

HIGHLAND BAYOU WATERSHED PROTECTION PLAN



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Photo by Highland Bayou water quality volunteer, Cindy Lienen

Highland and Marchand Bayous Watershed Protection Plan

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Galveston Bay Estuary Program
17041 El Camino Real, Ste. 210
Houston, Texas 77058



Prepared By:

Texas Coastal Watershed Program
Texas A&M University
1335 Regents Park Dr., Suite 260
Houston, Texas 77058



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Planning Meeting Refreshments

Galveston County MUD 12

City of La Marque

Galveston County Commissioner, Precinct 2

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Highland Bayou WPP Project Team: Texas Coastal Watershed Program

Steven Mikulencak, AICP, Extension Program Specialist, Project PI

Celina Lowry, Extension Associate and Project Staff

Amanda Solitro, Extension Assistant and Project Staff

Yu Wen Chou, Extension Associate, GIS Analyst & Cartographer

Rebecca Davanon, Extension Associate, GIS Analyst

Valeria Rodriguez, Graduate Student Intern

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Executive Summary

Highland & Marchand Bayous Watershed Protection Plan

Prepared by the Texas A&M University AgriLife Extension Service's Texas Coastal Watershed Program
In Cooperation with the Galveston Bay Estuary Program
Grant No. 582-14-41415

The Watershed Protection Plan (WPP) is a vision and set of ideas for voluntary action from community participants, stakeholders, and the project team for improving water quality in Highland and Marchand Bayous. These bayous are listed by the TCEQ's 303(d) for high levels of bacteria and low levels of oxygen in the water. The reason for action though is more than a listing- the poor condition of the Bayous poses risks to public health and diminishes its value as a recreational, aesthetic, and ecological resource for its communities. The bayou can sustain all these values if steps are taken to reverse the impact of land-based factors. No one action identified in this plan will 'fix' the Bayou. Progress will take coordination, time, and a sustained commitment from the various communities in the basin. The WPP document is a community resource, compiling in one place the wide range of factors impacting water quality here, estimated pollution loads and reductions, specific stakeholder concerns, and potential pathways for action.

The Highland Bayou WPP Working Group began in 2012 as an ad hoc group to direct the development of the recommendations here. The group consists of the project team and participants from state, county and municipal agencies, together with private citizens and not-for-profit organizations. The project is led by Texas A&M's Texas Coastal Watershed Program. The project team engaged the work group over the course of many months to hear their experiences and concerns. This process resulted in collecting over 100 project ideas, which were further organized into 38 action areas. Through the work group, 10 were selected for development into detailed strategies. A broad-based and cross-collaborative strategy for stakeholder involvement will be necessary for implementing activities and coordinating priorities in the basin. The structure of the plan is based on the U.S. Environmental Protection Agency's (EPA) 9 element watershed protection plan, an outline of major components needed for a successful watershed protection plan.

The Bayou's water quality is the result of multiple land-based factors, primarily non-point source (NPS) pollutants, although sewage infrastructure, considered a point source, plays an important role. NPS includes stormwater and all the pollutants it picks up along the way, everything from fertilizer and sediment, to pet waste. Pollutant loads were modeled using the Simple Method, a land-use based approach, for each of the six catchments in the watershed. Load values were calculated for bacteria, nitrogen, and phosphorous. Maps and figures are included in Element A.

Load reductions were estimated assuming that certain of the 10 priority action areas would be implemented. Using a 10 year implementation horizon and conservative implementation rates, the watershed could see a 42% reduction in bacteria, a 10% reduction in nitrogen, and a 12% reduction in phosphorous. Load reductions were calculated for wastewater collection system repairs, pet waste pick-up programs, green infrastructure (GI), and stormwater wetlands (SWW). Calculations, tables and maps are included in Element B.

The next steps will be up to the communities and organizations in the watershed. All 38 action areas in this plan are described in Element C. For the 10 Priority Action Areas, detailed tables were prepared with goals, objectives, and phases. Technical support, milestones, and timelines are identified in Elements D, F, and G. Potential grant funding opportunities specific to water quality projects are included in the appendices. Resources for support in education and outreach efforts are identified in Element E. Water quality criteria and a proposed water quality sampling program are documented in Elements H and I.

Next Steps

The actions needed to implement this plan are actually ordinary steps, and the experiences of others inside and outside the basin can be relied on to support work in the basin. In other words, there is no need to reinvent the wheel. The most critical next step is continued engagement of the work group and other stakeholders in the watershed. Projects will require that partners use existing funding or manage to bring in project-specific grant funding. As stakeholders implement various aspects of this plan, it will be important that the plans priorities and milestones be updated to reflect new realities and a better understanding of pollution in the basin. There are several data gaps that if addressed could help the watershed stakeholders improve actions for targeted areas.

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List of Acronyms

µg/L- micrograms per liter
ALU- Aquatic life uses
AU- Assessment Unit
AVMA- The American Veterinary Medical Association
BMP- Best Management Practices
BNSF- Burlington Northern and Santa Fe Railway
BOD- biological oxygen demand
BST- Bacteria Source Tracking
CAD- County Appraisal District
C-CAP- Coastal Change Analysis Program
CCTV- closed-circuit television
CDBG- Community Development Block Grants
CFU- Colony Forming Units
CHARM- Community Health and Resources Management
CN- curve number
CWA- Clean Water Act
DO- Dissolved Oxygen
DOI- U.S. Department of the Interior
DU- Dwelling Units
DUA- Dwelling Units per Acre
EMC- event mean concentration
EPA- U.S. Environmental Protection Agency
FOG- Fats, Oils, and Grease
GBAN- Galveston Bay Action Network
GBEP- Galveston Bay Estuary Program
GBF- Galveston Bay Foundation
GCDD2- Galveston County Drainage District 2
GCHD- Galveston County Health District
GI- Green Infrastructure
GIS- Geographic Information System
H-GAC- Houston-Galveston Area Council
HOA- Homeowners Association
I/I- Infiltration and inflow
KAST-Kills and Spills Team
Lbs- pounds
LU- Land Use
LULC- Land use/Land Cover
mg/L- milligram per liter
MGD- million gallons per day
mL- milliliter
MOU- management/ maintenance agreement
MS4- Municipal Separate Storm Sewer Systems
MUD- Municipal Utility District
NA- Not Assessed
NOAA-National Oceanic and Atmospheric Agency
NPS- Non-Point Source
NRCS- Natural Resource Conservation Service
OSSF- Onsite Sewage Facility

SSO- Sanitary Sewer Overflow
SSOI- Sanitary Sewer Overflow Initiative
SSS- Sanitary Sewer System
SWQ- Surface Water Quality
SWQM-Surface Water Quality Monitoring
SWW- Stormwater Wetlands
TCEQ- Texas Commission on Environmental Quality
TCWP- Texas Coastal Watershed Program
TMDL- Total Maximum Daily Load
TPDES- Texas Pollutant Discharge Elimination System
TPWD- Texas Parks and Wildlife
TSS- Total Suspended Solids
TSSWCB- Texas State Soil and Water Conservation Board
TSWQS- Texas Surface Water Quality Sampling
TWDB- Texas Water Development Board
TX GLO- Texas General Land Office
UH- University of Houston
UHCC- University of Houston Coastal Center
UID- Unique ID Number
US HUD-US Department of Housing and Urban Development
USACE- U.S. Army Corps of Engineers
USDA- U.S. Department of Agriculture
USEPA- U.S. Environmental Protection Agency
USFWS- U.S Fish and Wildlife Service
USGS- U.S. Geological Survey
WCID- Water Control and Improvement District
WPP- Watershed Protection Plan
WQMP- Water Quality Management Plans
WWTP- Waste Water Treatment Plant

Introduction

Why a Watershed Protection Plan?

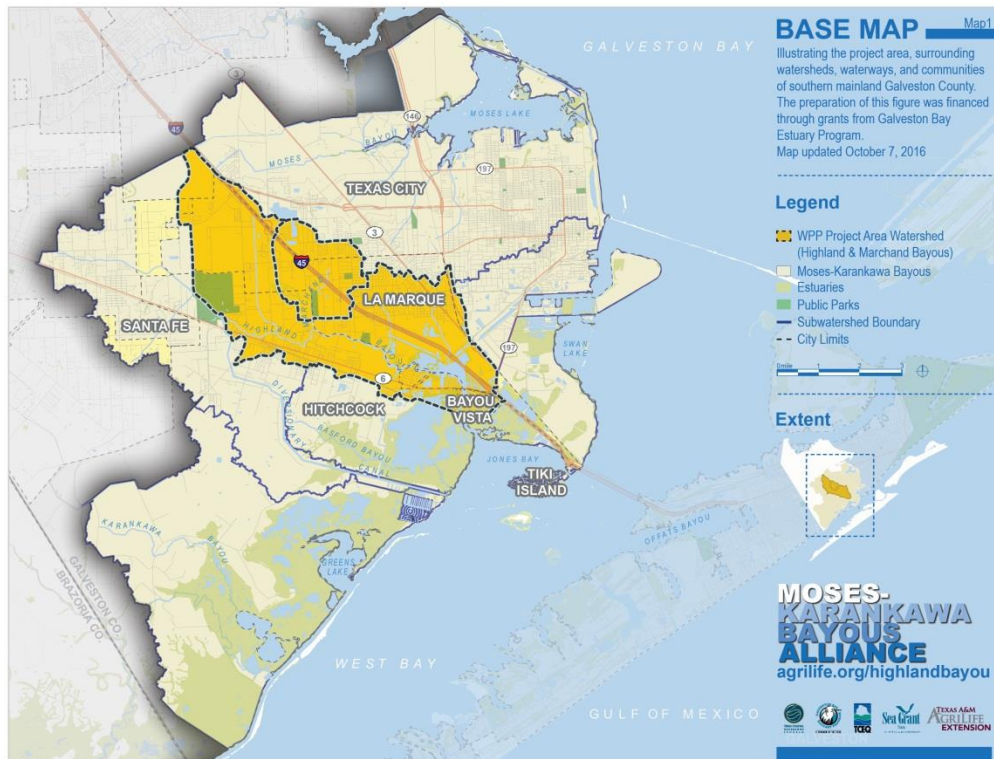
A watershed protection plan (WPP) is a stakeholder-driven, voluntary plan of action to address water quality issues in the watershed. Stakeholders bring to the planning process their local knowledge of their watershed, communities and projects. It is imagined that a voluntary plan developed through sustained stakeholder participation will lead to individual ownership and follow through of activities that will have a positive impact on the area's water quality. An EPA approved WPP also opens opportunities to bring in state and federal support for these projects. The WPP document is a community resource, compiling in one place the wide range of factors impacting water quality, estimated pollution loads and reductions, specific stakeholder concerns, and potential pathways for action. The plan includes narratives about how these issues and concerns relate and fit within the larger picture.

What is a Watershed?

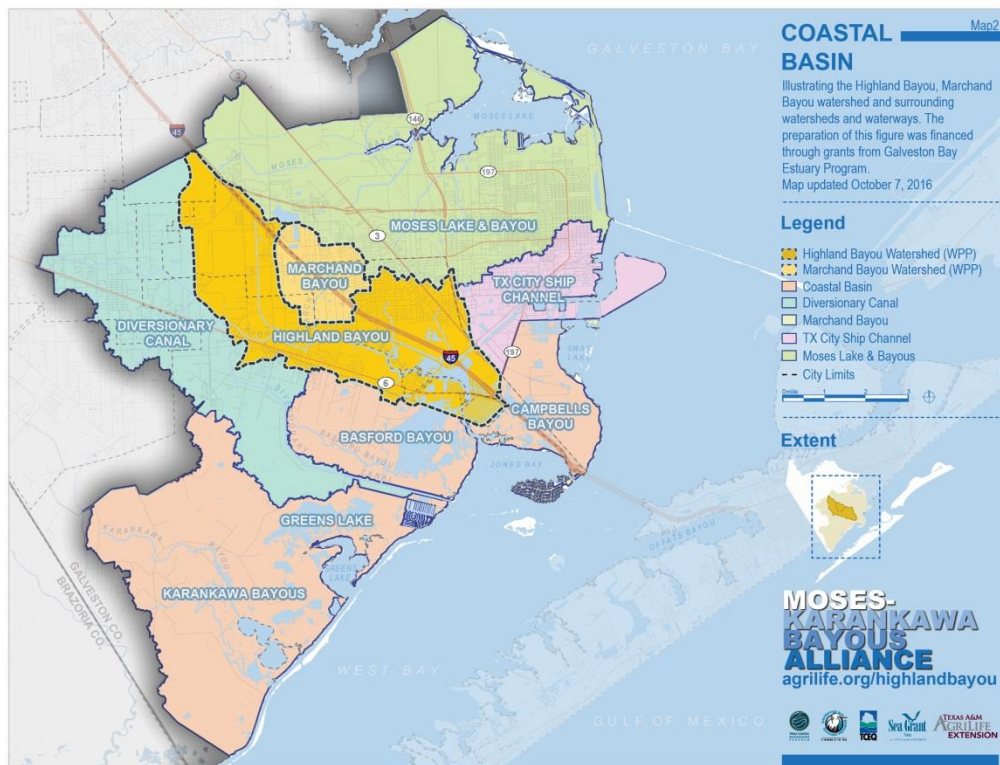
A watershed is the area of land drained by a water body, such as a river or bayou. As stormwater flows over the land, it collects into a system of ditches, creeks, bayous, and ultimately Galveston Bay. The water, from the time it hits the ground, transports all water-borne compounds it encounters along the way, such as bacteria, chemicals, paint, oil, sediment, fertilizers, lawn clippings, sewage, litter, and more. A popular misconception by average citizens is that stormwater is treated by the 'City.' This is not true. Stormwater is not sent to wastewater treatment plants, and instead flows into larger and larger stormwater systems and then into the bayou, untreated. What we do on the land ends up in the bayou. A watershed approach is a holistic way to deal with all the land-based factors that impact stormwater before it flows in to the bayou.

The Highland & Marchand Bayous Watershed

The Highland Bayou and Marchand Bayou watershed are located in Galveston County's southern mainland. Marchand Bayou is a tributary that flows into Highland Bayou, which then drains into Jones Bay and the West Bay of Galveston Bay (Map-1). The Highland and Marchand bayous watershed covers almost 23 square miles of land, and are the focus of this WPP. Marchand and Highland Bayous are referred to in this plan as 'Highland Bayou' or the 'Highland Bayou Watershed,' or simply the *watershed*. Both bayous are listed by TCEQ for water quality impairments from high bacteria levels and low dissolved oxygen (DO) levels- these issues are the focus of this plan.



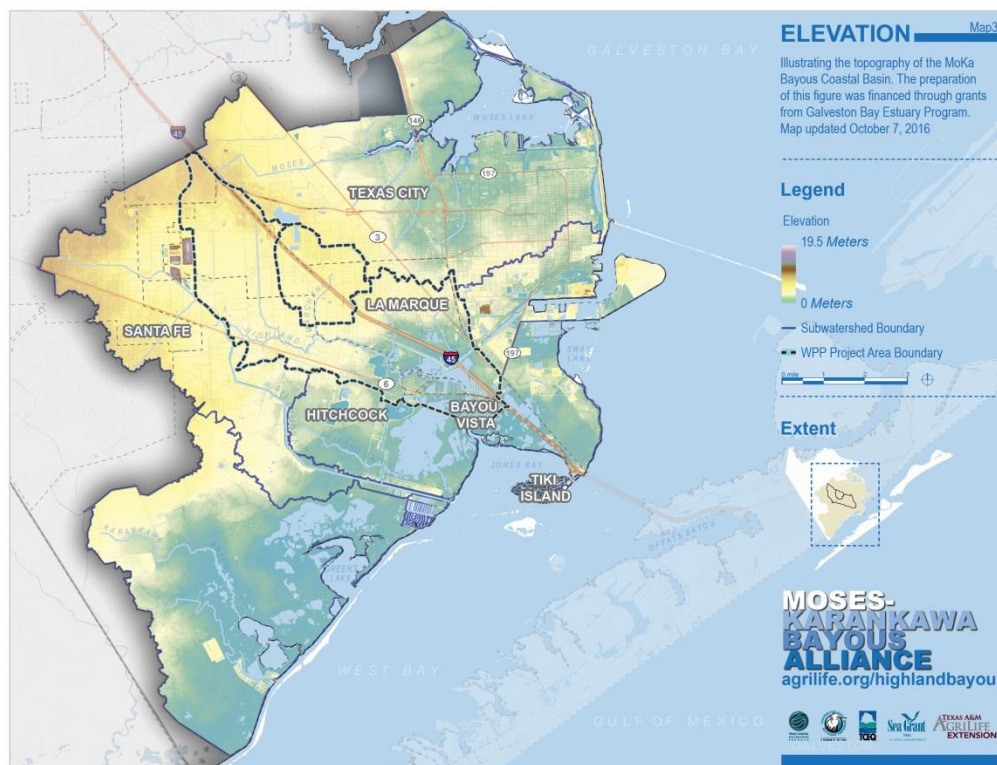
Map- 1. (Above) Base Map of the Project Area



Map- 2. (Above) Coastal Basin Map Highland, Marchand, and Surrounding Bayou Watersheds

Highland and Marchand Bayous are part of a larger *coastal basin*, a collection of separate, small bayous, each draining directly into Galveston Bay and West Bay. The coastal basin consists of Highland and Marchand Bayous, Moses Lake and Bayou, the Diversionary Canal, the Texas City Ship Channel, and the estuarial bayous of Campbell, Basford, Greens Lake, and Carancahua (alternatively spelled Karankawa) bayous. (Map-2) The coastal basin is referred to as the Moses-Karankawa coastal basin, or MoKa Bayous for short. The coastal basin is nearly 126 square miles in area in southern Galveston County. Most of the bayous in this basin are tidal or tidally influenced. Communities in the coastal basin include the cities of Santa Fe, Hitchcock, La Marque, Texas City, and Bayou Vista. The basin is bounded on the north by the Dickinson Bayou watershed and to the west by the Halls Bayou watershed. All of these watersheds drain into the Galveston Bay system.

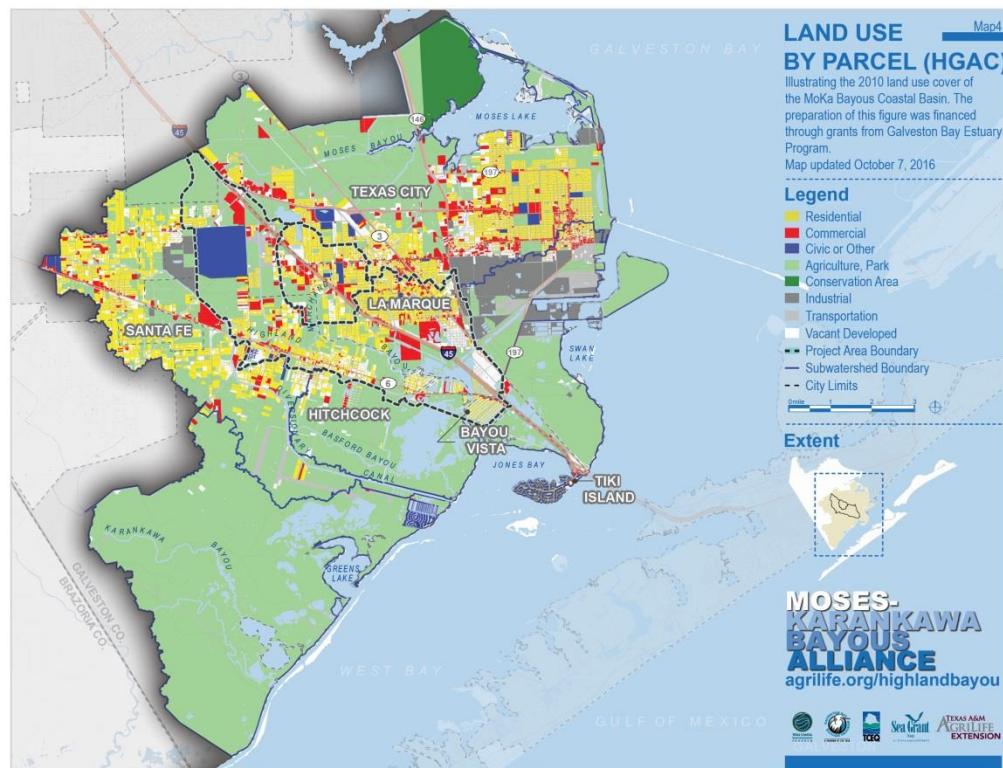
The Highland Bayou Watershed's boundaries have been altered by human activity. Historically, the headwaters of Highland Bayou were in Santa Fe. In the 1970's the Diversionary Canal was constructed, intercepting the headwaters of Highland Bayou at a point near Jack Brooks park, and diverting it southward through old Basford Bayou and into West Bay. These historical headwaters are now considered the Diversionary Canal watershed and are separate from the Highland Bayou Watershed. The diversion is visible on the coastal basin watershed map.



Map- 3. Elevation Map

Highland Bayou's original course below the interception point continues for approximately 7.5 miles through the communities of La Marque, Hitchcock, and Bayou Vista. Within the Highland Bayou

Watershed, the topography is flat (Map-3) and drained by a system of ditches and other drainage infrastructure maintained by the communities and Drainage District 2. Land in the study area is a mix of residential, industrial, and undeveloped lands, including farms, coastal prairies, wetlands and estuaries (Map- 4).



Map- 4. 2010 Parcel Land Use Map

In 2012, The Highland Bayou Watershed Characterization Report was prepared in anticipation of this WPP. The Report includes historical background about the habitats and communities in the basin. It includes summaries of physical and natural features in the watershed, along with observed and measured water quality conditions. The report also includes details about land development and demographic trends in the watershed. The report is available online at agrilife.org/highlandbayou.

Elements of a Successful WPP

The following nine elements are identified by the US EPA as critical parts of a watershed protection plan to achieve water quality improvements. A Watershed Protection Plan must address these elements before it can be approved by the US EPA and thus be eligible for Clean Water Act section 319-funded projects (Environmental Protection Agency, 2008), along with other funding sources. All watershed protection plans are structured somewhat differently. The WPP planning team made a conscious decision early in the process to follow the sequence of the 9 Element Plan. This WPP and its sections are structured as follows:

Element A. Identify Causes and Sources of Impairment

Identify the causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed.

Element B. Expected Load Reductions

Estimate load reductions expected from management measures.

Element C. Proposed Management Measures

Describe the nonpoint source management measures that will need to be implemented to achieve load reductions, and include a description of the critical areas in which those measures will be needed to implement this plan. Management measures are referred to as Action Areas (AA) in this WPP.

Element D. Technical and Financial Assistance Needs

Estimate the amount of technical and financial assistance, associated costs, and authorities that will be relied upon to implement this plan.

Element E. Information, Education, and Public Participation

Include an information and education component to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

Element F. Implementation Schedule

Prepare a schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious. For this plan, a 10 year time horizon is used for load reduction estimates.

Element G. Milestones

Prepare interim measureable milestones for determining whether nonpoint source management measures or other control actions are being implemented.

Element H. Load Reduction and Evaluation Criteria

Set forth water quality or other environmental criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.

Element I. Monitoring

Propose a monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item H. above.

Project Team: Lead Entity & Sponsor Agency

Project Lead Entity: The Texas Coastal Watershed Program (TCWP) is the project lead. TCWP is a Texas A&M University program housed within Texas AgriLife Extension Service and Texas Sea Grant. As lead entity, TCWP is responsible for the development and delivery of the Watershed Protection Plan and the coordination of public events and stakeholder involvement. All meetings in the work plan were held and conducted by TCWP and its staff.

Sponsor Agency: GBEP is a program of the TCEQ, is the sponsoring agency and administers the funds for the WPP. TCWP works in partnership with GBEP to inform them of the project's status through personal communications and progress reports. GBEP is also a potential partner on projects in the watershed and whose mission is to promote environmental awareness in the region and support projects that have a positive impact on water quality.

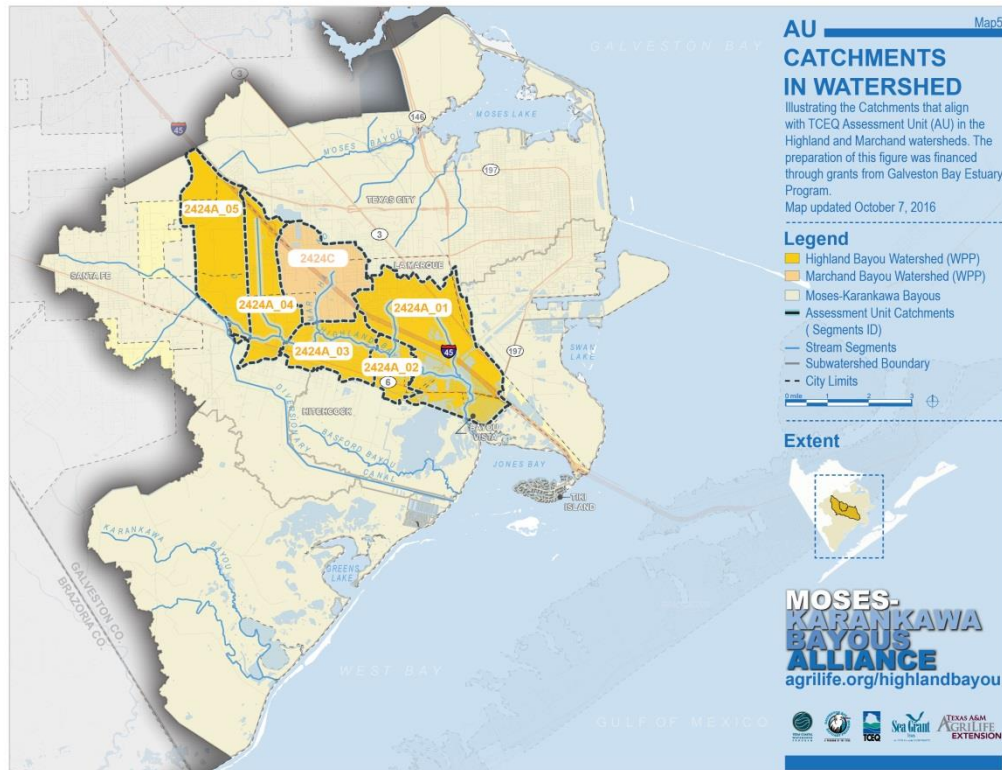
Highland Bayou Stakeholder Working Group

This plan would not be possible without the stakeholder working group. The working group was established with community stakeholders, regional organizations, and state agencies. Details of this process are included in Element E. Stakeholder outreach activities targeted municipal and county staff and officials, resource agencies, and private citizens. The ad hoc group was charged with identifying and sharing their concerns along with specific projects and project ideas. These activities were facilitated by the project team to support the development of this plan's objectives and goals. Nine workgroup meetings were held at the Galveston County Extension Office in La Marque from 2015-2016 to support the development of the watershed protection plan.

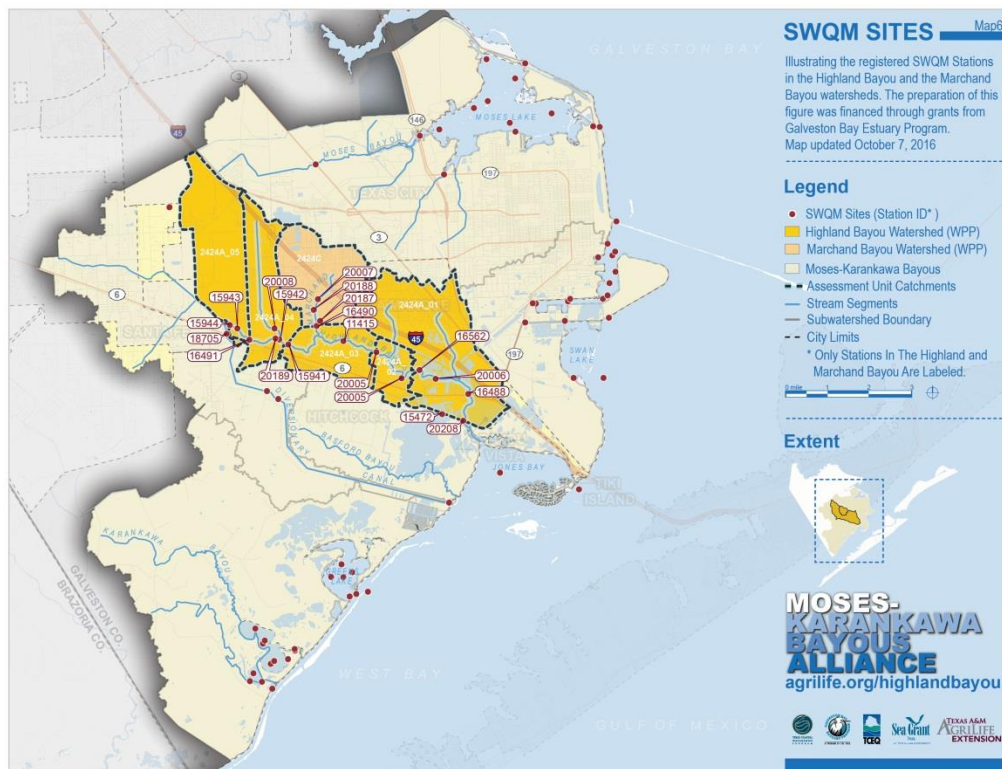
Regulatory Standards and Water Quality

Stream Segments and TCEQ Designation

How does the State of Texas classify these watersheds? All major waterbodies in Texas are classified by TCEQ into basins and segments. Both bayous are in Basin 24, 'Bays and Estuaries,' which includes all Texas bayous and inland surface waters that are tidally influenced through the Gulf of Mexico. The basin is divided into subbasin 2424, the West Bay subbasin. The TCEQ segment IDs are numbered using the subbasin id for Highland and Marchand Bayous, 2424A and 2424C, respectively. The segments are further divided by TCEQ into assessment units (AUs). AUs for Highland and Marchand Bayous are listed in Table 1 below. AUs are the smallest unit of analysis TCEQ uses for water quality issues in the watershed. All AUs are classified as tidally influenced by TCEQ. The catchment areas defined by these AUs are depicted in Map-5.



Map-5. Catchments that Align with TCEQ Assessment Units



Map- 6. Registered SWQM Stations and Assessment Units in the Watershed

Table 1: Assessment Unit and Locations for Highland and Marchand Bayou Segments

| Assessment Unit | Location Description |
|--------------------------------|---|
| Highland Bayou 2424A_01 | From the Jones Bay confluence upstream to Bayou Lane |
| Highland Bayou 2424A_02 | From Bayou Lane upstream to Lake Road |
| Highland Bayou 2424A_03 | From Lake Road upstream to FM 519 |
| Highland Bayou 2424A_04 | From FM 519 upstream to FM 2004 |
| Highland Bayou 2424A_05 | From FM 2004 to the headwaters just west of FM 1764 |
| Marchand Bayou 2424C_01 | From Highland Bayou confluence 0.72 km (0.45 mi) north of IH-45 |

Each segment is assigned a designated use and a water quality standard associated with that use. The primary use for waterways in the watershed is primary contact recreation, the most stringent use class after drinking water sources. TCEQ assesses water quality in each segment using the standards and methods described in the *2010 Guidance for Assessing and Reporting Surface Water Quality (SWQ) in Texas* (Texas Commission on Environmental Quality, 2010a). When an evaluation of water quality samples results in a set number of exceedances, the agency determines that the segment has failed particular water quality standards. Water quality assessments are based upon a rolling 7-year period, and it is updated every two years. The latest assessment was released in 2014. Water quality sampling events must be taken from at least two years, and no more than two-thirds of the samples can be assessed from any one year. A minimum of ten samples are needed to calculate a use attainment, although smaller sample sizes can be considered.

303(d) Listing

The federal Clean Water Act (CWA) requires that states identify and list segments that do not attain their designated water quality standards. The name ‘303(d)’ refers to the section of the Federal CWA that describes the process states must use to list impaired waterways. TCEQ publishes the Texas 303(d) list in the *2014 Texas Integrated Report - Texas 303(d) List*. Segments on the list are identified by the segment ID, the type of impairment, and the pollutant resulting in the impairment. Highland and Marchand bayous are currently listed on the 303(d) list of impaired waters, and this is the impetus behind the funding for this WPP. According to the 2014 Texas Integrated Report, Highland Bayou (2424A)—AUs 2-5—have been listed on the 303(d) list since 2002. Marchand Bayou (2424C_01) was also first listed in 2002. Highland Bayou segment 2424A_01 is listed as ‘concerned’ for low DO. The reason for the listing is depressed levels of DO and elevated levels of bacteria. The listed causes for the impairment are ‘NPS’ (EPA code 141) and ‘Urban Runoff/Storm Sewers’ (EPA code 177), and ‘Source Unknown’ (EPA code 140).

Table 2 summarizes the analyses done by TCEQ to justify the 303(d) listing of Highland and Marchand Bayous in the *2014 Texas Integrated Report*. ‘Assessed’ refers to the number of samples assessed. The table indicates a significant number of exceedances for bacteria, in particular *Enterococcus*. The inland segments generally have more exceedances than those downstream towards Jones Bay.

Table 2: Assessment by Parameter for each Assessment Unit

| Assessment Unit | | DO (grab screening) | DO (grab minimum) | DO (24hr average) | DO (24hr minimum) | <i>Enterococcus</i> (single) | <i>Enterococcus</i> (geomean) | Nitrate | Ammonia | Orthophosphorus | Total Phosphorus | Chlorophyll-a |
|-----------------------|-----------------|---------------------|-------------------|-------------------|-------------------|------------------------------|-------------------------------|---------|---------|-----------------|------------------|---------------|
| Criteria | | 4 | 3 | 4 | 3 | 89 | 35 | 1.1 | 0.46 | 0.46 | 0.66 | 21 |
| Highland Bayou | | | | | | | | | | | | |
| 2424A_01 | Assessed | 70 | 70 | 5 | 5 | 72 | 72 | 38 | 35 | 29 | 35 | 19 |
| | Exceedances | 8 | 1 | 0 | 1 | 11 | -- | 0 | 0 | 0 | 1 | 2 |
| | Mean exceedance | 3.5 | 1.9 | -- | 2.3 | 2670.18 | -- | -- | -- | -- | 8.28 | 25.5 |
| 2424A_02 | Assessed | 31 | 31 | 6 | 6 | 27 | 27 | 17 | 16 | 7 | 13 | 5 |
| | Exceedances | 0 | 0 | 0 | 2 | 7 | -- | 0 | 0 | 0 | 1 | 5 |
| | Mean exceedance | -- | -- | -- | 2.25 | 810.86 | -- | -- | -- | -- | 10 | 35.6 |
| 2424A_03 | Assessed | 54 | 54 | 6 | 6 | 50 | 50 | 37 | 34 | 28 | 34 | 6 |
| | Exceedances | 8 | 3 | 1 | 2 | 18 | -- | 3 | 0 | 0 | 1 | 5 |
| | Mean exceedance | 2.83 | 1.7 | 2.6 | 1.85 | 1010.5 | -- | 2.08 | -- | -- | 1.89 | 40.4 |
| 2424A_04 | Assessed | 32 | 32 | na | na | 19 | 19 | 9 | 9 | 1 | 6 | na |
| | Exceedances | 6 | 2 | na | na | 9 | -- | 0 | 0 | 0 | 0 | na |
| | Mean exceedance | 3.13 | 2.85 | na | na | 1237 | -- | -- | -- | -- | -- | na |
| 2424A_05 | Assessed | 54 | 54 | 7 | 7 | 50 | 50 | 37 | 33 | 27 | 33 | 5 |
| | Exceedances | 26 | 19 | 7 | 7 | 37 | -- | 1 | 0 | 0 | 0 | 3 |
| | Mean exceedance | 2.13 | 1.66 | 2.17 | 1.07 | 527.68 | -- | 2.34 | -- | -- | -- | 34.67 |
| Marchand Bayou | | | | | | | | | | | | |
| 2424C_01 | Assessed | 68 | 68 | 7 | 7 | 36 | 36 | 38 | 28 | 34 | 34 | 6 |
| | Exceedances | 10 | 5 | 2 | 3 | 17 | -- | 0 | 0 | 0 | 0 | 2 |
| | Mean exceedance | 2.74 | 1.85 | 3.25 | 2.03 | 2132 | -- | -- | -- | -- | -- | 28.5 |

-- "No Value

NA – Not Assessed

DO – dissolved oxygen

Criteria – Value that the data is compared against to determine level of support.

Assessed - Number of samples assessed; some data are averaged, as with profile data, some are eliminated because criteria do not apply during certain conditions such as low flow.

Exceedances - The number of samples that exceed criteria for single sample, or binomial, methods (not averaged data).

Mean exceedance - The mean of the samples that exceeded criteria for the single sample, or binomial, methods (not averaged data).

Data Source - 2010 Texas Integrated Report

Pollutant of Concern- Bacteria

Highland and Marchand Bayous are listed on the 303(d) list of impaired waters for high bacteria levels.

Bacteria can enter the bayou from point sources like wastewater treatment plants and NPSs such as sewage collection systems, pet waste, urban runoff, and wildlife. These sources are described in more detail later in Element A. Bacteria usually enter waterways attached to sediment or other particles.

Reductions in sediment loads could reduce bacteria loads.

High bacteria levels are a public health risk which can result in human sickness. The National Water Quality Inventory lists bacteria as the leading cause of water quality impairment in rivers and streams in the US (Environmental Protection Agency, 2000). Bacteria concentrations in stormwater samples from developed areas usually exceed limits for primary contact recreation. Bacterial infections occur through ingestion of water containing bacteria or via contact through cuts, the nose, eyes, and ears. Infections from waterborne bacteria can result in rashes, flu-like symptoms, nausea, diarrhea, vomiting, and gastroenteritis. In the elderly or infant populations with weakened immune systems, severe cases of bacterial infection can result in chronic illness and death. While no specific limit is a guarantee against infection, higher levels of bacteria increases the risk of infection.

There are many species of bacteria in contaminated water. Not all can be measured or counted. Water quality analysts test for certain bacteria species, referred to as *indicator bacteria*. The presence of indicator bacteria implies the presence of other bacteria in the water. In the case of tidally influenced waterways, the indicator *Enterococcus* bacterium is used. These bacteria are present in the intestines of warm-blooded animals and indicate the presence of human or animal waste in the water. *E. coli* is used as the fecal bacteria indicator in freshwater segments. All segments in Highland and Marchand Bayou are tidal segments, and *Enterococcus* is the indicator bacteria of concern.

Observed values for *Enterococcus* in Highland and Marchand bayous exceed Primary Contact Recreation limits established by TCEQ. Recreational uses include primary contact recreation such as swimming and other activities that have a high likelihood ingesting some water. Although exceedances were observed throughout the year, the highest values were observed during the warm season (April-October). There is also a clear trend of lower values as one travels downstream, likely due to greater mixing with tidal waters. The lowest values for Highland Bayou are at its confluence with Jones Bay, SWQM Station 16488, though exceedances have been observed there as well. The TCEQ limit for Primary Contact Recreation is 126 colony forming units (CFU) per 100 mL for *E. coli* in freshwater segments and 35 cfu per 100 mL for *Enterococcus* for saltwater segments (Texas Commission on Environmental Quality, 2010b)(Texas Administrative Code §307.7)

- Maximum *Enterococcus* counts on Highland Bayou ranged from 108 (stn. 16488) to 14,100 (stn. 16491) CFUs per 100mL for *Enterococcus*. Marchand Bayou's high value for *Enterococcus* was 3,200 CFU's per 100 mL.
- Maximum *E. coli* values on Highland Bayou range from 500 (stn. 16488) to 46,000 (stn 16491), and range from 20,000 (stn. 20007) to 24,000 (stn. 16490) CFU's per 100 mL for Marchand Bayou.

Pollutants of Concern- Low Dissolved Oxygen and Nutrients

Low Dissolved Oxygen

Oxygen levels are a measure of the overall health and the ability of waterways to support aquatic life. Low DO is not itself a pollutant, but it is correlated with excessive levels of nutrients and other pollutants. DO in water increases when aquatic plants and algae use sunlight and produce oxygen. Oxygenated water sustains other living organisms. For this reason, Texas regulatory limits for DO are defined as a standard

for *Aquatic Life Uses* (ALU). In healthy water quality conditions, DO concentrations should be between 7-10 milligrams per liter (mg/L), depending on the salinity and temperature. The minimum regulatory standard for DO in segments designated with a 'High' ALU is 4.0 mg/L for freshwater segments and 3.0 mg/L for saltwater segments. Below these levels, aquatic species are stressed and can die (discussion below).

From 2001-2011, water samples taken from Highland and Marchand bayou show that average values for DO are generally above standard minimums, ranging from 3.9-8.6 mg/L. However, there were numerous measurements of values below the standard minimum, ranging from 0.2-3.8 mg/L. DO impairments are most evident during the warm season months, while impairments during the cool season months are rare, measured once out of 133 cold season samples.

Fish kills are sudden die offs of large numbers of fish, and are observed or reported every year in the watershed. Many species of the Gulf fisheries spend phases of their life cycle in the bayous before migrating to Galveston Bay or the open waters of the Gulf. The water quality of the Bayous is tied to the health of fish populations along the Gulf Coast. Along the Upper Texas Coast, low DO is the most common cause for fish kills. Many aquatic organisms cannot survive when the oxygen levels fall below 2 mg/L for any significant period of time, and sensitive organisms or life stages cannot survive very long below 4 mg/L. TCEQ requires the DO level in a 24 hour period to be greater than 3mg/L and the average one day average value to be above 4 mg/L.

Low Dissolved Oxygen Correlated to Nutrients and Other Phenomena

It is highly likely that NPS is a factor explaining observed levels of oxygen. Nutrients including nitrates and phosphorous from a variety of activities and sources, including fertilizers, untreated sewage from Sanitary Sewer Overflow (SSO) discharges, organic decomposition, and even atmospheric deposition. Runoff rich in nutrients promotes the growth of algae and other plant life in the water. In turn, the eventual decay of the algae starts a chemical process that consumes oxygen from the water, resulting in a condition called eutrophication.

Evidence of these processes is seen in the water quality data analyzed in the 2012 Characterization Report, particularly through measurements for biological oxygen demand (BOD), chlorophyll-a, phosphorous, and nitrogen. For example, algal blooms, which can be observed as a milky green coloration in the water, is indicated as measurements of chlorophyll-a. Of 96 tests for chlorophyll-a, 27 tests showed values exceeding the state limit of 21 micrograms per liter ($\mu\text{g/L}$). Only three of those occurred during the cool weather season. Because algae uses phosphate as a growth nutrient, phosphate levels decline during summertime algae blooms and rebound during the cool season. This indicates that algae is consuming phosphorous nutrients in the water during the high growth season, lowering observed levels. Low algae growth in the cool season may explain the increase in measured phosphorous during the cool months.

Ammonia. Ammonia is very soluble in water. It is a primary and secondary plant nutrient, promoting excessive plant growth and eventual eutrophication of the waterway. Elevated levels of ammonia can interfere with fish health. Ammonia is produced in natural settings through decomposition of biological matter. Residential sources of ammonia are fertilizer and cleaning products.

Nitrates. Nitrate is a form of nitrogen usable by plant species. Nitrate can interfere with animal health by binding to blood and blocking the uptake of oxygen. In freshwater aquatic systems the limiting nutrient for plant growth is phosphorous, whereas in saline aquatic systems nitrate is the limiting nutrient. Algal blooms may occur at concentrations greater than 0.1 mg/L. Excessive nitrogen can promote plant and algal growth, resulting in eutrophic conditions, clogging of water channels, and lowered aesthetic quality. Sources from agriculture include animal waste, fertilizer, and irrigation return flows. Residential sources include septage, fertilizer, and pet waste. Industrial sources include water treatment plants and production activities relating to glass making, fertilizer, petrochemicals, and meat processing.

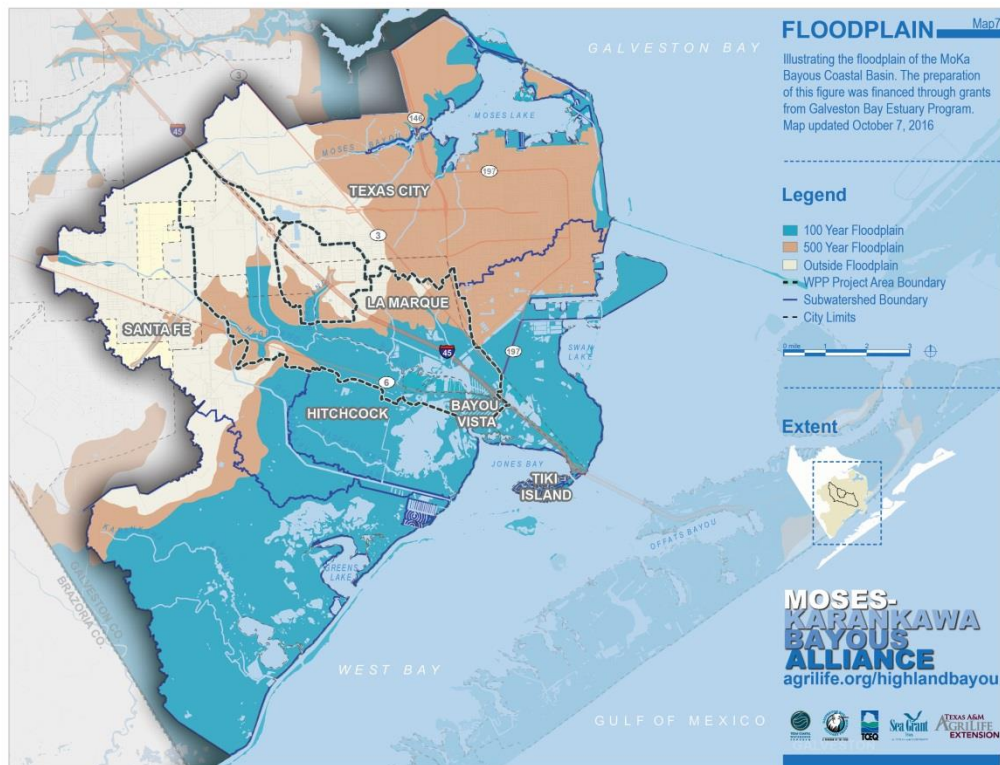
Orthophosphate/Total Phosphorous. Phosphorous is a commonly occurring element, and it can be found naturally in various chemical states and in combination with other elements. Orthophosphate refers to the water soluble form of phosphorous. Total phosphate includes organic P, precipitates, colloidal phosphorous, and phosphorus adsorbed to suspended solids and sediment. Soluble forms of phosphorous do not persist in the environment for much longer than five days, when they become incorporated into soil or taken up by plant life. There are several pathways for phosphorous to move through the environment, but phosphorous adsorption to the surfaces of suspended solids may account for a sizable portion of phosphorous transport. If soluble forms such as orthophosphate are measured in the environment, they are likely recent and indicate a nearby source, such as wastewater treatment plants, septic systems, and/or crops. Excessive phosphorous promotes excessive plant growth. Sources of phosphorous are fertilized fields and lawns, and domestic wastewater.

Chlorophyll-a. Chlorophyll is a green chemical compound found in algae and other plant life. It is the basic molecule in plant-based photosynthesis. The compound exists in several forms, but the most prevalent is chlorophyll-a. Its measurement in water provides a direct measure of phytoplankton in the water and provides a proxy measurement for other pollutants like nitrates and phosphorous. Excessive growth of algae can result in eutrophication and cause fish kills. High levels of chlorophyll can arise from anthropogenic sources of nitrogen and phosphorous.

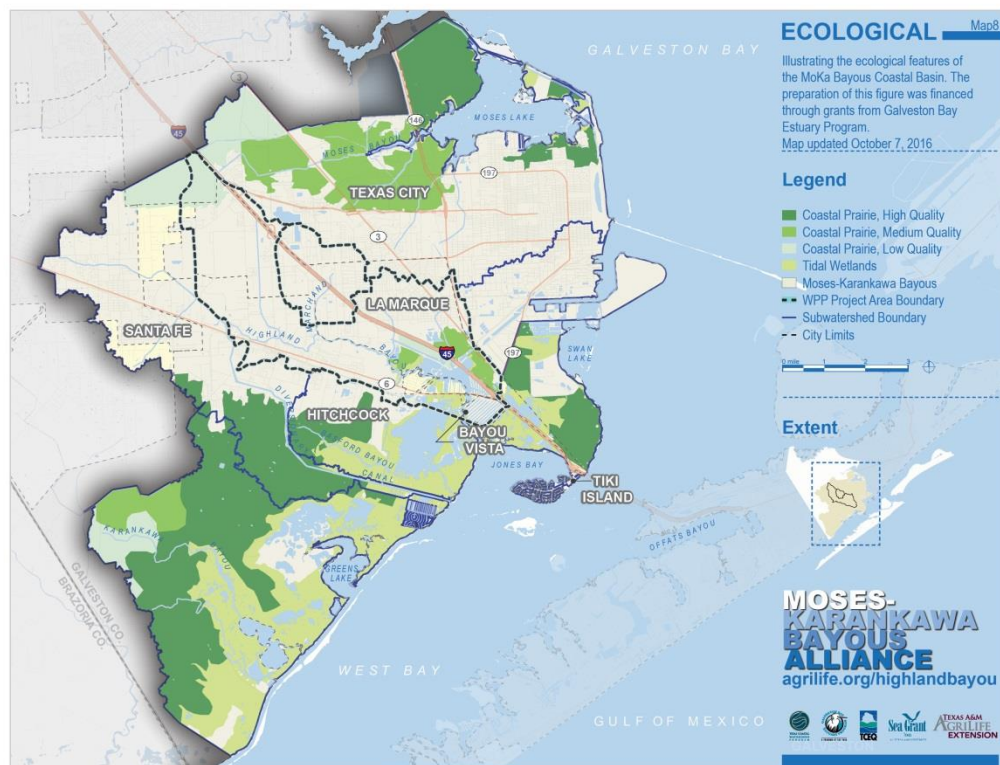
Physical Conditions. Levels of oxygen in the water are the result of several factors, but perhaps not all of them resulting from runoff. For example, cold water can hold more oxygen than warm water, a condition that can partially account for the seasonality of oxygen levels in the waterways. At the freezing point (0°C), fully saturated water can hold 14mg/L, a difference of 6.0 mg/L compared with what water can hold at 70°F (21°C), 8.0mg/L. Because Highland Bayou, like most coastal bayous, is a slow moving warm-water bayou, naturally depressed levels of DO might be the norm, although the ‘normal’ level in a bayou in its pristine state is not understood, and there is disagreement among experts about what that figure would be for waterways like Highland Bayou.

Other Existing Conditions in the Bayou:

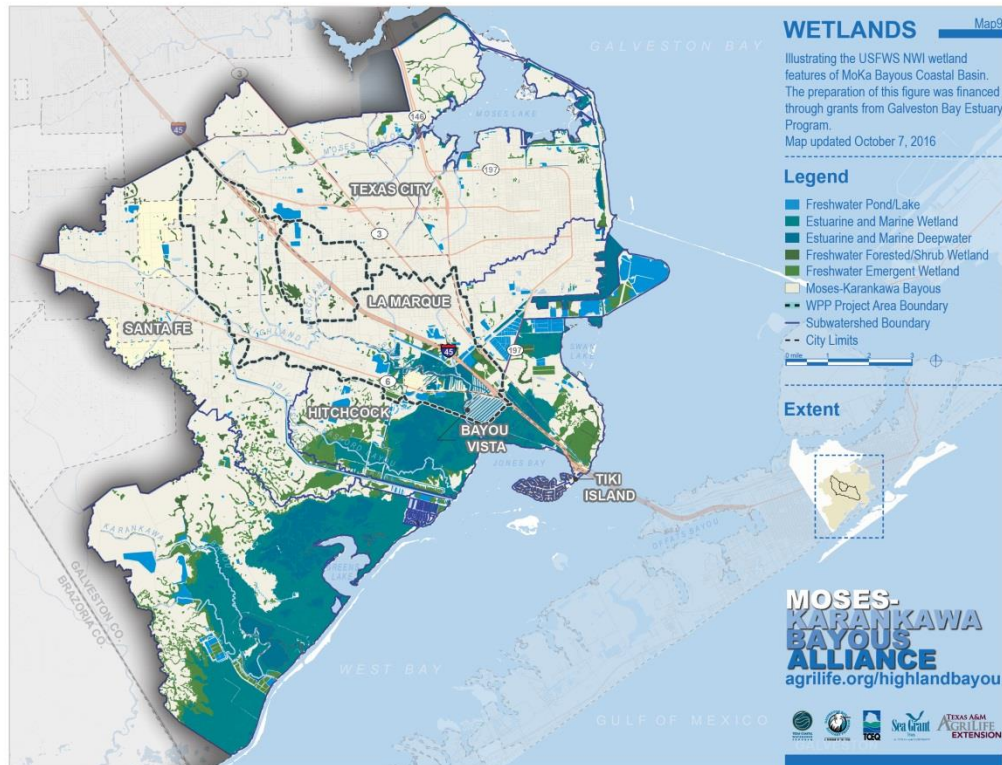
The following maps are included for informational purposes. The flood plain map (Map- 7) indicates the location of flood risk in the watershed. The Ecological map and the wetland map (Map- 8 & Map- 9) identifies the locations of medium and high quality prairies along with wetland areas, which may be candidate locations for conservation efforts. The final map is a population density map (Map- 10) showing areas of human settlement in the basin.



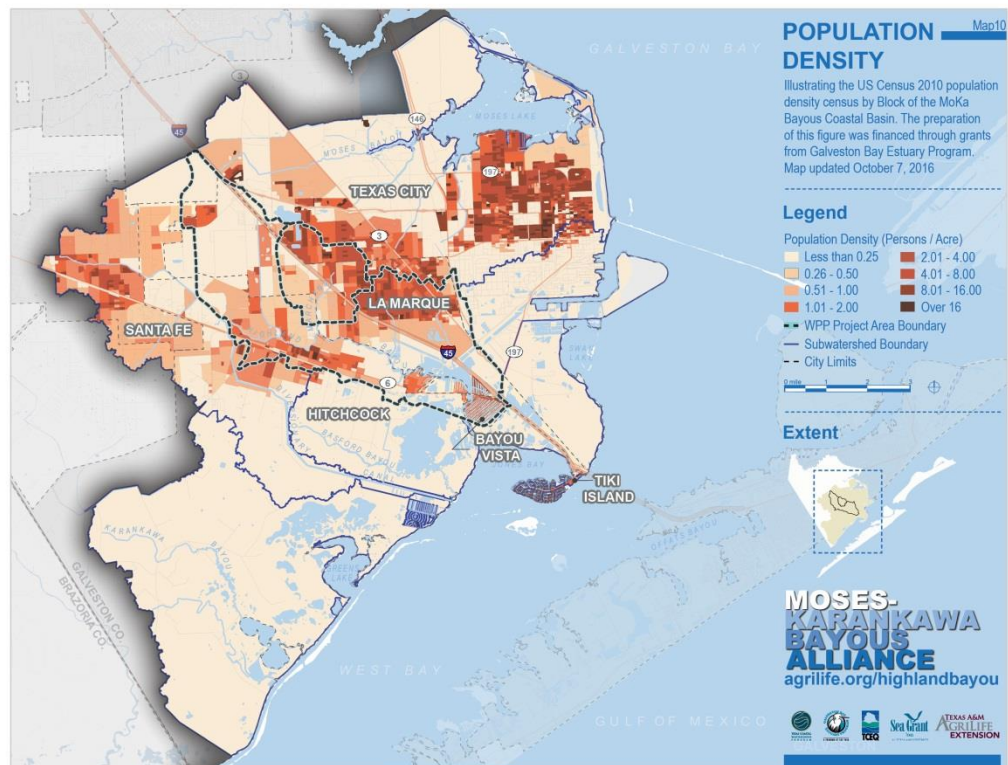
Map- 7. Floodplain within the MoKa Bayous Coastal Basin



Map- 8. Ecological Features of the MoKa Bayous Coastal Basin



Map- 9. USFWS NWI Wetland Features of the MoKa Bayous Coastal Basin



Map- 10. US Census 2010 Population Density Census by Block of the MoKa Bayous Coastal Basin

Element A: Identify Sources of Impairments and Loads

Stormwater Runoff is a fingerprint of the land

Water pollutants originate from both point and NPS on the land. Point sources have an identifiable origin such as a pipe or ditch from an industrial or commercial process discharging directly into a waterway. Discharges from point sources are usually covered by federal and state regulations and permits. Stormwater NPS pollution, also commonly called *runoff pollution*, refers to diffuse sources of pollution originating from multiple locations, such as lawns, roadways, homes, and businesses. Runoff from NPS is commonly understood to include fertilizers, insecticides, oils, sediment, and bacteria. Each NPS source might be small, but when considered together, they can exceed the pollution contribution from point sources. In fact, in many watersheds around the county, NPS pollution is the leading cause of water quality problems.

This means that how land is used determines what we see in the water. Development, for example, impacts both the *quantity* and the *quality* of stormwater runoff. Impervious surfaces alter stormwater runoff patterns and are a key indicator of loading and overall watershed health (Figure A-1). Impervious surfaces include all hard surfaces, such as roofs, driveways, parking lots, roadways, and even compacted soil. Due to changes in surface cover, developed or urbanized areas exhibit higher stormwater pollutant levels when compared with their pre-development runoff levels. As the amount of impervious surface cover increases in the watershed, the water quality of receiving water bodies degrades. Two neighboring properties, one developed and one undeveloped, both receive the same amount of rainfall but exhibit different runoff characteristics. The undeveloped property will allow water to infiltrate into the ground while the developed property sees increased runoff.

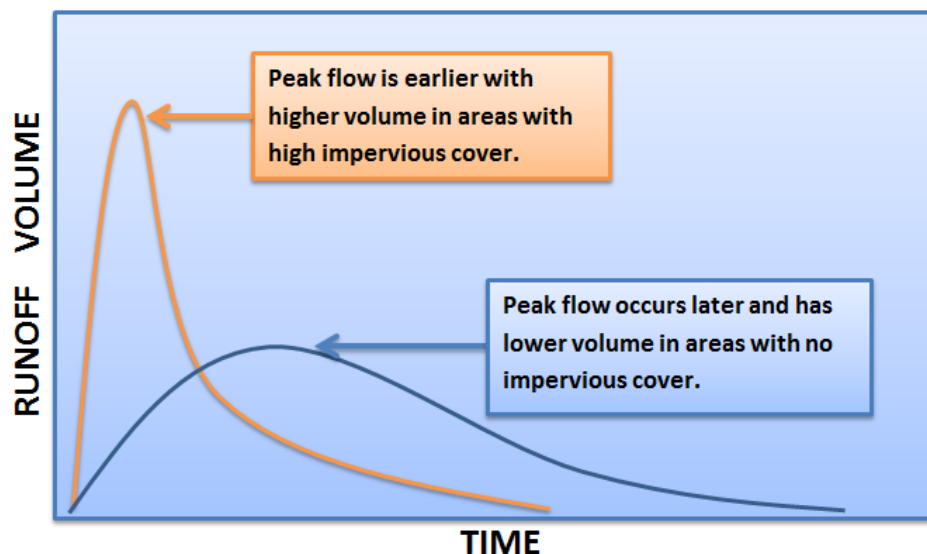


Figure A- 1. Generalized Hydrograph of Areas With and Without Impervious Surface Cover
The Origin Denotes the Rainfall Event

NPS Quadrants in Highland Bayou

Stakeholder concerns about water quality were gathered and organized by the project team through a series of meetings and one-on-one conversations. The project team organized these concerns into four major categories. These quadrants were used to organize ideas and focus conversations on particular areas of activity (Figure 2). It is worth noting here that ‘Flow and Dredging’ (technically, hydrologic changes) is an unusual category for a WPP and is not itself a ‘source’ of pollutant loading. However, this quadrant was a primary concern for many, many stakeholders, and the prospect of addressing the bayou’s flow conditions kept participants engaged. More on this background is discussed in sections below.

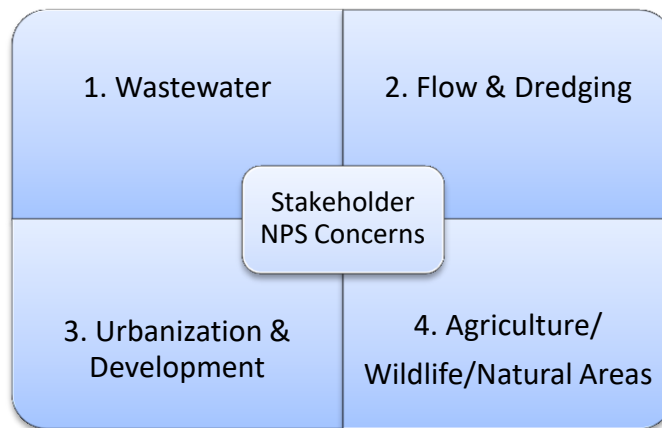


Figure A- 2. Quadrants used to organize project ideas

Activities associated these quadrants determine the NPS pollutant issues of significance and focuses the work group’s attention on what kinds of activities would be helpful for reducing NPS loads. The following table summarizes NPS sources that stakeholders discussed as likely contributors of NPS loads in the watershed.

Table A- 1. Pollutants by Source

| Source | Bacteria | Nutrients ¹ | Sediment |
|---|----------|------------------------|----------|
| Quadrant 1: Wastewater | | | |
| Wastewater Treatment Facilities | x | x | |
| Sanitary Sewer Systems | x | x | |
| Septic Systems (OSSFs) | x | x | |
| Quadrant 2: Flow & Dredging (see discussion below) | | | |
| Quadrant 3: Urbanization & Development | | | |
| Urban Stormwater Runoff | x | x | x |
| Construction Runoff | | | x |

| Source | Bacteria | Nutrients ¹ | Sediment |
|---|----------|------------------------|----------|
| Lawn Care & Landscaping | | x | x |
| Litter and Illegal Dumping | | x | |
| Pets | x | x | |
| Quadrant 4: Agriculture/Wildlife/Natural Areas | | | |
| Feral Hogs | x | | |
| Livestock and Pasture | x | x | x |
| Wildlife and Non Domestic Animals | x | x | x |
| Streambank Erosion | | x | x |

¹ Nutrients – nitrogen and phosphorus compounds.

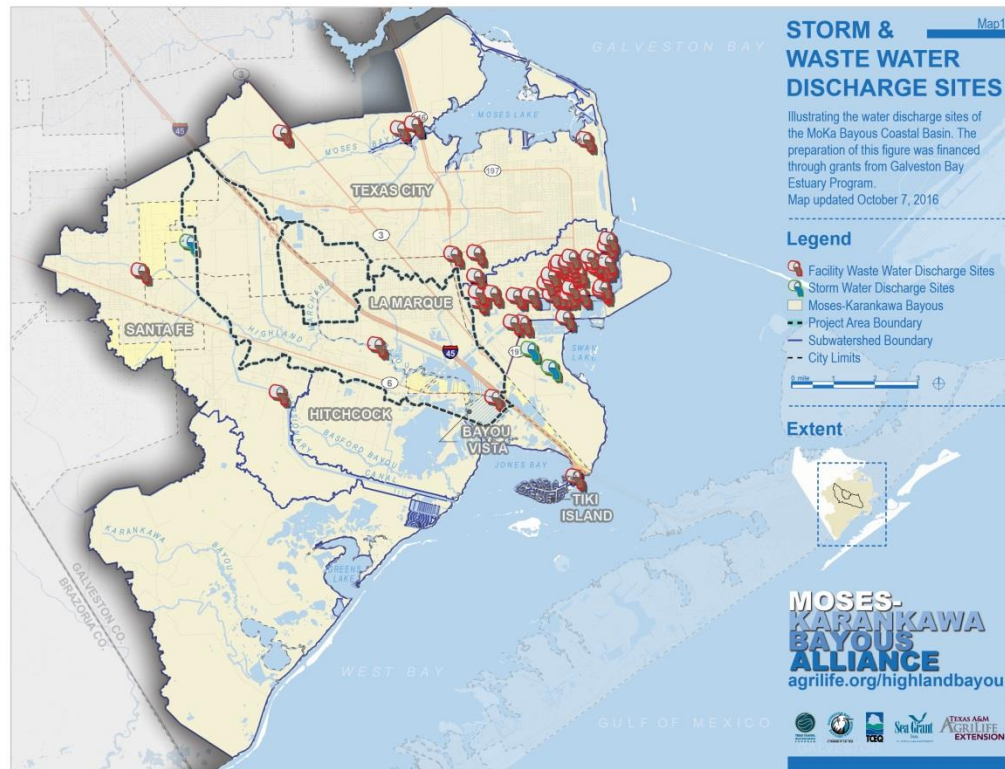
Quadrant 1: Wastewater

Permitted Wastewater Treatment Facilities

There are two permitted wastewater treatment facilities in the watershed. (Map-11). The Galveston County Municipal Utility District (MUD) 12 Wastewater Treatment Plant (WWTP) and La Marque's Westside WWTP discharge into Highland Bayou. These two major sources, City of Hitchcock and La Marque's Westside facility, are authorized by the TCEQ to discharge treated wastewater at a volume not to exceed an annual average flow of 3 million gallons per day (MGD). The Galveston County MUD 12 facility, considered a minor source, is authorized to discharge a daily average flow at a volume not to exceed 0.4 MGD. While the City of Hitchcock's WWTP lies outside of the watershed boundaries and discharges to the Diversionary Canal (a separate watershed), much of the associated collection system occurs within the Highland Bayou Watershed.

Table A-2 lists current permit and discharge information for the three permitted WWTPs. In the last five years La Marque has had three TCEQ inspections and Galveston County MUD 12 has had two, none resulting in enforcement actions. Two formal enforcement actions were reported for the City of Hitchcock. There have been nine reported effluent exceedances for both Hitchcock and La Marque and one for Galveston County MUD 12 between 7-31-2012 and 7-31-2015. Effluent measurements in Table A-2 are reported for the 2014 calendar year to ensure a complete dataset (at the time of the request, November and December 2015 data was unavailable). The *Enterococci* daily maximum threshold was exceeded during only on month for both the City of Hitchcock and Galveston County MUD 12. Other effluent parameters remain within discharge limits: nitrogen (ammonia total, as nitrogen), biochemical oxygen demand, and flow. Though not reported in the table, the following exceedances were noted for January through October 2015. The La Marque facility had nitrogen exceedances during three separate months. The daily average value for nitrogen for both the City of Hitchcock and La Marque facilities showed an approximate 200% increase when compared with 2014 values. Average nitrogen measured in lbs/day for the La Marque facility was 16.45 in 2014 and 47.27 in 2015. Average nitrogen measured in lbs/day for the Hitchcock facility was 1.60 in 2014 and 4.93 in 2015. The City of Hitchcock had an *Enterococci* daily maximum value exceedance during only month of 149 CFU/100mL. In October of

2015, the La Marque facility had a daily maximum value of 2420 CFU/100mL, their only exceedance of the 104 CFU/100mL discharge limitation. MUD 12 did not report any effluent limitation exceedances for January through October 2015.



Map- 11. Storm and Wastewater Discharge Sites

The Galveston County Health District (GCHD) Water Pollution Services Program offers quarterly inspections of WWTP operations for compliance with state and federal regulations as a contract, and have assisted Hitchcock and La Marque as recent as 2015. For the City of La Marque in FY2015, the GCHD reported an annual average removal rate for ammonia nitrogen of 88%, which exceeds the monthly removal rate of 85% required by the permit. The average *Enterococci* quantity was 1.53 CFU/100mL.

WWTP effluent is considered a point source of pollution, highly regulated through the Texas Pollutant Discharge Elimination System (TPDES) program. Due to the episodic nature of discharges that exceed established thresholds for bacteria and other contaminants, stakeholders expressed greater concern for releases from the sanitary sewer collection system. With additional growth in the basin and extra sewage to treat, it is reasonable to expect volumes to increase accordingly though discharges would be required to remain within the permit limitations.

Table A- 2. Permitted Wastewater Treatment Facilities in the Project Area including Permit and Discharge Information

| | | City of Hitchcock WWTP (Hitchcock) | Galveston County MUD 12 WWTP (Hitchcock) | Westside WWTP (La Marque) |
|---|---|---|--|------------------------------|
| EPA ID and TPDES Permit Number | | TX0062243; WQ0010690001 | TX0020311; WQ0010435002 | TX0114821; WQ0010410003 |
| Permit Type and Expiration Date | | Major; October 1, 2018 | Minor; October 1, 2018 | Major; October 1, 2016 |
| Receiving Waters | | Diversiory Canal (outside of watershed); Collection system is in Highland Bayou Watershed | Highland Bayou | Highland Bayou |
| Comprehensive Compliance Inspections (5 yrs) | | 4 | 2 | 3 |
| Effluent Exceedances (3 yrs) | | 9 | 1 | 9 |
| Formal Enforcement Actions (5 yrs) | | 2 | 0 | 0 |
| Date of Last Formal Action | | 04/07/2013 | - | - |
| Penalties (5 yrs) | | \$64,137 | - | - |
| Effluent Measurements Calendar year 2014 | Ammonia as N, NH ₃ (lbs/year) | 579 | - | 5,963 |
| | BOD (lbs/year) | 8,640 | 1,790 | 11,808 |
| | Ammonia as N, NH ₃ (lbs daily) | 1.60 | - | 16.45 |
| | BOD (lbs daily) | 23.21 | 5.36 | 32.22 |
| | <i>Enterococci</i> Daily Maximum Concentration (count/100mL) | 155 | 186 | 93 |
| | <i>Enterococci</i> Daily Average Concentration (count/100mL) | 5.97 | 5.29 | 7.04 |
| | Total Annual Flow (MMGal) | 471 | - | - |
| | Average Daily Flow (MGD) | 0.61 | - | 1.41 |

“ - “

Bold values indicate an exceedance in reported discharge concentrations when compared to authorized permit limits.

Abbreviations: BOD – Biochemical Oxygen Demand; lbs – pounds; MGD – million gallons per day; MGal – MGal/year x 12 (the number of months); MUD – municipal utility district; N – nitrogen; TPDES – Texas Pollutant Discharge Elimination System; WWTP – wastewater treatment plant

Data Source: EPA Discharge Monitoring Report Pollutant Loading Tool and TCEQ Region 12 Water Section staff.

Sanitary Sewer Systems

Collection systems bring sewage from home and businesses to wastewater treatment facilities. The collection systems include a network of sewer lines, pump stations, and supporting infrastructure. Most areas of the Highland Bayou Watershed are serviced by a collection system. Main lines usually follow highways and routes, into neighborhoods, and finally connecting to buildings. Anything poured or flushed down a drain flows into the collection system, meaning that sewage is a collection of human waste, urine, paper products, detergents, cosmetics, pharmaceuticals, cleaners, and any other liquids used at home or in businesses. SSOs are releases of untreated sewage from these collection systems. These releases can

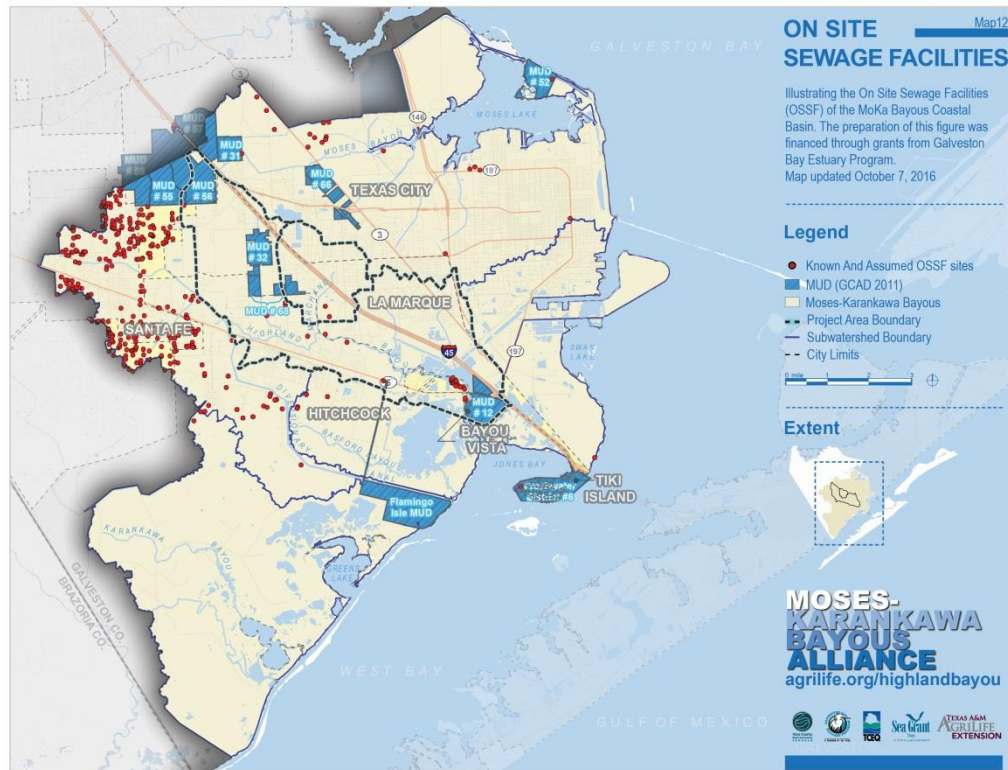
transmit high levels of bacteria to stormwater runoff. SSO of certain sizes or happening in certain locations (i.e., near drinking water sources) must be reported by the collection system TPDES permittee. SSOs usually occur as the result of a break, stoppage, or exceedance of capacity in the sanitary sewer conveyance system. If not directly discharged into the bayou, the overflows typically drain to the stormwater conveyance system and are transported to the bayou by stormwater runoff. Load reduction estimates are included in Element B. Since most of the watershed study area is serviced by a collection system, reductions are allocated on a pro-rated share of population in each watershed AU (Map-5).

