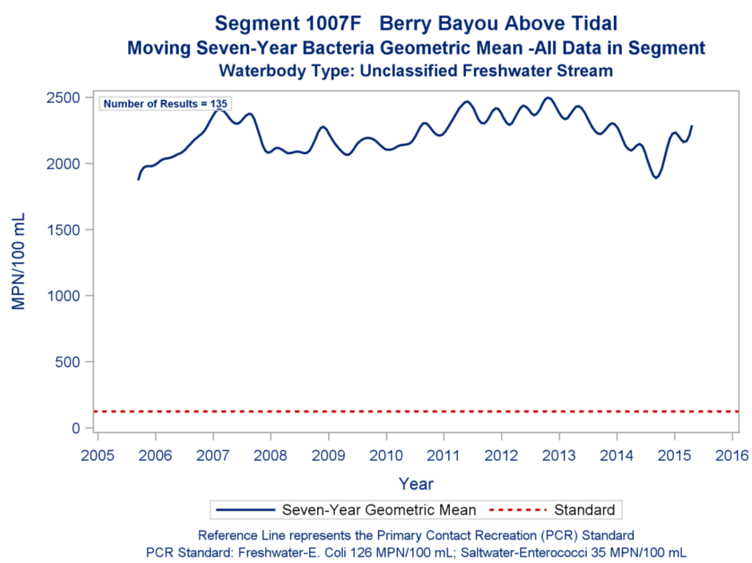
3. White Oak



4. Plum Creek Above Tidal

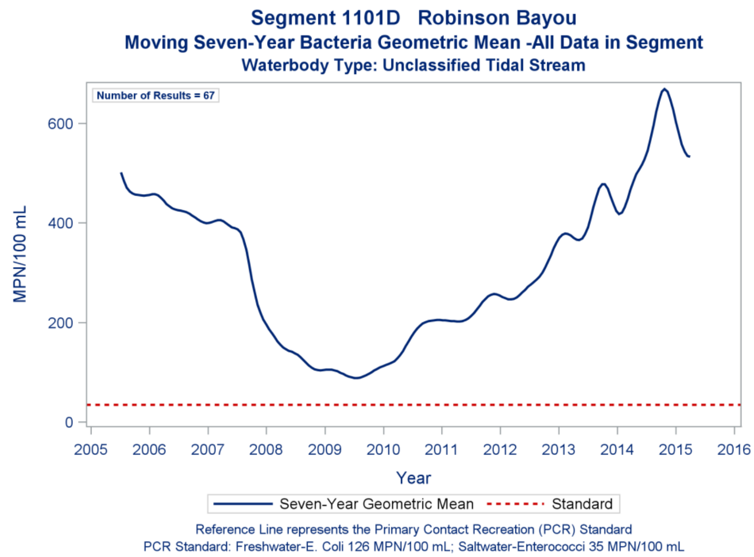


5. Berry Bayou Above Tidal



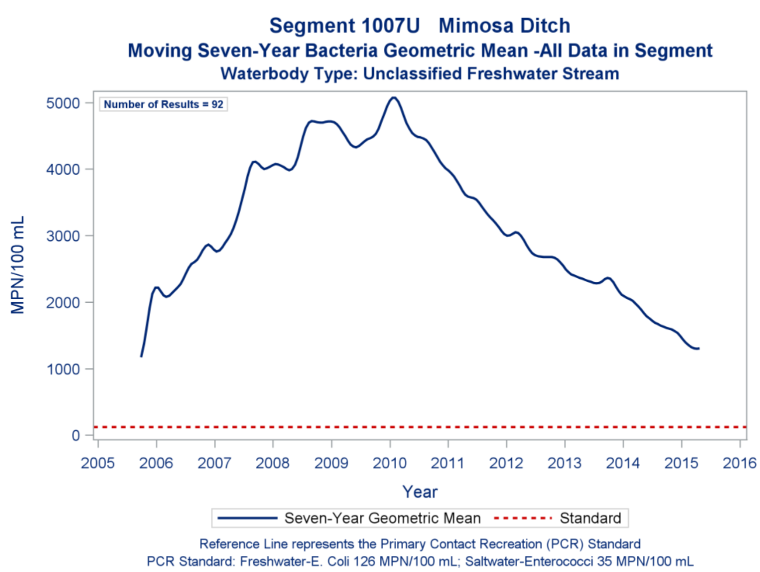
MOST WANTED

6. Robinson Bayou

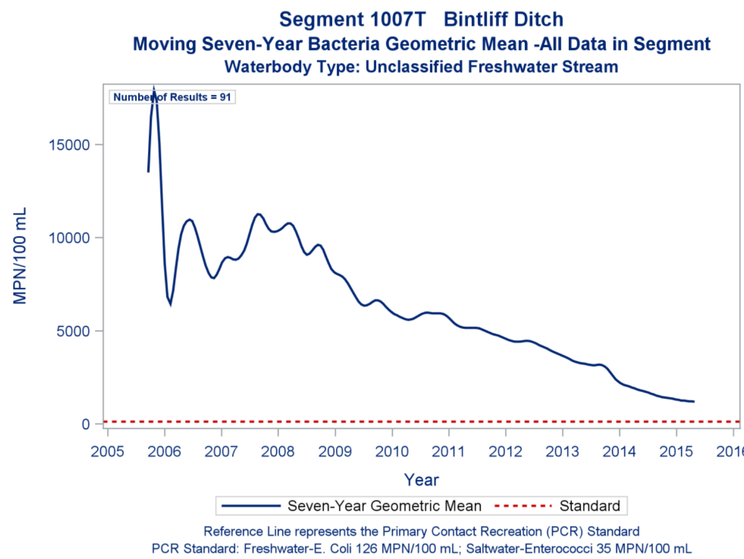


MOST WANTED

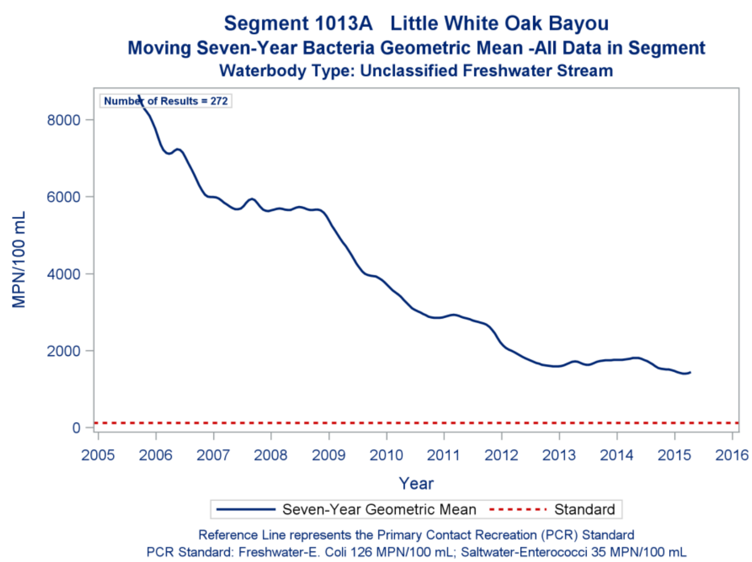
7. Mimosa Ditch



8. Bintliff Ditch

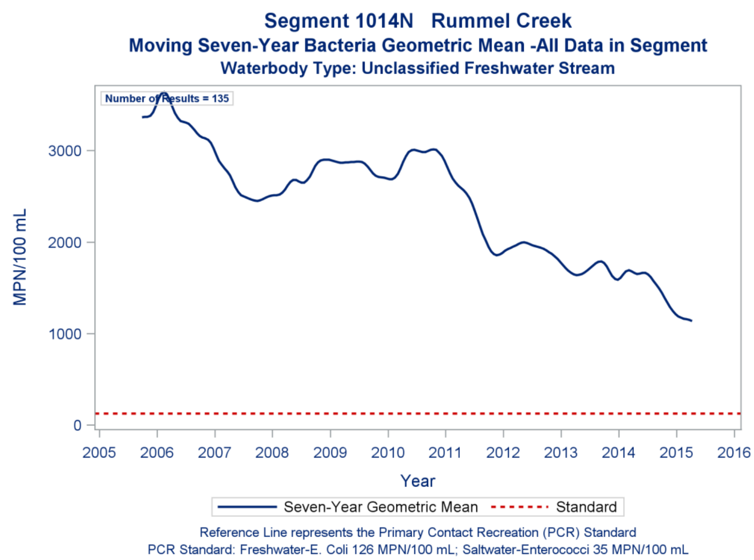


9. Little White Oak Bayou



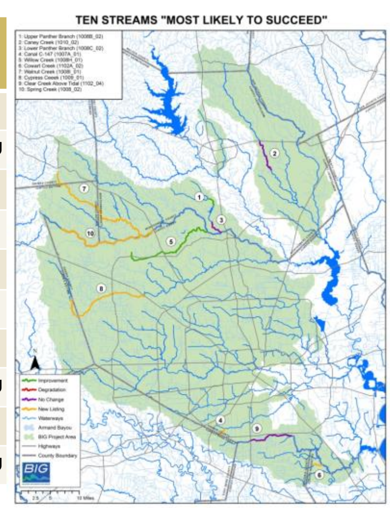
MOST WANTED

10. Rummel Creek

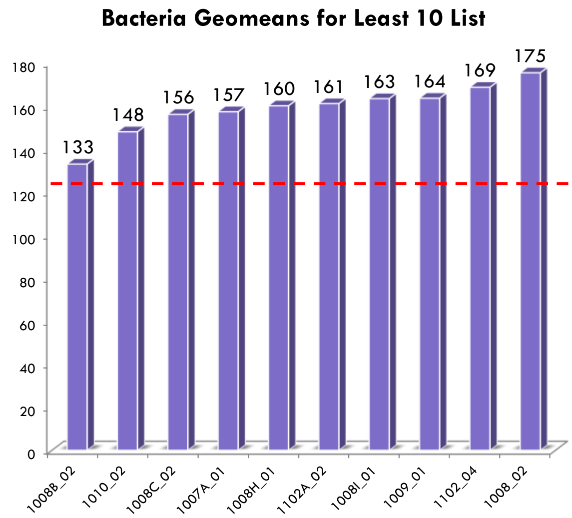


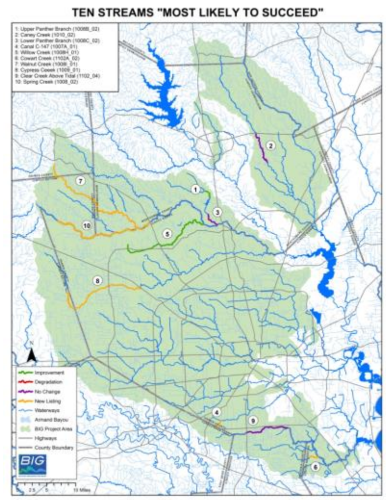
Top 10 Most Likely to Succeed

Rank	Assessment Unit	Use Level
1	Upper Panther Branch (1008B_02)	ALU; FCU; GU; RU
2	Caney Creek (1010_02)	ALU; GU; PWSU; RU
3	Lower Panther Branch (1008C_02)	ALU; FCU; GU; RU
4	Canal C-147 (1007A_01)	ALU; GU; RU
5	Willow Creek (1008H_01)	ALU; GU; RU
6	Cowart Creek (1102A_02)	ALU; GU; RU
7	Walnut Creek (1108I_01)	ALU; GU; RU
8	Cypress Creek (1009_01)	ALU; GU; PWSU; RU
9	Clear Creek Above Tidal (1102_04)	ALU; FCU; GU; RU
10	Spring Creek (1008_02)	ALU; GU; PWSU; RU

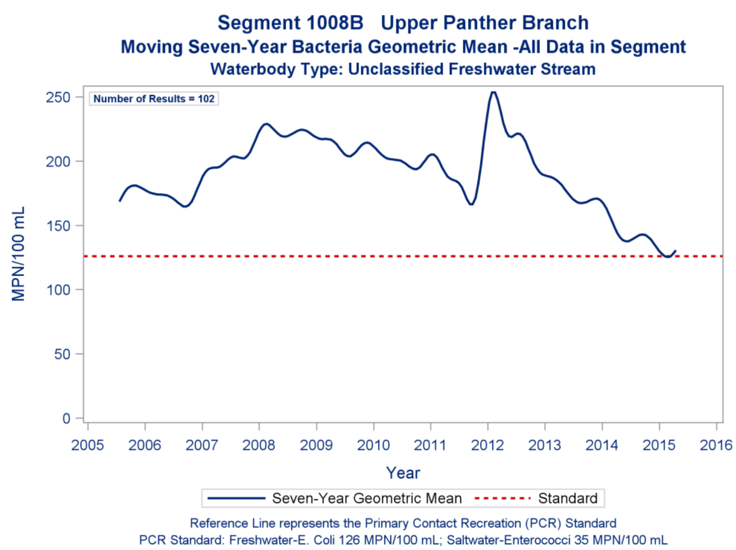


Top 10 Most Likely to Succeed

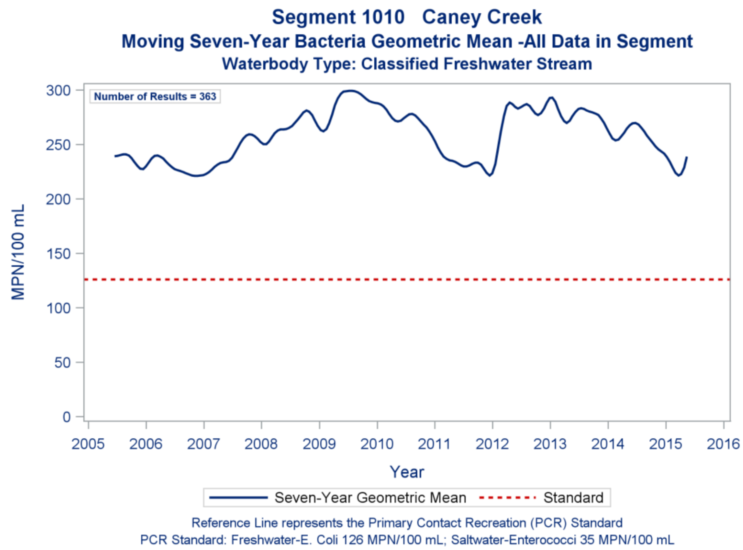




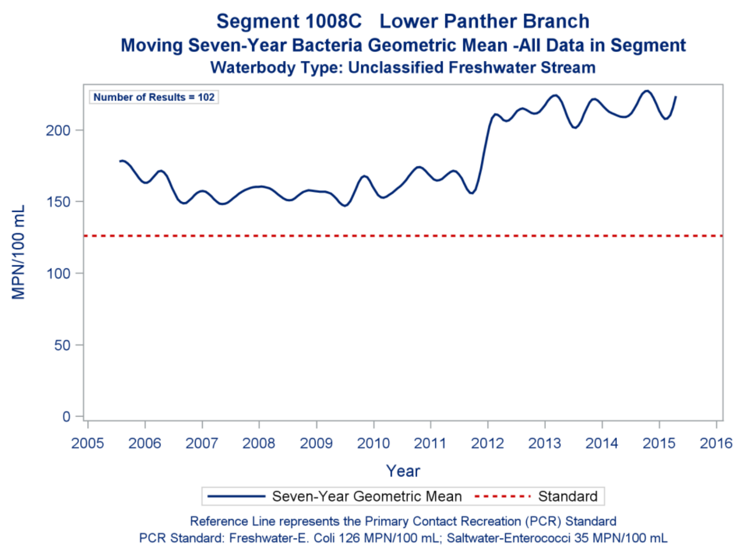
1. Upper Panther Branch



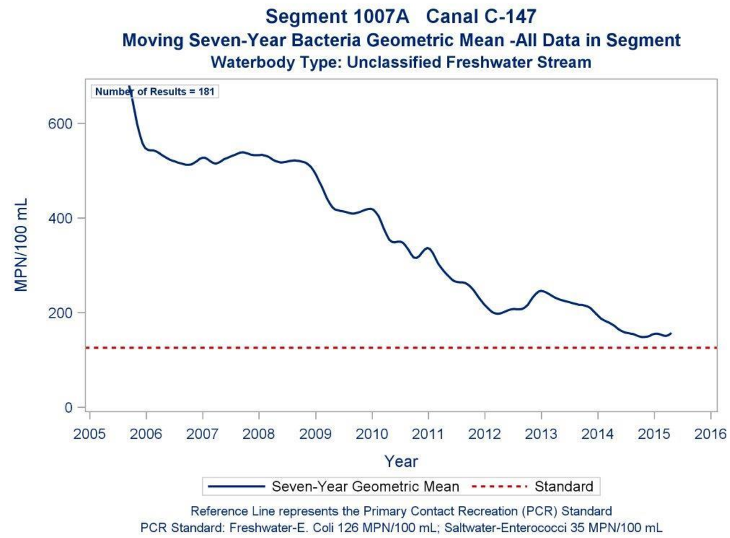
2. Caney Creek



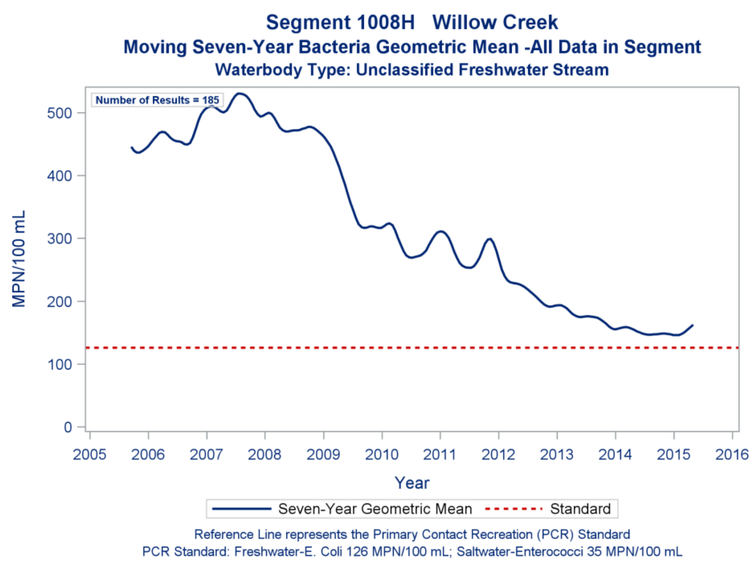
3. Lower Panther Branch



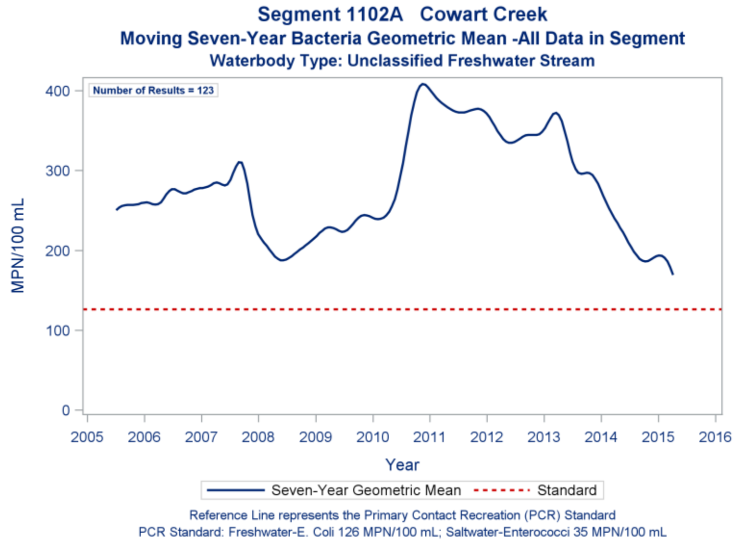
4. Canal C-147



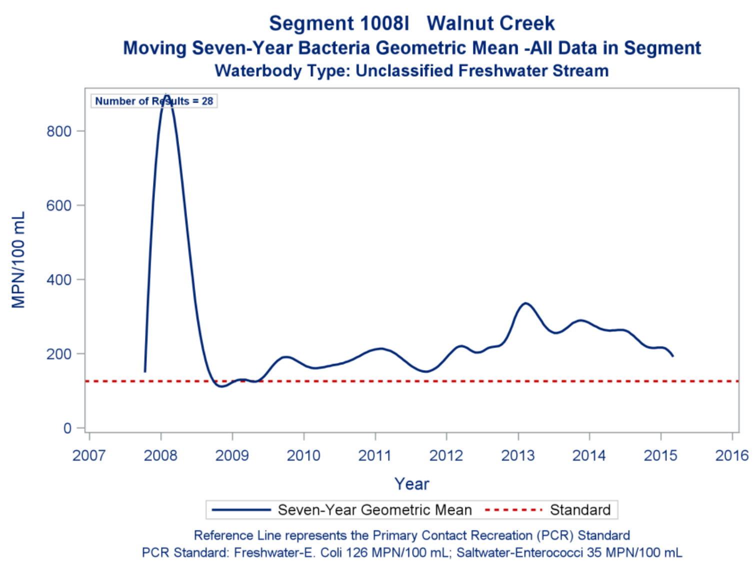
5. Willow Creek



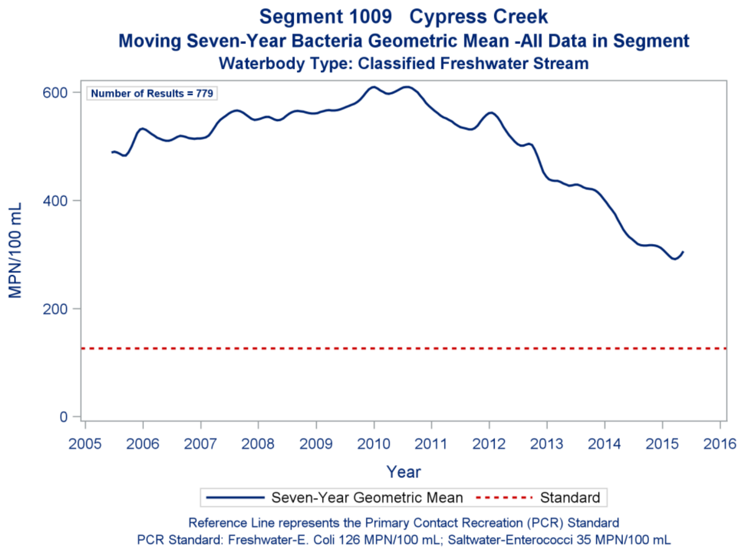
6. Cowart Creek



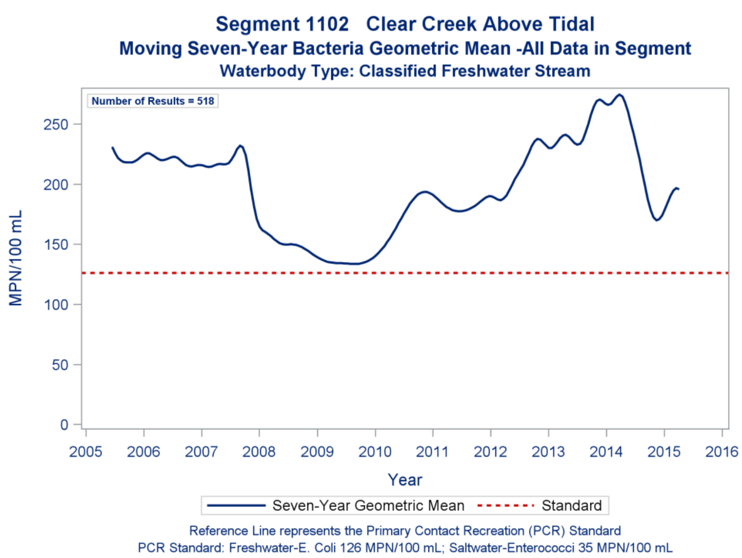
7. Walnut Creek



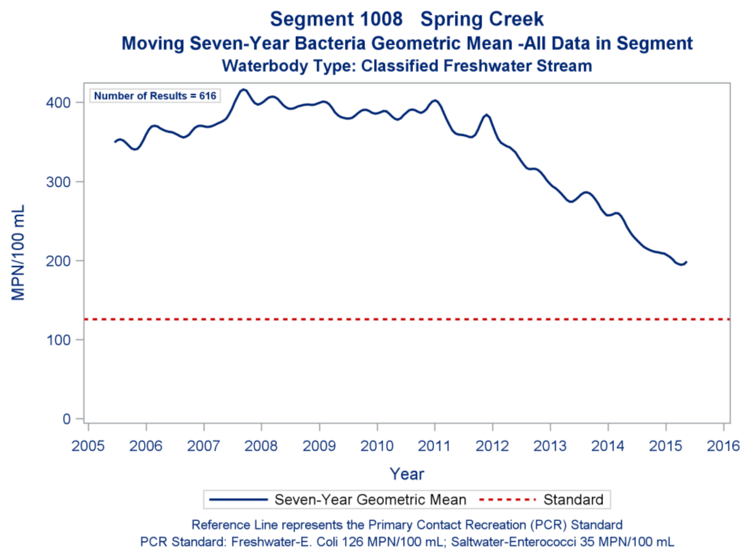
8. Cypress Creek



9. Clear Creek Above Tidal



10. Spring Creek



Next Steps

- **Phase I completion by June 30th, 2016**
  - Review 1 ~ April, 2016
  - Review 2 ~ May, 2016
  - AU Intensive Study ~ June, 2016
- **Phase II completion by October 31st, 2016**
  - Sample Collection & NELAP Testing ~ July - Aug, 2016
  - Data Analysis & Source ID ~ Sep - Oct, 2016
- **Phase III completion by April 30th, 2017**
  - Reporting to Local Authorities ~ Nov 2016 – Jan, 2017
  - Follow up monitoring ~ Feb – March, 2017
  - Final data analysis ~ April, 2017

Top 5 / Least 5 Workgroup Meeting Notes

Wednesday, April 20, 2016

1:00 PM to 3:00 PM
H-GAC Conference Room D
3555 Timmons Lane, 2nd Floor

1. Introductions

Paniz began the meeting at approximately 1:05 PM. Paniz welcomed and thanked everyone for coming and initiated self-introductions.
Persons in Attendance:
Paniz Miesen – H-GAC
William Merrell – H-GAC
Becki Begley – H-GAC
Rachel Fields – H-GAC
Steven Johnston – H-GAC
Lisa Marshall – GBEP
Robert Snoza – HCFCD
Steve Hupp – Bayou Preservation
Lisa Groves – City of Houston

Persons on Conference Line:
Denis Hall – Harris County Pollution Control

2. Project Overview

Paniz briefly reviewed the project flow chart with the group. Project is split into three phases.