Septic Systems

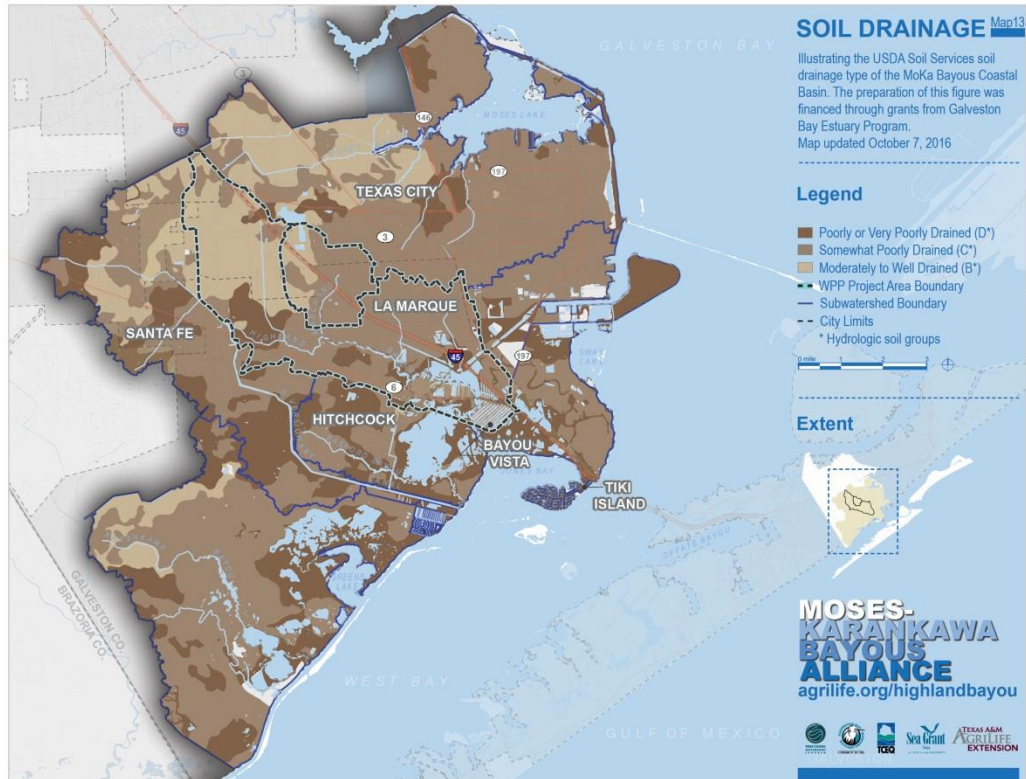
Onsite Sewage Facilities (OSSFs), commonly referred to as septic systems, are a standard method for treating home and business sewage on site. This is particularly true in areas of low population density. OSSFs within the watershed are not considered a significant source of pollutants for Highland Bayou. The number of permitted systems is low and unpermitted systems are assumed to be low, too. Known locations are based on permit information. Assumed locations are estimated by identifying structures both without a permitted OSSF and situated outside of a municipal service area boundary for sanitary sewer within the watershed; there is a cluster of OSSFs located near TX Highway 6 in the parts of unincorporated Galveston County, referred to as Freddieville and Old Highland Bayou, just west of Bayou Vista. Parts of this area have been recently brought into Hitchcock's collection system service area. GCHD is sometimes contacted by residents reporting leakages from pipes and bulkheads in this area. These reports usually result in a determination that the leakage is connected to abandoned or unpermitted OSSFs. The area is limited in size and few other unknown OSSFs are believed to exist in the area. Outside of the watershed, the largest clusters of permitted OSSFs are in and around the City of Santa Fe, areas draining into the Diversionary Canal to the south or Dickinson Bayou to the north.

Although there are only a few OSSFs in the watershed, failing OSSFs contribute bacteria and nutrients by seepage from failing drain fields or from overflowing systems. Proper operation and maintenance of OSSFs is critical for protecting public health and surface water resources. System owners (i.e., homeowners) are responsible for the proper maintenance of their systems. Aerobic systems require specialized attention, and it is common that owners forget to add chlorine or utilize the wrong chlorine (i.e., pool chlorine). Poor or improper maintenance practices can result in the system becoming unbalanced and non-performing. With these kinds of failures, aerobic systems could be spraying raw sewage onto the ground. Maintenance agreements when required seem to help this.

Before the mid 1970's, no permit was required to install an onsite septic system in Galveston County, resulting in a legacy of unpermitted and possibly poorly performing or failing systems dotting the landscape. No federal permits are required for installing OSSFs. County regulations now require that the property owner acquire a permit and conduct a site evaluation of water tables and soil permeability, the two factors most likely to contribute to a septic system treatment failure. It is likely that older, unpermitted systems were not designed for the poor soil conditions especially if one assumes that the conventional soil leaching systems were used when they were installed in. Most soils in this watershed have shallow water tables and low permeability (Map-13). During periods of extended wet weather, there is a high probability of soil saturation, when untreated septage could rise to the surface and thence to nearby drainage ditches.



Map-12. Onsite Sewage Facilities



Map-13. USDA Soil Services Soil Drainage Types

Table A-3 includes the number of permits issued by year. (Source: Martin Entringer, Galveston County Health District in 2008.)

Table A- 3. Relative Change in Galveston County New OSSF Permits from Selected Years

| Year | Percent standard soil treatment systems | Percent aerobic chlorinated (advanced) systems |
|-------------|---|--|
| 1995 | 84 | 16 |
| 1998 | 68 | 32 |
| 2003 | 51 | 49 |
| 2006 | 23 | 77 |

Quadrant 2: Hydrologic Change- Flow and Dredging

Hydrological changes is an unusual NPS category and is not itself a pollutant ‘source,’ however it may impact loading characteristics in the bayou. Changes in the watershed since the 1970’s has resulted in what stakeholders call a very perceptible change in the flow and character of the bayou. Stakeholders believe two forces are responsible for this. The first is the construction of the Diversionary Canal by the US Army Corps of Engineers in the early 1970’s. Highland Bayou draining the City of Santa Fe was diverted at a point near Jack Brooks Park and into a constructed canal that now drains through the old Basford Bayou watershed south of Highland Bayou. The intent of the diversionary canal was to reduce flooding in Highland Bayou, but the resulting canal diverted over half of the headwaters towards another watershed. Floods do not occur as frequently now in Highland Bayou, but the average flow of water has predictably declined since then.

A second factor has been the steady development of the watershed over the decades. Sediment from development is transported down the drainage ditches and into the bayou. The combination of slower flow and increased accumulation of sediment has according to stakeholders resulted in a shallower and more stagnant bayou. Representatives from Drainage District 2 characterize the local soil as highly erodible, and they spend considerable resources managing and removing sediment from their ditches. The bayou channel itself, outside of the jurisdiction of the drainage district, has seen sediment accumulate. Several stakeholders shared pictures from decades ago of swimming holes in Highland Bayou that could be fished and used for jumping and swimming, places which now have only inches of stagnant, foul water.

The connection between hydrology and NPS loading is not entirely understood here. Many stakeholders in the watershed believe that an improved flow regime in the bayou would logically result in improved water quality. By dredging sediment from the bayou channel and managing the inflow of sediment, they believe that the bayou’s flow conditions and tidal dynamics would improve. It is the opinion of the project team that the stakeholder group’s foremost concern about the bayou’s changes over the years is a powerful pathway for engaging community to understand the full range of land-based factors that are impacting the bayou. For this reason the project team has designated Flow and Dredging as a fully-fledged NPS quadrant.

Quadrant 3: Urbanization Activities

Construction

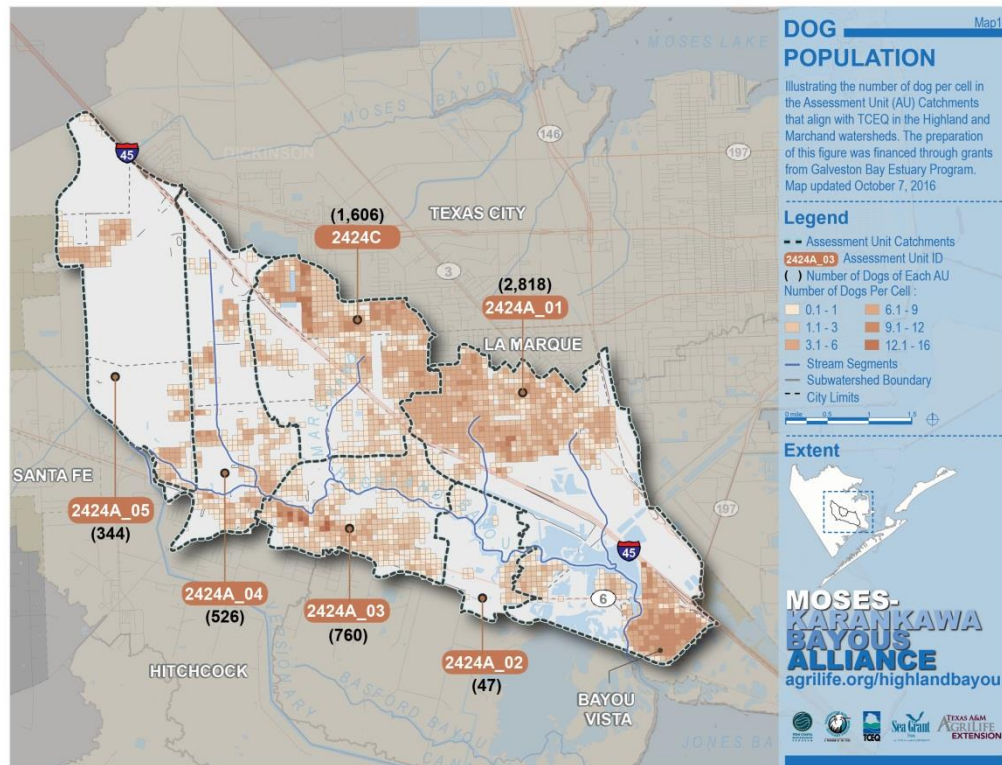
Construction and development activities usually disturb acres of soil surface and which can remain exposed for months or more. Disturbed surfaces include the construction pad, roads, maintenance yards, and newly excavated detention ponds. If not managed properly, erosion at these sites can transport significant sediment into drainage conveyances and eventually waterways. Erosion adds turbidity to the water column, and the accumulation of eroded sediment in waterways removes flow capacity and can harm habitat for aquatic species. As development continues into the watershed, particularly in the Highland bayou headwaters (AUs 2424A_4 and 2424A_5), the potential for sediment erosion is high. While Municipal Separate Storm Sewer Systems (MS4) rules are supposed to protect against construction site runoff, the impact of construction activities are still likely impacting the watershed.

Litter and Illegal Dumping

Stakeholders expressed concern for litter and illegal dumping near waterways and throughout the surrounding communities. Illegal dumping refers to improper disposal of tires, batteries, cars, boats, construction litter, and similar waste items. It has also been directly observed by the project team the illegal discharge of RV septic waste directly into the bayou. Problem areas for illegal dumping include vacant properties, dead end streets, the ditches along I-45, and within Highland Bayou Park (Stakeholder Meeting, 2015). Reducing litter and illegal disposal through clean-up efforts and community education would promote pride and awareness of the surrounding natural environment and good stewardship principals.

Pets

Dogs and cats are a significant contribution to surface water contamination when their fecal material is left on the ground (Environmental Protection Agency, 2001). Pet waste is washed into storm drains, where it eventually enters nearby surface waters and brings with it bacteria, resulting in conditions where fishing and swimming are not recommended and can lead to illness. Based on the number of homes and average pet ownership rates, it is estimated that there are over 5,000 dogs in the Highland Bayou Watershed, (see Map- 14 below). Since the Highland and Marchand Bayou watershed includes well developed areas, pet waste is expected to be a large source of contamination. Other pets such as horses, hogs, poultry, and rabbits exist in the watershed, but their numbers are not believed to be sizable enough to contribute significantly to bacteria levels.



Map- 14. Dog Population in the MoKa Coastal Basin

Lawn Care and Landscaping Practices

Improper management of landscaping debris, fertilizers, and pesticides was a prominent concern of stakeholders. Grass clippings, leaves, mulch and other plant matter swept or blown onto the road, driveway and storm drains introduce pollution to local waterways. There is a need for public education about water quality impacts associated with landscaping practices. Homeowner education for spraying pesticides was specifically recommended by stakeholders, including, how much to use, when to spray in relation to rain events, and for the homeowner to consider nearby waterbodies. Education for lawn contractors was also brought up by stakeholders as essential to reducing the amount of the above mentioned materials entering surface waters. Taken together, these related activities are a critical source of NPS load in developed areas.

Urban Stormwater: MS4

MS4s Phase II regulations began in 1999 to regulate the management of NPS pollution from MS4 systems, which refers to the system of stormwater conveyances that transfer stormwater into local waterways. Stormwater runoff is untreated and should not be confused with a centralized sewage treatment system. There are four Phase II regulated MS4s in the watershed, included in Table A-4 below. MS4 permittees must address 6 areas of stormwater management through local laws and enforcement. The primary concern of MS4s is the regulation of construction and post-construction activities, activities that generate disturbed soil surfaces and lead to erosion of sediment into the MS4 and local water ways.

MS4 entities must also have a program in place for illegal discharge detection and elimination, referring to non-stormwater discharges into the MS4.

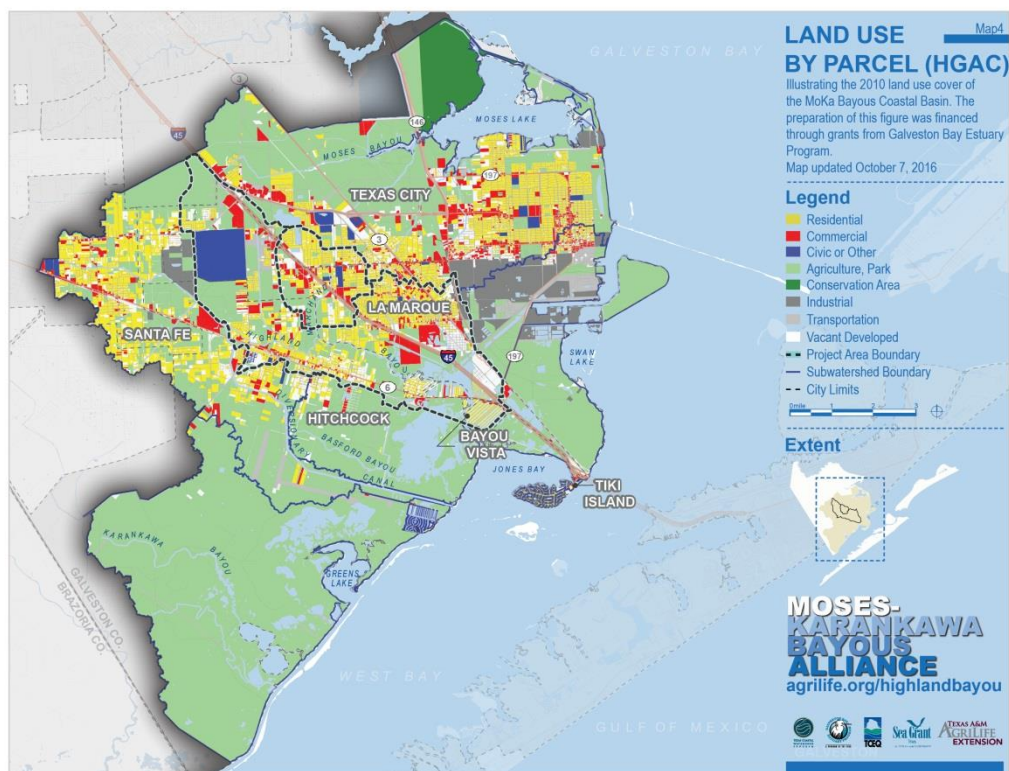
Table A- 4. Phase II Regulated MS4s in the Watershed

| Regulated Entity Number | Active MS4 Permit | Permittee |
|-------------------------|-------------------|--------------------|
| RN105477434 | TXR040590 | City of Hitchcock |
| RN105538763 | TXR040178 | City of La Marque |
| RN105604987 | TXR040364 | Galveston County |
| RN105479513 | TXR040024 | City of Texas City |

The GCHD Water Pollution Services Program monitors and evaluates stormwater samples for bacteria, DO, pH, chlorine, BOD, and ammonia. Many of the observed exceedances occur within three days of a rainfall event. During FY2015, bacteria levels at the eight stormwater sites within the City of La Marque exceeded the standard for single grab samples 50% of the time.

Urban Stormwater: Land Use

Land use is how people use the landscape (farm, pave, restore, etc) and what activities they conduct on that land (commercial, industrial, residential, etc). Map-4 illustrates existing land use on a parcel by parcel basis in the study area. The Houston-Galveston Area Council (H-GAC) assigned land use categories to data sets maintained by the Galveston County Appraisal District (CAD). Parcel data is primarily maintained for taxing purposes, but it can also inform an analysis for how land is used. In addition, not every use is utilized at the same intensity across parcels. So, together with information about impervious surface and building density for certain uses, it is possible to estimate how much NPS pollution is generated in each subbasin- this is the approach utilized for NPS pollutant load estimates later in this section. Finally, the parcel land use map is useful in understanding where to emphasize certain public education efforts and implementation of Action Area projects.



Map- 4. 2010 Land Use Cover of the MoKa Coastal Basin

Urban Stormwater: Land Cover & Impervious Surface

A land use-land cover change analysis was performed as part of this WPP effort, utilizing data from the National Oceanic and Atmospheric Agency (NOAA) Coastal Change Analysis Program (C-CAP) program, 1996-2010. The analysis looks at changes in how land is utilized and how much surface cover has increased from development over time. Maps and full tables of the analyses are included in Appendix 2, LULC Analyses. The following table (A-5) shows the increase in developed acreage in the watershed over a 14-year period. Impervious surface cover is the most important factor concerning land use changes and water quality indicators.

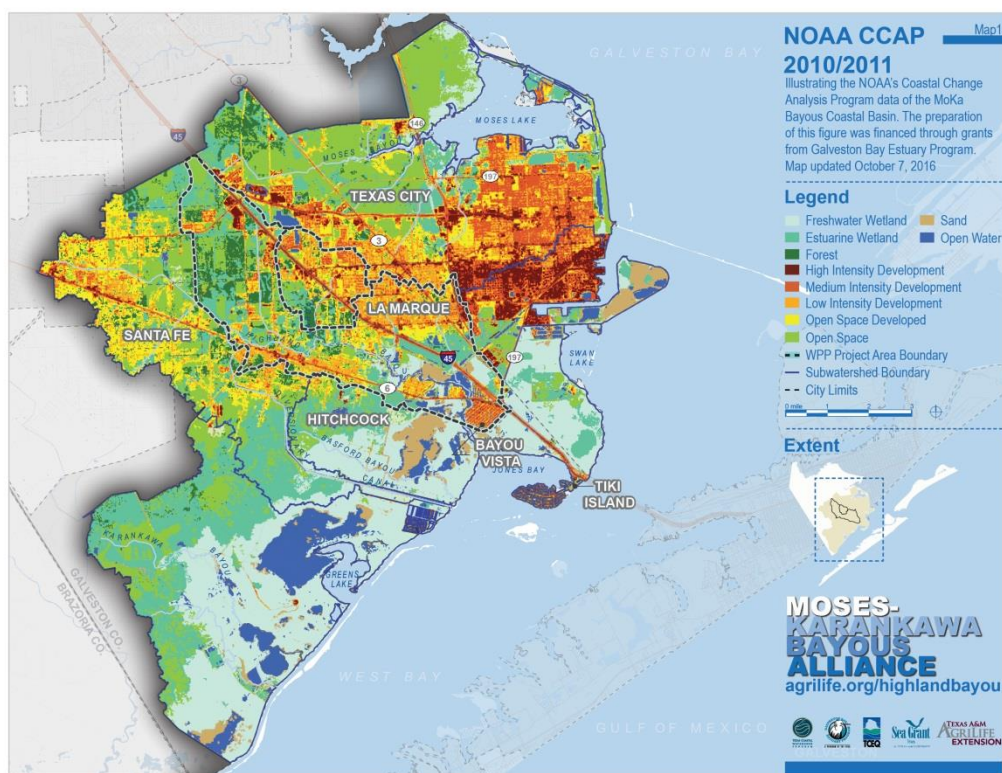
Table A- 5. Increase in Developed Land, Highland and Marchand Bayou, 1996-2010

| Watershed | Acres developed 1996 | Acres developed 2010 | Relative % increase | Increase as a % of the watershed |
|----------------|-------------------------|-------------------------|---------------------|-------------------------------------|
| Highland Bayou | 3,397 | 3,687 | 8.5 | 2.4 |
| Marchand Bayou | 1,046 | 1,138 | 8.8 | 3.7 |
| Total | 4,443 | 4,825 | 8.6 | 3.2 |

Land Cover and Impervious Surface in Highland Bayou. Highland saw a 14-year increase of 381 acres in developed land, including a 57 acre increase in high intensity development. Agricultural lands declined by 39 acres, undeveloped vegetated space declined by 247 acres, and wetlands of all types declined by 88 acres; this resulted in a net loss of 374 acres of undeveloped land. A loss of 90 acres of open water potentially corresponds with the 83 acres gained as beach or unconsolidated land. Although some of this

may result from new sand mining operations in the basin. Approximately 7% of all developed land was high intensity development, 22% was medium intensity, 40% as low intensity, and 31% as open developed land. Approximately 44% of land in the basin is classified as developed, and it is estimated that 16% of the watershed is impervious surface cover. See Appendix 2 for detailed tables and maps.

Land Cover and Impervious Surface in Marchand Bayou. The Marchand Bayou watershed saw a 14-year increase of 109 acres of developed land, including a 20 acre increase in high intensity development and a 43 acre increase in medium intensity development. Pastures and vegetated undeveloped land decreased by 66 and 35 acres respectively, and wetlands of all types decreased by 6 acres; this resulted in a net loss of 103 acres of undeveloped land. A loss of only 2 acres of total beach or unconsolidated land was lost, however total open water did not change. These values indicated that suburbanization is the primary land conversion in the basin. Approximately 8% of all developed land in the basin was high intensity development, 23% was medium, 38% was low, and 31% was open developed land. Developed land constitutes approximately 68 % of the basin, and it is estimated that 21% of the watershed is impervious surface cover. See Appendix 2 for detailed tables and maps.



Map- 15. NOAA's C-CAP Data for the MoKa Bayous Coastal Basin

Quadrant 4: Agriculture/Wildlife/Natural Areas

Livestock

Farm animals such as cattle, horses, and goats contribute to bacterial loading, but they are not considered to be a significant source of bacteria in this watershed. Large scale domestic animal facilities or operations are not present in this urban watershed. Approximately 9% of Galveston County is categorized as agricultural by NOAA C-CAP. The 2012 USDA's National Agricultural Statistics Service was reviewed for the cattle and calves inventory in Galveston County. The total cattle population for the county was 9,772, ranking Galveston County 220 out of 254 Texas counties. At approximately 14,548 acres, the watershed covers only 2.6% of Galveston County and agricultural land use accounts for only 3% of the agricultural land use in Galveston County. Using NOAA C-CAP and USDA data, the estimated number of cattle within the watershed is 293.

Wildlife and Non Domestic Animals

Contributions of bacteria from wildlife are less easily controlled when compared to other sources since these animals move freely over the landscape and some are only present on a seasonal basis (e.g. migratory birds). Wildlife species in the watershed includes deer, raccoon, opossum, squirrels, birds, feral dogs and cats, and others. Stakeholders have reported pigeons in large numbers throughout the canal communities in the lower reach of the watershed. Pigeons are seen at bayou access points and nesting under boat houses. Whereas the population of many wildlife species is unknown, the Texas Colonial Waterbird Census conducted between 1973 and 2006 offers an example of just how many birds may present in the watershed during different seasons. The census consists of counts for 31 species at colonies along the north Texas Gulf Coast, many of which are observed in the watershed. Colony populations can be highly variable, from a few dozen to tens of thousands and beyond. Such a high volume of birds can significantly impact water quality near these areas. Common wading birds observed are the great blue heron, great egret, snowy egret, tricolor heron, little blue heron, ibises, and roseate spoonbills. Open water birds include royal terns, Caspian tern, least terns, sandwich terns, and neotropic cormorants.

Feral Hogs

Feral hogs are invasive non-domesticated hogs that disturb soils, eat small livestock, and transmit disease. Stakeholders within the watershed have observed wild hogs damaging property. Wild hogs prefer moist bottomlands along streams and marshes, and can be significant source of soil erosion. As feral hogs consume roots and ground vegetation, they can disturb substantial areas of soil, stripping away any stabilizing ground cover and making the area prone to soil erosion. As hogs continue to trample, eat, and damage crops, they pose a financial burden to agricultural producers. In Texas alone, feral hogs cause an estimated \$52 million of damage to agriculture annually and they are increasing in numbers across the state (Timmons, et al., 2012). A combination of pig rooting behavior and deposits of fecal matter increases nitrogen levels in water, impacting water quality.

Feral hogs have established a population in the watershed and are frequently observed in Jack Brooks Park, the UH Coastal Center, and Mahan Park. Although, the exact population numbers are unknown at this time, interviews with stakeholders in the watershed have indicated their presence is impactful: "Feral hogs use the park as a playground, the UH Coastal Center as a hotel, and the landfill as a buffet."

Trapping efforts have occurred in both Jack Brooks Park and the UH Coastal Center. Management of feral hogs can be difficult for a variety of reasons including their ability to reproduce quickly and their lack of natural predators.

Streambank Erosion

Fallen trees and sediment from drainage ditches have filled in sections of Highland Bayou, creating stagnant pools of water in some areas. Trees and brush falling onto the banks is partly a natural process and it provide valuable habitat for aquatic organisms. However, the silting in of culverts and obstruction of flow within the channel has been a long standing concern for residents. In 1996 dozens of volunteers removed brush and trash from Highland Bayou during a bayou cleanup effort.

Open Space Preservation.

Individual properties within the watershed do not function as separate, isolated components but as a single, integrated natural system. Significant alteration of individual properties can disrupt the functioning of the watershed. Fragmentation of land tracts resulting from the breakup of larger undeveloped lands and habitat loss from development are some of the threats wildlife populations

Estimating NPS Loads: The Simple Method

To estimate pollutant loads for selected indicators (nitrogen, phosphorus, biochemical oxygen demand, sediment, and *Enterococci* bacteria), the Simple Method (Schueler, 1987) was determined to be the most appropriate model for the Highland Bayou Watershed. The Simple Method is just that –a very simple model based on just a few parameters. The Simple Method model is specifically designed for use in urbanized areas. The capacity of this method to easily estimate pollutant load for multiple land uses is one of its strengths. Schueler notes that the Simple Method “is designed to provide a quick, easy, and versatile means for estimating pollutant loads. Therefore, the method sacrifices precision for the sake of simplicity and generality. Despite its limitations, the Simple Method is considered precise enough to make reasonable and reliable nonpoint pollution management decision at the site-planning level” (1987).

The Simple Method is based on two key features –the coverage of impervious surface and an “event mean concentration” (EMC). The impervious cover directly impacts runoff: the more impervious a site, the greater the runoff. The EMC is a “flow-weighted” concentration of pollution that is representative of runoff from a particular land use. Impervious values in this plan were derived from NOAAs C-CAP data. EMC values were obtained from the literature.

According to Schueler, “the Simple Method provides estimates of pollutant loading that are probably close to the ‘true’ but unknown value for the site. It is important to not overemphasize the precision of the results obtained (1987). His example notes that a distinction between 34.3% and 36.9% would be “inappropriate.” This same reasoning applies to interpretation of results here as aggregated load values for the watershed.

Known Data Gaps. Due to the lack of stream flow data in the basin, the loading values from the contributing runoff could not be calibrated with flow data, and thus obtain predictive values as to how

reductions in loading will impact water quality in the stream. As of late 2016, a remedy for this deficiency is being sought through a supplementary study that will update the loadings estimated here.

The loading calculations were developed using the Community Health and Resources Management (CHARM) model data framework. The CHARM data is a 2.5 acre grid-based system for tracking characteristics about the land and community such as land area by different cover types, number of homes, and elevation. Primary data sources for the CHARM data are federal and state data sets (i.e., US Census, USSURGO). The watershed consists of 5,886 CHARM cells. Total NPS loads for catchments and the watershed are calculated by summing all cell values in those areas. This geospatial data structure provides a ready-made platform for using the Simple Method.

The Simple Method Load Equations

The primary equation for estimating loads using the Simple Method consists of three main variables and one unit-conversion value term. For estimating nutrients and sediment loads, the formula is:

$$L = 0.226 * R * C * A$$

Where:

L = annual load (pounds)

0.226 = unit conversion factor

R = annual runoff (inches)

C = pollutant concentration (mg/L)

A = area (acres)

For estimating bacteria loads, the equation is:

$$L = 0.00103 * R * C * A$$

Where:

L = annual load (billion colonies)

0.00103 = unit conversion factor

R = annual runoff (inches)

C = pollutant concentration (colonies/100mL)

A = area (acres)

Description of Simple Equation Terms

The terms R , C , A , and the unit conversion factor are further described here.

Runoff (R).

The value for runoff, R , is the product of the annual rainfall for the region in inches, the fraction of rainfall events producing measurable runoff, and a coefficient for the fraction of impervious surface cover in the analysis area. Output units are in inches. The formula per the Simple Method is:

$$R = P * P_j * R_v$$

Where:

R = annual runoff (inches)

P = annual rainfall (inches)

P_j = Fraction of effective rainfall (usually 0.9)
 R_v = Runoff coefficient

Annual Rainfall (P). Rainfall units are inches. For this effort, the assumed annual rainfall value for the basin is 40 inches. This is based on an average figure for the basin. Historical values vary widely.

Percentage of Rainfall Events Producing Runoff (Pj). The P_j component of the Annual Runoff formula is an empirical value representing the percentage of precipitation events producing measurable runoff, in effect, reducing the annual rainfall by that fraction of non-runoff rainfall events. According to Schueler's analysis (based on National Urban Runoff Program data), 90% of rain events will produce runoff (1987), and this is the assumed value for this effort.

Runoff Coefficient (Rv). The runoff coefficient is dimensionless and is based on the fraction of impervious surface cover for the area. This formula is determined by Schueler to be the best fit line for the empirical relationship between stormwater runoff and imperviousness (1987). This coefficient is calculated using the formula:

$$R_v = 0.05 + (0.9 * I_a)$$

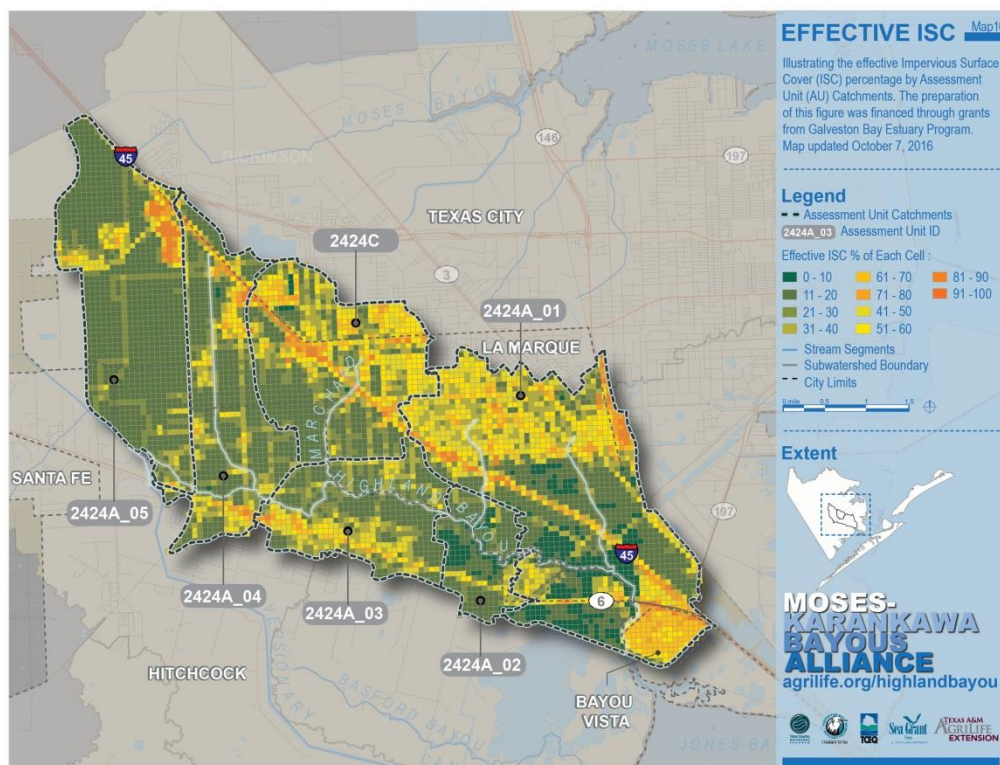
Where:

I_a = Fraction of impervious surface

The value I_a is the percent of impervious surface cover in the area of analysis. Geographic Information System (GIS) is used to assign this value through an analysis of development intensity in the CHARM data, derived from NOAA's C-CAP data. Values are taken from NOAA C-CAP data definitions for all developed coverages (See Appendix 2, Table 4). For undeveloped coverages, the underlying soil curve number (CN) was alternatively utilized. While the Simple method term I_a is utilized here, the more accurate term would be *effective impervious surface cover*, since GIS weights runoff values by the percent share of multiple surface types in each CHARM cell. The following table defines the values for I_a per cover type.

Table A- 6. Values for I_a Per Land Use Cover Type

| Land Cover Classification | I_a (% effective Impervious Surface Cover) |
|---|---|
| High Intensity Development | 0.9 |
| Medium Intensity Development | 0.65 |
| Low Intensity Development | 0.35 |
| Open Space Development | 0.1 |
| Road | 0.9 |
| All Undeveloped Areas (based on soil CN) | 0.05-0.15 |



Map-16. Effective Impervious Surface Cover Percentage by Assessment Unit Catchments

Event Mean Concentration, C.

The EMC is the concentration of pollutant mass per runoff volume from a particular land use, such as residential, commercial or industrial. In order to determine the appropriate EMC, the land use must be known. In this modeling effort, the land use classification for each cell was assigned based on the dominant land use in that cell. Land uses for each cell were determined in GIS using a series of if-then statements assessing the number of homes, overlapping parcel land use code, and acreage of undeveloped open space to determine the most likely land use in each CHARM cell (See Map- 17). Nine primary land uses were defined for this modeling effort, and are utilizing the EMC listed in Table A-7.

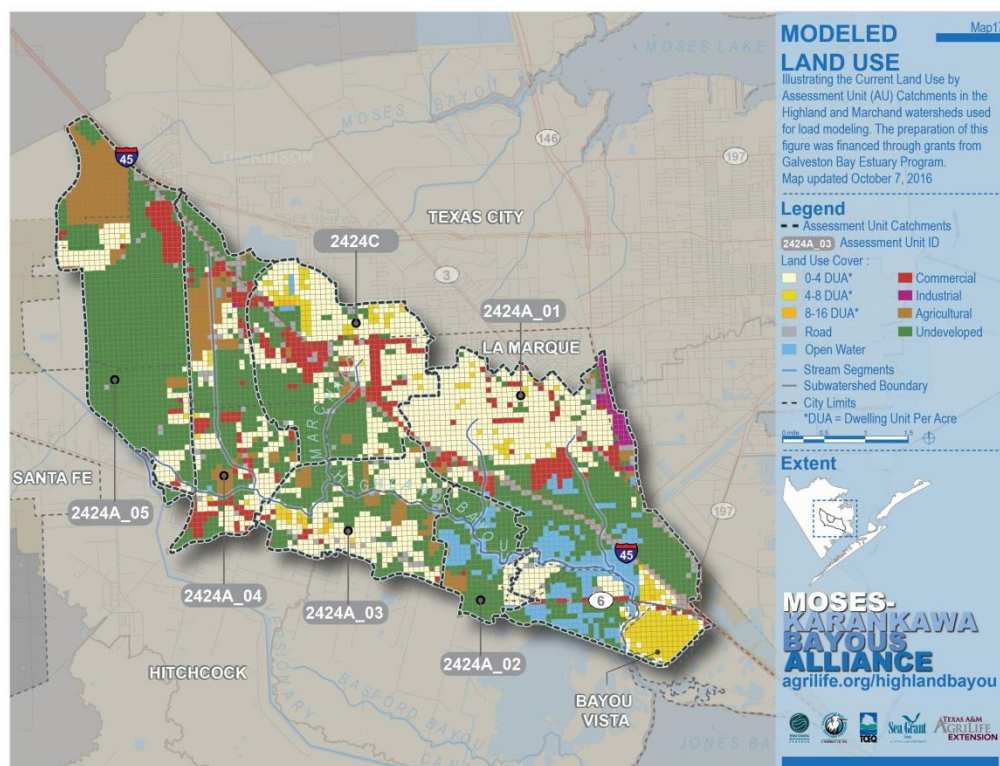
Table A- 7. Nine Primary Land Uses and Associated Event Mean Concentration

| Land Use Category | Total Nitrogen (mg/L) | Total Phosphorus (mg/L) | Total Biochemical Oxygen Demand (mg/L) | Total Suspended Solids (mg/L) | Total <i>Enterococci</i> (colonies/100mL) |
|-------------------|-----------------------|-------------------------|--|-------------------------------|---|
| 0 to 4 DUA | 1.80 | 0.26 | 6.2 | 190 | 22,000 |
| 4 to 8 DUA | 2.00 | 0.31 | 8.7 | 190 | 22,000 |
| 8 to 16 DUA | 2.25 | 0.36 | 10.8 | 190 | 22,000 |
| Agriculture | 2.20 | 0.42 | 3.9 | 130 | 2,500 |
| Commercial | 1.80 | 0.20 | 7.7 | 60 | 22,000 |
| Industrial | 1.60 | 0.27 | 8.2 | 135 | 22,000 |

| Land Use Category | Total Nitrogen (mg/L) | Total Phosphorus (mg/L) | Total Biochemical Oxygen Demand (mg/L) | Total Suspended Solids (mg/L) | Total <i>Enterococci</i> (colonies/100mL) |
|--------------------|-----------------------|-------------------------|--|-------------------------------|---|
| Water | 0.00 | 0.00 | 0.0 | 0 | 0 |
| Road | 1.90 | 0.23 | 7.5 | 135 | 22,000 |
| Undeveloped | 1.65 | 0.23 | 4.8 | 65 | 2,500 |

DUA stands for dwelling units per acre, and describes the residential density of the land use.

0-4 DUA per acres represents single family homes, while the higher end 8-16 DUA per acre consist of duplexes and apartment complexes.



Map-17. Current Land Use by Assessment Unit Catchments Used for Load Modeling

Area, A

The area, A, is acres of land. Each CHARM grid cell is prepopulated with attribute information about land cover and open water. The values for A in each cell range from 2.5 acres (all land) to zero (all open water).

Conversion Factor

The conversion factor is a fixed, dimensionless value that converts input units to output units. For nutrients, the factor converts the input ‘volume- mass per volume’ to pounds. For bacteria, the factor converts the input ‘volume-count per volume’ to billions of CFUs.

Calculation Methods

Software

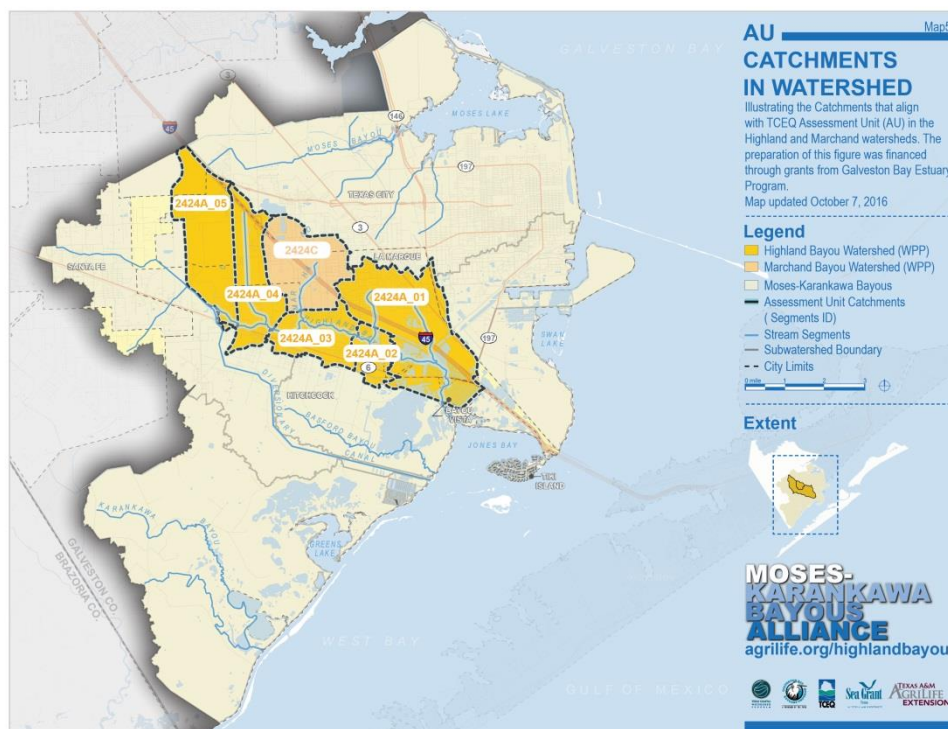
GIS was used to organize data and run calculations for the Simple Method. For this effort, ESRI ArcGIS 10.3 Advanced was utilized with a third-party software plug in, CommunityViz 360 ®. CommunityViz provides additional GIS functionality not included with ESRI software, primarily the ability to update data based on user defined formulae for variable assumptions or for how to interpret overlaying mapping data. As users update input values, CommunityViz recalculates all dependent data and attributes in real time. Aggregate load values by AU catchment were exported to excel for formatting and layout.

Unit of Analysis: the CHARM Grid

The unit of analysis is a CHARM grid cell, a regular grid of 2.5 acre cells. Each cell represents a discrete area and is stored as a unique record in a geodatabase. Twenty four pre-defined attributes are included in the CHARM grid, of which several are used for the Simple Method. Outputs are recorded for each cell, including dominant land use, land coverage fraction, intermediate calculated values, and final load calculations for each pollutant of concern.

NPS Loads by Assessment Unit Catchments

Pollutant loads that were calculated for each CHARM cell were then aggregated by their overlapping assessment unit (AU) catchment area. The AU catchment areas were generated using ESRI's Spatial Analyst tools and digital elevation data. Initially, the project team used each of the 19 surface water quality monitoring (SWQM) points in the watershed to define their upstream catchment area, that is, select all areas upstream that flow to each SWQM point. This analysis generated 19 unique catchments in the watershed. Then, using the SWQM point nearest to the bayou's segment ID, these 19 unique catchments were dissolved into one of 6 catchments coincident with each AU segment ID. These 6 AU catchments are used consistently in this WPP for NPS load estimates here and load reductions in Element B.



Map-5. Catchments that Align with TCEQ Assessment Units

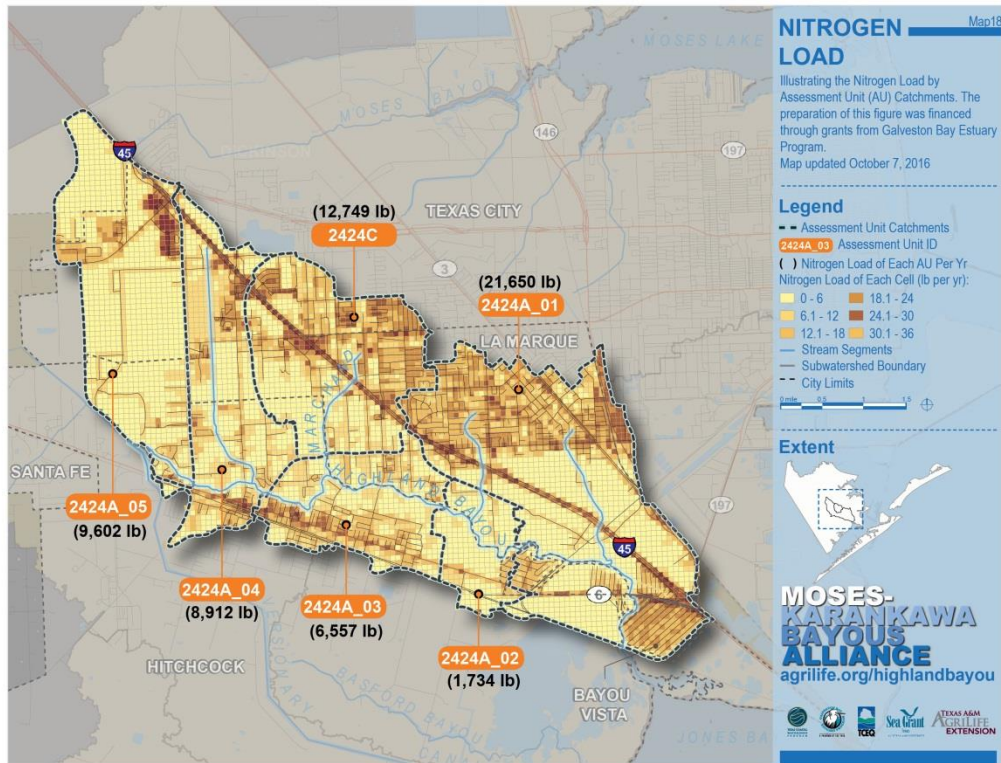
NPS Pollutant Loads

Loading totals were calculated by summing all cells within each AU and the entire watershed. Summary totals for each AU and the entire watershed are included in Table A-8 below. Detailed calculation tables are included in Appendix 3, Loading Tables. Loading tables in the appendices include summaries of each NPS pollutant of concern by AU (6 tables) and each AU by NPS pollutant of concern (5 tables). Values in detailed by the 9 land use classes and their acreages.

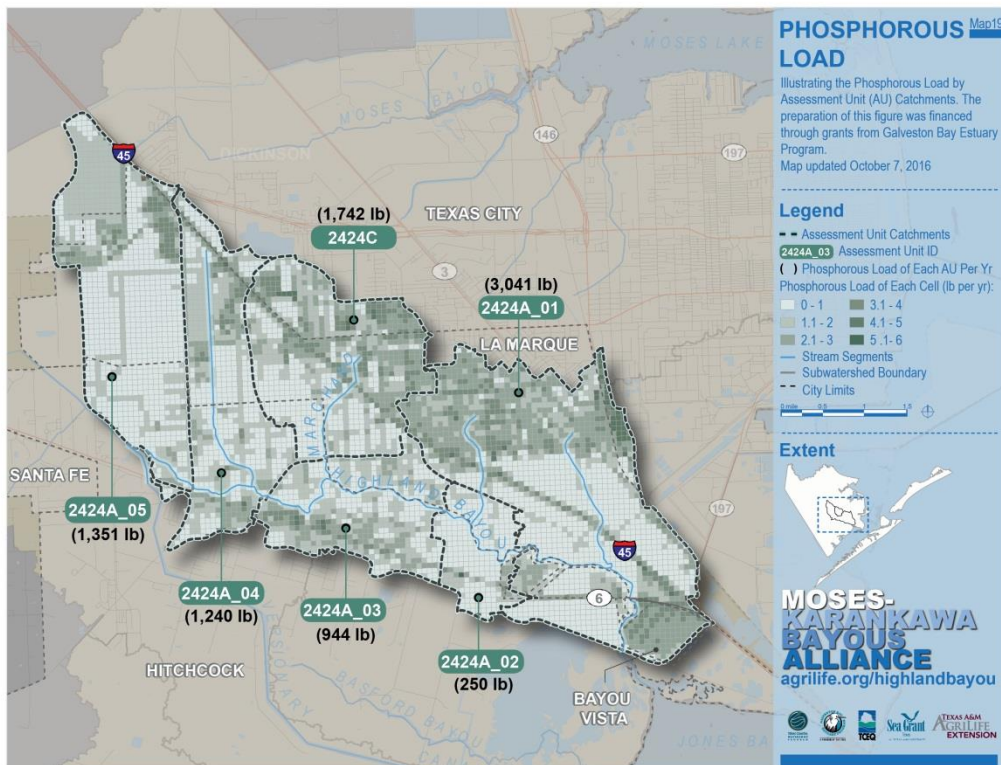
Based on Map-18 through Map-22, and as one would expect from the simple equation, the loads are largest for the largest catchments and where there is the most development. The maps illustrate quite nicely through a graded color scheme pollutant loads across the watershed and ‘hot spots’ that are likely priority areas for action areas defined in this plan (see Element C for action areas). Load reductions for selected Action Areas are provided in Element B.

Table A- 8. Pollutant Load Summary Totals for Each Assessment Unit.

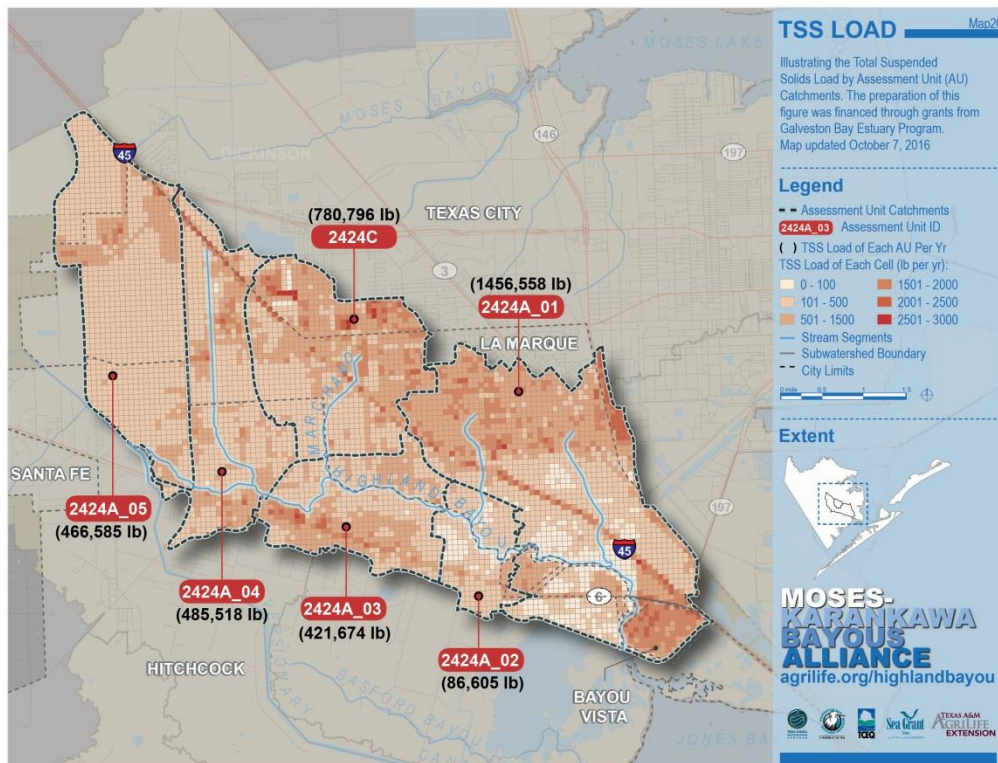
| Pollutant of Concern | Total | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|--------------------------|------------------|-----------|----------|----------|----------|----------|----------|
| N (lb) | 61,204 | 21,650 | 1,734 | 6,557 | 8,912 | 9,602 | 12,749 |
| P (lb) | 8,568 | 3,041 | 250 | 944 | 1,240 | 1,351 | 1,742 |
| BOD (lb) | 3,697,738 | 1,456,559 | 86,605 | 421,674 | 485,518 | 466,585 | 780,797 |
| TSS (lb) | 212,567 | 79,361 | 5,152 | 21,835 | 29,760 | 30,381 | 46,078 |
| Enterro (B. CFUs) | 422,535 | 175,635 | 5,396 | 44,646 | 54,349 | 41,936 | 100,573 |



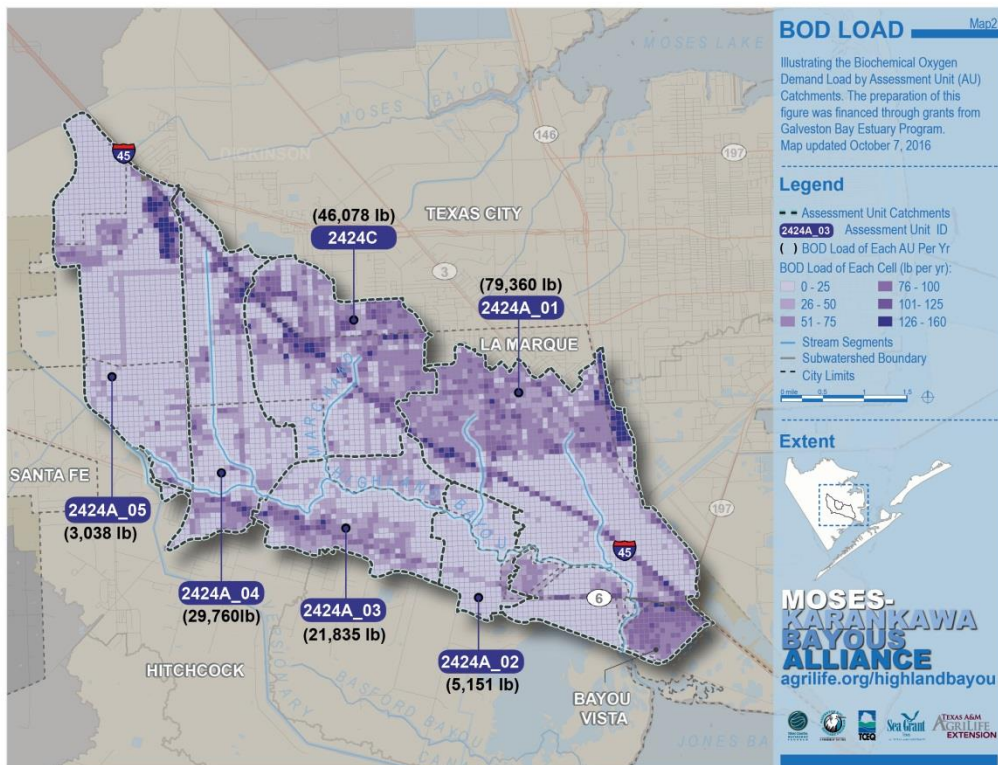
Map-18. Nitrogen Load by Assessment Unit Catchment



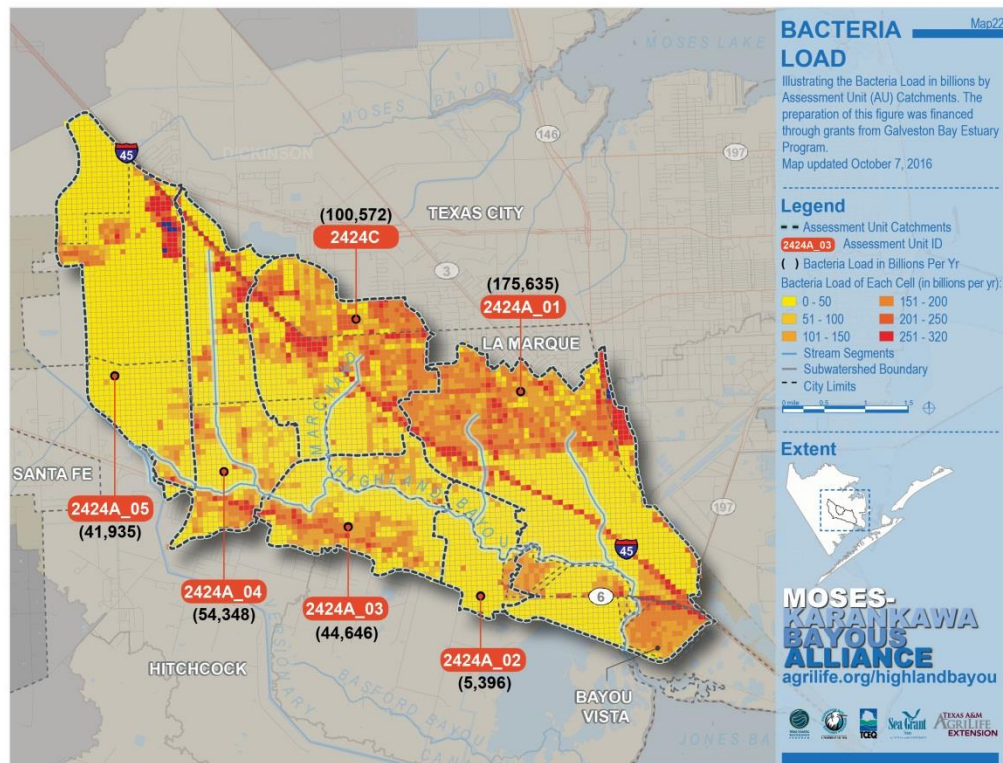
Map-19. Phosphorus Load by Assessment Unit Catchments



Map-20. Total Suspended Solids (TSS) Load by Assessment Unit Catchments



Map-21. Biochemical Oxygen Demand Load by Assessment Unit Catchments



Element B: Load Reductions

Load reductions are calculated for four priority action areas (Table B–1). For each reduction, a brief narrative about reasoning, assumptions, and calculations is provided, followed by reduction tables for each practice. In short, under these assumptions, the watershed could observe a 42.1% load reduction in bacteria, a 10.5% reduction in nitrogen, and a 12.1% reduction in phosphorous at the end of a 10-year implementation horizon. There is reason to believe that greater reductions could be achieved through the implementation of related practices (i.e., WWTP improvements), or improved implementation or higher participation rates.

Table B- 1. Pollutant of concern by action area

| Projects | Bacteria | Nitrogen | Phosphorous |
|------------------------------------|----------|----------|-------------|
| SSS Upgrades AA (09) | x | -- | -- |
| Pet Waste Pickup AA (18) & AA (19) | x | -- | -- |
| Green Infrastructure AA (24) | x | x | x |
| Stormwater Wetlands AA (24) | x | x | x |

Load Reductions from Action Area (09) SSS Upgrades and Improvements

For this load reduction, the focus is on the repair of sanitary sewer system (SSS) infrastructure to reduce the number of SSOs leakages and spills into the environment. SSOs are typically due to failures from cracking of lines from age, accumulation of fats and grease, clogging from rags and foreign objects, and penetration by tree roots. These failures occur in neighborhoods and along streets, and from there, raw sewage flows into drainage conveyances and eventually the bayou. Actions for this load reduction include replacement of damaged or corroded lines, the point repair of lines at specific locations, man hole cover upgrades, and the repair of pump or lift stations. These repairs combined, together with improved monitoring technologies, can bring an aging collection system into proper working order and reduce the number of SSO discharges.

For an estimate of load reduction of indicator bacteria from SSS improvements, the reductions are based on SSO discharge figures from the City of La Marque, which is participating in TCEQ's Sanitary Sewer Overflow Initiative (SSOI) program. Other communities like Texas City and Hitchcock have a very similar development style and age, which likely translates to comparable collection system characteristics and comparable SSO discharge volumes across much of the watershed. Loads and load reductions can be calculated by pro-rating SSO volumes by population in each AU. This approach points to a known data gap--actual discharge volumes--which could be addressed in part by other WPP action areas.

From April 2011 to March 2013, the City of La Marque reported an estimated 100,000 gallons of SSO discharges. It is assumed that these overflows are from the public side of the collection system, versus private property sewage lines connecting into the public system (see discussion section below). La Marque has a population of approximately 15,141 residents, compared to 22,008 in the Highland and Marchand Bayous watershed. Pro-rated by population in incorporated areas, that is, areas likely serviced

by a central collection system, results in an average SSO discharge of 73,356 gallons per year in the watershed. Using a low to high range of average concentrations of indicator bacteria in untreated sewage, loads and load reductions can be estimated from these discharges. SSO discharges from the collection system are assumed for purposes of this plan to be a regular leak into the environment, although heavy rainfall events can result in sporadic and high volume discharges. Similarly, stormwater infiltration from the environment and into the collection system can overwhelm the system's treatment plant, resulting in the untreated discharge of hundreds of thousands of gallons from a single event.

Repair Activities. Using estimates of the City of La Marque SSOI upgrade program, we can approximate the types of repairs and potential load reductions achieved from those repairs. The City estimates from its system survey that approximately 25 line points needs major repair, 9350 linear feet (lf) of broken or corroded line needs replacement, and approximately 20 lift stations need upkeep at a cost of \$1.4 million dollars over 10 years and servicing approximately 15,000 residents (La Marque Meeting Minutes, Jan 2015). Assuming these repair characteristics hold for the entire watershed, these figures translate to the following watershed-wide repair figures (Table B-2).

Table B- 2. Sanitary Sewer System Repairs

| Activity | La Marque (pop. 15,141) | Watershed Wide (pop. 22,008) |
|------------------------------------|----------------------------|---------------------------------|
| Points with major repairs | 25 | 36.7 |
| Line replacement (lf) | 9,350 | 13,718 |
| Lift stations repaired or replaced | 20 | 29 |

Rate of effectiveness. The City of La Marque SSOI upgrade program utilizes a 10 year program timeline. Ten percent progress per year would result in a complete repair of the system, yet not all needed repairs can be initially known and new failures will continue to occur elsewhere over the course of ten years. Combining a 80% repair effectiveness with a 15% failure rate over ten years, results in a net effective rate of 65% over 10 years, or 6.5% per year using the above repair program. Using these assumptions about repair activities and load reduction, we calculate the following 10 year load reduction of indicator bacteria per AU, utilizing both the low- and high-end bacteria concentrations.

Calculation assumptions

- 1) Reductions assume a 10 year implementation horizon
- 2) Low *E. coli* concentration of 1.05×10^7 and a high value of 1.05×10^8 CFUs per 100mL
- 3) A bacteria conversion factor of 0.278 *Enterococcus* per *E. coli*.
- 4) Effective rate of volume reduction is 65% for ten years, or 6.5% per year.
- 5) Unreported SSOs from the collection system and from private lines are not factored, but are a known source.
- 6) Wastewater treatment plant SSO discharges are not factored, but are a known source.
- 7) All populations in incorporated areas are assumed to be serviced by a collection system and not on OSSF. GIS was used to allocate population by AU and incorporated areas; see load reduction table, Table B-3 below.

Calculations

Low assumption Load per Gallon SSO = $(1.0 \times 10^7 \text{ CFU } E. coli / 100\text{ml}) * (0.278 \text{ Enterococcus}/E. coli) * (100\text{mL}/0.0264172\text{gal}) = 1.05 \times 10^8 \text{ CFU Enterococcus/gallon}$

High Assumption Load per Gallon SSO = $(1.0 \times 10^8 \text{ CFU } E. coli / 100\text{ml}) * (0.278 \text{ Enterococcus}/E. coli) * (100\text{mL}/0.0264172\text{gal}) = 1.05 \times 10^9 \text{ CFU Enterococcus/gallon}$

Effective reduction rate = (effective repair rate) – (new failure rate) = (80%) – (15%) = 65%

Indicator Bacteria Load Reduction = (Load per gallon) * (Effective rate of volume reduction)

Percent Reduction = (Load Reduction) / (Total Load)

Loads and reductions are allocated on a pro-rated share of the incorporated population in each AU (Table B–3).

Table B- 3. Bacteria load and reductions by assessment unit

| | Total | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|--|----------|----------|----------|----------|----------|----------|----------|
| Population (incorporated) | 22,008 | 9,243 | 61 | 2,919 | 1,957 | 1,508 | 6,320 |
| Share of Population | 100% | 42.0% | 0.3% | 13.3% | 8.9% | 6.9% | 28.7% |
| Share of SSO Gallons per year | 73,356 | 30,808 | 203 | 9,729 | 6,523 | 5,026 | 21,066 |
| Annual Load Entero from SSO (Low Concentration) (CFU/Gallon = 1.05×10^7) | 7.70E+11 | 3.23E+11 | 2.13E+09 | 1.02E+11 | 6.85E+10 | 5.28E+10 | 2.21E+11 |
| Annual Load Entero from SSO (High Concentration) (CFU/Gallon = 1.05×10^9) | 7.70E+13 | 3.23E+13 | 2.13E+11 | 1.02E+13 | 6.85E+12 | 5.28E+12 | 2.21E+13 |
| Annual Load Entero from SSO (in Billion CFUs) (Low Concentration) | 770.24 | 323.49 | 2.13 | 102.16 | 68.49 | 52.78 | 221.19 |
| Annual Load Entero from SSO (in Billion CFUs) (High Concentration) | 77023.8 | 32348.7 | 213.5 | 10215.9 | 6849.1 | 5277.7 | 22118.8 |
| Assumed 10-year Net Effectiveness of Action Area (xx) activities | 65% | 65% | 65% | 65% | 65% | 65% | 65% |

| | Total | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|--|----------|----------|----------|----------|----------|----------|----------|
| Bacteria load reduction (in Billions of CFUs) after 10 years (Low Concentration) | -500.7 | -210.3 | -1.4 | -66.4 | -44.5 | -34.3 | -143.8 |
| Bacteria load reduction (in Billion CFUs) after 10 years (High Concentration) | -50065.5 | -21026.7 | -138.8 | -6640.4 | -4451.9 | -3430.5 | -14377.2 |
| Total <i>Entero</i> Load from all sources in Billions of CFUs (source Table: A-8) | 422,534 | 175,635 | 5,396 | 44,646 | 54,349 | 41,936 | 100,573 |
| Action Area as percent reduction in load after 10 years (Low Concentration) | 0.12% | 0.12% | 0.03% | 0.15% | 0.08% | 0.08% | 0.14% |
| Action Area as percent reduction in load after 10 years (High Concentration) | 11.85% | 11.97% | 2.57% | 14.87% | 8.19% | 8.18% | 14.30% |

Discussion of load reduction: SSS

The location of SSS repair activities will be prioritized by cities, public works, or MUDs based on competing priorities, resources, and urgency of the repair. In any given year certain neighborhoods will see substantial improvements to their collection system, while other neighborhoods may see no action until years later. From the perspective of a water quality monitoring program in each AU, progress may appear irregular, where some AUs attain large reductions while others realize none. The goal is that after 10 years, SSS repair activities will have been undertaken across most or all AUs, and that the 65% percent net effectiveness will be realized along with associated load reductions.

The reported SSO figures of 100,000 gallons between 2011 and 2013 are for discharges from the public side of the collection system, and do not factor in leakages and failures in private lines that connect into the collection system. La Marque estimates that SSO discharges from the public side of the collection system may represent only 40% of system wide leakages, meaning that private property lines may constitute 60% of all discharges. Improving private maintenance of private lines could have a substantial impact on the watershed's water quality, possibly accounting for more than a doubling in load reductions from this source. These private lines and their contribution are not included as an action area in this load reduction section. Other action areas may address the impact of private lines.

Load Reductions from Action Area (06) Fats, Oils, Grease and Wipes

For this load reduction, the focus is on educating homeowners on the impacts of fats, oils, grease, and wipes on their plumbing and the larger collection system for the community. It is assumed here that through education efforts a fraction of homeowners will recognize issues with their home plumbing and see to it that their system is repaired at their personal expense. This reduction depends on a chain of

particular events, such that a fraction of homeowners will receive educational material, a fraction of them will recognize an issue with their system, and a fraction will take action to have their pipes cleared or replaced. While the number of homes may be small, the impact on reducing the volume of raw sewage leaking from private lines could be large.

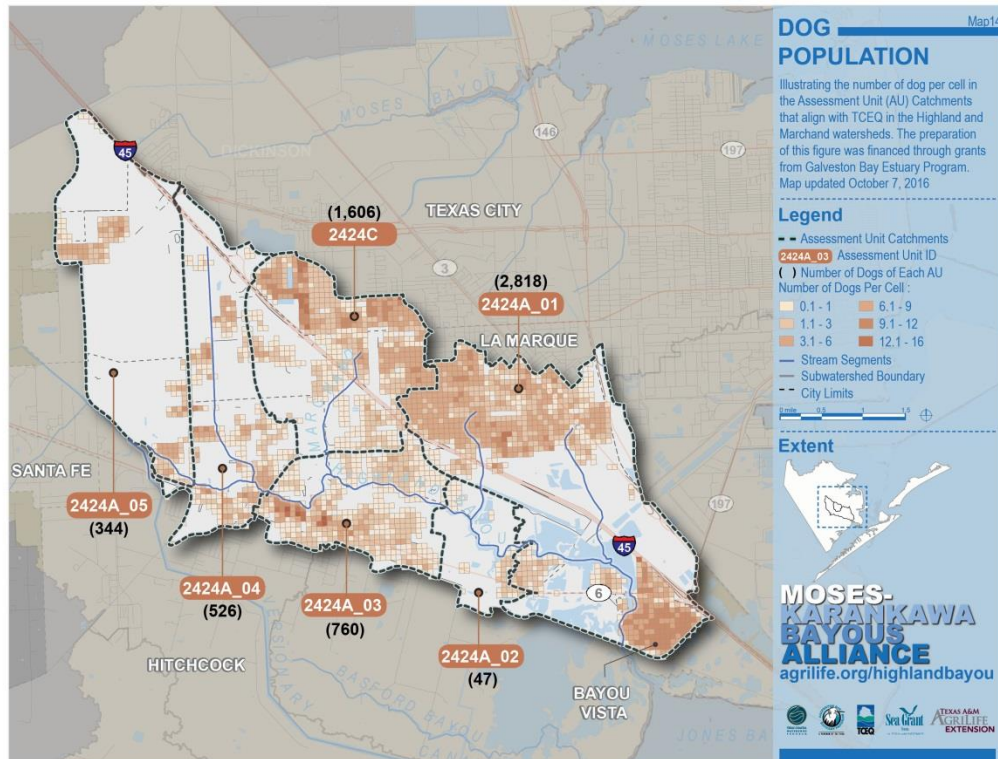
No attempt is made here to estimate the potential reduction in SSO volumes from private lines connecting to the main collection system. Several key figures are missing, namely a likely estimate for the number of homes with failing private lines, and the volume flowing from the average failure. For total volume of leakages from private lines, an estimate can be made here based on figures from the La Marque study (see above). Pro rating the losses reported in La Marque, and applying the 60% volume figure for private lines, there may be over 110,034 gallons of raw sewage leaking from private lines. Applying the reduction assumptions from SSOI improvements to the potential volume reduction from private lines could result in a net reduction of almost 20% across the watershed.

Through a combination of reporting and homeowner education, it is possible that failing private lines could be identified. However, this is no legal enforcement mechanism to compel a private home owner to upgrade their system. The most compelling reason for a homeowner is likely the most immediate: overflowing bathrooms and foul odors from the lawn.

Load Reductions from Action Area (18) and Action Area (19) Pet Waste Pickup

For this load reduction, the focus is on pet owner education and behavior change about pet waste pickup. Pet waste, particularly dog waste, left on a lawn or any outdoor area will eventually be washed away via stormwater and into local waterways, contributing to the Bayou's bacteria load. Through education about the impact and importance of pet waste on water quality, it is assumed that pet owners will act responsibly and pick up their pet's waste and dispose of it in garbage. Most cat waste is collected in a litter box and disposed of in the garbage.

Using figures on ownership rates from the American Veterinary Medical Association (AVMA) and GIS analysis, the project team estimated the dog population by AU (see Map-14 and Table B-4 below). The AVMA (2012) estimates that 36.5 percent of households own dogs, and that of owning households have an average of 1.6 dogs. This results in a blended rate of .584 dogs per household. Using these ownership rates and load reduction estimates from pet waste pickup participation rate, and load reduction can be calculated for this Action Area. The National People and Pets survey found that around 44 percent of dog owners stated that they 'always' or 'sometimes' pick up their dog's waste. For this analysis, we assume 40% percent of owners pick up dog waste.



Map-14. The number of dogs per Assessment unit

Calculation Assumptions

- 1) Reductions assume a 10 year implementation horizon
- 2) The average dog produces 5.0×10^9 fecal coliform per day
- 3) A bacteria conversion factor of 0.278 *Enterococcus* per *E. coli*, and a bacteria conversion factor of 0.63 *E. coli* per fecal coliform.
- 4) Only 40% of dog waste is picked up; 60% is assumed left outdoors
- 5) A 20% increase in pick up rates over ten years, i.e., 48% pick up rate and 52% leave rate
- 6) 100% of bacteria in fecal waste left outdoors will end up in the bayou.

Calculations

Dogs per household = (36.5% of households own dogs) * (1.6 dogs / owning household) = 0.584 dogs / household (Source AVMA, 2012)

Dogs in watershed = (0.584 dogs / household) * (10,040 households in watershed) = 5,863 dogs in watershed

Effective load reduction rate = (current load-future load) / (current load) = $60\% - 52\% / 60\% = 13.6\%$

Load Reduction of Indicator Bacteria in Billions = $(5.0 \times 10^9 \text{ fecal coliform/dog / day}) * (0.63 \text{ } E. coli / \text{fecal coliform}) * (0.278 \text{ } Enterococcus / E. coli) * (365 \text{ days / year}) * (13.6\% \text{ effective reduction through increased pick up rates}) * (1/1,000,000,000) * (5,963 \text{ dogs in watershed}) = 24,987 \text{ load reduction of indicator bacteria in billions for entire watershed.}$

Table B-4 allocates the dog population and load reduction by AU (from GIS analysis using DUs by AU) and shows the allocation of indicator bacteria load reduction and bacteria load reduction as percent of total indicator bacteria load in the watershed and by AU.

Table B- 4. Bacteria load and reductions by assessment unit

| | Total | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|--|---------|----------|----------|----------|----------|----------|----------|
| Est. Dog Population | 5,863 | 2,707 | 46 | 731 | 505 | 331 | 1,544 |
| Percent Allocation by AU | 100% | 46.2% | 0.8% | 12.5% | 8.6% | 5.6% | 26.3% |
| Load <i>Entero</i> in Billions from all sources | 422,534 | 175,635 | 5,396 | 44,646 | 54,349 | 41,936 | 100,573 |
| Action Area Load Reduction in Billions | 24,987 | 11,537 | 196 | 3,115 | 2,152 | 1,411 | 6,580 |
| Action Area Load Reduction as percent of all sources, year 2026 | 5.9% | 6.6% | 3.6% | 7.0% | 4.0% | 3.4% | 6.5% |

Discussion of Load Reduction: Pet Waste Pickup

The cost of education is comparatively low to other practices and the return on load reductions is potentially high. Several critical facts will determine whether or not bacteria reductions will exceed or fall short of estimated figures, apart from participation rates. Very little literature exists on the amount of fecal coliform in dog waste, with one study cited by numerous publications on the topic of dog waste, Van der Wel's 1995 journal publication "*Dog Pollution.*" A study by the University of Nevada Cooperative Extension analyzing dog waste around Lake Tahoe found that "fresh feces contained an average of 50 million CFU/gram with a range of two million to 200 million CFU/g." The wide range was "attributed to the highly variable nature of dog food, digestive health and diets" (p.3) (UNV fact sheet, 2008). 23 million was used for calculations in this WPP (see assumptions above).

Bacteria are living organisms and need certain conditions to live and replicate. It is likely that temperature and weather conditions play a significant role on the fate of bacteria as it is transported to waterways from the point of deposition outdoors, and that some amount may never reach the waterway. For example, dry conditions may degrade bacteria quickly. While estimates of dog populations or pick-up rates may reasonably vary by 20 or more percentage points from national averages, the differences in bacterial concentration and the transport dynamics could impact loadings by orders of magnitude.

Load Reductions from Action Area (24) Green Infrastructure and Stormwater Wetlands

For this load reduction, activities focus on implementing GI practices and SWW. These stormwater management practices mimic natural features by slowing the flow of water and allowing it time to infiltrate into the ground. Load reductions are achieved through a combination of ground infiltration and plant uptake. GI refers to a range of stormwater management practices and includes here grassed swales, dry and wet infiltration basins, porous pavements, bioretention areas, and sand or vegetated filter strips,

and SWW. SWW are constructed ponds that integrate natural wetland vegetation. SWW are also referred to as artificial wetlands or constructed wetlands. In addition to providing water quality benefits, they provide aesthetic value. The rule of thumb for sizing SWW is 1% of the area draining into it.

Load reductions are estimated as two calculations, once for GI and once for SWW (Table B-5; Table B-6). It is assumed that to achieve load reductions, these practices will be implemented in or near existing development over a 10 year implementation horizon. It is also assumed that approximately 20% of runoff load from existing development will be intercepted by these practices. Existing development includes pollutant load values from land use classes referred to as road, commercial, industrial and all residential classes (0-16 DUA). No single GI approach is prescribed here. Rather, the WPP assumes that communities and developers will select from among these options as warranted by site conditions, thus an average figure from all practices is utilized for percent removal rates. Based on figures from over 30 studies, the average percent removal for all practices is 41% for nitrogen, 43% for phosphorous, and 54% for bacteria.

Table B- 5. Percent reduction for pollutants of concern by Green Infrastructure practice

| Green Infrastructure Practice | N | P | Bacteria |
|---|-----|-----|----------|
| Grassed Swale | 38% | 33% | -- |
| Infiltration Basin | 54% | 60% | 82% |
| Infiltration Trench | 56% | 58% | 82% |
| Permeable Pavement | 69% | 59% | -- |
| Bioretention Areas | 51% | 66% | 52% |
| Water Quality Inlets | 11% | 6% | 5% |
| Sand and Organic Filter Strips | 37% | 49% | 49% |
| Vegetated Filter Strips | 24% | 19% | 33% |
| Dry Detention Basin | 32% | 29% | 67% |
| Wet Detention Basin | 36% | 52% | 62% |
| Average Percent Removal Across All Practices | 41% | 43% | 54% |

Table B- 6. Percent reduction for pollutants of concern for Stormwater Wetlands

| Green Infrastructure Practice | N | P | Bacteria |
|-------------------------------|-----|-----|----------|
| Stormwater Wetlands | 35% | 47% | 72% |

For sources and methods regarding these practices, please see Appendix D, Stormwater Best management Practices (BMP) Factsheets.

Calculation Assumptions

- 1) Reductions assume a 10 year implementation horizon
- 2) Management practices intercept 20% of existing runoff load
- 3) Loads and Load reductions do not factor in future growth
- 4) GI load reduction values
 - a. 41% reduction for nitrogen
 - b. 43% reduction for phosphorous
 - c. 60% reduction for bacteria
- 5) Stormwater Wetland load reduction values
 - a. 35% reduction assumed for nitrogen
 - b. 47% reduction for phosphorous
 - c. 72% reduction for bacteria
- 6) Intercepted runoff loads are based on loads from developed acreages

Calculations

Load mass reduced from developed areas= (load from developed areas) * (Load intercept rate) * (percent removal)

Percent reduction in total load = (Load Reduction mass from developed areas) / (Existing load from all areas)

Table B- 7. Nitrogen load reductions from GI practices by assessment unit

| Nitrogen Load Reduction from GI practices | All AUs | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|---|---------|----------|----------|----------|----------|----------|----------|
| Load (lbs) from Existing Development in AU | 42,377 | 17,963 | 452 | 4,481 | 5,345 | 3,859 | 10,277 |
| Load Intercept Rate | | 20% | 20% | 20% | 20% | 20% | 20% |
| Removal Rate | | 41% | 41% | 41% | 41% | 41% | 41% |
| Load Reduction (lbs) | 3,475 | 1,473 | 37 | 367 | 438 | 316 | 843 |
| Total Load for AU | 61,304 | 21,650 | 1,734 | 6,657 | 8,912 | 9,602 | 12,749 |
| Percent Reduction for AU | 5.7% | 6.8% | 2.1% | 5.5% | 4.9% | 3.3% | 6.6% |

Table B- 8. Phosphorus load reductions from GI practices by assessment unit

| Phosphorous Load Reductions from GI Practices | All AUs | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|---|---------|----------|----------|----------|----------|----------|----------|
| Load (lbs) from Existing Development in AU | 5,773 | 2,517 | 63 | 633 | 685 | 488 | 1,387 |
| Load Intercept Rate | | 20% | 20% | 20% | 20% | 20% | 20% |
| Removal Rate | | 43% | 43% | 43% | 43% | 43% | 43% |

| Phosphorous Load Reductions from GI Practices | All AUs | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|---|---------|----------|----------|----------|----------|----------|----------|
| Load Reduction (lbs) | 496 | 216 | 5 | 54 | 59 | 42 | 119 |
| Total Load for AU | 8,568 | 3,041 | 250 | 944 | 1,240 | 1,351 | 1,742 |
| Percent Reduction for AU | 5.8% | 7.1% | 2.2% | 5.8% | 4.8% | 3.1% | 6.8% |

Table B- 9. *Enterococcus* load reductions from GI practices by assessment unit.

| <i>Enterococcus</i> Load Reductions from GI Practices | All AUs | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|--|---------|----------|----------|----------|----------|----------|----------|
| Load (billions) from Existing Development in AU | 407,529 | 172,757 | 4,384 | 42,985 | 51,437 | 37,332 | 98,634 |
| Load Intercept Rate | | 20% | 20% | 20% | 20% | 20% | 20% |
| Removal Rate | | 54% | 54% | 54% | 54% | 54% | 54% |
| Load Reduction (billions) | 44,013 | 18,658 | 473 | 4,642 | 5,555 | 4,032 | 10,652 |
| Total load (billions) for AU | 422,535 | 175,635 | 5,396 | 44,646 | 54,349 | 41,936 | 100,573 |
| Percent Reduction for AU | 10.4% | 10.6% | 8.8% | 10.4% | 10.2% | 9.6% | 10.6% |

Table B- 10. Nitrogen load reductions from stormwater wetlands by assessment unit

| Nitrogen Load Reductions from Stormwater Wetlands | All AUs | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|---|---------|----------|----------|----------|----------|----------|----------|
| Load (lbs) from Existing Development in AU | 42,377 | 17,963 | 452 | 4,481 | 5,345 | 3,859 | 10,277 |
| Intercept Rate | | 20% | 20% | 20% | 20% | 20% | 20% |
| Removal Rate | | 35% | 35% | 35% | 35% | 35% | 35% |
| Load Reduction (lbs) | 2,966 | 1,257 | 32 | 314 | 374 | 270 | 719 |
| Total Load for AU | 61,304 | 21,650 | 1,734 | 6,657 | 8,912 | 9,602 | 12,749 |
| Percent Reduction for AU | 4.8% | 5.8% | 1.8% | 4.7% | 4.2% | 2.8% | 5.6% |

Table B- 11. Phosphorus load reductions from stormwater wetlands by assessment unit

| Phosphorous Load Reductions from Stormwater Wetlands | All AUs | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|--|---------|----------|----------|----------|----------|----------|----------|
| Load (lbs) from Existing Development in AU | 5,773 | 2,517 | 63 | 633 | 685 | 488 | 1,387 |
| Intercept Rate | | 20% | 20% | 20% | 20% | 20% | 20% |
| Removal Rate | | 47% | 47% | 47% | 47% | 47% | 47% |

| | | | | | | | |
|---------------------------------|-------|-------|------|------|-------|-------|-------|
| Load Reduction (lbs) | 543 | 237 | 6 | 60 | 64 | 46 | 130 |
| Total Load for AU | 8,568 | 3,041 | 250 | 944 | 1,240 | 1,351 | 1,742 |
| Percent Reduction for AU | 6.3% | 7.8% | 2.4% | 6.3% | 5.2% | 3.4% | 7.5% |

Table B- 12. *Enterococcus* load reductions from stormwater wetlands by assessment unit

| <i>Enterococcus</i> Load Reductions from Stormwater Wetlands | All AUs | 2424A_01 | 2424A_02 | 2424A_0 3 | 2424A_04 | 2424A_05 | 2424C_01 |
|---|------------|----------|----------|--------------|----------|----------|----------|
| Load (billions) from Existing Development in AU | 407,529 | 172,757 | 4,384 | 42,985 | 51,437 | 37,332 | 98,634 |
| Intercept Rate | | 20% | 20% | 20% | 20% | 20% | 20% |
| Removal Rate | | 72% | 72% | 72% | 72% | 72% | 72% |
| Load Reduction (billions) | 58,684 | 24,877 | 631 | 6,190 | 7,407 | 5,376 | 14,203 |
| Total load (billions) for AU | 422,535 | 175,635 | 5,396 | 44,646 | 54,349 | 41,936 | 100,573 |
| Percent Reduction for AU | 13.9% | 14.2% | 11.7% | 13.9% | 13.6% | 12.8% | 14.1% |

Discussion of Load Reduction: GI and SWW

Load reduction and load reduction costs will vary by the specific practice utilized. An average value for all practices was utilized here. Effectiveness of the practices will depend on proper implementation, sizing, and siting. Implementation will be voluntary and undertaken by local public entities, private land owners, or developers. To reiterate, these load reductions are achieved by installing these management measures in a way that intercepts flow from existing developed areas, and not new development. For purposes of water quality monitoring in the basin, load reductions will be offset by load increases from future development in the watershed. One way to stay a step ahead of this offsetting dynamic is for municipalities to update their subdivision ordinance and site plan reviews to either require these practices as a condition of development or ensure that codes do not inadvertently prohibit developers from utilizing these practices.

Cumulative Load Reductions from All Practices

Bacteria

The following table shows estimated indicator bacteria load reductions from the implementation of all load reduction practices (Table B-13). The high value bacteria concentration for SSO discharges are utilized in this table. It is possible that in ten years, through the adoption of the practices and repair programs, that the watershed could see a 42% reduction in bacteria from today's load values. Because of a lack of flow data, it is not possible to estimate if these load reductions would result in the bayou's removal from the 303(d) list.

Table B- 13. Estimated *Enterococcus* load reductions from four priority action areas by assessment unit

| <i>Enterococcus</i> Load in Billions | All AUs | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|--|---------|----------|----------|----------|----------|----------|----------|
| Total Estimated Load | 422,534 | 175,635 | 5,396 | 44,646 | 54,349 | 41,936 | 100,573 |
| Load Reduction from SSOI improvements (high bacteria concentration value) | 50,065 | 21,027 | 139 | 6,640 | 4,452 | 3,430 | 14,377 |
| Load Reduction from Pet Waste Pick Up Program | 24,991 | 11,537 | 196 | 3,115 | 2,152 | 1,411 | 6,580 |
| Load Reduction from Green Infrastructure | 44,012 | 18,658 | 473 | 4,642 | 5,555 | 4,032 | 10,652 |
| Load Reduction from Stormwater Wetlands | 58,684 | 24,877 | 631 | 6,190 | 7,407 | 5,376 | 14,203 |
| Load Reduction from All Practices | 177,752 | 76,099 | 1,439 | 20,587 | 19,566 | 14,249 | 45,812 |
| Reduction as Percent of Total Load | 42.1% | 43.3% | 26.7% | 46.1% | 36.0% | 34.0% | 45.6% |

Dissolved Oxygen

Table B-14 shows estimated cumulative load reductions in nitrogen and phosphorous from the implementation of proposed GI practices and SWW. It is possible that in ten years, through the adoption of these practices, that that watershed could see a 10.5% reduction in nitrogen and a 12.1% reduction in phosphorous. While a reduction in nutrients would be a positive trend, the reduction's impact on the levels of DO is unknown. It is important to keep in mind that the 303(d) listing is for low DO and not for specific nutrients.

Table B- 14. Cumulative load reductions in nitrogen and phosphorus from green infrastructure practices and stormwater wetlands

| Nitrogen (lbs) | All AUs | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|---|---------|----------|----------|----------|----------|----------|----------|
| Total Estimated Load | 61,204 | 21,650 | 1,734 | 6,557 | 8,912 | 9,602 | 12,749 |
| Load Reduction from Green Infrastructure | 3,474 | 1473 | 37 | 367 | 438 | 316 | 843 |
| Load Reduction from Stormwater Wetlands | 2,966 | 1257 | 32 | 314 | 374 | 270 | 719 |
| Total Load Reduction | 6,440 | 2730 | 69 | 681 | 812 | 586 | 1562 |
| Reduction as Percent of Total Load | 10.5% | 12.6% | 4.0% | 10.4% | 9.1% | 6.1% | 12.3% |
| Phosphorous (lbs) | All AUs | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
| Total Estimated Load | 8,568 | 3,041 | 250 | 944 | 1,240 | 1,351 | 1,742 |
| Load Reduction from Green Infrastructure | 495 | 216 | 5 | 54 | 59 | 42 | 119 |

| Phosphorous (lbs) | All AUs | 2424A_01 | 2424A_02 | 2424A_03 | 2424A_04 | 2424A_05 | 2424C_01 |
|--|---------|----------|----------|----------|----------|----------|----------|
| Load Reduction from Stormwater Wetlands | 540 | 237 | 6 | 60 | 64 | 43 | 130 |
| Total Load Reduction | 1,035 | 453 | 11 | 114 | 123 | 85 | 249 |
| Reduction as Percent of Total Load | 12.1% | 14.9% | 4.4% | 12.1% | 9.9% | 6.3% | 14.3% |

Element C: Management Measures

Selecting Management Measures: 38 Action Areas

The project team worked with over 40 stakeholders through a series of workshops, mapping exercises, and one on one interviews to understand what projects have been done in the past, what projects are underway, and what could be done in the future. Stakeholders were asked about activities of any kind that might have an impact on water quality in the watershed. Through this exercise, over 100 specific project ideas were identified. From this pool of project ideas, similar ideas were merged into what became the “38 Action Areas.” The term Action Area arose from meetings and is synonymous with management measures or BMPs. Some Action Areas are related but represent different phases or aspects of an activity or project. For purposes of the WPP, the 38 Action Areas were grouped into the four NPS quadrants - Wastewater, Flow and Dredging, Urbanization, and Wildlife/Natural Areas.

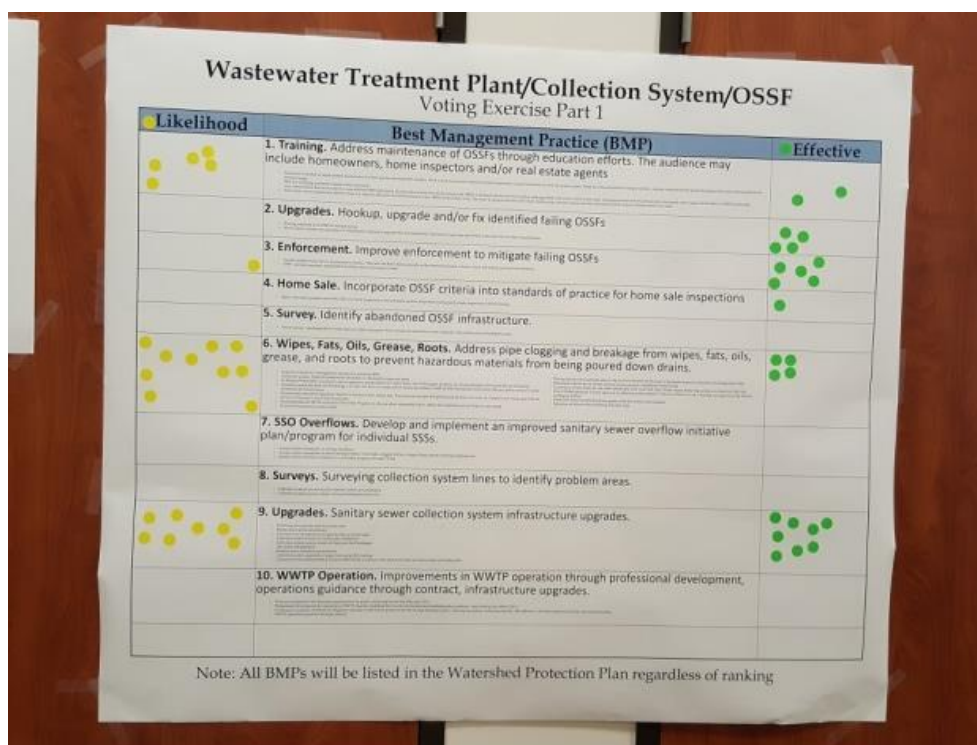


Figure C- 1. Quadrant 1, Wastewater Action Areas poster during the voting exercise

Ranking the 38 Action Areas

Participants prioritized the 38 action areas through a workshop and email voting exercise. Participants were asked to vote their preference based on two considerations- which projects were likely to happen and which projects were likely to be effective. The votes were merged and tallied for each project. After the tally, one more task was required: weighting the votes. Since dots for voting were handed out to participants for each NPS quadrant (i.e., wastewater, urbanization, flow, wildlife), and since each quadrant had different numbers of Action Areas, the final votes needed to be weighted to be able to rank Action Areas from among all quadrants. The final weighted totals were used to rank the Action Areas. The 38 Action Areas are listed on the table below (Table C-1), and are ranked by their vote preference.

Table C- 1. The 38 Action Areas prioritized by stakeholders including voting results

| | Action Area (No. and Project) | Highland Bayou NPS Quadrant | Votes Likely | Votes Effective | Total Votes | Weighted Totals | Final Rank |
|-----------|---|--------------------------------|-----------------|--------------------|----------------|--------------------|---------------|
| 9 | Sanitary Sewer Upgrades | Wastewater | 10 | 10 | 20 | 15.38 | 1 |
| 6 | Wipes, Fats, Oils, Grease | Wastewater | 10 | 5 | 15 | 11.54 | 2 |
| 11 | Improved Flow within Highland Bayou | Flow | 9 | 12 | 21 | 11.31 | 3 |
| 13 | Culvert Maintenance At Diversion | Flow | 8 | 9 | 17 | 9.15 | 4 |
| 19 | Pet Waste Education | Urbanization | 6 | 3 | 9 | 9.00 | 5 |
| 24 | Green Infrastructure & Stormwater Wetlands | Urbanization | 4 | 5 | 9 | 9.00 | 6 |
| 30 | Stormwater Infrastructure Assessment | Urbanization | 2 | 7 | 9 | 9.00 | 7 |
| 23 | Landscaping Debris Ordinances | Urbanization | 2 | 6 | 8 | 8.00 | 8 |
| 37 | Landowner Conservation Plans | Wildlife/Natural Areas | 6 | 6 | 12 | 7.38 | 9 |
| 34 | Preserve Existing Natural Areas | Wildlife/Natural Areas | 5 | 2 | 7 | 7.00 | 10 |
| 26 | Illegal Dumping Prevention | Urbanization | 7 | 4 | 11 | 6.77 | 11 |
| 35 | Restore and Repair Riparian Zones | Wildlife/Natural Areas | 1 | 9 | 10 | 6.15 | 12 |
| 21 | Water Conservation | Urbanization | 3 | 3 | 6 | 6.00 | 13 |
| 31 | Feral Hog Workshops | Wildlife/Natural Areas | 8 | 1 | 9 | 5.54 | 14 |
| 32 | Feral hog Hunting and Trapping | Wildlife/Natural Areas | 4 | 5 | 9 | 5.54 | 15 |
| 1 | OSSF Training | Wastewater | 5 | 2 | 7 | 5.38 | 16 |
| 3 | OSSF Enforcement | Wastewater | 2 | 5 | 7 | 5.38 | 17 |
| 27 | Residential Waste Disposal | Urbanization | 2 | 2 | 4 | 4.00 | 18 |
| 12 | Flow within Canal Communities | Flow | 5 | 2 | 7 | 3.77 | 19 |
| 14 | Living Shorelines | Wildlife/Natural Areas | 3 | 3 | 6 | 3.23 | 20 |
| 2 | OSSF Upgrades | Wastewater | 0 | 4 | 4 | 3.08 | 21 |
| 22 | Landscaping Education | Urbanization | 2 | 1 | 3 | 3.00 | 22 |
| 38 | Bacteria Source Tracking and Wildlife Surveys | Wildlife/Natural Areas | 1 | 3 | 4 | 2.46 | 23 |
| 10 | WWTP Operation Improvements | Wastewater | 2 | 1 | 3 | 2.31 | 24 |
| 17 | Regional Detention Wetlands | Urbanization | 2 | 2 | 4 | 2.15 | 25 |

| Action Area (No. and Project) | | Highland Bayou NPS Quadrant | Votes Likely | Votes Effective | Total Votes | Weighted Totals | Final Rank |
|-------------------------------|---|--------------------------------|-----------------|--------------------|----------------|--------------------|---------------|
| 15 | Review of Bulkhead Standards | Urbanization | 1 | 1 | 2 | 1.08 | 26 |
| 20 | Stray Animals | Urbanization | 1 | 0 | 1 | 1.00 | 27 |
| 25 | Watershed Signage | Wildlife/Natural Areas | 1 | 0 | 1 | 1.00 | 28 |
| 29 | Stormwater Program improvements | Urbanization | 1 | 0 | 1 | 1.00 | 29 |
| 4 | OSSF Criteria incorporated into home sales | Wastewater | 0 | 1 | 1 | 0.77 | 30 |
| 8 | Surveying collection systems | Wastewater | 0 | 1 | 1 | 0.77 | 31 |
| 36 | Natural Resource Education | Wildlife/Natural Areas | 1 | 0 | 1 | 0.62 | 32 |
| 16 | Shoreline Protection | Wildlife/Natural Areas | 1 | 0 | 1 | 0.54 | 33 |
| 5 | OSSF Pollution Survey | Wastewater | 0 | 0 | 0 | 0.00 | 34 |
| 7 | SSO Initiative TCEQ | Wastewater | 0 | 0 | 0 | 0.00 | 35 |
| 18 | Pet Waste Ordinances | Urbanization | 0 | 0 | 0 | 0.00 | 36 |
| 28 | Construction Site Erosion Control | Urbanization | 0 | 0 | 0 | 0.00 | 37 |
| 33 | Pigeon Feeding | Wildlife/Natural Areas | 0 | 0 | 0 | 0.00 | 38 |

Voting Results: 10 Priority Action Areas & 28 Additional Action Areas

The top ten vote-getting Action Areas became Priority Action Areas, and the project team prepared detailed tables identifying Action Area background, goals, objectives, costs, technical resources, timelines, and milestones. The remaining 28 Action Areas are still considered viable project areas for this WPP, and brief narratives about project directions and resources have been written for them following the Priority Tables. For the 10 Priority Action Areas, per the outline of EPA's 9 element watershed plan, project details are assigned to their respective elements in this WPP document:

Element C- Management Measures: Goals, Objectives, Likely Project Lead

Element D- Financial and Technical Resources: Costs, technical resources, and funding sources

Element F- Implementation Schedule: Divided into near-, medium- and long-term time horizons

Element G- Milestones: Progress points for projects and strategies

Priority Action Area Table Definitions

Problem. This section of the tables provides a brief narrative of the problem the Action Area is intended to address.

Goals. What are the primary water quality goals this action area is supposed to achieve?

Approach. What is the approach or strategy that the action area will take to reach its goals?

Location. Are there targeted locations for this Action Area or is it intended to be applied as a watershed-wide activity?

Objectives. What specific phases or steps need to be undertaken to implement this action area?

Likely Lead. What organization or agency is the likely lead for each objective?

Load Reduction Effectiveness. To what extent is the action area believed to be effective? Using ‘Low,’ ‘Medium,’ and ‘High,’ what is the estimated impact this will have on water quality? Priority action areas with a high impact on water quality were used to calculate load reductions in Element B, previous chapter.

Likelihood of Success. What likelihood does the action area or strategy have of succeeding attributed to voluntariness, cost, interest, level of difficulty, or any other reason? What additional information needed to implement successfully?

Technical and Financial Needs. What resources are necessary for implementation activities? These can range from personnel time to infrastructure investments.

Priority #1: Action Area (9) Infrastructure Upgrades to the Sanitary Sewer Collection System

Problem: The centralized collection system for wastewater treatment plants (WWTPs) includes a network of sewer lines, lift stations, and other infrastructure. Sanitary sewer pipes, if broken or malfunctioning, can release raw sewage into the runoff where it flows into streets and stormwater conveyances. These releases of sewage are called Sanitary Sewer Overflows, SSOs. SSOs associated with fats, oils, and grease (FOG) and wipes are discussed in Action Areas 6. Infiltration and inflow (I/I) are other contributing factors for SSOs. I/I is caused by unwanted water entering the collection system through manhole covers, sewer cleanouts, illicit connections, or damaged pipes. I/I volumes can overwhelm the collection system and WWTPs. Collection system problems resulting from I/I include: (1) back flooding of sewers into streets and private properties; (2) decreased capacity of the wastewater collection system; and (3) increasing collection system operating costs, e.g. adding to energy, maintenance, and repair costs by extending the run time for pumps and pump stations. SSO discharges may also result in substantial regulatory fines.

For GCHD's Water Pollution Division, the biggest complaint received from residents is sewage overflows, many from centralized sewage systems.

Goals:

- To reduce the volume of raw sewage discharging from failing sanitary sewer system infrastructure.

Approach: Collection systems need routine maintenance to identify and eliminate SSOs and I/I issues. A combination of sewer system surveys, repairs, and monitoring technologies can be utilized to bring a system into proper working order and reduce the release of untreated sewage into neighborhoods and ditches. This may include the replacement of corroded lines, failing lift stations, and repairs at specific line locations. Municipalities in the watershed are in the process of multi-year infrastructure improvement programs which will reduce the volume of raw sewage flowing into the environment and waterways.

Hitchcock and La Marque have both participated in TCEQ's SSOI program and are in different phases of assessment and implementation. Through the SSOI program, a plan for SSO reduction is submitted to TCEQ including a system inventory, sewer map update, inspections and testing, and system rehabilitation with multiple phases of construction. Video technology is used to survey the collection system and peak flow is measured to identify I/I. La Marque is in the process of issuing substantial capital improvement bonds for their SSO program. The City of Hitchcock completed their SSOI program agreement in 2013 and is continuing system rehabilitation construction activities for SSO reduction. While MUD 12 has not participated in TCEQ's SSOI program, they perform wastewater collection system surveys and also report information to TCEQ.

The GCHD offers inspections of WWTP operations for compliance with state and federal regulations as a contract service, and have assisted Hitchcock and La Marque as recent as 2015.

Location: Collection system infrastructure for three WWTPs occurs along highways and throughout

neighborhoods in Hitchcock, La Marque, and Bayou Vista. The Galveston County MUD 12 WWTP and La Marque's Westside WWTP discharge into Highland Bayou. While the City of Hitchcock's WWTP lies outside of the Highland Bayou Watershed boundaries and discharges to the Highland Bayou Diversionary Canal, much of its collection system is within the Highland Bayou Watershed.

| Implementation Objectives | Likely Lead Entity |
|---|--|
| 1. Adopt or update infrastructure management programs to plan and budget for proactive/preventative maintenance activities. | Wastewater service providers: City of Hitchcock, City of La Marque, MUD 12, City of Texas City |
| 2. Identify areas in the collection system where I/I or aging infrastructure is a problem. | Wastewater service providers: City of Hitchcock, City of La Marque, MUD 12, City of Texas City |
| 3. Rehabilitate collection system infrastructure to prevent SSOs and I/I. | Wastewater service providers: City of Hitchcock, City of La Marque, MUD 12, City of Texas City |
| 4. Upgrade or repair private line connections to the wastewater collection system. Performed as necessary. | Residents with guidance from the wastewater service provider. |
| Estimated Bacteria and/or Nutrient Load Reduction | |
| Reduction Effectiveness: High - Infrastructure repairs and surveying technologies are proven methods for reducing SSOs and leakages. | |
| Likelihood of Success: High –Hitchcock has completed a five year agreement through the TCEQ SSOI program. La Marque is currently participating in the TCEQ SSOI program. These are existing and new commitments to infrastructure improvements that will improve their collection systems. | |
| Technical and Financial Needs: Each wastewater service provider is responsible for their respective infrastructure improvements, have separate funding and approval processes. Constant maintenance of the collection system is necessary to ensure proper operation and parts can be expensive making ongoing operations a costly undertaking. See Element D for more information. | |

Priority #2: Action Area (6) Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System

Problem: The accumulation of FOG and wipes is a common problem resulting in sanitary sewer system overflows, malfunctions, and failures. As sewer lines clog and eventually break, raw sewage flows into local waterways or occur as backups into homes and businesses. The issue spans from private lines to the publicly maintained collection system. For private lines, homeowners and commercial customers are responsible for costs associated with blockages on private property. For a blockage on the public side of the collection system, costs can be substantial and some maintenance costs are passed along the all sewer rate payers. The utility provider may also face regulatory fines for the discharge of SSO volumes into the environment.

Goals:

- Minimize the introduction of SSO raw sewage into local waterways.
- Reduce the deposition FOG and wipes from entering sewer lines.
- Encourage proper disposal practices through education and outreach to residents and commercial entities on items that should not enter their drains.

Approach: *Commercial Practices.* Preventing FOG and wipes will reduce the incidence of blockages and other failures to the SSS and the release of raw sewage. Developing or strengthening regulations and policies that specifically address FOG for food service establishments and other commercial users is a priority. Wastewater treatment providers can employ a variety of requirements for users in their service area including:

- Local limits for oil and grease substances from animal or vegetable sources or from hydrocarbons discharges in wastewater to the sewage system;
- a minimum recovery charge per typical blockage incident attributed to the improper disposal of grease;
- outside interceptors for all new or remodeled food service establishments; and
- the development and implementation of a FOG best management plan as well as a grease interceptor cleaning log for food service establishments.

Rules can also be established for licensed waste haulers:

- grease interceptor cleaning practice standards;
- cleaning log requirements; and
- an expectation of communicating pertinent information to personnel of the food service establishment they service.

Public Education. Municipal wastewater entities can improve FOG awareness among their customer base by utilizing existing educational materials. Cease the Grease is a kitchen grease awareness campaign through the GBF that offers educational materials and an opportunity to learn from neighboring communities through GBF's Cease the Grease workgroup. In addition to keeping FOG out of our drains, GBF publicizes recycling locations for kitchen grease disposal and encourages the establishment of new recycling receptacles. Establishing more convenient recycling receptacles for residents is another way municipalities and other organizations can partner with GBF. Apartment complexes are a good option for pilot efforts as they offer an easy avenue for delivering educational material, measuring participation and surveying participants. Depending on the location and

partnerships the organization has in place, GBF can provide various levels of support with acquiring the recycling receptacle, maintaining the unit, or coordinating with the oil hauler.

Educating residents about wipes is important, especially since wipes are marketed to consumers as being flushable. Flushable is interpreted by the consumer to mean that the item can fit through a 4 inch pipe, not that the material should be flushed to the sanitary sewer or is septic safe. Patty Potty is an existing campaign that offers educational materials aiming to improve awareness among residents and businesses about what not to flush down the toilet.

Location: Developed areas of the watershed serviced by a centralized wastewater collection system.

| Implementation Objectives | Likely Lead Entity |
|---|---|
| <ol style="list-style-type: none"> 1. Regulation and Policy for FOG in commercial settings: <ol style="list-style-type: none"> 1. Compile existing regulations within the watershed and share. 2. Examine, establish, and/or update regulations as necessary to address gaps. 3. Include enforcement measures 4. Perform outreach to promote participation and aid in compliance. | <p>Wastewater treatment providers including City of Hitchcock, City of La Marque and MUD 12; County agencies; County Commissioners</p> |
| <ol style="list-style-type: none"> 2. Utilize existing educational messaging related to cooking grease –Cease the Grease campaign materials: <ol style="list-style-type: none"> 1. Join the Cease the Grease workgroup. 2. Utilize available online social media materials and website content. | <p>Wastewater treatment providers including City of Hitchcock, City of La Marque and MUD 12; County agencies; County Commissioners</p> |
| <ol style="list-style-type: none"> 3. Pilot project - establish one Cease the Grease kitchen grease collection station at an apartment complex. | <p>Wastewater treatment providers including City of Hitchcock, City of La Marque and MUD 12; County agencies; County Commissioners; GBF</p> |
| <ol style="list-style-type: none"> 4. Utilize existing educational messaging related to wipes - Patty Potty campaign materials: <ol style="list-style-type: none"> 1. Bolster online presence using free Patty Potty materials on social media sites and webpages. 2. Join the Patty Potty Patrol for access to videos, inserts, and public service announcements. Save Water Texas Coalition members receive a discount. Project ideas include: showing a Patty Potty video clip on the topic of flushable wipes in movie theatres (as the San Jacinto River Authority currently does); and setting up a standup cardboard cut-out of Patty Potty with a | <p>Wastewater treatment providers including City of Hitchcock, City of La Marque and MUD 12; County agencies; County Commissioners</p> |

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| <p>“don’t flush wipes” message in the City Hall lobby.</p> | |
| <p>5. Utilize utility bills for distribution of educational material to homeowners:</p> <ol style="list-style-type: none"> 1. Publicize costs for damages to sewer infrastructure to city taxpayers. “Cleaning out wipes that go down the drain is costing tax dollars”. Include a list of annual repairs for pump stations with costs, photos, the dos and don’ts of flushing and drains. | <p>Wastewater treatment providers including City of Hitchcock, City of La Marque and MUD 12; WCID 19.</p> |
| <p>6. Host education and outreach workshops for residents and commercial entities.</p> | <p>Wastewater treatment providers including City of Hitchcock, City of La Marque and MUD 12; County agencies; County Commissioners; AgriLife</p> |
| <p>Estimated Bacteria and/or Nutrient Load Reduction</p> | |
| <p>Reduction Effectiveness: Potentially high if education leads to physical improvement of private lines to public collection system; See Element B for discussion of the data gaps related to this activity. Educational activity if leading to behavior changes would lead to avoided bacterial loads in the future.</p> <p>Likelihood of Success: High – The educational component is largely available and ready for communities to utilize and educate homeowners and business. The costs and staff time associated with clearing sewer blockages or repairing equipment is significant versus the costs of homeowner education. To maximize existing resources, communities within the watershed should share existing practices and publicity activities with one another.</p> <p>Technical and Financial Needs: High – The educational component is largely available and ready for communities to utilize and educate homeowners and business. The costs and staff time associated with clearing sewer blockages or repairing equipment is significant versus the costs of homeowner education. To maximize existing resources, communities within the watershed should share existing practices and publicity activities with one another.</p> | |

Priority #3: Action Area (11) Stream Flow Within the Highland Bayou Channel

Problem: Flow within the Highland Bayou channel is currently impeded by accumulated sediment introduced to the bayou from urbanization and large storms including Hurricane Ike in 2008. The diversionary canal project in the late 1970's resulted in the most significant alteration to the bayou. The diversion succeeded in its design to provide flood protection for properties in the watershed, but recreational use and habitat quality has declined with the decreased flow and water depth. Detrimental changes to bayou hydrology and water quality are a result.

Streamflow management and maintenance responsibilities including potential modification to the channel were consistent topics of discussion for stakeholders during workgroup meetings. Within the canal communities of Bayou Vista and Omega Bay there is a recognized need for maintenance dredging of Highland Bayou. Many of the canal subdivisions have drafts that are deeper than the main channel of the bayou, 17' in canals versus 4' in the main channel. Several residents have requested debris be removed from the Bayou to improve flow conditions.

The bayou's slow and typically warm conditions provide an ideal environment for bacteria to grow. Increased flow may benefit water quality conditions and decrease the concentration of bacteria present in the bayou.

Goals:

- Improve flow conditions within the Highland Bayou channel by improving channel flow and by removing impediments to flow, such as fallen trees and sediment accumulation.

Approach: Improving the flow within the Highland Bayou channel may be achieved directly through dredging and debris removal activities. Before these activities are approved, further investigation to establish the scope of the project. Dredging and debris removal will not reduce future contributions of accumulated sediment and plant debris to the bayou. To accomplish this, the assessment of factors contributing to the decreased flow and introduction of sediment are needed.

Location: Highland Bayou Segment 2424A_01 originating from the headwaters to FM 2004, upstream areas within Jack Brooks Park as well as the residences downstream. Highland Bayou Segments 2424A_01 and 2424A_02 adjacent to unincorporated place, Freddiesville.

| Implementation Objectives | Likely Lead Entity |
|---|---|
| 1. Determine causes of flow reduction by requesting a study to identify contributing factors. | Galveston County Engineering with the USACE would perform the study. Other potential partners include the City of Hitchcock, City of La Marque, and MUD 12. |
| 2. Conduct a sediment source study to find the cause of sediment entering the bayou. | Galveston County Engineering with the USACE would perform the study. Other |

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| | potential partners include the City of Hitchcock, City of La Marque, and MUD 12. |
| 3. Selectively remove sediment and clear vegetation from the channel as recommended during assessments performed by the USACE. | Galveston County Engineering as the permit applicant would coordinate dredging activities with the USACE. Other potential partners include City of Hitchcock, City of La Marque, MUD 12 and Resource Agencies. |
| 4. Selectively remove accumulations of woody debris impeding flow within the channel in residential areas as recommended during assessments performed by the USACE. | Galveston County Engineering as the permit applicant would coordinate tree removal with the USACE. Other potential partners include City of Hitchcock, City of La Marque, and MUD 12. |
| Estimated Bacteria and/or Nutrient Load Reduction | |
| <p>Reduction Effectiveness: Likely to be low, as direct sources are not addressed by this activity. However, it is assumed that an improved flow regimen in the waterway would lead to a reduction in bacteria loading. A load reduction estimate for this action area is not estimated in Element B.</p> <p>Likelihood of Success: Medium – As the highest ranking priority among the stakeholders and a discussion topic that dominated many workgroup meetings, the level of commitment for this action area is expected to be high. State and federal involvement will be necessary due to regulatory requirements for activities within the bayou channel. These efforts will span the length of the watershed and coordination between several entities will be necessary for successful implementation. The next steps are to prepare studies. Natural resource agencies have expressed caution be used when modifying stream habitat by removing plant debris that provide beneficial structure for aquatic organisms.</p> <p>Technical and Financial Needs: Applicants for studies or dredging projects through the USACE may receive project support and financial assistance, though matching funds are a requirement. See Element D for more information.</p> | |

Priority #4: Action Area (13) Culvert Dam Maintenance in the Highland Bayou Channel

Problem: Accumulated sediment and plant debris are obstructing the flow of Highland Bayou within Jack Brooks Park. There are two separate locations where culverts are at least partially blocked by accumulated sediment both upstream and downstream of culverts. The culverts represent the intercept point where the diversionary canal drains old Highland Bayou to the south and away from the current channel. Obstruction of flow within the culvert has been a long standing concern for residents. In 1996, dozens of volunteers removed brush and trash from Highland Bayou during a cleanup effort adjacent to the culverts that comprise the earthen dam in Jack Brooks Park.

The bayou's slow and typically warm conditions provide an ideal environment for bacteria to grow. Increased flow may benefit water quality conditions and decrease the concentration of bacteria present in the bayou. It would not impact the load from bacteria sources.

Goals:

- Improve flow within the Highland Bayou channel, via the culvert
- Investigate maintenance needs for culverts within Jack Brooks Park.

Approach: Improving the flow within the Highland Bayou channel may be achieved directly through removing sediment and plant debris from the culverts within Jack Brooks Park. Before the culverts can be cleaned out, more information is needed on what maintenance activities are allowed, the process in which work is performed, and which parties are responsible for performing maintenance for these culverts.

Sediment and debris removal will not reduce future contributions of accumulated sediment and plant debris within these culverts. Increased flow could lower bacteria levels through dilution with contributing waters through the dam and culvert.

Location: Highland Bayou at the diversionary canal dam and culverts in Jack Brooks Park.

| Implementation Objectives | Likely Lead Entity |
|---|--|
| 1. Request information from the USACE about culverts to determine maintenance needs (potential removal of sediment and debris) to improve flow. | Galveston County Engineering; Municipalities; MUDs, AgriLife; USACE |
| 2. Remove sediment and clear vegetation from culverts. | Galveston County Engineering; Municipalities; MUDs, AgriLife; USACE |
| 3. Establish a management/maintenance agreement. | Galveston County Engineering; Municipalities; MUDs, AgriLife; USACE |

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Likely to be low, as direct sources are not addressed by this activity. However, it is assumed that an improved flow regimen in the waterway would lead to increased flow volumes and a concurrent a reduction in bacteria concentrations. A load reduction estimate for this action area is not estimated in Element B.

Likelihood of Success: High – As a top priority among the stakeholders, the level of commitment is expected to be high. More information is needed regarding the need for maintenance in these areas and the parties responsible for maintenance activities. Resource agencies have expressed caution about modifying stream habitat by removing plant debris that provide beneficial structure for aquatic organisms.

Technical and Financial Needs: The USACE provides project support and offers financial assistance, though matching funds are a requirement for applicants. See Element D tables for specific needs.

Priority #5: Action Area (19) Pet Waste Education

Problem: It is estimated that there are over 5,000 dogs in the watershed, generating tons of feces per year. Leaving pet waste in parks, yards or on sidewalks contributes a substantial amount of bacteria to surface waters. A single gram of dog feces can carry an estimated 23 million bacteria along with viruses and parasites. Bacteria and other living organisms travel with pet fecal material into our local waterways making it dangerous for swimming and ingesting. On the ground, fecal material can be harmful for children or even other pets. Due to the presence of suburban development within the Highland Bayou Watershed, pet waste is assumed to be a large source of bacterial contamination.

Goals:

- Reduce bacteria loads from pet waste.
- Encourage pet owners to pick up pet waste by providing pet waste stations in public areas.
- Provide education and outreach to pet owners on proper pet waste management and impact of pet waste on water quality.

Approach: To reduce bacteria loads from pet waste, it is important that it is disposed of in the garbage and not left on the ground. Since many cats use litter and remain indoors the focus here is on dogs. Feral or stray animals were discussed separately and are covered under Action Area (20).

Existing educational materials will be utilized to improve dog-owner awareness and result in behavior change. The H-GAC and the TCWP are local entities that have developed pet waste education and outreach materials that are available online. Materials available include fact sheets and posters that can be utilized in common areas within apartment complexes, public buildings or park bulletin boards.

Pet waste education would be coordinated with the installation of pet waste stations to maximize participation. Pet waste stations with bag dispensers encourage pet owners to pick up after their pets in public areas. Aside from refilling bags, the stations require little maintenance. Stakeholders recommended parks with trash cans and regular trash pickup as the most suitable location option.

The Moses-Karankawa Bayous Alliance has provided pet waste educational materials at several public events within the watershed (See Element E). More than 500 pet waste bag dispensers have been distributed during these events.

Location: Watershed-wide. High public-use areas including city parks, county parks, public buildings, and large apartment complexes are best for pet waste stations. High public use areas will be prioritized higher than individual households for educational materials.

| Implementation Objectives | Likely Lead Entity |
|---|--|
| 1. Distribute pet waste educational material to residents during public events including H-GAC's Trash Bash, La Marque Bayou Fest, and Hitchcock's Good Ole Days Celebration; at libraries, city hall, and other public facilities; | City of Hitchcock; City of La Marque; City of Bayou Vista; MUD 12; WCID 19; HOAs; Galveston County; AgriLife |

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| through mailers, utility inserts, Homeowners Association (HOAs), and various civic organizations. | |
| 2. Install pet waste stations with bag dispensers in parks and other public spaces. | City of Hitchcock; City of La Marque; City of Bayou Vista; MUD 12; HOAs; Galveston County |
| 3. Distribute pet waste bag dispensers to residents during public events including H-GAC's Trash Bash, La Marque Bayou Fest, and Hitchcock's Good Ole Days Celebration; through HOAs and civic organizations. | City of Hitchcock; City of La Marque; City of Bayou Vista; MUD 12; WCID 19; HOAs; Galveston County; AgriLife |
| Estimated Bacteria and/or Nutrient Load Reduction | |
| <p>Reduction Effectiveness: High – Bacteria load reductions could be high. Effectiveness will be determined by rates in behavior change among dog-owners. Load reduction estimates are included in Element B.</p> <p>Likelihood of Success: Medium to High. A sustained education effort is necessary to educate dog-owners in the watershed. While parks and other public areas where owners take their dogs to play and walk are ideal for outreach and deployment of pet waste stations, real load reductions will be seen at the neighborhood level where most dog owners allow their dogs outside (i.e., yards or neighborhood walks). As with any educational effort, the real outcome sought is behavior change, resulting in actual load reductions.</p> <p>Technical and Financial Needs: Low– Funding and labor for the installation of pet waste stations and for the delivery of education and outreach materials is minimal. Maintenance of the pet waste stations would include staff time within the scope of the participating agencies' capabilities. More information is included in Element D.</p> | |

Priority #6: Action Area (24) Green Infrastructure and Stormwater Treatment Wetlands

Problem: Impervious and low pervious surfaces alter stormwater runoff behavior, impacting both the quantity and quality of water. Buildings, pavement, and compacted landscapes cover much of the land in suburban communities. Impervious surfaces allow water to flow over the landscape more quickly, prevent opportunities for ground infiltration. This contributes to increased quantities of runoff, and potentially increased flooding. As new development brings additional impervious surface to the watershed, the volume of stormwater runoff will increase unless site development standards change.

Goals:

- Reduce the amount of stormwater runoff entering local waterways by retaining rainfall on site or in neighborhood and regional detention features.
- Treat stormwater runoff using GI and SSW

Approach: GI consists of designed systems that mimic the natural hydrology of an area, allowing water to infiltrate into the soil and reducing runoff. In addition, GI may reduce some flooding by encouraging infiltration and providing more time for filtration by retaining water during rain events - treating water where it falls. Designs are site specific and can be easily incorporated into new or existing yards, parking lots or landscapes. GSI is intended to work together with “gray infrastructure” (roads, bridges, etc.) that makes life possible along the Gulf Coast. Native vegetation should be used when possible as these plants are well adapted to local conditions of prolonged wet and then dry spells, requiring little to no additional water once plant populations are established. Rainwater harvesting systems also promote water conservation by providing an alternative water resource.

There are several locations in Galveston County providing local GI examples including the City of Dickinson Public Library rain garden, the San Leon Elementary School rain water harvesting system and the Texas City Tanger Outlet Center water conservation measures. Tanger Outlet Center has 11 water cisterns with 90,000 gallons of water storage capacity designed for landscape irrigation. The Ghirardi Family WaterSmart Park in League City showcases eight stormwater BMPs in one location: rain gardens, WaterSmart landscapes, vegetated swales, pervious pavers, a vegetated buffer, rainwater harvesting, a green roof, and compost for turf grass management. Incorporating GI on public buildings and in public spaces increases their visibility and serves as an educational opportunity to reach both residential and commercial audiences.

Municipalities should consider updating local development codes to ensure that either these kinds of practices are required or at a minimum not prohibited through arcane standards. The nearby community of League City proposed an ordinance for Low Impact Development as an alternative to conventional drainage, detention, and storm water conveyance systems in 2013. Example incentives and regulations to encourage GI for stormwater retrofits are available in the “Retrofit Policies” section of EPA’s “Managing Wet Weather with GI Municipal Handbook”. <https://www.epa.gov/green-infrastructure/green-infrastructure-municipal-handbook>.

Educating public officials, staff, developers and residents about GI will be necessary to build awareness

in the watershed. Online resources are available, including: Center for Watershed Protection, EPA's "Soak up the Rain", EPA's "GI Municipal Handbook", and the Low Impact Development (LID) Center located in Maryland. For GI guidance that considers local soil and climate conditions H-GAC offers "Designing for Impact: A Regional Guide to Low Impact Development" and the Texas Coastal Watershed Program offers technical assistance through their Stormwater Program. In 2015 they published the Ghirardi Family WaterSmart Park Stormwater BMP Assessment Report. Communities in the watershed can request rain barrel workshops (GBF) to educate residents on water conservation and provide participants with a rain barrel they can install the same day.

SWW can be constructed as retrofits of existing detention and conveyance systems, adding beauty, habitat and water quality benefits. Existing basins have wetland characteristics and can be converted relatively easily. SWW encounter relatively dramatic and frequent changes in water depth. They account for the variable stormwater flow and provide an alternative to stormwater detention basins. A misconception about this BMP is the risk of mosquitoes, which are not an issue in well-designed SWW. Objectives in approach for promoting stormwater treatment wetlands are much like the GI suggestions above. Existing workshops are available and can be offered to public entities and developers. Public entities will be approached to gauge interest in utilizing stormwater treatment wetlands. Planning and land development ordinances to consider these stormwater detention retrofits into wetlands and incorporate SWW into new development projects may encourage participation.

Location: Highly developed areas of the watershed, including commercial and residential sections of the watershed.

| Implementation Objectives | Likely Lead Entity |
|---|--|
| 1. Update development codes to allow for GI projects during new development and stormwater retrofits; example ordinances are available for reference. | City of Hitchcock; City of La Marque; City of Bayou Vista; MUD 12; County agencies; Developers; AgriLife |
| 2. GI for public buildings and in public spaces: 1. Identify public entities interested in utilizing GI. 2. Design and implement GI projects including rain gardens, permeable pavement, bio-swales, vegetated curb extensions, rain water harvesting cisterns and WaterSmart landscaping. | City of Hitchcock; City of La Marque; City of Bayou Vista; MUD 12; County agencies; Developers; AgriLife |
| 3. Educate residents and public entities about GI: 1. Distribute educational materials about GI practices, how they can be used locally, and their impact on water quality. 2. Partner with AgriLife to host GI workshops, lectures and field trips to educate homeowners, businesses and municipal officials. 3. Partner with GBF to host rain barrel | AgriLife; GBF; Galveston Bay Estuary Program |

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| workshops for residents to promote water conservation. | |
| <p>4. Encourage the use of constructed stormwater treatment wetlands:</p> <ol style="list-style-type: none"> 1. Host constructed SWW workshops for public entities and developers. 2. Identify public entities interested in utilizing stormwater treatment wetlands and establish ordinances to consider these practices. 3. Retrofit existing stormwater detention facilities into stormwater treatment wetlands where feasible. 4. Incorporate stormwater treatment wetlands during new development projects. | AgriLife; GBEP; GBF |
| Estimated Bacteria and/or Nutrient Load Reduction | |
| <p>Reduction Effectiveness: Medium to High, dependent on design, site selection and maintenance. Effectiveness on load reductions is contingent on use of these practices in areas that intercept runoff load from existing development. Load reductions were calculated and are included in Element B.</p> <p>Likelihood of Success: Medium – Project timelines require sustained commitment and then maintenance of the features, ideally intermittently. Education is needed for proper siting and design standards. Garden Clubs may be an avenue for outreach. Misconceptions about these practices are known obstacles to their consideration and use, requiring targeted education. Maintenance needs are expected to be different than for conventional practices but are not anticipated to be unreasonable. For stormwater treatment wetlands, the size of the wetland relative to the contributing watershed is the most important determining factor in how well the wetland will function.</p> <p>Technical and Financial Needs: High – Funding to identify, plan and implement projects; Resource management and technical expertise is needed from partner agencies/organizations.</p> | |

Priority #7: Action Area (30) Stormwater Infrastructure Assessment Surveys

Problem: Drainage does not stop at jurisdictional boundaries, but responsibility for infrastructure maintenance does. Sustainability of the stormwater system is critical for proper drainage. A survey would identify, inventory, and map this infrastructure in municipalities, and ideally identify opportunities for improved volume capacity and chances for where water quality practices could be implemented or prevent SSO discharges into the stormwater drainage system.

Stormwater infrastructure includes above and below ground conveyances for stormwater. Drainage District 2 (GCDD2) maintain drainage ditches north of Highland Bayou, and including large channels and detention basins. Improvements within GCDD2 are sized and maintained to accommodate runoff anticipated from maximum buildout conditions and using a 100-year rainfall event. The current system of ditches are built out to accommodate this growth, and GCDD2 focuses most of their efforts on maintenance activities. Roadside ditches within city limits are maintained by municipalities. Galveston County Road and Bridge is responsible for construction, repair and maintenance of county streets and drainage systems. The watershed area south of Highland Bayou is outside GCDD2 and the evaluation of stormwater infrastructure for repair, maintenance and upgrades is performed by several entities in an uncoordinated fashion.

A comprehensive countywide drainage plan was created in 2012 to identify potential drainage and flood control projects both inside and outside of municipalities, following damages during hurricane Ike in 2008. A large database of drainage conditions and facilities across Galveston county was assembled, including representative drainage channel characteristics, estimated culvert capacities, planning level dimensions of proposed projects, and bridge and culvert descriptions. Projects for localized street drainage and storm sewer improvements were not part of the Galveston County Master Drainage Plan because responsibilities are typically covered by local communities and subdivision developers (Klotz, 2012).

Goals:

- Assess stormwater drainage system infrastructure to improve system management and identify maintenance needs and opportunities for where water quality practices could be implemented.

Approach: Stormwater infrastructure inventories could be later utilized to assess and prioritize sources of NPS pollution. The inventory should identify infrastructure along with attribute information for asset management purposes; including enough information to allow the local jurisdiction to locate individual structures, record inspection results, prioritize maintenance needs, and issue maintenance work orders. At a minimum the map of the existing stormwater system should include outfall locations and intercepts with municipally owned conveyances. As new construction occurs, the map should be updated with relevant information. If existing outfalls/intakes are modified, add relevant information to the map. An assessment may include assigning risk, determining remaining life, replacement cost, or determining a maintenance schedule. Stormwater system components commonly included in infrastructure inventories are inlets, catch basins, stormwater drainage pipes and conveyances, swales and drainage ditches, culverts, outfalls, streams and receiving water bodies, manholes, weirs, spillways,

energy dissipaters, headwalls, structural stormwater controls, and BMP or structural device type.

Location: All areas of the watershed serviced by drainage infrastructure.

| Implementation Objectives | Likely Lead Entity |
|---|---|
| 1. Compile and review previous storm drainage system studies to determine the scope for an updated assessment. | Galveston County Storm Water Collaborative; Municipalities; Galveston County Engineering; GCDD2 |
| 2. Inventory stormwater infrastructure components: 1. Establish data objectives, requirements, and the data collection schedule. 2. Inventory and map public stormwater system. 3. Develop a plan to maintain and update inventory data. | Galveston County Storm Water Collaborative; Municipalities; Galveston County Engineering |
| 3. Characterize stormwater system components in the inventory to prioritize improvement needs and pollution prevention measures. | Galveston County Storm Water Collaborative; Municipalities; Galveston County Engineering |

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: No load reductions directly from this action area. Primary benefit is for assessment and planning purposes, leading to the ability to prioritize opportunities for implementation of water quality practices and projects such as SWW or GI.

Likelihood of Success: Medium - The action area will require coordination between various local agencies and departments. Drainage system maintenance needs are ongoing, requiring a long term commitment from participating entities.

Technical and Financial Needs: High – The level of complexity for a stormwater infrastructure inventory will vary between communities, depending on the existing system and resources for inventorying. See Element D.

Priority #8: Action Area (23) Landscaping and Landscaping Debris Ordinances

Problem: Grass clippings, leaves, mulch and other plant matter swept or blown onto the road, driveway or into storm drains introduce stormwater pollution to local waterways. Yard and household wastes contribute nutrients, fertilizers, pesticides, and bacteria to our bayous. Storm drains, streets and other stormwater drainage infrastructure are not part of the sanitary sewer system and stormwater is not treated. Stormwater carries lawn debris and discharges directly to local waterways.

Goals:

- Decrease and minimize the introduction of lawn debris and nutrients into stormwater.

Approach: By preventing landscaping debris from entering stormwater, homeowners and landscaping contractors play a critical role in reducing the pollutant load associated with these materials. Strengthening existing ordinances will ensure that communities have the tools to encourage residents and landscaping contractors to keep lawn debris out of storm drains.

The canal community of Bayou Vista has an ordinance against blowing lawn clippings and other refuse into canals. Bayou Vista residents are encouraged to call and request a warning or ticket be issued if they observe violations. The City of La Marque trains their landscaping contractors in these recommended practices; La Marque does not yet have ordinances to prohibit the disposal of landscaping debris in the stormwater system.

Public education and outreach for landscaping practices is covered under Action Area (22) in the section following the Priority Action Area tables. It is important; however, to communicate ordinance requirements to individuals and entities affected to encourage participation.

Location: Entire watershed.

| Implementation Objectives | Likely Lead Entity |
|---|---|
| 1. Develop new or strengthen existing ordinances addressing lawn clipping and landscaping debris management. Example ordinances are widely available for reference. | City of La Marque, City of Hitchcock, City of Texas City; City of Bayou Vista |
| 2. Communicate landscaping ordinance requirements or landscaping best practices to residents and landscaping contractors. | City of La Marque, City of Hitchcock, City of Texas City; City of Bayou Vista |
| 3. Develop enforcement measures for the ordinance including penalties due following multiple offenses. | City of La Marque, City of Hitchcock, City of Texas City; City of Bayou Vista |
| 4. Publicize contact information for reporting violations or poor disposal practices. | City of La Marque, City of Hitchcock, City of Texas City; City of Bayou Vista |

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Low – At this time, these actions are unlikely to result in a sizeable load

reduction overall, but may provide water quality improvements to localized sections. Preventing lawn clippings and debris from entering waterways will reduce nutrients and the carbon entering the waterway, but is unlikely to lessen bacteria loads since this is not understood to be a source of bacteria.

Likelihood of Success: Medium – The contribution of landscape clipping and debris into stormwater or directly into the bayou was brought up regularly by stakeholders as an important issue within the watershed. The level of commitment for this Action Area is expected to be high. At least one community in the watershed has an ordinance to address this issue with active participation from residents. When an enforcement component is included in the ordinance, participation increases. In the case of Bayou Vista, enforcement officers play a role in educating residents about the ordinance.

Technical and Financial Needs: Low – Example ordinances are widely available, even from neighboring communities.

Priority #9: Action Area (37) Landowner Conservation Plans

Problem: Land mismanagement can result in soil erosion and the destruction of important natural features such as riparian areas, wetlands, and shorelines. While most land owners are assumed to be good stewards of the land, there are some who may lack the knowledge of good land management practices. There are many incentives and BMPs landowners may not be aware of. Landowner participation in conservation and habitat management plans can reduce the amount of bacteria and nutrients entering waterways by addressing issues related to water quality, soil erosion and sedimentation.

Goals:

- Increase landowner participation in existing conservation and habitat management plans to decrease bacteria and nutrient loading and enhance water quality within the watershed.

Approach: The Natural Resources Conservation Service (NRCS), Texas State Soil and Water Conservation Board (TSSWCB) and Texas Wildlife Department (TPWD) administer a variety of voluntary programs which provide landowners with the technical and/or financial assistance to combine sustainable land stewardship activities with land production activities. Conservation and habitat management plans are typically coupled with agricultural activities. Highland Bayou Watershed does not have a significant agricultural sector, but stakeholders identified several private landowners that may be interested and ranked this item among the top ten Priority Action Areas.

NRCS. Conservation plans developed through NRCS are customized documents that outline the use and BMPs of the natural resources on public or private lands. Landowners benefit from NRCS conservation planning through increased productivity of agricultural land by conserving the soil, increasing rangeland health, improving water quality, and managing livestock waste. Conservation plans are also developed to improve habitat for fisheries, upland game birds, and other wildlife. Technical assistance can include engineering designs, operation and maintenance agreements, and information to support federal, state and local permits. Support provided by NRCS instills confidence in the design, implementation, and monitoring of a plan that is voluntary, flexible and specific to the property.

TSSWCB. Local Soil and Water Conservation Districts through TSSWCB develop site-specific Water Quality Management Plans (WQMPs) for landowners upon request. WQMPs provide agricultural producers with traditional, voluntary, incentive-based programs to comply with state water quality laws. Plans include improved land treatment practices, production practices and management and technology measures to achieve a level of pollution prevention or abatement consistent with state water quality standards. By contacting the directors of the soil and water conservation district, a farmer or rancher can get assistance on all phases of conservation. Districts are designed to deliver a local program, based on local needs, that best conserves and promotes the wise use of natural resources. Districts also work with the USDA-Farm Service Agency, Texas Agricultural Extension Service, Texas Forest Service, U.S. Forest Service and others when necessary to assist agricultural landowners/operators meet individual land use needs.

TPWD. Voluntary implementation efforts to establish more desirable wildlife habitat away from the riparian corridor is another approach to reduce bacteria entering local waterways. The Texas Landowner Incentive Program is a collaborative effort through TPWD funded with multiple partnerships to meet the needs of private, non-federal landowners wishing to enact good conservation practices on their lands for the benefit of healthy terrestrial and aquatic ecosystems.

Location: Large, privately owned properties. Properties adjacent to riparian corridors are considered the most critical.

| Implementation Objectives | Likely Lead Entity |
|---|--|
| 1. Identify existing conservation and habitat management plans within the watershed. | AgriLife; County agencies; NRCS; TSSWCB; TPWD; Resource agencies/organizations |
| 2. Identify interested landowners to participate in conservation and habitat management plans. Facilitate communication between voluntary programs and potential participants. <ol style="list-style-type: none"> 1. Host landowner workshops addressing land management practices. 2. Distribute educational materials to landowners regarding land stewardship practices. 3. Develop and implement individual NRCS conservation plans, WQMPs, and LIP participation. | AgriLife; Landowners; County agencies; Resource agencies/organizations |

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Low to Medium - The agricultural sector in the watershed is not as sizeable as in the past, and it continues to decline. Established landowner conservation plans are anticipated to be low in this highly urbanized watershed. Success is contingent identifying willing land owners with large acreage properties.

Likelihood of Success: Medium – The assistance programs identified above may already have involved landowners within the watershed. Additional information is needed to anticipate an increase in participation. Landowners may acknowledge the importance of good land stewardship practices and conservation plans but financial incentives offered through agency programs are necessary to increase the adoption of these plans. To increase implementation, financial assistance through the assistance programs is the primary need to overcome cost prohibitive obstacles. These are long range planning opportunities and the maintenance for continued effectiveness must be considered.

Technical and Financial Needs: Property acquisition can be a very capital intensive effort. Consideration for recreational opportunities and multi-use developments could be combined with land management and preservation efforts. See Element D.

Priority #10: Action Area (34) Preserve Existing Natural Areas

Problem: Undeveloped lands allow stormwater to infiltrate into the ground, much more so than in developed areas. Undeveloped natural and agricultural lands are under pressure for development – highways, residential and commercial building sites, and other uses. The decline of natural areas leads to water quality degradation, loss of habitat for wildlife, a decline in scenic beauty and livability for residents. Many stakeholders have expressed concern for the changes in landscape they have observed over the years. Riparian zones are a critical feature of natural areas because they buffer the flow of runoff to waterways and stabilize soil. Many sections of Highland Bayou shoreline has been converted to developed uses and open lawns. Riparian zone restoration is covered under Action Area (35).

Goals:

- Preserve priority undeveloped lands in their natural state and protect the water quality benefits of undeveloped land.
- Improve land management practices of undeveloped areas by providing education on habitat value for wildlife and water quality.

Approach: Conservation and restoration of coastal prairie, wetlands and other natural areas is an essential component of water quality management. These natural lands slow stormwater runoff and allow nutrients and bacteria to infiltrate into the ground. Targeted land acquisition can protect sensitive areas from developed and maintains it natural cover.

Natural lands are often protected in an uncoordinated and fragmented fashion. A regional planning approach may focus and coordinate conservation, planning and investment efforts to achieve land preservation goals and objectives. Artist Boat, the GBF, the Audubon Society, the Nature Conservancy, and Scenic Galveston are several resource and conservation organizations already acquiring property for preservation in areas near the watershed. Within the watershed, the University of Houston (UH) Coastal Center (UHCC) manages about 300 acres of highly endangered coastal tallgrass prairie habitat. UHCC maintains areas of pristine prairie, and, when possible, restores areas invaded by exotic species or disturbed by human activity. UHCC provides access and equipment to support environmental research and supports outreach activities with public groups.

Back the Bay is an educational campaign through the GBEP that aims to engage citizens in the Houston-Galveston region in lifestyle and habitat changes to improve water quality, conserve water, and protect fish and wildlife habitat. Back the Bay provides residents with tips to preserve Galveston Bay and information to understand their connection to the bay. Back the Bay also seeks to involve local governments in voluntary conservation measures.

Communities are able to protect natural lands and habitat through various regulatory techniques. During the building permit process, communities can require that developers show due diligence with respect to the U.S. Army Corps of Engineers Section 404 mitigation for destroyed wetlands. This review would enable communities to align mitigation activities with other comprehensive land use planning efforts. The H-GAC Eco-Logical online mapping tool can be used to identify valuable habitat areas.

Landowner conservation plans are covered separately under Action Area (37).

Location: Acquisition opportunities will be evaluated for undeveloped properties. Properties with portions in the riparian zone should be given preference. See Map-8 in Appendix A, Ecological.

| Implementation Objectives | Likely Lead Entity |
|--|---|
| <ol style="list-style-type: none"> 1. Support acquisition and conservation of undeveloped natural lands: <ol style="list-style-type: none"> 1. Review area conservation plans and consult with resource and conservation organizations to identify protected lands within the watershed. 2. Identify and prioritize properties with the potential for conservation management. 3. Acquire undeveloped natural lands and encourage conservation easements. | <p>Municipalities; MUDs; County agencies; AgriLife; Resource agencies/organizations; GBEP; GBF; Artist Boat; Houston Wilderness</p> |
| <ol style="list-style-type: none"> 2. Provide education for public entities and residents on loss of habitat for wildlife utilizing Back the Bay materials and other existing programs. | <p>Municipalities; MUDs; County agencies; AgriLife; GBEP</p> |
| <ol style="list-style-type: none"> 3. Use regulatory techniques to preserve natural lands: <ol style="list-style-type: none"> 1. Require inquiry through the USACE for Section 404 mitigation needs during the building permit process. 2. Enact ordinances to protect certain trees from removal or discourage developers from cutting down all trees prior to construction. | <p>Municipalities; MUDs; County agencies; AgriLife; Resource agencies/organizations</p> |

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Low – Preservation of existing natural areas will provide no reduction to current bacteria loads; however, without preservation the bacteria load will increase with the additional impervious surface promised by future development.

Likelihood of Success: Coordination among agencies and conservation groups will be necessary for property acquisition. Priority site selection should include meaningful water quality benefits. The need to mix and match various funding sources can be challenging. Land acquisition costs are high.

Technical and Financial Needs: Property acquisition can be a very capital intensive effort. Consideration for recreational opportunities and multi-use developments could be combined with land management and preservation efforts. See Element D.

28 Additional Action Areas

The remaining 28 Action Areas, those that did not become Priority Action Areas after the voting exercise, are still considered viable project areas for this WPP, and brief narratives about project directions and resources are provided for each. The Action Areas are grouped by quadrant and are listed in the order they were presented during the voting exercise. For complete project rankings, see Table C-1.