- Phase I includes two desktop reviews and initial groundtruthing of chosen assessment units (AUs).
- Phase II includes sample collection, NELAP testing, and analysis of data.
- Phase III includes working with local jurisdictions to implement bacteria reduction measures and conduct follow-up sampling.

This meeting was held to satisfy Review 1 tasks associated with Phase I of the project: *Reduce the Top 10 Most Wanted and Top 10 Most Likely to Succeed AU list to Top 5 Most Wanted and Top 5 Most Likely To Succeed.*

3. Review of Top 10 Most Wanted AUs

The workgroup reviewed subwatershed maps and moving bacteria geometric mean plots for each AU on the Top 10 Most Wanted list and discussed important considerations and information pertinent to each AU.

1-Buffalo Bayou Tidal:

- Portions of this AU go underground creating some accessibility issues.
- This AU has been subject to assessment and special studies by the City of Houston and the Bayou Preservation Association.
- Area still seems to have many problems that are worth analyzing.
- Potential sources of pollution include leaking OSSFs.

2-Greens Bayou:

- Steve Hupp mentioned an unknown outfall location west of Hwy 59. Outfall permit exists, but actual outfall itself is hard to find.
- Apartment complexes in the area have been known to have wastewater problems.
- Lots of poison ivy.
- Possible OSSF issues north of the Beltway.
- Area known to have suspect dry weather flows.
- Slight sewage odor noticeable near sample locations.

3-White Oak:

- Noticeable sewage odor present in area around TC Jester and 11th.
- Larger homeless population in area.
- Something is going on in and around the underground portions of the AU, especially near the hospital, around Hwy 290, and near station 16596.
- City of Houston has assessed the area but hasn't found any significant bacteria point sources.
- Ammonia levels have been high but were linked to leaking A/C unit.
- Lots of new infrastructure around station 16595 may have improved bacteria conditions in recent years.
- Safety and accessibility issues were mentioned.

4-Plum Creek:

- High bacteria hits have been found in the ditch near the stadium south of the 610 Loop.
- Lift station upstream of sampling location may be faulty and a potential source of bacteria.
- Areas upstream and downstream of the YMCA have had high bacteria levels. SSOs have been common in this area.
- Shallow concrete channels are common.
- May run into accessibility issues on private properties.

5-Berry Bayou:

- Station 16661 has had higher bacteria hits compared to the other sampling stations in this AU – assessment should focus upstream of this station.
- There is a network of open ditches in this AU which may make accessibility a potential issue.
- Not much work has been done in this AU, making it a good candidate for further assessment.
- Old and rusty infrastructure/collection systems are common in area.
- Based on samples collected, upstream portion seems to have higher bacteria levels. No hits in southern portions.
- Concrete lining is common in most areas upstream, many of which are newly constructed or are currently under construction.
- Steve Hupp suggested reviewing the most recent data to see if rehab in the area has made any impact on the water quality.
- Good option for further assessment.

6-Robinson Bayou:

- Enterococcus is the indicator bacteria for this AU. Top 5 / Least 5 project will be focusing only on AUs where *E.coli* is the indicator bacteria.

7-Mimosa Ditch:

- City of Bellaire mentioned dog shelter upstream of the sample location as possible bacteria source. Further discussion revealed that the shelter is too small and far from the waterway to be a significant source.
- High dry weather flows at Rice are suspect.
- A lot of construction and infrastructure rehab in the area.
- City of Bellaire jurisdiction.
- Good option for further assessment.

8-Bintliff Ditch:

- City of Houston did a special study in this area a few years ago.
- Accessibility is an issue; chain link fences/gates and high vegetation on private property block access in many areas. Robert Snoza of HCFCD followed up with information regarding property rights and Fee ownerships. He does not believe HCFCD maintains this waterway and COH has had Fee ownership since 1960.
- Potential OSSF problems.
- Previous assessments by Bayou Preservation have found the area south of Hwy 59 and North of Bellaire are problem areas.
- Steve Hupp of Bayou Preservation has assessed the western branch and Carol LaBreche of COH has assessed the eastern branch – both are having bacteria problems.
- Good option for further assessment.

9-Little White Oak:

- City of Houston samples show station 11148 with highest bacteria levels compared to other stations in this AU.
- Fish kills have occurred upstream of station 11148.
- Lisa Groves mentioned the COH did a characterization 5-6 years ago and did not get significant bacteria hits.
- Steve Hupp has assessed the upstream portion and got no bacteria hits but did find high chlorine levels in surface water. Lisa Groves said they found leaking potable water in that area when they did their characterization which may have been the chlorine source.
- Lisa Groves also mentioned a lift station upstream of station 16648 with foul odor (Woodland Park area).
- Accessibility issues in some areas.
- Would be a very time intensive assessment due to the density of development and mixed use.
- Good option for further assessment.

10-Rummel Creek:

- Clean Rivers Program (CRP) partners mentioned wanting an additional monitoring station added on this AU during the CMM meeting on 4/12/16 due to concerns about potential pollution sources in areas where contact recreation is common.
- Area directly south of I-10 has seen issues including a fish kill last summer. Mulch yard and nursery nearby may be source of nutrients and bacteria to the waterway causing fish kills.
- Robert Snoza mentioned there are two pumped TXDOT detention basins in this area.
- Good option for further assessment.

4. Review of Top 10 Most Likely to Succeed AUs

The workgroup reviewed subwatershed maps and moving bacteria geometric mean plots for each AU on the Top 10 Most Likely to Succeed list and discussed important considerations and information pertinent to each AU.

1-Upper Panther Branch:

- San Jacinto River Authority does the monitoring for this AU.
- Wildlife is a likely contributor of bacteria in this AU.
- Steve Hupp mentioned this may be a good AU for source tracking.
- No one at the meeting has done much work in this area.
- Good option for further assessment.

2-Caney Creek:

- Rural watershed.
- Cattle grazing is common.
- Failing OSSFs may be a potential bacteria contributor.
- Drain field issues related to lot size present in the area.
- There is currently a WPP underway for this area. That may be a more fitting means of characterizing this AU.

3-Lower Panther Branch:

- San Jacinto River Authority does the monitoring for this AU.
- Increasing bacteria trends are likely related to increased development in the area.
- Feral hogs may be a potential source here.
- No one at the meeting has done much work in this area.
- Good option for further assessment.

4-Canal C-147:

- Flood control did work on detention basin improvements.
- Flea market and bull fighting in eastern portion of the watershed.
- Recently constructed wastewater treatment facility in the area. Would be interesting to compare before and after samples to see the impact.
- Not much work done in this AU by meeting attendees.
- Good option for further assessment.

5-Willow Creek:

- Lisa Groves of COH samples at station 11185.
- Wastewater treatment facility (WWTF) installed 10-11 years ago upstream of sample location.
- There are a lot of wastewater outfalls in this AU.
- May be a good area for regionalization of WWTFs.
- Good option for further assessment.

6-Cowart Creek:

- Environmental Institute of Houston (EIH) does the monitoring in this AU.
- May run into some accessibility issues (private properties).
- No one at meeting has done much work in this area.
- Good option for further assessment.

7-Walnut Creek:

- H-GAC staff has encountered an angry homeowner concerned about trespassing in the area when monitoring.
- There is currently a WPP underway for this area. That may be a more fitting means of characterizing this AU.

8-Cypress Creek:

- Upcoming development planned for the area.
- There has been some research done on overflow conditions in this AU.
- South of sample location is a large wetland mitigation area.
- Livestock is a likely bacteria contributor in this AU.
- Private properties may cause accessibility issues.
- Good option for further assessment.

9-Clear Creek Above Tidal:

- Environmental Institute of Houston (EIH) does the monitoring for this AU.
- There is a high variety of pollution sources in this area.
- Good option for further assessment.

10-Spring Creek:

- Covers a very large geographic area.
- Rural residential watershed.
- Bacteria geomeans have been gradually improving since 2012.

5. Next Steps:

Paniz reviewed the project timeline with the workgroup.

- Phase I completion by June 30th, 2016
- Phase II completion by October 31st, 2016
- Phase III completion by April 30th, 2017

There will be another workgroup meeting scheduled in May to discuss Phase I, Review 2 tasks: *Reducing the Top 5 / Least 5 list to the final Top 2 / Least 2 AUs.*

6. Adjourn

Paniz thanked the group again for attending. Meeting adjourned at 3:15 PM.

Appendix B: Desk Review 2 Materials



BIG'S TOP FIVE MOST & TOP FIVE LEAST IMPAIRED WATER BODIES

May 26, 2016

Workgroup Meeting

Project Overview

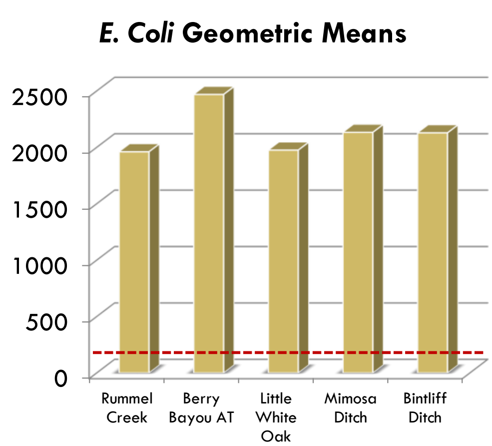
- **Phase I completion by June 30th, 2016**
  - Pare down Top 10 / Least 10 to Top 2 / Least 2
  - AU intensive study of Top 2 / Least 2
- **Phase II completion by October 31st, 2016**
  - Sample collection & NELAP testing
  - Data analysis and source identification
- **Phase III completion by April 30th, 2017**
  - Report to local authorities and work with local jurisdictions to implement bacteria reduction measures
  - Follow up monitoring and data analysis

Phase I: Review 2

- Review Top 5 Most Wanted AUs
  - Moving seven-year bacteria geomeans
  - Trend analysis
  - LDCs or bacteria vs days since last rain
  - GIS maps
- Review Top 5 Most Likely to Succeed AUs
  - Moving seven-year bacteria geomeans
  - Trend analysis
  - LDCs or bacteria vs days since last rain
  - GIS maps
- Rank Top 5 / Least 5 in order of priority

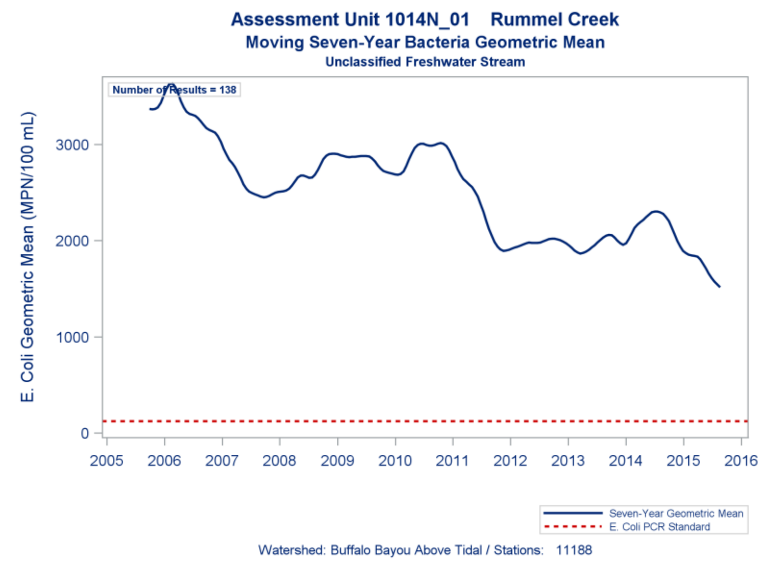
Top 5 Most Wanted

Top 5 Most Wanted
1) Rummel Creek (1014N_01)
2/3) Berry Bayou Above Tidal (1007F_01)
2/3) Little White Oak Bayou (1013A_01)
4) Mimosa Ditch (1007U_01)
5) Bintliff Ditch (1007T_01)



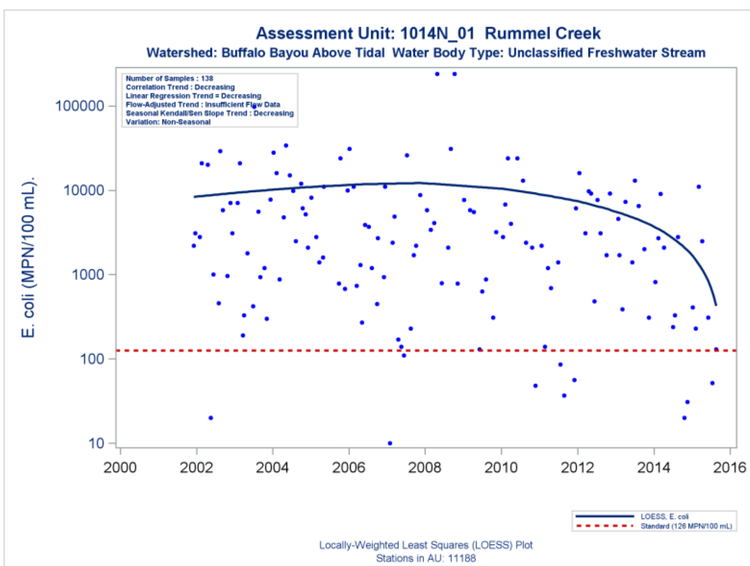
Rummel Creek (1014N_01)

MOST WANTED

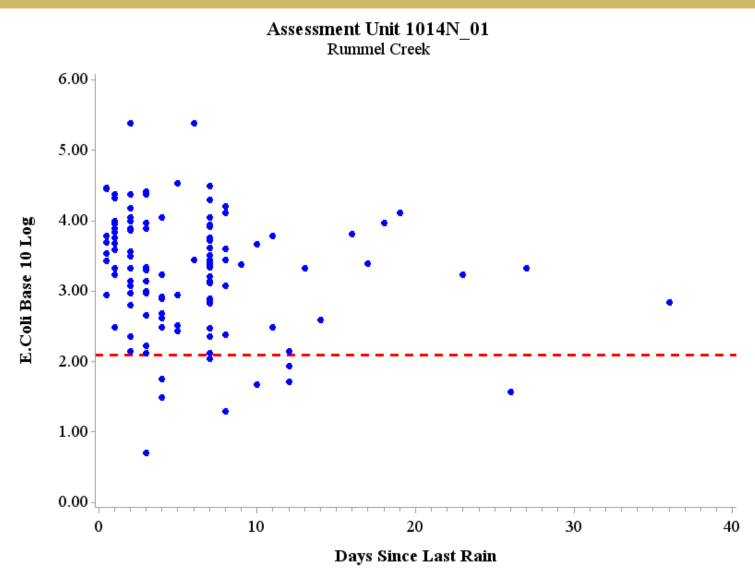


Rummel Creek (1014N_01)

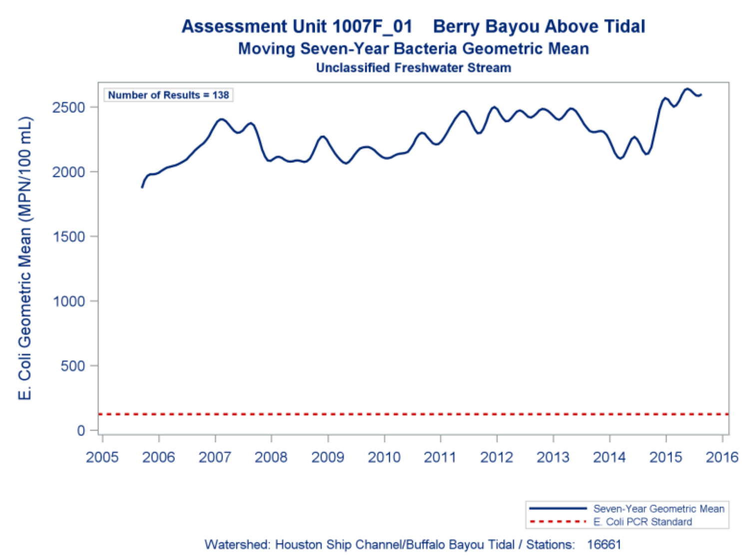
MOST WANTED



Rummel Creek (1014N_01)

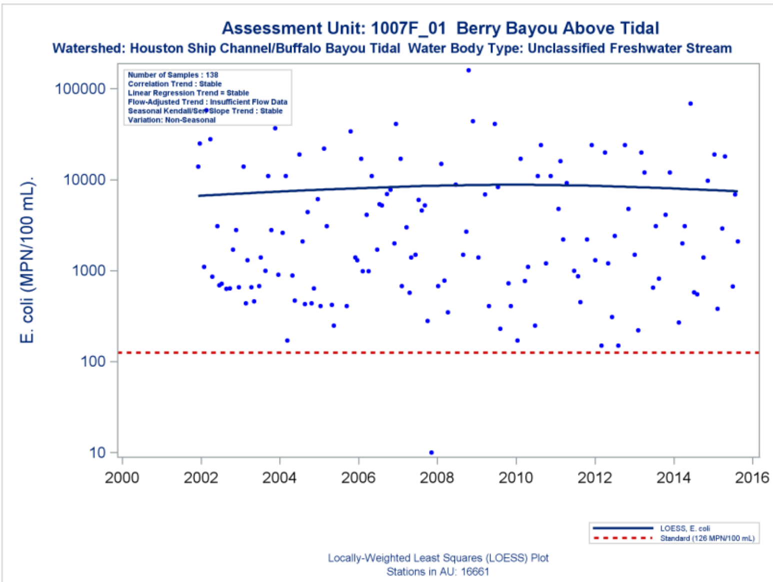


Berry Bayou (1007F_01)



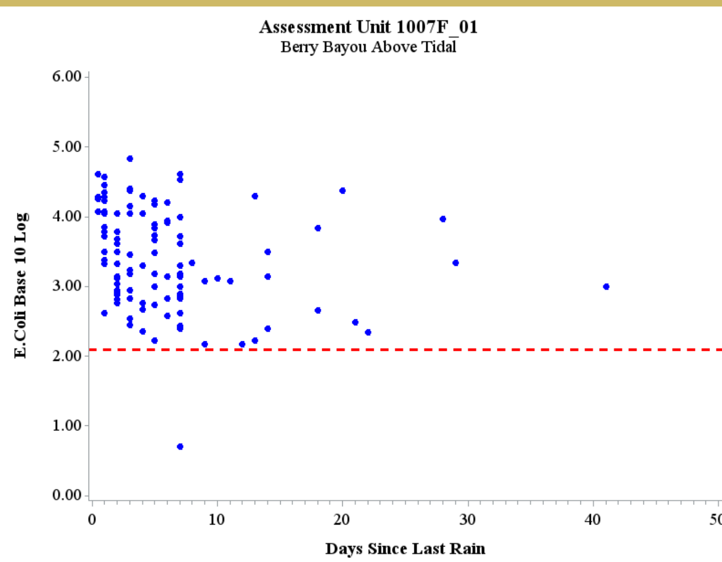
Berry Bayou (1007F_01)

MOST WANTED



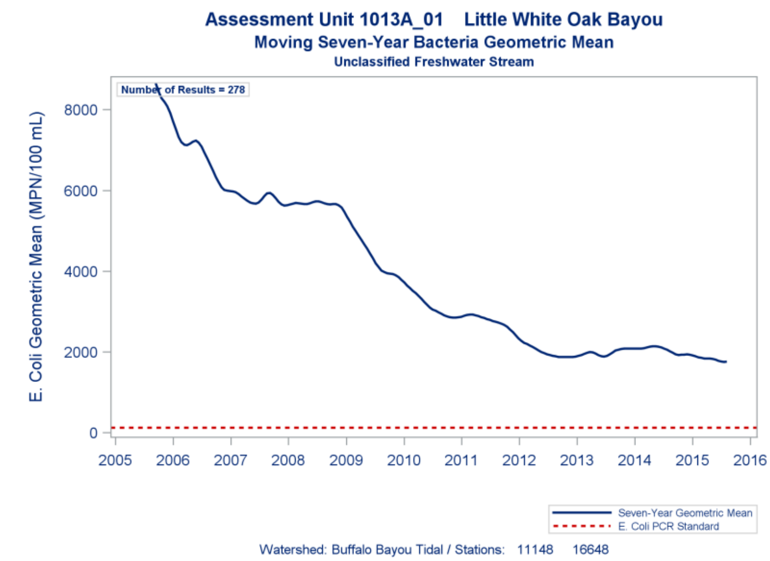
Berry Bayou (1007F_01)

MOST WANTED



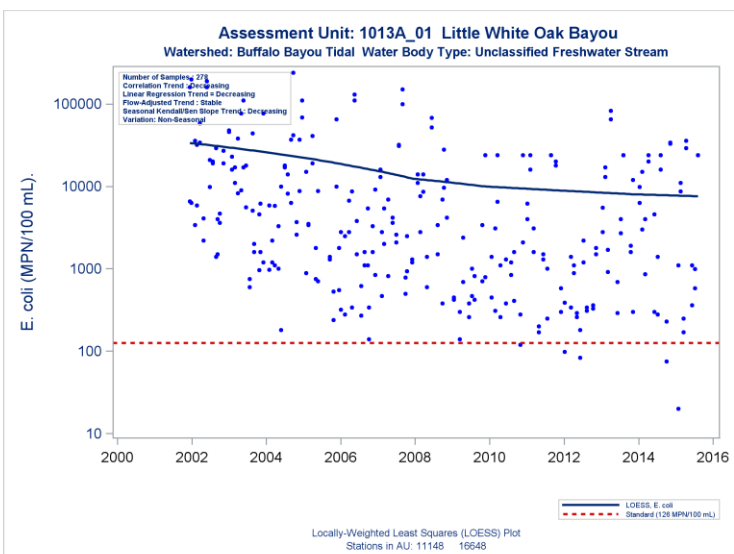
Little White Oak (1013A_01)

MOST WANTED



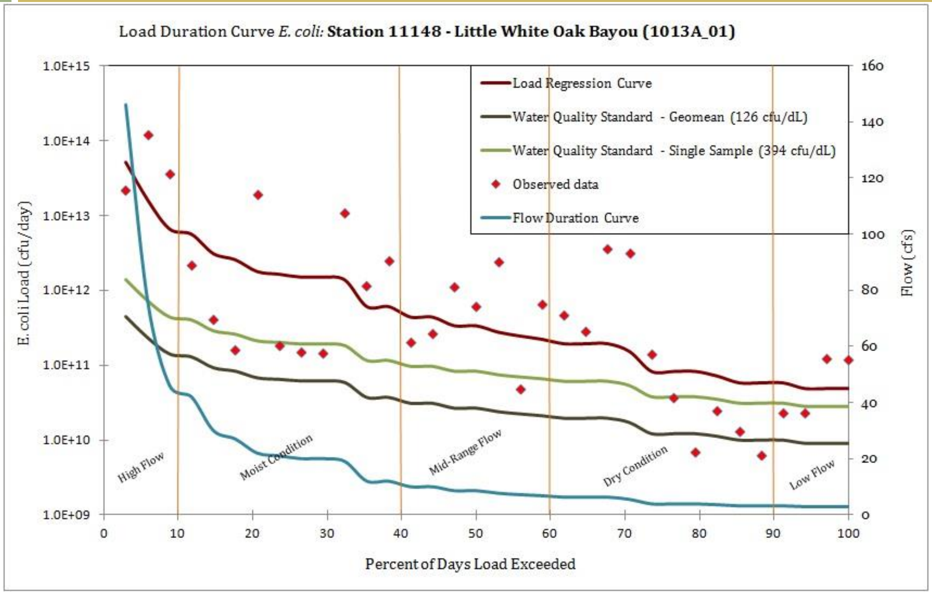
Little White Oak (1013A_01)

MOST WANTED



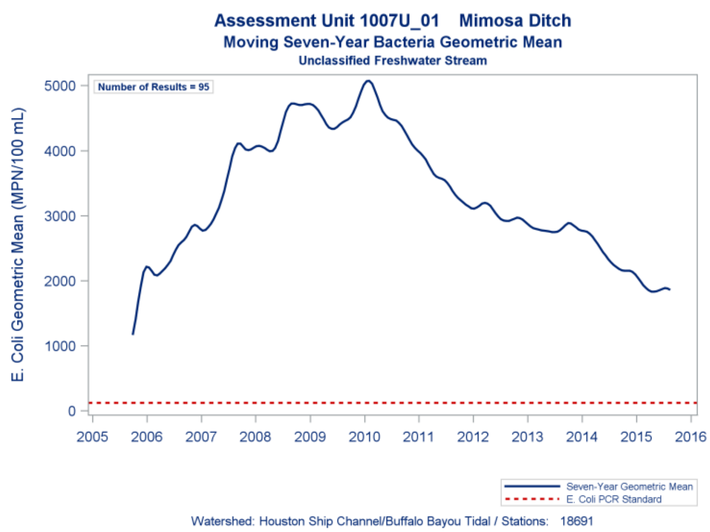
Little White Oak (1013A_01)

MOST WANTED

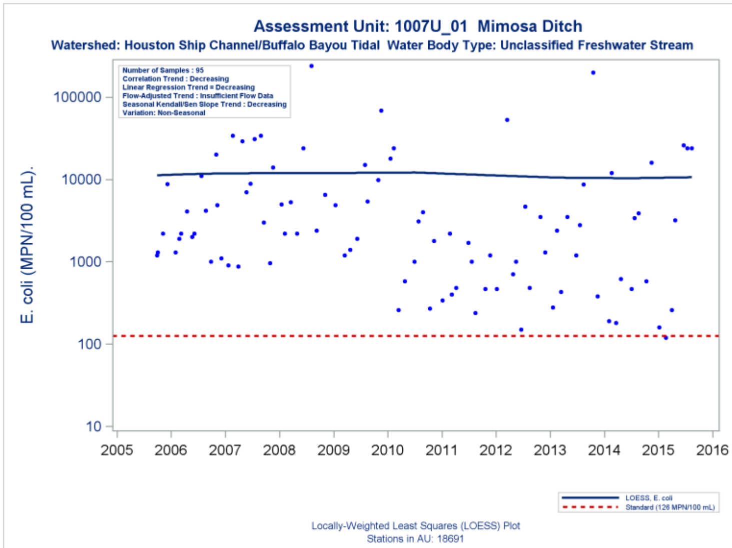


Mimosa Ditch (1007U_01)

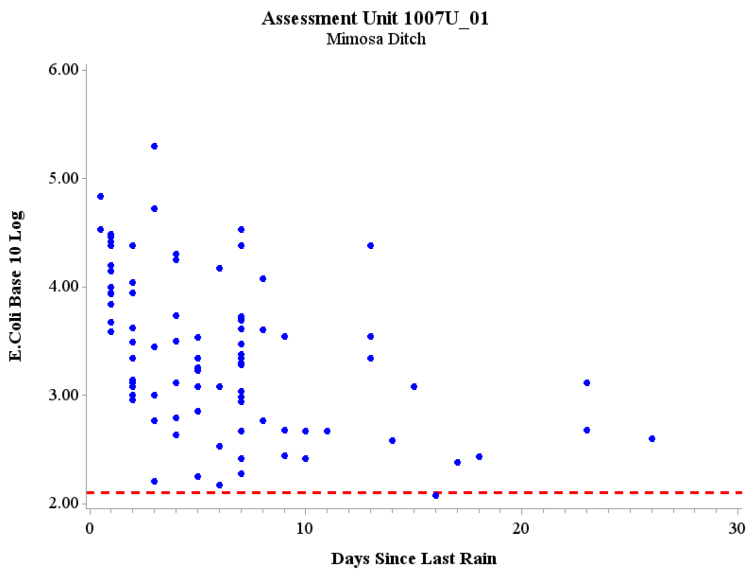
MOST WANTED



Mimosa Ditch (1007U_01) MOST WANTED

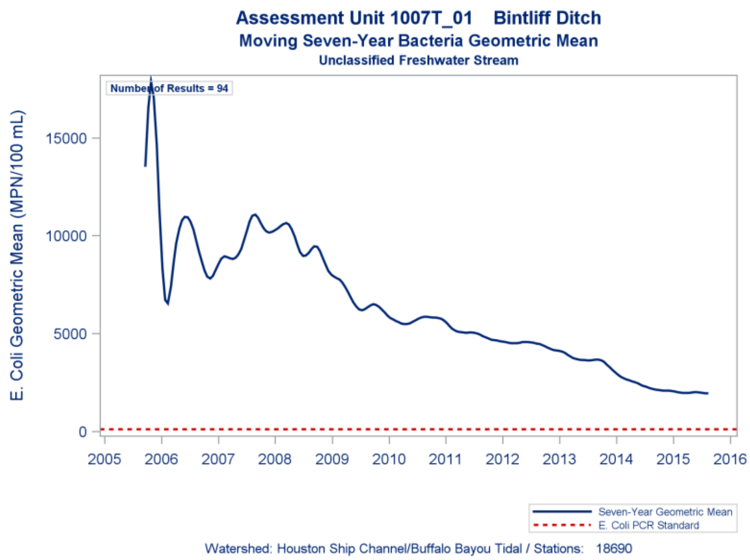


Mimosa Ditch (1007U_01) MOST WANTED



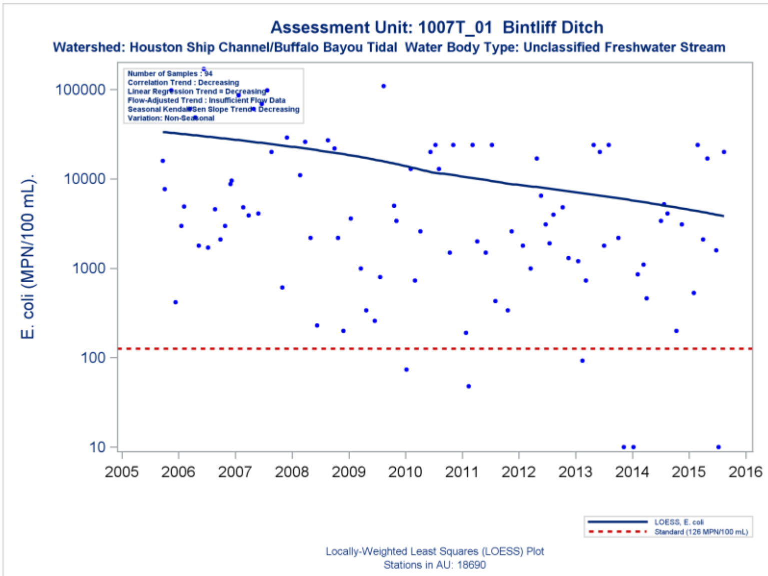
Bintliff Ditch (1007T_01)

MOST WANTED



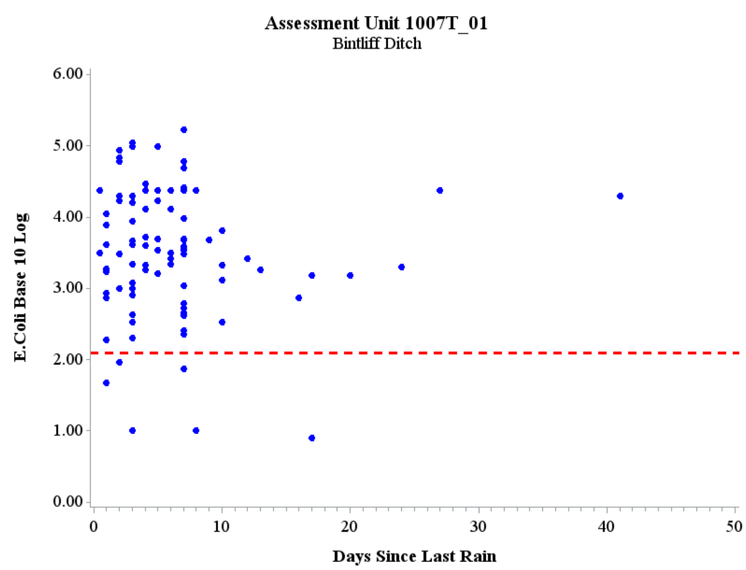
Bintliff Ditch (1007T_01)

MOST WANTED



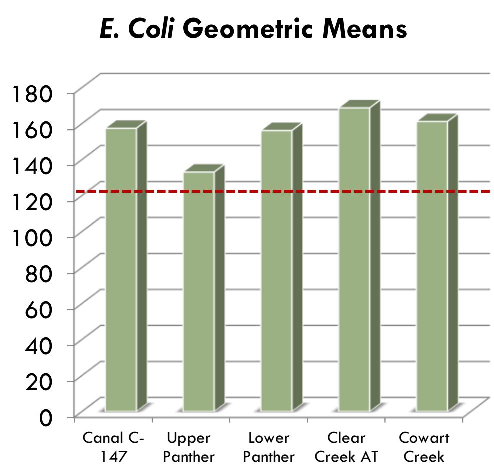
Bintliff Ditch (1007T_01)

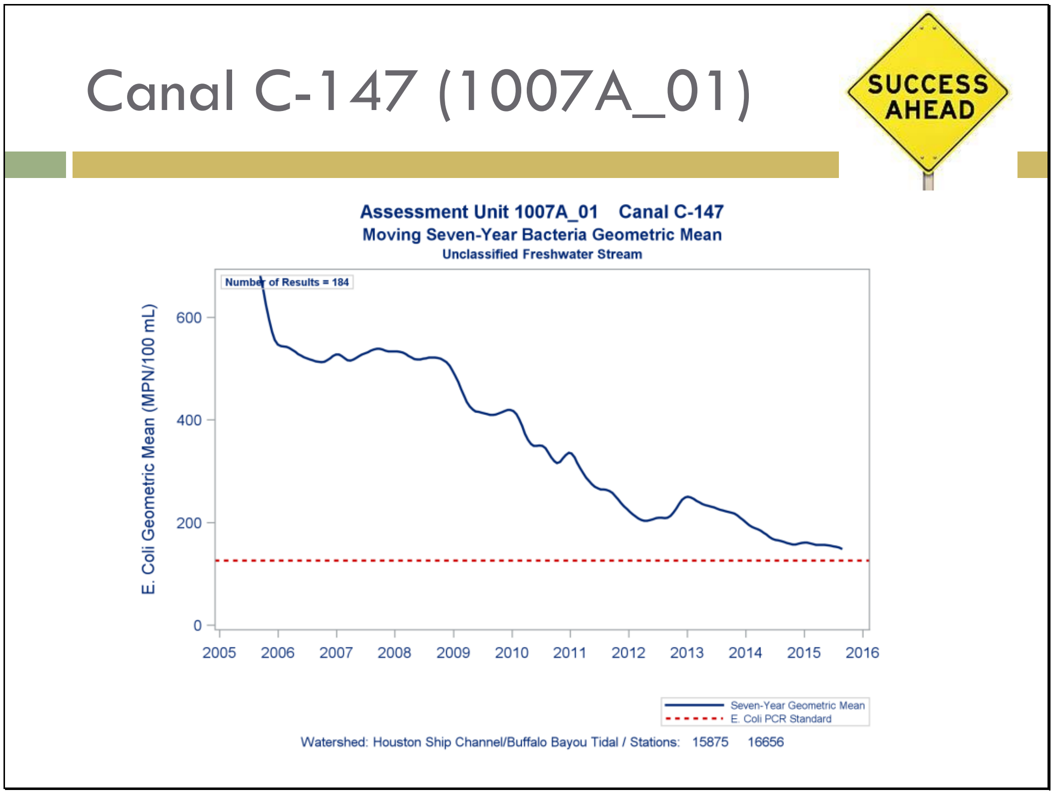
MOST WANTED

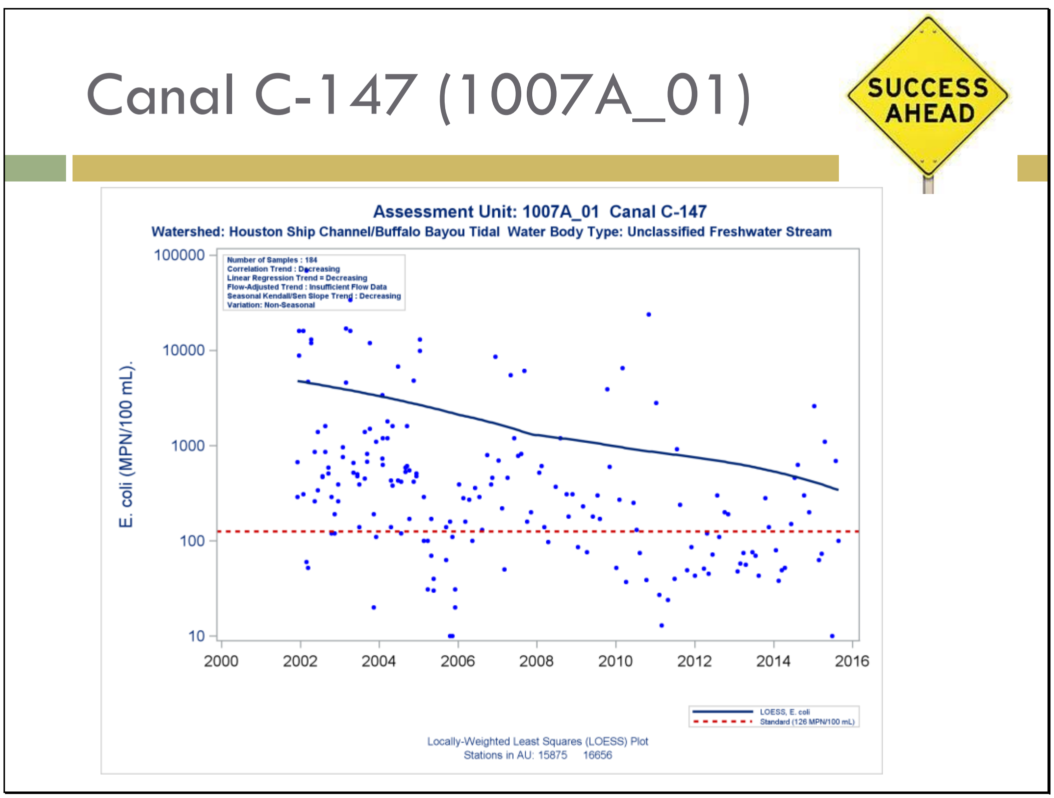


Top 5 Most Likely to Succeed

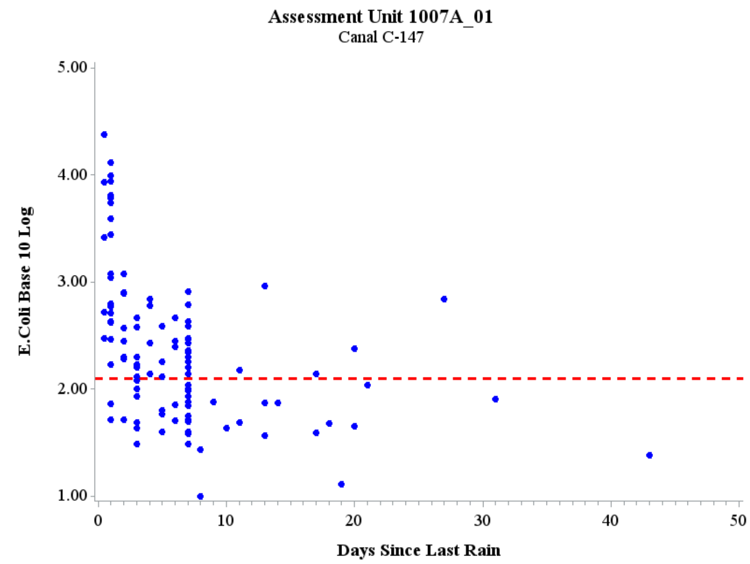
Top 5 Most Likely to Succeed
1) Canal C-147 (1007A_01)
2/3) Upper Panther Branch (1008B_02)
2/3) Lower Panther Branch (1008C_02)
4) Clear Creek Above Tidal (1102_04)
5) Cowart Creek (1102A_02)



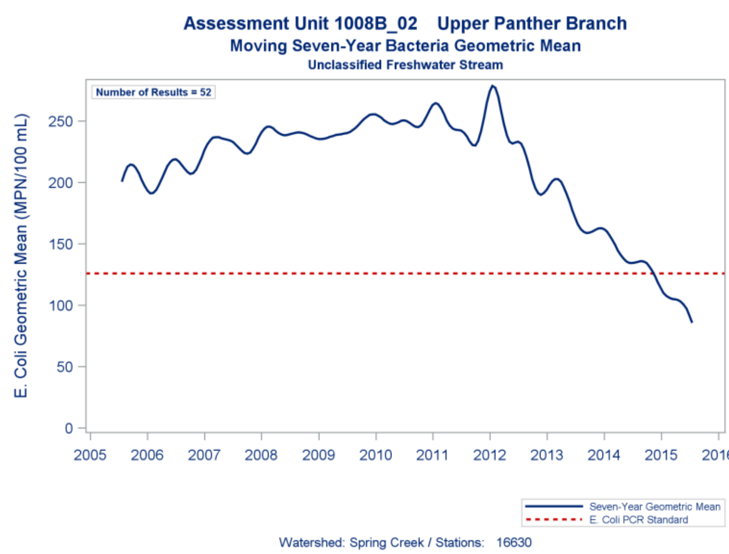

Canal C-147 (1007A_01)
SUCCESS AHEAD
Assessment Unit 1007A_01 Canal C-147
Moving Seven-Year Bacteria Geometric Mean
Unclassified Freshwater Stream
Number of Results = 184
E. Coli Geometric Mean (MPN/100 mL)
0
200
400
600
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Seven-Year Geometric Mean
E. Coli PCR Standard
Watershed: Houston Ship Channel/Buffalo Bayou Tidal / Stations: 15875 16656


Canal C-147 (1007A_01)
SUCCESS AHEAD
Assessment Unit: 1007A_01 Canal C-147
Watershed: Houston Ship Channel/Buffalo Bayou Tidal Water Body Type: Unclassified Freshwater Stream
Number of Samples : 184
Correlation Trend : Decreasing
Linear Regression Trend = Decreasing
Flow-Adjusted Trend : Insufficient Flow Data
Seasonal Kendall/Sen Slope Trend : Decreasing
Variation: Non-Seasonal
E. coli (MPN/100 mL)
10
100
1000
10000
100000
2000 2002 2004 2006 2008 2010 2012 2014 2016
LOESS, E. coli
Standard (126 MPN/100 mL)
Locally-Weighted Least Squares (LOESS) Plot
Stations in AU: 15875 16656

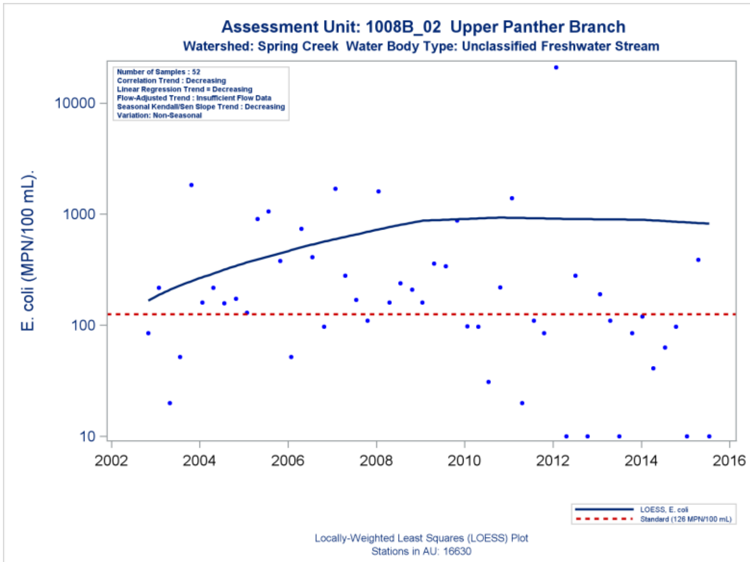
Canal C-147 (1007A_01)



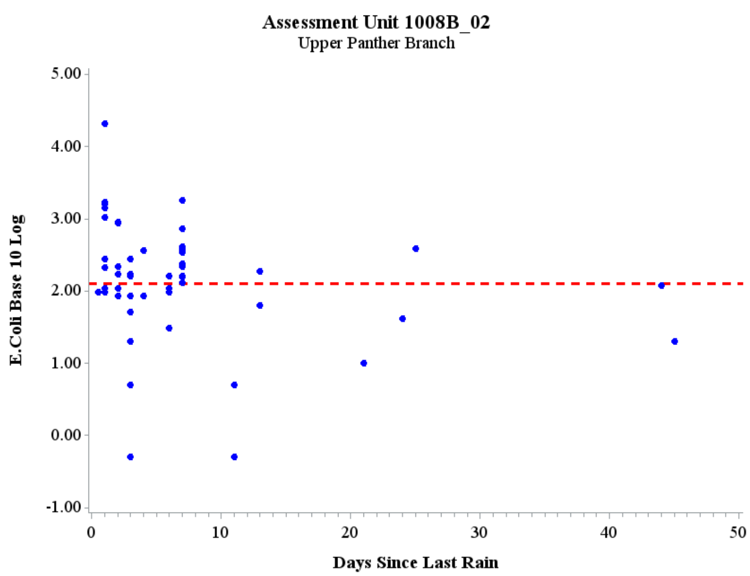
Upper Panther Branch (1008B_02)



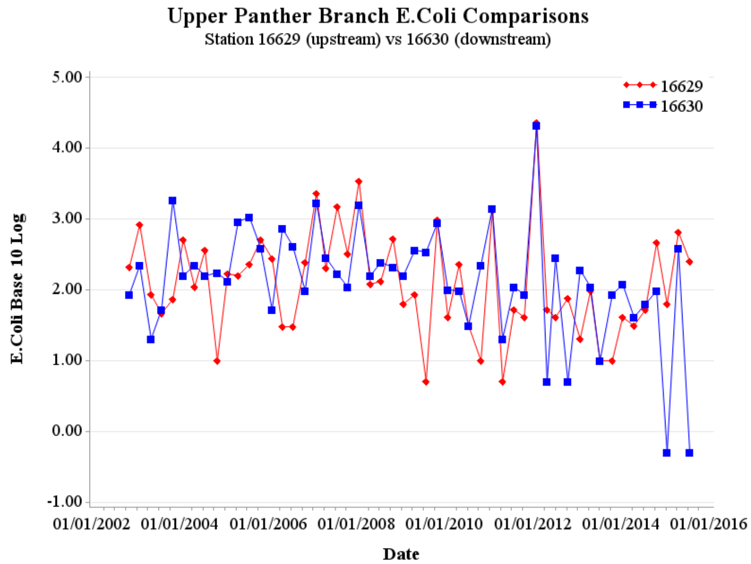
Upper Panther Branch (1008B_02)



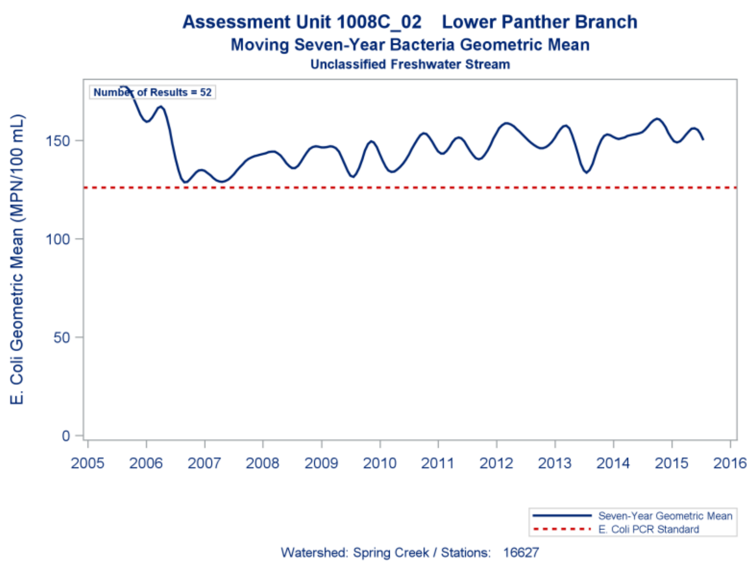
Upper Panther Branch (1008B_02)