Quadrant 1: Wastewater Action Areas

Action Area (1) Address maintenance of OSSFs through education efforts

This action area is intended to improve maintenance of OSSFs by educating home owners about proper OSSF operation and maintenance. Incorporating OSSF criteria into standards of practice for home sale inspections is covered under Action Area 4.

Education for OSSF owners about malfunctioning septic systems may help them identify problems and prompt them to properly maintain their systems. The Texas A&M AgriLife Extension Service offers OSSF workshops for home owners, creates and distributes OSSF educational materials that outline maintenance needs (<http://ossf.tamu.edu/>), and stress responsibility towards improving water quality in the bayou as well as the health risks and economic burden of illnesses that can be caused by untreated effluent from malfunctioning OSSFs. The GCHD has OSSF permitting, fees, and inspection information available on their Consumer Health Services webpage. Additional resources for homeowners include a septic system quiz, a list of OSSF installers, and information on why septic systems fail. The GCHD will continue existing OSSF education programs. Mailouts notifying residents of septic online resources were suggested by stakeholders. Households having OSSFs would first need to be identified to ensure a targeted approach.

Action Area (2) Hookup to central system or upgrade failing OSSFs

Where feasible, expanding service area boundaries shifts wastewater management from private, onsite systems to a professionally managed, centralized treatment system. This option is available when municipalities are prepared to make the capital investments to expand their service areas. Hitchcock recently completed such an expansion towards the Freddieville area. Due to the limited use of septic systems in the area, the impact of this activity on load reductions is expected to be limited at best.

Action Area (3) Improve enforcement to mitigate failing OSSFs

After 1997, Galveston County stopped issuing permits for the construction of standard drain field OSSF systems in clay soils or in areas where the shallow groundwater surface was less than 2 feet deep. In these conditions common to the watershed, there were frequent instances of untreated septage flowing from drain fields. Older systems in the watershed have been “grandfathered” and home owners have not been required to replace them with alternative systems. Funding levels limit the number of inspectors who can make inspections and identify failing systems. Currently, calls from neighbors or others to report a discharge are the typical cause for an OSSF inspection. An increased budget for better inspection and enforcement would result in better identification of malfunctioning OSSFs. This, in turn, would result in an increase in repairs or replacement of malfunctioning systems. GHCD currently funds and trains new

inspectors. The Highland Bayou Watershed group will help solicit grant funding for the additional resources to support these activities. This activity is being pursued in other watersheds in the county, and partnerships with those watershed efforts could provide efficiencies of scale.

Action Area (4) Incorporate OSSF criteria into standards of practice for home sale inspections

Currently, home inspectors are not required to inspect OSSFs for home buyers, nor is there an accepted standard procedure for inspections. Without a standard procedure, the methods to determine the operational status of OSSFs may vary with the inspector's knowledge of OSSFs. Buyers may not be aware of an undersized, under-maintained, or improperly functioning system. In order to ensure consistency and competency of OSSF inspections at the a point of sale, rules specifying standardized procedures for OSSF inspections, at the sale of the home for all types of OSSF systems, must be developed and enforced. A thorough inspection will provide the home buyer the information needed to determine if their lifestyle and water usage is within the capabilities of the OSSF associated with the home that is being sold.

Texas A&M AgriLife Extension Service is developing an inspection manual for conventional OSSFs. The manual provides step-by-step guidance for inspecting the septic tank and treatment area. A checklist is used to determine the operation status and identify inspection and maintenance frequencies. Texas A&M AgriLife Extension Service will recommend that inspectors in Galveston County follow the manual for conventional systems until such time that the rules required to standardize inspection of OSSFs are established (statewide or in Galveston County). The watershed group will work with the GCHD, GBF, TREC and other watershed groups to advance this action area.

The H-GAC hosts a course on OSSF visual inspection for home inspectors. Participants learn how to identify failing OSSFs through visual inspection during this one-day course and will receive six continuing education hours from the Texas Real Estate Commission. (<http://www.h-gac.com/community/water/ossf.aspx>)

Action Area (5) Target areas for intensive water quality sampling based on OSSF pollution

Sampling efforts alone will not contribute directly to reduced bacteria counts; rather, the information obtained from sampling would be used to prioritize implementation efforts, and stakeholders expect to see decreases in bacteria counts as failing OSSFs are repaired or replaced. The recommended monitoring schedule included in Element I describes existing and recommended sampling programs to assess progress towards attaining water quality standards during the implementation activities within the Highland Bayou. Before sampling locations can be selected for water quality monitoring, it is important to identify the location or likely of all OSSFs (both permitted and non-permitted) to improve the monitoring strategy. H-GAC has an online mapping system for OSSFs in the region, as well as local knowledge on behalf of the staff of GCHD could be used to support the goals of this activity. Several ambient sampling locations could then be selected by the GCHD on Highland Bayou. Stakeholder workgroup members plan to seek grant funding for sustained sampling and analysis.

Action Area (6) Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System

FOG and wipes were ranked by stakeholders as #2 among the priority action areas. The goals, approach, and implementation objectives for this action area are discussed in the corresponding *Priority Action Area Table*.

Action Area (7) Develop and implement an improved sanitary sewer overflow initiative plan/program

The SSO Initiative is a voluntary program initiated in 2004 by the TCEQ, in an effort to address an increase in SSOs due to aging collection systems throughout the state and encourage corrective action before there is harm to human health and safety or the environment. Breaks, leaks, and overflows in these systems, collectively referred to as sanitary sewage overflows (SSOs), create overflows of untreated sewage into the stormwater system and ultimately waterways.

(<http://www.tceq.state.tx.us/field/ssoinitiative>)

Hitchcock and La Marque have both participated in TCEQ's SSOI program and are in different phases of assessment and implementation to reduce SSOs. Through the SSOI program, a plan for SSO reduction is submitted to TCEQ including a system inventory, sewer map update, inspections and testing, and system rehabilitation with multiple phases of construction. La Marque is in the process of issuing substantial capital improvement bonds for their SSO program. The City of Hitchcock completed their SSOI program agreement in 2013 and is continuing system rehabilitation construction activities for SSO reduction. While MUD 12 has not participated in TCEQ's SSOI program, they perform wastewater collection system surveys and also report information to TCEQ. Collection system improvements made by the City of Hitchcock, the City of La Marque and MUD 12 regarding SSO reduction is a continuous endeavour that each of these wastewater service providers are committed to overcome. Stakeholder workgroup members proposed owners and operators of WWTPs in the Highland Bayou Watershed revisit their SSO reduction plan/program if completed and implement an SSOI plan/program if the entity has not participated in the SSOI through TCEQ, aiming for each WWTP in the watershed to have an implemented plan.

The TCEQ is responsible for distributing educational materials about existing SSOI programs. Sanitary sewer system owners and operators are responsible for developing and implementing any SSOI plans. When appropriate, stakeholder workgroup members who are owners and operators should collaborate during the development or implementation of their respective SSOI plans. The stakeholder workgroup plans to seek funding for these activities from federal or state grant programs such as the CWA 319(h) grant program.

Action Area (8) Surveying collection system lines to identify problem areas

This action area specifically addresses the survey of collection system lines to identify problem areas. In order to address blockages effectively, a program expanded to entire sanitary sewer system is ideal. System rehabilitation projects (replacement of damaged or corroded lines, etc.) combined together with improved monitoring technologies can bring an aging collection system into proper working order and reduce the number of SSO discharges. La Marque, as an SSOI participant, documents their progress within an annual progress report. For sewer pipes, lift stations, manholes, etc., the frequency of inspections is included as a required operations and maintenance activity. The evaluation of I/I in the

sanitary sewer is covered by the annual report through flow monitoring (wastewater treatment facility, lift stations, rainfall records, etc.), dye or smoke testing to identify leaks and illegal connections, and/or system and mapping updates.

Analog closed-circuit television (CCTV) technology is an industry standard for pipe inspection and are designed for small diameter (less than 60 inch diameter) pipelines to provide high resolution images of infrastructure. Barriers for this technology are flow (the vehicle used to transport the CCTV cameras can only be used with low or no flows in the pipe), and high volumes of sediment or debris. Man-entry pipe inspection is typically done for larger pipes. These inspections would typically involve two inspectors to enter and document the pipe condition using photo and video as well as other general condition assessments. La Marque has used CCTV inspection robot cameras to inspect their lines.

Action Area (9) Infrastructure Upgrades to the Sanitary Sewer Collection System

Infrastructure upgrades to the sanitary sewer collection system were ranked by stakeholders as #1 among the priority action areas. The goals, approach, and implementation objectives for this action area are discussed in the corresponding *Priority Action Area Table*.

Action Area (10) Improvements in WWTP operation

The objective of this action area is to improve treatment operations at facilities permitted by the TCEQ to treat domestic wastewater. In 2008, the TCEQ instituted a state-wide requirement to include water quality based bacteria effluent limitations and monitoring requirements for facilities permitted to treat domestic wastewater. All new permits issued after 2008 for these types of facilities will contain the new state-wide requirements. Facilities with existing permits to treat domestic sewage will be required to incorporate the new requirements when they seek permit renewals or amendments. All three permitted WWTPs in the watershed treat domestic wastewater and therefore have a potential to contribute to the bacteria load and are operating under permits issued after the new permit requirements were initiated Table A-3.

The TCEQ has issued notices of violations to WWTPs in the watershed and, as of 2015; one facility is under enforcement orders issued by the TCEQ for violating their permits. In the last five years La Marque has had three TCEQ inspections and Galveston County MUD 12 has had two, none resulting in enforcement actions. Two formal enforcement actions were reported for the City of Hitchcock. There have been nine reported effluent exceedances for both Hitchcock and La Marque and one for Galveston County MUD 12 between 7-31-2012 and 7-31-2015. The GCHD offers inspections of WWTP operations for compliance with state and federal regulations as a contract service and have assisted Hitchcock and La Marque as recent as 2015. During the comprehensive compliance inspection, samples from the effluent are collected to verify compliance with the permit, adequate operations of the processing units are verified, and records are reviewed for compliance with TCEQ permit requirements. Results are reported annually to the wastewater service provider and are publicly available. Stakeholders suggested these facilities continue to participate in this voluntary program and that the MUD 12 WWTP consider joining as well.

Workshops for plant operators, specifically addressing bacteria and troubleshooting methods, were recommended by stakeholders. There are various professional development opportunities for public

works employees that offer free CEUs. Texas A&M Engineering Extension Service (TEEX) offers a two-week training cycle for wastewater personnel interested in obtaining a TCEQ Class-C license exam. Sequentially delivered courses, offered at a reduced tuition, are taught over a two week period. <https://teex.org/>

Quadrant 2: Stream Flow and Dredging Action Areas

Action Area (11) Stream Flow within the Highland Bayou Channel, Improve flow within Highland Bayou by dredging sediment and clearing vegetation

Stream flow within the Highland Bayou channel was ranked by stakeholders as #3 among the priority action areas. The goals, approach, and implementation objectives for this action area are discussed in the corresponding *Priority Action Area Table*.

Action Area (12) Flow within the canal communities. Dredging of canals with beneficial uses for dredge material and partnership for volunteer planting

This action refers to improving the flowing water in the various canal communities along Highland Bayou. Over time, the flow of water throughout the watershed has noticeably decreased according to stakeholders, they believe attributed in part to sediment accumulation. Differences in depths between the canals (17') and the bayou (4') result in 'trapped' water in the canals, resulting in stagnant flow and eutrophic conditions. Multiple fish kills have been observed in these communities. Bayou Vista, to improve water flow in its canals, has installed SolarBee water mixers, what have proven expensive and delivered mixed results. In addition to contributing to the ecological health of the watershed, leaders in local communities have expressed a need to dredge for recreational boating. As such, this action area may fulfill multiple priorities.

A principle action identified for this activity involves the removal of sediment build-up. Improved flow and tidal exchange may result in lower bacteria levels. Reducing sediments in these areas can provide a number of secondary benefits. For example, excavated dredge material can be used to create living shorelines (see action 14), restore habitats, and enhance natural vegetation, all of which can further contribute water quality benefits. The US Army Corps of Engineers and Galveston County have completed a number of projects in recent years using dredged material for beach nourishment and shoreline restoration.

Organizations such as the GBF, Texas Parks and Wildlife, the GBEP, the Galveston County Consolidated Drainage District, and the US Army Corp of Engineers (USACE) can collaborate with communities to remove dredge material and use it for sustainable purposes (refer to Element D for further information). Further, these organizations can assist in water quality studies and sediment reduction studies. USACE should be contacted prior to conducting and dredging and habitat restoration projects.

Action Area (13) Culvert Dam Maintenance in the Highland Bayou Channel

Culvert dam maintenance in the Highland Bayou channel was ranked by stakeholders as #4 among the priority action areas. The goals, approach, and implementation objectives for this action area are discussed in the corresponding *Priority Action Area Table*.

Action Area (14) Encourage living shorelines as an alternative form of shoreline protection when possible

This action refers to stabilizing the shoreline using native vegetation alone or in combination with offshore sills. Living shorelines provide a natural alternative to ‘hard’ shorelines like stone sills or bulkheads, and provide numerous benefits including nutrient pollution remediation, fish habitat provision, and buffering of land from waves and storms. Living Shorelines are composed of materials such as wetland plants, soil, stone, oyster reefs, dredge material, submerged aquatic vegetation and other organic resources. Due to the aquatic make-up of these shorelines, they help to improve water quality by removing nutrients such as nitrogen and phosphorous from the water, and even trapping sediments during storm events.

For areas along Highland Bayou, and even in the canal communities, living shorelines can be added around bank edges to reduce erosion and stabilize the shoreline. The use of this alternative approach has proven to be successful along the nearby diversionary canal in Hitchcock, Texas. GBF along with community partners graded the shoreline back from the waterline in order to plant smooth cordgrass; due to the low wave energy in this area no hard structure was deemed necessary. The result yielded beautiful vegetation, and prevention of coastal erosion.

GBF and its partners aids in project design, material selection, permit application, construction, plant selection and installation, and may even be available help identify grant funding opportunities. On average the creation of such projects from concept to completion averages from 5-7 years.

Action Area (15) Review of bulkhead standards to include maintenance enforcement

The installation of bulkheads in the Highland Bayou Watershed region is regulated by many local entities within the region. Cities such as the City of La Marque have ordinances for the design, and construction of bulkheads. Generally an inspection is conducted to test the integrity of the bulkhead and ensure it is in compliance with local codes. In some instances the code may include language stating the owner must “maintain” the installation. Such language is subject to interpretation by each individual person and cannot be measured. For these reasons, bulkheads decline over time and fail to prevent erosion of sediment into waterways. A solution may be requiring inspections to be conducted biannually, every five years, or what the local entity deems appropriate. For guidance, local jurisdictions should gather model ordinances and assess for suitability for local adoption. Communities should also review their ordinances over time to assess effectiveness, and improvement areas.

Action Area (16) Shoreline protection for the railroad south of Bayou Vista to maintain boat access and Reduce erosion

A berm located south of Bayou Vista is experiencing severe erosion from wakes created by passing boats. This berm not only acts as a buffer against the wakes, it also supports rail road tracks. To maintain canal access for boaters and minimize erosion of the berm, several solutions were discussed by stakeholders. Areas that would benefit from coastal erosion protection have multiple solutions that both solve the problem of erosion and benefit the environment. Texas Parks and Wildlife Department administers a Boating Access Grant that can potentially dredge an area and use the dredge material to fill low lying

areas that are prone to flooding. Dredge materials could also be used to create “living shorelines.” The site would need to be assessed for suitability, as living shorelines are not always possible. Another solution mentioned by the stakeholder group is to use rip-rap materials to control erosion, and fill the areas subject to flooding. Collaboration between multiple entities would be necessary, likely involve Bayou Vista, MUD 12, the U.S. Army Corps of Engineers, Burlington Norther and Santa Fe Railway (BNSF), and natural resource agencies. The property is owned by MUD 12 and the railroad is operated by BNSF.

Action Area (17) Combine detention areas into multi-use areas (regional stormwater detention facilities) where possible

Stormwater detention is a requirement for new development throughout the Highland and Marchand Bayous watershed, except in limited instances. New development must provide detention of sufficient runoff volume so as to minimize the impact of the development in terms of flooding. Most of the Highland-Marchand Bayou Watershed falls within GCDD2, with a small part in the extreme NW falling in Galveston County Drainage District No 1. South of the Highland Bayou main stem there is no separate drainage district, and Galveston County drainage rules apply. GCDD2 defers to Galveston County drainage rules, such that the entire watershed is governed by Galveston County rules.

Regional stormwater detention refers to consolidating smaller, individual detention projects into larger more extensive projects. Concentrating detention regionally provides more opportunity for better maintenance and many more opportunities for multiple uses of detention basins, such as athletic fields, playgrounds, and picnic areas. Larger detention facilities also enable the incorporation of SWW into the detention basins. SWW are one of the very best practices for cleaning polluted stormwater runoff. Well-designed SWW also add a measure of beauty and ecology. Birdwatching stations, for example, can be designed into the basins.

There is local recognition of the value of larger detention facilities. For example, regional detention is referred to as a policy preference in the Galveston County Consolidated Drainage District drainage manual. There is currently no known activity to push for regional detention in this watershed.

The water quality impact of SWW is significant (Jacob et al, 2012; International Stormwater BMP Database, 2014). Bacteria (*E. coli*) removal can easily be as high as 80-90%. Nitrate nitrogen (NO₃) removal frequently exceeds 70% (International Stormwater BMP Database, 2014). These numbers put SWW in the highest performing group of GI practices. A very important example of a multi-use detention facility that incorporates the full gamut of cleansing wetlands, nature trails, and athletic facilities can be found in the Exploration Green Park, now under construction in Clear Lake. (<http://www.explorationgreen.org>)

Quadrant 3: Urbanization & Development Action Areas

Action Area (18) Pet waste ordinances and bylaws

Municipal ordinances and HOA bylaws can provide an incentive for residents to dispose of waste properly. Common areas and parks are good areas to publicize these rules. Model ordinances are available online, and should be reviewed by localities for suitability and opportunities to improve applicability.

Together with these rules is the need for enforcement and willingness to follow through on penalties for violations.

Action Area (19) Pet waste education

Pet waste education was ranked by stakeholders as #5 among the priority action areas. The goals, approach, and implementation objectives for this action area are discussed in the corresponding *Priority Action Area Table*.

Action Area (20) Reduce the population of stray animals

Reducing stray pet populations can decrease the bacteria that enter our local waterbodies. Registration requirements include spaying and neutering pets in Bayou Vista, Hitchcock, La Marque, and unincorporated Galveston County. Many spay/neuter programs, including some shelters offer a reduced price for these services. Stakeholder workgroup members can partner with local shelters and veterinarians to provide education on the benefits of spaying and neutering.

Action Area (21) Encourage water conservation through education

Through the installation of rain barrels and rain gardens using native plants, residents can learn about water use, conservation, and its impact on polluted runoff. Communities interested in water conservation education can contact GBF and Texas A&M Agrilife's Texas Coastal Watershed Program. The Texas Coastal Watershed Program's WaterSmart program has a track record of successful demonstration projects around Galveston County.

GBF has developed a workshop on the environmental benefits of collecting rainwater, and proper rain barrel installation instructions and tips. Registration is \$35, which includes one 35-gallon barrel + one connector kit, and workshop registration. Workshop participants can purchase a maximum of 2 barrels + 2 kits. Attendees are encouraged to ask questions and take advantage of the resources offered, which help improve water quality in Galveston Bay. (<http://www.galvbay.org/rainbarrel>)

Action Area (22) Effective landscaping practices through education

Improper management of landscaping debris, fertilizers, and pesticides was a prominent concern of stakeholders. These materials, in excess, lead to increased BOD and can contribute to fish kills, and there is a need for public education about water quality impacts associated with landscaping practices. Homeowner education for spraying pesticides (e.g. *Cutter® Backyard™* Bug Control Spray and similar products) was specifically recommended by stakeholders, including, how much to use, when to spray in relation to rain events, and for the homeowner to consider nearby waterbodies. Education for lawn contractors was also brought up by stakeholders as essential to reducing the amount of the above mentioned materials entering surface waters.

Stakeholders in the watershed will work with programs like WaterSmart, Grow-Green and Earth-Kind Landscaping to provide materials to homeowners about proper application rates for fertilizer and pesticides. Resources for sustainable landscape management are also available through AgriLife Extension's Master Gardener and Master Naturalist programs, and Texas A&M's Texas Coastal

Watershed Program. Soil nutrient tests are offered free through AgriLife Extension for homeowners and landscape managers to utilize soil nutrient analysis to ensure proper fertilizer application rates.

Action Area (23) Use landscaping debris ordinances to discourage homeowners from contributing lawn clippings and debris into stormwater

Landscaping debris ordinances were ranked by stakeholders as #8 among the priority action areas. The goals, approach, and implementation objectives for this action area are discussed in the corresponding *Priority Action Area Table*.

Action Area (24) Encourage the use of green infrastructure and stormwater treatment wetlands through demonstration projects, ordinances, and education

GI and stormwater treatment wetlands were ranked by stakeholders as #6 among the priority action areas. The goals, approach, and implementation objectives for this action area are discussed in the corresponding *Priority Action Area Table*.

Action Area (25) Install educational watershed signage

Many residents do not know what a watershed is and are certainly not aware that everyone lives in a watershed. Recognizing the connection between runoff entering our storm drains and Galveston Bay can help residents and visitors recognize Highland Bayou as a valuable natural resource, promoting awareness and stewardship. Installation of educational watershed signage within parks, along watershed boundaries, and on roads can help promote awareness and educate citizens. Stakeholder workgroup members mentioned that including a map of the watershed, or pictures on signs could be positive ways to attract attention. Initial funding for watershed signage is only the first step. Maintenance and replacement issues were brought up by stakeholders as a potential barrier for this action area. Likely lead agencies for this effort are municipal public works departments, Galveston County Parks and Cultural Services Department, the Galveston County Road and Bridge Department, and GCHD.

Action Area (26) Discourage illegal dumping through education and programs

Illegal dumping refers to the unlawful disposal of used tires, construction debris, appliances, vehicles, boats, as well as household, commercial and industrial wastes in places other than permitted facilities such as landfills and transfer stations. Illegal dumping impairs water quality through the inflow of debris, chemicals, oils, and fuels that are hazardous to aquatic life and recreational uses. While illegal dumping is not necessarily a direct source of bacteria or nutrients, stakeholders expressed concern for litter near waterways and throughout the surrounding communities. According to stakeholders, problem areas for illegal dumping include vacant properties, dead end streets, the ditches along I-45, and within Highland Bayou Park.

To deter illegal dumping, municipal entities could establish a hotline, websites, social media platforms, or apps for residents to report illegal dumping. For example, the GBF's GBAN allows residents to report sightings of illegal dumping online or through a smart phone app, which are then relayed to the appropriate enforcement agency. Other prevention actions include installing signs with phrases such as, "No dumping", "Violators will be prosecuted", "Illegal dumping is a crime", "Do Not Litter", etc. Lead organizations can also use resources from the "Don't Mess with Texas Campaign" (see Element E for

more information). During this planning process, stakeholders reported that although the installation of signs works in some cases, it can have the counter-intuitive result of encouraging dumping in those areas. Another approach to illegal dumping may involve collaborating with not-for-profit organizations, municipalities, and state and county agencies to provide locations to dispose of materials properly. The City of Dickinson offers monthly tire recycling for any Galveston resident.

Trash Bash is an annual event where thousands of volunteers gather along Texas waterways to do their part in cleaning up the environment by participating in the largest single day waterway cleanup in the state of Texas. The Virginia Point Peninsula Preserve is located at the mouth of Highland Bayou just south of Bayou Vista. <http://www.trashbash.org/>

Action Area (27) discourage residential waste from entering the environment or sanitary sewer system

Residential waste includes solutions and compounds commonly found in homes and garages. This may include fuel, oil, paint, solvents, cleaners, detergents, fertilizers, pesticides, and in particular pharmaceuticals. Residents are known to pour these outdoors in lawns or gutters where it flows into nearby waterways, or down kitchen and bathroom drains into the collection system; once in the system, these wastes may find their way into the environment through SSOs, leaks or WWTP discharges. WWTPs and OSSFs are not designed to treat many of the waste items described here. Once dispersed into the watershed, residential waste can impair water quality, harm aquatic life and make contact recreation and fishing problematic. One frequent misconception is that pouring kerosene or gasoline on fire ant mounds is an effective ant control practice, when in fact that is not true.

This action area seeks to educate residents and provide options for the proper disposal of these items. Activities that can address residential waste include household hazardous waste collection events, stormwater inlet marking with phrases such as “Only Rain Down the Drain” and “Drains to the Bay”, public awareness campaigns and signs. The “National Take Back Prescription Initiative” is one of many take back programs offered to help decrease the occurrence of accidental poisoning, overdose, and abuse posed by unwanted prescription medicines. Ensuring proper disposal also keeps prescriptions from being flushed down the toilet making it through the sewage treatment process and into our waterways. Local police departments can join this campaign to offer an alternative for residents looking to clean out their medicine cabinets. There are several tire recycling events in Galveston County. Galveston County residents may drop off up to 5 tires for recycling at the Dickinson Public Works building located at 3120 Deats Road from 7–10:30 a.m, the first Friday of every month. This free service is not available for commercial disposal and residents must be able to load and stack tires into the recycling trailer. The City of Dickinson’s Public Works Department can be contacted with questions. H-GAC has a list of places that you can drop off hazardous household waste. <http://www.recycleinfo.org/recycling-galveston-county.html>

Action Area (28) Improve erosion control practices during construction and development

Construction and development activities usually disturb acres of soil surface and which can remain exposed for months or more. Disturbed surfaces include the construction pad, roads, maintenance yards, and newly excavated detention ponds. If not managed properly, erosion at these sites can transport

significant sediment into drainage conveyances and eventually waterways. Erosion adds turbidity to the water column, and the accumulation of eroded sediment in waterways removes flow capacity and can harm habitat for aquatic species. As development encroaches into the watershed, particularly in the highland bayou headwaters (AUs 2424A_4 and 2424A_5), the potential for sediment erosion is high. Drainage District 2 has observed and characterized soils in the watershed as highly erodible, and the district frequently has to manage sediment removal from their conveyances.

Construction erosion BMPs range from hydraulic seed spreaders to silt fencing and traps. The objective in these situations is to stabilize the surface or collect sediment via traps. Developments or common plans of development larger than acre within a regulated MS4 are subject to local ordinances governing erosion and sediment control during the construction phase. There are very few areas in the watershed that are unincorporated and fall outside of a regulated MS4. MS4 municipalities in the watershed have used a ‘model ordinance’ approach when they adopted their local ordinance and which do not prescribe specific practices. This approach can allow for flexibility and innovation, but it can also result in minimal compliance. As with all BMPs, effective erosion control BMPs comes down to proper installation and maintenance during the construction phase. The image below (Figure C-1) was taken north of the watershed in 2016. The practice shown is clearly not being maintained and sediment is flowing freely into the stormwater collection system. While communities may inspect sites using municipal inspectors, this duty is usually outsourced to third-party, consultant enforcement and reporting, which is the case for communities in the watershed.



Figure C- 2. Example of a failing stormwater BMP; Photo taken just north of the watershed

There are opportunities for communities to recommend higher standards for erosion control BMPs and to form cooperative agreements for inspection and enforcement. Multiple violations may result in penalties until the violations are remedied by the developer or its contractors. Similarly, the MS4 program requires the inclusion of language for educating the public about stormwater, and could form the basis for a municipally led outreach program relating to this action area. Also, the GBF’s GBAN program provides an online tool for collecting reports of pollution in the area, and this tool could be used to report failing erosion control BMPs or observations of excessive erosion.

Action Area (29) Evaluate existing stormwater strategies for education needs and opportunities to collaborate

In the past, the Galveston County ‘stormwater collaborative’ of public sector professionals would meet monthly at County offices to share knowledge and ideas about stormwater management and the Phase II regulatory program. If the group still exists, it should be made aware of the Highland Bayou WPP process and consulted about ways to mutually support the goals of these two efforts.

EPAs Phase II Stormwater rules came into force in 1999 and require that municipalities be responsible for regulating unpermitted discharges into their stormwater conveyances, or MS4s (Municipal Separate Storm Sewer System). Phase II requires that municipalities adopt ordinances and programs to address six areas of activity (minimum control measures) and which relate to several NPS pollutants of concern and stormwater, generally speaking. As noted in Action Area 28, most communities have taken the approach of adopting a ‘model ordinance’ which are usually generic and not tailored to local conditions or the priorities of the communities that adopt them. Municipalities in the basin should revisit their stormwater and construction site ordinances to assess for opportunities to update known weak points as understood through previous enforcement actions. This may mean enhanced inspection frequencies or clearer standards about erosion abatement practices.

Cooperative agreements or MOUs could be utilized by municipalities in the watershed and nearby watersheds such as Dickinson Bayou to pool limited resources to address issues common to all communities, such as education or the creation of construction site standards. Street sweeping is one activity that sometimes falls under a community’s Phase II program, but the equipment can be costly to purchase and maintain under any one community’s annual budget. One minimum control measure within the Phase II program is a requirement to have an outreach program to educate the public on stormwater and stormwater pollution. No communities in the basin are formally integrating existing educational programs offered by a range of entities such as Texas A&M AgriLife Extension Service, TCEQ, GBEP, or H-GAC into their Phase II outreach programs. Even short-term activities such as storm drain inlet stenciling can provide an educational benefit and enhance a community’s compliance with Phase II rules.

Action Area (30) Stormwater Infrastructure Assessment Surveys

Stormwater infrastructure assessment surveys were ranked by stakeholders as #7 among the priority action areas. The goals, approach, and implementation objectives for this action area are discussed in the corresponding *Priority Action Area Table*.

Quadrant 4: Agricultural/Wildlife/Land Management Action Areas

Action Area (31) Host feral hog awareness and training workshops to promote the reduction of feral hog populations

Feral hog populations are known to live within the watershed, although numbers are not estimated. Their ability to disturb the natural soil cover is surprising for people unaware of the damage they can do. Disturbed areas contribute sediment erosion, and feral hog fecal matter is a likely source of bacteria in the watershed. Feral hogs also carry disease and are a nuisance, non-native species. To address this, stakeholders identified hosting feral hog awareness and training workshops to promote education about methods for reducing feral hog populations. In 2013, stakeholders hosted a successful feral hog workshop at Carbide Park on a Saturday in 2013, which included free bar-b-q. Other organizations that have

experience with these types of activities and which could be involved in future efforts include the Texas A&M AgriLife Extension Service and the UH Coastal Center.

Action Area (32) Participate in feral hog hunting and trapping programs

In addition to hosting feral hog awareness and training workshops, stakeholders identified a need to promote feral hog hunting and trapping programs. Stakeholders suggested that sterilization or extermination is necessary to be truly effective. During this planning process stakeholder suggested developing a feral hog bounty program, which could include tracking how many hogs are killed. While this program should be watershed wide, stakeholders identified areas near Jack Brooks Park as being a high priority. Organizations or groups which could take the lead on this project include the Texas Youth Hunting Program, through Texas Wildlife Association. The Harris County National Wild Turkey Federation may also be willing to host a feral hog hunting event. Other possibilities include hiring a consultant trapper for public property and private homeowners responsible for trapping on private land. There are state regulations that govern the transport of non-native species across county lines, and there are Galveston County restrictions on hunting and trapping in the county. The specifics of these rules need to be better understood by the watershed group when designing a hunting and trapping program.

Action Area (33) Discourage the public from feeding pigeons and other birds

Stakeholders have reported pigeons in large numbers throughout the canal communities in the lower reach of the watershed. Pigeons are seen at bayou access points and nesting under boat houses. Stakeholders reported seeing large numbers of pigeons at Louis Bait Camp. Such a high volume of birds will inevitably contribute to the bacteria and nutrient load of the waterway through bird droppings. The presence wild birds is natural and desirable. It is appropriate to consider bacterial loadings resulting from wildlife as part of natural or ambient conditions, and this is mentioned in the proposed monitoring program described in Element I. To reduce the attractiveness for wildlife, food sources can be kept to a minimum by prohibiting feeding by the public and removing trash (Environmental Protection Agency, 2001). Stakeholders suggested an education program be established to inform the public about the harmful effects caused by feeding waterfowl, both on the environment and the overall health of their population.

Action Area (34) Preserve existing natural areas

The preservation of existing natural areas was ranked by stakeholders as #10 among the priority action areas. The goals, approach, and implementation objectives for this action area are discussed in the corresponding *Priority Action Area Table*.

Action Area (35) Restore and repair riparian zones

A riparian zone is the strip of land along a river or stream. It is a transition zone and captures surface runoff from higher ground, filtering out sediment and nutrients before it reaches the waterway. In particular, vegetation traps sediment before it reaches rivers, and stabilizes the shoreline, reducing erosion. Likewise, soil microbes that thrive in this moist environment break down chemical pollutants like hydrocarbons, further protecting water quality. Their natural functions can counteract the effects of polluted runoff from pavement and buildings, protecting water quality and the river channel itself.

There are a number of projects that can be employed to restore and repair these zones. Projects identified during this planning process include 1) restoring native vegetation during projects within riparian areas, 2) utilizing native plants for bank stabilization or capturing pollutants in storm water runoff, 3) hosting a riparian and stream ecosystem workshop in the watershed, and 4) Identifying property owners and providing assistance in evaluating their property for restoration projects. The Texas Riparian and Stream Ecosystem workshop is a free, one-day workshop through the Texas Riparian Association where Texas A&M AgriLife Extension co-presents with local watershed protection groups to provide stakeholders with classroom presentations and field demonstrations highlighting the hydrology, natural healthy riparian function and possible causes of riparian degradation. <http://texasriparian.org/>

The GBEP has worked to restore and repair riparian zones in the region. GBEP recently partnered with City of League City to enhance and restore riparian areas within Clear Creek Nature Park – located next to the tidally influenced reaches of Clear Creek, a tributary of Galveston Bay. Other potential partners include the Texas Riparian Association, USDA, USFWS, TPWD, and TSSWCB.

Activity Area (36) Encourage use of the bayou by the public as a natural resource through education

Stakeholders expressed an interest in seeing more swimming or direct contact recreation in Highland Bayou as they had in years past. Residents and visitors recognize Highland Bayou as a valuable natural asset to the community.

A few stakeholders expressed the “education of youngsters as being the most critical part” because children are more likely to incorporate what they learn into their daily lives. In addition, they will typically remind adults of the environmental impacts of their actions. Artist Boat offers youth eco-art workshops and kayak adventures to student groups on bayous leading into Galveston Bay. (<http://www.artistboat.org/eco-art-adventures.html>) Students on these field trips learn how their everyday actions on land can have a long reaching impact water quality and the health of the environment. The EPA supports environmental education projects that promote environmental awareness and stewardship through the Environmental Education Grant proposal process.

Texas Parks and Wildlife Department describes involving residents in outdoor recreation as a “critical component of conservation”, citing numerous studies that confirm the connection between outdoor recreation and caring for natural resources. The Texas Parks and Wildlife Department provides 50% matching funds to municipalities, counties, MUDs, and other local units of government with a population less than 500,000 to acquire and develop parkland or to renovate existing public recreation areas.

Action Area (37) Promote landowner involvement with existing conservation plans and cost share programs

Landowner conservation plans were ranked by stakeholders as #9 among the priority action areas. The goals, approach, and implementation objectives for this action area are discussed in the corresponding *Priority Action Area Table*.

Action Area (38) Bacteria source tracking (BST) and wildlife surveys

BST analysis on ambient surface water samples is used to identify the animal species sources of fecal bacteria contamination in water samples. BST is a relatively new approach that compares water quality monitoring samples to a bacteria DNA library, which is prepared using known sources from within the watershed. This enables watershed planning participants to determine the most significant contributors of bacteria. Utilizing BST results was recommended by stakeholders to adjust implementation efforts and facilitate adaptive management during watershed planning. <http://texasbst.tamu.edu/>.

First, funding for BST analysis would be needed to initiate efforts for under this action area. Funding for targeted BST analysis within the Highland Bayou Watershed will be pursued as a part of the implementation strategy. Costs to perform this analysis have come down sharply in recent years, enhancing the feasibility of this type of monitoring in future years. A report describing the results of the BST analysis at the subwatershed level for the Highland Bayou Watershed was proposed with a focus on evaluating human sources (WWTPs, sanitary sewer collection systems), domestic animals (both pets and livestock), and feral hogs.

While BST analysis alone will not reduce bacteria entering Highland Bayou and its tributaries, the information obtained can be used to prioritize efforts targeting specific sources. The recommended monitoring schedule included in Element I includes BST analysis to supplement existing sampling programs to assess progress towards attaining water quality standards during the implementation activities within the Highland Bayou Watershed.

Element D- Technical and Financial Assistance

Successful implementation of the Highland Bayou WPP relies on the active participation of local stakeholders, as well as support and assistance from a variety of other sources. The technical expertise, equipment, and staffing required for many priority action areas are beyond the capacity of any one stakeholder alone. Direct support from one or a combination of several sources listed below will be essential to achieve water quality goals in the Highland Bayou Watershed. In Table D-3 below, an estimate of associated costs and potential funding source are listed for each Priority Action Area UID. All priority action areas are dependent upon funding and resources.

Potential Funding Sources

A comprehensive narrative of funding sources is provided in Appendix 5, Funding Sources. Funding sources are grouped by federal and state agencies, listed by program name and include eligibility, criteria, and funding limitations. Tables D-1 and D-2 below list programs discussed in the Appendix 5 narrative.

Electing to pursue a funding source requires a clear understanding of your project scope and requirements and a clear understanding of the sponsor's funding priorities. The two have to line up for applications to be a success. Many funding sources (but not all) have a lengthy review process and the disbursement of funding may not happen for several fiscal quarters after approval, meaning that it can be over a year between submittal of an application and access to funding. Not all funding sources are grants. Some programs offer low interest loans or technical support. Some grants require a local, non-federal match, which can be a challenge. This is an additional layer to the application that requires match commitments in advance, either in dollars or non-cash contributions such as equipment or staffing.

Education and outreach support programs (a form of technical support) are listed separately in Element E, Education and Outreach, (see Table E-4). Many of these educational programs are specific to Texas issues and are administered by state and regional agencies. Almost half have some presence in the Houston region and are excellent candidate programs for Highland Bayou education objectives.

Table D- 1. Federal funding source for water quality activities; more information for each of the sources is provided in Appendix 5.

| Federal Programs | Agency or Organization |
|--|--------------------------|
| Agricultural Water Enhancement Program | NRCS |
| Coastal and Estuarine Land Conservation Program | NOAA |
| Community Development Block Grants (CDBG) | US HUD |
| Conservation Reserve Program | NRCS |
| Environmental Education Grants | EPA |
| Environmental Quality Incentive Program | NRCS |
| Target Watersheds Grant Program | River Network and EPA |
| WaterSMART: Cooperative Watershed Management Program | US Dept. of the Interior |
| Water and Environmental Programs | USDA |
| Wetlands Reserve Program | NRCS |

Table D- 2. State funding sources for water quality activities; more information for each of the sources is provided in Appendix 5.

| State Programs | Agency or Organization |
|---|--------------------------------------|
| Beach Maintenance Reimbursement Fund Program | Texas General Land Office (TX GLO) |
| Boating Access Grants | TPWD |
| Clear Water State Revolving Fund | Texas Water Development Board (TWDB) |
| Coastal Impact Assistance Program | TX GLO |
| Economically Distressed Areas Program | TWDB |
| Landowner Incentive Program | TPWD |
| Recreation Grant Program- Boating Access Grant | TPWD |
| Recreation Grant Program - Boat Sewage Pumpout Grant | TPWD |
| Reginal Water Supply and Wastewater Facilities Planning Program | TWDB |
| TCEQ 319 Grant | TSSWCB |
| Texas Clean River Programs | TCEQ |
| Texas Coastal Management Program | TX GLO |
| Texas Farm and Ranch Lands Conservation Program | TPWD |

Technical and Financial Resources Required for Priority Action Areas

Table D-3 lists likely costs and technical assistance requirements for each priority action area and its objectives. Required resources are organized by Priority Action Area and its objectives

Table D- 3. Technical and Financial Assistance

| Action Area | | Objective | Cost (\$) | Technical Assistance |
|-------------|---|--|---|---|
| 9 | Infrastructure Upgrades to the Sanitary Sewer Collection System | To reduce the volume of raw sewage discharging from failing sanitary sewer system infrastructure. | | |
| 9.1 | Infrastructure Upgrades to the Sanitary Sewer Collection System | Adopt or update asset management programs to encourage proactive/preventative maintenance activities | No cost | SSS infrastructure design and capacity standards, plan/program writing for specific community |
| 9.2 | Infrastructure Upgrades to the Sanitary Sewer Collection System | Identify areas in the collection system where I/I or aging infrastructure is a problem. | Variable | None |
| 9.3 | Infrastructure Upgrades to the Sanitary Sewer Collection System | Rehabilitate collection system infrastructure | \$140,000 per year for approx. 2-3 lift stations, 900 linear feet of line replacement, and major line repairs | SSS infrastructure design and capacity standards; heavy/excavation equipment, professional planning and labor |
| 9.4 | Infrastructure Upgrades to the Sanitary Sewer Collection System | Upgrade or repair private line connections to the wastewater collection system. Performed as necessary | To refurbish water and sewer lines for 130 houses and convert 2 old lift stations from gravity to | Heavy/excavation equipment, best practices for line maintenance and repairs. |

| Action Area | Objective | Cost (\$) | Technical Assistance |
|-------------|--|--|--|
| | | forced main: \$500,000. Potential monetary help in the form of CDBG funds; IKE funding | |
| 6 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | To minimize the introduction of SSO raw sewage into local waterways. Reduce the deposition FOG and wipes from entering sewer lines. Encourage proper disposal practices through education and outreach to residents and commercial entities on items that should not enter their drains. | |
| 6.1 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Regulation and Policy for Fats, Oils, and Grease in commercial settings | No cost, Staff time to compile and report, to outreach to city councils |
| 6.1.1 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Compile existing regulations within the watershed and share. | No cost, Staff time to compile and report, to outreach to city councils |
| 6.1.2 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Examine, establish, and/or update regulations as necessary to address gaps. | No cost, Staff time to compile and report, to outreach to city councils |
| 6.1.3 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Include enforcement measures | No cost, Staff time to compile and report, to outreach to city councils |
| 6.1.4 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Perform outreach to promote participation and aid in compliance. | \$5,000-\$10,000 per year for staff support, printing, and limited travel resources |
| 6.2 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Utilize existing educational messaging related to cooking grease –Cease the Grease campaign materials | \$5,000-\$10,000 one time cost to compile, ongoing staff time to follow through with campaign, assuming this ‘piggy backs with other efforts |
| 6.2.1 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Join the Cease the Grease workgroup. | No cost |
| 6.2.2 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Utilize available online social media materials and website content. | No cost |
| 6.3 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Pilot project - establish one Cease the Grease kitchen grease collection station at an apartment complex | \$850/receptacle (collection station). Does not include maintenance costs |

| Action Area | | Objective | Cost (\$) | Technical Assistance |
|-------------|--|--|--|--|
| 6.4 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Utilize existing educational messaging related to wipes - Patty Potty campaign materials | No cost | None |
| 6.4.1 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Bolster online presence using free Patty Potty materials on social media sites and webpages | No cost, staff time | None |
| 6.4.2 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Join the Patty Potty Patrol for access to videos, inserts, and public service announcements. Save Water Texas Coalition members receive a discount. Project ideas include: showing a Patty Potty video clip on the topic of flushable wipes in movie theatres (as the San Jacinto River Authority currently does); and setting up a standup cardboard cut-out of Patty Potty with a “don’t flush wipes” message in the City Hall lobby | Variable | None |
| 6.5 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Utilize utility bills for distribution of educational material to homeowners | \$0.10/page | None |
| 6.5.1 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Publicize costs for damages to sewer infrastructure to city taxpayers. “Cleaning out wipes that go down the drain is costing tax dollars”. Include a list of annual repairs for pump stations with costs, photos, the dos and don’ts of flushing and drains. | \$0.10/page | None |
| 6.6 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | Host education and outreach workshops for residents and commercial entities | \$5,000- \$20,000 for staff time and coordination. First time costs likely to be high, as workshop becomes routine, costs expected to fall | Technical presentation at workshop |
| 11 | Stream flow within the Highland Bayou Channel | Improve flow conditions within the Highland Bayou channel by improving channel flow and by removing impediments to flow, such as fallen trees and sediment accumulation. | | |
| 11.1 | Stream flow within the Highland Bayou Channel | Determine causes of flow reduction by requesting a study to identify contributing factors | Potentially zero cost or partial match (65/35) , federal cap at \$5,000,000 | Section 205 program authority; USACE provides professional expertise, and technical analysis |
| 11.2 | Stream flow within the Highland Bayou Channel | Conduct a sediment source study to find the cause of sediment entering the bayou | Potentially zero cost or partial match (65/35) , federal cap at \$5,000,000 | Section 204 program authority; USACE provides professional expertise, and technical analysis |
| 11.3 | Stream flow within the Highland Bayou Channel | Selectively remove sediment and clear vegetation from the channel as recommended during assessments performed by the | Potentially zero cost or partial match (65/35) , federal cap at \$10,000,000 | Section 204 program authority; USACE provides professional expertise and technical analysis. |

| Action Area | | Objective | Cost (\$) | Technical Assistance |
|-------------|--|---|---|---|
| | | USACE | | |
| 11.4 | Stream flow within the Highland Bayou Channel | Selectively remove accumulations of woody debris impeding flow within the channel in residential areas as recommended during assessments performed by the USACE | \$150-\$1,500/tree | Possibly USACE Section 14 program authority; Removal plan, equipment and disposal plan are required |
| 13 | Culvert Dam Maintenance in the Highland Bayou Channel | To improve flow within the Highland Bayou channel, via the culvert and investigate maintenance needs for culverts within Jack Brooks Park. | | |
| 13.1 | Culvert Dam Maintenance in the Highland Bayou Channel | Request information from the USACE about culverts to determine maintenance needs (potential removal of sediment and debris) to improve flow | No cost | None |
| 13.2 | Culvert Dam Maintenance in the Highland Bayou Channel | Remove sediment and clear vegetation from culverts | Potentially zero cost or partial match (65/35) , federal cap at \$10,000,000 | Heavy equipment to excavate, technical plans to repair culverts if repairs deemed necessary; access to site from County Parks; disposal site for sediment |
| 13.3 | Culvert Dam Maintenance in the Highland Bayou Channel | Establish a management/maintenance agreement. | No cost | Coordination between jurisdictional agencies |
| 19 | Pet Waste Education | To reduce bacteria loads from pet waste, encourage pet owners to pick up pet waste by providing pet waste stations in public areas, and provide education and outreach to pet owners on proper pet waste management and impact of pet waste on water quality. | | |
| 19.1 | Pet Waste Education | Distribute pet waste educational material to residents during public events | \$200 per station + \$32 per box of 800 replacement bags annually | None |
| 19.2 | Pet Waste Education | Install pet waste stations with bag dispensers in parks and other public spaces | Total of \$360 for the installment and bag replacement for each station. | Waste collection agreement/maintenance schedule |
| 19.3 | Pet Waste Education | Distribute pet waste bag dispensers to residents during public events | \$1,000 for materials biannually | None |
| 24 | Green Infrastructure and Stormwater Treatment Wetlands | To reduce the amount of stormwater runoff entering local waterways by retaining rainfall on site or in neighborhood and regional detention features and to treat stormwater runoff using GI and SWW. | | |
| 24.1 | Green Infrastructure and Stormwater Treatment Wetlands | Update development codes to allow for GI projects during new development and stormwater retrofits; example ordinances are available for reference | No cost | Technical expertise in design and siting standards for inclusion in drafting of ordinances and practices to match local conditions/resources |
| 24.2 | Green Infrastructure and Stormwater Treatment Wetlands | GI for public buildings and in public spaces | \$2,000 - \$100,000 per site, for design-construction. Projects range from minor installations to multi-acre projects. The cost depends on the goals for the property and the projects. Labor costs can be offset with volunteer efforts. | Heavy/Excavation equipment, vegetation, technical designs, acquisition costs, volunteer management |

| Action Area | | Objective | Cost (\$) | Technical Assistance |
|-------------|--|---|---|---|
| 24.2.1 | Green Infrastructure and Stormwater Treatment Wetlands | Identify public entities interested in utilizing GI | None | None |
| 24.2.2 | Green Infrastructure and Stormwater Treatment Wetlands | Design and implement GI projects including rain gardens, permeable pavement, bio-swales, vegetated curb extensions, rain water harvesting cisterns and WaterSmart landscaping | \$2,000 - \$100,000 per site, for design-construction. Projects range from minor installations to multi-acre projects. The cost depends on the goals for the property and the projects. Labor costs can be offset with volunteer efforts. | Heavy/Excavation equipment, vegetation, technical designs, acquisition costs, volunteer management |
| 24.3 | Green Infrastructure and Stormwater Treatment Wetlands | Educate residents as well as public entities about GI | \$1,000 for materials biannually, Total of \$2,000/year | Layout, design, & printing |
| 24.3.1 | Green Infrastructure and Stormwater Treatment Wetlands | Distribute educational materials about GI practices, how they can be used locally, and their impact on water quality | \$1,000 for materials biannually, Total of \$2,000/year | None |
| 24.3.2 | Green Infrastructure and Stormwater Treatment Wetlands | Partner with AgriLife to host GI workshops, lectures and field trips to educate homeowners, businesses and municipal officials | \$20,000 | None |
| 24.3.3 | Green Infrastructure and Stormwater Treatment Wetlands | Partner with GBF to host rain barrel workshops for residents to promote water conservation | No fee to request workshops. Participants pay a \$35 registration fee. Sponsors can purchase kits for a raffle to encourage attendance. | None |
| 24.4 | Green Infrastructure and Stormwater Treatment Wetlands | Encourage the use of constructed stormwater treatment wetlands | \$2,000-\$10,000 staff time to compile outreach materials and to network/outreach | Design standards, GI practices, Specialized outreach to targeted entities |
| 24.4.1 | Green Infrastructure and Stormwater Treatment Wetlands | Host constructed stormwater wetlands workshops for public entities and developers | \$20,000 from scratch for staff and resources, costs could be half or less if presentations are packaged and if outreach is streamlined. | Technical presentation at workshop |
| 24.4.2 | Green Infrastructure and Stormwater Treatment Wetlands | Identify public entities interested in utilizing stormwater treatment wetlands and establish ordinances to consider these practices | No cost | Specialized outreach to targeted entities |
| 24.4.3 | Green Infrastructure and Stormwater Treatment Wetlands | Retrofit existing stormwater detention facilities into stormwater treatment wetlands where feasible | \$100,000+ | Heavy/Excavation equipment, design-construction plans, labor, property acquisition or easements, permitting |
| 24.4.4 | Green Infrastructure and Stormwater Treatment Wetlands | Incorporate stormwater treatment wetlands during new development projects | \$1,000-\$15,000, cost varies by practice and design, primarily capacity volume, See Appendix 4 for average costs for specific practices by unit | Heavy/Excavation equipment, design-construction plans, labor, property acquisition or easements, permitting |
| 30 | Stormwater Infrastructure Assessment Surveys | To assess stormwater drainage system infrastructure to improve system management and identify maintenance needs and opportunities for where water quality practices could be implemented. | | |

| Action Area | | Objective | Cost (\$) | Technical Assistance |
|-------------|--|--|---|--|
| 30.1 | Stormwater Infrastructure Assessment Surveys | Compile and review previous storm drainage system studies to determine the scope needed for an updated assessment | No cost | Municipalities; MUDs; County agencies; Drainage districts; AgriLife; Resource agencies/organizations |
| 30.2 | Stormwater Infrastructure Assessment Surveys | Inventory stormwater infrastructure components | \$60,000 | GIS, field surveys, infrastructure and design standards |
| 30.2.1 | Stormwater Infrastructure Assessment Surveys | Establish data objectives, requirements, and the data collection schedule | Part of above cost, 30.2 | GIS, infrastructure and design standards |
| 30.2.2 | Stormwater Infrastructure Assessment Surveys | Inventory and map public stormwater system | Part of above cost, 30.2 | Field survey and staff, knowledge of infrastructure and design standards |
| 30.2.3 | Stormwater Infrastructure Assessment Surveys | Include a plan to maintain data and update inventory as required | Uncertain | GIS, infrastructure and design standards |
| 30.3 | Stormwater Infrastructure Assessment Surveys | Characterize stormwater system components in the inventory to prioritize improvement needs and pollution prevention measures | Part of above cost, 30.2 | Field survey and staff, knowledge of infrastructure and design standards |
| 23 | Landscaping and Landscaping Debris Ordinances | To decrease and minimize the introduction of lawn debris and nutrients into stormwater. | | |
| 23.1 | Landscaping and Landscaping Debris Ordinances | Develop new or strengthen existing ordinances addressing lawn clipping and landscaping debris management. Example ordinances are widely available for reference | No cost | Knowledge of landscaping standards, knowledge of drafting ordinances and compliance |
| 23.2 | Landscaping and Landscaping Debris Ordinances | Communicate landscaping ordinance requirements or landscaping best practices to residents and landscaping contractors. | \$1,000 for materials biannually, Total of \$2,000/year | None |
| 23.3 | Landscaping and Landscaping Debris Ordinances | Develop enforcement measures for the ordinance including penalties due following multiple offenses. | No cost | Knowledge of landscaping standards, knowledge of drafting ordinances and compliance |
| 23.4 | Landscaping and Landscaping Debris Ordinances | Publicize contact information for reporting violations or poor disposal practices. | \$1,000 for materials biannually, Total of \$2,000/year | None |
| 37 | Landowner Conservation Plans | To increase landowner participation in existing conservation and habitat management plans to decrease bacteria and nutrient loading and enhance water quality within the watershed. | | |
| 37.1 | Landowner Conservation Plans | Identify existing conservation and habitat management plans within the watershed | No cost | None |
| 37.2 | Landowner Conservation Plans | Identify interested landowners to participate in conservation and habitat management plans. Facilitate communication between organizations with existing voluntary programs with potential participants when appropriate | No cost | Technical knowledge of plan requirements and management practices and standards |
| 37.2.1 | Landowner Conservation Plans | Host landowner workshops addressing land management practices | 2 public workshops on land conservation- \$50,000; initial costs are high and could be shared | Technical presentation |

| Action Area | | Objective | Cost (\$) | Technical Assistance |
|-------------|---------------------------------|---|---|--|
| | | | across multiple watershed | |
| 37.2.2 | Landowner Conservation Plans | Distribute educational materials to landowners regarding land stewardship practices. | \$1,000 for materials biannually, Total of \$2,000/year | None |
| 37.2.3 | Landowner Conservation Plans | Develop and implement individual NRCS conservation plans, WQMPs, and LIP participation | Variable | None |
| 34 | Preserve Existing Natural Areas | To preserve priority undeveloped lands in their natural state and protect the water quality benefits of undeveloped land and improve land management practices of undeveloped areas by providing education on habitat value for wildlife and water quality. | | |
| 34.1 | Preserve Existing Natural Areas | Support acquisition of undeveloped natural lands for conservation | Cost varies, expected to be a 6-7 dollar figure acquisition, depending on size of property, assuming large properties with meaningful conservation value. Acquisition costs in addition to property costs | Legal assistance with title search, acquisition, use restrictions, and easements; technical assistance with habitat and water quality merits of the property; Knowledge of funding sources, grant writing, and grant management. |
| 34.1.1 | Preserve Existing Natural Areas | Review area conservation plans and consult with resource and conservation organizations to identify protected lands within the watershed | No cost | Technical knowledge of land management practices and their application |
| 34.1.2 | Preserve Existing Natural Areas | Identify and prioritize properties with the potential for conservation management | No cost | Technical assistance with habitat and water quality merits of the property |
| 34.1.3 | Preserve Existing Natural Areas | Acquire undeveloped natural lands and encourage conservation easements | Cost varies, expected to be a 6-7 dollar figure acquisition, depending on size of property, assuming large properties with meaningful conservation value. Acquisition costs in addition to property costs | Legal assistance with title search, acquisition, use restrictions, and easements; technical assistance with habitat and water quality merits of the property; Technical knowledge of land management practices and their application; Knowledge of funding sources and grant writing, and grant management |
| 34.2 | Preserve Existing Natural Areas | Provide education for public entities and residents on loss of habitat for wildlife utilizing Back the Bay materials and other existing programs | Variable | None |
| 34.3 | Preserve Existing Natural Areas | Use regulatory techniques to preserve natural lands | No cost | Technical knowledge of standards for effective ordinance drafting |
| 34.3.1 | Preserve Existing Natural Areas | Require inquiry through the USACE for Section 404 mitigation needs during the building permit process | No cost | Technical knowledge of standards for effective ordinance drafting |
| 34.3.2 | Preserve Existing Natural Areas | Enact ordinances to protect certain trees from removal or discourage developers from cutting down all trees prior to construction | No cost | Technical knowledge of standards for effective ordinance drafting |

Element E- Education and Outreach

Overview

Element E addresses three broad areas of outreach activities in this WPP:

- 1) Stakeholder outreach and participation refers to the targeted engagement and involvement of watershed stakeholders in the planning process, such as the stakeholder working group.
- 2) General Public Education & Outreach refers to activities to inform the public about how to become involved and more informed about their watershed, such as websites and community publicity.
- 3) Programs for Water Quality Education and Awareness refer to implementing WPP action areas that focus on outreach and education, such as homeowner education or feral hog training.

The Importance of Stakeholder Participation

NPS impairments result from multiple sources spread across a wide area. Individual action is essential, but it will take coordination and cooperation to address them. A broad-based and cross-collaborative strategy for stakeholder involvement is necessary for coordinating different activities and priorities in the basin, and also for understanding what resources are available. The Highland Bayou WPP Working Group began in 2012 and was revived in 2015 to foster participation in the development and of the recommendations in this WPP. The Working Group consists of stakeholders from multiple state, county and local agencies, together with private citizens. Their involvement in the planning process and in future years during the implementation phase will be critical.

'Stakeholder' is a term that includes concerned citizens, businesses, municipal officials, and agency representatives, among others. Any individual or agency that could be able to have an impact on the conditions of the bayou is considered a stakeholder. Since these individuals and their organizations have a role in the plan's implementation, it is important that the plan's goals and tasks match the abilities and resources of these groups.

10 Guiding Principles for Public Participation

Public participation should...

1. Provide opportunities to all interested persons to develop or implement the WPP;
2. Develop a public process that is transparent, responsive, and reliable;
3. Keep the public participation process informed, on target, and on time;
4. Create a forum where stakeholders can coordinate activities, projects, and programs;
5. Help participants understand the need for the project and about what happens next;
6. Communicate to stakeholders about issues identified in this process and the context of the planning effort;
7. Inform participants about the types of actions required by stakeholder for success;
8. Bring together citizens to evaluate options, to foster discussions, and to develop consensus directions about the plan's implementation;
9. Create an environment where participants felt that their ideas were heard;

10. Develop an online setting where announcements are placed, progress can be documented, and comments recorded.

What if we do nothing?? The Price of Inaction

- Water quality projects carried out by agencies may be uncoordinated or work at cross-purposes with other projects;
- Opportunities for substantial project funding from state and federal sources will be lost;
- Increases the likelihood that a Total Maximum Daily Load (TMDL) will be developed, which is less flexible and less voluntary than a WPP;
- Highland & Marchand Bayous will continue to fail water quality standards, limiting how the waterway is enjoyed by the community as a resource for recreation, economic uses, quality of life, and natural habitat;
- Opportunities for a coordinated and multi-community response to NPS and coastal hazards will be deferred or forgone for years, while the driving issues of NPS will deteriorate local waterways.

Stakeholder Participation Process

Designing the Stakeholder Participation Process

Challenges. The WPP project team anticipated several challenges that became the basis for designing the planning process.

1. Quickly informing a diverse stakeholder group about the background and context for planning;
2. Seeking candid input from participants about their perspectives, vision, and experiences in the watershed; and
3. Promoting whole group discussion to build common purpose, identify priority projects, and foster familiarity among participants.

Role of the Planning Team. As lead facilitators, the planning team's role was to keep the process and meetings on track, reach out to newly identified stakeholders, inform participants about the process and their role in it, and to gather and organize the group's ideas and priorities.

Role of Stakeholders. Stakeholders were asked to share with the group their role or their agency's role in the basin, to become familiar with the purpose of the WPP, to contribute to the group's understanding of issues in the basin, and to provide their ideas and their vision for priorities in the WPP.

Stakeholder Inspired Plan. Stakeholders were routinely reminded by the project team that the WPP is not the project team's plan; rather, it is the stakeholders' plan. As facilitators, the project team's goal is to bring out the ideas and issues that the group believes are relevant to the WPP. It is the role of stakeholders to provide the recommendations in the plan and determine action area priorities.

Building the Stakeholder Working Group

To start the process, the project team sought individuals from the local governments and agencies. Using this initial group, the question was posed to them about who else should be part of the planning process?

Who else has a stake in the conditions of the bayou? Who else has resources to improve those conditions? Who do you believe should be aware of this planning effort? This incremental approach to growing the list of stakeholders enabled the project team to bring together from a range of perspectives over 56 individuals. The project team contacted potential stakeholders via email, phone, and personal visits to describe the WPP process and why their involvement on the planning working group would help the bayous (Table E-1).

Table E- 1. Contacted stakeholder group

| Organization | Title | First Name | Last Name |
|---------------------------------------|---|------------|-------------|
| Artist Boat | Education Program Manager | Amanda | Rinehart |
| Bayou Vista Resident | Resident /Real Estate Broker | Nick | Stepchinski |
| City of Bayou Vista | Mayor Pro-Tem | Vaun | Henry |
| City of Bayou Vista | Mayor | Daniel | Konyha |
| City of Bayou Vista | Court Clerk | Lisa | Mitchell |
| City of Bayou Vista | City Secretary | Paula | Eshelman |
| City of Hitchcock | Engineer | Llarance | Turner |
| City of Hitchcock | Mayor | Anthony | Matranga |
| City of Hitchcock | City Secretary | Lucy | Dieringer |
| City of La Marque | Finance Director | Suzy | Kou |
| City of La Marque | Emergency Management Coordinator | Charlene | Warren |
| City of La Marque | City Manager | Carol | Buttler |
| City of La Marque | Director of Public Works | Les | Rumburg |
| City of La Marque | Public Works | Chaise | Cary |
| City of La Marque | WWTP Operations Supervisor | Jason | Hubbell |
| City of La Marque | Mayor | Bobby | Hocking |
| City of La Marque City Council | City Council District C | Robert | Michetich |
| City of Texas City | Engineer | Doug | Kneupper |
| City of Texas City | Parks Superintendent | Byron | Sefcik |
| Galveston Bay Estuary Program | Technical Programs Coordinator | Michelle | Krause |
| Galveston Bay Estuary Program | Water and Sediment Quality/ Monitoring and Research Coordinator | Lisa | Marshall |

| Organization | Title | First Name | Last Name |
|--|---|------------|-------------------|
| Galveston Bay Estuary Program | Natural Resource Uses Coordinator | Lindsey | Lippert |
| Galveston Bay Foundation | Water Quality Volunteer Coordinator | Sarah | Gossett |
| Galveston Bay Foundation | Water Programs Manager | Nathan | Johnson |
| Galveston County | Galveston County Commissioner, Precinct 2 | Joe | Giusti |
| Galveston County Drainage District #2 | Director | Allen | Kuehl |
| Galveston County Engineering | Assistant County Engineer | Nancy | Baher |
| Galveston County Engineering | County Engineer | Michael | Shannon |
| Galveston County AgriLife Extension | County Extension Agent | Phoenix | Rogers |
| Galveston County AgriLife Extension/ TX Sea Grant | County Extension Agent | Julie | Massey |
| Galveston County Health District | Air and Water Pollution Services | Taylor | Sanford |
| Galveston County Health District | Consumer Health Manager | Martin | Entringer |
| Galveston County Health District | Air and Water Pollution Manager | Lori | Fitzsimmons-Evans |
| Galveston County MUD 12 | President | Bill | Alcorn |
| Galveston County MUD 12 | Board | Bob | Bassett |
| Galveston County Parks and Cultural Services | Director | Julie | Diaz |
| Galveston County Parks and Cultural Services | Operations Manager | Robert | Simoneau |
| Galveston County Road and Bridge | Director of Road & Bridge | Lee | Crowder |
| Highland Bayou Estates | Resident Stakeholder | Jim | Bethune |
| Hitchcock Industrial Development Corporation | Chairman | Harry | Robinson |
| Hitchcock Industrial Development Corporation | Director of Economic Development | Sabrina | Schwertner |
| Omega Bay HOA | Vice President | Marcy | Scates |
| Private Resident | Resident Stakeholder | Tim | O'Connell |
| Scenic Galveston, INC. | Habitat Restoration Chair | Lalise | Mason |
| TCEQ Region 12 | Aquatic Scientist in Surface Water Quality Monitoring | Linda | Broach |
| TCEQ Region 12 | Technical Specialist Water Section, former wastewater inspector | Kim | Laird |
| Texas A&M AgriLife Extension | Assistant Professor & Specialist - | Jake | Mowrer |

| Organization | Title | First Name | Last Name |
|---|---|------------|--------------|
| | Soil Nutrient and Water Resource Management | | |
| Texas A&M AgriLife Extension – Texas Coastal Watershed Program | Extension Program Specialist | Charriss | York |
| Texas Parks and Wildlife Department | Regional Biologist, Water Quality Program | Marty | Kelly |
| Texas Parks and Wildlife Department - KAST | KAST Region 3 | Stephen | Mitchell |
| Texas State Soil & Water Conservation Board | Regional Watershed Coordinator | Brian | Koch |
| U.S. Army Corp of Engineers | Deputy Chief, Project Management Branch | Byron | Williams |
| U.S. Army Corps of Engineers | Hydraulic Engineer, H&H/Water Management Branch | Mario | Beddingfield |
| University of Houston Coastal Center | Director | Steven | Pennings |
| WCID #19 | Operator | Lee | Grundmann |
| WCID #19 | Board of Directors, Secretary | Phil | Harrison |

One-on-One Meetings, Feb-April 2016

“Every Little Bit Helps.”- Most frequent comment from one on one meetings.

A “One-on-one meeting” is an approach taken by the project team to work with stakeholders through an in-person, one-hour meeting at their place of work. The goal was to solicit feedback in a way that was otherwise difficult to do in a group setting and where participants were more likely to be guarded. The project team met with individual stakeholders to introduce project goals and to hear detailed stories about activities they are doing or have done that had a positive impact on the bayou. Stakeholders were also asked which issues are most important for the group to address. The informal, free-form conversation gave the project team a detailed perspective about that stakeholders’ role and activities. Similarly, stakeholders expressed appreciation to the project team for taking time to work with them individually.

56 individuals were contacted and 40 one-on-one meetings were held. Stakeholders were informed that the single text would be prepared and shared with the working group, but that no notes would be attributed to individuals. This was intended so that the full working group could be aware of the kinds of activities happening in the basin. The one-on-one meetings were held during the same phase as the stakeholder working group.

Table E- 2. Entities Contacted for 1-on-1s

| Entity |
|------------------------------------|
| Artist Boat |
| City of Bayou Vista |
| City of Hitchcock City Hall |

| Entity |
|--|
| City of La Marque |
| City of La Marque City Council |
| City of La Marque Public Works |
| City of La Marque WWTP |
| City of Santa Fe |
| City of Texas City |
| Galveston Bay Estuary Program |
| Galveston Bay Foundation |
| Galveston County |
| Galveston County Drainage District #1 |
| Galveston County Drainage District #2 |
| Galveston County Engineering Department |
| Galveston County Extension |
| Galveston County Health District |
| Galveston County MUD 12 |
| Galveston County Parks |
| Highland Bayou Estates |
| Hitchcock Industrial Development Corporation |
| La Marque Economic Development Corporation |
| Omega Bay HOA |
| Scenic Galveston, INC. |
| TCEQ Region 12 |
| Texas A&M AgriLife Extension |
| Texas Parks and Wildlife Department |
| Texas Parks and Wildlife Department - KAST |
| Texas State Soil & Water Conservation Board |
| U.S. Army Corps of Engineers |
| UH Coastal Center |
| WCID #19 |

Stakeholder Working Group Meetings: Dec 2015-Aug 2016

Whole Group Meetings. Stakeholder working group meetings were the primary way for developing and prioritizing recommendations in the WPP. The advisory meetings were designed as ‘whole group meeting,’ a process where all stakeholders are involved in a single, large meeting. This gave stakeholders the opportunity to directly engage and learn about others’ work in the watershed. This approach was a deliberate choice by the project team. The use of subcommittees to reduce meeting size was purposely avoided. For this planning effort, it was a priority of the project team that participants become familiar

with a broad range of leaders, agencies, organizations, and issues involved in the basin. Hearing about what others were doing and what they believed were required would lead participants to conversations about how to coordinate and prioritize seemingly unrelated activities. The project team believed that from this mix of individual perspectives, a shared sense of purpose and understanding of roles would emerge.

Nine working group meetings were held from December 2015 to September 2016. Working group meetings were weekdays, from lunch to 2:30. Lunches were offered gratis. Three stakeholder agencies- MUD #12, Galveston County Precinct #2 Commissioner, and the City of LaMarque each sponsored a lunch for the group.

Scheduling. Working group meetings were scheduled by selecting dates around key progress points in the project. Tentative meetings dates, usually two options, were sent to the entire advisory list as an online survey. The dates that received the most votes were selected by the project team. In the days leading up to the meeting, an agenda and prior meeting minutes were sent to the group. Working group meeting minutes, agendas, and handouts were uploaded to the website and are publicly accessible.

Project Binders. All participants were given project binders, a three ring binder with tabs for organizing handouts for each meeting and including agenda, meeting minutes, presentations and other relevant documents, such as maps and factsheets (Figure E-1). All maps in the binder have been updated and are in appendix A. Participants were asked to bring the binder with them to each meeting, where the project team would then hand out documents for that meeting. Stakeholders that joined the meetings mid-calendar were given binders complete up to that meeting. The binder included approximately 200 pages of material by the final meeting.



Figure E- 1. Project binders given to stakeholders

Meeting 1. December 08, 2015. The first meeting for the advisory group was held in December 2015. The presentation to the group provided an overview of the WPP process and how the Highland Bayou WPP relates to other watershed planning efforts in Texas. The project team also introduced to the participants

the specific water quality issues that triggered the 303(d) listing and why this impacts community quality of life. The team presented the major project milestones and the role of their participation in coming up with plan recommendations.

Meeting 2. January 19, 2016. The second meeting presented a recap of meeting 1 and core concepts to the WPP process. Up and coming events related to water quality issues were covered. Participants were asked which other stakeholders should be contacted for this effort. The second half of the meeting covered specific sources of NPS sources. The concluding portion of the presentation introduced the major subwatersheds of Highland Bayou and the group was asked to contribute to a group discussion about the scope of potential issues in each subwatershed.

Meeting 3. February 24, 2016. In this meeting participants were again asked which other stakeholders should be contacted for this effort. NPS sources and issues were discussed in more detail. The discussion was facilitated and comments were recorded on the whiteboard for group memory. Charriss York, watershed coordinator for the Dickinson Bayou Watershed Protection Plan and Implementation Plan presented to the group and described the process used by that project to move forward. Notes from On-on-One meetings were reviewed as a group.

Meeting 4. March 10, 2016. Discussion on NPS sources was continued from meeting 3. Notes from On-on-One meetings were reviewed. Possible funding sources were covered as a whole group discussion. Group participants discussed the difficulty measuring flow in the bayou.

Meeting 5. May 18, 2016. One on one meeting notes were summarized by the project team in advance of the meeting and distributed to the participants for their review. The meeting included two of four mapping exercises designed for the group (Figure E-2). The goal of the mapping exercise was to review each project idea documented through the one-on-one meetings. What areas of the map do these projects apply to? Is there a history behind these projects that lead us to believe they would be successful or not? Is more information needed to assess if the projects belong in the WPP? The goal was to start organizing over a hundred project ideas into a manageable list for future voting, as well as to foster a group discussion about what implementing these projects would require. Participants were organized randomly around one of two tables to work as team through each of the project ideas. Over two dozen project ideas were involved in the mapping exercise. Wildlife and wastewater were the two quadrants included in the mapping exercise.