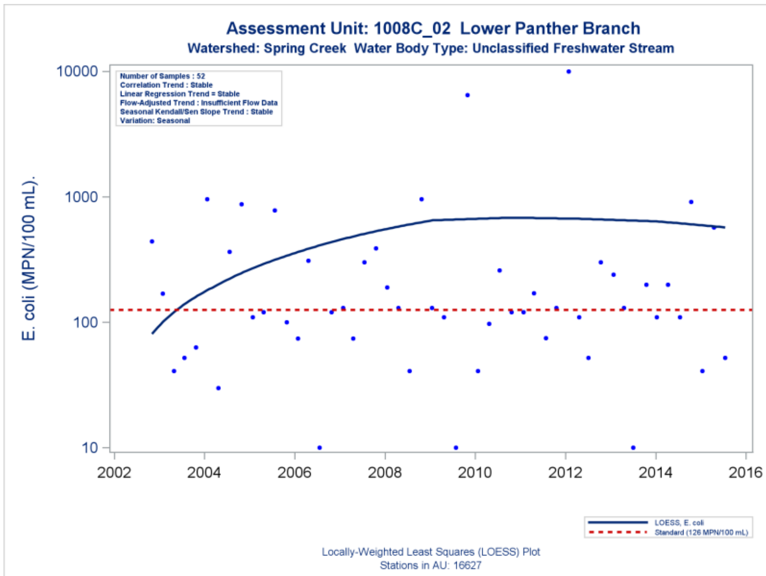
Upper Panther Branch (1008B_02)



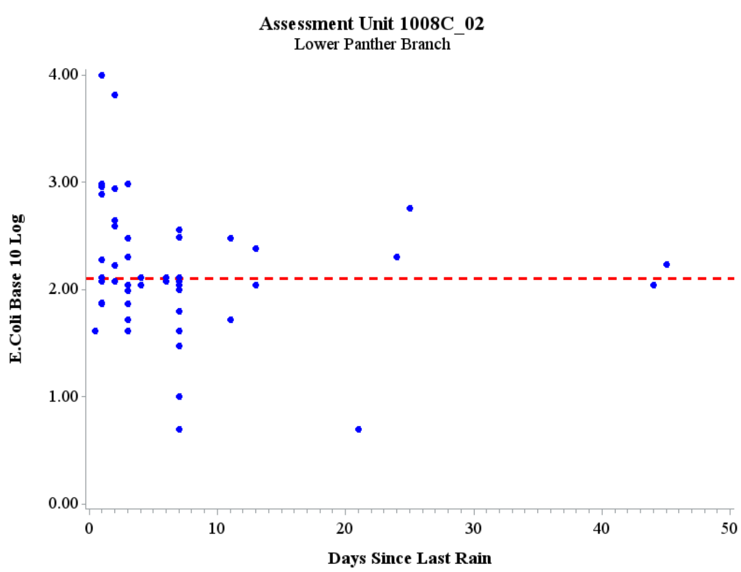
Lower Panther Branch (1008C_02)



Lower Panther Branch (1008C_02)

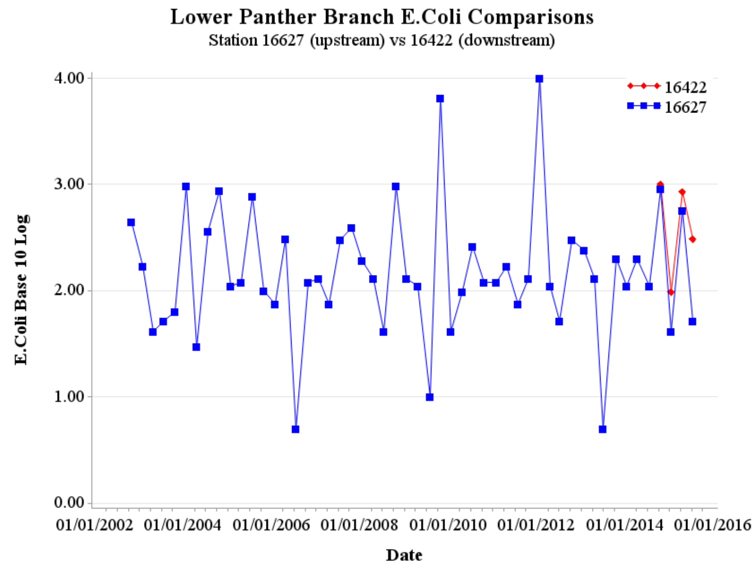


Lower Panther Branch (1008C_02)



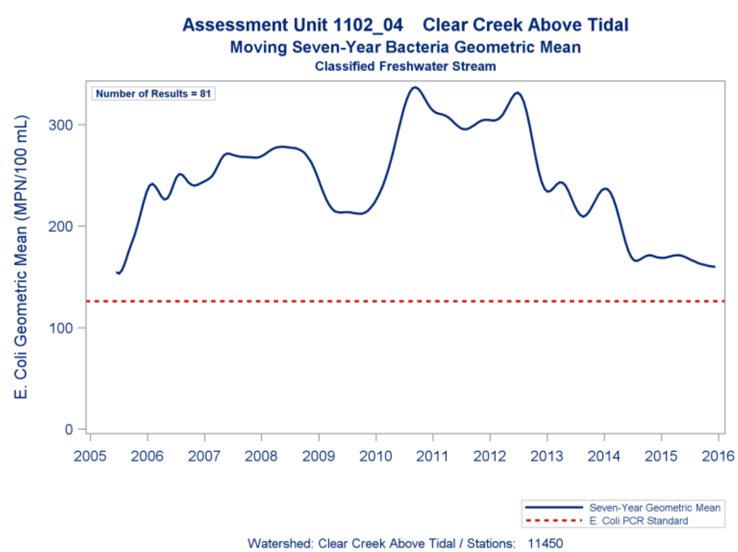
Lower Panther Branch (1008C_02)

SUCCESS AHEAD

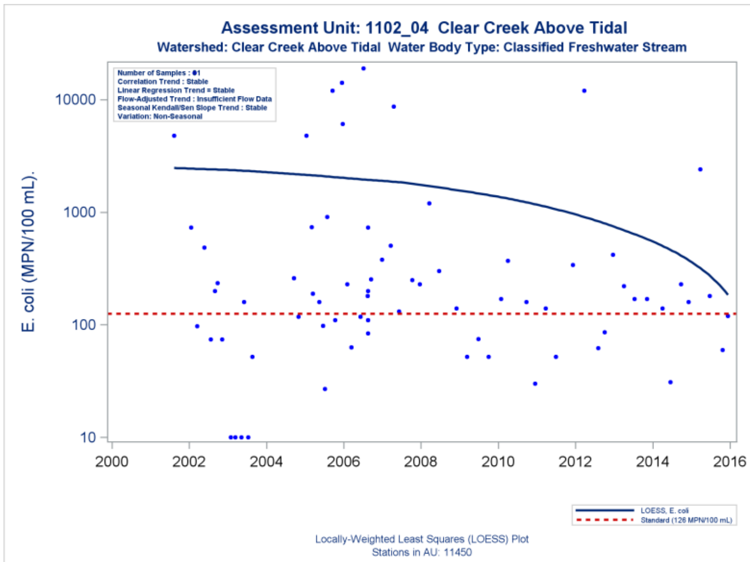


Clear Creek Above Tidal (1102_04)

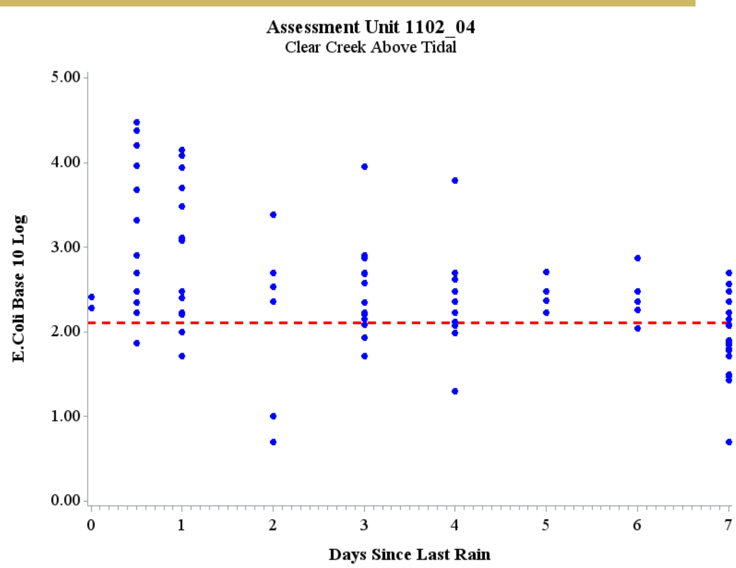
SUCCESS AHEAD



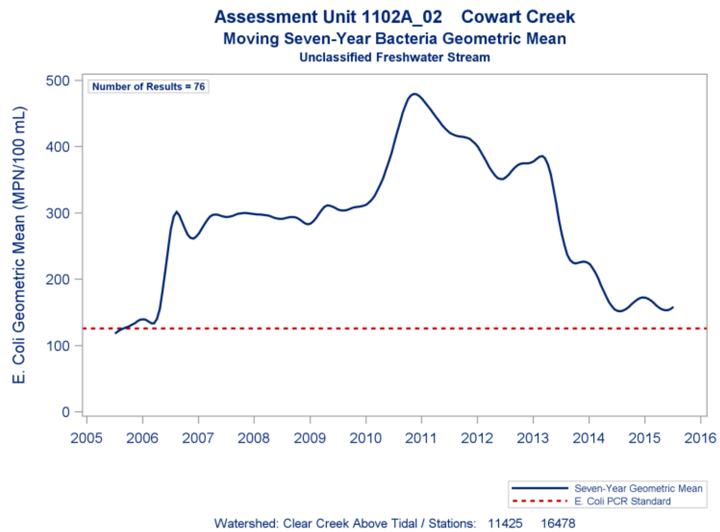
Clear Creek Above Tidal (1102_04)



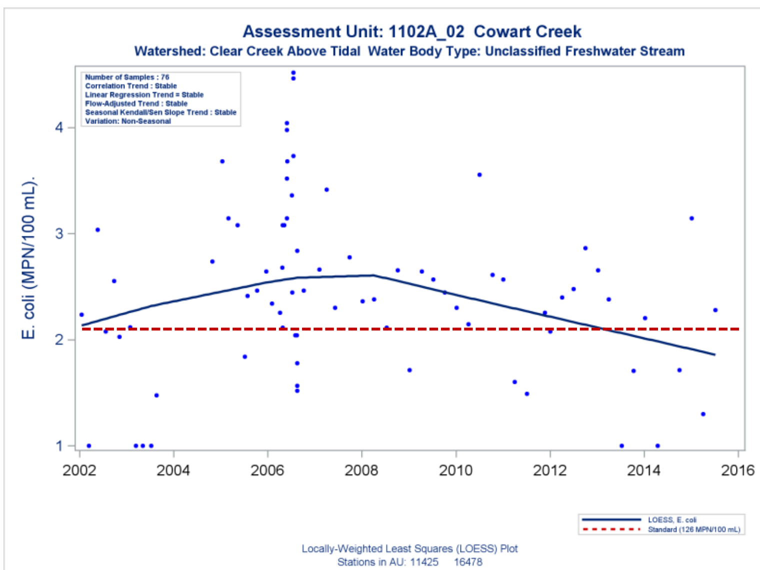
Clear Creek Above Tidal (1102_04)



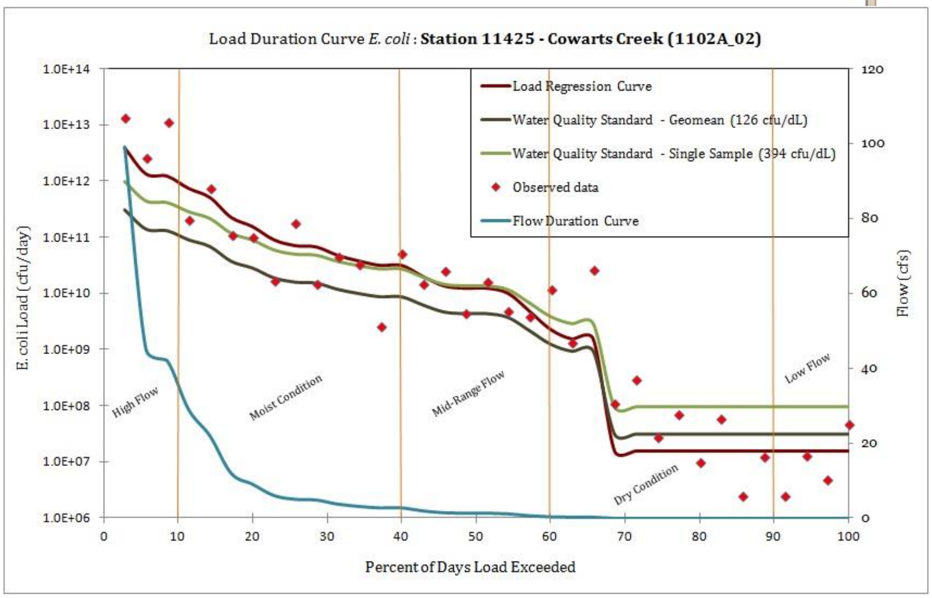
Cowart Creek (1102A_02)



Cowart Creek (1102A_02)



Cowart Creek (1102A_02)



Top 5/ Least 5 in Order of Priority

Top 5 Most Wanted	Top 5 Most Likely to Succeed
1) Rummel Creek (1014N_01)	**1) Canal C-147 (1007A_01)**
2) Little White Oak Bayou (1013A_01)	**2) Upper Panther Branch (1008B_02)**
3) Mimosa Ditch (1007U_01)	3) Lower Panther Branch (1008C_02)
4) Berry Bayou Above Tidal (1007F_01)	4) Cowart Creek (1102A_02)
5) Bintliff Ditch (1007T_01)	5) Clear Creek Above Tidal (1102_04)

Top 5 / Least 5 Workgroup Meeting Notes
Thursday, May 26, 2016
1:00 PM to 3:00 PM
H-GAC Conference Room D
3555 Timmons Lane, 2nd Floor

7. Introductions

Persons in Attendance:
Paniz Miesen – H-GAC
Steven Johnston – H-GAC
Denise Hall – Harris County Pollution Control
Steve Hupp – Bayou Preservation
Danielle Cioce – Harris County Watershed Protection
Robert Snoza – Harris County Flood Control
Carol LaBreche – City of Houston
Lisa Leja – City of Houston
Ambrose Okpokpo – City of Houston

Persons on Conference Line:
Lisa Groves – City of Houston

8. Project Overview

- This meeting was held to satisfy Review 2 tasks associated with Phase I of the project: *Prioritize the Top 2 Most Wanted and Top 2 Most Likely to Succeed AUs that will be subject to characterization and identification of bacteria sources.*

9. Review of Top 5 Most Wanted AUs

The workgroup reviewed statistical graphs and subwatershed maps for each AU on the Top 5 Most Wanted list. Graphical analysis included moving seven-year bacteria geomeans, *E. coli* trend analysis, LDCs, and *E. coli* vs days since last rain plots. Maps included outfall locations, OSSFs, land use information, and potential bacteria sources. The following are important notes and considerations pertinent to each AU based on the analysis provided.

1-Rummel Creek:
- Analysis of *E. coli* data revealed a slight decreasing trend in bacteria concentrations, but the geometric mean of 1960 MPN/100 mL is still well above the 126 MPN/100 mL standard.
- High *E. coli* concentrations during dry periods are common.

- Potential bacteria sources include dirt yards using manure based products and the plant nursery adjacent to I-10 at the Belteway.
- There are two stormwater detention basins adjacent to 1-10 and the Beltway.
- Clean Rivers Program (CRP) partners have expressed concern about Rummel Creek and the need for additional monitoring/characterization to find and eliminate bacteria sources due to known contact recreation.
- Accessibility is favorable.
- City of Houston offered access to GIS layer with lift station locations.
- City of Houston's Gims would also be a useful tool for finding information about current or planned rehab projects in the greater Houston area.

2-Berry Bayou:

- *E. coli* concentrations have remained well above the 126 MPN/100 mL standard with more than 90% of the data exceeding the state water quality standard.
- Current *E. coli* geometric mean is 2469 MPN/100 mL.
- Heavy residential and industrial land uses in the watershed.
- It was mentioned that there may be old grandfathered in OSSFs in this watershed than are not shown on the map.
- Berry Bayou watershed is one of the larger AUs on the Most Wanted list measuring at 12.69 square miles.
- Concrete lining is common in most areas, many of which are newly constructed or are currently under construction, making accessibility an issue in some areas.

3-Little White Oak:

- A slight decreasing trend in *E. coli* concentrations detected.
- Geomean is still well above the 126 MPN/100 mL standard at 1975 MPN/100 mL.
- LDC curve shows dry weather bacteria exceedances are common.
- Highly mixed use area with potential for illicit discharges.
- No wastewater outfalls are located along this AU.
- Lift station upstream of station 16648.
- City of Houston conducted a characterization in 2009 and found homes discharging gray water into Little White Oak.
- A fish kill occurred last summer from unknown causes.
- Bayou Preservation characterizations found high chlorine levels and low *E. coli*. City of Houston found leaking potable water in that area which may have been the chlorine source.
- A lot of interest in this AU due to the lack of information and knowledge about bacteria point sources. Workgroup curious about what the cause of

high *E. coli* concentrations are in a highly urbanized and residential area with no WWTF outfalls.

4-Mimosa Ditch:

- Slight decreasing trend detected for *E. coli* in this AU.
- Geometric mean is 2133 MPN/ 100 mL compared to the 126 MPN/100 mL standard.
- *E. coli* concentrations have been significantly higher than the standard even during dry periods.
- Mimosa Ditch watershed borders City of Houston and City of Bellaire but is in the City of Houston jurisdiction.
- Bellaire WWTF outfall located on the downstream end of the AU.
- High dry weather flows at Rice are suspect.
- Likely that bacteria sources are originating from the northern portions of the watershed with the majority of inputs coming from underground.
- Underground systems may make it difficult to identify bacteria sources.

5-Bintliff Ditch:

- Trend analysis detected slight decreasing trend in *E. coli* concentrations in Bintliff Ditch.
- Bacteria geomean is 2133 MPN/100 mL
- High *E. coli* concentrations during dry periods are common.
- Accessibility is an issue; chain link fences/gates and high vegetation on private property block access in many areas.
- Samples collected from bridges due to difficult accessibility.
- Underground system north of Bellaire.
- City of Houston found leaking storm drain last year, problem has been fixed.
- Bayou Preservation and City of Houston assessments found areas adjacent to Hwy 59 as problem areas for both stems.

10. Review of Top 5 Most Likely to Succeed AUs

The workgroup reviewed statistical graphs and subwatershed maps for each AU on the Top 5 Most Likely to Succeed list. Graphical analysis included moving seven-year bacteria geomeans, *E. coli* trend analysis, LDCs, *E. coli* vs days since last rain, and station comparison plots. Maps included outfall locations, OSSFs, land use information, and potential bacteria sources. The following are important notes and considerations pertinent to each AU based on the analysis provided.

1-Canal C-147:

- *E. coli* trend analysis and moving geomeans have been decreasing.
- Nearly half the data points collected still exceed the 126 MPN/100 mL geomean.

- *E. coli* geomean is 157 MPN/100 mL.
- *E. coli* exceedances during dry weather periods occur on an infrequent basis.
- Canal located in unincorporated Fort Bend County in the City of Missouri City.
- Flea market and bull fighting in eastern portion of the watershed.
- Recently constructed wastewater treatment facility in the area. Would be interesting to compare before and after samples to see the impact.
- No previous characterizations or assessments we are aware of have taken place in this area.
- Good option for further assessment.

2-Upper Panther Branch:

- Moving seven-year geometric means have been decreasing to near compliance, but current *E. coli* geomean is still slightly above the 126 MPN/100 mL standard at 133 MPN/100 mL.
- *E. coli* exceedances during dry periods are rare.
- Comparison of monitoring stations upstream and downstream of the WWTF outfall revealed similar fluctuations in bacteria concentrations for both stations.
- San Jacinto River Authority does the monitoring for this AU.
- Wildlife is a likely contributor of bacteria in this AU.
- Concentrated area of OSSFs NE of the AU with a small tributary running through that area. No monitoring stations are located immediately downstream of these OSSFs so any potential bacteria loadings from OSSFs would go undetected.
- No previous characterizations or assessments we are aware of have taken place in this area.
- Good option for further assessment.

3-Lower Panther Branch:

- Moving seven-year bacteria geomeans have been fluctuating slightly above the standard since 2006.
- Nearly half the samples collected have exceeded the state bacteria standard with concentrations reaching as high as 10,000 MPN/100 mL between 2011-2013.
- Current *E. coli* geomean is 156 MPN/100 mL.
- *E. coli* exceedances during dry weather occurs on an infrequent basis.
- San Jacinto River Authority does the monitoring for this AU.
- Increasing bacteria trends are likely related to increased development in the area.
- Feral hogs may be a potential source here.
- No previous characterizations or assessments we are aware of have taken place in this area.

-

4-Clear Creek Above Tidal:

- Moving seven-year bacteria geomeans have been fluctuating above the standard since late 2005.
- Trend analysis detected stable *E.coli* trends with more than half the samples collected still exceeding the state standard.
- *E. coli* geomean for this AU is 169 MPN/100 mL.
- New development in the area.
- No WWTF outfalls located in this AU.
- AU supports wildlife; alligator gars are commonly seen in this AU.
- Environmental Institute of Houston (EIH) does the monitoring for this AU.
- There would be value in comparing historical data from upstream stations to downstream stations to help identify problem areas.
- Very high flows at times would make it difficult to find bacteria sources.

5-Cowart Creek:

- Moving seven-year bacteria geomeans have been fluctuating above the standard since late 2005.
- *Stable E. coli* trend detected for this AU with more than half the samples collected exceeding the state standard.
- *E. coli* geomean is currently 161 MPN/100 mL.
- Frequent and extreme exceedances were common around 2006-2007 but have since improved.
- Relatively easy access along the AU, but may run into accessibility issues on private properties.
- There are possibly more grandfathered in OSSFs present in this watershed that are not on the current maps.
- Horses and other animals living on small ranchettes may be a potential contributor of bacteria.
- Environmental Institute of Houston (EIH) does the monitoring in this AU.
- No previous characterizations or assessments we are aware of have taken place in this area.

11. Top 5 / Least 5 Prioritizations

- Based on the available information, the workgroup discussed how to prioritize the Top 5 / Least 5 list based on where we should focus our characterizations moving forward.

Top 5 Most Wanted	Top 5 Most Likely to Succeed
1) Rummel Creek (1014N_01)	**1) Canal C-147 (1007A_01)**
2) Little White Oak Bayou (1013A_01)	**2) Upper Panther Branch (1008B_02)**
3) Mimosa Ditch (1007U_01)	3) Lower Panther Branch (1008C_02)
4) Betty Bayou Above Tidal (1007F_01)	4) Cowart Creek (1102A_02)
5) Bintliff Ditch (1007T_01)	5) Clear Creek Above Tidal (1102_04)

12. Next Steps:

- H-GAC staff will begin conducting field surveys and collecting baseline data for the Top 2 AUs on each list in June, 2016.
- If no bacteria hits are detected during any of the Top 2 / Least 2 assessments, H-GAC staff will move down the prioritization list and assess the next AU listed.
- Workgroup will convene again in late summer/early fall to review baseline data and discuss findings.

13. Adjourn

Appendix C: AU Intensive Study:

Little White Oak Bayou

Figure C1. Windshield survey route for Little White Oak Bayou

Table C1. Bacteria screening results for Little White Oak Bayou

Sample No	Date	Time	Sample Type	Outfall Characteristics			Latitude	Longitude	*E. coli* *(cfu/100ml)*	Comments/Description
				Material	Pipe Diameter	Water Depth				
001	7/13/2016	8:57	Outfall	Metal pipe	24"	0.5"	29.7975	-95.37048	575	Waypoint No. 040. Foam and algae present. Small fish in water.
002	7/13/2016	9:09	Outfall	Metal pipe	24"	3"	29.79642	-95.37062	700	Waypoint No. 041. Partially submerged outfall.
003	7/13/2016	9:28	SW	Natural channel			29.79464	-95.37029	450	Waypoint No. 042. Lots of trash. Large birds nearby.
004	7/13/2016	9:48	SW	Natural channel			29.79296	-95.36852	250	Waypoint No. 043. Sampled downstream of two outfalls. Dead mammal smell.
005	7/13/2016	10:27	Outfall	Concrete storm drain	48"	4"	29.79247	-95.36649	1025	Waypoint No. 044. Water from outfall cooler with a chlorine smell. Three people observed on bank.
006	7/13/2016	10:47	SW	Natural channel			29.7909	-95.36438	150	Waypoint No. 045. Lots of trash.
007	7/13/2016	10:56	Outfall	Metal pipe	24"	0.5"	29.79076	-95.3639	0	Waypoint No. 046. Sweet smell. Soil discoloration below outfall opening.
008	7/18/2016	8:31	Outfall	Concrete storm drain	120"	30"	29.79039	-95.36263	0	Waypoint No. 047. Fish. Large waterfall sound.
009	7/18/2016	8:45	SW	Natural channel			29.78994	-95.36188	TNTC	Waypoint No. 048. Upstream of bend/large storm drain.
010	7/18/2016	8:54	Outfall	Concrete storm drain	108"	3"	29.78984	-95.36163	TNTC	Waypoint No. 049. Large storm drain. Strange smell - acid?
011	7/18/2016	9:20	Tributary	Natural channel			29.78782	-95.36334	0	Waypoint No. 050. Natural tributary. Turtle.
012	7/18/2016	9:57	SW	Natural channel			29.78683	-95.36567	TNTC	Waypoint No. 051. Lots of trash. Downstream of construction site.
013	7/18/2016	10:22	SW	Natural channel			29.78513	-95.36585	TNTC	Waypoint No. 052. Upstream of Main St. bridge. Lots of rocks and ripples.
014	7/18/2016	11:18	SW	Natural channel			29.7826	-95.3706	TNTC	Waypoint No. 049 (yellow gps). Downstream of 45. Adjacent to stormwater wetlands.
015	7/18/2016	11:39	SW	Natural channel			29.78119	-95.3707	TNTC	Waypoint No. 050 (yellow gps). Lots of gar.
016	7/18/2016	11:53	SW	Natural channel			29.77933	-95.37054	TNTC	Waypoint No. 051 (yellow gps). Near hike and bike trail. Lots of trash.
017	7/20/2016	8:44	SW	Natural channel			29.80087	-95.37254	10900	Waypoint No. 053.
018	7/20/2016	9:10	Outfall	Concrete storm drain	72"	Unkown	29.80378	-95.37322	13300	Waypoint No. 054. Fish jumping. Downstream of Calvalcade bridge. Sampled at mouth of storm drain.
019	7/20/2016	9:20	SW	Natural channel			29.80414	-95.37343	7300	Waypoint No. 055. Upstream of Calvalcade bridge. Downstream of outfall and drain line on right bank
020	7/20/2016	9:40	Outfall	Metal pipe	48"	2"	29.80751	-95.37463	1350	Waypoint No. 056. Clear discharge.
021	7/20/2016	9:50	SW	Natural channel			29.80787	-95.37498	6650	Waypoint No. 057. Downstream of metal outfall pipe. Upstream of bridge at Link.
022	7/20/2016	10:25	SW	Natural channel			29.80884	-95.37589	9450	Waypoint No. 058. Surface water adjacent to outfall No. 056. Redish tint to sediment.
023	7/20/2016	10:44	SW	Natural channel			29.81165	-95.37593	4300	Waypoint No. 059. Downstream of underground 610.
024	7/20/2016	11:00	SW	Natural channel			29.81589	-95.37767	5800	Waypoint No. 060. Upstream of 610 underground.
025	7/20/2016	11:20	SW	Natural channel			29.81901	-95.37845	TNTC	Waypoint No. 061. Surface water sample downstream of Stokes bridge.

Appendix D: AU Intensive Study:
Rummel Creek

Figure D1. Windshield survey route for Rummel Creek

Table D1. Bacteria screening results for Rummel Creek

Sample No	Date	Time	Sample Type	Outfall Characteristics			Latitude	Longitude	*E. coli (cfu/100ml)*	Comments/Description
				Material	Pipe Diameter	Depth of Water				
031	7/11/2016	9:00	SW	Natural channel			29.76429	-95.5607	125	Low flow. Algae present
032	7/11/2016	9:20	Tributary	Natural channel		18"	29.76397	-95.56178	225	H_2S/rotten egg smell present. Slimy/mucky soil.
033	7/11/2016	9:36	Tributary	Natural channel		6"	29.76438	-95.56191	775	Sheen on water. Trash on bank. Groundwater from soil on bank slowly flowing into creek.
034	7/11/2016	10:03	SW	Natural channel			29.76519	-95.56248	525	Old and rusty water pipe nearby.
035	7/11/2016	10:40	SW	Natural channel			29.772	-95.5694	425	Waypoint No. 032. Small fish present. Sample taken from inside the Edith L. Moore Nature Sanctuary
036	7/11/2016	11:00	Outfall	Metal pipe	48"	2"	29.77316	-95.57065	2275	Waypoint No. 033. Water snake nearby. Heavy algae in water.
037	7/11/2016	11:18	Outfall	Concrete storm drain	48"	1"	29.77559	-95.57374	100	Waypoint No. 034. Heavy algae inside outfall and in water.
038	7/11/2016	11:30	SW	Natural channel			29.7763	-95.5733	400	Waypoint No. 035. Downstream of concrete slab (erosion control?). Small fish present.
039	7/11/2016	11:31	SW	Natural channel			29.7763	-95.5733	700	Upstream of concrete slab (erosion control?). Heavy algae.
040	7/11/2016	12:30	SW	Concrete channel			29.78381	-95.56509	925	Houston Garden Center and 10. Very steep concrete bank. Heavy plant accumulation and growth.
041	7/11/2016	12:39	SW	Concrete channel			29.78252	-95.56563	350	Waypoint No. 037. Very steep concrete bank. Heavy plant accumulation and growth.
042	7/11/2016	12:50	Outfall	Metal pipe	36"	1"	29.7806	-95.56744	125	Waypoint No. 038. Snake skin nearby. Heavy algae.
043	7/11/2016	12:58	Outfall	Metal pipe	48"	1"	29.78044	-95.56762	225	Waypoint No. 039. Heavy algae. Stagnant water.

Appendix E: AU Intensive Study:

Canal C-147

Figure E1. Windshield survey route for Canal C-147

Table E1. Bacteria screening results for Canal C-147

Sample No	Date	Time	Sample Type	Outfall Characteristics			Latitude	Longitude	*E. coli (cfu/100ml)*	Comments/Description
				Material	Pipe Diameter	Depth of Water				
008	6/30/2016	9:00	Outfall	Metal pipe lined with rubber	24"	1.5"	29.61648	-95.45901	800	Outfall upstream of CRP monitoring station. Some algae present
009	6/30/2016	9:10	SW	Concrete channel			29.61599	-95.45975	230	
010	6/30/2016	9:21	SW	Concrete channel			29.61424	-95.46069	290	Manhole on either side of bridge crossing. Slight yellow tint to water
011	6/30/2016	9:32	SW	Concrete channel			29.61206	-95.46129	200	Cliff swallows and ducks present. Some algae present
012	6/30/2016	9:38	Tributary	Concrete lined at discharge point; natural channel upstream		2"	29.61161	-95.46149	180	Snail. Some algae present
013	6/30/2016	9:51	Outfall	Concrete storm drain (left)	114"	6"	29.61142	-95.46475	TNTC	Algae common
014	6/30/2016	9:52	Outfall	Concrete storm drain (right)	108"	3"	29.61145	-95.46475	1770	Algae common
015	6/30/2016	10:02	SW	Concrete channel; natural channel upstream			29.61140	-95.46519	190	Concrete lining ends here; natural channel upstream of bridge
016	6/30/2016	10:17	SW	2 metal outfall pipes directly upstream; natural channel	30"	0"	29.60781	-95.46939	510	Downstream of 2 outfalls (not flowing). Lots of fish at mouth of outfalls
017	6/30/2016	10:26	Tributary	Natural channel		7"	29.60601	-95.47043	TNTC	
018	6/30/2016	10:48	Outfall	Metal pipe with concrete lining at discharge point			29.60564	-95.47581	40	Algae common
020	6/30/2016	11:51	SW	Natural channel			29.60504	-95.47677	320	Upstream of Beltway 8 bridge. Lots of fish, big and small. Some algae present
021	6/30/2016	11:58	Tributary	Natural channel			29.60412	-95.47678	190	Trib adjacent to WWTF outfall; 2 different color waters at mixing point
022	6/30/2016	12:01	SW	Natural channel			29.60413	-95.47684	230	SW downstream of WWTF outfall & upstream of tributary; 2 different color waters at mixing point
023	6/30/2016	12:10	Outfall	Metal pipe	48"	9"	29.60404	-95.47752	50	WWTF outfall; high flow
024	6/30/2016	12:16	Outfall	Metal pipe with concrete lining at discharge point	30"	1"	29.60406	-95.47842	10	Lots of vegetation growing out of outfall
025	6/30/2016	12:22	SW	Natural channel			29.60412	-95.47890	530	
026	6/30/2016	12:37	Outfall	Metal pipe lined with rubber; concrete at discharge	48"	2"	29.60392	-95.48441	0	Water had a sweet smelling odor similar to detergent or soap; thick algal growth at discharge
027	6/30/2016	12:50	Outfall	Metal pipe	48"	0.5"	29.60384	-95.48948	2130	Yellow tinted water; lots of fish
029	6/30/2016	13:00	SW	Natural channel			29.60379	-95.49318	230	
030	6/30/2016	13:14	SW	2 concrete lined storm drains directly upstream; natural channel			29.60378	-95.49982	520	

Appendix F: AU Intensive Study:

Upper Panther Branch

Figure F1. Windshield survey route for Upper Panther Branch

Table F1. Bacteria screening results for Upper Panther Branch

Sample No	Date	Time	Sample Type	Outfall Characteristics			Latitude	Longitude	*E. coli (cfu/100m*	Comments/Description
				Material	Pipe Diameter	Depth of Water				
001	7/26/2016	9:17	Tributary	Natural channel			30.18642	-95.47234	170	Waypoint No. 062. Drainage/tributary conveyance point. Fish/snake/mushrooms present.
002	7/26/2016	9:30	SW	Natural channel			30.18568	-95.47247	310	Waypoint No. 063. Chlorine smell. Brownish cloudy water.
003	7/26/2016	9:37	Tributary	Natural channel			30.18542	-95.47245	3420	Waypoint No. 064. Tributary from stormwater outfall near chlorine smell. Small fish.
004	7/26/2016	10:11	SW	Natural channel			30.18191	-95.47338	140	Waypoint No. 065. Wide channel. Sweet smell. Chlorine test strip >1.0ppm, <4.0ppm
005	7/26/2016	10:35	Tributary	Natural channel			30.17983	-95.47214	100	Waypoint No. 067. Tributary No. 068. Chlorine smell. Chlorine test strip ~4.0ppm
006	7/26/2016	10:44	Tributary	Natural channel			30.17966	-95.47181	580	Waypoint No. 068. Tributary No. 069. Red color. Chlorine test strip ~0.8ppm
007	7/26/2016	11:07	Tributary	Natural channel			30.17765	-95.47079	60	Waypoint No. 069. Tributary No. 070. Chlorine smell. Chlorine test strip ~4.0ppm
008	7/26/2016	11:54	SW	Natural channel			30.18661	-95.47267	50	Waypoint No. 072. Downstream of tributary 071. Chlorine smell. Chlorine test strip ~10.0ppm
009	7/27/2016	9:45	Tributary	Natural channel			30.1911	-95.47796	1040	Waypoint No. 073. Tributary No. 072. Petrol smell.
010	7/27/2016	10:02	Tributary	Natural channel			30.19172	-95.48064	390	Waypoint No. 074. Tributary No. 073.
011	7/27/2016	10:12	SW	Natural channel			30.19201	-95.48141	230	SW sample upstream of Gosling bridge. Chlorine smell.
012	7/27/2016	10:39	Tributary	Natural channel			30.19266	-95.48696	270	Waypoint No. 075. Cloudy water. Bear Branch Tributary.
013	7/27/2016	10:32	SW	Natural channel			30.19277	-95.48708	400	Waypoint No. 076. SW sample upstream of Bear Branch. Chlorine smell/wetland H_2S smell.
014	7/27/2016	10:57	Outfall	Natural channel			30.19528	-95.48886	20	Waypoint No. 077. SW sample at wastewater treatment outfall. Chlorine smell.
015	7/27/2016	11:10	SW	Natural channel			30.195927	-95.48851	260	SW sample upstream of wastewater treatment outfall.

Appendix C: Bacteria Source Identification Report

Bacteria Source Identification Report

BIG's Top Five Most and Top Five Least Impaired Water Bodies Project

Galveston Bay Estuary Program
A PROGRAM OF THE TCEQ

H-GAC Water Resources

TCEQ

Bacteria Source Identification Report

BIG's Top Five Most and Top Five Least Impaired Water Bodies Project

Prepared for:

Galveston Bay Estuary Program
Texas Commission on Environmental Quality
Local Jurisdictions

Prepared by:

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Table of Contents

Introduction

In the Houston-Galveston region, approximately 41% of stream miles exceed state water quality standards for bacteria. That equates to over 6,500 miles of streams and shoreline that pose a risk to human health during recreational activities and ingestion of untreated waters. There have been several initiatives throughout the region to address this issue. One of the more robust efforts includes implementation plan (I-Plan) development by the Bacteria Implementation Group (BIG), a partnership of government, business, and community leaders, that address elevated levels of bacteria in 72 bacteria-impaired stream segments in the Houston-Galveston region. The *BIG's Top Five Most and Top Five Least Impaired Water Bodies* project was developed as a result of the BIG's tracking of bacteria levels and development of the Top 10 Most and Top 10 Least Impaired Water Bodies lists. These lists identified the 10 waterways with the highest bacteria concentrations above the state standard and the 10 closest to meeting state water quality standards.

The purpose of *BIG's Top Five Most and Top Five Least Impaired Water Bodies* project is to investigate sources of bacteria in select AUs from the BIG's Top 10 Most and Top 10 Least lists, and to eliminate the sources by working with local jurisdictions. Focusing on the most and least bacteria-impaired waterways increases the potential for significantly reducing bacteria levels and ultimately removing streams from the state's list of bacteria-impaired waterways. The Houston-Galveston Area Council (H-GAC) is designated as the lead agency responsible for administration of the *BIG's Top Five Most and Top Five Least Impaired Water Bodies* project.

The project has been split into phases, Phase I, Phase II, and Phase III. The initial phase included prioritization of the BIG's Top 10 Most and Top 10 Least Impaired Water Bodies lists based on desktop reviews, analysis of preexisting data, and input from a technical workgroup made up of water resource professionals and representatives from local jurisdictions. Table 1 lists the Top 2 Most and Top 2 Least Impaired Water Bodies that were selected based on Phase I analysis and input. Refer to H-GAC's Preliminary Action Report for more information about how AUs were prioritized for this project.

TABLE 8. TOP 2 MOST AND TOP 2 LEAST IMPAIRED WATER BODIES SELECTED FOR BACTERIA SOURCE IDENTIFICATION.

Top 2 Most Impaired Water Bodies	Top 2 Least Impaired Water Bodies
Little White Oak Bayou (1013A_01)[1]	Upper Panther Branch (1008B_02)
Rummel Creek (1014N_01)	Canal C-147 (1007A_01)

[1]*Identification number included in parentheses represent TCEQ segment AUs.*

The following report summarizes the Phase II assessment and bacteria source identification for the four AUs in Table 1. The information contained in this report is intended to assist local jurisdictions in the identification and further investigation of illicit discharges and other significant sources of bacteria impacting the water bodies discussed herein. H-GAC will not correct the sources but will work with local jurisdictions to remove and/or eliminate the sources identified in this report.

Phase I Bacteria Screening & Station Selection

The Phase I bacteria screening process included exhaustive on the ground surveys where each of the four selected AUs were investigated, all outfalls were documented, and initial bacteria samples were collected from discharging outfalls, tributaries, and surface waters. This initial phase of bacteria screening was intended to provide baseline data used to identify potential illicit discharges, hot spots, and areas of greatest concern for each of the four AUs surveyed.

Phase I samples were analyzed using the Coliscan Easygel petri dish method to test for *E.coli* concentrations by counting the number of bacteria colonies that form on the Easygel medium (Figures 1 and 2). Two dilutions of each sample were tested using this methodology and the average bacteria concentration was reported. However, colony counting using this method provides limited measurement capability for *E.coli* due to the possibility of too numerous to count (TNTC) results that occur if greater than 200 colonies are formed on a dish. Results and findings from the bacteria screening process were used as a precursor to Phase II assessments where only the stations with the highest bacteria screening concentrations from Phase I were subject to follow up investigation. The following is a summary of Phase I bacteria screening results for the four selected AUs and details on the station selection process for Phase II investigations.

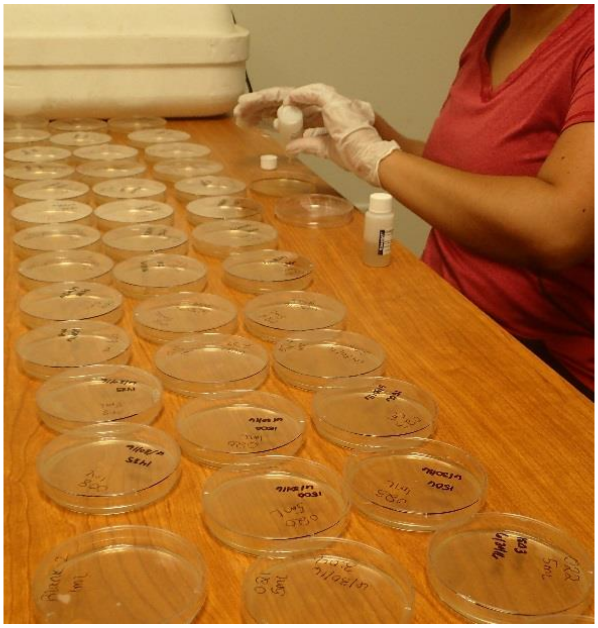

Figure 9. Coliscan Easygel set up

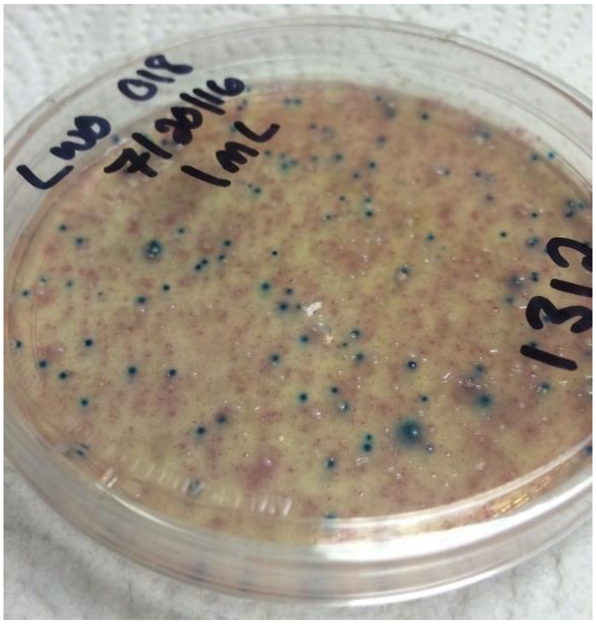

Figure 8. Bacteria Colony Counts using CoIiScan Easygel Methods

Canal C-147 (1007A_01)

A total of 21 bacteria screening samples were collected along Canal C-147 during the Phase I survey conducted on June 30, 2016. Based on the bacteria screening results, stations that were TNTC or measured greater than 600 cfu/100mL were flagged as significant sources of bacteria subject to further sampling and investigation during Phase II. Refer to Table 2 for a list of chosen Canal C-147 stations and their initial bacteria screening *E.coli* concentrations. Sample numbers from Phase I are re-used for Phase II assessments to ensure facilitated tracking of sample locations.

Table 9. Phase I Bacteria Screening Stations Chosen for Follow Up Phase II Investigations

Water Body	Survey Date	Sample No.	Sample Type	*E.coli* (cfu/100mL)
Canal C-147 (1007A_01)	06/30/2016	8	Outfall	800
Canal C-147 (1007A_01)	06/30/2016	13	Outfall	TNTC
Canal C-147 (1007A_01)	06/30/2016	14	Outfall	1770
Canal C-147 (1007A_01)	06/30/2016	17	Tributary	TNTC
Canal C-147 (1007A_01)	06/30/2016	27	Outfall	2130

Upper Panther Branch (1008B_02)

A total of 15 bacteria screening samples were collected along Upper Panther Branch during the Phase I survey conducted on July 26 and 27, 2016. Based on the bacteria screening results, stations that measured greater than 500 cfu/100mL were flagged as significant sources of bacteria subject to further sampling and investigation during Phase II. Refer to Table 3 for a list of chosen Upper Panther Branch stations and their initial bacteria screening *E.coli* concentrations. Sample numbers from Phase I are re-used for Phase II assessments to ensure facilitated tracking of sample locations.

Table 10. Phase I Bacteria Screening stations chosen for follow up Phase II investigations

Water Body	Survey Date	Sample No.	Sample Type	*E.coli* (cfu/100mL)
Upper Panther Branch (1008B_02)	07/26/2016	3	Tributary	3420
Upper Panther Branch (1008B_02)	07/26/2016	6	Tributary	580
Upper Panther Branch (1008B_02)	07/27/2016	9	Tributary	1040

Little White Oak Bayou (1013A_01)

A total of 25 bacteria screening samples were collected during the Phase I Little White Oak survey conducted on July 13, 18, and 20, 2016. Due to the significant number of extremely high *E.coli* concentrations found throughout this AU during the screening process, the City of Houston was consulted during the station selection process to help prioritize areas that should be further investigated during Phase II. Based on the knowledge and interests communicated by City of Houston personnel, a total of 7 stations were chosen for follow up monitoring at Little White Oak Bayou (refer to Phase II section for more details). Table 4 lists the chosen stations and their initial bacteria screening *E.coli* concentrations. Sample numbers from Phase I are re-used for Phase II assessments to ensure facilitated tracking of sample locations.

Table 11. Phase I Bacteria Screening stations chosen for follow up Phase II investigations

Water Body	Survey Date	Sample No.	Sample Type	*E.coli* (cfu/100mL)
Little White Oak Bayou (1013A_01)	07/18/2016	8	Outfall	0
Little White Oak Bayou (1013A_01)	07/18/2016	10	Outfall	TNTC
Little White Oak Bayou (1013A_01)	07/18/2016	15	Surface Water	TNTC
Little White Oak Bayou (1013A_01)	07/18/2016	16	Surface Water	TNTC
Little White Oak Bayou (1013A_01)	07/20/2016	17	Surface Water	10,900
Little White Oak Bayou (1013A_01)	07/20/2016	18	Outfall	13,300
Little White Oak Bayou (1013A_01)	07/20/2016	25	Surface Water	TNTC

Rummel Creek (1014N_01)

A total of 13 bacteria screening samples were collected during the Phase I Rummel Creek survey conducted on July 11, 2016. Based on Phase I results, areas that measured greater than 500 cfu/100mL were flagged as significant sources of bacteria subject to further sampling and investigation during Phase II. Refer to Table 5 for a list of chosen Rummel Creek stations and their initial bacteria screening *E.coli* concentrations. Multiple samples were collected at the downstream end of Rummel Creek during Phase I that had bacteria concentrations ranging from 500 to 750 cfu/100mL. Station 34 was chosen as the representative downstream station for Phase II investigations due to accessibility factors. Sample numbers from Phase I are re-used for Phase II assessments to ensure facilitated tracking of sample locations.

Table 12. Phase I Bacteria Screening stations chosen for follow up Phase II investigations

Water Body	Survey Date	Sample No.	Sample Type	*E.coli* (cfu/100mL)
Rummel Creek (1014N_01)	07/11/2016	34	Surface Water	525
Rummel Creek (1014N_01)	07/11/2016	36	Outfall	2275
Rummel Creek (1014N_01)	07/11/2016	40	Surface Water	925

Phase II Investigations

Phase II investigations focused on areas in the prioritized AUs that had the highest bacteria screening concentrations or the greatest level of interest expressed by the technical workgroup and local jurisdictions. Sample collection during Phase II was intended to further refine source identification and aid in tracking the sources of bacteria impairment up the tributaries and ditches to the greatest extent practicable. Phase II investigations included three main components:

1) Collection of wet weather and dry weather samples at each Phase II station.
2) Bacteria samples analyzed at a NELAP certified laboratory using the IDEXX Colilert method.
3) Collection of field water quality data using a multiparameter datasonde to supplement the bacteria samples collected at each Phase II station.

All dry weather samples were collected following a minimum 72-hour antecedent dry period. Wet weather sampling was conducted during or immediately after a rain event with greater than 0.50 inches of rain following a minimum 72-hr antecedent dry period. The Harris County Flood Warning System website was used to determine if a monitoring event qualified as either wet or dry weather.

In an effort to improve source identification, selected monitoring locations from Phase I were further investigated and new sample stations were created to assess the areas surrounding the original station location. For example, if station number 14 was flagged during Phase I for follow up investigation, additional samples collected upstream or downstream of this location during Phase II are labeled as 14.1, 14.2, etc.

The following sections provide descriptions for each AU surveyed and summarize the findings associated with each Phase II sample location.

Canal C-147 (1007A_01)

Canal C-147, TCEQ segment AU 1007A_01, is located in an urban area of southwest Houston in Harris County. Major thoroughfares within the 2.63 square mile watershed area include West Fuqua Street and the Sam Houston Tollway. Primary land uses are residential and light commercial with auto body shops, small car dealerships, and restaurants representing the majority of businesses in the area.