Meeting 6. June 14, 2016. The mapping exercise was continued for a third quadrant- Urbanization.

Meeting 7 June 28, 2016. The mapping exercise concluded with the fourth and final quadrant- Stream flow & hydrology.

Meeting 8. July 14, 2016. The mapping exercise outcomes from previous meetings were organized into set of BMPs and program activities for load reductions and awareness. All projects were ranked by their share of votes, and the outcomes were shared with the group.



Figure E- 2. Mapping Exercise to compile list of best management practices and program activities

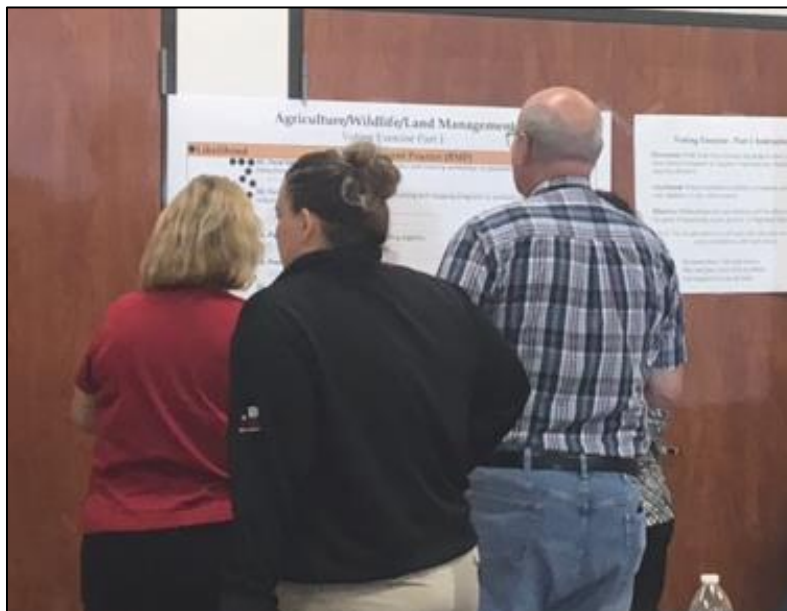


Figure E- 3. Voting exercise used to rank priority project ideas

Meeting 9. August 23, 2016. The stakeholder group was reconvened for meeting 9 to hear a presentation by the US Army Corps of Engineers SW District Galveston about opportunities for funding, projects, and assistance to communities.

Selecting and Ranking Priority Action Areas

BMPs and program activities for load reductions were ranked by a voting exercise for the stakeholder working group. Using project ideas from the one-on-one interviews, a comprehensive list of organized by the project team and released to the stakeholder working group. All BMPs and program activities were included on a poster-sized sheet and divided into one of four quadrants.

A dot voting exercise was prepared where participants were asked to vote on which projects they believed would be most effective and which would be most likely to happen. This approach was taken because stakeholders recognized that a project idea might be effective, but unlikely to happen for a variety of reasons. Their vote changed depending on whether they were being asked about effectiveness or likelihood. The dots for likelihood and effectiveness exercise were combined into a single score for each project. Participants who could not attend were sent a ballot by email. The top ten projects became priority action areas for which detailed tables were prepared. All other action areas are also included in the WPP.

Future work with the Stakeholder Working Group

After Fall 2016, the continuation of the Highland Bayou WPP will depend on several factors, including funding and related nearby watershed planning projects. The Galveston County Coalition of Watersheds, a group lead and managed by the lead project coordinator for Dickinson Bayou, Charriss York in Texas A&M's Texas Coastal Watershed Program will be starting at the same time. Additional funding is sought to update certain parts of the modeling, and once the analysis is released, it will require that the group revisit and approve certain parts of the WPP. The target timeline is for 2017-2018 for the updated modeling data.

The stakeholder working group will continue to exist as an email list, whereby information and project next steps can be communicated to the group. It is likely that the working group will form working committees to take on specialized projects and tasks in the basin.

General Outreach & Publicity

General outreach and publicity refers to methods and activities for publicizing the planning process to citizens and stakeholders. This set of activities will be conducted by Texas A&M AgriLife Extension Service, volunteers, and active stakeholders, as appropriate to the purpose of the outreach.

Facebook. A Facebook group page, the "Moses-Karankawa Bayous Alliance" was created for the project and planning process. Administrators for the page are Extension staff. The Facebook page is a key outreach tool for informing citizens and building awareness about issues in the basin. The page posts project related information, such as meetings, project status, events, survey results, relevant news items, and posts that congratulate the work of volunteers and stakeholders. By clicking on the Facebook page "Like" button, thirty-two people are directly linked with MoKa Bayous Alliance as of summer 2016.

Website. A project website, <http://agrilife.org/highlandbayou/>, has been created for the project. Administrators for the page are Extension staff. The project web site is the primary online presence for the Characterization Report and the Watershed Protection Plan. The site contains pages where documents,

maps and images are stored online and retrieved by the public. Stakeholder registration forms will be included on the website as a way to bring in additional stakeholders.

The website is organized by the following tabs (*italics*) and pages (*bullets*):

About

- Project Background
- What is a watershed?
- What is a watershed protection plan?

Project Documents

- Highland Bayou Characterization
- Project Maps

Meetings

- Workgroup Meetings
- Events

Get Involved

- Stakeholders
- Volunteers

Actions Matter

- Water Conservation
- Automotive
- Boating
- Household Hazardous Waste
- Fats, Oils & Greases
- Landscaping and Lawn Care
- Pet Waste
- Septic Systems
- Feral Hogs
- SWW

Learn & Teach

- Estuaries & Jobs
- Books & Publications
- Fact Sheets & Posters
- Games, Quizzes & Worksheets



Figure E- 4. Screen capture of the website

WaterNews RoundUp. WaterNews RoundUp was a weekly posting of news articles covering water quality issues in Texas and re-posted on MoKaBayousAlliance.org. Using the Google alerts service and local news outlets, a selection of timely local articles were selected for the Round-Up. Posts consist of a brief description of the article and a comment about the potential significance, concluding with a link to the article. Articles may be selected because they highlight a local issue or serve to educate the public about important water related issues.

TrashBash. On April 02, 2016, the Moka Bayous Alliance set up a table at Trash Bash on Reitan Point near Highland Bayou. The event is a semi-annual program where volunteers come to collect trash and litter from public areas. The event is an opportunity to reach out to people about work being done in the bayou and how they can make a difference cleaning up the bayous. The April event attracted 167 volunteers and the outreach table the alliance hosted reached 45 direct contacts. The table was set up with a pledge for volunteers to improve their stewardship of water and resources and a mapping exercise to communicate the connection between storm drains and the Galveston Bay ecosystem.



Figure E- 5. Students learning about how their storm drain *connects* to Galveston Bay at the Moka Bayous Alliance table during Trash Bash.

Ghirardi Watersmart Park Tour. In May 2016, the project team and stakeholders joined the Watersmart Park Tour to learn about WaterSmart practices and GI. The event brought together approximately 7 stakeholders and residents.

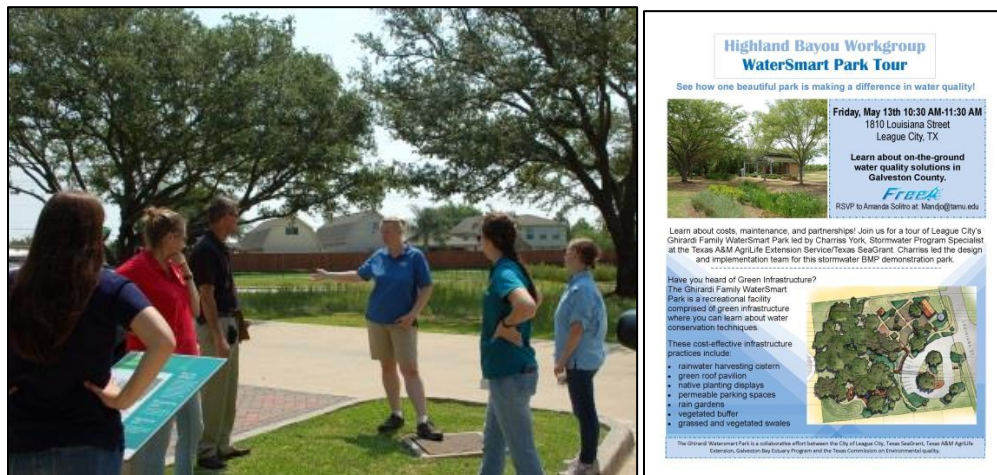


Figure E- 6. Ghirardi WaterSmart park tour facilitated for the stakeholder group.

Stakeholder Email. An email list is used to notify stakeholders of up-and-coming meetings and to share information about the project.

Media Relations. Extension project staff will reach out to local press and media sources to publicize events, meetings, timely issues, and public education. Media postings and press releases will be designed to educate, inform, engage, or motivate the target public or build general awareness, support, and interest.

Logo & Project Image. A logo has been designed and will be used consistently on project documents. The logo will be used consistently online, in presentations, and in project documents.

City Council Meetings. Extension has contacted each municipality and certain stakeholders. This was completed before the Kick-Off meeting. Extension staff presented the project, its importance, and the next steps.

Table E- 3. City Council meeting days, times, and locations

| Municipality | Calendar | Time | Address |
|--------------------|--|-----------|--|
| La Marque | The 2nd and 4th Monday | 6:00 p.m. | City Council Chambers. 1109-B Bayou Road, La Marque, Texas 77568 |
| Hitchcock | City Commission Meetings are regularly scheduled for the third Monday of the month | 6:30 p.m. | Hitchcock City Hall. 7423 Highway 6, Hitchcock, TX 77563 |
| Texas City | The City Commissioners meet the first and third Wednesday of each month | 5:00 p.m. | City Hall. 1801 9th Avenue North, Texas City |
| Bayou Vista | The City Council meets the last Tuesday of the month. | 6:30 p.m. | Community Center. 783 "C" Marlin (the corner of Neptune Drive and Marlin.) |

Newsletters and Letters to the Editor: Many organizations in the watershed have in-house newsletters they send to their members. For example, the City of Bayou Vista sends a city newsletter to each household on a regular schedule. On a case-by-case basis, the project team will approach those organizations about the possibility of including information and articles in their newsletters.

WPP Action Area Outreach Activities

The Highland Bayou project team and stakeholder group will engage the resources of multiple organizations and programs to support the needs of outreach and environmental awareness in the basin. Activities listed here are divided into selected WPP Action Areas.

Education and outreach programs can be implemented through a number of approaches. Localities can take the initiative by creating their programs. Or, they can partner with existing programs and customizing those existing programs to the needs specific to that community.

10 out of 38 Action Areas have some focus on education and outreach in the watershed. Action Areas with minor outreach activities are not included here. Detailed information on all 38 activity areas are in Element C: Management Measures.

Action Area (06) - Wipes, Fats, Oils, Grease This activity area addresses homeowner awareness about the disposal of waste at home. The disposal of wipes and FOG in sinks and toilets is a major cause of leakages and backups in the municipal sewage system result in untreated sewage flowing into the stormwater system. System blockages result in costly repairs borne by the city (and taxpayers) and contribute bacteria and nutrients to local waterways. The primary goal is to educate residents about the proper disposal of these items and the impact improper disposal has on the city's system and ultimately the bayou. The most likely lead agency on this activity are the municipalities in the basin, although GBF and other entities may have programs that compliment this activity area.

Program activities include a mix of approaches including inserts in utility bills, Cease the Grease collection supplies, and Potty Potty educational resources for residents and students. Approaches should consider the targeted audience, whether that includes schools, city hall, public parks, or apartment complex mailbox areas, among other locations.

Action Area (19) - Pet Waste Education Pet waste is a public health issue, and pet owners should be educated about the impacts to health and the environment by not picking up pet waste. Bacteria from pet waste is a known contributor to bacteria levels in waterways. The project team estimates that there are over 5000 dogs in the watershed, and as Highland Bayou becomes more developed, the number of pets will increase. Education will focus on the connection between pet waste and water quality. Resources for this may include public awareness posters, pet waste pick up bags, and pet waste pick up stations in public areas. Likely lead agencies are Texas A&M AgriLife and municipalities.

Action Area (21) - Water Conservation Water conservation fits within the broad goal of stewardship for how water resources are used and wasted in the watershed. Through the use of WaterSmart landscaping and rain water reuse, site level stormwater runoff can be reduced while lowering water bills. Watershed partners can achieve this through a combination of sponsored workshops, practice demonstrations, factsheets, web resources, and public information campaigns. Municipalities can also use utility bills to distribute awareness campaign materials about practices around the home that can reduce water use. Likely lead agencies are state resources agencies, university programs, and municipalities.

Action Area (22) - Landscaping Education Multiple university and agency programs have resources to educate residents and landscaping professionals about residential yard waste and fertilizer management. In the City of Bayou Vista, homeowners are made aware of the impact that grass clippings have on water quality, reduced oxygen and resulting fish kills. The City even has an ordinance prohibiting the disposal of clippings in canals. More broadly in the basin, the educational focus will be on following recommended fertilizer applications and educating users about the negative impacts that excessive use has on nutrient levels in the bayou, including algae blooms and fish kills. Landscaping education is also includes WaterSmart practices and raingarden design principles. These practices can slow and reduce stormwater runoff from sites. Through a mix of educational workshop and demonstration exercises, residents can learn about best practices and benefits to the homeowner and the bayou. Programs exist in the region for providing things like rain barrels at a discount cost. Likely lead agencies are local resource conservation groups and Texas A&M AgriLife.

Action Area (24) - Green Infrastructure GI is an emerging practice where developers through the design of their projects harness the ability of natural systems to slow down and infiltrate stormwater runoff. This can include such simple practices as planters in parking lots to more sophisticated features like permeable pavement, engineered bioswales and green roofs. Education on this topic should take two approaches. The first is to educate designers and construction firms about the benefits to their bottom line and to the environment of incorporating these practices into their designs. The other approach is to improve public awareness through interpretive signage at demonstration sites about the benefits of these practices. Likely lead agency is Texas A&M AgriLife Extension Service.

Action Area (25) - Watershed Signage Watershed signage can help improve awareness that local drainages are actually part of the larger bayou system. Road-side signs about watershed boundaries have an official appearance and may reinforce awareness about watersheds. The likely lead agencies are municipal public works and County Road and Bridge department.

Action Area (26) - Illegal Dumping Prevention Prevention is about providing people with alternatives to illegal dumping and through education and awareness. There are multiple programs administered by not-for-profits, municipalities and the county for the disposal of various waste items, ranging from litter to surplus construction materials and tires. Priority tasks may target vacant properties, dead end streets, and public access points, such as parks. Alerting residents to opportunities for proper disposal of hazardous materials, usually scheduled throughout the year, can improve participation in these programs. Likely lead agencies are not-for-profit organizations, municipalities, state and county agencies.

GBAN is a system that allows residents to report online their sightings of illegal dumping. The GBAN sponsor, the GBF, relays these reports to the appropriate enforcement agency. The program utilizes a smartphone app and websites to facilitate the reporting process.

H-GAC sponsors a camera sharing program that allows participants the use of a camera to surveil and photograph illegal dumping. Incidents are reported to H-GAC and ultimately to the appropriate authorities.

Action Area (27) - Residential Waste Galveston County operates a hazardous materials collection for household hazardous waste. This can include household items like solvents, oils, batteries, and fuels. Improved awareness among residents in the basin about this program can improve participation and reduce the instances of these materials being dumped down drains and outdoors. League City, although not in the basin, collects unused pharmaceuticals, so that they are not flushed into the wastewater system. Likely lead agencies are Texas A&M AgriLife, municipalities, and not-for-profit conservation groups.

Illegal dumping may also be achieved through public signage or marking. This may include drainage stenciling or markers to alert residents that yard and street runoff flows into nearby waterways, and to limit the disposal of waste, oil, or other hazardous materials in the storm drain.

Action Area (31) - Feral Hog Workshops. Feral hog populations in the bayou contribute bacteria and sediment into the bayou. Knowing how to manage hog populations, along with state and county regulations, is important. Texas A&M AgriLife sponsors a training program for local hunters and

residents, although hunting is not allowed within the county.. Awareness should be targeted to rural property owners or land owners having or are near large open spaces. Jack Brooks Park and the adjoining UH Prairie Center are known to have feral hog populations. Likely lead agencies are Galveston county parks and Texas A&M AgriLife.

Action Area (36) - Natural Resource Education The bayou can be a great natural asset, particularly for recreation and education. Kayak tours (Artist Boat) are a way to bring youth and adults into the bayou to observe this natural system, its biota, and see how activities on the land impact the waterway, such as litter and junk, fishing line, algae blooms, and pollutant sheen on the water surface. A visceral connection with the natural system is a high impact educational activity, and can leave a lasting impression about the impact humans have on their waterways. Likely lead agencies are Texas A&M AgriLife and not-for-profit conservation groups like Artist Boat and GBF.

Program Resources Available for Action Area Activities

Numerous programs are available to support and potentially lead education and outreach activities in the basin. These programs were identify by the stakeholder working group, and are listed in Table E-4. Detailed information for some of these programs can be found in Element D: Technical and Financial Assistance.

Table E- 4. Education and Outreach resources available for Action Area activities

| Organization | Program |
|---------------------------------------|--|
| Artist Boat | Youth Eco-Art Workshop and Adventures |
| Galveston County/City of Dickinson | County Tire Recycling Program |
| City of League City Police Department | National Drug Take Back Event |
| Don't Mess With Texas | Adopt A Highway |
| Don't Mess With Texas | Trash Off |
| Galveston Bay Estuary Program | Back the Bay Program |
| Galveston Bay Foundation | Cease the Grease |
| Galveston Bay Foundation | Dockwalkers |
| Galveston Bay Foundation | Galveston Bay Action Network |
| Galveston Bay Foundation | Living Shorelines |
| Galveston Bay Foundation | Pump Don't Dump Campaign |
| Galveston Bay Foundation | Rain Barrel Workshops |
| Galveston Bay Foundation | Water Warriors |
| H-GAC | Disaster Debris Clearance and Removal Services |
| H-GAC | H-GAC Texas Stream Team |
| H-GAC | Illegal Dumping & Camera Sharing Program |
| H-GAC | Household Hazardous Waste Disposal |
| H-GAC | OSSF Visual Inspection Training |

| Organization | Program |
|---------------------------------------|--|
| Houston-Galveston Subsidence District | Water Detective WaterWise Kit |
| Keep Texas Beautiful | KTB Training |
| Keep Texas Beautiful | KTB Youth & Education Program |
| National Wild Turkey Foundation | Hunter Education Program |
| Potty Patty | Potty Patty Patrol |
| TCEQ | Sanitary Sewer Overflow Initiative |
| Texas A&M AgriLife | Bacterial Source Tracking |
| Texas A&M AgriLife | Feral Hog Bounty Program |
| Texas A&M AgriLife | Feral Hog Management Seminar |
| Texas A&M AgriLife (TCWP) | Galveston Coalition of Watersheds |
| Texas A&M AgriLife | Texas Riparian and Stream Ecosystem Workshop |
| Texas A&M AgriLife | WaterSmart Program |
| Texas A&M AgriLife (TCWP) | Wetland Restoration Program |
| Texas Wildlife Association | Texas Youth Hunting Program |
| TPWD | Texas Landowner Incentive Program |
| TWDB | Major Rivers Education Program |
| TWDB | Rainwater Harvesting Training |
| TWDB | Water Resource Educator Workshops |

Element F & G- Interim Milestones and Implementation Schedule

This watershed protection plan identifies strategies for achieving both the implementation schedule and measurable milestones of the Highland Bayou Watershed. Milestones are used to benchmark progress in implementing specific management measures from the 10 priority action areas. Implementation of the Highland Bayou Watershed Protection Plan is divided into 3 parts: Near (1-2 years), Medium (3-5 years), and Long (6-15 years). Multi-year increments also take into account the fact that many of the priority action areas will be contingent on funding, staffing, and the implementation of new programs, all of which will have initial time demands. Additionally, changes in water quality are often delayed following initial implementation of management measures, and substantial changes generally require several years to be noticeable.

Implementation for the Highland Bayou actions areas is anticipated to take place over a 15 year timeframe. Table F-1 provides targeted implementation timelines and milestones for specific objectives from each priority action areas. Some of these priority action areas could take longer or less than the estimated timeframes provided. These implementation milestones may need to be adjusted through the adaptive management process if they are found to be unrealistic or ineffective.



Figure F/G- 1. Review of priority action area voting exercise results

Table F & G- 1. Action Area Implementation Schedule

| Action Area | | Objective | Schedule of Implementation (years) | | | Milestones |
|-------------|---|--|------------------------------------|---------------|--------------|--|
| | | | Near 1-2 | Medium 3-5 | Long 6-15 | |
| 9 | Infrastructure Upgrades to the Sanitary Sewer Collection System | To reduce the volume of raw sewage discharging from failing sanitary sewer system infrastructure. | | | | |
| 9.1 | Infrastructure Upgrades to the Sanitary Sewer Collection System | Adopt or update asset management programs to encourage proactive/preventative maintenance activities | ✓ | ✓ | ✓ | 5% of asset management programs adopting preventative maintenance techniques |

| Action Area | Objective | Schedule of Implementation (years) | | | Milestones |
|-------------|---|--|---------------|--------------|--|
| | | Near 1-2 | Medium 3-5 | Long 6-15 | |
| 9.2 | Infrastructure Upgrades to the Sanitary Sewer Collection System | | ✓ | ✓ | See Table B-2. 6.5 % SSO volume discharge reduction per year. 2-3 points with major repairs per year, approx. 900 linear feet of line replaced a year, and 1-3 lift stations repaired per year, for a 10 year implementation horizon |
| 9.3 | Infrastructure Upgrades to the Sanitary Sewer Collection System | | | ✓ | 10% of identified private line connections needing repair replaced for a 10 year implementation horizon |
| 9.4 | Infrastructure Upgrades to the Sanitary Sewer Collection System | | ✓ | ✓ | 10% of identified private line connections needing repair replaced for a 10 year implementation horizon |
| 6 | Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System | To minimize the introduction of SSO raw sewage into local waterways. Reduce the deposition FOG and wipes from entering sewer lines. Encourage proper disposal practices through education and outreach to residents and commercial entities on items that should not enter their drains. | | | |
| 6.1 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | ✓ | ✓ | | Draft and adopt updated ordinance and policies for grease maintenance at commercial entities |
| 6.1.1 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | ✓ | | | Final report of existing local regulations, and assessment for how to improve and update compliance and enforcement |
| 6.1.2 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | ✓ | ✓ | | Draft and adopt updated ordinance and policies for grease maintenance at commercial entities |
| 6.1.3 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | | ✓ | ✓ | Municipalities and municipal agencies have updated |
| 6.1.4 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | ✓ | ✓ | ✓ | Educational materials handed out to 10 commercial entities per month |
| 6.2 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | ✓ | ✓ | | Provide existing handouts and educational materials to 100 contacts per year at events, workshops, meetings, etc. |

| Action Area | | Objective | Schedule of Implementation (years) | | | Milestones |
|-------------|---|--|------------------------------------|---------------|--------------|---|
| | | | Near 1-2 | Medium 3-5 | Long 6-15 | |
| 6.2.1 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | Join the Cease the Grease workgroup. | ✓ | | | Join the Cease the Grease workgroup |
| 6.2.2 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | Utilize available online social media materials and website content. | ✓ | ✓ | | 1-3 social media posts per month utilizing materials from Cease the Grease |
| 6.3 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | Pilot project - establish one Cease the Grease kitchen grease collection station at an apartment complex | | ✓ | ✓ | Establish 1 Cease the Grease kitchen grease collection location within the watershed with 50 contacts per month utilize the kitchen grease collection station |
| 6.4 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | Utilize existing educational messaging related to wipes - Patty Potty campaign materials | ✓ | ✓ | ✓ | Provide existing handouts and educational materials to 100 contacts per year at events, workshops, meetings, etc. |
| 6.4.1 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | Bolster online presence using free Patty Potty materials on social media sites and webpages | ✓ | ✓ | | 1-3 social media posts per month utilizing materials from Patty Potty Patrol |
| 6.4.2 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | Join the Patty Potty Patrol for access to videos, inserts, and public service announcements. Save Water Texas Coalition members receive a discount. Project ideas include: showing a Patty Potty video clip on the topic of flushable wipes in movie theatres (as the San Jacinto River Authority currently does); and setting up a standup cardboard cut-out of Patty Potty with a “don’t flush wipes” message in City Hall lobby | ✓ | | | Join the Patty Potty Patrol |
| 6.5 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | Publicize costs for damages to sewer infrastructure to city taxpayers. “Cleaning out wipes that go down the drain is costing tax dollars”. Include a list of annual repairs for pump stations with costs, photos, the dos and don’ts of flushing and drains. | ✓ | ✓ | | Development of 1 municipal specific, public education handout or brochure per city |
| 6.6 | Wipes, Fats, Oils, Grease and Roots in the Sanitary Sewer Collection System | Host education and outreach workshops for residents and commercial entities | ✓ | ✓ | ✓ | Host 1-2 workshops per year |

| Action Area | | Objective | Schedule of Implementation (years) | | | Milestones |
|-------------|---|---|------------------------------------|---------------|--------------|--|
| | | | Near 1-2 | Medium 3-5 | Long 6-15 | |
| 11 | Stream flow within the Highland Bayou Channel | Improve flow conditions within the Highland Bayou channel by improving channel flow and by removing impediments to flow, such as fallen trees and sediment accumulation. | | | | |
| 11.1 | Stream flow within the Highland Bayou Channel | Determine causes of flow reduction by requesting a study to identify contributing factors | ✓ | | | Request 1 study to identify contributing factors to flow issues faced in the Highland Bayou Watershed; study agency USACE |
| 11.2 | Stream flow within the Highland Bayou Channel | Conduct a sediment source study to find the cause of sediment entering the bayou | ✓ | | | Conduct 1 sediment source study; study agency USACE |
| 11.3 | Stream flow within the Highland Bayou Channel | Selectively remove sediment and clear vegetation from the channel as recommended during assessments performed by the USACE | | ✓ | ✓ | Remove sediment and vegetation selectively 1 time per year; Reuse sediment as feasible for ecological wetland restoration activities near Jones Bay. |
| 11.4 | Stream flow within the Highland Bayou Channel | Selectively remove accumulations of woody debris impeding flow within the channel in residential areas as recommended during assessments performed by the USACE | | ✓ | ✓ | Removal of 5 trees per year in residential areas to improve flow and remove obstacles. |
| 13 | Culvert Dam Maintenance in the Highland Bayou Channel | To improve flow within the Highland Bayou channel, via the culvert and investigate maintenance needs for culverts within Jack Brooks Park. | | | | |
| 13.1 | Culvert Maintenance in the Highland Bayou Channel | Request information from the USACE about culverts to determine maintenance needs (potential removal of sediment and debris) to improve flow | ✓ | | | Submit 1 request for USACE to provide information about culverts so maintenance needs can be determined |
| 13.2 | Culvert Maintenance in the Highland Bayou Channel | Remove sediment and clear vegetation from culverts | | ✓ | ✓ | Responsible entities manage sediment and vegetation removal from culverts |
| 13.3 | Culvert Maintenance in the Highland Bayou Channel | Establish a management/maintenance agreement | ✓ | | | 1 MOU established for culvert maintenance |
| 19 | Pet Waste Education | To reduce bacteria loads from pet waste, encourage pet owners to pick up pet waste by providing pet waste stations in public areas, and provide education and outreach to pet owners on proper pet waste management and impact of pet waste on water quality. | | | | |
| 19.1 | Pet Waste Education | Distribute pet waste educational material to residents during public events | ✓ | ✓ | ✓ | Provide existing handouts and educational materials to 200 at events, workshops, meetings, etc. per year |
| 19.2 | Pet Waste Education | Install pet waste stations with bag dispensers in parks and other public spaces | | ✓ | ✓ | Installation of 10 pet waste stations at high visibility, pet friendly public locations or apartment complexes |
| 19.3 | Pet Waste Education | Distribute pet waste bag dispensers to residents during public events | ✓ | ✓ | ✓ | 100 pet waste bag dispensers given to residents per year |

| Action Area | | Objective | Schedule of Implementation (years) | | | Milestones |
|-------------|--|--|------------------------------------|---------------|--------------|---|
| | | | Near 1-2 | Medium 3-5 | Long 6-15 | |
| 24 | Green Infrastructure and Stormwater Treatment Wetlands | To reduce the amount of stormwater runoff entering local waterways by retaining rainfall on site or in neighborhood and regional detention features and to treat stormwater runoff using GI and SWW. | | | | |
| 24.1 | Green Infrastructure and Stormwater Treatment Wetlands | Update development codes to allow for GI projects during new development and stormwater retrofits; example ordinances are available for reference | | ✓ | | Final report on existing local ordinances and recommended strategies for updating specific codes or site review procedures. |
| 24.2 | Green Infrastructure and Stormwater Treatment Wetlands | GI for public buildings and in public spaces | | ✓ | ✓ | Design and construction of demonstration project at municipal or public facility with high public visibility. |
| 24.2.1 | Green Infrastructure and Stormwater Treatment Wetlands | Identify public entities interested in utilizing GI | ✓ | ✓ | | Stormwater coordinator identifies and contacts 1 business interested in GI per month, or 12 per year |
| 24.2.2 | Green Infrastructure and Stormwater Treatment Wetlands | Design and implement GI projects including rain gardens, permeable pavement, bio-swales, vegetated curb extensions, rain water harvesting cisterns and WaterSmart landscaping | | ✓ | ✓ | 1 GI demonstration project designed and built every two years |
| 24.3 | Green Infrastructure and Stormwater Treatment Wetlands | Educate residents as well as public entities about GI | ✓ | ✓ | ✓ | Host 1 GI workshop in watershed for homeowners per year |
| 24.3.1 | Green Infrastructure and Stormwater Treatment Wetlands | Distribute educational materials about GI practices, how they can be used locally, and their impact on water quality | ✓ | ✓ | ✓ | Development of 6 handout/brochures about 6 GI practices |
| 24.3.2 | Green Infrastructure and Stormwater Treatment Wetlands | Partner with AgriLife to host GI workshops, lectures and field trips to educate homeowners, businesses and municipal officials | | ✓ | ✓ | 1 GI workshop held per year for businesses, municipal officials, and homeowners |
| 24.3.3 | Green Infrastructure and Stormwater Treatment Wetlands | Partner with GBF to host rain barrel workshops for residents to promote water conservation | | ✓ | ✓ | 20 rain barrels created or given away per workshop hosted per year in watershed |
| 24.4 | Green Infrastructure and Stormwater Treatment Wetlands | Encourage the use of constructed stormwater treatment wetlands | ✓ | ✓ | ✓ | 10 acre stormwater treatment wetlands created within the Highland Bayou Watershed |
| 24.4.1 | Green Infrastructure and Stormwater Treatment Wetlands | Host constructed SWW workshops for public entities and developers | | ✓ | ✓ | 1 constructed SWW workshop held per year |

| Action Area | | Objective | Schedule of Implementation (years) | | | Milestones |
|-------------|--|---|------------------------------------|------------|-----------|--|
| | | | Near 1-2 | Medium 3-5 | Long 6-15 | |
| 24.4.2 | Green Infrastructure and Stormwater Treatment Wetlands | Identify public entities interested in utilizing stormwater treatment wetlands and establish ordinances to consider these practices | ✓ | ✓ | ✓ | Identify and contact 1 business interested in GI per month |
| 24.4.3 | Green Infrastructure and Stormwater Treatment Wetlands | Retrofit existing stormwater detention facilities into stormwater treatment wetlands where feasible | | ✓ | ✓ | Design and implement green infrastructure systems to intercept and treat existing load runoff, approx. 3% per year, for 6 years. |
| 24.4.4 | Green Infrastructure and Stormwater Treatment Wetlands | Incorporate stormwater treatment wetlands during new development projects | | ✓ | ✓ | Review and update local development codes to require or not prohibit the use of stormwater treatment wetlands in new development |
| 30 | Stormwater Infrastructure Assessment Surveys | To assess stormwater drainage system infrastructure to improve system management and identify maintenance needs and opportunities for where water quality practices could be implemented. | | | | |
| 30.1 | Stormwater Infrastructure Assessment Surveys | Compile and review previous storm drainage system studies to determine the scope needed for an updated assessment | ✓ | ✓ | | Previous storm drainage system study scopes compiled and reviewed |
| 30.2 | Stormwater Infrastructure Assessment Surveys | Inventory stormwater infrastructure components | | ✓ | | Development of inventory for stormwater infrastructure within the Highland Bayou Watershed |
| 30.2.1 | Stormwater Infrastructure Assessment Surveys | Establish data objectives, requirements, and the data collection schedule | | ✓ | | Development of data collection schedule, data objectives, and data requirements |
| 30.2.2 | Stormwater Infrastructure Assessment Surveys | Inventory and map public stormwater system | | ✓ | | Develop 1 map showing public stormwater systems |
| 30.2.3 | Stormwater Infrastructure Assessment Surveys | Include a plan to maintain data and update inventory as required | | ✓ | ✓ | Development of stormwater infrastructure inventory plan |
| 30.3 | Stormwater Infrastructure Assessment Surveys | Characterize stormwater system components in the inventory to prioritize improvement needs and pollution prevention measures | | ✓ | ✓ | Development of characterized stormwater system components in the inventory |
| 23 | Landscaping and Landscaping Debris Ordinances | To decrease and minimize the introduction of lawn debris and nutrients into stormwater. | | | | |
| 23.1 | Landscaping and Landscaping Debris Ordinances | Develop new or strengthen existing ordinances addressing lawn clipping and landscaping debris management. Example ordinances are widely available for reference | | ✓ | | Work with all 5 municipalities in the basin to identify potential updates to local ordinances |
| 23.2 | Landscaping and Landscaping Debris Ordinances | Ordinance requirements will be communicated to residents and landscaping crews | | ✓ | ✓ | Number of violations reported by year |

| Action Area | Objective | Schedule of Implementation (years) | | | Milestones |
|---------------|---|---|---------------|--------------|--|
| | | Near 1-2 | Medium 3-5 | Long 6-15 | |
| 23.3 | Landscaping and Landscaping Debris Ordinances | | ✓ | ✓ | Work with all 5 municipalities in the basin to identify potential updates to enforcement measures and penalties |
| 23.4 | Landscaping and Landscaping Debris Ordinances | ✓ | | | Distribute contact information to stakeholders at public events |
| 37 | Landowner Conservation Plans | To increase landowner participation in existing conservation and habitat management plans to decrease bacteria and nutrient loading and enhance water quality within the watershed. | | | |
| 37.1 | Landowner Conservation Plans | ✓ | | | Review all existing conservation and habitat management plans found |
| 37.2 | Landowner Conservation Plans | ✓ | ✓ | ✓ | Identification of 2 interested landowners in medium and long term periods |
| 37.2.1 | Landowner Conservation Plans | ✓ | ✓ | | 2 Workshops held per year, target attendance 10-20 land owners |
| 37.2.2 | Landowner Conservation Plans | ✓ | ✓ | ✓ | 50 contacts reached with educational materials per year |
| 37.2.3 | Landowner Conservation Plans | | ✓ | ✓ | Development of 1 conservation plan, WQMP, or LIP participation |
| 34 | Preserve Existing Natural Areas | To preserve priority undeveloped lands in their natural state and protect the water quality benefits of undeveloped land and improve land management practices of undeveloped areas by providing education on habitat value for wildlife and water quality. | | | |
| 34.1 | Preserve Existing Natural Areas | ✓ | ✓ | ✓ | 10-40 acres at critical locations with high potential for realizing water quality improvement, per five year period |
| 34.1.1 | Preserve Existing Natural Areas | ✓ | | | Review complete, with recommendations for improvement of existing plans and to encourage adoption of new plans by currently non-participating land owners. |
| 34.1.2 | Preserve Existing Natural Areas | ✓ | ✓ | ✓ | Identification of 5 properties with potential for conservation management within the watershed |
| 34.1.3 | Preserve Existing Natural Areas | | ✓ | ✓ | 10-40 acres at critical locations with high potential for water quality improvement, per five year period |

| Action Area | Objective | Schedule of Implementation (years) | | | | Milestones |
|-------------|---------------------------------|--|-------------|---------------|--------------|--|
| | | | Near 1-2 | Medium 3-5 | Long 6-15 | |
| 34.2 | Preserve Existing Natural Areas | Provide education for public entities and residents on loss of habitat for wildlife utilizing Back the Bay materials and other existing programs | | ✓ | | Work with 3 city councils to identify appropriate ordinances for consideration and adoption. |
| 34.3 | Preserve Existing Natural Areas | Use regulatory techniques to preserve natural lands | | ✓ | ✓ | Preserve natural land using regulatory techniques |
| 34.3.1 | Preserve Existing Natural Areas | Require inquiry through the USACE for Section 404 mitigation needs during the building permit process | | | ✓ | Inquiry through the USACE for Section 404 mitigation needs during the building permit process required |
| 34.3.2 | Preserve Existing Natural Areas | Enact ordinances to protect certain trees from removal or discourage developers from cutting down all trees prior to construction | | ✓ | | Sparse tree removal ordinance for new construction established |

Element H- Criteria for Reduction Achievements/Monitoring and Measuring Progress

This watershed protection plan identifies strategies for achieving both the measurable milestones of the Highland Bayou Watershed stakeholders as well as a closer approximation to the current state water quality standards for the watershed. Milestones (Element G) are used to evaluate progress in implementing specific action areas recommended in the Plan. It is likely that some milestones will be accomplished sooner than anticipated while others will be completed slower than expected. Interim measurable milestones are identified in the implementation schedule presented in Element G. As these action areas are implemented within the watershed, water quality benchmarks and environmental indicators will need to be assessed to measure nutrient and bacteria reductions at the sub-watershed level. WPP implementation success will also be gauged by evaluating improvements in water quality. Table H-1 below illustrates bacteria reduction goals from levels reported in the 2010 Texas Integrated Report (TCEQ, 2010a). Measuring progress is an important component of adaptive management, which will be used to guide decisions throughout the implementation of this WPP. If the WPP is not meeting interim targets or making progress towards attaining State water quality standards, the WPP will be revised to update management practices.

Table H- 1. *Enterococcus* Reduction Milestones

| Implementation Year | Reduction Goals in percent |
|-----------------------|----------------------------|
| Year 3 (2019) | Reduce by <u>5%</u> |
| Year 5 (2021) | Reduce by <u>15%</u> |
| Year 10 (2025) | Reduce by <u>42.1%</u> |

The Highland Bayou Watershed is located in TCEQ Basin 24, ‘Bays and Estuaries.’ Furthermore, Highland Bayou is classified by TCEQ into ‘segments’ for water quality management purposes. The assignment of a designated use to a specific segment is contingent upon a range of factors relating to historical uses, actual uses, and desired uses of that segment. Uses are designated by TCEQ through agency study and review of specific segments. Of the five use categories, there are two use categories that are relevant to the Highland Bayou’s 303(d) listing: Recreational Use and ALU.

Recreational Uses refer to human recreational use of water, and are divided into four levels of activity. Water quality criteria become more stringent when there is an increased likelihood of ingestion of water from recreational use. Unless a specified recreational use is designated in for a specified segment, the assumed use is Contact Recreation. ALU standards for waterbodies depend on the desired human use for aquatic life and the environmental conditions of the waterway. ALU standards for unclassified waterbodies are presumed to be high.

Bacteria standards are linked to Recreational Uses and DO standards are linked to ALU. The standard increases with increasing quality of the ALU designation. Low levels of DO may be the result of excessive algae growth which uses pollutants like nitrates and phosphorous to grow.

Table H-2 below outlines environmental strategies and progress indicators that will determine if load reductions are being achieved. Water bodies not specified in the TSWQS for specific chlorophyll-a

criteria are protected from excessive nutrient levels in order to support the general uses through the use of screening levels. The screening levels listed for nutrients and chlorophyll a are statistically derived from SWQ monitoring data and are to be used when site specific criteria have not been developed in the TSWQS (TCEQ, 2012).

Table H- 2. Criteria for Load Reduction Goals

| Strategies | Description of Activities | Progress Indicators | Monitoring Component |
|---|--|--|---|
| Criteria 303(d) Listing Pollutant Reduction Goals | | | |
| Reduce the number of dissolved oxygen minimum standards exceedances | Between 2001 and 2011 there were 18 exceedances for DO minimum standards over 77 sampling events. | Reduce the number of measured exceedances in routine ambient sampling to fewer than two events per year | Monitored by Texas Stream Team Volunteers or other 3 rd party with monitoring and reporting duties |
| Reduce the number of bacteria (enterococcus) exceedances in routine ambient water quality monitoring | Between 2001 and 2011 there were 436 sampling events in the SWQM database and a total of 188 exceedances for the criteria of 89 CFUs/100mL. The rate of observed values exceeding these limits is 43% of all sampling events and a count of approximately 19 sampling events out of 43 events. The median value across all sampling stations in the basin is 79, while the average is 1,049, indicating the influence of extreme counts on values overall. | Reduce the number of measured exceedances in routine ambient water quality monitoring to fewer than 12 per year in the near term phase (5 years), and to fewer than 8 per year in the long term phase (beyond 5 years) | See ambient water quality monitoring program |
| Criteria NPS Pollutants of Concern Related to 303(d) Criteria Goals | | | |
| Sustain Total Phosphate screening limits and exceedances | Between 2001 and 2011 there were 47 sampling events for Total Phosphate and no observed exceedances for the screening limit | Sustain the number of screening limit exceedances in routine ambient sampling to zero on a rolling 7 year basis | See ambient water quality monitoring program |
| Sustain Nitrate screening limits and exceedances | Between 2001 and 2011 there were 207 sampling events in the SWQM database for the study area. No exceedances were observed in measured values | Sustain the number of screening limit exceedance in routine ambient monitoring to zero on a rolling 7 year basis | See ambient water quality monitoring program |
| Sustain average Chlorophyll-a screening limits; Reduce exceedances occurring in warm season sampling | Chlorophyll-a can be an indicator of excessive nutrients. Between 2001 and 2011 there were 96 sampling events in the basin and 27 exceedances of screening limits (21 micrograms/L). 26 exceedances were measured in the warm season | Keep median and average values on a rolling 7 year basis to be below the screening limit. Reduce the number of measured exceedances to fewer than 1 in 5 warm season sampling events | See ambient water quality monitoring program |
| Criteria for TCEQ Water Quality and Aesthetic Standard Goals | | | |
| Meet TCEQ water quality standards for primary contact recreational uses | Refers to activities where there is a significant likelihood of ingestion of water. This includes activities such as wading, swimming, water skiing, diving, tubing, surfing, and whitewater paddling or rafting. | Bacteria levels under 35/89 for <i>Enterococcus</i> CFU's | See ambient water quality monitoring program |

| Strategies | Description of Activities | Progress Indicators | Monitoring Component |
|--|--|---|---|
| Meet TCEQ water quality standards for High ALU | Refers to water quality conditions that support levels of aquatic life activity. High ALU waters have high diversity and the usual assemblage of species expected for that waterbody. Also, species diversity and richness will be high, although not exceptional. The trophic structure or food chain may be slightly imbalanced. | High measured diversity in macro- and microbenthic biotic assemblages and trophic orders from primary producers to apex species. | Monitoring activity is outside of specific recommendation in this WPP. Results will rely on 3 rd party with monitoring and reporting duties |
| Meet TCEQ Aesthetic Standards: Water free of debris | Debris and litter removal improves the perceived quality by the public of the waterway. | Noticeable changes in amount of debris found near banks of the bayou or free floating within the Highland Bayou Watershed | |
| Meet TCEQ Aesthetic Standards: Water has no odor | Increased organic matter can cause reductions in DO, alter taste and create odors in drinking water, and it can cause destruction of fish and aquatic plant habitat. | Chlorophyll <i>a</i> limits from 0.005 to 0.15 mg/L | |
| Meet TCEQ Aesthetic Standards: No foam, oil, or other residues on water surface | Boating activities and illicit dumping through storm drains or on land can result in sheens and residues on the waterway, fouling its use for recreational and other aquatic uses. | Fewer observed or reported oil or fuel sheens, whether from boating activities or the illegal disposal of materials in storm drains | Monitored by Texas Stream Team Volunteers or other 3 rd party with monitoring and reporting duties |
| Meet TCEQ Aesthetic Standards: No suspended solids | Suspended solids consists of fine particulates of organic and non-organic residue that stay suspended in the water column, either from NPS runoff or through effluent from wastewater treatment plants or other commercial and industrial activities. | Fewer observed exceedances of screening limits for TSS | See ambient water quality monitoring program; else, monitored by Texas Stream Team Volunteers or other 3 rd party with monitoring and reporting duties |
| Criteria for General Goals | | | |
| Reduction in algal blooms per year | Algal blooms may occur when concentrations of nitrate are greater than 0.1 mg/L. Excessive nitrogen can promote plant growth that interferes with ambient levels of DO, clogs channels, and lowers the aesthetic quality of waterways. | Nitrate concentrations below 0.1 mg/L Reduction in nuisance algal blooms per year | See ambient water quality monitoring program |
| Reduction in fish kills per year | Algal blooms interfere DO and can cause DO to drastically decrease. Algal blooms may occur when nitrate levels are over 0.1 mg/L. | Nitrate concentrations below 0.1 mg/L to avoid nuisance algal blooms leading to fish kills. Fewer than two reported fish kills per year for segments 2424A and 2424C_01, combined. | Monitoring activity is outside of specific recommendation in this WPP. Results will rely on 3 rd party with monitoring and reporting duties |

Element I- Monitoring Program & Schedule

The Highland Bayou Watershed is on the TCEQ 303(d) list for elevated bacteria and low DO. Nutrients are also understood to be contributing to the impairment. The monitoring resources and strategies outlined here will be implemented to verify that bacteria and nutrient reductions are occurring in the Highland Bayou Watershed, and that the water quality goals set in this WPP are being achieved. The monitoring strategy will rely on the use of water quality data collected through routine sampling to ultimately demonstrate success. As currently implemented, the existing monitoring network cannot achieve all the objectives recommended to measure actual environmental progress. Additionally, no sampling is currently being conducted in support of the Highland Bayou Watershed Protection Plan. As of today, existing sampling programs are insufficient to assess progress towards attaining water quality standards. However there are programmatic resources in the region that through cooperative agreements and program adjustments can provide support in resources and capacity for a successful monitoring program in the watershed.

Historical and Current Monitoring

Several programs have monitored or currently monitor water quality in the Highland Bayou Watershed:

1. TCEQ's SWQM program
2. Texas Stream Team
3. Galveston County Health District
4. 2010-2011 Highland Bayou Sampling Program
5. Real Time Monitoring USGS stations

TCEQ's SWQM Program

TCEQ monitors water quality through its SWQM Program. The program consists of four monitoring categories: routine, special, permit-support, and systematic. The routine and systematic categories both support TCEQ's objective to evaluate aquatic systems in the state for attainment of use standards. Routine monitoring is generally long-term (longer than five years) and is conducted at most of the Texas' 367 classified streams. Systematic monitoring is conducted for shorter time frames and in support of TMDL implementation and assessment of 303(d) segments. Permit support and special monitoring are localized project-specific sampling programs.

Sampling locations are coordinated through the Texas Clean Rivers Program and is funded through TCEQ, in partnership with regional and local organizations. The program is coordinated by Texas State University (San Marcos) and in partnership with TCEQ, H-GAC, and the US EPA. Sampling is conducted by professional water quality specialists and under strict quality assurances using National Environmental Laboratory Accreditation Conference certified labs and methods. *At this time no sampling under this program is being conducted in support of the Highland Bayou Watershed Protection Plan.*

Texas Stream Team

In the Houston region, the Clean Rivers Program also supports the Texas Stream team program conducted by citizen volunteers. This too is administered in part by H-GAC and supports TCEQ's SWQM program. The Texas Stream Team program is structured into volunteer groups that are managed at the community level by organizations such as the GBF and the Galveston Master Naturalists. This program is not covered

by the same quality assurances whereas the main SWQM program is. Rather, the results from the Stream Team are used to identify emerging water quality issues and trends, which may be used to justify a more rigorous and quality-assured sampling effort through TCEQ's SWQM programs. *Texas Stream Team conducts sampling in the study area, but no sampling is being conducted in support of the Highland Bayou Watershed Protection Plan.*

Galveston County Health District

The Air and Water Pollution Services Division of GCHD conducts a water quality sampling program supported by county funds, staff, and facilities. The sampling program is conducted in support of sewage treatment plant inspections, stormwater sampling, and investigation of citizen complaints. Its sampling program relies on standards and locations that differ from the SWQM program. This means that any monitoring supported by GCHD as part of this WPP will require coordination about these standards and locations. Funding for non-Health District sampling efforts is extremely limited or non-existent, and any support from the county will have to be coupled with additional funding to cover the effort, either as grants or as county appropriations.

2010-2011 Highland Bayou Sampling Program

The Highland Bayou Sampling program was a short-term water quality study conducted in support of the characterization report and watershed protection planning. Sampling was funded by the American Recovery and Reinvestment Act and conducted in accordance with an existing amended Quality Assurance Project Plan. The effort was managed by the Texas Coastal Watershed Program and conducted by water quality specialists from the Environmental Institute of Houston, University of Houston Clear-Lake. The program was designed to assist with the characterization of the watershed and to monitor the impacts of NPS on local waterways in the basin. Results of the program were submitted for entry in TCEQ's SWQM database and will be used in ongoing efforts by TCEQ to assess segments in the study area.

The sampling program consisted of six events at 6 stations within the Highland Bayou Watershed. Sampling began in November 2010 and concluded in July, 2011. All the major non-point source water quality parameters were tested, including:

- Water Temperature
- Specific Conductance
- Salinity
- DO
- pH
- Instantaneous Flow
- Secchi Depth
- Chlorine
- Total Suspended Solids
- Chloride
- Chlorophyll-a
- *Enterococci*
- Total Nitrates
- Orthophosphate
- Total Phosphate
- Sulfate

USGS Real Time Monitoring

As of 2016, there is one operating USGS stream gauge in the project area. The USGS gauges monitor flow conditions and precipitation, but they do not monitor water quality parameters. The operating USGS station in the basin is located at the La Marque pump station in the Texas City Levee, station 08077740. The station is supported in part by Galveston County (USGS, 2016).

Two other stations were established within the Highland Bayou Watershed, but their use has been discontinued. Between 1997 and 2003, a USGS station (08077690) was operating at a point near the diversion point from Highland Bayou to the Diversionary Canal. For fourteen months, beginning in 2006, a continuously data monitoring station was set up for field sampling where TX Route 6 crosses Highland Bayou.

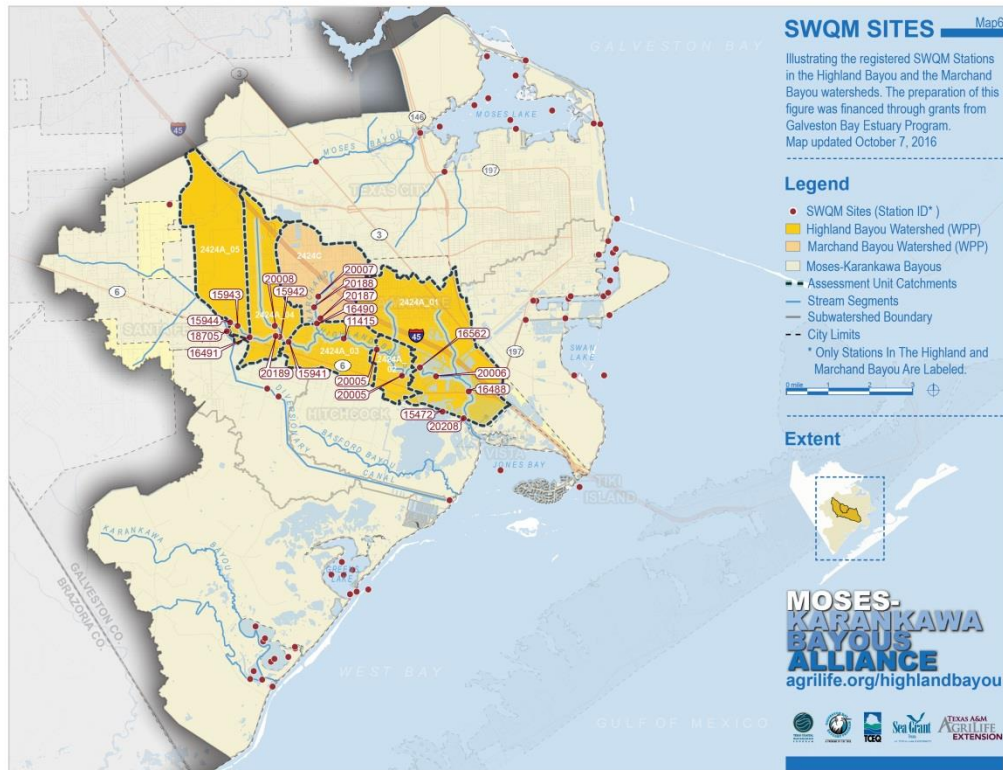
Proposed Monitoring

Watershed Protection Plans have certain levels of uncertainty when they are developed and implemented. As the action areas outlined in Element C are put into practice it will be necessary to measure and test water quality for certain parameters over time and adjust the WPP as necessary if water quality goals are not being achieved. This practice of adaptive management will allow results to guide future strategies and implementation efforts. The monitoring strategy outlined below will be implemented to check if bacteria and nutrient reductions are occurring at a sub-watershed level, and that the goals set by this WPP are being achieved according to schedule. Ambient water quality data will be routinely monitored at downstream SWQM stations at the subwatershed level.

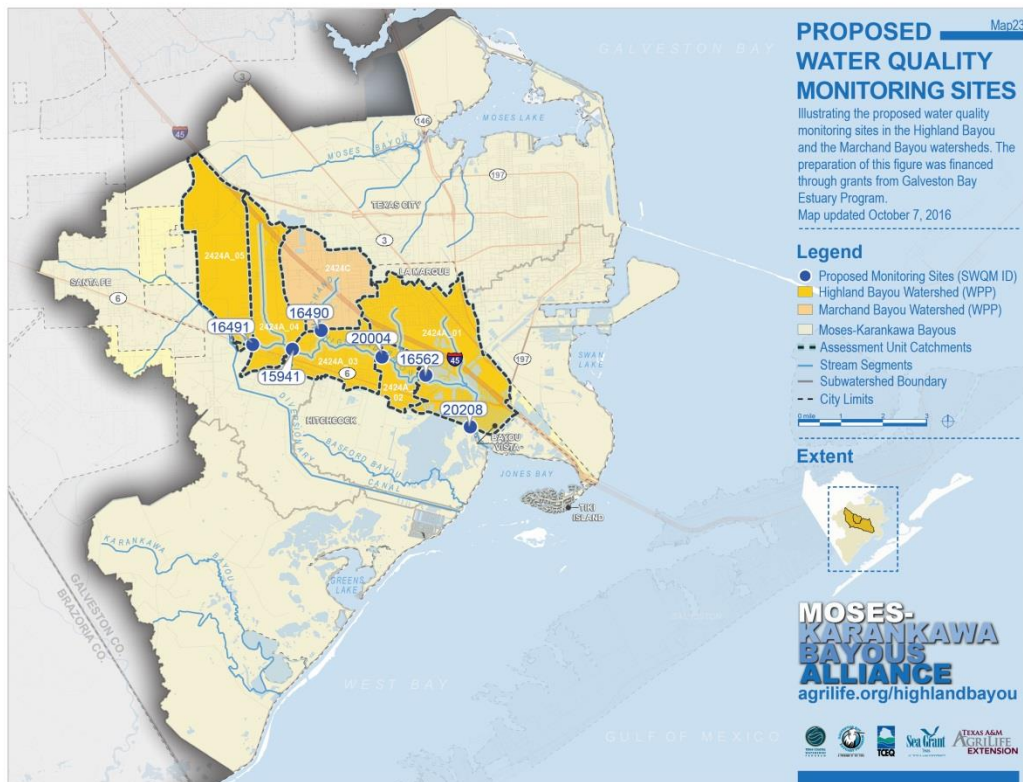
Table I-1 below summarizes the SWQM stations that will be used for evaluating short term and long term water quality conditions at the subwatershed level to guide the adaptive management approach. SWQM stations were selected for coincidence with the limits of listed segments, or alternatively AU ID catchments. Data collection will focus on collecting routine water quality samples from the 6 stations listed in Table I-1 and shown on Map-23. These samples can be used for WPP implementation and in future waterbody assessments. Parameters monitored are listed in Table 1-2. Data from the last 7 years of bacteria and nutrient levels should be analyzed every 2 years and compared to interim target goals. Analyzing results every 2 years will also show spatial and historical trends that will assist with adjusting management strategies.

Table I- 1. Priority Monitoring Stations Selected for Measuring Progress

| Subwatershed | Segment ID | SWQM Station ID | SWQM Station Description | County | Monitoring Frequency Proposed in WPP |
|-----------------------|------------|-----------------|--|-----------|--------------------------------------|
| Highland Bayou | 2424A_01 | 16562 | Highland Bayou at end of Bayou Lane in Freddiesville | Galveston | Monthly |
| Highland Bayou | 2424A_02 | 15941 | Highland Bayou tidal at FM 519, 335 meters north of HWY 6 in City of Hitchcock | Galveston | Monthly |
| Marchand Bayou | 2424C_01 | 16490 | Marchand Bayou tidal at FM 519 in City of Hitchcock | Galveston | Monthly |
| Highland Bayou | 2424A_03 | 16491 | Highland Bayou at FM 2004 in City of Hitchcock | Galveston | Monthly |
| Highland Bayou | 2424A_04 | 20004 | Highland Bayou approximately 100 m downstream of City of La Marque. WWTP #WQ0010410001 is located 170 m upstream of Lake Road terminus | Galveston | Monthly |
| Highland Bayou | 2424A_05 | 20208 | Highland Bayou at railroad bridge 1.10 km downstream of HWY 6 near City of Texas City | Galveston | Monthly |



Map- 6. Registered SWQM Stations



Map- 23. Proposed WQM Stations for Tracking Water Quality Improvements

Table I-2 provides a subset of key parameters collected through the routine monitoring program that will be utilized to demonstrate progress toward reducing bacteria and nutrient concentrations in subwatersheds over time.

Table I- 2. Water Quality Parameters Used for Measuring Progress.

| Field Data | |
|--|---|
| Dissolved oxygen (mg/L) | Specific conductance |
| pH | Flow (collected at USGS gage station) |
| Days since last rainfall | Instantaneous Flow |
| Odor of water | Biological activity |
| Water temperature | Illegal dumping activity |
| Salinity | Animal activity |
| Total Suspended Solids | Secchi Depth |
| Bacteria Data (All Sections of 2424A & C are tidally influenced) | |
| <i>E. coli</i> (#/100mL) freshwater only | <i>Enterococci</i> (#/100mL) saltwater only |
| Nutrients Data | |
| Chlorine | Chloride |
| Total Nitrates | Chlorophyll-a |
| Total Phosphate | Sulfate |
| Orthophosphate | Total dissolved solids |

Additional Monitoring

The Highland Bayou work group expressed interest in employing Bacterial Source Tracking techniques as an additional management tool for the Highland Bayou Watershed, even though it did not rise to the level of a top-10 priority action area. Bacterial Source Tracking is a relatively new approach that utilizes a bacteria DNA library, which is prepared using known sources from within the watershed. Water quality monitoring samples are compared to the library to determine the most significant contributors of bacteria. This data could be used to confirm and/or adjust ongoing and planned implementation efforts. Funding for targeted Bacterial Source Tracking analysis within the Highland Bayou Watershed will be pursued as a part of the implementation strategy. Costs to perform this analysis have come down sharply in recent years, enhancing the feasibility of this type of monitoring in future years.

Monitoring Objectives and Timeline

Continue Texas Stream Team & Clean Rivers Program surface water quality monitoring

- Establish an interest in Texas Stream Team with Universities and schools within the Highland Bayou Watershed

- Recruit more volunteers for Texas Stream Team water quality monitoring efforts within the Highland Bayou Watershed
- Train more volunteers for Texas Stream Team water quality monitoring efforts that can sample within the Highland bayou Watershed
- Work with the Clean Rivers Program to include Priority Monitoring Sites in their monitoring program
 - Timeline: Recruit volunteers in Year 1. Monthly sampling throughout the year beginning in Year 2 and ongoing thereafter

Galveston County Health District stormwater sampling

- Identify locations in the Highland Bayou Watershed ideal for stormwater sampling (areas with OSSFs, near sewage treatment plants, drainage ditches or water bodies that flow into State waters) and that align with the GCHD sampling program
- Compile and review stormwater monitoring results within MS4 Phase II annual reports from the City of Hitchcock, the City of La Marque and Galveston County
- Compile and review WWTP effluent reports, in particular the occurrence of bacteria exceedances in effluent and how that might relate to ambient water quality monitoring results
- Evaluate relationships between ambient water quality monitoring results and management activities of entities in the basin that discharge effluent, and collaborate to improve coordination
 - Timeline: Contingent on discussions with GCHD.

TCEQ's SWQM Program

- Work with TCEQ to include priority monitoring sites in their SWQM program
 - Timeline: Sampling event every 1-2 months throughout the year.

Conduct Bacterial Source Tracking to determine leading sources of bacteria

- Utilize library dependent methods at the subwatershed level to improve targeting of management strategies
- Focus on evaluating human sources (OSSFs, collection systems), domestic animals (pets, cattle), birds, and feral hogs
- Support tracking by identifying funding sources for BST analysis
- Develop a report based on results from BST at the sub-watershed level (AU catchments) in the Highland Bayou Watershed
 - Timeline: Contingent on grant funding; begin after Year 1.

Any sampling program timeline mentioned above will be contingent on available funding and resources.

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- Joe Giusti – Galveston County Commissioner. Personal Communication, February 2, 2016.
- Julie Diaz, Robert Simoneau – Galveston County parks & Cultural Services. Personal Communication, May 6, 2016.
- Kim Laird – TCEQ. Personal Communication, April 6, 2016.
- Lalise Mason. Personal Communication, October 18, 2011.
- Lee Crowder - Galveston County Road and Bridge. Personal Communication, July 11, 2016.
- Lee Grundmann, Phil Harrison – WCID 19. Personal Communication, February 16, 2016.
- Linda Broach – TCEQ. Personal Communication, March 28, 2016.
- Llarance Turner. Personal Communication, February 11, 2016.
- Lori Fitzsimmons-Evans, Martin Entringer - Galveston County Health District. Personal Communication, February 2, 2016.
- Mayor Matranga, Lucy Dieringer – City of Hitchcock. Personal Communication, April 12, 2016.
- Michael Shannon, Nancy Baher – Galveston County Engineer. Personal Communication, March 7, 2016.
- Michelle Krause, Lindsey Lippert, Lisa Marshall – Galveston Bay Estuary Program. Personal Communication, February 18, 2016.
- Nathan Johnson – Artist boat. Personal Communication, February 15, 2016.
- Nick Stepchinski, Jim Bethune – Resident Stakeholders. Personal Communication, April 4, 2016.

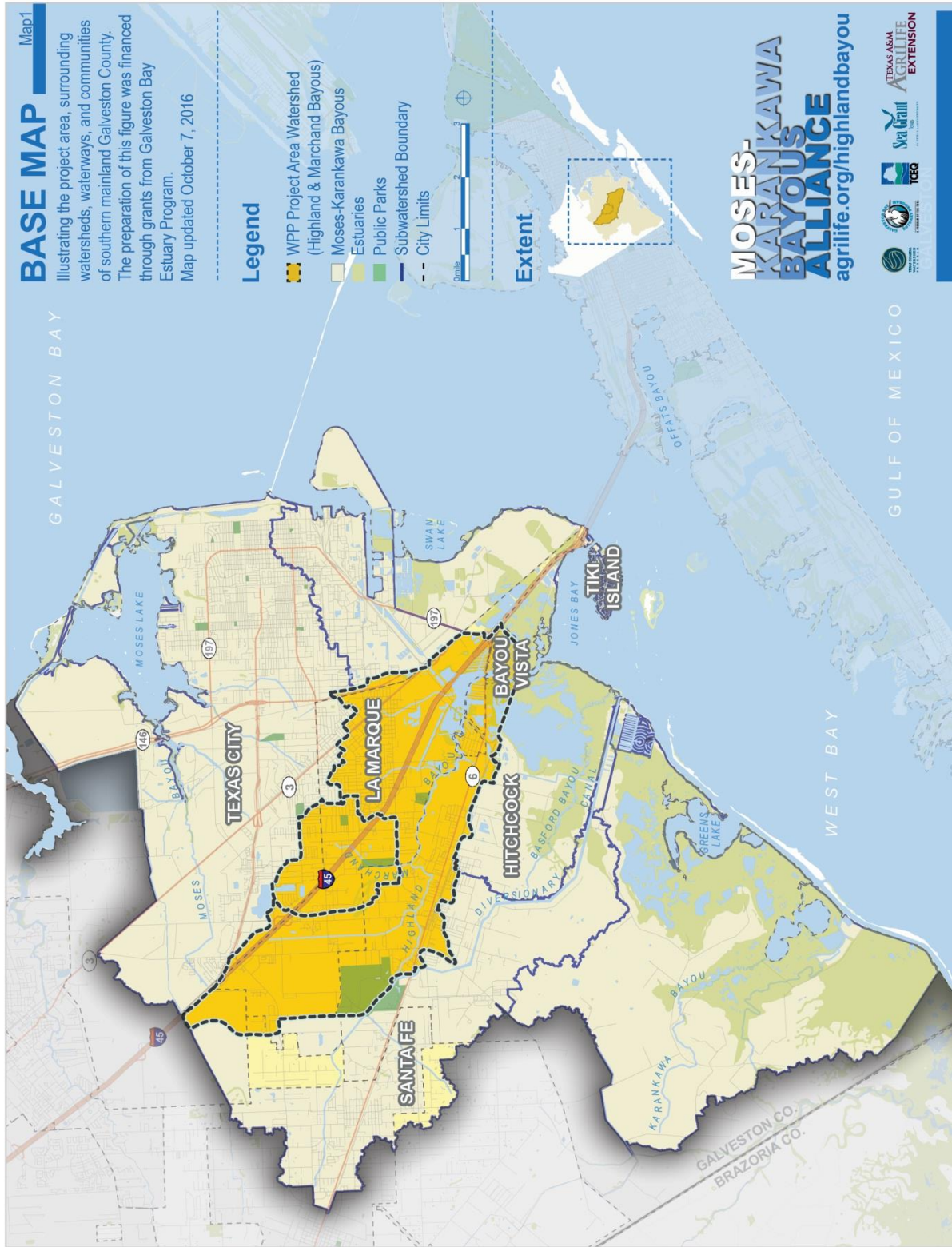
Paula Eschelman, Mayor Konyha. Personal Communication, February 11, 2016.

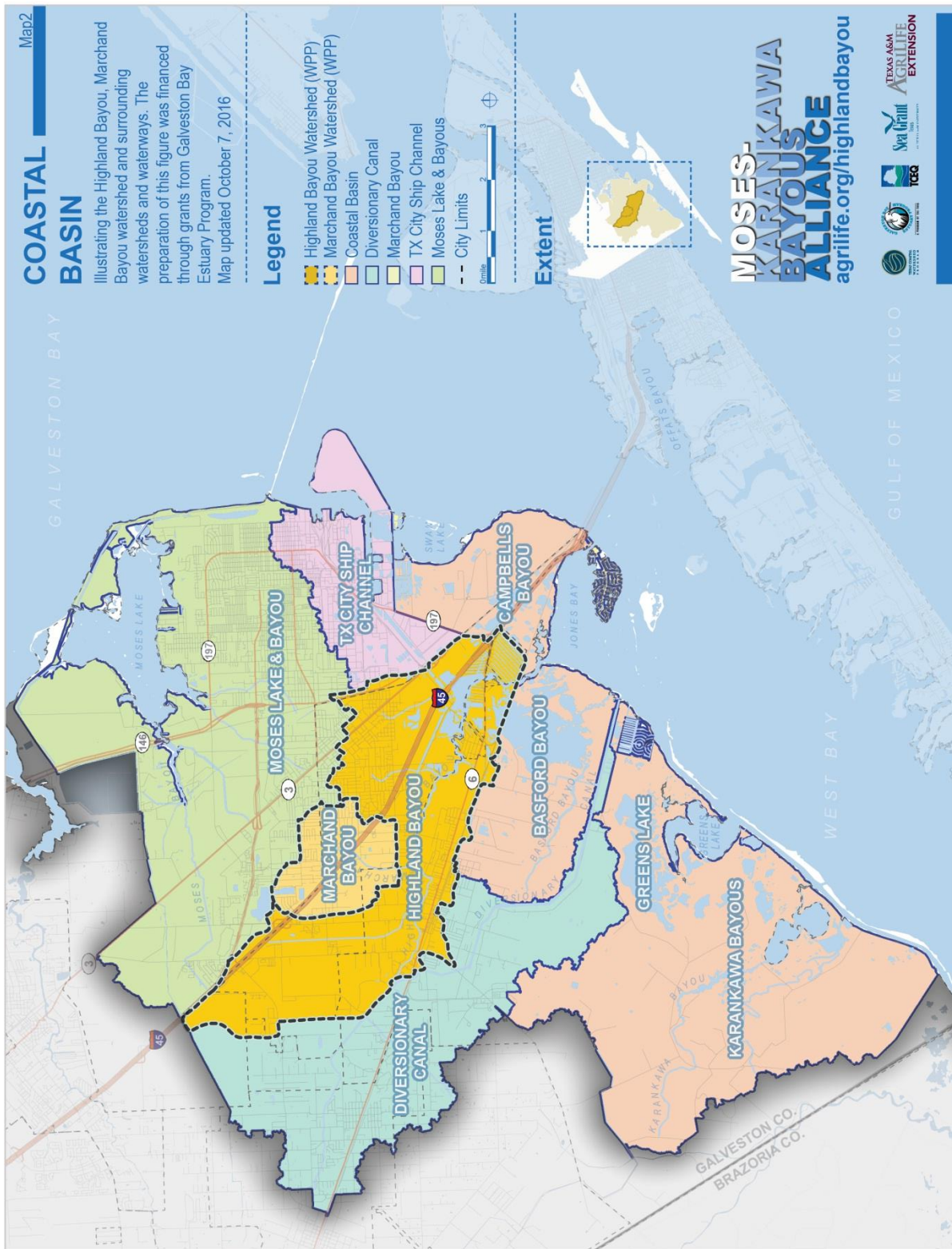
Robert Michetich - La Marque City Council. Personal Communication, April 13, 2016.