Canal C-147 has been on TCEQ’s 303(d) list of impaired waterways for bacteria since 2006. It is also included as the fourth AU on the BIG’s Top 10 Least Impaired Water Bodies list from 2015. With a seven-year *E.coli* geometric mean value of 157 MPN/100mL, this AU is close to meeting the state water quality standard of 126 MPN/100mL and being removed from TCEQ’s 303(d) list all together. Figure 3 shows the wet weather and dry weather bacteria concentrations from the Phase II Canal C-147 surveys by sample number. Figure 4 illustrates the location of Phase II sample stations for Canal C-147.

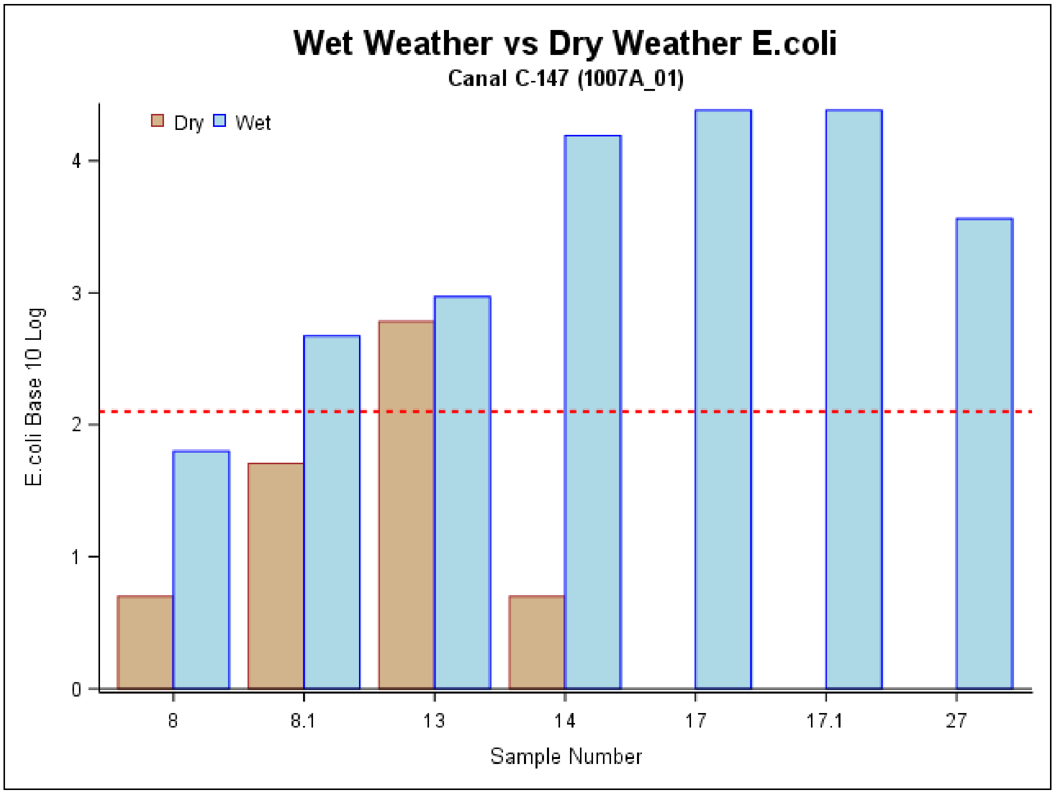

Figure 10. Wet weather and dry weather e.coli concentrations from Phase II Canal C-147 surveys. Red dotted line represents the state water quality standard for bacteria.

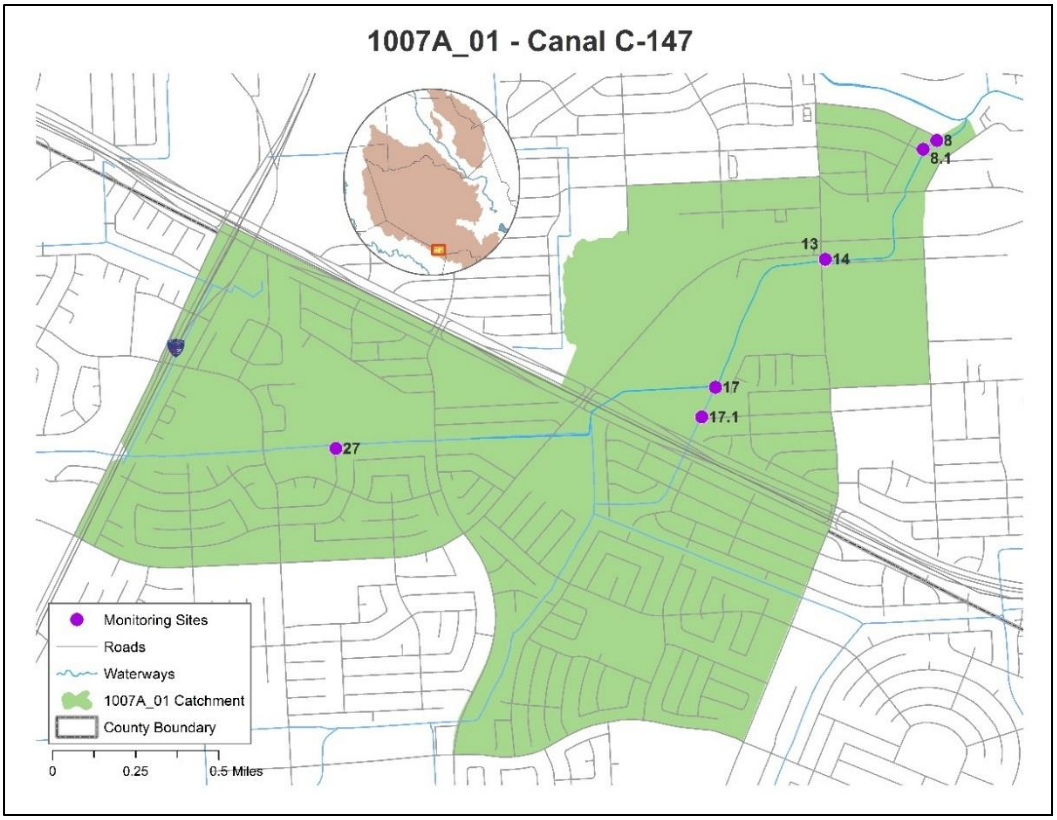

Figure 11. Phase II Canal C-147 monitoring stations

Station 8

Station 8 is a metal outfall located at the downstream end of the Canal C-147 watershed boundary adjacent to a residential neighborhood and a number of auto body junk yards. Illegal dumping of trash, tires, and large debris was common in the area (Figure 5). Figures 6 and 7 are photos of the outfall taken during the dry weather sampling event. Based on these results, the City of Houston initiated an investigation at this outfall location in September 2016 and detected a potable water leak. Information about corrective actions related to the potable leak are unknown. However, Phase II investigations resulted in wet and dry weather samples with *E.coli* concentrations that are now in compliance with state standards (Table 6).

Figure 12

Figure 13

Figure 14

TABLE 13. PHASE II WATER QUALITY DATA FOR CANAL C-147 STATION 8

Parameter	Wet Weather	Dry Weather
Latitude	29.61648	
Longitude	-95.45901	
Survey Date	11/7/2016	10/19/2016
Days Since Last Rain	1	8
Total Depth (m)	0.14	0.07
Temperature (°C)	23.19	26.79
Specific Conductance (µs/cm)	291	771.2
pH (standard units)	7.53	7.9
Dissolved Oxygen (mg/L)	7.8	10.17
E.coli (MPN/100mL)	63	<10
Turbidity (ntu)	>1.2	>1.2
Observed Turbidity	Low	Low
Water Clarity	Excellent	Excellent
Water Color	Brownish	Clear
Water Odor	None	None
Present Weather	Cloudy	Partly Cloudy
Wind Intensity	Calm	Calm
Water Surface	Ripples	Ripples
Flow Severity	Normal	Normal

Station 8.1

Station 8.1 is a metal outfall located approximately 85 meters upstream of the station 8 outfall (Figure 8). This outfall was not discharging during the Phase I survey so no bacteria screening samples were collected. However, during the Phase II survey, this outfall was intermittently discharging water during both wet and dry weather sampling events. The outfall is located directly underneath the Tiffany Street bridge across the street from a number of junk yards and residential homes. H-GAC field staff attempted to follow the outfall pipe to its origin and found that it is connected to the ditch running along the north side of Tiffany Street (Figures 9 and 10).

Samples were collected directly from the discharging outfall during both wet and dry weather events. Only the wet weather sample had an *E.coli* concentration that exceeded the state water quality standard of 126 MPN/100mL (Table 7).

Figure 15

Figure 16

Figure 17

TABLE 14. PHASE II WATER QUALITY DATA FOR CANAL C-147 STATION 8.1

Parameter	Wet Weather	Dry Weather
Latitude	29.61612	
Longitude	-95.45970	
Survey Date	11/7/2016	10/19/2016
Days Since Last Rain	1	8
Total Depth (m)	0.05	0.03
Temperature (°C)	23.04	-
Specific Conductance (µs/cm)	288.3	-
pH (standard units)	7.61	-
Dissolved Oxygen (mg/L)	7.7	-
E.coli (MPN/100mL)	471	51
Turbidity (ntu)	>1.2	>1.2
Observed Turbidity	Low	Low
Water Clarity	Excellent	Excellent
Water Color	Brownish	Clear
Water Odor	None	Musky/Earthy
Present Weather	Cloudy	Partly Cloudy
Wind Intensity	Calm	Calm
Water Surface	Ripples	Ripples
Flow Severity	Normal	Normal

Station 13

Station 13 is a large round storm drain located on the right side of Canal C-147 at the South Post Oak Road bridge directly across from station 14 (Figures 11 and 12). A tire shop and car dealership are located adjacent to Canal C-147 at this location. The bacteria screening *E.coli* concentration at this station was TNTC, representing one of the highest bacteria sources to Canal C-147 identified during Phase I of this project.

Both wet weather and dry weather samples collected at this location had *E.coli* concentrations that exceeded the state water quality standard of 126 MPN/100mL (Table 8). The high bacteria concentrations detected during both wet and dry weather events implies there is a consistent source of bacteria discharging into Canal C-147 at this location regardless of weather conditions. Schools of fish were observed swimming in the storm drain during all sampling events. Additionally, the pH level inside the storm drain during the wet weather event was significantly higher than levels outside the storm drain. Further investigation is recommended at this station.

Figure 19

Figure 18

Table 15. Phase II water quality data for Canal C-147 STATION 13

Parameter	Wet Weather	Dry Weather
Latitude	29.61142	
Longitude	-95.46475	
Survey Date	11/7/2016	10/19/2016
Days Since Last Rain	1	8
Total Depth (m)	0.23	0.05
Temperature (°C)	23.45	24.95
Specific Conductance (µs/cm)	201.2	1020
pH (standard units)	9.67	7.7
Dissolved Oxygen (mg/L)	6.32	5.44
E.coli (MPN/100mL)	934	605
Turbidity (ntu)	0.28	0.53
Observed Turbidity	High	Medium
Water Clarity	Poor	Fair
Water Color	Brownish	Brownish
Water Odor	None	None
Present Weather	Cloudy	Partly Cloudy
Wind Intensity	Calm	Calm
Water Surface	Ripples	Calm
Flow Severity	Normal	Normal

Station 14

Station 14 is a large square storm drain located on the left side of Canal C-147 at the South Post Oak Street bridge directly across from station 13. A tire shop and car dealership are located adjacent to Canal C-147 at this location.

During the dry weather event, there was only a shallow trickle of water discharging from the storm drain (Figures 13 and 14). The water appeared clean and colorless with no particular odor, but was too shallow for the collection of field water quality data using the multiparameter data sonde. There was a significant difference in *E.coli* concentrations between the wet weather and dry weather sampling events (Table 9). Further investigation is recommended at this location to identify the cause for this variation during different weather conditions.

Figure 21

Figure 20

TABLE 16. PHASE II WATER QUALITY DATA FOR CANAL C-147 STATION 14.

Parameter	Wet Weather	Dry Weather
Latitude	29.61145	
Longitude	-95.46475	
Survey Date	11/7/2016	10/19/2016
Days Since Last Rain	1	8
Total Depth (m)	0.06	<0.01
Temperature (°C)	23.31	-
Specific Conductance (μs/cm)	156	-
pH (standard units)	8.11	-
Dissolved Oxygen (mg/L)	7.46	-
E.coli (MPN/100mL)	15,500	<10
Turbidity (ntu)	0.72	>1.2
Observed Turbidity	Medium	Low
Water Clarity	Fair	Excellent
Water Color	Brownish	Clear
Water Odor	None	None
Present Weather	Cloudy	Partly Cloudy
Wind Intensity	Calm	Calm
Water Surface	Ripples	Calm
Flow Severity	Normal	Low

Station 17 and 17.1

Station 17 is a tributary of Canal C-147 located approximately 600 meters northeast of the intersection of Sam Houston Tollway and West Fuqua Street. The tributary primarily runs through dense residential neighborhoods.

The tributary was dry during the dry weather event on October 19, 2016, so no dry weather sample was collected at this location (Figure 15). Wet weather samples were collected on November 7, 2016 following a significant rain event. The sample for station 17 was collected at the confluence of the tributary with Canal C-147 (Figure 16). A second sample was collected at station 17.1 located approximately 150 meters upstream of station 17. Both wet weather samples collected along this tributary resulted in an *E.coli* concentration of 24,200 MPN/100mL. This station was the most significant source of bacteria to Canal C-147 identified during Phase I and Phase II of the project. Further investigation is recommended.

Figure 22

Figure 23

Table 17. Wet weather water quality data for Canal C-147 stations 17 and 17.1

Parameter	Station 17	Station 17.1
Latitude	29.60601	29.60473
Longitude	-95.47043	-95.47116
Survey Date	11/7/2016	11/7/2016
Days Since Last Rain	1	1
Total Depth (m)	0.21	0.13
Temperature (°C)	22.63	22.67
Specific Conductance (µs/cm)	204	188.4
pH (standard units)	7.27	7.25
Dissolved Oxygen (mg/L)	2.99	1.28
E.coli (MPN/100mL)	24,200	24,200
Turbidity (ntu)	0.35	0.51
Observed Turbidity	High	Medium
Water Clarity	Fair	Fair
Water Color	Brownish	Brownish
Water Odor	None	None
Present Weather	Partly Cloudy	Partly Cloudy
Wind Intensity	Calm	Calm
Water Surface	Calm	Calm
Flow Severity	Normal	Normal

Station 27

Station 27 is a metal outfall located on the right bank of Canal C-147 between Blue Ridge Road and Chimney Rock Road. The easiest access point is through a residential neighborhood at the end of Ohara Drive.

There was no discharge observed during the dry weather event conducted on October 19, 2016 (Figures 17 and 18) resulting in no dry weather samples collected at this location during Phase II investigations. A wet weather sample was collected on November 7, 2016. A sample was collected directly from the outfall and field water quality data from the data sonde were taken from the shallow pool of water accumulated in front of the outfall. The resulting bacteria concentration was 3,650 MPN/100mL which is significantly greater than the state water quality standard for *E.coli* (Table 11).

Figure 25

Figure 24

TABLE 18. WATER QUALITY DATA FOR CANAL C-147 STATION 27.

Parameter	Wet Weather	Dry Weather
Latitude	29.60384	
Longitude	-95.48948	
Survey Date	11/7/2016	10/19/2016
Days Since Last Rain	1	8
Total Depth (m)	0.25	0
Temperature (°C)	22.16	-
Specific Conductance (µs/cm)	109.3	-
pH (standard units)	7.71	-
Dissolved Oxygen (mg/L)	6.64	-
E.coli (MPN/100mL)	3,650	-
Turbidity (ntu)	0.91	-
Observed Turbidity	Low	-
Water Clarity	Good	-
Water Color	Brownish	-
Water Odor	None	-
Present Weather	Partly Cloudy	Partly Cloudy
Wind Intensity	Calm	Calm
Water Surface	Calm	-
Flow Severity	Normal	Dry

Upper Panther Branch (1008B_02)

Upper Panther Branch, TCEQ segment AU 1008B_02, is located in the Woodlands area west of Interstate 45 off Research Forest Drive in Montgomery County. The watershed area is approximately 2.01 square miles with primarily wooded and natural terrain lining the waterway. All outfalls and storm drains observed in the Upper Panther Branch watershed during the Phase I and II surveys were designed to discharge from an outfall pipe approximately 50 meters or more away from Upper Panther Branch. The water flows over rocky or natural buffer areas before discharging into the main stream. These discharges were classified as tributaries of Upper Panther Branch during the surveys conducted for this project. Land use within the watershed is primarily residential with recreation centers, sporting facilities, and golf courses representing key facilities and businesses in the area.

Upper Panther Branch has been listed as impaired for bacteria on the Texas Integrated Report (IR) since 2006. It is the first AU on the BIG's Top 10 Least Impaired Water Bodies list from 2015, meaning that Upper Panther Branch is the AU on the list closest to meeting the state water quality standard for bacteria. The seven-year *E.coli* geometric mean value for Upper Panther Branch is 133 MPN/100mL compared to the *E.coli* water quality standard of 126 MPN/100mL. Figure 19 shows the wet weather and dry weather bacteria concentrations from the Phase II Upper Panther Branch surveys by sample number. Figure 20 illustrates the location of Phase II sample stations for Upper Panther Branch.

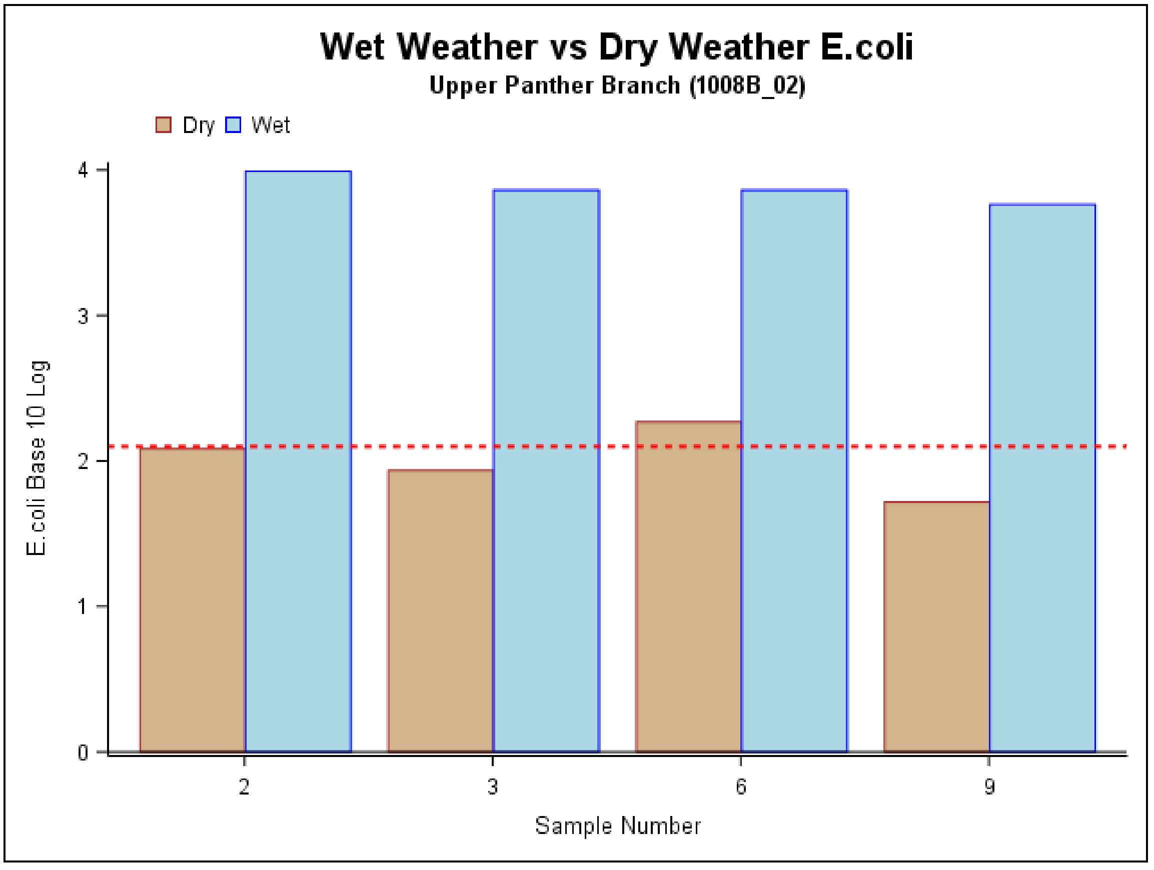

FIGURE 26. WET WEATHER AND DRY WEATHER *E.COLI* CONCENTRATIONS FROM PHASE II UPPER PANTHER BRANCH SURVEYS. RED DOTTED LINE REPRESENTS THE STATE WATER QUALITY STANDARD FOR BACTERIA.

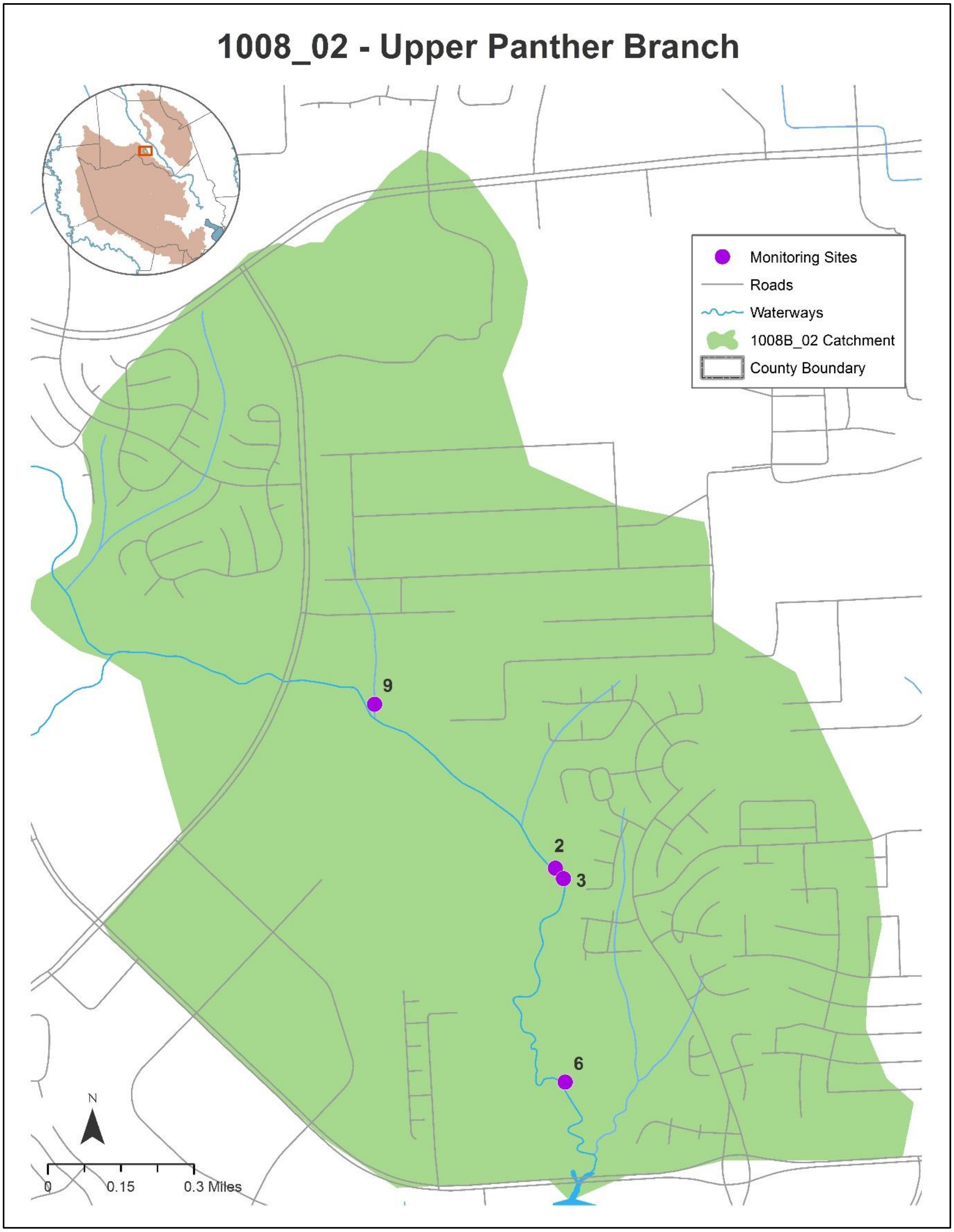

Figure 27. Phase II Upper Panther Branch monitoring stations

Station 2

Station 2 is located directly upstream of the station 3 tributary. Station 3 was identified as a potential source of bacteria to Upper Panther Branch during Phase I investigations. Station 2 was sampled during Phase II in an effort to compare upstream bacteria concentrations with samples collected from station 3.