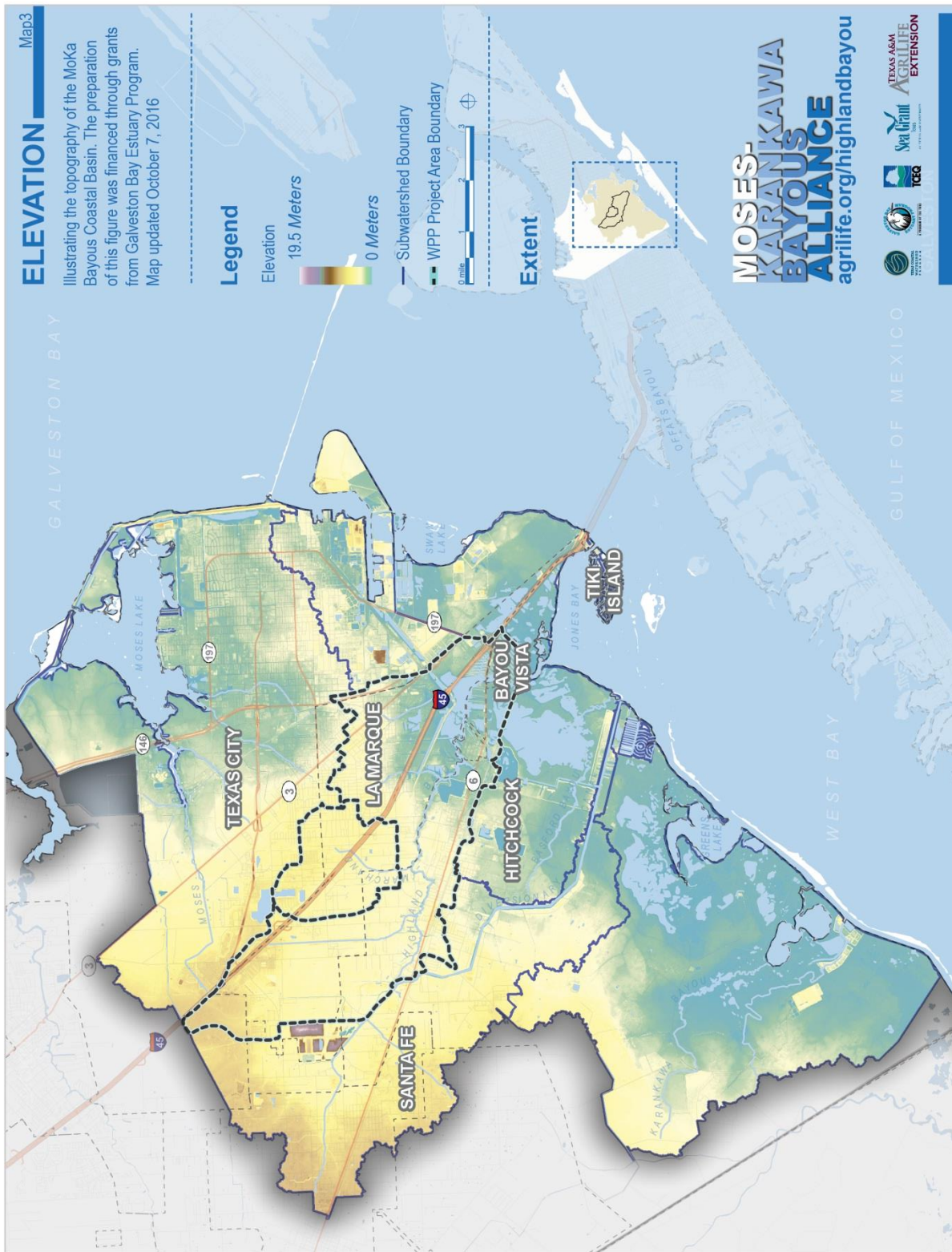
Steve Pennings – University of Houston Coastal Center. Personal Communication, April 18, 2016.

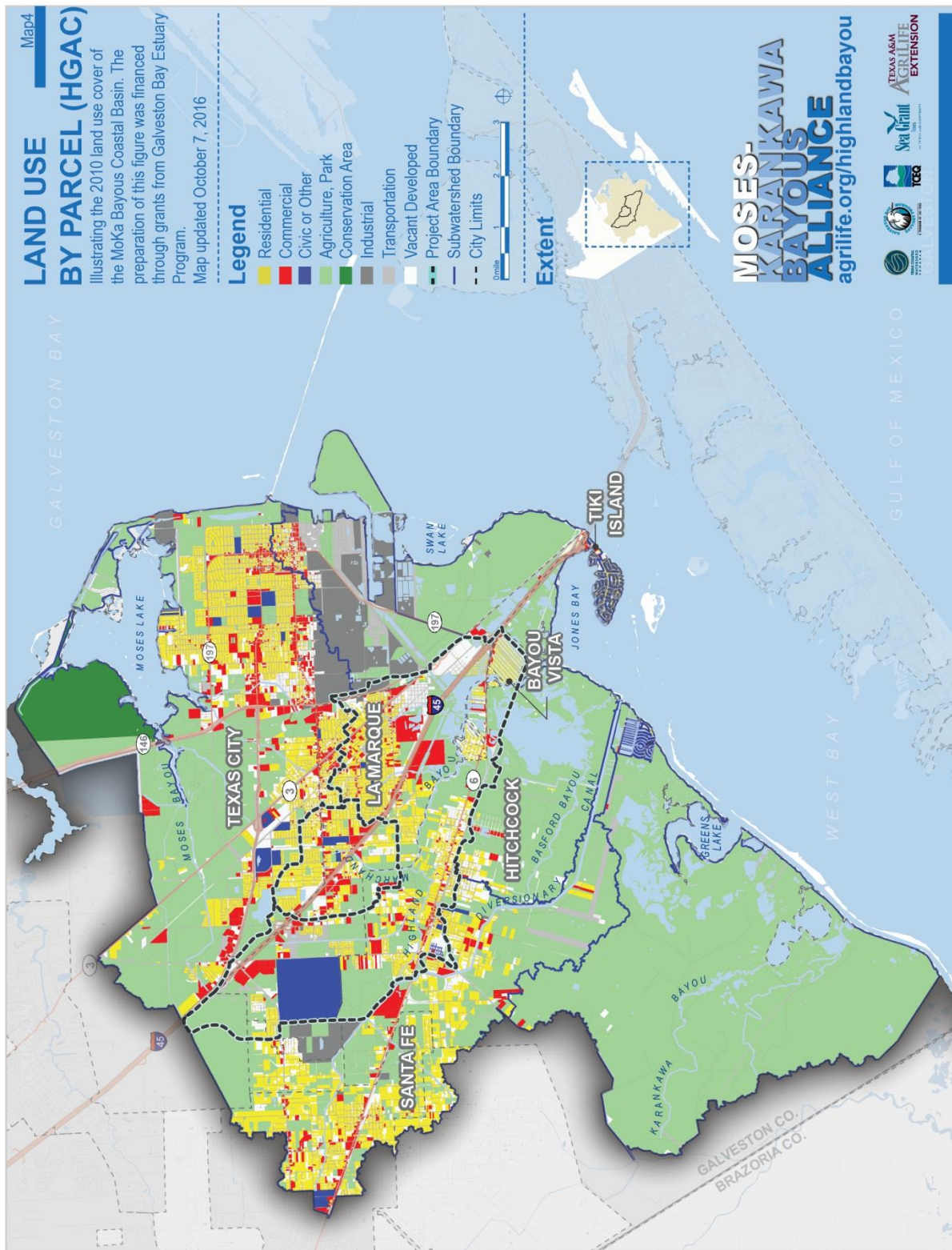
Tim O'Connell – Resident Stakeholder. Personal Communication, March 1, 2016.

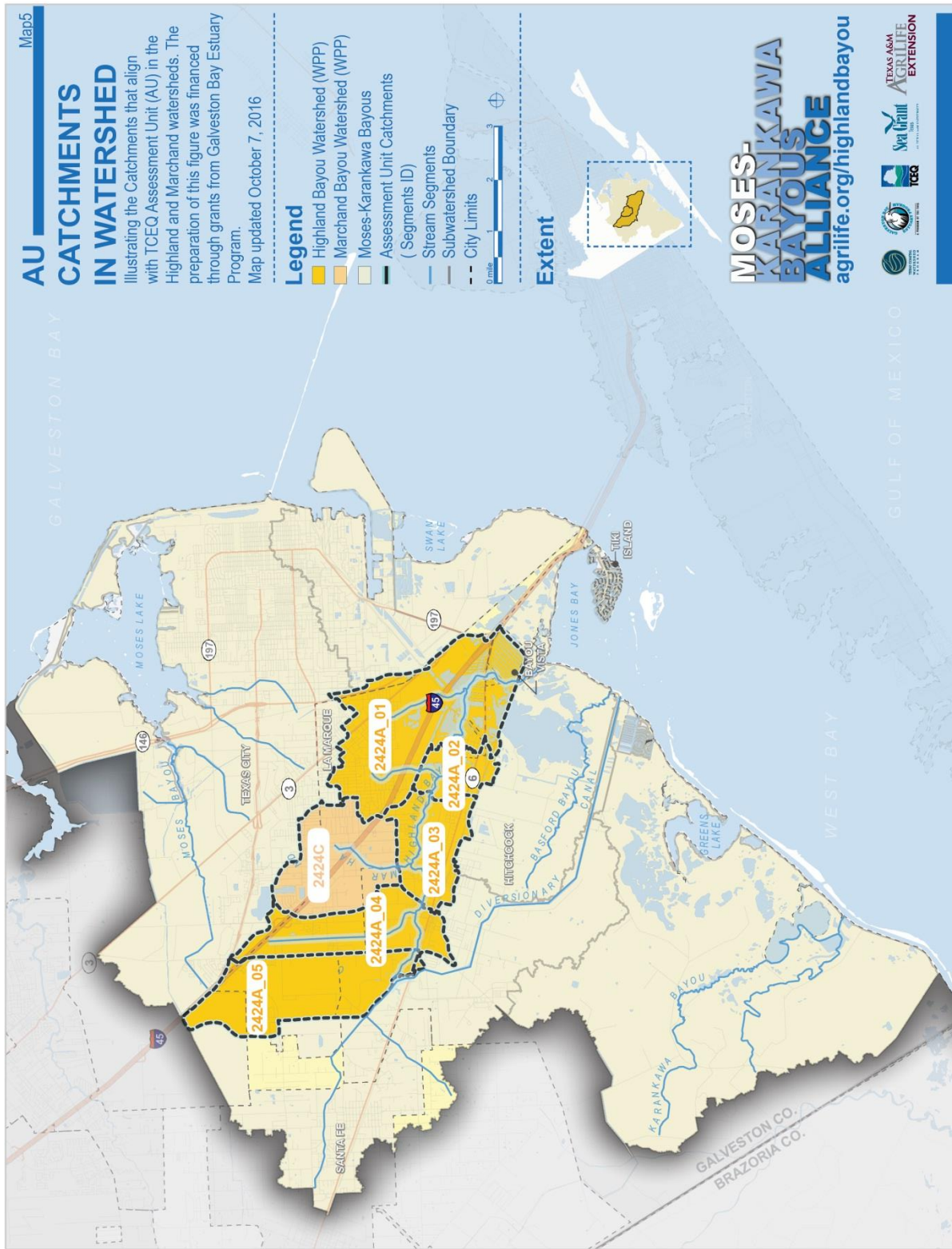
Appendix 1 – Maps

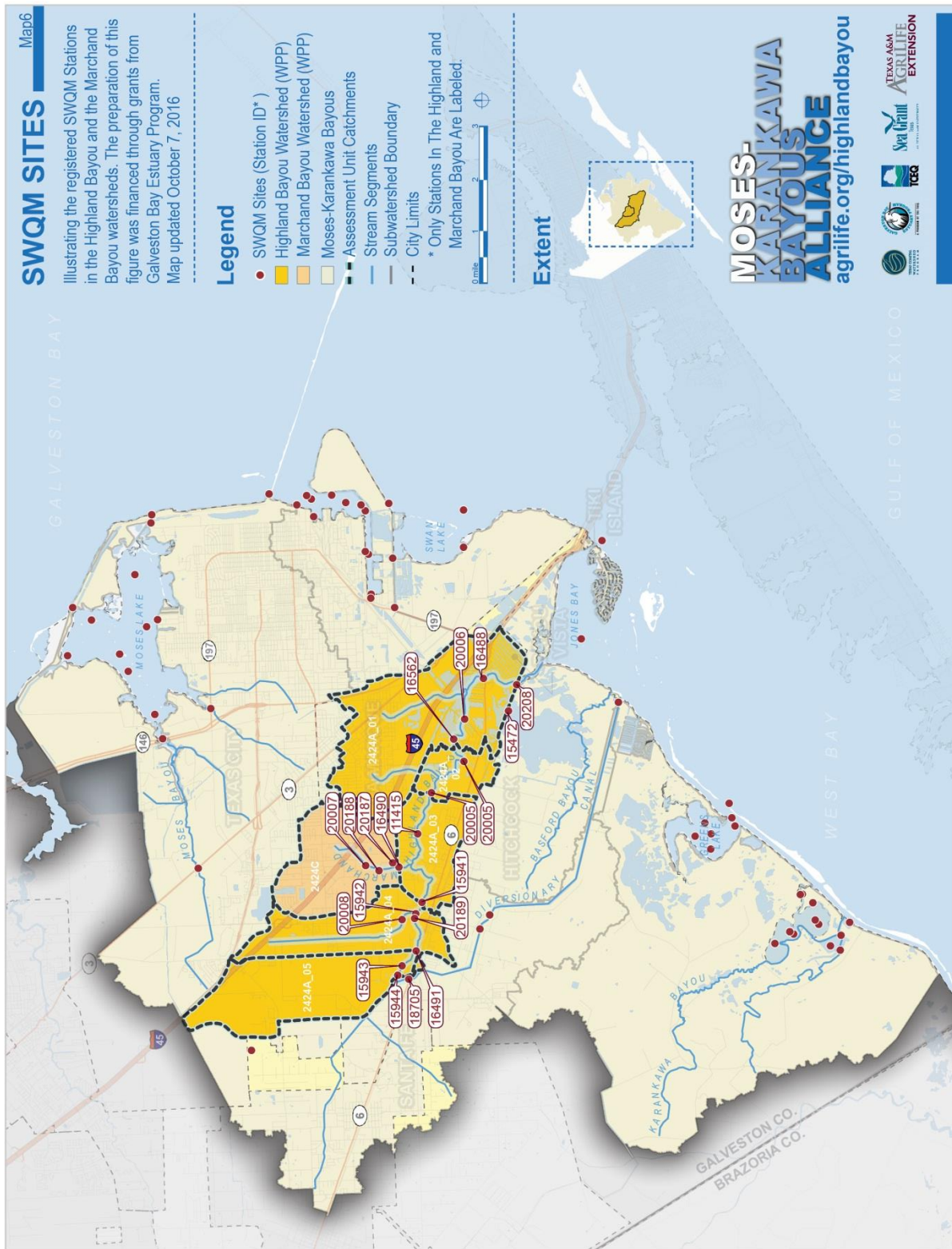


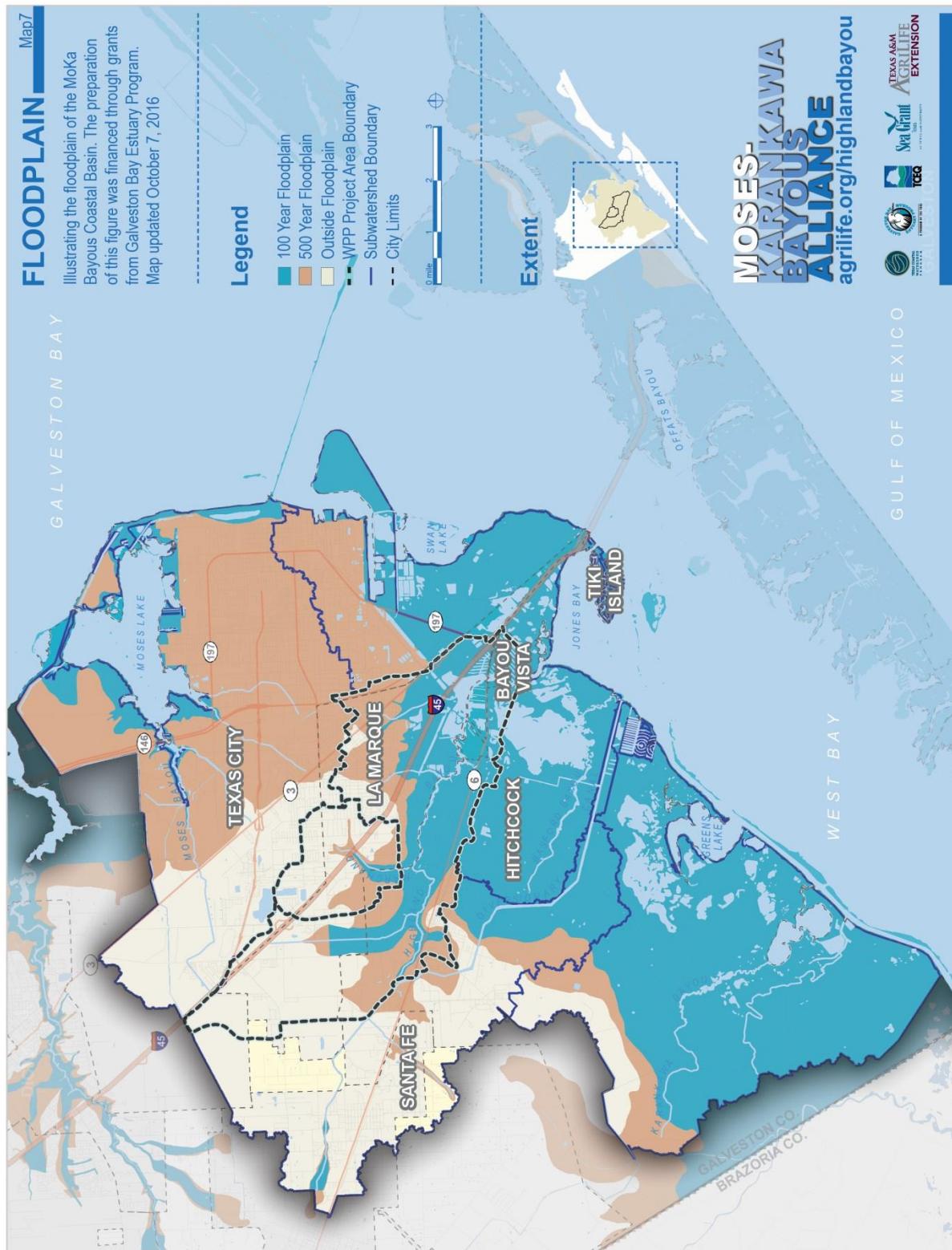












Map8

Illustrating the ecological features of the MoKa Bayous Coastal Basin. The preparation of this figure was financed through grants from Galveston Bay Estuary Program.

Map updated October 7, 2016

Legend

- Coastal Prairie, High Quality
- Coastal Prairie, Medium Quality
- Coastal Prairie, Low Quality
- Tidal Wetlands
- Moses-Karankawa Bayous
- WPP Project Area Boundary
- Subwatershed Boundary
- City Limits



Extent



**MOSES-
KARANKAWA
BAYOUS
ALLIANCE**
agrifile.org/highlandbayou



TEXAS CITY

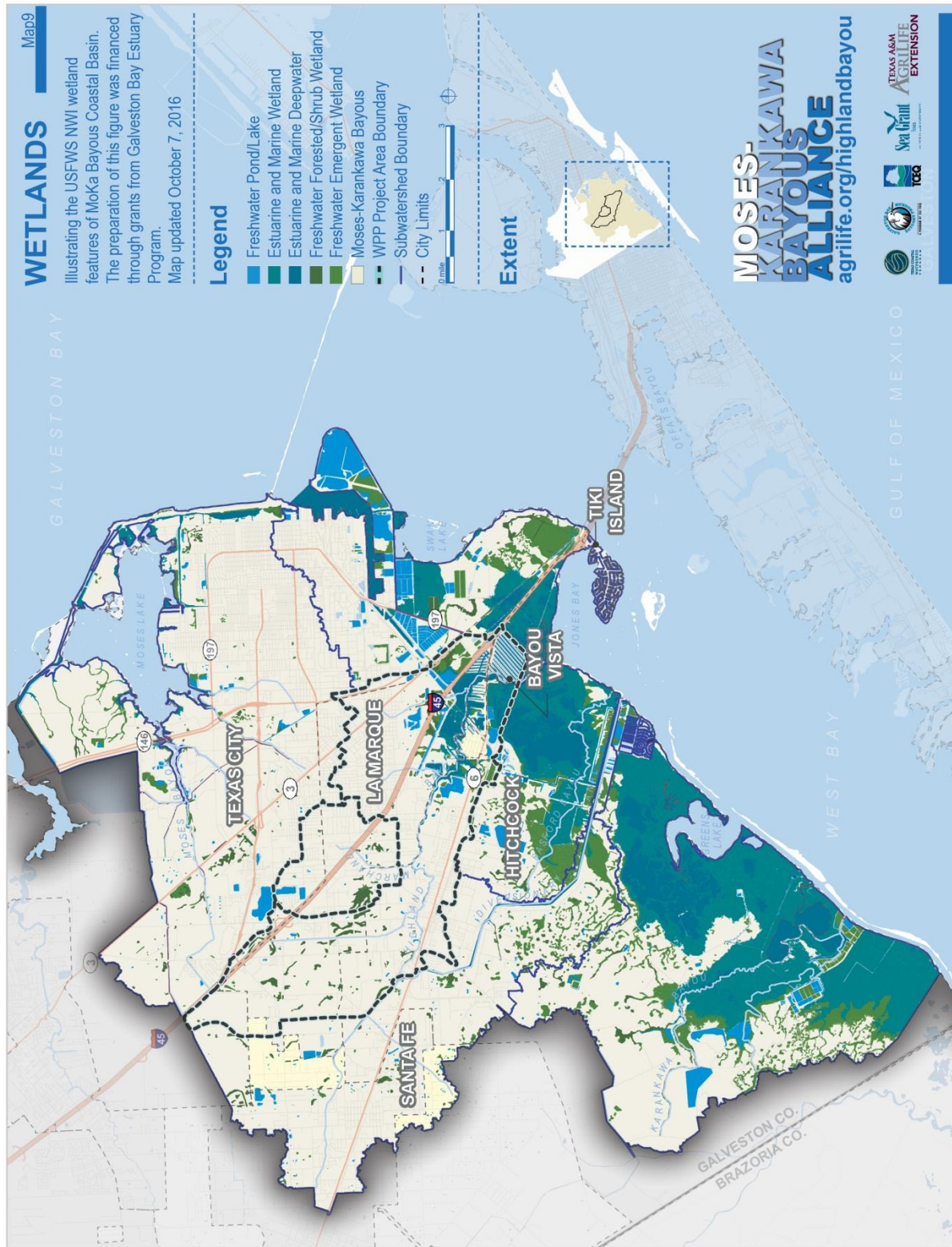
LAMARQUE

HITCHCOCK

CANAL

SANTA FE

GALVESTON CO.
BRAZORIA CO.



Map10

Map updated October 7, 2016

Population Density (Persons / Acre)

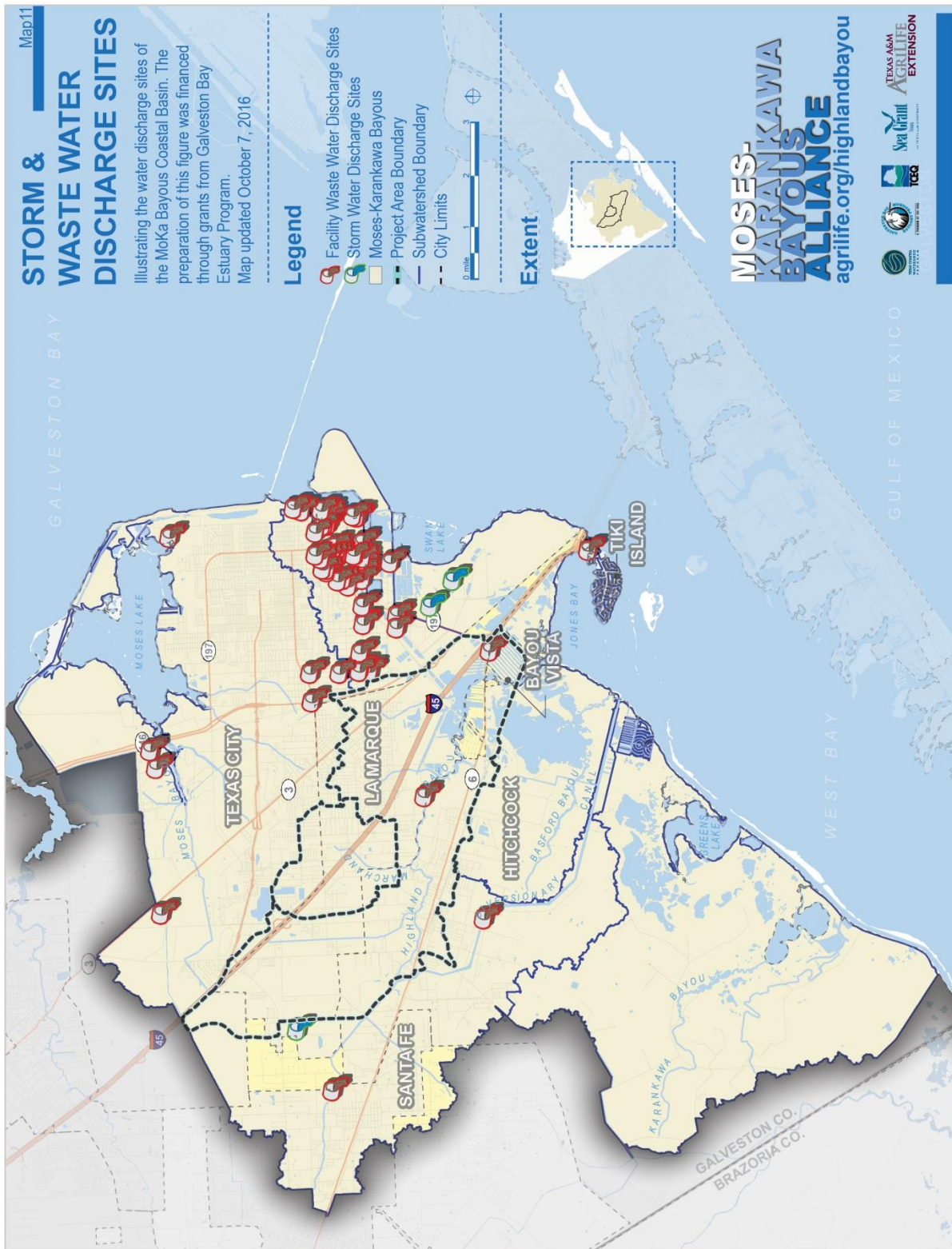


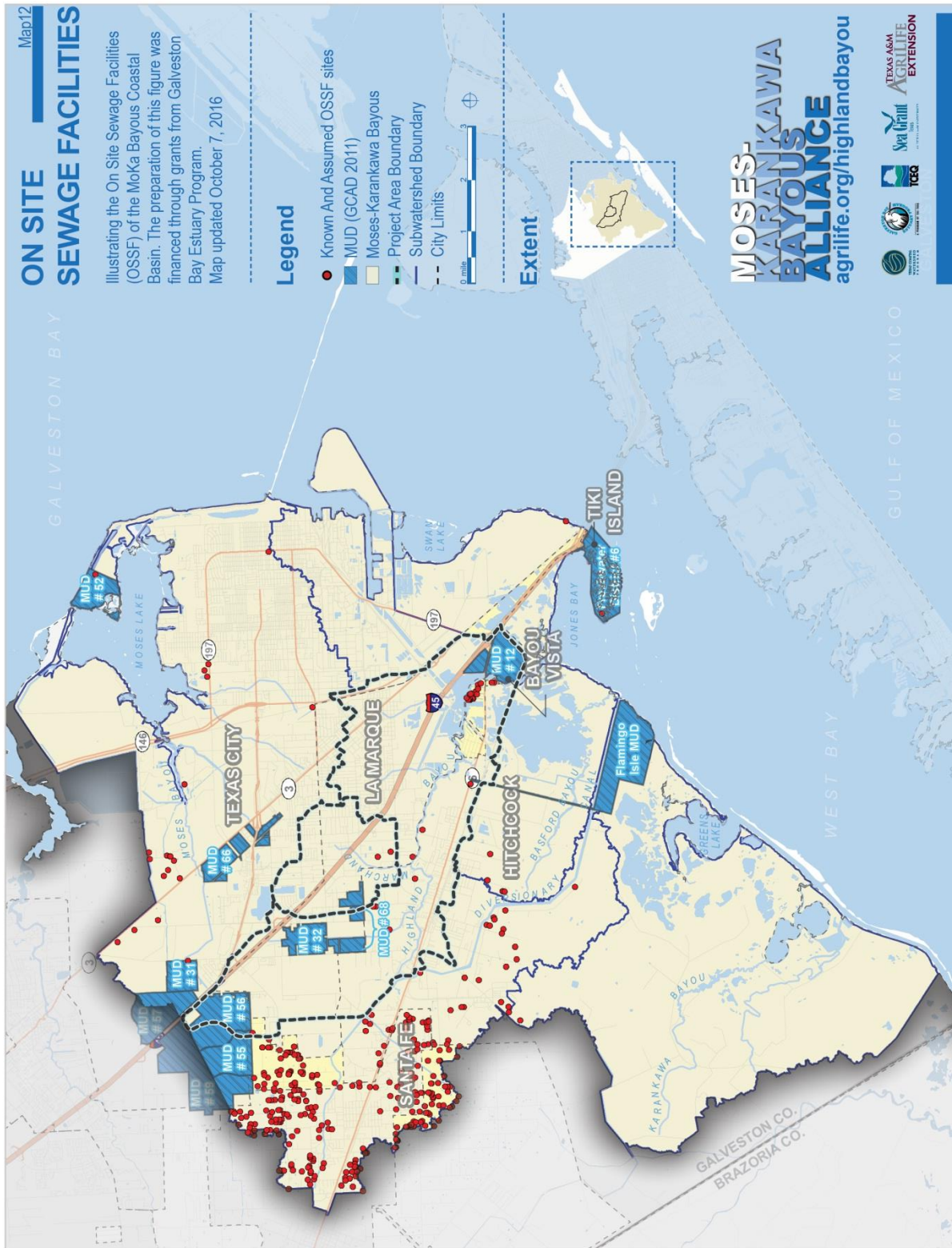
- - City Limits

| Response | Percentage |
|----------|------------|
| Yes | 75% |
| No | 25% |

Galveston Co.
Brazoria Co.







Map13

Illustrating the USDA Soil Services soil drainage type of the MoKa Bayous Coastal Basin. The preparation of this figure was financed through grants from Galveston Bay Estuary Program.

Map updated October 7, 2016

Legend

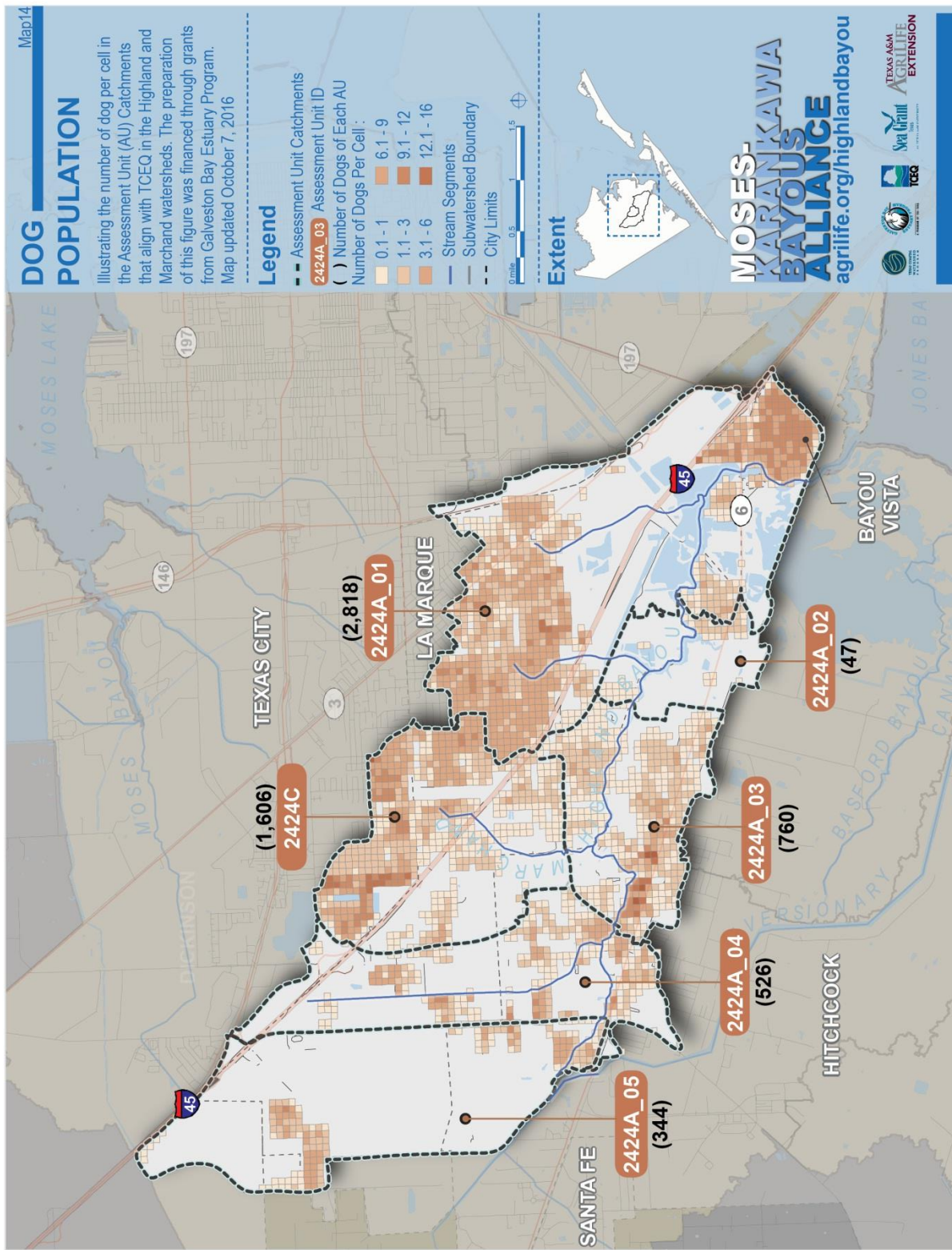
- Poorly or Very Poorly Drained (D*)
 Somewhat Poorly Drained (C*)
 Moderately to Well Drained (B*)
 WPP Project Area Boundary
 Subwatershed Boundary
 City Limits
 * Hydrologic soil groups

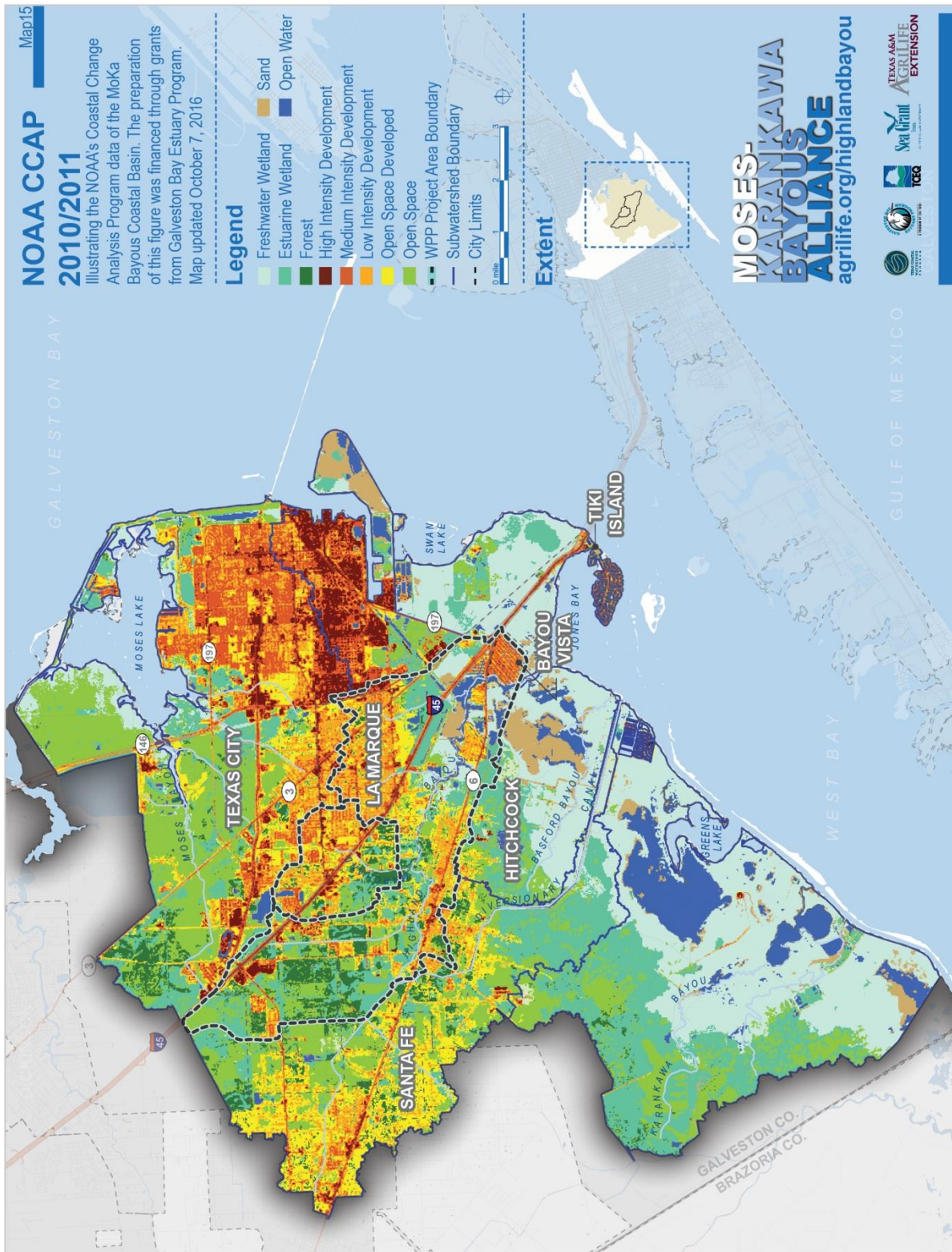
Extent

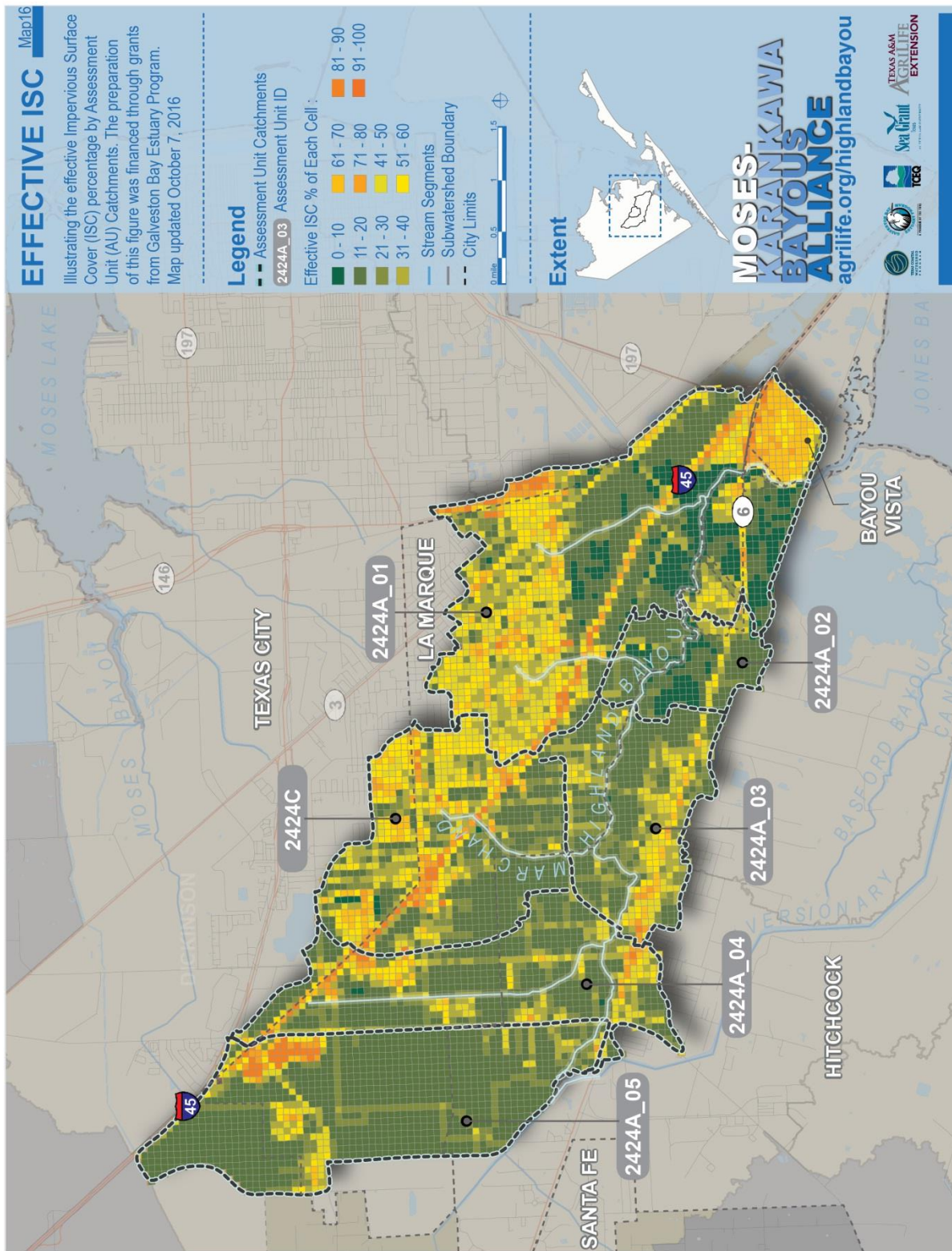


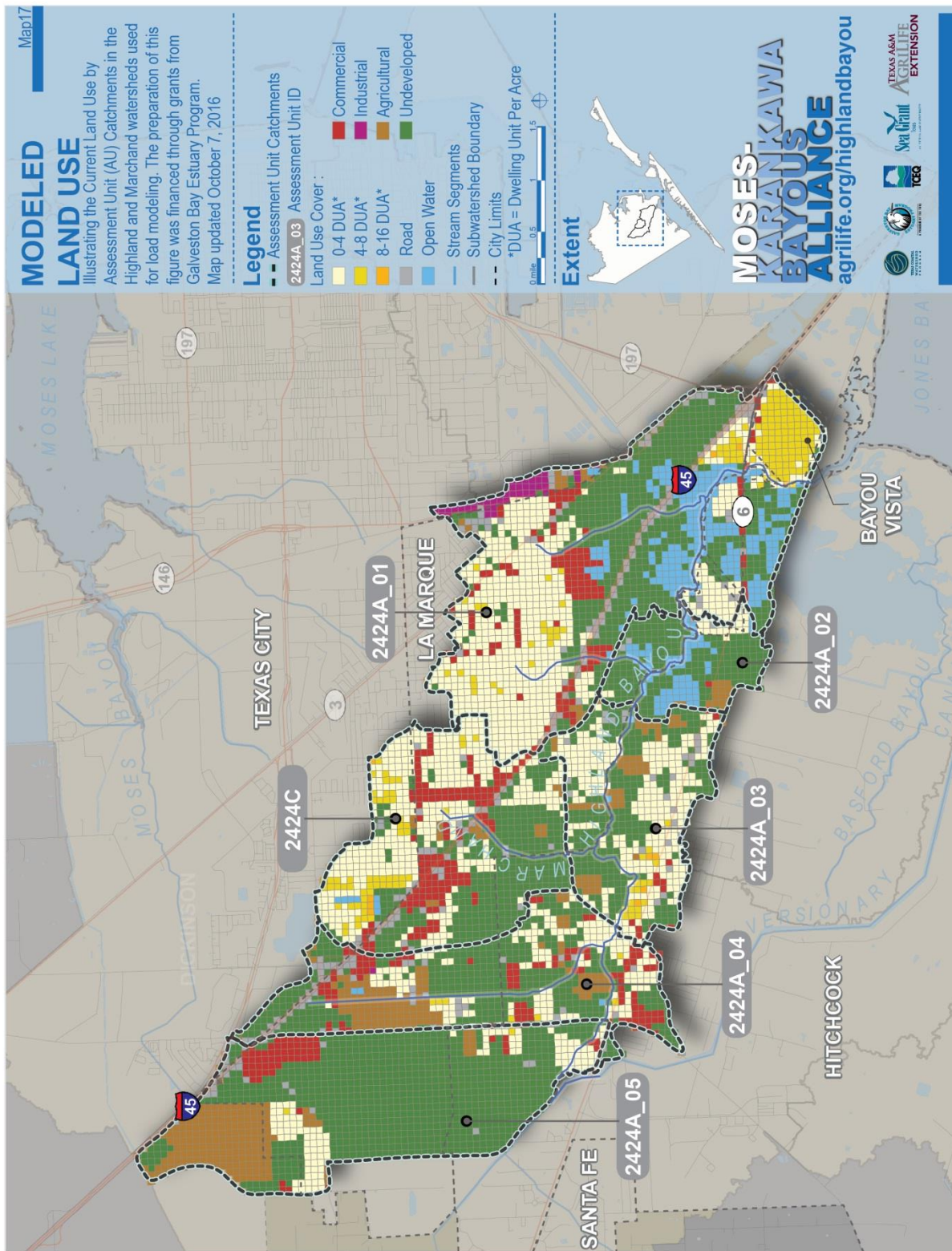
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ALLIANCE**
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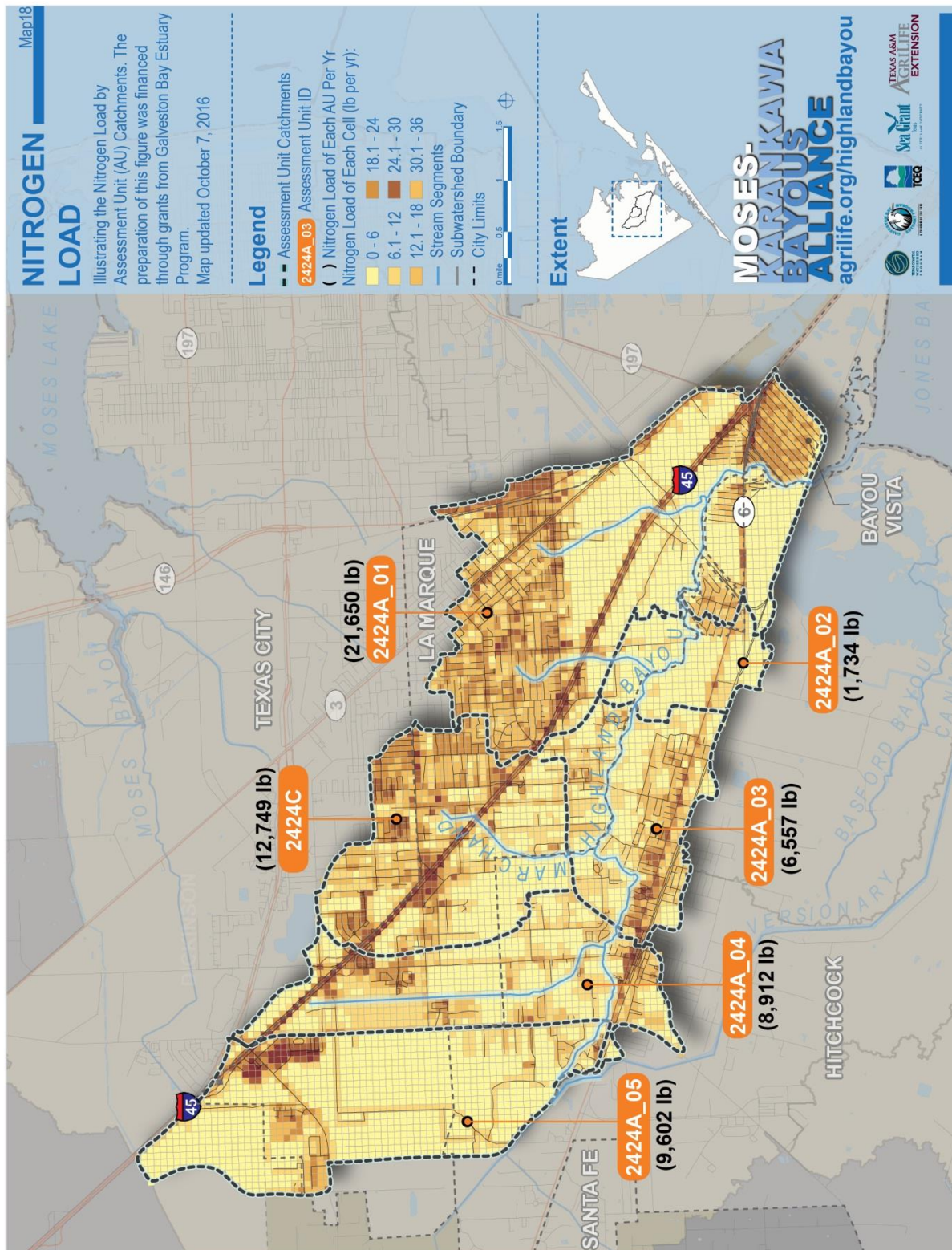


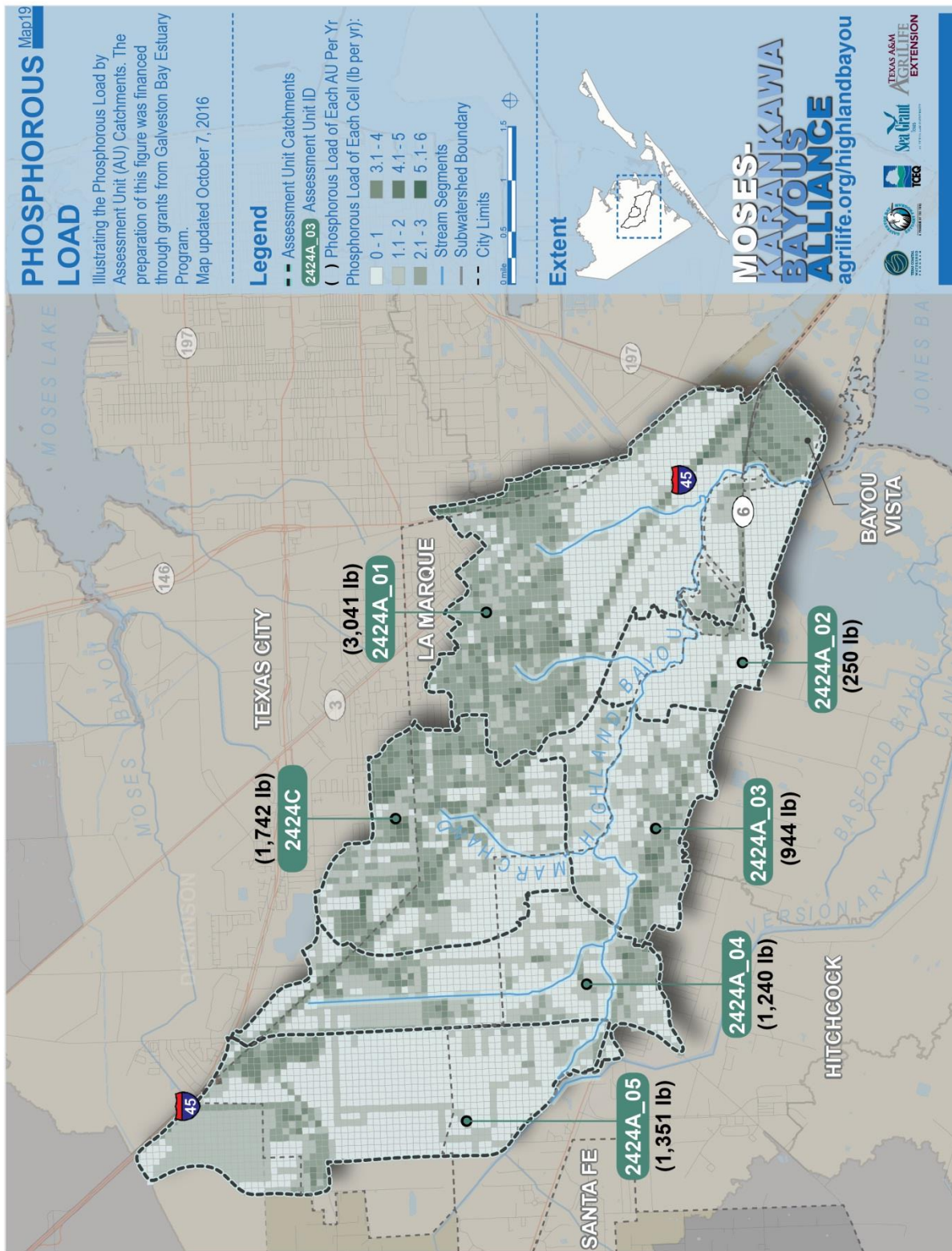


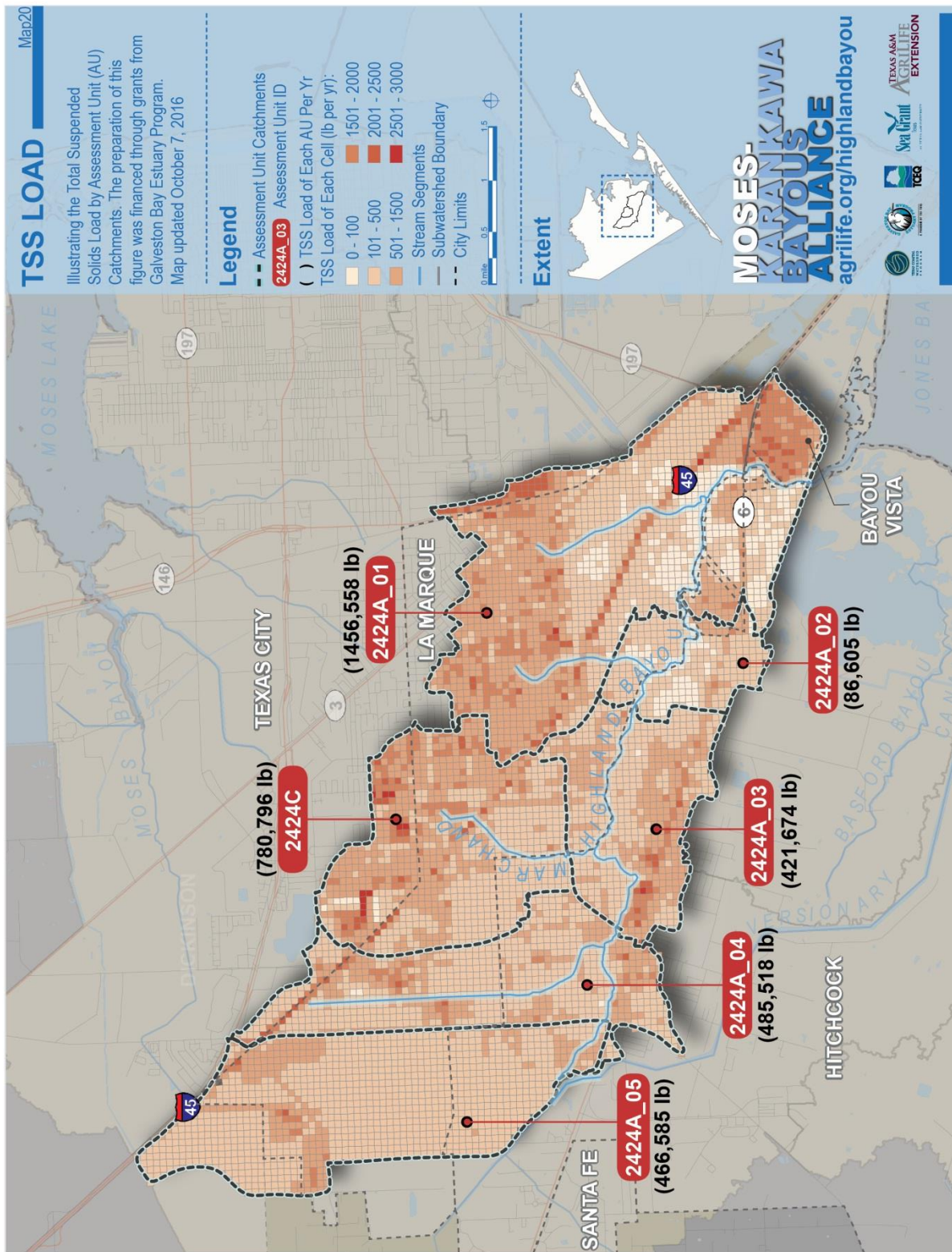












Illustrating the Biochemical Oxygen Demand Load by Assessment Unit (AU) Catchments. The preparation of this figure was financed through grants from Galveston Bay Estuary Program.
Map updated October 7, 2016

Legend

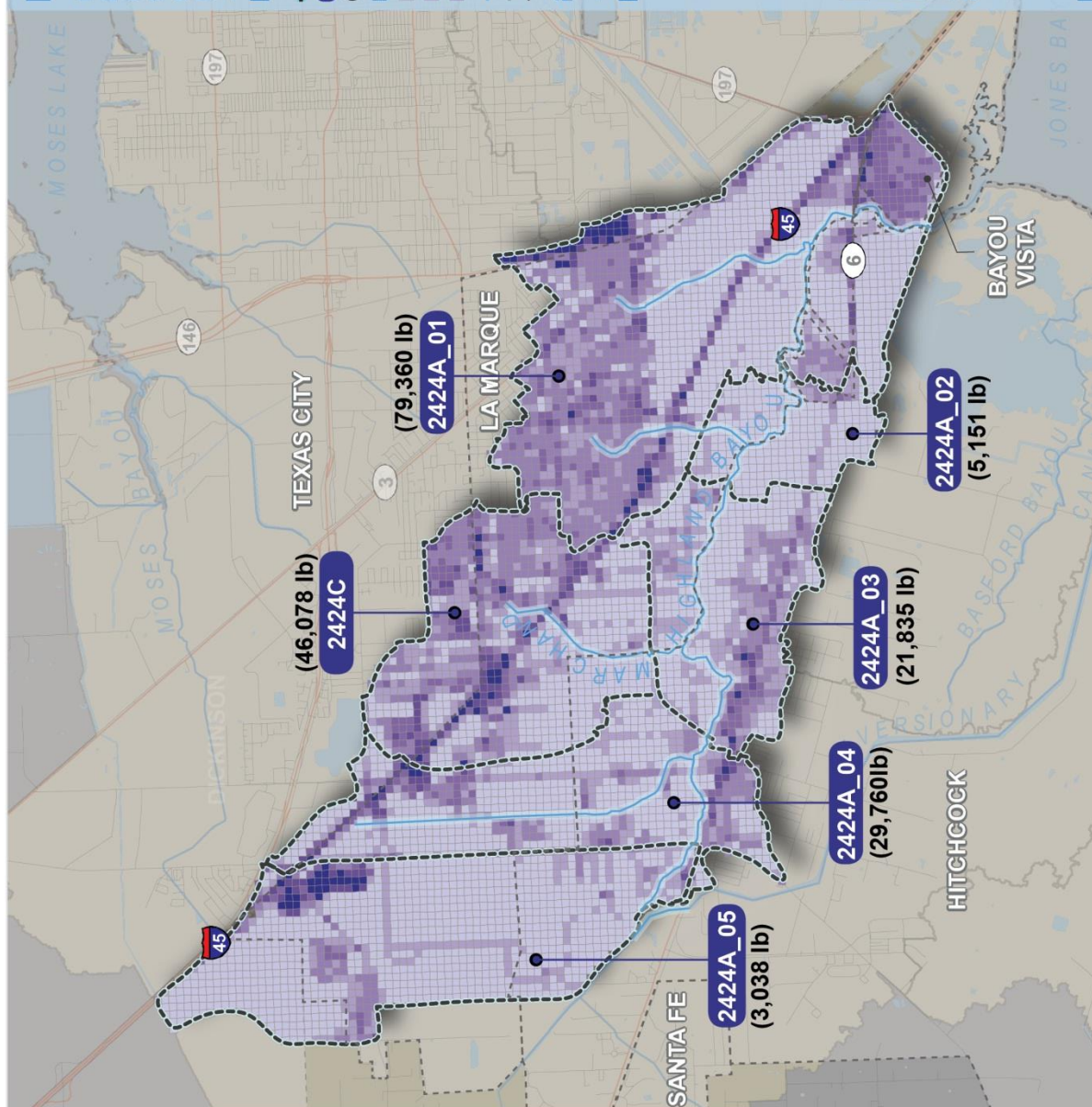
- Assessment Unit Catchments
 2424A_03 Assessment Unit ID
 () BOD Load of Each AU Per Yr
 BOD Load of Each Cell (lb per yr):
 0 - 25 26 - 50 51 - 75 76 - 100 101 - 125 126 - 160
 Stream Segments
 Subwatershed Boundary
 City Limits

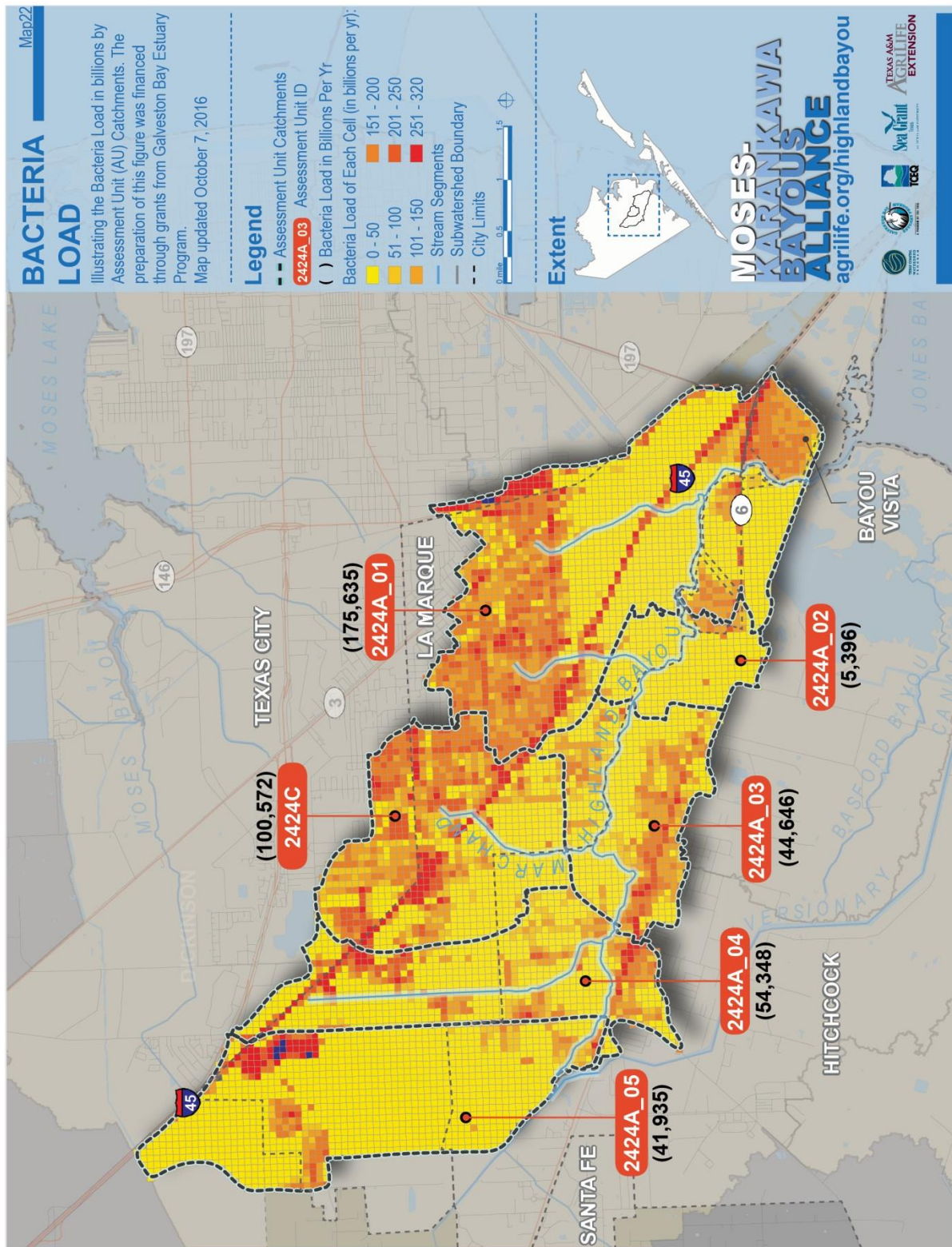


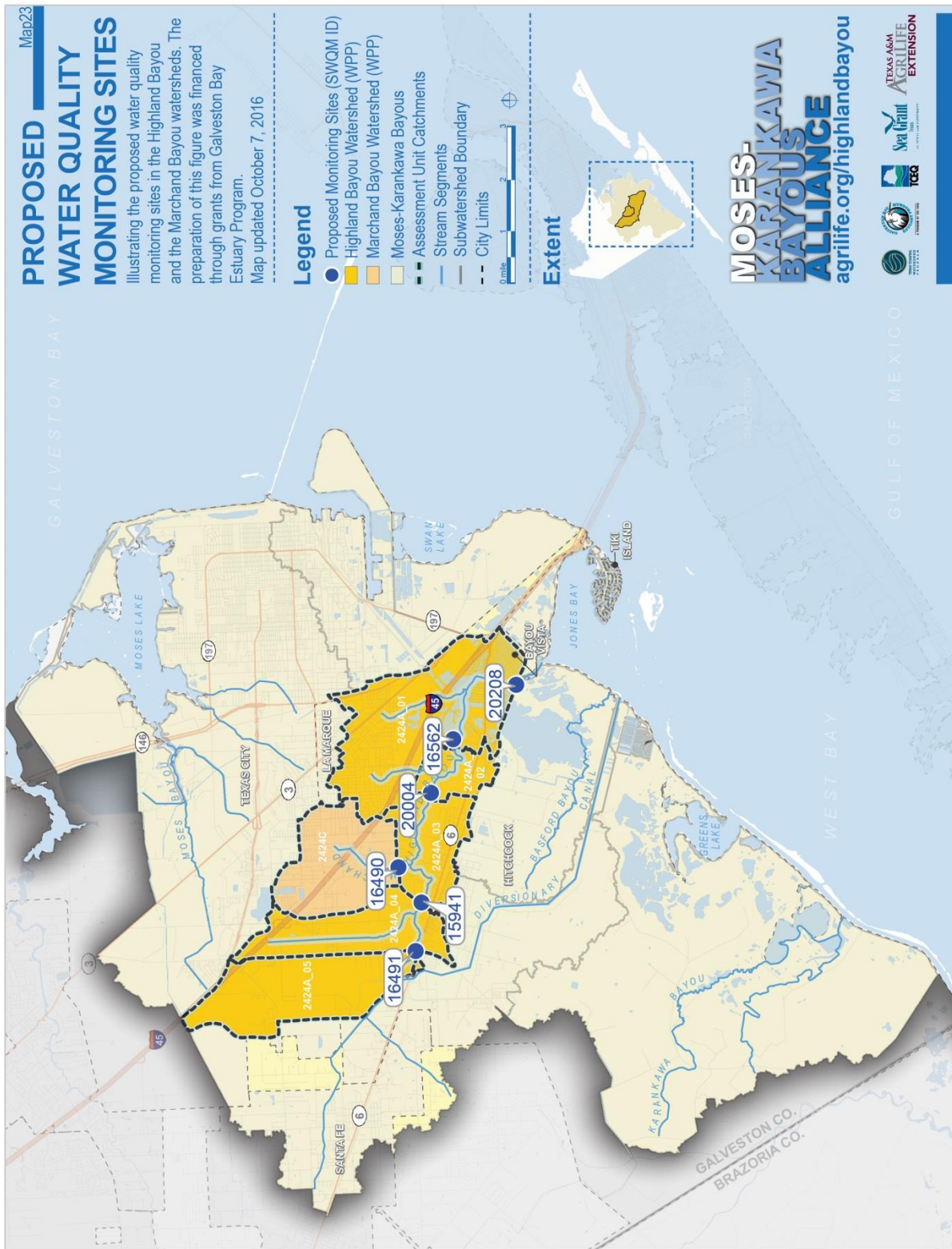
Extent

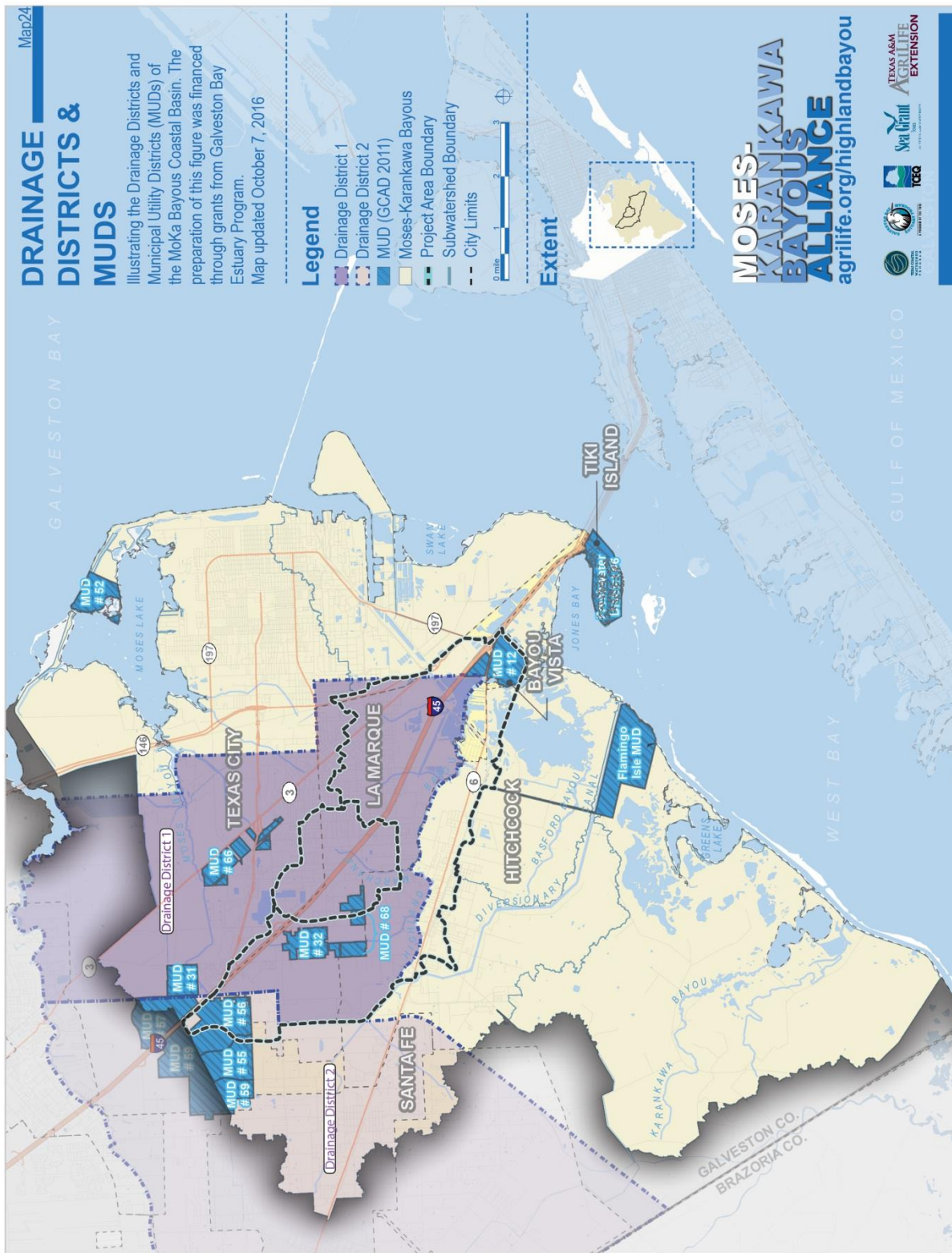


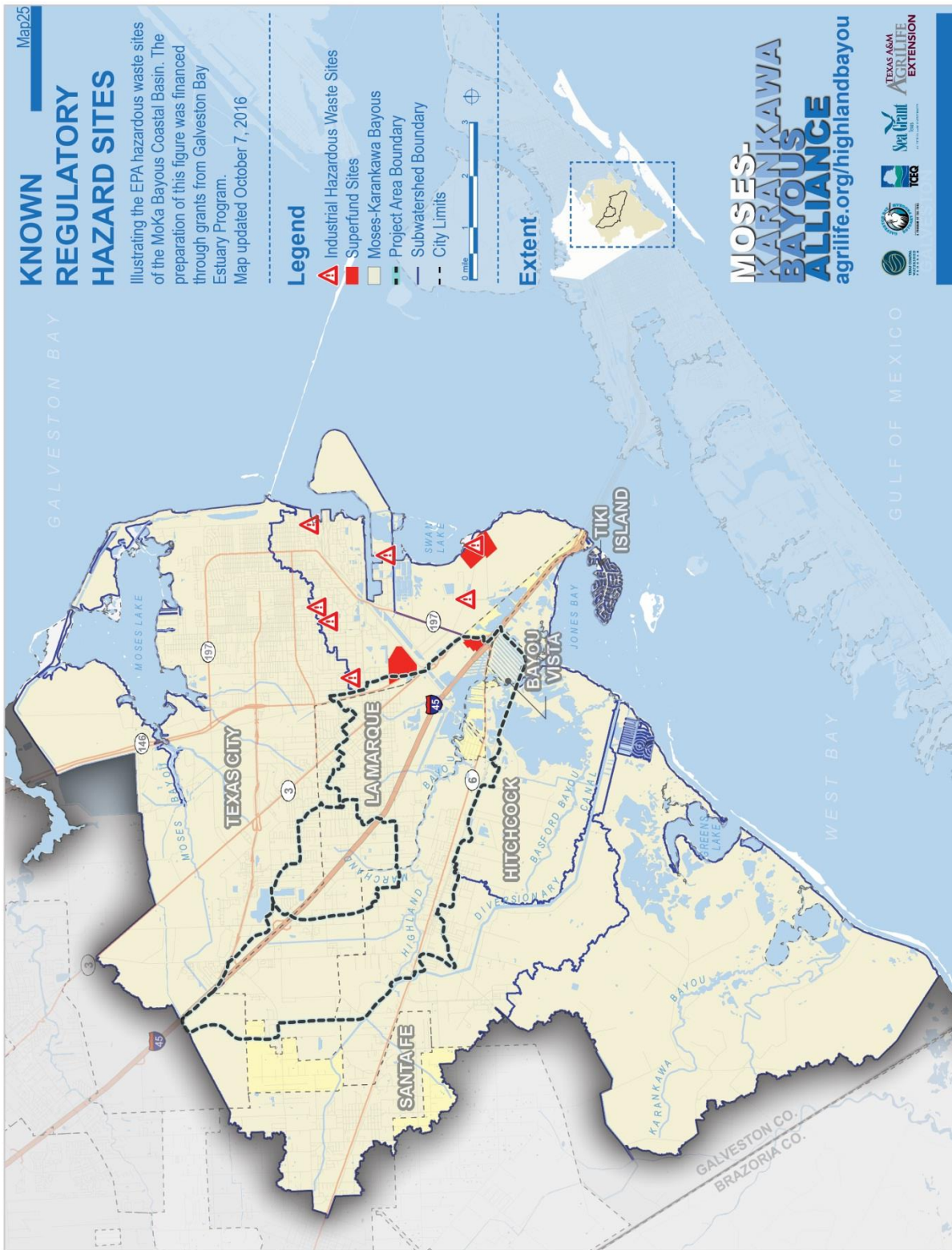
**MOSES-
KARANKAWA
BAYOU
ALLIANCE**
agrillife.org/highlandbayou











Appendix 2 – Land Use/Land Cover Analyses (1996-2010)

Measuring Land Cover

NOAA's Coastal Change Analysis Program (C-CAP) is a remote sensing program designed to measure the type and extent of land coverage. The program provides standardized data for coastal communities to measure changes to land coverages and usages over time. High resolution data is provided for certain targeted coastal areas, including around Galveston Bay. C-CAP categorizes land cover data into over 20 categories (See Appendix 2, Table 4 for definitions), and which were used for the analyses in this report. Maps 26-29, in this appendix depicts data used from years 1996, 2001, 2006, 2010, respectively.

Changes in land coverage by type as measured over a fifteen year period are summarized in Tables 2 and 3 in this section. Analyses indicate that some minor acreage was converted to land development in both watersheds. There is a similar decline in most other land use categories, such as agricultural lands and vegetated undeveloped lands. As a percentage of the total land over the 15 year period, about 2-3% of the land was converted to developed uses.

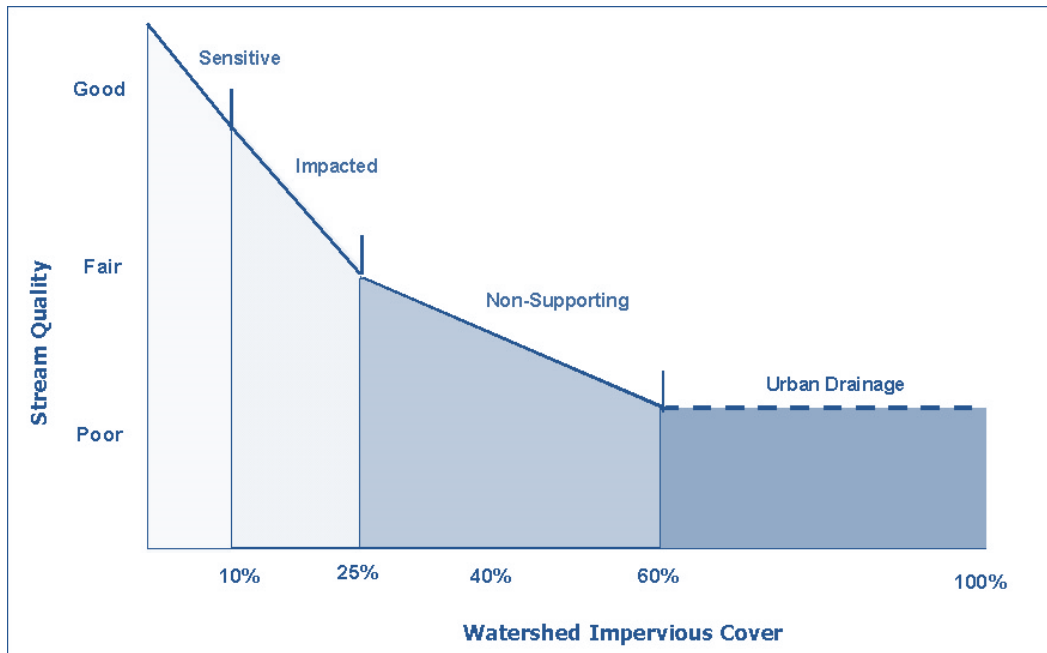
Using C-CAP data, estimates for impervious surface (IS) cover can be made for each subbasin. Ratios of impervious surface cover are defined for each C-CAP land use classification. These values range from under 20% impervious surface cover for 'open space development,' to over 80% for 'high intensity development.' Values for impervious surface cover by land cover/use are in Table 4, definitions.

Highland Bayou and Marchand Bayou are 44% and 68% developed, respectively. Based on the IS cover ratios for each development intensity, impervious surface covers an estimated 16% of Highland Bayou and 21% of Marchand Bayou (Appendix 2, Table 1). Each basin experienced an increase in impervious surface cover, ranging from 2% to 11% increases in 2006 values over 1996 values. In Highland Bayou, this means an additional 85 acres of impervious cover and in Marchand Bayou another 14 acres of impervious cover.

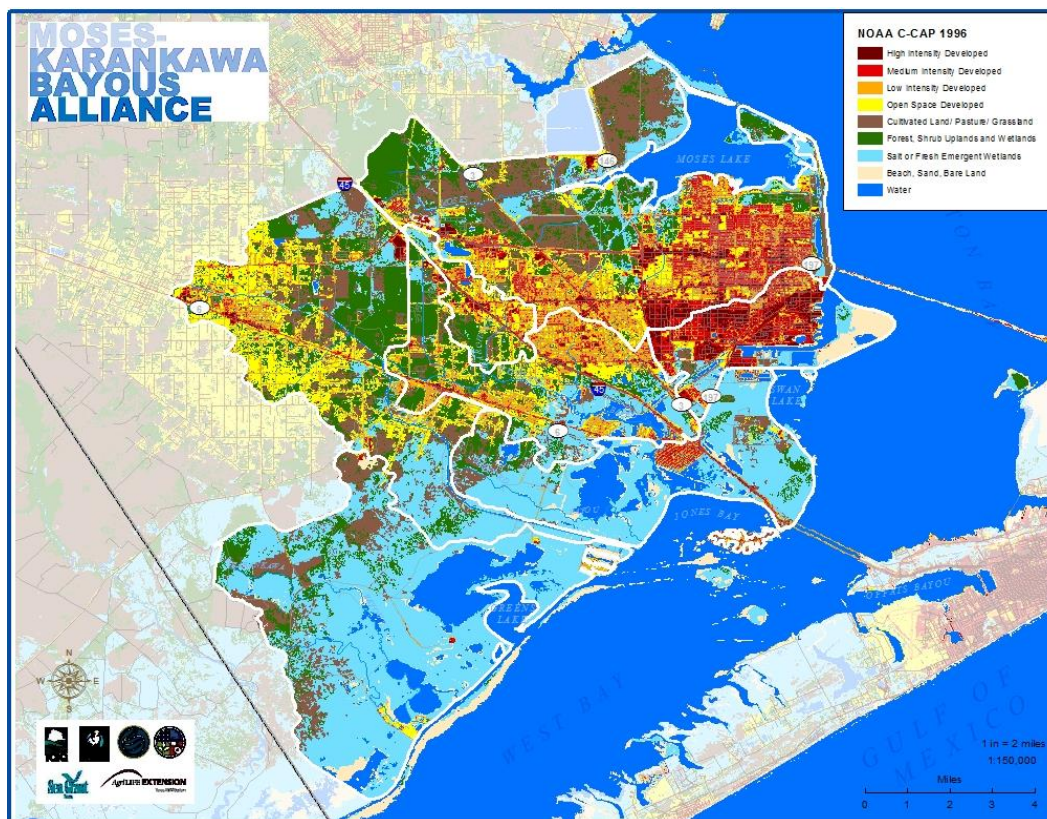
Appendix 2, Table 1. Estimate Impervious Surface (IS) Cover for the Subbasins using NOAA C-CAP Data.

| | Highland Bayou | Marchand Bayou |
|---|----------------|----------------|
| Percent Developed Acres | 44% | 68% |
| Percent Impervious Surface Cover | 16% | 21% |

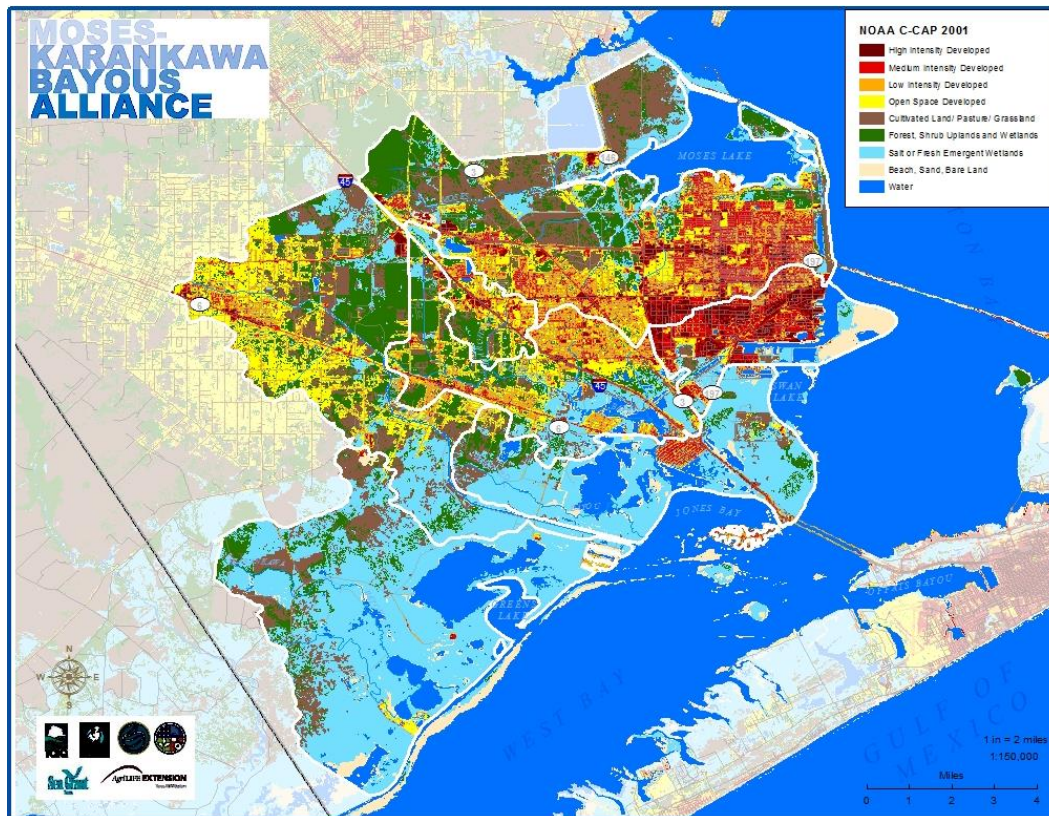
Stream habitat quality declines rapidly as impervious surface increases in the surrounding watershed. Figure 1 shows that above 25% imperviousness, stream quality indicators rapidly become non-supporting. Even with as low as 10% imperviousness, stream quality is significantly impacted. This model suggests we will get a better bang for our buck if we preserve those sensitive watersheds that have less than 25% imperviousness, and especially those that have less than 10% imperviousness.



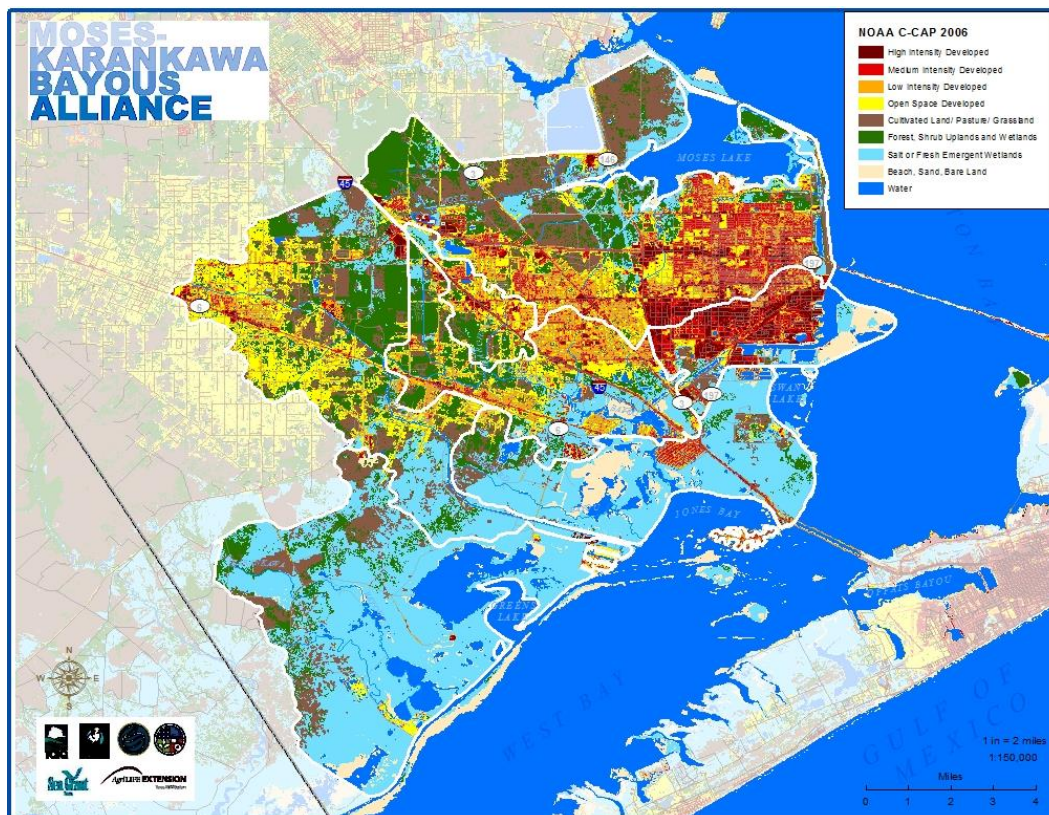
Appendix 2, Figure 1. Stream quality impacts by percent impervious cover in a watershed. Watershed Impervious Cover Model. Source: Stormwater Management Resource Center.



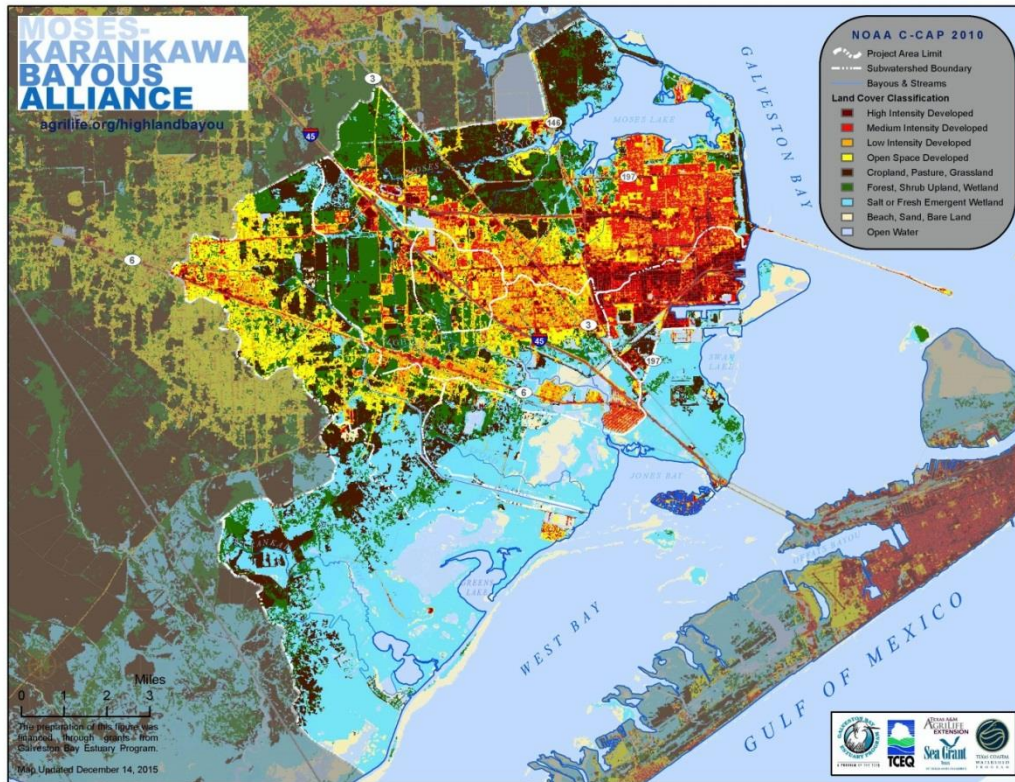
Map- 26. NOAA Coastal Change Analysis Program (C-CAP) for the entire Highland Bayou Coastal Basin Study Area, 1996.



Map- 27. NOAA C-CAP for the entire Highland Bayou Coastal Basin Study Area, 2001.



Map- 28. NOAA C-CAP for the entire Highland Bayou Coastal Basin Study Area, 2006.



Map- 29. NOAA C-CAP for the entire Highland Bayou Coastal Basin Study Area, 2010.

Appendix 2, Table 2. Summary of NOAA C-CAP for Highland Bayou Subbasin, Years 1996-2010.

| Highland Bayou | 1996 | | 2001 | | 2006 | | 2010 | 15 yr. net change |
|--|---------------|--------------|---------------|---------------|---------------|--------------|---------------|-------------------------|
| | Acres | % change | Acres | % change | Acres | % change | Acres | |
| Developed, High Intensity | 357 | 1.3% | 361 | 12.1% | 405 | 2.1% | 413 | 15.9% |
| Developed, Medium Intensity | 1058 | 1.5% | 1074 | 5.1% | 1128 | 4.2% | 1175 | 11.1% |
| Developed, Low Intensity | 1982 | 1.0% | 2001 | 2.5% | 2052 | 2.3% | 2099 | 5.9% |
| Developed, Open Space | 1532 | 0.3% | 1538 | 3.2% | 1587 | 2.2% | 1623 | 5.9% |
| Total Developed Lands | 4929 | 0.9% | 4974 | 4.0% | 5172 | 2.7% | 5310 | 7.7% |
| Cultivated Crops | 6 | 0.0% | 6 | 3.4% | 7 | 0.0% | 7 | 3.4% |
| Pasture/ Hay | 731 | -0.9% | 725 | -5.4% | 686 | -1.2% | 677 | -7.3% |
| Grassland/ Herbaceous | 638 | 1.3% | 646 | 4.6% | 676 | -3.5% | 652 | 2.3% |
| Total Agricultural Lands | 1375 | 0.1% | 1377 | -0.6% | 1368 | -2.3% | 1336 | -2.8% |
| Deciduous Forest | 608 | -1.2% | 600 | -6.3% | 563 | -4.1% | 540 | -11.2% |
| Evergreen Forest | 582 | -5.8% | 548 | -0.9% | 543 | -3.1% | 526 | -9.6% |
| Mixed Forest | 215 | -2.9% | 209 | -8.4% | 191 | -8.7% | 175 | -18.8% |
| Scrub/ Shrub | 550 | 1.4% | 558 | -11.3% | 495 | -5.5% | 467 | -15.0% |
| Total Vegetated Undeveloped Lands | 1955 | -2.0% | 1915 | -6.4% | 1792 | -4.7% | 1708 | -12.6% |
| Palustrine Forested Wetland | 937 | 0.1% | 938 | -2.6% | 914 | -1.3% | 902 | -3.7% |
| Palustrine Scrub/ Scrub Wetland | 355 | -0.5% | 354 | -4.5% | 338 | -3.2% | 327 | -8.1% |
| Palustrine Emergent Wetland | 991 | 0.8% | 999 | -2.5% | 974 | 0.3% | 977 | -1.4% |
| Estuarine Forested Wetland | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Estuarine Scrub/ Shrub Wetland | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Estuarine Emergent Wetland | 699 | 1.2% | 708 | -1.8% | 695 | -1.1% | 688 | -1.6% |
| Total Palustrine Wetlands | 2283 | 0.3% | 2290 | -2.8% | 2226 | -0.9% | 2206 | -3.4% |
| Total Estuarine Wetlands | 699 | 1.2% | 708 | -1.8% | 695 | -1.1% | 688 | -1.6% |
| Unconsolidated Shore | 216 | 0.0% | 216 | 50.4% | 325 | -0.3% | 324 | 50.0% |
| Barren Land | 30 | -77.8% | 7 | -20.0% | 5 | 0.0% | 5 | -82.2% |
| Total Beach/ Bare Lands | 246 | -9.5% | 223 | 48.3% | 331 | -0.3% | 330 | 33.9% |
| Open Water | 599 | 0.1% | 600 | -16.2% | 503 | 1.2% | 509 | -15.0% |
| Palustrine Aquatic Bed | 6 | 0.0% | 6 | 3.4% | 7 | 0.0% | 7 | 3.4% |
| Estuarine Aquatic Bed | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Total Open Water | 606 | 0.1% | 606 | -16.0% | 510 | 1.2% | 516 | -14.8% |
| Sum Check | 12,093 | | 12,093 | | 12,093 | | 12,093 | |

Appendix 2, Table 3. Summary of NOAA C-CAP for Marchand Bayou Subbasin, Years 1996-2010.

| Marchand Bayou | 1996 | | 2001 | | 2006 | | 2010 | 15 yr. net change |
|--|--------------|---------------|--------------|---------------|--------------|--------------|--------------|-------------------------|
| | Acres | % change | Acres | % change | Acres | % change | Acres | |
| Developed, High Intensity | 113 | 1.3% | 115 | 15.3% | 132 | 0.7% | 133 | 17.6% |
| Developed, Medium Intensity | 337 | 0.1% | 338 | 12.2% | 379 | 0.3% | 380 | 12.6% |
| Developed, Low Intensity | 595 | 0.0% | 596 | 4.6% | 623 | 0.2% | 625 | 4.9% |
| Developed, Open Space | 503 | 0.0% | 503 | 2.9% | 517 | 0.5% | 520 | 3.4% |
| Total Developed Lands | 1549 | 0.1% | 1551 | 6.5% | 1652 | 0.4% | 1658 | 7.0% |
| Cultivated Crops | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Pasture/ Hay | 183 | 0.0% | 183 | -28.0% | 131 | -1.2% | 130 | -28.9% |
| Grassland/ Herbaceous | 89 | 0.0% | 89 | -18.4% | 73 | 3.7% | 75 | -15.4% |
| Total Agricultural Lands | 272 | 0.0% | 272 | -24.8% | 204 | 0.5% | 205 | -24.4% |
| Deciduous Forest | 152 | 0.0% | 152 | -2.0% | 149 | 0.0% | 149 | -2.0% |
| Evergreen Forest | 121 | 0.0% | 121 | -3.4% | 117 | 6.1% | 124 | 2.5% |
| Mixed Forest | 27 | 0.0% | 27 | -3.3% | 26 | 0.0% | 26 | -3.3% |
| Scrub/ Shrub | 104 | 0.0% | 104 | -21.0% | 82 | -14.9% | 70 | -32.7% |
| Total Vegetated Undeveloped Lands | 404 | 0.0% | 404 | -7.4% | 375 | -1.4% | 369 | -8.6% |
| Palustrine Forested Wetland | 126 | 0.0% | 126 | -1.6% | 124 | 11.0% | 138 | 9.2% |
| Palustrine Scrub/ Scrub Wetland | 47 | 0.0% | 47 | -0.9% | 47 | -33.1% | 31 | -33.8% |
| Palustrine Emergent Wetland | 16 | 0.0% | 16 | -6.8% | 15 | 0.0% | 15 | -6.8% |
| Estuarine Forested Wetland | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Estuarine Scrub/ Shrub Wetland | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Estuarine Emergent Wetland | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Total Palustrine Wetlands | 190 | 0.0% | 190 | -1.9% | 186 | -1.1% | 184 | -2.9% |
| Total Estuarine Wetlands | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Unconsolidated Shore | 6 | 0.0% | 6 | 0.0% | 6 | 0.0% | 6 | 0.0% |
| Barren Land | 2 | -100.0% | 0 | 0.0% | 0 | 0.0% | 0 | -90.0% |
| Total Beach/ Bare Lands | 8 | -27.1% | 6 | 3.7% | 6 | 0.0% | 6 | -24.4% |
| Open Water | 30 | 0.0% | 30 | 0.0% | 30 | 0.0% | 30 | 0.0% |
| Palustrine Aquatic Bed | 2 | 0.0% | 2 | 0.0% | 2 | 0.0% | 2 | 0.0% |
| Estuarine Aquatic Bed | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Total Open Water | 32 | 0.0% | 32 | 0.0% | 32 | 0.0% | 32 | 0.0% |
| Sum Check | 2,455 | | 2,455 | | 2,455 | | 2,455 | |

Appendix 2, Table 4. Legend for Land Cover Types for Coastal Change Analysis Program.

| | |
|-----------------------------------|--|
| High Intensity Developed | areas where people reside or work in relatively high numbers. Examples include apartment complexes, row houses and commercial and industrial uses. Impervious Surfaces account for 80-100% of total cover. |
| Medium Intensity Developed | areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79% of the total cover. These area most commonly include single-family housing units |
| Low Intensity Developed | areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49% of the total cover. These areas most commonly include single- family housing units |
| Open Space Developed | areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single family housing units, parks, golf courses, and vegetation planting in developed settings for recreation, erosion control, or aesthetic purposes. |
| Cultivated Land | areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled. |
| Pasture/ Hay | areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation |
| Grassland | areas dominated by grammoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing |
| Deciduous Forest | areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change. |
| Evergreen Forest | areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree special maintain their leaves all year. Canopy is never without green foliage. |
| Mixed Forest | areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover. |
| Scrub/Shrub | areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions |
| Forested Wetland | areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water |
| Scrub/Shrub Wetland | areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water |
| Emergent Wetland | areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water |
| Beach; Bare Land | areas of sand, gravel pits, and other accumulations of earthen material. Generally, vegetation account for less than 15% of total cover. |
| Water; Aquatic Beds | areas of open water, generally with less than 25% cover of vegetation or soil. |

Appendix 3 – NPS Loading Table

Appendix 3, Table 1. NPS Loading in 2424A_01 by Land Use

Pollutant of Concern

Nitrogen

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 1.90 | 1.80 | 1.60 | 1.80 | 2.00 | 2.25 | 2.20 | 1.65 | - | |
| r (inches) | 21 | 16 | 26 | 16 | 21 | 19 | 9 | 7 | - | |
| a (ac.) | 267 | 321 | 107 | 1,495 | 260 | 4 | 1,271 | 42 | 490 | 4,258 ac. |
| L (lbs) | 2,460 | 2,121 | 1,013 | 9,892 | 2,436 | 41 | 182 | 3,506 | - | 21,650 lbs. |

Phosphorous

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 0.23 | 0.20 | 0.27 | 0.26 | 0.31 | 0.36 | 0.42 | 0.23 | - | |
| r (inches) | 21 | 16 | 26 | 16 | 21 | 19 | 9 | 7 | - | |
| a (ac.) | 267 | 321 | 107 | 1,495 | 260 | 4 | 1,271 | 42 | 490 | 4,258 ac. |
| L (lbs) | 298 | 236 | 171 | 1,429 | 378 | 7 | 35 | 489 | - | 3,041 lbs. |

TSS

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|----------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-----------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 135.00 | 60.00 | 135.00 | 135.00 | 190.00 | 190.00 | 130.00 | 65.00 | - | |
| r (inches) | 21 | 16 | 26 | 16 | 21 | 19 | 9 | 7 | - | |
| a (ac.) | 267 | 321 | 107 | 1,495 | 260 | 4 | 1,271 | 42 | 490 | 4,258 ac. |
| L (lbs) | 174,808 | 70,696 | 85,512 | 741,875 | 231,377 | 3,434 | 10,749 | 138,107 | - | 1,456,559 lbs. |

BOD

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 7.50 | 7.70 | 8.20 | 6.20 | 8.70 | 10.80 | 3.90 | 4.80 | - | |
| r (inches) | 21 | 16 | 26 | 16 | 21 | 19 | 9 | 7 | - | |
| a (ac.) | 267 | 321 | 107 | 1,495 | 260 | 4 | 1,271 | 42 | 490 | 4,258 ac. |
| L (lbs) | 9,712 | 9,073 | 5,194 | 34,071 | 10,595 | 195 | 322 | 10,199 | - | 79,361 lbs. |

Enterrococci

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|---------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|---------------------|
| unit conversion | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | |
| c (CFUs/100mL) | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 437.75 | 280.16 | - | |
| r (inches) | 21 | 16 | 26 | 16 | 21 | 19 | 9 | 7 | - | |
| a (ac.) | 267 | 321 | 107 | 1,495 | 260 | 4 | 1,271 | 42 | 490 | 4,258 ac. |
| L (CFUs in billions) | 22,739 | 20,691 | 11,123 | 96,501 | 21,385 | 317 | 165 | 2,714 | - | 175,635 CFUs |

Appendix 3, Table 2. NPS Loading in 2424A_02 by Land Use

Pollutant of Concern

Nitrogen

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 1.90 | 1.80 | 1.60 | 1.80 | 2.00 | 2.25 | 2.20 | 1.65 | - | |
| r (inches) | 15 | 15 | - | 15 | - | - | 8 | 6 | - | |
| a (ac.) | 9 | 3 | - | 60 | - | - | 468 | 41 | 134 | ac. |
| L (Lbs) | 57 | 16 | - | 380 | - | - | 155 | 1,126 | - | 1,734 lbs. |

Phosphorous

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-----------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 0.23 | 0.20 | 0.27 | 0.26 | 0.31 | 0.36 | 0.42 | 0.23 | - | |
| r (inches) | 15 | 15 | - | 15 | - | - | 8 | 6 | - | |
| a (ac.) | 9 | 3 | - | 60 | - | - | 468 | 41 | 134 | ac. |
| L (Lbs) | 7 | 2 | - | 55 | - | - | 30 | 157 | - | 250 lbs. |

TSS

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 135.00 | 60.00 | 135.00 | 135.00 | 190.00 | 190.00 | 130.00 | 65.00 | - | |
| r (inches) | 15 | 15 | - | 15 | - | - | 8 | 6 | - | |
| a (ac.) | 9 | 3 | - | 60 | - | - | 468 | 41 | 134 | ac. |
| L (Lbs) | 4,071 | 517 | - | 28,465 | - | - | 9,186 | 44,366 | - | 86,605 lbs. |

BOD

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 7.50 | 7.70 | 8.20 | 6.20 | 8.70 | 10.80 | 3.90 | 4.80 | - | |
| r (inches) | 15 | 15 | - | 15 | - | - | 8 | 6 | - | |
| a (ac.) | 9 | 3 | - | 60 | - | - | 468 | 41 | 134 | ac. |
| L (Lbs) | 226 | 66 | - | 1,307 | - | - | 276 | 3,276 | - | 5,152 lbs. |

Enterococci

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | |
| c (CFUs/100mL) | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 437.75 | 280.16 | - | |
| r (inches) | 15 | 15 | - | 15 | - | - | 8 | 6 | - | |
| a (ac.) | 9 | 3 | - | 60 | - | - | 468 | 41 | 134 | ac. |
| L (CFUs in billions) | 530 | 151 | - | 3,703 | - | - | 141 | 872 | - | 5,396 CFUs |

Appendix 3, Table 3. NPS Loading in 2424A_03 by Land Use

Pollutant of Concern

Nitrogen

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 1.90 | 1.80 | 1.60 | 1.80 | 2.00 | 2.25 | 2.20 | 1.65 | - | |
| r (inches) | 16 | 18 | - | 12 | 16 | 21 | 6 | 7 | 6 | |
| a (ac.) | 67 | 30 | - | 675 | 40 | 10 | 634 | 140 | 3 | ac. |
| L (Lbs) | 475 | 225 | - | 3,383 | 294 | 105 | 416 | 1,659 | - | 6,557 lbs. |

Phosphorous

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-----------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 0.23 | 0.20 | 0.27 | 0.26 | 0.31 | 0.36 | 0.42 | 0.23 | - | |
| r (inches) | 16 | 18 | - | 12 | 16 | 21 | 6 | 7 | 6 | |
| a (ac.) | 67 | 30 | - | 675 | 40 | 10 | 634 | 140 | 3 | ac. |
| L (Lbs) | 58 | 25 | - | 489 | 45 | 17 | 79 | 231 | - | 944 lbs. |

TSS

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|---------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|---------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 135.00 | 60.00 | 135.00 | 135.00 | 190.00 | 190.00 | 130.00 | 65.00 | - | |
| r (inches) | 16 | 18 | - | 12 | 16 | 21 | 6 | 7 | 6 | |
| a (ac.) | 67 | 30 | - | 675 | 40 | 10 | 634 | 140 | 3 | ac. |
| L (Lbs) | 33,784 | 7,487 | - | 253,693 | 27,883 | 8,890 | 24,568 | 65,369 | - | 421,674 lbs. |

BOD

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 7.50 | 7.70 | 8.20 | 6.20 | 8.70 | 10.80 | 3.90 | 4.80 | - | |
| r (inches) | 16 | 18 | - | 12 | 16 | 21 | 6 | 7 | 6 | |
| a (ac.) | 67 | 30 | - | 675 | 40 | 10 | 634 | 140 | 3 | ac. |
| L (Lbs) | 1,877 | 961 | - | 11,651 | 1,277 | 505 | 737 | 4,827 | - | 21,835 lbs. |

Enterococci

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | |
| c (CFUs/100mL) | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 437.75 | 280.16 | - | |
| r (inches) | 16 | 18 | - | 12 | 16 | 21 | 6 | 7 | 6 | |
| a (ac.) | 67 | 30 | - | 675 | 40 | 10 | 634 | 140 | 3 | ac. |
| L (CFUs in billions) | 4,395 | 2,191 | - | 33,000 | 2,577 | 822 | 377 | 1,284 | - | 44,646 CFUs |

Appendix 3, Table 4. NPS Loading in 2424A_04 by Land Use

Pollutant of Concern

Nitrogen

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 1.90 | 1.80 | 1.60 | 1.80 | 2.00 | 2.25 | 2.20 | 1.65 | - | |
| r (inches) | 19 | 17 | 20 | 13 | 15 | - | 7 | 7 | 5 | |
| a (ac.) | 145 | 264 | 3 | 425 | 18 | - | 979 | 334 | 5 | ac. |
| L (Lbs) | 1,204 | 1,824 | 18 | 2,182 | 117 | - | 1,134 | 2,433 | - | 8,912 lbs. |

Phosphorous

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 0.23 | 0.20 | 0.27 | 0.26 | 0.31 | 0.36 | 0.42 | 0.23 | - | |
| r (inches) | 19 | 17 | 20 | 13 | 15 | - | 7 | 7 | 5 | |
| a (ac.) | 145 | 264 | 3 | 425 | 18 | - | 979 | 334 | 5 | ac. |
| L (Lbs) | 146 | 203 | 3 | 315 | 18 | - | 217 | 339 | - | 1,240 lbs. |

TSS

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|---------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|---------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 135.00 | 60.00 | 135.00 | 135.00 | 190.00 | 190.00 | 130.00 | 65.00 | - | |
| r (inches) | 19 | 17 | 20 | 13 | 15 | - | 7 | 7 | 5 | |
| a (ac.) | 145 | 264 | 3 | 425 | 18 | - | 979 | 334 | 5 | ac. |
| L (Lbs) | 85,555 | 60,791 | 1,502 | 163,668 | 11,160 | - | 67,013 | 95,830 | - | 485,518 lbs. |

BOD

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 7.50 | 7.70 | 8.20 | 6.20 | 8.70 | 10.80 | 3.90 | 4.80 | - | |
| r (inches) | 19 | 17 | 20 | 13 | 15 | - | 7 | 7 | 5 | |
| a (ac.) | 145 | 264 | 3 | 425 | 18 | - | 979 | 334 | 5 | ac. |
| L (Lbs) | 4,753 | 7,801 | 91 | 7,517 | 511 | - | 2,010 | 7,077 | - | 29,760 lbs. |

Enterococci

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|---------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | |
| c (CFUs/100mL) | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 437.75 | 280.16 | - | |
| r (inches) | 19 | 17 | 20 | 13 | 15 | - | 7 | 7 | 5 | |
| a (ac.) | 145 | 264 | 3 | 425 | 18 | - | 979 | 334 | 5 | ac. |
| L (CFUs in billions) | 11,129 | 17,792 | 195 | 21,290 | 1,031 | - | 1,029 | 1,883 | - | 54,349 CFUs |

Appendix 3, Table 5. NPS Loading in 2424A_05 by Land Use

Pollutant of Concern

Nitrogen

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 1.90 | 1.80 | 1.60 | 1.80 | 2.00 | 2.25 | 2.20 | 1.65 | - | |
| r (inches) | 18 | 25 | - | 13 | 14 | - | 5 | 6 | - | |
| a (ac.) | 67 | 171 | - | 300 | 7 | - | 1,942 | 466 | - | ac. |
| L (Lbs) | 524 | 1,716 | - | 1,571 | 48 | - | 1,193 | 4,550 | - | 9,602 lbs. |

Phosphorous

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 0.23 | 0.20 | 0.27 | 0.26 | 0.31 | 0.36 | 0.42 | 0.23 | - | |
| r (inches) | 18 | 25 | - | 13 | 14 | - | 5 | 6 | - | |
| a (ac.) | 67 | 171 | - | 300 | 7 | - | 1,942 | 466 | - | ac. |
| L (Lbs) | 63 | 191 | - | 227 | 8 | - | 228 | 634 | - | 1,351 lbs. |

TSS

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|---------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|---------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 135.00 | 60.00 | 135.00 | 135.00 | 190.00 | 190.00 | 130.00 | 65.00 | - | |
| r (inches) | 18 | 25 | - | 13 | 14 | - | 5 | 6 | - | |
| a (ac.) | 67 | 171 | - | 300 | 7 | - | 1,942 | 466 | - | ac. |
| L (Lbs) | 37,205 | 57,195 | - | 117,834 | 4,599 | - | 70,500 | 179,252 | - | 466,585 lbs. |

BOD

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 7.50 | 7.70 | 8.20 | 6.20 | 8.70 | 10.80 | 3.90 | 4.80 | - | |
| r (inches) | 18 | 25 | - | 13 | 14 | - | 5 | 6 | - | |
| a (ac.) | 67 | 171 | - | 300 | 7 | - | 1,942 | 466 | - | ac. |
| L (Lbs) | 2,067 | 7,340 | - | 5,412 | 211 | - | 2,115 | 13,237 | - | 30,381 lbs. |

Enterrococci

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | |
| c (CFUs/100mL) | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 437.75 | 280.16 | - | |
| r (inches) | 18 | 25 | - | 13 | 14 | - | 5 | 6 | - | |
| a (ac.) | 67 | 171 | - | 300 | 7 | - | 1,942 | 466 | - | ac. |
| L (CFUs in billions) | 4,839 | 16,739 | - | 15,328 | 425 | - | 1,082 | 3,522 | - | 41,936 CFUs |

Appendix 3, Table 6. NPS Loading in 2424C by Land Use

Pollutant of Concern

Nitrogen

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 1.90 | 1.80 | 1.60 | 1.80 | 2.00 | 2.25 | 2.20 | 1.65 | - | |
| r (inches) | 19 | 19 | - | 15 | 17 | 21 | 8 | 7 | - | |
| a (ac.) | 112 | 345 | - | 941 | 138 | 5 | 849 | 48 | 17 | ac. |
| L (Lbs) | 928 | 2,629 | - | 5,588 | 1,083 | 49 | 190 | 2,282 | - | 12,749 lbs. |

Phosphorous

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 0.23 | 0.20 | 0.27 | 0.26 | 0.31 | 0.36 | 0.42 | 0.23 | - | |
| r (inches) | 19 | 19 | - | 15 | 17 | 21 | 8 | 7 | - | |
| a (ac.) | 112 | 345 | - | 941 | 138 | 5 | 849 | 48 | 17 | ac. |
| L (Lbs) | 112 | 292 | - | 807 | 168 | 8 | 36 | 318 | - | 1,742 lbs. |

TSS

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|---------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|---------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 135.00 | 60.00 | 135.00 | 135.00 | 190.00 | 190.00 | 130.00 | 65.00 | - | |
| r (inches) | 19 | 19 | - | 15 | 17 | 21 | 8 | 7 | - | |
| a (ac.) | 112 | 345 | - | 941 | 138 | 5 | 849 | 48 | 17 | ac. |
| L (Lbs) | 65,931 | 87,649 | - | 419,071 | 102,922 | 4,127 | 11,217 | 89,880 | - | 780,797 lbs. |

BOD

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 7.50 | 7.70 | 8.20 | 6.20 | 8.70 | 10.80 | 3.90 | 4.80 | - | |
| r (inches) | 19 | 19 | - | 15 | 17 | 21 | 8 | 7 | - | |
| a (ac.) | 112 | 345 | - | 941 | 138 | 5 | 849 | 48 | 17 | ac. |
| L (Lbs) | 3,663 | 11,248 | - | 19,246 | 4,713 | 235 | 337 | 6,637 | - | 46,078 lbs. |

Enterococci

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|---------------------|
| unit conversion | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | |
| c (CFUs/100mL) | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 437.75 | 280.16 | - | |
| r (inches) | 19 | 19 | - | 15 | 17 | 21 | 8 | 7 | - | |
| a (ac.) | 112 | 345 | - | 941 | 138 | 5 | 849 | 48 | 17 | ac. |
| L (CFUs in billions) | 8,576 | 25,653 | - | 54,512 | 9,512 | 381 | 172 | 1,766 | - | 100,573 CFUs |

Appendix 3, Table 7. Nitrogen Loading in Pounds by Assessment Unit**2424A_01**

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 1.90 | 1.80 | 1.60 | 1.80 | 2.00 | 2.25 | 2.20 | 1.65 | - | |
| r (in.) | 21 | 16 | 26 | 16 | 21 | 19 | 9 | 7 | - | |
| a (ac.) | 267 | 321 | 107 | 1,495 | 260 | 4 | 1,271 | 42 | 490 | 4,258 ac. |
| L (lb) | 2,460 | 2,121 | 1,013 | 9,892 | 2,436 | 41 | 182 | 3,506 | - | 21,650 lbs |

2424A_02

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 1.90 | 1.80 | 1.60 | 1.80 | 2.00 | 2.25 | 2.20 | 1.65 | - | |
| r (in.) | 15 | 15 | - | 15 | - | - | 8 | 6 | - | |
| a (ac.) | 9 | 3 | - | 60 | - | - | 468 | 41 | 134 | 715 ac. |
| L (lb) | 57 | 16 | - | 380 | - | - | 155 | 1,126 | - | 1,734 lbs |

2424A_03

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 1.90 | 1.80 | 1.60 | 1.80 | 2.00 | 2.25 | 2.20 | 1.65 | - | |
| r (in.) | 16 | 18 | - | 12 | 16 | 21 | 6 | 7 | 6 | |
| a (ac.) | 67 | 30 | - | 675 | 40 | 10 | 634 | 140 | 3 | 1,599 ac. |
| L (lb) | 475 | 225 | - | 3,383 | 294 | 105 | 416 | 1,659 | - | 6,557 lbs |

2424A_04

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 1.90 | 1.80 | 1.60 | 1.80 | 2.00 | 2.25 | 2.20 | 1.65 | - | |
| r (in.) | 19 | 17 | 20 | 13 | 15 | - | 7 | 7 | 5 | |
| a (ac.) | 145 | 264 | 3 | 425 | 18 | - | 979 | 334 | 5 | 2,172 ac. |
| L (lb) | 1,204 | 1,824 | 18 | 2,182 | 117 | - | 1,134 | 2,433 | - | 8,912 lbs |

2424A_05

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 1.90 | 1.80 | 1.60 | 1.80 | 2.00 | 2.25 | 2.20 | 1.65 | - | |
| r (in.) | 18 | 25 | - | 13 | 14 | - | 5 | 6 | - | |
| a (ac.) | 67 | 171 | - | 300 | 7 | - | 1,942 | 466 | - | 2,955 ac. |
| L (lb) | 524 | 1,716 | - | 1,571 | 48 | - | 1,193 | 4,550 | - | 9,602 lbs |

2424C

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (CFU/100mL) | 1.90 | 1.80 | 1.60 | 1.80 | 2.00 | 2.25 | 2.20 | 1.65 | - | |
| r (in.) | 19 | 19 | - | 15 | 17 | 21 | 8 | 7 | - | |
| a (ac.) | 112 | 345 | - | 941 | 138 | 5 | 849 | 48 | 17 | 2,455 ac. |
| L (CFUs in Billions) | 928 | 2,629 | - | 5,588 | 1,083 | 49 | 190 | 2,282 | - | 12,749 lbs |

Total Load (lbs) in Basin = 61,204

Appendix 3, Table 8. Phosphorus Loading in Pounds by Assessment Unit**2424A_01**

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 0.23 | 0.20 | 0.27 | 0.26 | 0.31 | 0.36 | 0.42 | 0.23 | - | |
| r (in.) | 21 | 16 | 26 | 16 | 21 | 19 | 9 | 7 | - | |
| a (ac.) | 267 | 321 | 107 | 1,495 | 260 | 4 | 1,271 | 42 | 490 | 4,258 ac. |
| L (lb) | 298 | 236 | 171 | 1,429 | 378 | 7 | 35 | 489 | - | 3,041 lbs |

2424A_02

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|----------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 0.23 | 0.20 | 0.27 | 0.26 | 0.31 | 0.36 | 0.42 | 0.23 | - | |
| r (in.) | 15 | 15 | - | 15 | - | - | 8 | 6 | - | |
| a (ac.) | 9 | 3 | - | 60 | - | - | 468 | 41 | 134 | 715 ac. |
| L (lb) | 7 | 2 | - | 55 | - | - | 30 | 157 | - | 250 lbs |

2424A_03

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|----------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 0.23 | 0.20 | 0.27 | 0.26 | 0.31 | 0.36 | 0.42 | 0.23 | - | |
| r (in.) | 16 | 18 | - | 12 | 16 | 21 | 6 | 7 | 6 | |
| a (ac.) | 67 | 30 | - | 675 | 40 | 10 | 634 | 140 | 3 | 1,599 ac. |
| L (lb) | 58 | 25 | - | 489 | 45 | 17 | 79 | 231 | - | 944 lbs |

2424A_04

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 0.23 | 0.20 | 0.27 | 0.26 | 0.31 | 0.36 | 0.42 | 0.23 | - | |
| r (in.) | 19 | 17 | 20 | 13 | 15 | - | 7 | 7 | 5 | |
| a (ac.) | 145 | 264 | 3 | 425 | 18 | - | 979 | 334 | 5 | 2,172 ac. |
| L (lb) | 146 | 203 | 3 | 315 | 18 | - | 217 | 339 | - | 1,240 lbs |

2424A_05

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 0.23 | 0.20 | 0.27 | 0.26 | 0.31 | 0.36 | 0.42 | 0.23 | - | |
| r (in.) | 18 | 25 | - | 13 | 14 | - | 5 | 6 | - | |
| a (ac.) | 67 | 171 | - | 300 | 7 | - | 1,942 | 466 | - | 2,955 ac. |
| L (lb) | 63 | 191 | - | 227 | 8 | - | 228 | 634 | - | 1,351 lbs |

2424C

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (CFU/100mL) | 0.23 | 0.20 | 0.27 | 0.26 | 0.31 | 0.36 | 0.42 | 0.23 | - | |
| r (in.) | 19 | 19 | - | 15 | 17 | 21 | 8 | 7 | - | |
| a (ac.) | 112 | 345 | - | 941 | 138 | 5 | 849 | 48 | 17 | 2,455 ac. |
| L (CFUs in Billions) | 112 | 292 | - | 807 | 168 | 8 | 36 | 318 | - | 1,742 lbs |

Total Load (lbs) in Basin = 8,568

Appendix 3, Table 9. TSS Loading in Pounds by Assessment Unit**2424A_01**

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|----------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|----------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 135.00 | 60.00 | 135.00 | 135.00 | 190.00 | 190.00 | 130.00 | 65.00 | - | |
| r (in.) | 21 | 16 | 26 | 16 | 21 | 19 | 9 | 7 | - | |
| a (ac.) | 267 | 321 | 107 | 1,495 | 260 | 4 | 1,271 | 42 | 490 | 4,258 ac. |
| L (lb) | 174,808 | 70,696 | 85,512 | 741,875 | 231,377 | 3,434 | 10,749 | 138,107 | - | 1,456,559 lbs |

2424A_02

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 135.00 | 60.00 | 135.00 | 135.00 | 190.00 | 190.00 | 130.00 | 65.00 | - | |
| r (in.) | 15 | 15 | - | 15 | - | - | 8 | 6 | - | |
| a (ac.) | 9 | 3 | - | 60 | - | - | 468 | 41 | 134 | 715 ac. |
| L (lb) | 4,071 | 517 | - | 28,465 | - | - | 9,186 | 44,366 | - | 86,605 lbs |

2424A_03

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|---------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 135.00 | 60.00 | 135.00 | 135.00 | 190.00 | 190.00 | 130.00 | 65.00 | - | |
| r (in.) | 16 | 18 | - | 12 | 16 | 21 | 6 | 7 | 6 | |
| a (ac.) | 67 | 30 | - | 675 | 40 | 10 | 634 | 140 | 3 | 1,599 ac. |
| L (lb) | 33,784 | 7,487 | - | 253,693 | 27,883 | 8,890 | 24,568 | 65,369 | - | 421,674 lbs |

2424A_04

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|---------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 135.00 | 60.00 | 135.00 | 135.00 | 190.00 | 190.00 | 130.00 | 65.00 | - | |
| r (in.) | 19 | 17 | 20 | 13 | 15 | - | 7 | 7 | 5 | |
| a (ac.) | 145 | 264 | 3 | 425 | 18 | - | 979 | 334 | 5 | 2,172 ac. |
| L (lb) | 85,555 | 60,791 | 1,502 | 163,668 | 11,160 | - | 67,013 | 95,830 | - | 485,518 lbs |

2424A_05

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|---------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 135.00 | 60.00 | 135.00 | 135.00 | 190.00 | 190.00 | 130.00 | 65.00 | - | |
| r (in.) | 18 | 25 | - | 13 | 14 | - | 5 | 6 | - | |
| a (ac.) | 67 | 171 | - | 300 | 7 | - | 1,942 | 466 | - | 2,955 ac. |
| L (lb) | 37,205 | 57,195 | - | 117,834 | 4,599 | - | 70,500 | 179,252 | - | 466,585 lbs |

2424C

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|---------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (CFU/100mL) | 135.00 | 60.00 | 135.00 | 135.00 | 190.00 | 190.00 | 130.00 | 65.00 | - | |
| r (in.) | 19 | 19 | - | 15 | 17 | 21 | 8 | 7 | - | |
| a (ac.) | 112 | 345 | - | 941 | 138 | 5 | 849 | 48 | 17 | 2,455 ac. |
| L (CFUs in Billions) | 65,931 | 87,649 | - | 419,071 | 102,922 | 4,127 | 11,217 | 89,880 | - | 780,797 lbs |

Total Load (lbs) in Basin = 3,697,738

Appendix 3, Table 10. BOD Loading in Pounds by Assessment Unit**2424A_01**

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 7.50 | 7.70 | 8.20 | 6.20 | 8.70 | 10.80 | 3.90 | 4.80 | - | |
| r (in.) | 21 | 16 | 26 | 16 | 21 | 19 | 9 | 7 | - | |
| a (ac.) | 267 | 321 | 107 | 1,495 | 260 | 4 | 1,271 | 42 | 490 | 4,258 ac. |
| L (lb) | 9,712 | 9,073 | 5,194 | 34,071 | 10,595 | 195 | 322 | 10,199 | - | 79,361 lbs |

2424A_02

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 7.50 | 7.70 | 8.20 | 6.20 | 8.70 | 10.80 | 3.90 | 4.80 | - | |
| r (in.) | 15 | 15 | - | 15 | - | - | 8 | 6 | - | |
| a (ac.) | 9 | 3 | - | 60 | - | - | 468 | 41 | 134 | 715 ac. |
| L (lb) | 226 | 66 | - | 1,307 | - | - | 276 | 3,276 | - | 5,152 lbs |

2424A_03

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 7.50 | 7.70 | 8.20 | 6.20 | 8.70 | 10.80 | 3.90 | 4.80 | - | |
| r (in.) | 16 | 18 | - | 12 | 16 | 21 | 6 | 7 | 6 | |
| a (ac.) | 67 | 30 | - | 675 | 40 | 10 | 634 | 140 | 3 | 1,599 ac. |
| L (lb) | 1,877 | 961 | - | 11,651 | 1,277 | 505 | 737 | 4,827 | - | 21,835 lbs |

2424A_04

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 7.50 | 7.70 | 8.20 | 6.20 | 8.70 | 10.80 | 3.90 | 4.80 | - | |
| r (in.) | 19 | 17 | 20 | 13 | 15 | - | 7 | 7 | 5 | |
| a (ac.) | 145 | 264 | 3 | 425 | 18 | - | 979 | 334 | 5 | 2,172 ac. |
| L (lb) | 4,753 | 7,801 | 91 | 7,517 | 511 | - | 2,010 | 7,077 | - | 29,760 lbs |

2424A_05

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (mg/L) | 7.50 | 7.70 | 8.20 | 6.20 | 8.70 | 10.80 | 3.90 | 4.80 | - | |
| r (in.) | 18 | 25 | - | 13 | 14 | - | 5 | 6 | - | |
| a (ac.) | 67 | 171 | - | 300 | 7 | - | 1,942 | 466 | - | 2,955 ac. |
| L (lb) | 2,067 | 7,340 | - | 5,412 | 211 | - | 2,115 | 13,237 | - | 30,381 lbs |

2424C

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | 0.226 | |
| c (CFU/100mL) | 7.50 | 7.70 | 8.20 | 6.20 | 8.70 | 10.80 | 3.90 | 4.80 | - | |
| r (in.) | 19 | 19 | - | 15 | 17 | 21 | 8 | 7 | - | |
| a (ac.) | 112 | 345 | - | 941 | 138 | 5 | 849 | 48 | 17 | 2,455 ac. |
| L (CFUs in Billions) | 3,663 | 11,248 | - | 19,246 | 4,713 | 235 | 337 | 6,637 | - | 46,078 lbs |

Total Load (lbs) in Basin = 212,568

Appendix 3, Table 11. Entero Loading in CFUs (billions) by Assessment Unit**2424A_01**

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|---------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|---------------------|
| unit conversion | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | |
| c (mg/L) | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 437.75 | 280.16 | - | |
| r (in.) | 21 | 16 | 26 | 16 | 21 | 19 | 9 | 7 | - | |
| a (ac.) | 267 | 321 | 107 | 1,495 | 260 | 4 | 1,271 | 42 | 490 | 4,258 ac. |
| L (CFUs in Billions) | 22,739 | 20,691 | 11,123 | 96,501 | 21,385 | 317 | 165 | 2,714 | - | 175,635 CFUs |

2424A_02

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|-------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|-------------------|
| unit conversion | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | |
| c (mg/L) | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 437.75 | 280.16 | - | |
| r (in.) | 15 | 15 | - | 15 | - | - | 8 | 6 | - | |
| a (ac.) | 9 | 3 | - | 60 | - | - | 468 | 41 | 134 | 715 ac. |
| L (CFUs in Billions) | 530 | 151 | - | 3,703 | - | - | 141 | 872 | - | 5,396 CFUs |

2424A_03

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | |
| c (mg/L) | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 437.75 | 280.16 | - | |
| r (in.) | 16 | 18 | - | 12 | 16 | 21 | 6 | 7 | 6 | |
| a (ac.) | 67 | 30 | - | 675 | 40 | 10 | 634 | 140 | 3 | 1,599 ac. |
| L (CFUs in Billions) | 4,395 | 2,191 | - | 33,000 | 2,577 | 822 | 377 | 1,284 | - | 44,646 CFUs |

2424A_04

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|---------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | |
| c (mg/L) | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 437.75 | 280.16 | - | |
| r (in.) | 19 | 17 | 20 | 13 | 15 | - | 7 | 7 | 5 | |
| a (ac.) | 145 | 264 | 3 | 425 | 18 | - | 979 | 334 | 5 | 2,172 ac. |
| L (CFUs in Billions) | 11,129 | 17,792 | 195 | 21,290 | 1,031 | - | 1,029 | 1,883 | - | 54,349 CFUs |

2424A_05

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|--------------------|
| unit conversion | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | |
| c (mg/L) | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 437.75 | 280.16 | - | |
| r (in.) | 18 | 25 | - | 13 | 14 | - | 5 | 6 | - | |
| a (ac.) | 67 | 171 | - | 300 | 7 | - | 1,942 | 466 | - | 2,955 ac. |
| L (CFUs in Billions) | 4,839 | 16,739 | - | 15,328 | 425 | - | 1,082 | 3,522 | - | 41,936 CFUs |

2424C

| <i>Primary Use or Cover</i> | <i>Road</i> | <i>Commercial</i> | <i>Industrial</i> | <i>0-4 DUA</i> | <i>4-8 DUA</i> | <i>8-16 DUA</i> | <i>Agriculture</i> | <i>Non-Ag/Undev</i> | <i>Water</i> | <i>Total</i> |
|-----------------------------|--------------|-------------------|-------------------|----------------|----------------|-----------------|--------------------|---------------------|--------------|---------------------|
| unit conversion | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | 0.00103 | |
| c (CFU/100mL) | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 3,852.20 | 437.75 | 280.16 | - | |
| r (in.) | 19 | 19 | - | 15 | 17 | 21 | 8 | 7 | - | |
| a (ac.) | 112 | 345 | - | 941 | 138 | 5 | 849 | 48 | 17 | 2,455 ac. |
| L (CFUs in Billions) | 8,576 | 25,653 | - | 54,512 | 9,512 | 381 | 172 | 1,766 | - | 100,573 CFUs |

Total Load (CFUs in billions) in Basin = 422,534

Appendix 4 – Stormwater BMP Factsheets



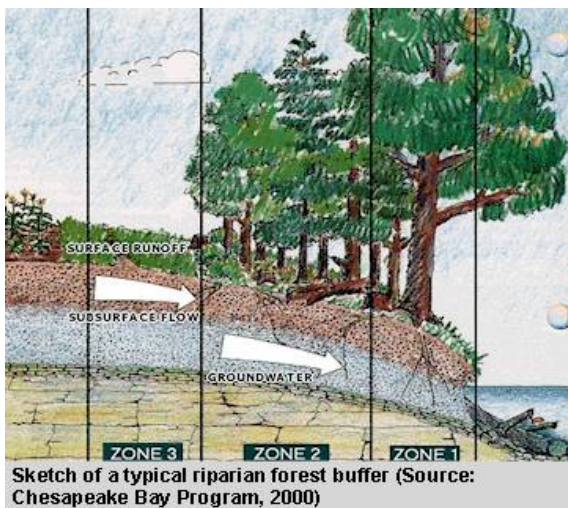
FORESTED RIPARIAN BUFFER

Stormwater Best Management Practices

8

What is a forested riparian buffer?

A forested riparian buffer is a stretch of land that intercepts surface runoff and groundwater before reaching a body of water such as a stream, lake or wetland. It can help reduce pollution in the water body, provide stormwater management and can act as a floodway during major storm events. Buffer widths vary by slope and existing conditions.



Sketch of a typical riparian forest buffer (Source: Chesapeake Bay Program, 2000)

Are there other names for this type of system?

Yes, there are three types of buffers that make up this system. A forested riparian buffer may also be called a Water Pollution Hazard Setback, Vegetated Buffer or Engineered Buffer.

How is a forested riparian buffer designed?

Zone 1 is a minimum of 25 feet wide plus wetland and critical habitats. The typical vegetation in this zone is an established forest. **Zone 2** is typically 50 – 100 feet wide and the vegetation should be a managed forest. **Zone 3** is a minimum of 25 feet wide. The vegetation in this zone should be either a managed forest or turf-grass. With good design and conditions, buffer widths can be as narrow as soft. The slope of the buffer should be between 1% and 15%. One study performed by the California Stormwater Quality Association determined that the maximum width of the tributary area should be 60 ft. and the length should be equal to the buffer. This design standard is able to handle a 2 year-storm without altering its performance. Maintenance of vegetation s and banks may be necessary.

Are there any secondary uses for a forested riparian buffer?

Yes, but there are some restrictions on what you can put in each of the zones. **Zone 1** is only allowed to be used for flood control, utility right-of-ways or footpaths. **Zone 2** can be used for some recreational activities, some stormwater BMPs and bike paths. There are no restrictions for **Zone 3**.



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How much does it cost to install and maintain a forested riparian buffer?

The actual amount to construct and maintain a riparian buffer is highly dependent on the length and width of the buffer and existing conditions. One study conducted in 2006 by the Chesapeake Bay Program determined that it would cost approximately \$3,000.00 - \$7,500.00 per acre to plant and maintain a forested riparian buffer.

Are there any special considerations?

A forested riparian buffer is effective at removing pollutants when the incoming stormwater runoff is evenly distributed along the buffer. If a channel were to be created in the buffer, large quantities of water would flow through the channel and not get filtered by the buffer. Special care should be taken so that channels do not form in the buffer and that the water is evenly dispersed throughout the buffer.

Who should use a forested riparian buffer?

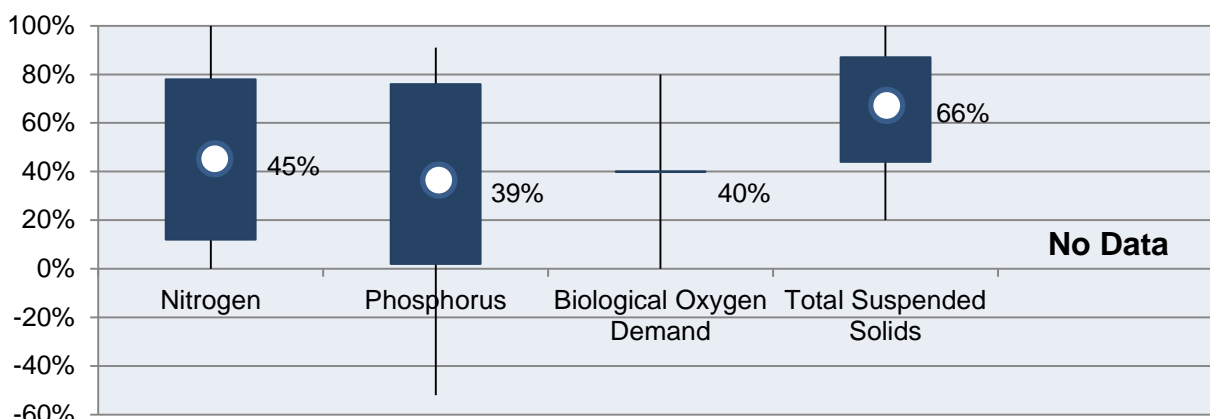
The larger size required for a forested riparian buffer limits the possible land applications.

Typically, they are applied near new developments with the buffer as an established preservation area. They are then maintained through easements or a community association. Buffers can also be installed in existing developed areas but may require an easement from landowners.

How effective is a forested riparian buffer at removing pollutants?

The data shown in the graph was obtained from 8 separate studies. A forested riparian buffer is able to remove approximately 45% of the nitrogen, 39% of the phosphorus, 40% of the BOD and 66% of the TSS from stormwater runoff.

Percent Removal of Pollutants



The top of the line represents the maximum value found and the bottom of the line represents the minimum value found. The white point signifies the average of all the found values, also shown numerically next to the white point. The solid colored box represents one standard deviation plus or minus the average. This means 68% of the found values lie within the range of the solid colored box.

Content in this fact sheet was extracted from U.S. EPA National Menu of Best Management Practices



Texas NEMO is an educational program of Texas A&M University, Texas Sea Grant and the Texas AgriLife Extension service, and is an official partner of the National NEMO Network. In addition to support from TAMU, NEMO is funded by grants from the EPA, TCEQ and GBEP.



GRASSED SWALE

Stormwater Best Management Practices

9

What is a grassed swale?

A grassed swale is a stretch of land with a depression that is designed to remove pollutants from stormwater runoff. It is able to do this by slowing down the water before draining offsite. A grassed swale can be thought of as a broad, shallow vegetated drainage ditch. The main difference between a swale and a filter strip is that swales receive concentrated flows and filter strips receive evenly distributed flows.



Grassed swales can be used along roadsides and parking lots to collect and treat stormwater runoff

Source: EPA, 2001

Are there any secondary uses for a grassed swale?

Grassed swales are typically also used to transport stormwater runoff. A well designed grass swale should be able to handle a 2-year storm with little to no erosion. This same grassed swale should also be capable of handling a 10-year storm safely.

How is a grassed swale designed?

It is recommended that grassed swales be built on land with a 1-2 percent slope. However, it is acceptable to build a grassed swale on land with up to a 4 percent slope. Grassed swales typically have a trapezoidal or semi-circular cross-sectional area and the rate of pollutant removal is directly proportional to the cross-sectional area. The swale should be 2-8 ft. wide at the bottom and the length should be long enough to hold the water for 10 minutes. The length of the swale is calculated by multiplying the velocity (ft. / s.) by 600 s., the residence time of the water. Swales can be used to treat up to 5 acres of on-site drainage. The soil in the grassed swale area should also be permeable to allow for infiltration. Any water pooled after a storm event should be completely gone within 48 hours. Grassed swales work best in series with other best management practices to achieve the highest rate of pollution removal. For example, a grassed swale could drain into a dry detention basin for further treatment.

Are there other types of swales?

Yes, there are four variations on this type of system which include dry swale, wet swale, biofilter, and bioswale. A grassed swale can also be referred to as an open channel, infiltration swale, or vegetated swale.



BEST MANAGEMENT PRACTICES 9

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How much does it cost to install and maintain a grassed swale?

A grassed swale requires regular maintenance like any grassy area or lawn. Litter that accumulates through the stormwater runoff must be frequently collected to maintain its effectiveness. One evaluation performed by the EPA in 2001 suggests that it would cost \$0.50 per square ft. to install a grassed swale.

Are there any special considerations?

Grassed swales also act as a drainage ditch for many different types of projects. If a drainage ditch is already planned it is more appropriate to look at the cost of a grassed swale versus a concrete drainage ditch. Generally, it is much cheaper to construct a grassed swale than it is to construct a concrete drainage ditch.

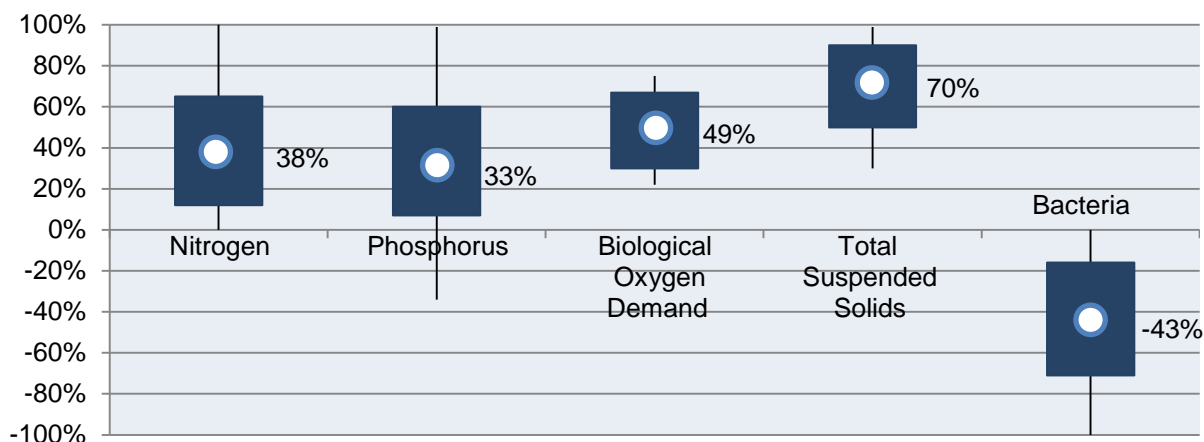
Who should use a grassed swale?

Grassed swales are ideal for residential areas and near roads and highways. They are well suited for these locations because they are a more environmentally friendly solution to the typical concrete drainage ditch. The linearity of the swale mirrors the road and swales are less hazardous than the steep and deep concrete drainage ditches.

How effective is a grassed swale at removing pollutants?

The data shown in the following table and graph were obtained from 42 separate studies. A grassed swale is able to remove approximately 38% of the nitrogen, 33% of the phosphorus, 49% of the BOD, 70% of the TSS, and -43% of the bacteria from stormwater runoff.

Percent Removal of Pollutants



The top of the line represents the maximum value found and the bottom of the line represents the minimum value found. The white point signifies the average of all the found values, also shown numerically next to the white point. The solid colored box represents one standard deviation plus or minus the average. This means 68% of the found values lie within the range of the solid colored box.

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INFILTRATION BASIN

Stormwater Best Management Practices

10

What is an infiltration basin?

An infiltration basin is a shallow reservoir that is intended to let stormwater permeate into the ground. By letting the stormwater soak into the soil, this system is able to filter out many of the large and small particles and dissolved pollutants. The biggest difference between an infiltration basin and a dry detention basin is that all water that enters an infiltration basin should permeate the ground.



Infiltration basins are designed to collect stormwater from impervious areas and provide pollutant removal benefits through detention and filtration

Source: EPA, 2001

Are there any secondary uses for an infiltration basin?

Yes, the water that flows into the infiltration basin can recharge the groundwater. Stream systems will also benefit from this because the groundwater flows into the streams.

How is an infiltration basin designed?

Infiltration basin sizes are typically 2%-3% of the site that is draining to them. Typically, an infiltration basin will be used in areas less than 10 acres. The soil surrounding the basin should be highly stable so that it does not clog the basin with sediment. The soil in the basin should be highly permeable; soils in infiltration basins are typically sandy, in order to prevent clogging or slow drainage. Most basins are designed so that they can be emptied within 3 or 4 days. Infiltration basins cannot handle very large inflows and therefore are typically used in conjunction with a flow separator to divert excess stormwater from the basin. Many times a drain is also installed so that if the basin becomes clogged, the basin can still be drained and maintenance can be performed.