A chlorine odor was detected during the Upper Panther Branch Phase I and Phase II investigations. Chlorine test strips detected concentrations measuring greater than 0.5 mg/L at this location during the dry weather sampling event (Figure 21). The local wastewater treatment facility was notified, but a source for the chlorine is still unknown.

A dry weather sample was collected on September 28, 2016 (Figure 22) resulting in an *E.coli* concentration of 121 MPN/100mL which is just below the state water quality standard of 126 MPN/100mL. The wet weather sample collected on February 15, 2017 had a much greater *E.coli* concentration measuring at 9,800 MPN/100mL (Table 12).

Figure 28

Figure 29

TABLE 19. WATER QUALITY DATA FOR UPPER PANTHER BRANCH STATION 2.

Parameter	Wet Weather	Dry Weather
Latitude	30.18568	
Longitude	-95.47247	
Survey Date	2/15/2017	09/28/2016
Days Since Last Rain	1	3
Total Depth (m)	0.42	0.41
Temperature (°C)	16.4	26.04
Specific Conductance (µs/cm)	247.3	432.7
pH (standard units)	7.4	6.99
Dissolved Oxygen (mg/L)	9.65	5.77
E.coli (MPN/100mL)	9,800	121
Turbidity (ntu)	0.24	0.34
Observed Turbidity	Medium	Medium
Water Clarity	Fair	Fair
Water Color	Brownish/ Reddish	Brownish
Water Odor	None	Chlorine
Present Weather	Partly Cloudy	Clear
Wind Intensity	Calm	Calm
Water Surface	Ripples	Ripples
Flow Severity	High	Normal

Station 3

Station 3 is a tributary of Upper Panther Branch located adjacent to a residential neighborhood off Grogans Mill Road at Tapestry Park Drive. The tributary's confluence with Upper Panther Branch is approximately 120 meters west of where the water discharges from a storm drain. The water flows over a grassy buffer area before discharging into Upper Panther Branch.

The dry weather sample collected on September 28 (Figure 23) was in compliance with state water quality standards for bacteria (Table 13). Chlorine test strips detected a chlorine level of approximately 0.65 mg/L at this location during the dry weather event. The wet weather event conducted on February 15, 2017 (Figure 24) resulted in a significantly higher bacteria concentration with levels measuring at 7,270 MPN/100mL (Table 13).

Figure 30

Figure 31

TABLE 20. WATER QUALITY DATA FOR UPPER PANTHER BRANCH STATION 3.

Parameter	Wet Weather	Dry Weather
Latitude	30.18542	
Longitude	-95.47245	
Survey Date	2/15/2017	09/28/2016
Days Since Last Rain	1	3
Total Depth (m)	0.43	0.28
Temperature (°C)	15.81	25.95
Specific Conductance (µs/cm)	299.1	433.4
pH (standard units)	7.41	7.04
Dissolved Oxygen (mg/L)	8.38	5.66
E.coli (MPN/100mL)	7,270	86
Turbidity (ntu)	0.24	0.45
Observed Turbidity	Medium	Medium
Water Clarity	Fair	Fair
Water Color	Brownish	Brownish
Water Odor	None	Chlorine
Present Weather	Partly Cloudy	Clear
Wind Intensity	Calm	Calm
Water Surface	Ripples	Ripples
Flow Severity	High	Normal

Station 6

Station 6 is a tributary of Upper Panther Branch located adjacent to a gated community off Grogans Mill Road and North Parkgate Circle. The tributary's confluence with Upper Panther Branch is approximately 55 meters southwest of where the water discharges from a storm drain. The water flows over rocky and natural terrain before discharging into Upper Panther Branch.

The dry weather sample collected on September 28 (Figure 25) was just above the state water quality standard for *E.coli* measuring at 185 MPN/100mL (Table 14). The water was consistently red in color at this location during all dry weather surveys conducted for this project. No chlorine was detected at this station. The wet weather event conducted on February 15, 2017 (Figure 26) resulted in the significantly higher bacteria concentration of 7,270 MPN/100mL (Table 14).

Figure 32

Figure 33

TABLE 21. WATER QUALITY DATA FOR UPPER PANTHER BRANCH STATION 6.

Parameter	Wet Weather	Dry Weather
Latitude	30.17967	
Longitude	-95.47174	
Survey Date	2/15/2017	09/28/2016
Days Since Last Rain	1	3
Total Depth (m)	0.19	0.23
Temperature (°C)	15.41	27.1
Specific Conductance (µs/cm)	471.9	941.2
pH (standard units)	7.55	8.09
Dissolved Oxygen (mg/L)	9.86	5.75
E.coli (MPN/100mL)	7,270	185
Turbidity (ntu)	0.27	0.4
Observed Turbidity	Medium	Medium
Water Clarity	Fair	Fair
Water Color	Brownish/ Reddish	Reddish
Water Odor	None	None
Present Weather	Partly Cloudy	Clear
Wind Intensity	Calm	Calm
Water Surface	Ripples	Calm
Flow Severity	Normal	Normal

Station 9

Station 9 is a tributary of Upper Panther Branch located adjacent to a sporting facility off Marisco Place. The tributary's confluence with Upper Panther Branch is approximately 250 meters south of the facility which includes tennis courts, soccer and baseball fields, and concession stands. The tributary continues to the north of the sporting facility into a neighborhood that is serviced through on-site sewage facilities (OSSFs).

The dry weather sample collected on September 28 (Figure 27) was in compliance with state water quality standards for bacteria (Table 15). The water had a strong chemical odor during this sampling event and chlorine test strips detected a chlorine concentration of approximately 0.1 mg/L. The wet weather event conducted on February 15, 2017 (Figure 28) resulted in a bacteria concentration of 5,790 MPN/100mL (Table 15).

Figure 34

Figure 35

TABLE 22. WATER QUALITY DATA FOR UPPER PANTHER BRANCH STATION 9.

Parameter	Wet Weather	Dry Weather
Latitude	30.19107	
Longitude	-95.47797	
Survey Date	2/15/2017	09/28/2016
Days Since Last Rain	1	3
Total Depth (m)	0.19	0.04
Temperature (°C)	14.31	26.8
Specific Conductance (µs/cm)	168.7	50.1
pH (standard units)	7.27	7.12
Dissolved Oxygen (mg/L)	13.11	5.98
E.coli (MPN/100mL)	5,790	52
Turbidity (ntu)	0.55	0.68
Observed Turbidity	Medium	Low
Water Clarity	Fair	Good
Water Color	Brownish	Brownish
Water Odor	None	Oily/Chemical/ Chlorine
Present Weather	Partly Cloudy	Clear
Wind Intensity	Calm	Calm
Water Surface	Calm	Ripples
Flow Severity	High	Normal

Little White Oak Bayou (1013A_01)

Little White Oak Bayou, TCEQ segment AU 1013A_01, is located in a highly urbanized area of central Houston in Harris County. The waterway is located at the intersection of the IH-610 North Loop and I-45 with a watershed area of 7.29 square miles. Significant amounts of litter and debris was commonly observed throughout the watershed area, especially in portions of the waterway that are difficult to access. Primary land uses are residential and commercial with much of the area under transition from older homes and neighborhoods to updated real estate and new development of upscale apartment complexes.

Little White Oak Bayou has been on TCEQ's 303(d) list of impaired waterways for bacteria since 2002. It is also included as the ninth AU on the BIG's Top 10 Most Impaired Water Bodies list from 2015. With a seven-year *E.coli* geometric mean value of 1,975 MPN/100mL, this AU is far from meeting the state water quality standard of 126 MPN/100mL. Figure 29 shows the wet weather and dry weather bacteria concentrations from the Phase II Little White Oak Bayou surveys by sample number and figure 30 illustrates the location of Phase II sample stations.

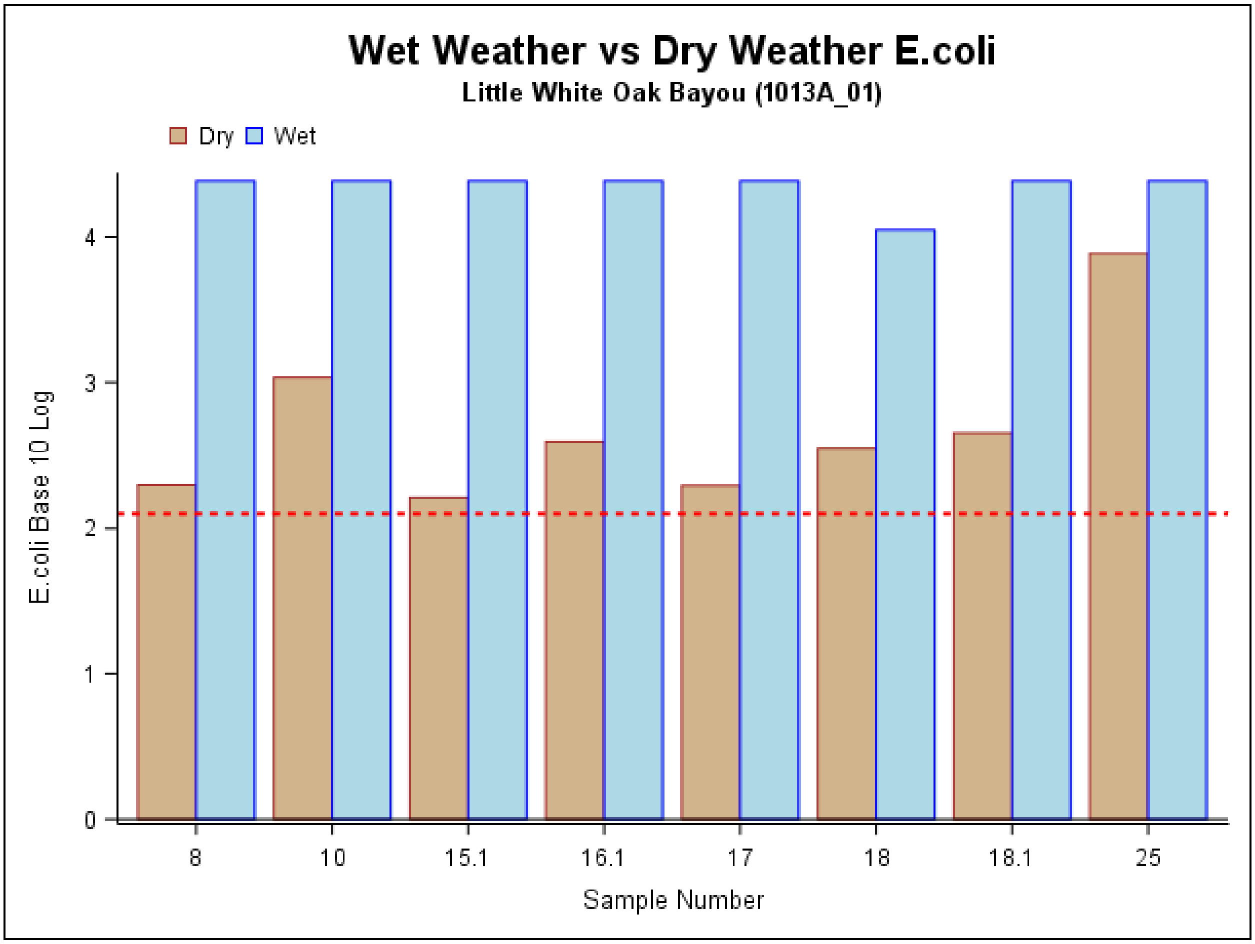

FIGURE 36. WET WEATHER AND DRY WEATHER *E.COLI* CONCENTRATIONS FROM PHASE II LITTLE WHITE OAK BAYOU SURVEYS. RED DOTTED LINE REPRESENTS THE STATE WATER QUALITY STANDARD FOR BACTERIA.

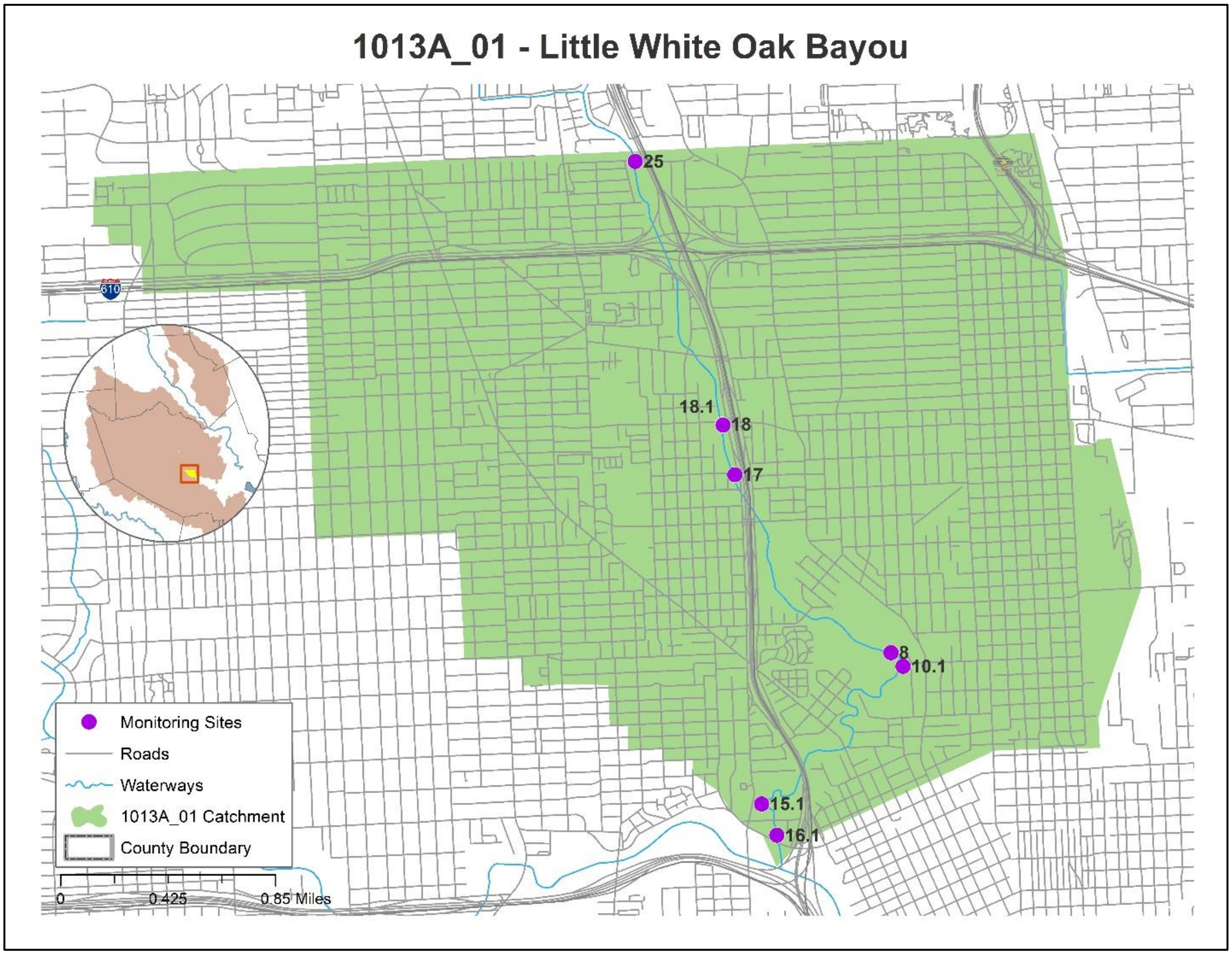

FIGURE 37. PHASE II LITTLE WHITE OAK BAYOU MONITORING STATIONS

Station 8

Station 8 is a large outfall located at the southern end of Moody Park adjacent to a parking lot off Fulton Street. The outfall was consistently discharging large volumes of water into Little White Oak Bayou during all Phase I and II investigations (Figures 31-32). Homeless activity was commonly observed at this location.

Samples were collected directly downstream of the outfall during Phase II investigations (Figure 33). The dry weather sample collected on October 11, 2016 was just over the state water quality standard for bacteria measuring at 199 MPN/100mL (Table 16). However, the wet weather sample collected on February 15, 2017 resulted in the much higher bacteria concentration of 24,200 MPN/100mL.

Figure 38

Figure 39

Figure 40

TABLE 23. WATER QUALITY DATA FOR LITTLE WHITE OAK BAYOU STATION 8.

Parameter	Wet Weather	Dry Weather
Latitude	29.79033	
Longitude	-95.36252	
Survey Date	2/15/2017	10/11/2016
Days Since Last Rain	1	16
Total Depth (m)	0.19	0.43
Temperature (°C)	17.57	24.95
Specific Conductance (µs/cm)	414.8	772.9
pH (standard units)	7.72	7.59
Dissolved Oxygen (mg/L)	7.62	6.42
E.coli (MPN/100mL)	24,200	199
Turbidity (ntu)	0.45	0.85
Observed Turbidity	Medium	Low
Water Clarity	Fair	Good
Water Color	Brownish	Brownish
Water Odor	None	None
Present Weather	Cloudy	Partly Cloudy
Wind Intensity	Calm	Slight
Water Surface	Ripples	Calm
Flow Severity	Normal	Normal

Station 10.1

Figure 41

Station 10 is a large storm drain located at Hays Street next to an apartment complex (Figure 34). Litter and debris build up is significant at this location, especially after rain events, with trash from upstream getting trapped at the bend in Little White Oak Bayou located at this station (Figure 35-36).

Samples were collected directly downstream of the storm drain during Phase II investigations. The dry weather sample collected on October 11, 2016 resulted in an *E.coli* concentration of 1,080 MPN/100mL, making it one of the highest bacteria sources to Little White Oak Bayou during the dry weather event (Table 17). However, the wet weather sample collected on February 15, 2017 resulted in a much higher bacteria concentration of 24,200 MPN/100mL.

Figure 43

Figure 42

TABLE 24. WATER QUALITY DATA FOR LITTLE WHITE OAK BAYOU STATION 10.1

Parameter	Wet Weather	Dry Weather
Latitude	29.78984	
Longitude	-95.36163	
Survey Date	2/15/2017	10/11/2016
Days Since Last Rain	1	16
Total Depth (m)	0.28	0.24
Temperature (°C)	16.46	25.13
Specific Conductance (µs/cm)	309.5	761.0
pH (standard units)	7.62	7.56
Dissolved Oxygen (mg/L)	8.35	6.83
E.coli (MPN/100mL)	24,200	1,080
Turbidity (ntu)	0.47	0.75
Observed Turbidity	Medium	Medium
Water Clarity	Fair	Good
Water Color	Brownish	Brownish
Water Odor	None	None
Present Weather	Cloudy	Cloudy
Wind Intensity	Calm	Calm
Water Surface	Ripples	Calm
Flow Severity	Normal	Normal

Station 15.1

Station 15.1 is located approximately 110 meters upstream of Wrightwood Street. A sewer system junction box is located at Wrightwood Street at Little White Oak Bayou that has had several overflow incidents during wet weather events. Stations 15.1 and 16.1 were investigated to identify the extent of contamination originating from this junction box (Figure 37).

The dry weather sample collected at this location on October 11, 2016 (Figure 38) resulted in an *E.coli* concentration of 161 MPN/100mL, slightly exceeding the state water quality standard. The wet weather was sample collected approximately 20 minutes after a significant rain event on February 14, 2017. The water level was high and large amounts of trash and debris were flowing with the water downstream (Figure 39). The *E.coli* concentration for the wet weather event was 24,200 MPN/100 mL, significantly higher than the dry weather concentration (Table 18).


Figure 44


Figure 45


Figure 46

TABLE 25. WATER QUALITY DATA FOR LITTLE WHITE OAK BAYOU STATION 15.1

Parameter	Wet Weather	Dry Weather
Latitude	29.78194	
Longitude	-95.37144	
Survey Date	2/14/2017	10/11/2016
Days Since Last Rain	<1	16
Total Depth (m)	0.53	0.41
Temperature (°C)	18.32	24.86
Specific Conductance (µs/cm)	150.6	741.7
pH (standard units)	7.81	7.82
Dissolved Oxygen (mg/L)	9.11	7.62
E.coli (MPN/100mL)	24,200	161
Turbidity (ntu)	0.07	0.46
Observed Turbidity	High	Medium
Water Clarity	Poor	Fair
Water Color	Brownish	Brownish
Water Odor	None	None
Present Weather	Cloudy	Partly Cloudy
Wind Intensity	Calm	Slight
Water Surface	Ripples	Calm
Flow Severity	High	Normal

Station 16.1

Station 16.1 is located approximately 85 meters downstream of the faulty sewer junction box at Wrightwood Street. The station is also adjacent to the White Oak walking and biking trail and a new up-scale apartment complex is currently under construction directly to the east of Little White Oak Bayou at this location.

The dry weather sample collected on October 11, 2016 (Figure 40) resulted in an *E.coli* concentration of 393 MPN/100mL. This concentration is more than twice the concentration observed upstream of the junction box. However, the wet weather sample collected on February 14, 2017 (Figure 41) had the same bacteria concentration as the sample collected upstream of the junction box (Table 19).

Figure 47

TABLE 26. WATER QUALITY DATA FOR LITTLE WHITE OAK BAYOU STATION 16.1

Parameter	Wet Weather	Dry Weather
Latitude	29.78012	
Longitude	-95.37051	
Survey Date	2/14/2017	10/11/2016
Days Since Last Rain	<1	16
Total Depth (m)	0.71	0.15
Temperature (°C)	18.14	25.13
Specific Conductance (µs/cm)	125.9	738.7
pH (standard units)	7.98	7.76
Dissolved Oxygen (mg/L)	9.36	6.89
E.coli (MPN/100mL)	24,200	393
Turbidity (ntu)	0.05	0.25
Observed Turbidity	High	Medium
Water Clarity	Poor	Fair
Water Color	Brownish	Brownish
Water Odor	Musky	Chlorine
Present Weather	Cloudy	Cloudy
Wind Intensity	Calm	Slight
Water Surface	Ripples	Calm
Flow Severity	High	Normal

Figure 48

Station 17

Station 17 is located at Vincent Street and Coronado Avenue directly upstream of where the waterway goes underground at I-45 (Figure 42). A faulty manhole was observed on the right bank approximately 52 meters upstream of this station. The manhole was about 6 feet above ground and the cement casing had a large hole. A hole in the ground was also observed next to the manhole with evidence of recent sewage overflows visible (Figure 43).

The dry weather sample collected on October 11, 2016 had an *E.coli* concentration of 197 MPN/100mL. The wet weather sample collected on February 15, 2017 was significantly higher at 24,200 MPN/100mL (Table 20).

Figure 49

Figure 50

TABLE 27. WATER QUALITY DATA FOR LITTLE WHITE OAK BAYOU STATION 17.

Parameter	Wet Weather	Dry Weather
Latitude	29.80083	
Longitude	-95.37273	
Survey Date	2/15/2017	10/11/2016
Days Since Last Rain	1	16
Total Depth (m)	0.46	0.55
Temperature (°C)	15.05	24.05
Specific Conductance (µs/cm)	311.4	792.0
pH (standard units)	7.51	7.46
Dissolved Oxygen (mg/L)	10.3	6.09
E.coli (MPN/100mL)	24,200	197
Turbidity (ntu)	0.55	0.35
Observed Turbidity	Medium	Medium
Water Clarity	Fair	Fair
Water Color	Brownish	Brownish
Water Odor	None	None
Present Weather	Partly Cloudy	Partly Cloudy
Wind Intensity	Calm	Calm
Water Surface	Ripples	Ripples
Flow Severity	Normal	Normal

Station 18

Station 18 is an outfall located on the left bank of Little White Oak Bayou to the south of the Cavalcade Street bridge (Figure 44). Homeless activity is common at this location with furniture and other debris observed on the bank (Figure 45). Alligator gar and other large fish species were observed at the mouth of this outfall during Phase I and Phase II investigations.

The dry weather sample collected on October 11, 2016 resulted in a bacteria concentration of 355 MPN/100mL. The wet weather sample collected on February 15, 2017 was significantly higher measuring at 11,200 MPN/100mL (Table 21). Although the wet weather sample concentration was slightly lower than the surface water samples collected upstream of this location, this outfall is still considered to be contributing a consistent amount of bacteria into Little White Oak Bayou regardless of weather conditions.

Figure 52

Figure 51

TABLE 28. WATER QUALITY DATA FOR LITTLE WHITE OAK BAYOU STATION 18.

Parameter	Wet Weather	Dry Weather
Latitude	29.80274	
Longitude	-95.37321	
Survey Date	2/15/2017	10/11/2016
Days Since Last Rain	1	16
Total Depth (m)	0.60	0.59
Temperature (°C)	19.0	25.71
Specific Conductance (µs/cm)	884.5	1080.0
pH (standard units)	7.66	7.43
Dissolved Oxygen (mg/L)	7.69	7.08
E.coli (MPN/100mL)	11,200	355
Turbidity (ntu)	0.82	>1.2
Observed Turbidity	Low	Low
Water Clarity	Good	Excellent
Water Color	Brownish	Brownish
Water Odor	None	None
Present Weather	Partly Cloudy	Partly Cloudy
Wind Intensity	Calm	Slight
Water Surface	Ripples	Calm
Flow Severity	Normal	Normal

Station 18.1

Station 18.1 is located directly upstream of outfall station 18 south of the Cavalcade Street bridge. A surface water sample was collected at this location to compare upstream bacteria levels to concentrations found at outfall 18.