Where is this type of system most effective?

Infiltration basins can be constructed most anywhere in the country. The biggest exception is areas that are near regions with highly contaminated runoff. The contaminated runoff is less likely to be filtered properly, and could leach into the groundwater. Also, infiltration basins typically require 2%-3% of the site draining to them, and would not be an appropriate system to place in an ultra-urban area.



How much does it cost to install and maintain an infiltration basin?

Costs are highly variable and are largely based upon the permeability of the soil. CED Engineering estimated in 2001 that it would cost approximately \$2 per cubic ft. of storage. Maintenance is also variable. A large portion of the cost comes intermittently to unclog the system.

Are there any special considerations?

Infiltration basins work well in many conditions. When infiltration basins were first put into use they would frequently clog and leave standing water in the basin for many days. This kept the removal rates very low. If an infiltration basin is used as a BMP it should be rigorously maintained so that clogging does not occur. If the area has highly permeable soil it is less likely to clog.

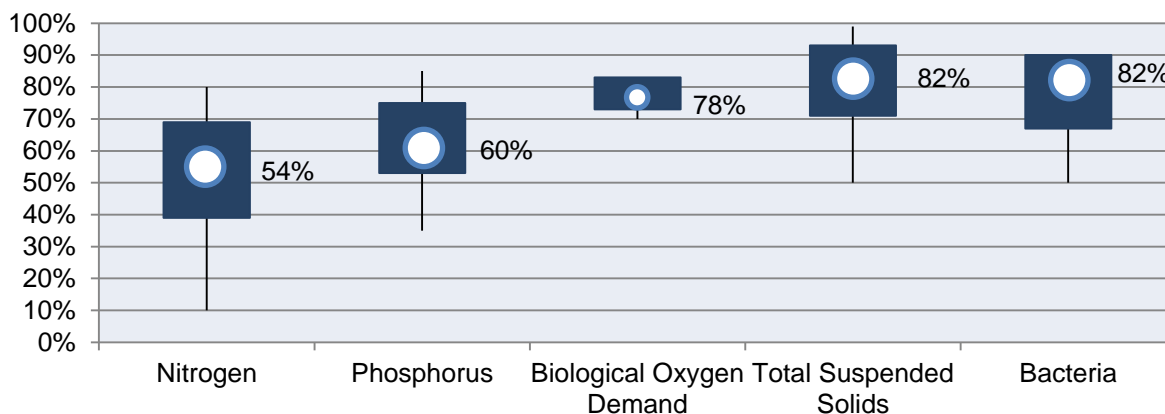
Who should use an infiltration basin?

Typically, infiltration basins have been used as regional facilities, serving for both water quantity and quality control. An infiltration basin's quality control is highly variable upon the type of soil in the area. This type of BMP is most appropriate for areas with sandy soil.

How effective is an infiltration basin at removing pollutants?

The data shown in the following table and graph were obtained from 23 separate studies. An infiltration basin is able to remove approximately 54% of the nitrogen, 60% of the phosphorus, 78% of the BOD, 82% of the TSS and 82% of the bacteria from stormwater runoff.

Percent Removal of Pollutants



The top of the line represents the maximum value found and the bottom of the line represents the minimum value found. The white point signifies the average of all the found values, also shown numerically next to the white point. The solid colored box represents one standard deviation plus or minus the average. This means 68% of the found values lie within the range of the solid colored box.



INFILTRATION TRENCH

Stormwater Best Management Practices

11

What is an infiltration trench?

An infiltration trench is a channel with no outlet that is filled with rocks. The trench receives stormwater runoff which is held in the trench until it is absorbed into the soil. The soil filters the stormwater so that it may then recharge the groundwater.



Source: http://www.csc.temple.edu/tvssi/bmps/survey/delaware_countycc.htm

Are there any secondary uses for an infiltration basin?

Yes, the water that flows into the infiltration trench can recharge the groundwater. Stream systems will also benefit from this because the groundwater flows into the streams as base flow.

Are there other names for this type of system?

Yes, infiltration trenches are also known as infiltration galleys.

How is an infiltration trench created?

Infiltration trenches are typically used for smaller sites, less than 5 acres, which have high amounts of impervious cover. They are usually installed in areas with sandy soils. The trench itself should be sited on a flat area. The land that surrounds the trench can be as steep as 15 percent. The soil in the trench should be highly permeable, 0.5-3 in. / hr., to reduce the likelihood of clogging. The stormwater runoff should be pretreated by another BMP before entering the trench. Most trenches are designed to be emptied within 24 hours. An observation well should be installed so that the rate of infiltration can be measured. Many times a drain is also installed so that if the trench becomes clogged, it can be drained and maintained.

Where is this type of system most effective?

Infiltration trenches can be constructed most anywhere in the country. The biggest exception is with highly contaminated runoff. The contaminated runoff is less likely to be filtered properly and could leach into the groundwater. There are also some issues with infiltration trenches in colder climates because of permafrost, snowmelt, and road salt.



How much does it cost to install and maintain an infiltration trench?

Costs are highly variable and are largely based upon the permeability of the soil. The California Stormwater Quality Association estimated that it would cost \$5 per cubic ft. of treated volume. Maintenance is also variable and a large portion comes intermittently when the trench becomes clogged.

Are there any special considerations?

When the infiltration trench was first put into use, clogging was an issue. Since the standing water is below grade, mosquitoes and pests are not an issue. Maintenance needs have been determined to reduce the occurrence of clogging. If an infiltration trench is used as a BMP it should be routinely maintained so that clogging is limited.

Who should use an infiltration trench?

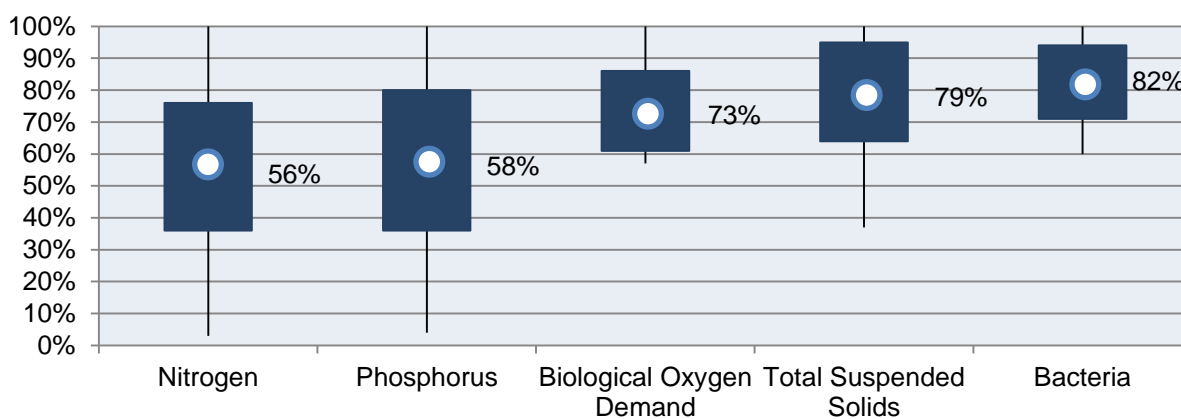
Infiltration trenches are generally used on sites less than 5 acres that have a high impervious cover. Native soil conditions will determine design capacity for all locations.

How effective is an infiltration trench at removing pollutants?

The data shown in the following table and graph were obtained from 18 separate studies.

Infiltration trenches are able to remove approximately 56% of the nitrogen, 58% of the phosphorus, 73% of the BOD, 79% of the TSS and 82% of the bacteria from stormwater runoff.

Percent Removal of Pollutants



The top of the line represents the maximum value found and the bottom of the line represents the minimum value found. The white point signifies the average of all the found values, also shown numerically next to the white point. The solid colored box represents one standard deviation plus or minus the average. This means 68% of the found values lie within the range of the solid colored box.

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PERMEABLE PAVEMENT

Stormwater Best Management Practices

12

What is permeable pavement?

Permeable pavement is specially designed pavement with extra pores that allows water to pass through it without compromising the integrity of the material. The permeability of the pavement controls runoff volumes and rates.



Figure 1. Pervious concrete allows water to flow through it. Photo courtesy of the National Ready Mix Concrete Association

Are there any secondary uses for permeable pavement?

Permeable pavement was designed to be used in lieu of typical asphalt or concrete. It can replace most traditional impervious pavement.

How is permeable pavement designed?

Most systems use reduced amounts of sand or fine particles so that more gaps are created in the structure of the pavement. The additional gaps allow water to drain through it. The typical amount of void space in permeable pavement is between 15 and 35 percent, compared to 3-5 percent void space in traditional concrete. Many times pretreatment systems, such as swales and filter strips, are used in conjunction with pervious pavement to prevent clogging. The soil beneath the pavement should be stable and permeable so that the water may be filtered by the soil. When a pavement is poured above a clay base, a drain located underneath the pavement is used to drain the water properly. Most soils around the Houston/Galveston area are clayey. Therefore it is highly recommended.

Are there other names for this type of system?

Yes, there are many different types of permeable pavement including pervious concrete, porous concrete, gap-graded concrete, enhanced porosity concrete, porous pavement, and porous asphalt. There are other materials and designs that are similar to permeable pavement such as permeable interlocking concrete pavement, concrete grid pavement, and modular porous paver system.



How much does it cost to install and maintain permeable pavement?

This technology is recent and is still going through adjustments as more providers enter the market. As of 2005 the National Cooperative Highway Research Program (NCHRP) estimated that the cost of the pervious concrete material would be \$2-\$7 per square ft. The pavement needs the same maintenance as a typical roadway. It should also be unclogged by a vacuum street cleaner when necessary.

Are there any special considerations?

The use of permeable pavement can help offset the amount of additional land and expenses that would be incurred by having to install the typical collection, conveyance, and detention stormwater components. Permeable pavement requires special installation although it is becoming a more frequent practice.

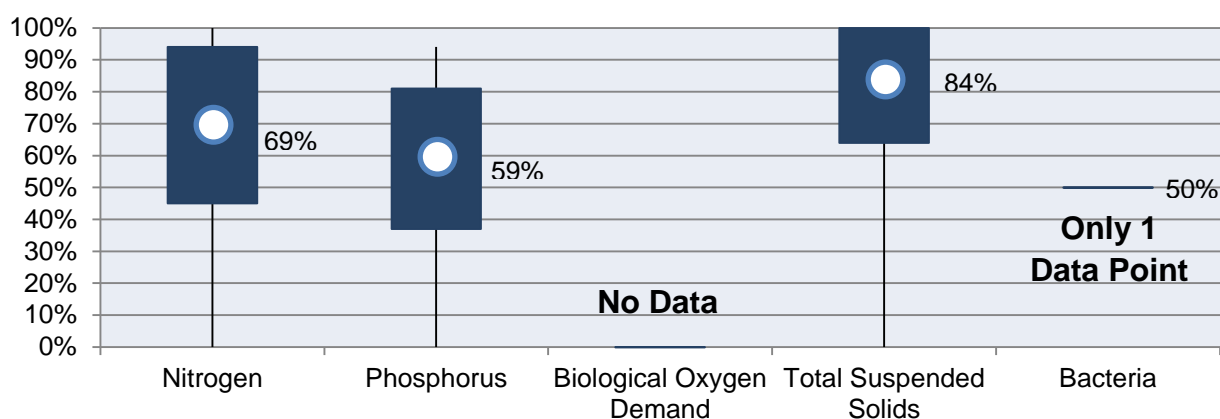
Who should use permeable pavement?

Permeable pavement is typically used as alternatives for sidewalks, driveways, parking lots, or lesser used streets. Permeable pavement can be either poured or built with pavers making it an accessible option for replacing material on any type of land.

How effective is permeable pavement at removing pollutants?

The data shown in the following table and graph were obtained from 22 separate studies. Permeable pavement is able to remove approximately 69% of the nitrogen, 56% of the phosphorus and 84% of the TSS from stormwater runoff.

Percent Removal of Pollutants



The top of the line represents the maximum value found and the bottom of the line represents the minimum value found. The white point signifies the average of all the found values, also shown numerically next to the white point. The solid colored box represents one standard deviation plus or minus the average. This means 68% of the found values lie within the range of the solid colored box.



BIORETENTION AREAS

Stormwater Best Management Practices

13

What is a bioretention area?

Bioretention areas are planted shallow depressions that collect and treat stormwater runoff through landscaping. They are typically found in suburban environments and small areas of land. The bioretention filters runoff then diverts it into the storm drain system. Bioretention areas are similar to infiltration basins but the emphasis is placed on vegetation in bioretention areas.



Source: EPA, 2001

Are there other names for this type of system?

Yes. A commonly used term for a bioretention area is rain garden.

Can I turn my yard into a bioretention area?

Yes. Most landscaped yards can easily be converted into a bioretention area by selecting the appropriate site and plants.

How is a bioretention area designed?

A bioretention area is typically created in suburban areas with little space for stormwater best management practices. A typical bioretention area is approximately 5%-10% of the size of land that drains to the bioretention area. The maximum amount of land a bioretention area can accommodate is 5 acres, including the bioretention area. Bioretention areas can be created in any type of soil. The slope of the surrounding land should be toward the bioretention area. The filtered water is typically drained to the stormwater system. Rain gardens at commercial sites should use a perforated under drain to move the filtered runoff to the stormwater system. Residential rain gardens do not typically need an under drain system.

What kinds of plants should I put in my bioretention area?

It is preferable to plant native vegetation that also provides habitat value and attracts beneficial insects. The plants selected should be able to withstand both wet and dry conditions. Trees can also be used in bioretention areas. Plants preferring wet soils should be planted in the middle and plants preferring dryer soils along the edge.



How much does it cost to install and maintain bioretention areas?

The EPA uses the following equation to estimate the construction, design, and permitting cost of a bioretention area, approximately as $C = 7.30V$, Where C is the total cost and V is the volume of water treated by the bioretention area in cubic ft. In 2011, the Texas AgriLIFE Extension Service estimated that it would cost \$6 per sq. ft. to install a bioretention area. The maintenance of the bioretention area is similar to the cost of maintaining a typical yard.

Are there any special considerations?

Bioretention areas can be used near stormwater hot spots, areas where highly contaminated runoff may occur. There is one design constraint that should be followed before applying it to this type of area: an impermeable liner should be installed underneath the bed. The liner should be installed so that if any of the runoff bypasses the drain it will not cause any contamination problems to the groundwater.

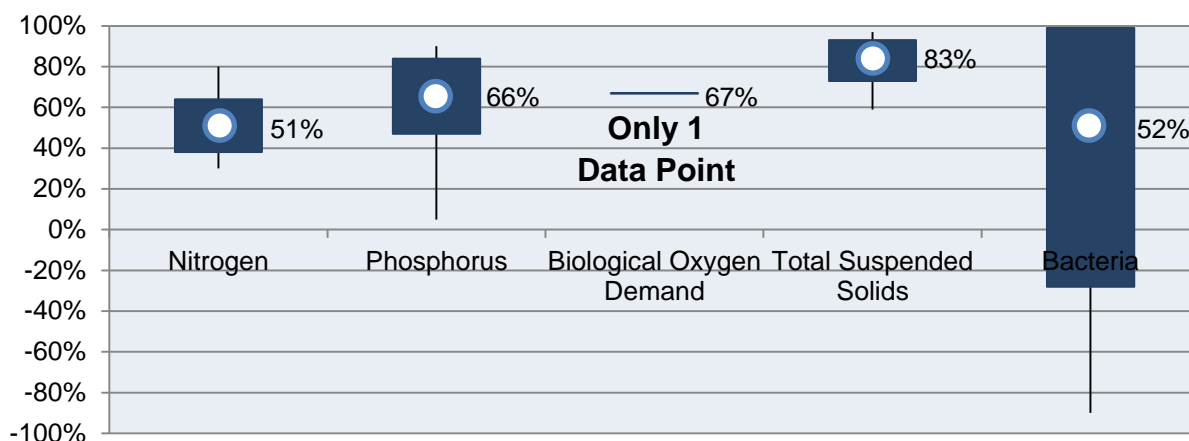
Who should use a bioretention area?

Bioretention areas are typically used to treat parking lot runoff, residential or roof runoff. Bioretention areas are also well suited for highly urbanized areas.

How effective is a bioretention area at removing pollutants?

The data shown in the following table and graph were obtained from 25 separate studies. A bioretention area is able to remove approximately 51% of the nitrogen, 66% of the phosphorus, 83% of the TSS and 52% of the bacteria from storm water runoff.

Percent Removal of Pollutants



The top of the line represents the maximum value found and the bottom of the line represents the minimum value found. The white point signifies the average of all the found values, also shown numerically next to the white point. The solid colored box represents one standard deviation plus or minus the average. This means 68% of the found values lie within the range of the solid colored box.



Content in this fact sheet was extracted from U.S. EPA National Menu of Best Management Practices

Texas NEMO is an educational program of Texas A&M University, Texas Sea Grant and the Texas AgriLife Extension service, and is an official partner of the National NEMO Network. In addition to support from TAMU, NEMO is funded by grants from the EPA, TCEQ and GBEP.



WATER QUALITY INLETS

Stormwater Best Management Practices

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What is a water quality inlet?

Water quality inlets are a group of methods that capture or separate sediment, debris, and pollutants from stormwater runoff as it enters a catchment basin. It typically acts as a pretreatment for other stormwater best management practices. Water quality inlets are typically used in areas with little available space as they normally require only an insert into an existing storm drain.



A worker inserts a catch basin insert for oil and grease, trash, debris, and sediment removal from stormwater as it enters the storm drainage system (Source: Ab Tech Industries, 2001)

Are there other names for this type of system?

Yes. Water quality inlets are also known as catch basin inserts, storm drain inlets or curb inlets. There are many specific types of each of these such as an oil/grit separator which removes oil from incoming runoff.

How does a water quality inlet work?

A water quality inlet can operate in a variety of ways. Most use physical processes to remove larger particles and trash. A grate or curb inlet only allows materials smaller than the inlet area into the basin. A series of media filters can be used to remove smaller particles. The efficiency of the water quality inlet depends heavily on the design of the inlet and on regular maintenance.

How big does the water quality inlet need to be?

The catch basin is the area where the stormwater runoff eventually enters before passing through the water quality inlet. The EPA suggests the following estimates to determine the catch basin size. First, the diameter of the catch basin should be 4 times the size of the outlet pipe diameter. Secondly, the depth should be at least 4 times the size of the outlet pipe diameter. Lastly, the top of the outlet pipe should be 1.5 times the size of the outlet pipe diameter, from the bottom of the inlet to the catch basin. Most catch basins are sized with a margin of safety so if an extremely large rainfall event occurs the catchment basin will still be able to handle most of the incoming rain.



How much does it cost to install and maintain a water quality inlet?

Water quality inlets are highly variable in price. They are priced based upon how efficient they are and the size of particles they can remove. A catch basin insert costs approximately \$2,000-\$3,000 per insert (Study performed by Cambridge University in 2012). Another cost consideration is the cost to remove the debris from the basin and inlets. Cleaning the debris from the inlets will require routine maintenance.

Are there any special considerations?

Water quality inlets and catch basins have three major limitations. First, even if they are designed and maintained properly they cannot remove pollutants as efficiently as other structural stormwater best management practices such as wet ponds or sand filters. Secondly, they require routine maintenance. Lastly, water quality inlets and catch basins cannot successfully remove many of the smaller or soluble particles.

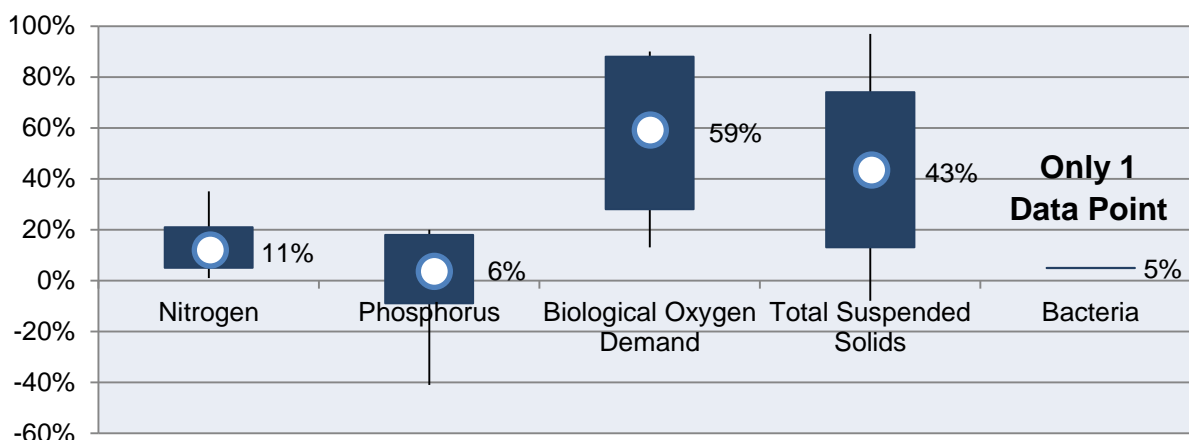
Who should use water quality inlets?

Water quality inlets are typically placed before or in municipal storm sewer lines. Water quality inlets are also placed in storm sewer lines that are exiting commercial buildings. Water quality inlets are generally not used by individual residents of a community.

How effective is a water quality inlet at removing pollutants?

The data shown in the following table and graph were obtained from 18 separate studies. Water quality inlets remove approximately 11% of the nitrogen, 6% of the phosphorus, 59% of the BOD and 43% of the TSS from stormwater runoff.

Percent Removal of Pollutants



The top of the line represents the maximum value found and the bottom of the line represents the minimum value found. The white point signifies the average of all the found values, also shown numerically next to the white point. The solid colored box represents one standard deviation plus or minus the average. This means 68% of the found values lie within the range of the solid colored box.



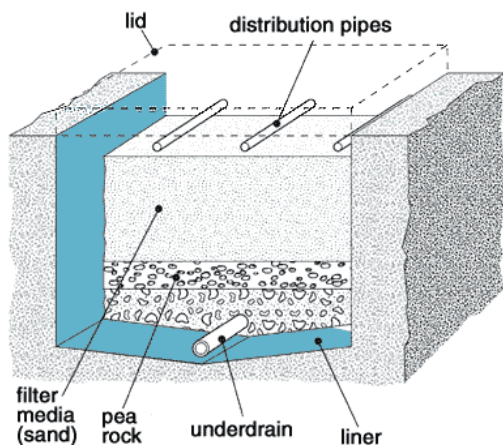
SAND AND ORGANIC FILTERS

Stormwater Best Management Practices

15

What is a sand and organic filter?

Sand and organic filters typically consist of two chambers. The first chamber is a settling chamber and the second chamber is filled with sand or other filtering organic material. The bottom of the filter contains a drain so that the filtered water can be moved away from the filter. Gravel is used to hold both the drain and sand in place. Sand and organic filters may be used as a stand-alone practice or as a pretreatment for an infiltration practice.



Source:
<http://www.extension.umn.edu/distribution/naturalresources/DD7672.html>

Can sand and organic filters negatively affect groundwater?

No. However, it is advised that there should be at least 2 ft. of separation between the bottom of the filter and the high point of the groundwater to prevent structural damage to the filter.

How does a sand and organic filter work?

The first chamber, not filled with sand, allows large particles to settle out of the water on the top of the sand layer where they are caught. A small perforated pipe then removes the water from the first chamber and deposits it into the second chamber. The second chamber filters out the smaller particles by capturing the smaller particles in the spaces between the grains of sand. Sand and organic filters should not be used on large sites. They are most efficient at treating runoff from sites less than 10 acres for surface sand filters and less than 2 acres for perimeter or underground sand filters. There should be some slope from the land supplying the runoff because the filter requires an elevation drop between the land and the filter. It is suggested that a minimum elevation drop of 5 ft. for underground and surface sand filters while the perimeter sand filter requires a minimum of a 2 ft. elevation drop.

Are there other names for this type of system?

Yes. Sand and organic filters are also known as organic media filters, and multi-chamber treatment chains. There are variations of the basic sand and organic filters such as underground sand filters, surface sand filters, and perimeter sand filters. There are different rules, regulations, design standards, and placement concerns for each of the variations.



How much does it cost to install and maintain a sand and organic filter?

The cost varies widely and depends upon the type of filter and the variation of the filter. The EPA estimated in 2006 that it would cost approximately \$5 per cubic ft. of stormwater treated. The maintenance costs of the filters come from monthly cleaning of debris and the prevention of clogging. Clogging occurs when large particles are not effectively removed in the first chamber.

Are there any special considerations?

A sand and organic filter can be used to treat stormwater hotspots. Stormwater hotspots refer to any type of land that generates highly contaminated runoff such as commercial nurseries, storage areas, marinas, and vehicle cleaning facilities. Sand and organic filters are well equipped to treat the hotspots because they have no interaction with the groundwater.

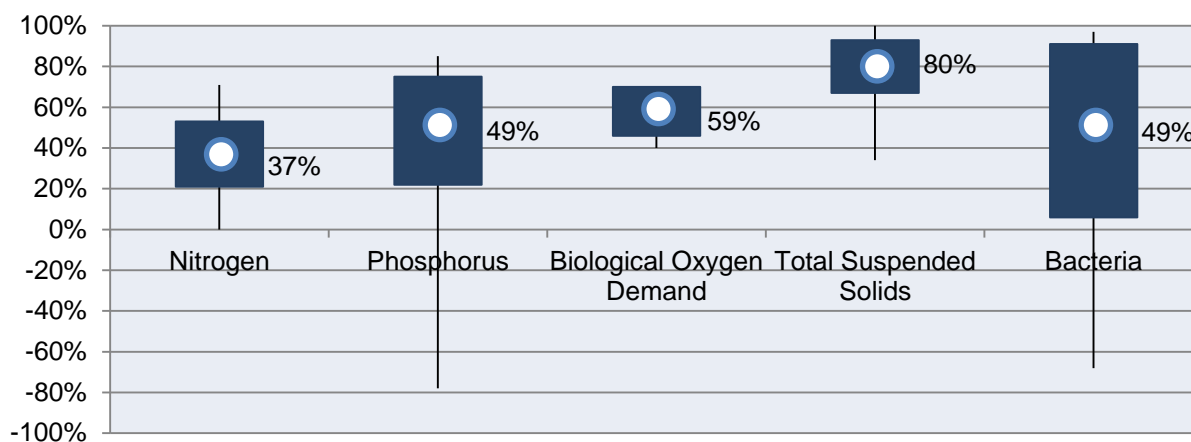
Who should use a sand and organic filter?

Underground and perimeter sand and organic filters are excellent choices for urban areas because of the minimal area needed. These types of filters work best for smaller drainage areas.

How effective is a sand and organic filter at removing pollutants?

The data shown in the following table and graph were obtained from 43 separate studies. A sand and organic filter is able to remove approximately 37% of the nitrogen, 49% of the phosphorus, 59% of the BOD, 80% of the TSS and 49% of the bacteria from stormwater runoff.

Percent Removal of Pollutants



The top of the line represents the maximum value found and the bottom of the line represents the minimum value found. The white point signifies the average of all the found values, also shown numerically next to the white point. The solid colored box represents one standard deviation plus or minus the average. This means 68% of the found values lie within the range of the solid colored box.



VEGETATED FILTER STRIPS

Stormwater Best
Management Practices

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What is a vegetated filter strip?

Vegetated filter strips are vegetated areas that slow and treat sheet flow from stormwater runoff. Typically they are rectangular but can be constructed in almost any shape. Vegetated filter strips are typically installed along the sides of roads and highways, near roof downspouts, and around parking lots. They require a large amount of space and are not normally seen in ultra-urban areas. Vegetated filter strips were originally an agricultural best management practice but have slowly caught on in urban areas. The main difference between a swale and a filter strip is that filter strips receive evenly distributed flows but do not direct water off site, whereas swales receive concentrated flows and direct these flows.



Source: <http://www.semcog.org/data/lid.report.cfm?lid=170>

Are there other names for this type of system?

Yes. Vegetated filter strips are also known as grassed filter strips, filter strips, and grassed filters.

How does a vegetated filter strip work?

Vegetated filter strips work by slowing the stormwater runoff. Slowing the runoff velocity allows larger particles to settle out of the water and into the filter strip. The vegetation is able to filter out many of the smaller particles. Slowing the water allows some of the water to infiltrate into the underlying soils which filters out more pollutants. Vegetated filter strips are used to treat small drainage areas, typically less than 1 acre.

How is a vegetated filter strip designed?

A small pea gravel trench runs along the top edge of the strip so flows can spread out along the length of the strip as well as for pretreatment. The bottom of the strip should contain a small area for ponding. Most filter strips are at least 25 ft. long and are built on land with a slope between 2 and 6 percent. The plant material used to fill the filter strip should be able to withstand both dry and wet conditions. Highly clayey soils may limit infiltration performance.



How much does it cost to install and maintain a vegetated filter strip?

The average cost of a vegetated filter strip in 2001 was around \$13,000-\$30,000 per acre. Filter strips have similar maintenance requirements as other vegetative practices, such as grassed swales. The biggest maintenance concern is making sure that the water flow does not get concentrated in channels allowing it to bypass the filter.

Are there any special considerations?

In determining if a vegetated filter strip is appropriate, remember that the vegetation is important to the success of the water filtration. This means that the vegetation needs to be properly maintained and watered during periods of drought or in arid regions of the country. Also, holding too much water may cause issues and breed pests.

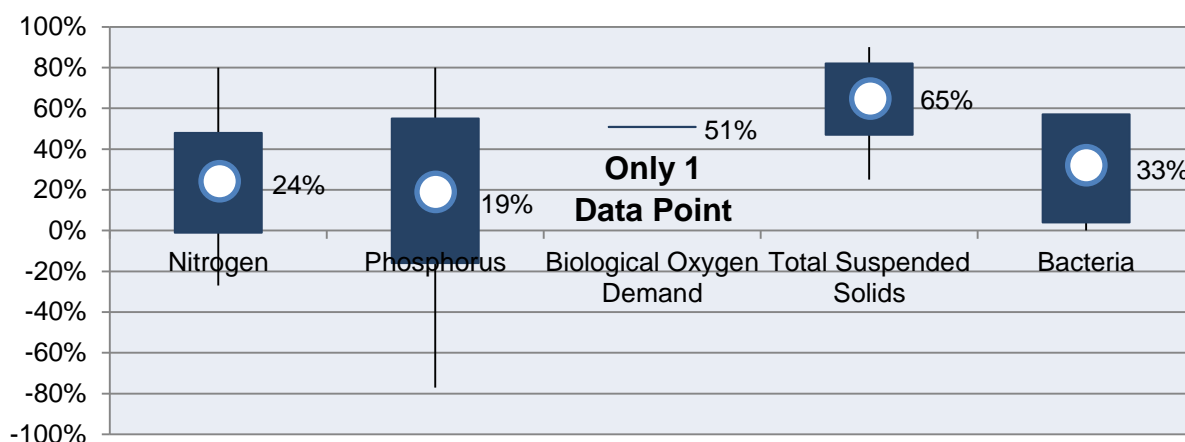
Who should use a vegetated filter strip?

Vegetated filter strips are best suited for treating runoff from roads and highways, roof downspouts, very small parking lots, and pervious surfaces. Vegetated filter strips are also occasionally used as the outer zone of a forested riparian buffer. They can also be used as pretreatment for other structural BMPs.

How effective is a vegetated filter strip at removing pollutants?

The data shown in the following table and graph were obtained from 19 separate studies. Vegetated filter strips are able to remove approximately 24% of the nitrogen, 19% of the phosphorus, 65% of the TSS and 33% of the bacteria from stormwater runoff.

Percent Removal of Pollutants



The top of the line represents the maximum value found and the bottom of the line represents the minimum value found. The white point signifies the average of all the found values, also shown numerically next to the white point. The solid colored box represents one standard deviation plus or minus the average. This means 68% of the found values lie within the range of the solid colored box.



DRY DETENTION BASIN

Stormwater Best
Management Practices

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What is a dry detention basin?

A dry detention basin is large, typically vegetated basin that only holds water for a short period after it rains. The basin has outlets designed to detain stormwater runoff for 24 hours. They are called dry detention basins because they do not hold water permanently. The biggest difference between an infiltration basin and a dry detention basin is that a majority of the water that enters a dry detention basin does not permeate into the ground.



Source: EPA, 2001

Are there other names for this type of system?

Yes. Dry detention basins are also known as dry ponds, extended detention basins, detention basins, extended detention ponds, and detention tanks.

Are there any secondary uses for this system?

Yes. Dry detention basins can also be used for flood control by providing flood detention storage.

How does a dry detention basin work?

Dry detention basins work by allowing larger particles and sediment to settle out of the water column. Once the particles have settled to the bottom of the pond they get caught in the soil. Dry detention basins should not be used as a single pollution solution because they do not have a high efficiency. Dry detention basins are primarily used for volume flood control.

How is a dry detention basin designed?

Dry detention basins are typically quite large and require a large amount of land to construct. A typical dry detention basin is generally used on sites larger than 10 acres, although smaller sites work. The slope of the adjacent land can be high. The slope immediately around the pond should be lower. The EPA recommends that the pond be built using a length-to-width ratio of at least 1.5:1. Almost all soil types can work in a dry detention basin with some minor adjustments. Dry detention basins that come in contact with highly contaminated runoff should be lined with an impermeable liner so that the groundwater does not become contaminated. Also, the basin should not be so deep that it intersects the groundwater table. This would cause a permanent pool of water in the bottom which could be a potential breeding ground for mosquitoes.



How much does it cost to install and maintain a dry detention basin?

A fairly common equation used to price a dry detention basin is:

$$C = 12.4 * V^{0.76}$$

Where C is the construction cost of the dry detention basin and V is the volume needed to control a 10-year storm in cubic ft. This equation was created in 1997 and should be adjusted for inflation to express a more accurate estimate.

Are there any special considerations?

A dry detention basin should never intersect the groundwater table. In Texas, specifically near the coast, the groundwater table is not very deep. This means that the detention basin cannot be dug deeper in order to have the required amount of volume in the dry detention basin. The length or width of the detention basin must be changed which would require a larger amount of land.

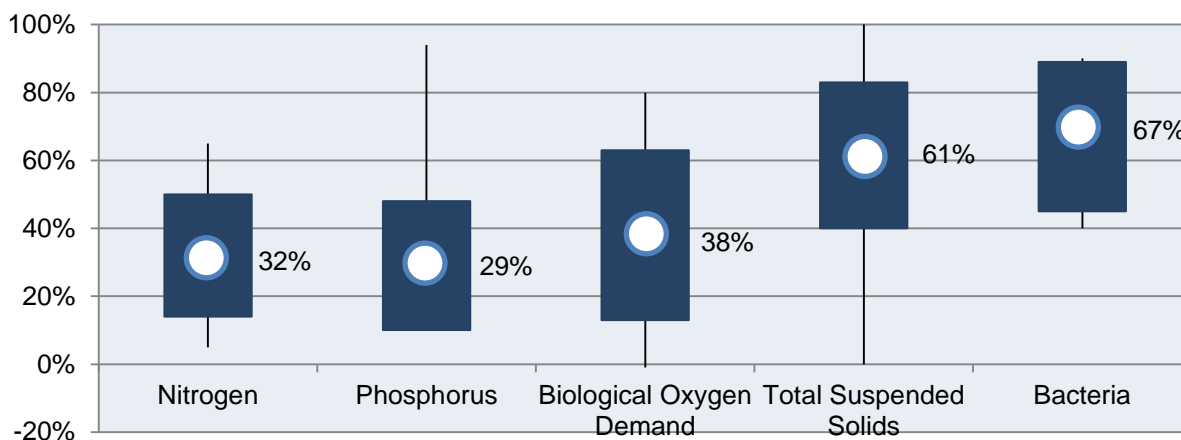
Who should use a dry detention basin?

Dry detention basins are one of the most widely used BMPs and can be applied to all regions of the country. Many dry detention basins are used for flood control as well as water quality improvement. Dry detention basins are typically used for sites larger than 10 acres.

How effective is a dry detention basin at removing pollutants?

The data shown in the following table and graph were obtained from 32 separate studies. A dry detention basin is able to remove approximately 32% of the nitrogen, 29% of the phosphorus, 38% of the BOD, 61% of the TSS and 67% of the bacteria from stormwater runoff.

Percent Removal of Pollutants



The top of the line represents the maximum value found and the bottom of the line represents the minimum value found. The white point signifies the average of all the found values, also shown numerically next to the white point. The solid colored box represents one standard deviation plus or minus the average. This means 68% of the found values lie within the range of the solid colored box.

Content in this fact sheet was extracted from U.S. EPA National Menu of Best Management Practices



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STORMWATER WETLAND

Stormwater Best Management Practices

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What is a stormwater wetland?

A stormwater wetland is a constructed pond that integrates natural wetland vegetation. Stormwater wetlands actively filter stormwater runoff by allowing the particles to settle in the standing water and by filtering the smaller particles through infiltration. Not only are stormwater wetlands efficient at removing pollutants from runoff, they also provide an aesthetic value and significant habitat for resident wildlife. The surface area of a stormwater wetland is typically 1% of the area draining into it.



A group of people help to plant new wetland vegetation

Source: EPA, 2001

Are there other names for this type of system?

Yes. Recent human disturbances have disrupted many of the natural wetlands. Therefore, many wetlands are now being artificially created, these are known as artificial or constructed wetlands.

Do I need a permit to replant or construct an artificial wetland?

It depends. If you are performing any restoration on a wetland you must get a permit from the U.S. Army Corps of Engineers. This is specified under the Clean Water Act, Section 404. It states that you need a permit if the wetland has a significant connection to a navigable waterway. Traditionally, the U.S. Army Corps of Engineers is not involved with artificial wetland permitting but it is highly advised to contact them to determine if you need a permit to construct the wetland.

What type of plants should I put in a wetland?

The proposed development site's history should be researched. This includes previous vegetation, typical conditions, and hydrologic characteristics. These factors will heavily influence which plants should be selected. It is important to keep the plant species diverse to keep one particular plant from dominating the wetland. It is also important to plant riparian vegetation along the banks of the wetland. Vegetation will help keep the banks stable and reduce water temperatures. The efficiency of using a stormwater wetland to remove pollutants is highly variable and depends on the types of plants used. A local Extension representative, such as the Texas Coastal Watershed Program, is a good source of technical information.



How much does it cost to install and maintain a stormwater wetland?

The cost to install an artificial wetland is highly variable and depends on the amount of restoration or construction. The EPA estimates that constructing a wetland is approximately 25% more expensive than a stormwater pond of an equivalent volume. The EPA also estimated that the annual maintenance of the wetland is about 3%-5% of the construction cost.

Are there any special considerations?

Regular maintenance is important, and steps should be taken to minimize erosion in areas surrounding the wetland. Sediment will accumulate and change the flow pattern in the wetland. The biggest maintenance consideration is invasion of non-native plant life. Invasive plant species should be removed wherever possible. Managing cattails should also be a maintenance priority because they are an optimal space for mosquito breeding. Cattails should be avoided and make up <10% of the total vegetation.

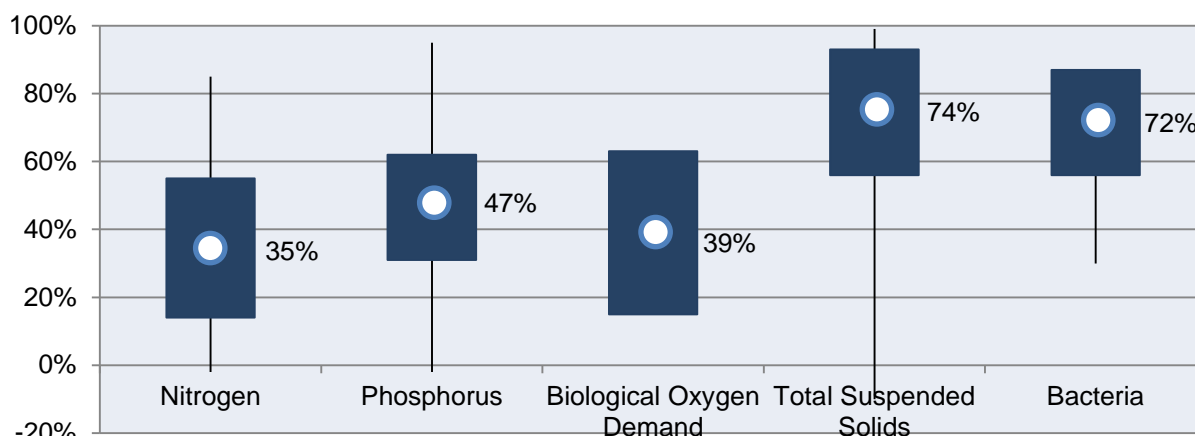
Who should use a stormwater wetland?

Stormwater wetlands are typically at least 1% of the drainage area and should have a length-to-width ratio of 1.5:1. Stormwater wetlands should not negatively impact natural wetlands or forests. Most stormwater wetlands are used for treatment in suburban or rural areas.

How effective is a stormwater wetland at removing pollutants?

The data shown in the following table and graph were obtained from 31 separate studies. A stormwater wetland is able to remove approximately 35% of the nitrogen, 47% of the phosphorus, 39% of the BOD, 74% of the TSS and 72% of the bacteria from stormwater runoff.

Percent Removal of Pollutants



The top of the line represents the maximum value found and the bottom of the line represents the minimum value found. The white point signifies the average of all the found values, also shown numerically next to the white point. The solid colored box represents one standard deviation plus or minus the average. This means 68% of the found values lie within the range of the solid colored box.



WET DETENTION POND

Stormwater Best Management Practices

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What is a wet detention pond?

A wet detention pond is a constructed basin with a permanent pool of water throughout the year. Wet detention ponds are a commonly seen stormwater best management practice. They can be applied to almost any situation and can be installed throughout the country. The primary limitations of a wet detention pond are the size of the pond and the use in more arid regions of the country. Wet detention ponds allow larger particles to settle out of the water. Smaller particles are removed through infiltration of the vegetation on the sides of the basin. The main difference between a wet detention pond and a stormwater wetland is that a wet detention pond does not rely on vegetation for filtration.



Source: EPA, 2001

Are there other names for this type of system?

Yes. Wet detention ponds are also called wet ponds, stormwater ponds, wet retention ponds, wet extended detention ponds, settling basins, retention basins, or sediment basins.

How is a wet detention pond designed?

Wet detention ponds need a large enough drainage area so that they can maintain the permanent pool. In more humid regions, like the Texas Gulf Coast, it typically requires about 25 acres. The drainage area size should be larger in areas where it rains less. The slope of the adjacent land can be up to 15 percent but the land near the pond should be relatively flat with a slight slope toward the outlet of the pond. This will ensure that the water continuously flows toward the outlet. Wet detention ponds can be used in almost any soil type. A wet detention pond, unlike a dry detention pond, is able to cross the boundary of the groundwater. However, some studies have shown that when groundwater contributes significant amounts of water to the pond, it may decrease the pollutant removal efficiency. Water should pass through a small basin before reaching the detention pond so that the largest particles can settle out of the water, decreasing sedimentation in the main pond and reducing the amount of maintenance needed. The EPA recommends that the pond be built using a length-to-width ratio of at least 1.5:1. The EPA also recommends using underwater berms so water travels a further distance, thus allowing the particles to have a longer time to settle. A vegetated buffer should be placed along the edges of the pond to provide shade.



How much does it cost to install and maintain a wet detention pond?

One commonly used equation by the EPA to estimate the construction cost of a wet detention pond was created in 1997 but is adjusted for inflation:

$$C = 24.5 * V^{0.705}$$

Where C is the construction cost and V is the volume of the pond that is capable of carrying a 10-year storm. Annual maintenance costs are about 3% to 5% of the construction cost.

Are there any special considerations?

Some companies are beginning to reuse the pond water for non-potable uses such as irrigation. In this case, then the daily amount of water intake and output should be calculated for the pond to ensure that a constant pool of water is maintained. One study performed at a Florida golf course concluded that reusing the pond water would cost about 1/7th the typical irrigation cost.

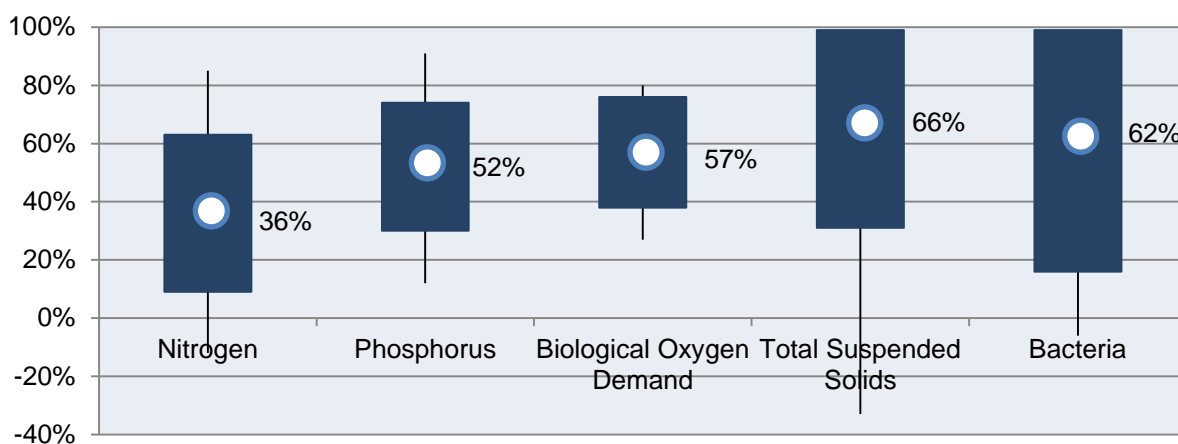
Who should use a wet detention pond?

Typically, a wet detention pond is used in a neighborhood, community, or recreational parks. If a wet detention pond is landscaped well it adds to the aesthetic value of these places and can make the wet detention pond an asset to that community. The water in the pond may also be used for other needs such as irrigation.

How effective is a wet detention pond at removing pollutants?

The data shown in the following table and graph were obtained from 31 separate studies. A wet detention pond is able to remove approximately 36% of the nitrogen, 52% of the phosphorus, 57% of the BOD, 66% of the TSS and 62% of the bacteria in stormwater runoff.

Percent Removal of Pollutants



The top of the line represents the maximum value found and the bottom of the line represents the minimum value found. The white point signifies the average of all the found values, also shown numerically next to the white point. The solid colored box represents one standard deviation plus or minus the average. This means 68% of the found values lie within the range of the solid colored box.



HOW TO PICK THE RIGHT BEST MANAGEMENT PRACTICE

Stormwater Best Management Practices

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What is a Best Management Practice?

Best Management Practices (BMPs) are practices that help treat, store, and infiltrate stormwater runoff from impermeable areas. If BMPs were not installed, the contaminated stormwater runoff would negatively impact the local water bodies downstream. The technology used in BMPs varies widely. Some rely on complicated chemical processes while others rely on simple, physical processes. They range in size from a few square feet to many cubic yards. Some BMPs are not based on structure or technology at all. For example, if you can educate the local community to stop performing adverse behavior, that action will help reduce the amount of pollutants in the water with no installation of a physical structure. BMPs, if properly installed and maintained can last for many years and help lessen water contamination.

Is it required that I install a Best Management Practice?

Yes, but only if it is a new development or redevelopment that disturbs more than one acre and happens in either a Phase I or Phase II MS4 (Municipal Separate Storm Sewer Systems). Everyone is encouraged to install a BMP on their property but it is only required by the people meeting the criteria mentioned above.

Why do I need a Best Management Practice?

Water that runs through impermeable areas is highly susceptible to becoming contaminated with pollutants that it picks up on its way out. That runoff eventually enters either a natural body of water or a storm drain. Either way, the contaminated runoff water then negatively affects the water it mixes with. This can cause serious impairments to water that are used as recreation sites or as a drinking water source. BMPs help reduce the amount of contaminants that make it into these bodies of water.

How do I know which BMP is right for me?

There are many questions that must be addressed before a final decision can be made. The first questions that should be asked are:

1. How big is your property?
2. How much space and what shape of the space is available for a BMP?
3. How effective should the BMP be?
4. Are there any BMPs already installed on the property?

More questions may need to be asked before making a final decision. If there are multiple practices that fit into these categories then a secondary tool that can be used is called a score sheet.



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What is a score sheet?

A score sheet is a method of determining which BMP would best fit your needs. Make a table that has the BMPs that match what you are looking for in each column. Each row has various concerns that should be taken into consideration such as, pollutant reduction (one column for each pollutant), cost, secondary uses, public acceptance, and maintenance costs. Any other special considerations that you would like to consider should also be entered. Each cell would then be numbered on a scale of 1-5, based on the appropriate measures, with 1 being the worst and 5 being the best. During this process you should make the assumption that each practice will be installed and maintained properly. After each number has been selected, take the average number of each column. The BMP with the highest average would be the most appropriate selection for your land. Make sure to write notes on the method used to select a BMP.

Can I use multiple BMPs in a series?

Yes. If you choose to use multiple BMPs in a series, the rate of flow will decrease and the amount of contaminants will significantly decrease. If you do choose to use multiple BMPs in a series you cannot add the removal efficiencies together to determine the final removal efficiency. You must perform the removal efficiencies separately. This is because the water flows through the first BMP and some percentage of contaminated water still remains. The second removal efficiency only alters the remaining contaminant concentration.

Is there someone who can help me select the appropriate BMPs?

Any local Extension office should be able to answer any questions or help you select BMPs that would best suit your needs should you run into any conflicts.

| Management Practice | Bioretention Area | Riparian Buffer | Wetland |
|--------------------------------|-------------------|-----------------|---------|
| Nitrogen Removal* | 3 | 3 | 2 |
| Phosphorus Removal* | 4 | 2 | 3 |
| BOD Removal* | 4 | 3 | 2 |
| TSS Removal* | 5 | 4 | 4 |
| Bacteria Removal* | 3 | No Data | 4 |
| Cost [†] | 1 | 5 | 3 |
| Secondary Uses [†] | 3 | 5 | 3 |
| Public Acceptance [†] | 5 | 5 | 3 |
| Maintenance [†] | 3 | 3 | 5 |
| Average Score | 3.44 | 3.75 | 3.22 |

*Based on a numbering system of 0%-19% = 1, 20%-39% = 2, 40%-59% = 3, 60%-79% = 4, 80%-100% = 5.

[†] Chosen when compared to the other selected BMPs.



Content in this fact sheet was extracted from U.S. EPA National Menu of Best Management Practices

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Appendix 5 - Funding Sources

Federal

Agricultural Water Enhancement Program (AWEP)

Entity: Natural Resources Conservation Service (NRCS)

Provides financial and technical assistance to agricultural producers to implement agricultural water enhancement activities on agricultural land to conserve surface and ground water and improve water quality. Eligible entities or organizations form multi-year partnership agreements with NRCS to promote ground and surface water conservation.

Eligibility: Individual producers are not eligible. Eligible partners include: Federally recognized Indian Tribes, States, units of local government, agricultural or silvicultural associations or other groups of such producers and other nongovernmental organization with experience working with agricultural producers. Agricultural land must be in AWEP approved project areas.

Funding limitations: Financial assistance changes every fiscal year depending upon appropriations and agency priorities.

Coastal and Estuarine Land Conservation Program (CELCP)

Entity: National Oceanic Atmospheric Association (NOAA)

This program is intended to provide financial assistance to purchase significant coastal and estuarine lands, or conservation easements on such lands, from willing sellers. Lands or conservation easements acquired under this program are to be protected in perpetuity due to their importance for their ecological, conservation, recreational, historical or aesthetic values.

Eligibility: Participants must be in a state that has developed a CELCP plan for NOAA approval. The Texas CELCP plan was approved in 2010. An eligible public entity such as local governments, state or federal agencies, institutions of higher education, or other authority such as park districts must submit the project proposal. Projects must complement working waterfront needs and advance the goals, objectives or implementation of local coastal management plans in addition to the state's CELCP plan.

Funding limitations: The program funds up to \$3M per project, which is matched 1:1 with non-federal funds from the public entity participant. The budget for projects under this program may vary annually contingent on the fiscal year budget. NOAA maintains a contingency list of projects in the case that a project falls through or additional funds become available. Projects unable to be funded for a particular fiscal year will remain on the list until it is superseded.

Community Development Block Grants

Entity: States and local jurisdictions

This program is intended to address one or more of the following: benefit low- and moderate-income persons, prevention or elimination of slums or blight, or address community development needs having a particular urgency because existing conditions pose a serious and immediate threat to the health or welfare of the community for which other funding is not available.

Eligibility: Business, Community/Watershed Group, Nonprofit Groups, Educational Institution, Private Landowner, Water and Wastewater Utilities, Local Government, State/Territorial Agency

Funding limitations: Program uses formula allocations to determine grant amount to the state and local jurisdiction which allocate funds to community projects. A match is not required for this program. Funding is based on appropriations for the fiscal year.

Conservation Reserve Program (CRP)

Entity: Natural Resource Conservation Service (NRCS)

Provides financial assistance to agricultural landowners in establishing approved conservation practices. The goals of the CRP program are to reduce water runoff and sedimentation, protect groundwater and help improve conditions of lakes, rivers, ponds and streams.

Eligibility: Agricultural landowners

Funding limitations: Eligible participants can receive annual rental payments based on the agriculture rental value of the land and cost-share assistance for up to 50 percent of the participant's costs in establishing approved conservation practices.

Environmental Education (EE) Grants

Entity: EPA

Under the Environmental Education Grants Program, EPA seeks grant proposals from eligible applicants to support environmental education projects that promote environmental awareness and stewardship and help provide people with the skills to take responsible actions to protect the environment. This grant program provides financial support for projects that design, demonstrate, and/or disseminate environmental education practices, methods, or techniques.

Eligibility: Applicants must represent one of the following types of organizations to be eligible for an environmental education grant: local education agency, state education or environmental agency, college or university, non-profit organization as described in section 501(c)(3) of the Internal Revenue Code, noncommercial educational broadcasting entity, tribal education agency (which includes schools and community colleges controlled by an Indian tribe, band, or nation). Applicant organizations must be located in the United States or territories and the majority of the educational activities must take place in the United States; or in the United States and Canada or Mexico; or in the U.S. Territories.

Funding limitations: EPA has distributed between \$2 and \$3.5 million in grant funding per year, supporting more than 3,600 grants.

Environmental Quality Incentive Program

Entity: Natural Resources Conservation Service (NRCS)

Financial and technical assistance is provided to help plan and implement conservation practices that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and non-industrial private forestland. Funds may also be used to help develop conservation plans which are required to obtain financial assistance. This program also aims to help producers meet Federal, State, Tribal and local environment regulations.

Eligibility: Owners of land in agricultural or forest production or persons who are engaged in livestock, agricultural or forest production on eligible land and that have a natural resource concern on the land may participate in EQIP. Limited resource farmers/ranchers, beginning farmers/ranchers, and socially disadvantaged producers and tribes may be eligible for higher practice payment rates for the implementation of conservation practices and conservations plans.

Funding limitations: Financial assistance payments are based on a portion of the average cost associated with practice implementation. Financial assistance is awarded through contracts up to a maximum term of ten years in length. Participants are limited to a \$300,000 total payment for all contracts within any six-year period. Projects deemed to have special environmental significance by the NRCS may be eligible to receive a maximum of \$450,000.

Target Watersheds Grant Program

Entity: River Network and EPA

Program is intended to provide financial and technical assistance for projects designed to strengthen the participant's organization. The program will provide local organizations, tribal and local governments with skills and techniques to protect their urban waterways and promote more vibrant, economically sustainable communities. The EPA's purpose is to encourage successful community-based approaches to protect and restore the nation's watersheds.

Eligibility: Funding will be provided for projects designed to strengthen an organization's capacity-building and ability to carry out programs to protect human health and the environment.

Funding limitations: Funding will range from \$30,000-70,000.

WaterSMART: Cooperative Watershed Management Program (CWMP)

Entity: Department of the Interior, Bureau of Reclamation, Policy and Administration

The objective of this FOA is to invite States, Indian tribes, irrigation districts, water districts, local governmental entities, non-profit organizations, existing watershed groups, and local and special districts (e.g., irrigation and water districts, county soil conservation districts) to submit proposals for Phase I activities to establish or further develop a watershed group. Funding provided under this FOA may be used to develop a mission statement, project concepts, and/or a restoration plan.

Eligibility: Task A—Establishment of a Watershed Group: States, Indian tribes, local and special districts (e.g., irrigation and water districts, etc.), local governmental entities, interstate organizations, and non-profit organizations. To be eligible, applicants must also meet all of the requirements listed in Sec. III.A, Eligible Applicants. Task B—Further Development of an Existing Watershed Group: In order to be eligible to receive an award to fund activities under Task B, the applicant must be an eligible entity as described immediately above for Task A, and must be either be: (1) An existing "watershed group," (i.e., a grassroots, non-regulatory legal entity that otherwise meets the definition of a watershed group as described in Section I.B., Objective of Funding Opportunity Announcement; or (2) a participant in an existing watershed group. See also Sec. III.A, Eligible Applicants.

Funding limitations: Up to \$100,000 in Federal funds may be awarded to an applicant per award, with no more than \$50,000 awarded in each year of the project, under this FOA. The period of performance shall not exceed two years.

Water and Environmental Programs

Entity: United States Department of Agriculture (USDA)

Program provides financial assistance for drinking water, sanitary sewer, solid waste and storm drainage facilities in rural areas and cities and towns of 10,000 or less. Technical assistance and training is also available to assist rural communities with their water, wastewater, and solid waste problems.

Eligibility: Public bodies, non-profit organizations and recognized Indian Tribes

Funding limitations: Financial assistance is provided in various ways including direct or guaranteed loans, grants, technical assistance, research and educational materials. Different amounts of assistance exist depending on the project type and financial tool the participant is seeking.

Wetlands Reserve Program

Entity: Natural Resources Conservation Service (NRCS)

Provides technical and financial support to landowners with their wetland restoration efforts. The programs aims to offer landowners the opportunity to protect, restore, and enhance wetlands on their property.

Eligibility: Lands that are eligible under this program include: wetlands farmed under natural conditions, farmed wetlands; prior converted cropland; farmed wetland pasture; certain lands that have the potential to become a wetland as a result of flooding; rangeland, pasture, or forest production lands where the hydrology has been significantly degraded and can be restored; riparian areas which link protected wetlands; lands adjacent to protected wetlands that contribute significantly to wetland functions and values; and wetlands previously restored under a local, State, or Federal Program that need long-term protection.

Funding limitations: Depends on fiscal year appropriations and agreement terms with NRCS.

State

Beach Maintenance Reimbursement Fund Program

Entity: Texas General Land Office

The program aims to share the responsibility of maintaining public beaches between the Land Office and local governments.

Eligibility: The Land Office provides support to cities or counties bordering the seaward shoreline of the Gulf of Mexico and are qualified local governments with state financial assistance for the purpose of cleaning and maintaining public beaches

Funding limitations: Funds are reimbursed based on actual expenses. Seventy-five percent of the funds are allocated based on proportionate share of participant expenditure during the previous two fiscal years preceding application. Twenty-five percent is allocated based on the proportionate share of linear footage of gulf beach cleaned or maintained.

Boating Access Grants

Entity: Texas Parks and Wildlife Department (TPWD)

The Boating Access Grant Program provides 75% matching fund grant assistance to construct new, or renovate existing, public boat ramps that provide public access to public waters for recreational boating.

Eligibility: Local government sponsors must make an application, provide the land, provide access to the proposed boat ramp, supply 25% of the development costs, and accept operation and maintenance responsibilities for a minimum 25-year period. The grant funds dredging, stump removal, and aquatic weed control when activity can be shown to clear lanes to make water body more accessible primarily for recreational motorboats as opposed to general navigation. Retaining walls to protect integrity of boat ramps and associated parking lots (limited to 200 feet on either side of constructed facilities). Engineering (planning and design), and environmental clearance and permit costs

Funding limitations: This grant program provides 75% matching grant funds for the construction of public boat ramp facilities throughout Texas.

Clean Water State Revolving Fund (CWSRF)

Entity: State of Texas

This program provides low-interest loans that can be used for planning, design, and construction of wastewater treatment facilities, wastewater recycling and reuse facilities, collection systems, storm water pollution control, nonpoint source pollution control, and estuary management projects.

Eligibility: The program is open to a range of borrowers including municipalities, communities of all sizes, farmers, homeowners, small businesses, and nonprofit organizations. Project eligibility varies

according to each state's program and priorities. Loans for wastewater treatment plant projects are only given to political subdivisions with the authority to own and operate a wastewater system.

Funding limitations: The program offers fixed and variable rate loans at subsidized interest rates. The maximum repayment period for a CWSRF loan is 30 years from the completion of project construction. Mainstream funds offer a net long-term fixed interest rate of 1.30% below market rate for equivalency loans (project adheres to federal requirements) and 0.95% for non-equivalency (project adheres to state requirements) loans. Disadvantaged community funds may be offered to eligible communities with principal forgiveness of 30%, 50%, or 70% based upon the adjusted annual median household income and the household cost factor.

Coastal Impact Assistance Program (CIAP)

Entity: Bureau of Ocean Energy Management, Regulation & Enforcement and Texas General Land Office

Eligible projects must target one of the following: conservation, protection or restoration of coastal areas, including wetlands, mitigation of damage to fish, wildlife, or natural resources, planning assistance and the administrative costs of complying with this section, implementation of a federally approved marine, coastal, or comprehensive conservation management plan, and mitigation of the impact of development along the Outer Continental Shelf through funding of onshore infrastructure projects and public service needs.

Eligibility: State, federal agencies, along with universities (public or private), county and local governments, other state subdivisions and non-profit organizations.

Funding limitations: Funds for this program may only be granted to the 18 Texas coastal counties of Orange, Jefferson, Chambers, Harris, Galveston, Brazoria Matagorda, Jackson, Calhoun, Refugio, San Patricio, Nueces, Kleberg, Willacy, and Cameron. After review process and approval, the Land Office will contract with vendors or sub-grantees to perform projects. Project expenses are reimbursed after they are incurred. Funding advancements may be allowed only under special conditions.

Economically Distressed Areas Program

Entity: Texas Water Development Board (TWDB)

Program provides financial assistance for water and wastewater services in economically distressed areas where present facilities are inadequate to meet residents' minimal needs. The program also includes measures to prevent future substandard development.

Eligibility: Projects must be located in an area that was established as a residential subdivision as of June 1, 2005, has an inadequate water supply or sewer services to meet minimal residential needs and a lack of financial resources to provide water supply or sewer services to satisfy those needs. All political subdivisions, including cities, counties, water districts, and nonprofit water supply corporations, are eligible to apply for funds. The applicant, or its designee, must be capable of maintaining and operating the completed system.

Funding limitations: Financial support is in the form of grant or combination of a grant and a loan. The program does not fund ongoing operation and maintenance expenses, nor does it fund new development.

Landowner Incentive Program (LIP)

Entity: Texas Parks and Wildlife Department (TPWD)

The program offers project cost-sharing for projects that positively impact the valuable riparian areas and watershed in Texas. Projects showing the greatest benefit to targeted watersheds will receive priority as do projects offering long-term protection, long-term monitoring and greater than the required minimum landowner contribution.

Eligibility: Eligible parties include private, non-federal landowners wishing to enact good conservation practices on their lands in targeted ecoregions. Targeted ecoregions may change from year to year.

Funding limitations: Contracts will require a minimum of 25% landowner contribution (in-kind labor, materials, monetary, etc.).

Recreation Grant Program-Boating Access Grant

Entity: Texas Parks and Wildlife Department (TPWD)

This program provides financial assistance in the construction of public boat ramp facilities throughout Texas.

Eligibility: Local government sponsors must make an application, provide the land, provide access to the proposed boat ramp and accept operation and maintenance responsibilities for a minimum 25-year period.

Funding limitations: Local government sponsor must provide 25% of the development costs. The grant program provides 75% matching grant funds of the construction costs.

Recreation Grant Program-Boat Sewage Pumpout Grant

Entity: Texas Parks and Wildlife Department (TPWD)

This grant program offers financial assistance for the construction and/or renovation, operation, and maintenance of pump out and portable toilet dump stations.

Eligibility: Private marinas and local governments are qualified for this grant.

Funding limitations: Funds for this program are distributed on a first-come, first-served basis and can constitute up to 75% of all approved project costs. Participants may charge a maximum fee of \$5.00 to cover use and maintenance costs.

Regional Water Supply and Wastewater Facilities Planning Program

Entity: Texas Water Development Board (TWDB)

The program provides funds for studies and analyses to evaluate and determine the most feasible alternatives to meet regional water supply and wastewater facility needs, estimate the costs associated with implementing feasible regional water supply and wastewater facility alternatives, and identify institutional arrangements to provide regional water supply and wastewater services for areas in Texas. All proposed solutions must be consistent with applicable regional or statewide plans and relevant laws and regulations. A water conservation plan must be included in the proposed plan.

Eligibility: Political subdivisions, such as cities, counties, districts or authorities created under the Texas Constitution with the legal authority to plan, develop, and operate regional facilities are eligible applicants. Additional applicants include any interstate compact commission to which the State is a party and any nonprofit water supply corporation created and operating under Texas Civil Statutes Article 1434a.

Funding limitations: Funds are in the form of grants. Applicants must provide evidence of local matching funds on or before the date specified for negotiation and execution of a contract. Funds are generally limited to 50% of the total cost of the project, except that the board may supply up to 75% of the total cost to political subdivisions under certain conditions. Funds will be released only as reimbursement of costs actually incurred for approved activities. In-kind services may be substituted for any part of the local share if certain criteria are met.

TCEQ 319 Grant

Entity: TCEQ and Texas State Soil and Water Conservation Board (TSSWCB)

This program is intended to fund activities that prevent or reduce nonpoint source pollution. Proposed projects should focus on agricultural and/or silvicultural nonpoint source pollution prevention and abatement activities within the boundaries of impaired or threatened watersheds. Specific activities that can be funded include development of nine-element watershed protection plans including the formation and facilitation of stakeholder groups, surface water quality monitoring, data analysis and modeling, implementation of nine-element watershed protection plans and the nonpoint source portion of total maximum daily load implementation plans, demonstration of innovative best management practices, technical assistance to landowners for conservation planning, public outreach/education, and monitoring activities to determine the effectiveness of specific pollution prevention methods.

Eligibility: All state agencies or political subdivisions of the State of Texas including cities, counties, school districts, state universities, nonprofit organizations, and special districts can apply for funding. Private organizations may participate in projects as partners or contractors but may not apply directly for funding.

Funding limitations: Grants are awarded annually and funds projects for up to three years.

Texas Clean Rivers Program

Entity: TCEQ

The program's main purpose is to develop partnerships to provide quality-assured data to the TCEQ for use in decision-making, identification and evaluation of water quality issues, promote cooperative watershed planning, recommend management strategies, inform and engage stakeholders and adapt to changing priorities.

Eligibility: Partnerships range from river authorities, other agencies, regional entities, local government, industry and citizens. TCEQ provides most of the funding for to conduct the monitoring, quality assurance, and data management functions of the program.

Funding limitations: Unknown

Texas Coastal Management Program

Entity: Texas General Land Office

This program funded by NOAA is designed to ensure long-term environmental and economic health of the Texas Coast. The program has funded a wide variety of coastal management activities but has also developed the following categories for use of these funds: coastal natural hazards response, critical areas enhancement, Public Access, Waterfront Revitalization and Ecotourism Development, Permit Streamlining/Assistance, Governmental Coordination, Local Government Planning Assistance, and Water Sediment Quantity and Quality Improvements.

Eligibility: State and Local

Funding limitations: For on-the-ground habitat protection, restoration and land acquisition projects, eligible entities can expect up to \$400,000 for individual large-scale projects and up to \$100,000 for small-scale projects. Local Match must be 40% of the total project cost for this cycle. Match may be in the form of a "cash" match or an "in-kind" match or a combination of both.

Texas Farm and Ranch Lands Conservation Program

Entity: Texas Parks and Wildlife Department (TPWD)

The Texas Farm and Ranch Lands Conservation Program (TFRLCP) was established by the Texas Legislature in 2005 with the purpose of conserving working lands with high values for water, fish and wildlife, and agricultural production; especially lands at risk of development. TFRLCP maintains and

enhances the ecological and agricultural productivity of these lands through Agricultural Conservation Easements.

Eligibility: State and Local

Funding limitations: Unknown

Appendix 6 – Geospatial Databases for Pollutant Load Estimation Modeling

| Data Type | | Date | Resolution or Accuracy | | |
|---|--|-------------------|------------------------|--|--------|
| NOAA C-CAP | | 2006, 2011 | 30 meter | | |
| Data Source | | Coordinate System | Geographic Coverage | | Format |
| NOAA | | NAD 83 | Coastal Regions | | TIFF |
| Scale | Acceptance Criteria (See Instructions) | | | | |
| 1:100,000 | Only source available in a format with consistent coverage | | | | |
| Intended Use | | | | | |
| Impervious surface and land cover data is assigned to each coverage class in data set. This information is needed for modeling. | | | | | |

| Data Type | | Date | Resolution or Accuracy | | |
|---|--|-------------------|------------------------|--|---------------------------|
| Land Use | | 2006, 2011 | NA | | |
| Data Source | | Coordinate System | Geographic Coverage | | Format |
| HGAC | | WGS 1984 | HGAC Region | | dBASE Table/ Shapefile |
| Scale | Acceptance Criteria (See Instructions) | | | | |
| 1:2,400 per HCAD | Only source available in a format with consistent coverage | | | | |
| Intended Use | | | | | |
| Land use data is assigned to each parcel; this information is intended for use modeling | | | | | |

| Data Type | | Date | Resolution or Accuracy | | |
|---|--|-------------------|------------------------|--|-----------|
| SSURGO County Soil Surveys | | 1999 | 1:50 at scale | | |
| Data Source | | Coordinate System | Geographic Coverage | | Format |
| USDA NRCS | | NAD 83 | Nationwide | | Shapefile |
| Scale | Acceptance Criteria (See Instructions) | | | | |
| 1:20,000 | Only source available in a format with consistent coverage | | | | |
| Intended Use | | | | | |
| Water infiltration rates are assigned to each class of soil. Infiltration rates will be factored in the model to estimate effective runoff. | | | | | |

| Data Type | | Date | Resolution or Accuracy | | |
|---|--|-------------------------|------------------------|--|-----------|
| TCEQ 2010 Stream Segments | | 2011 | 1:50 at scale | | |
| Data Source | | Coordinate System | Geographic Coverage | | Format |
| TCEQ | | Decimal Degrees, NAD 83 | Statewide | | Shapefile |
| Scale | Acceptance Criteria (See Instructions) | | | | |
| NA | Only source available in a format with consistent coverage | | | | |
| Intended Use | | | | | |
| This is reference data set to be used for illustration purposes. This dataset is not a model input. | | | | | |

| Data Type | | Date | Resolution or Accuracy | | |
|--|--|-------------------|------------------------|--|--------|
| Digital Elevation Data | | 2006 | 10 meters | | |
| Data Source | | Coordinate System | Geographic Coverage | | Format |
| USGS | | WGS84 | Nationwide | | DEM |
| Scale | Acceptance Criteria (See Instructions) | | | | |
| N/A | Only source available in a format with consistent coverage | | | | |
| Intended Use | | | | | |
| This data set is used to define subbasins in the study area. | | | | | |

| Data Type | | Date | Resolution or Accuracy | |
|-----------|--|------|------------------------|--|
|-----------|--|------|------------------------|--|

| | | | |
|--|---|---------------------|-----------|
| CHARM Grid | | 2014 | NA |
| Data Source | Coordinate System | Geographic Coverage | Format |
| TCWP | DD, NAD83 | Galveston County | Shapefile |
| Scale | Acceptance Criteria (See Instructions) | | |
| 1:2,400 | A shell dataset prepared for purposes of managing and parsing modeling inputs, intermediate steps, and outputs. | | |
| Intended Use | | | |
| This geospatial layer is not a data set in the sense of input or output data. It is, in effect, a spatial spreadsheet. It is used to manage data relationships between spatial layers and modeling inputs and outputs. | | | |