Both the dry weather (Figure 46) and wet weather (Figure 47) bacteria concentrations were greater than levels found at outfall station 18.1 (Table 22) indicating that a more significant source of bacteria is located upstream of this location.

Figure 53

Figure 54

TABLE 29. WATER QUALITY DATA FOR LITTLE WHITE OAK BAYOU STATION 18.1.

Parameter	Wet Weather	Dry Weather
Latitude	29.80374	
Longitude	-95.37321	
Survey Date	2/15/2017	10/11/2016
Days Since Last Rain	1	16
Total Depth (m)	0.58	0.77
Temperature (°C)	15.17	24.04
Specific Conductance (µs/cm)	317.1	763.0
pH (standard units)	7.52	7.38
Dissolved Oxygen (mg/L)	8.17	6.53
E.coli (MPN/100mL)	24,200	450
Turbidity (ntu)	0.19	0.35
Observed Turbidity	Medium	Medium
Water Clarity	Fair	Fair
Water Color	Brownish	Brownish
Water Odor	None	None
Present Weather	Cloudy	Partly Cloudy
Wind Intensity	Slight	Calm
Water Surface	Calm	Calm
Flow Severity	Normal	Normal

Station 25

Station 25 is located directly downstream of the Stokes Street bridge at the upstream boundary of the Little White Oak Bayou watershed. This station was considered the largest contributor of bacteria to the waterway during the Phase I and Phase II investigations.

A dry weather sample was collected on October 11, 2016. At the time of sample collection, a strong odor of diesel was detected and an oily sheen was observed on the surface of the water (Figure 48). The *E.coli* concentration was 7,700 MPN/100mL which was the highest bacteria concentration collected during the dry weather event at Little White Oak Bayou. The wet weather sample collected on February 15, 2017 (Figure 49) resulted in a significantly higher bacteria concentration of 24,200 MPN/100mL. The same *E.coli* concentration was detected for all surface water samples collected on February 15, 2017 that were located downstream of this station. Further investigation upstream of this location is recommended to better evaluate specific bacteria sources impacting Little White Oak Bayou.

Figure 56

Figure 55

Table 30. Water quality data for Little White Oak Bayou station 25.

Parameter	Wet Weather	Dry Weather
Latitude	29.818995	
Longitude	-95.378497	
Survey Date	2/15/2017	10/11/2016
Days Since Last Rain	1	16
Total Depth (m)	0.58	0.15
Temperature (°C)	15.17	24.46
Specific Conductance (µs/cm)	317.1	825.4
pH (standard units)	7.52	7.47
Dissolved Oxygen (mg/L)	8.17	7.76
E.coli (MPN/100mL)	24,200	7,700
Turbidity (ntu)	0.19	0.91
Observed Turbidity	Medium	Low
Water Clarity	Fair	Good
Water Color	Brownish	Oily/Chemical
Water Odor	None	None
Present Weather	Cloudy	Partly Cloudy
Wind Intensity	Slight	Calm
Water Surface	Calm	Ripples
Flow Severity	Normal	Normal

Rummel Creek (1014N_01)

Rummel Creek, TCEQ segment AU 1014N_01, is located in west Houston in Harris County at the intersection of I-10 and the Beltway. Primary land uses in the 4.62 square mile watershed area are residential and commercial with hospitals and manufacturing facilities present along the I-10 corridor. The Edith L Moore Nature Sanctuary is also located in the southern portion of the watershed at Memorial Drive and Wilchester Boulevard.

Rummel Creek has been listed as impaired for bacteria on the Texas Integrated Report (IR) since 2002. It is also included as the tenth AU on the BIG's Top 10 Most Impaired Water Bodies list from 2015. With a seven-year *E.coli* geometric mean value of 1,960 MPN/100mL, this AU is far from meeting the state water quality standard of 126 MPN/100mL. Figure 50 shows the wet weather and dry weather bacteria concentrations from the Phase II Rummel Creek surveys by sample number and figure 51 illustrates the location of Phase II sample stations.

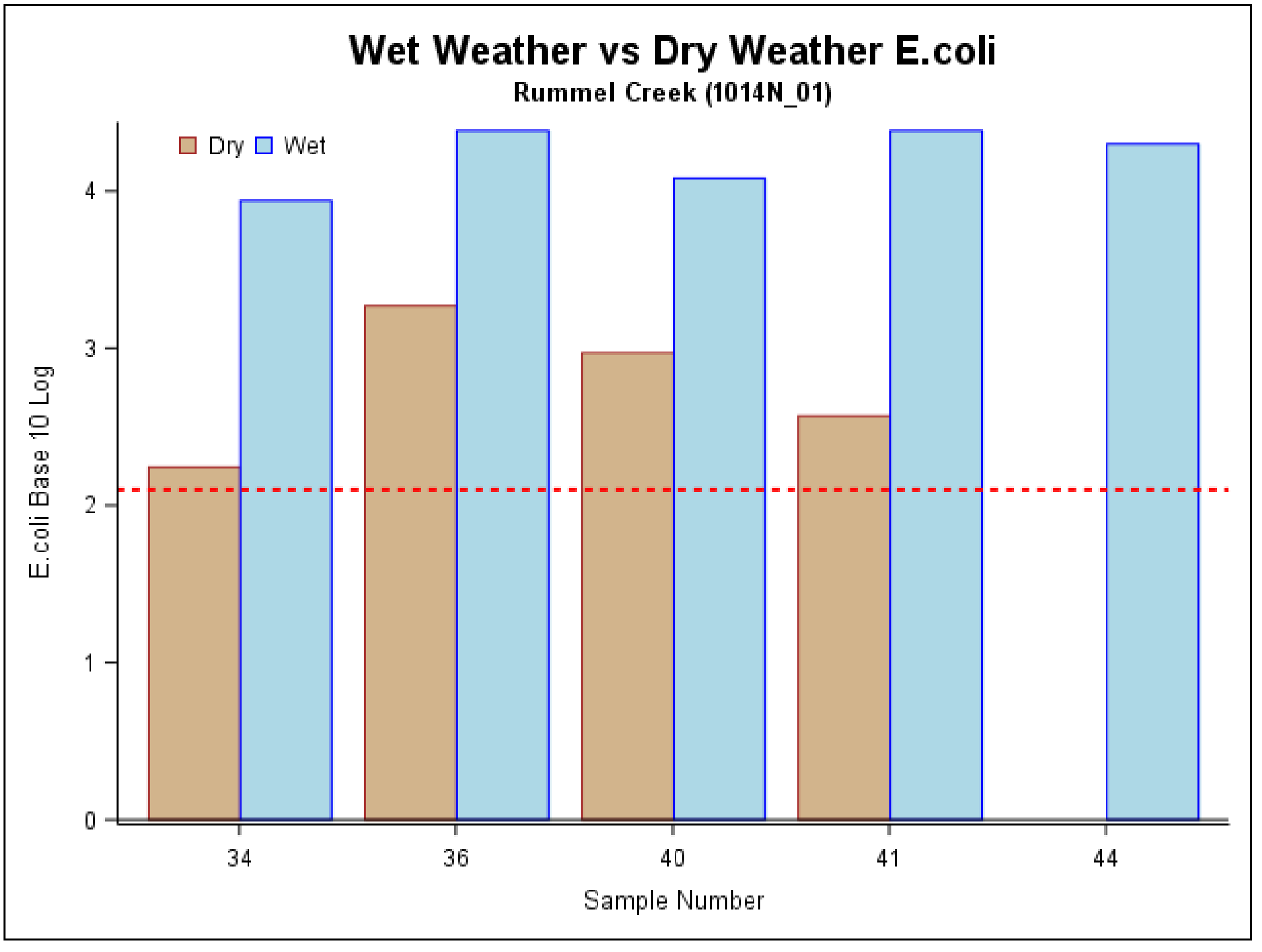

FIGURE 57. WET WEATHER AND DRY WEATHER *E.COLI* CONCENTRATIONS FROM PHASE II RUMMEL CREEK SURVEYS. RED DOTTED LINE REPRESENTS THE STATE WATER QUALITY STANDARD FOR BACTERIA.

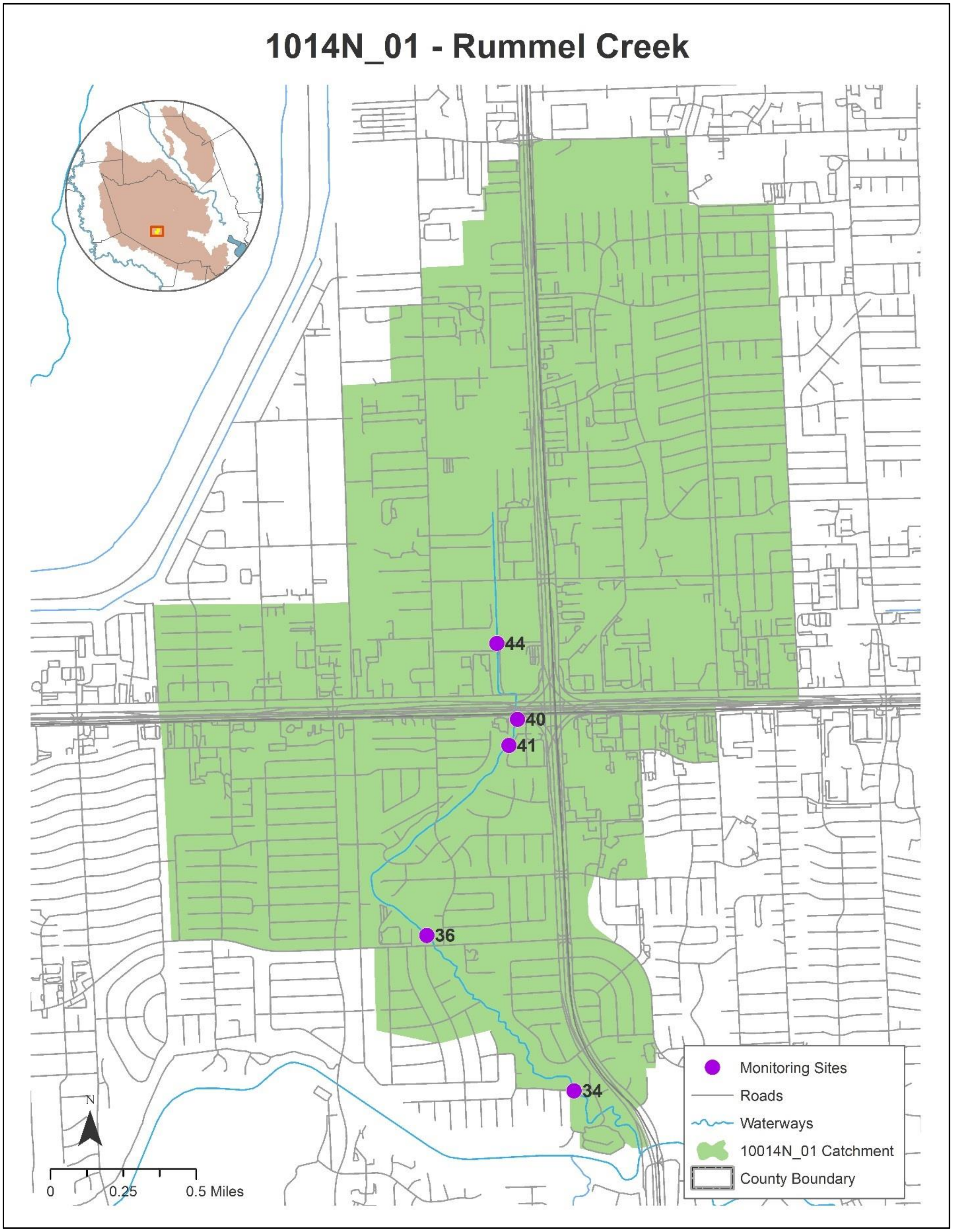

FIGURE 58. PHASE II RUMMEL CREEK MONITORING STATIONS

Station 34

Station 34 is located at the southern end of the Rummel Creek watershed boundary downstream of the Edith L Jones Nature Conservancy. The station can be accessed through dense vegetation at the end of Hermitage Lane in a residential neighborhood. Old pipelines were observed along the stream bottom, although it was unclear if they were still operating or not (Figure 52).

A dry weather sample was collected on December 14, 2016 resulting in a bacteria concentration slightly exceeding the state water quality standard (Table 24). The wet weather sample was collected on February 14, 2017 immediately following a significant rain event (Figure 53). The bacteria concentration for the wet weather sample was 8,660 MPN/100mL which was significantly higher than the dry weather sample, but was the lowest wet weather concentration observed in Rummel Creek.

Figure 59

Figure 60

Table 31. Water quality data for Rummel Creek station 34.

Parameter	Wet Weather	Dry Weather
Latitude	29.76526	
Longitude	-95.56252	
Survey Date	2/14/2017	12/14/2016
Days Since Last Rain	<1	7
Total Depth (m)	0.88	0.11
Temperature (°C)	17.83	18.1
Specific Conductance (µs/cm)	96.8	526.5
pH (standard units)	8.07	7.23
Dissolved Oxygen (mg/L)	8.86	5.26
E.coli (MPN/100mL)	8,660	175
Turbidity (ntu)	0.175	>1.2
Observed Turbidity	High	Low
Water Clarity	Poor	Excellent
Water Color	Brownish	Clear
Water Odor	None	None
Present Weather	Cloudy	Partly Cloudy
Wind Intensity	Calm	Calm
Water Surface	Ripples	Ripples
Flow Severity	High	Normal

Station 36

Station 36 is an outfall located downstream of Rummel Creek Elementary directly upstream of the bridge at Memorial Drive (Figure 54). This station is one of the highest contributors of bacteria into Rummel Creek during both Phase I and Phase II investigations. The outfall was discharging during all station visits, regardless of weather conditions.

The dry weather sample collected on December 14, 2016 resulted in an *E.coli* concentration of 1,860 MPN/100mL. The wet weather sample collected immediately following a significant rain event on February 14, 2017 (Figure 55) was significantly higher measuring at 24,200 MPN/100mL.

Figure 61

Figure 62

TABLE 32. WATER QUALITY DATA FOR RUMMEL CREEK STATION 36.

Parameter	Wet Weather	Dry Weather
Latitude	29.77316	
Longitude	-95.57065	
Survey Date	2/14/2017	12/14/2016
Days Since Last Rain	<1	7
Total Depth (m)	0.36	0.23
Temperature (°C)	17.69	18.49
Specific Conductance (μs/cm)	148.4	534.9
pH (standard units)	8.04	7.45
Dissolved Oxygen (mg/L)	10.02	7.18
E.coli (MPN/100mL)	24,200	1,860
Turbidity (ntu)	0.54	>1.2
Observed Turbidity	Medium	Low
Water Clarity	Fair	Excellent
Water Color	Brownish	Clear
Water Odor	None	None
Present Weather	Cloudy	Partly Cloudy
Wind Intensity	Moderate	Calm
Water Surface	Ripples	Calm
Flow Severity	High	Low

Station 40

Station 40 is located directly downstream of where Rummel Creek emerges from I-10 underground. This portion of Rummel Creek is concrete lined but sediment has settled on the surface of the concrete downstream where vegetation is now growing (Figure 56). Additionally, a plant nursery and large detention basin are located on either side of the concrete lined canal at this location.

The dry weather sample collected on December 14, 2016 resulted in a bacteria concentration of 933 MPN/100mL, making this station one of the highest contributors of bacteria to Rummel Creek during dry weather conditions. At the time of the wet weather survey on February 14, 2017, the water discharging from the left bank was darker in color whereas water discharging on the right bank looked brown and cloudy, likely from heavy sediment loads from the recent rains (Figure 57). The wet weather *E.coli* concentration was significantly greater than the dry weather sample measuring at 12,000 MPN/100mL (Table 26).

Figure 64

Figure 63

TABLE 33. WATER QUALITY DATA FOR RUMMEL CREEK STATION 40.

Parameter	Wet Weather	Dry Weather
Latitude	29.78378	
Longitude	-95.56508	
Survey Date	2/14/2017	12/14/2016
Days Since Last Rain	<1	7
Total Depth (m)	0.72	0.08
Temperature (°C)	17.85	17.92
Specific Conductance (µs/cm)	141	504.2
pH (standard units)	7.64	7.56
Dissolved Oxygen (mg/L)	8.29	6.54
E.coli (MPN/100mL)	12,000	933
Turbidity (ntu)	0.2	1.09
Observed Turbidity	High	Low
Water Clarity	Poor	Excellent
Water Color	Brownish	Brownish
Water Odor	None	None
Present Weather	Cloudy	Partly Cloudy
Wind Intensity	Calm	Calm
Water Surface	Ripples	Calm
Flow Severity	High	Low

Station 41

Station 41 is located approximately 160 meters downstream of station 40 near where the concrete lining ends (Figure 58). There are several outfalls located between stations 40 and 41, most of which are storm water outfalls originating from the detention basin to the east of Rummel Creek at this location. There is also a weather emergency alert facility located adjacent to the detention basin that has some type of on-site sewage facility (OSSF) on location.

During the dry weather event conducted on December 14, 2016, a strong odor of sewage was detected at one of the large outfalls directly upstream of station 41. Toilet paper was also observed at the outfall, although no water was discharging at that time. The dry weather sample resulted in a bacteria concentration of 369 MPN/100mL. The wet weather sample collected on February 14, 2017 was 24,200 MPN/100mL making station 41 one of the highest contributors of bacteria during wet weather conditions.

Figure 65

TABLE 34. WATER QUALITY DATA FROM RUMMEL CREEK STATION 41.

Parameter	Wet Weather	Dry Weather
Latitude	29.78247	
Longitude	-95.56562	
Survey Date	2/14/2017	12/14/2016
Days Since Last Rain	<1	7
Total Depth (m)	0.47	0.13
Temperature (°C)	17.82	18.12
Specific Conductance (µs/cm)	100.7	493
pH (standard units)	7.94	8.12
Dissolved Oxygen (mg/L)	9.39	7.62
E.coli (MPN/100mL)	24,200	369
Turbidity (ntu)	0.19	>1.2
Observed Turbidity	High	Low
Water Clarity	Poor	Excellent
Water Color	Brownish	Clear
Water Odor	None	None
Present Weather	Partly Cloudy	Partly Cloudy
Wind Intensity	Calm	Calm
Water Surface	Ripples	Calm
Flow Severity	High	Low

Station 44

Station 44 is located approximately 260 meters upstream of I-10 right before Rummel Creek goes back underground. This is the most upstream station in the Rummel Creek watershed investigated during Phase I and II of this project. This portion of the stream normally runs dry except after significant rain events. A hospital and multiple flooring and manufacturing facilities are located along Rummel Creek at this location (Figure 59).

No sample was collected during the dry weather event on December 14, 2016 due to no flowing water at this station. The wet weather sample collected on February 14, 2017 resulted in an *E.coli* concentration of 19,900 MPN/100mL (Figure 60).

Figure 66

Figure 67

TABLE 35. WATER QUALITY DATA FOR RUMMEL CREEK STATION 44.

Parameter	Wet Weather	Dry Weather
Latitude	29.78763	
Longitude	-95.566144	
Survey Date	2/14/2017	12/14/2016
Days Since Last Rain	<1	7
Total Depth (m)	0.3	-
Temperature (°C)	18.07	-
Specific Conductance (µs/cm)	169.4	-
pH (standard units)	7.83	-
Dissolved Oxygen (mg/L)	7.91	-
E.coli (MPN/100mL)	19,900	-
Turbidity (ntu)	0.06	-
Observed Turbidity	High	-
Water Clarity	Poor	-
Water Color	Brownish	-
Water Odor	None	-
Present Weather	Cloudy	Partly Cloudy
Wind Intensity	Calm	Calm
Water Surface	Ripples	Calm
Flow Severity	High	Dry

Significant Bacteria Sources

Canal C-147 (1007A_01)

Table 29 lists the most significant bacteria sources to Canal C-147 identified during Phase I and Phase II of this project. Potential causes for these sources are also listed. Further investigation is recommended at these locations.

TABLE 36. SUMMARY OF BACTERIA SOURCES TO CANAL C-147

Station	Description	Latitude/Longitude	Potential Causes
8.1	Metal outfall located directly under the Tiffany Street bridge	29.61612, -95.45970	Illicit discharges; improper pet waste disposal (dogs, chickens)
13	Large concrete storm drain on the right bank of Canal C-147 at South Post Oak Street.	29.61142, -95.46475	Sewer system leaks; runoff or discharges from nearby auto body shops and car dealerships
14	Large concrete storm drain on the left bank of Canal C-147 at South Post Oak Street.	29.61145, -95.46475	Sewer system leaks; runoff or discharges from nearby auto body shops and car dealerships
17	Tributary of Canal C-147 at the Beltway 8 bridge	29.60601, -95.47043	Illicit discharges; improper pet waste disposal (dogs, chickens)
27	Metal outfall located adjacent to residential neighborhood off Ohara Drive.	29.60384, -95.48948	Sewer system leaks; runoff or discharges from neighborhood recreation center; stormwater runoff

Upper Panther Branch (1008B_02)

The most significant finding during the Phase I and Phase II investigations at Upper Panther Branch was the detection of high chlorine levels throughout the waterway during dry weather conditions. The majority of dry weather samples were in compliance with state water quality standards for bacteria, but these results may be impacted by the observed high chlorine concentrations. Further investigation into the source of chlorine is recommended.

All wet weather samples resulted in extremely high *E.coli* concentrations likely due to runoff of pet waste and other wildlife sources such as deer and feral hogs. Refer to Table 30 for more information about other significant bacteria sources to Upper Panther Branch.

TABLE 37. SUMMARY OF BACTERIA SOURCES TO UPPER PANTHER BRANCH

Station	Description	Latitude/Longitude	Potential Causes
9	Tributary of Upper Panther Branch	30.19107, -95.47797	Malfunctioning OSSFs or grease traps; runoff from sporting facility; improper pet waste disposal (dogs, horses); wildlife

Little White Oak Bayou (1013A_01)

The bacteria sources impacting Little White Oak Bayou are widespread and significant. Table 31 lists information about a few of the most significant sources detected during Phase I and II of this project. However, further investigation is recommended throughout the entire watershed as conditions seems to be degrading and bacteria concentrations are increasing based on the data collected.

Station 25 was detected as one of the most significant sources of bacteria to Little White Oak Bayou and is located at the upstream boundary of the watershed. Further investigation of upstream watersheds is recommended to better identify bacteria sources impacting Little White Oak Bayou.

TABLE 38. SUMMARY OF BACTERIA SOURCES TO LITTLE WHITE OAK BAYOU

Station	Description	Latitude/Longitude	Potential Causes
N/A	Sewer system junction box located at Wrightwood Street and Little White Oak Bayou	29.781074, -95.370219	Constructed stormwater controls failing; malfunctioning wastewater collection systems; overflows
N/A	Manhole located upstream of station 17 off Vincent Street and Coronado Avenue	29.80126, -95.37309	Constructed stormwater controls failing; malfunctioning wastewater collection systems; overflows
10	Large storm drain located at Little White Oak Bayou at Hays Street	29.78984, -95.36163	Constructed stormwater controls failing; sewer system leaks; illicit discharges
25	Little White Oak Bayou at Stokes Street bridge	29.818995, -95.378497	Rapid urbanization and impervious cover; illicit discharges; runoff of pet waste; homeless activity

Rummel Creek (1014N_01)

Table 32 lists the most significant bacteria sources to Rummel Creek identified during Phase I and Phase II of this project. Potential causes for these sources are also listed. Further investigation is recommended at these locations.

TABLE 39. SUMMARY OF BACTERIA SOURCES TO RUMMEL CREEK

Station	Description	Latitude/Longitude	Potential Causes
36	Metal outfall located downstream of Rummel Creek Elementary	29.77316, -95.57065	Leaking sewer systems; stormwater runoff
40	Concrete lined portion of Rummel Creek directly downstream of I-10 underground	29.78378, -95.56508	Runoff from plant nursery; Leaking sewer and stormwater systems; stormwater runoff
41	Concrete lined portion of Rummel Creek 160 meters downstream of station 40	29.78247, -95.56562	Runoff from plant nursery; malfunctioning OSSF; sewer overflows; stormwater runoff

Next Steps

Phase III of this project involves meeting with local jurisdictions to review Phase II results and discuss what corrective actions, if any, will be taken to address the sources of bacteria identified in this report. Follow up monitoring will take place in areas where corrective actions are implemented. A Final Report summarizing Phases I, II, and III of this project will be published in spring of 2017.