Dickinson Bayou
Watershed
Protection Plan

February 2009
Dickinson Bayou Watershed Partnership

PREPARED IN COOPERATION WITH
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND
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EXECUTIVE SUMMARY

The Dickinson Watershed Protection Plan (DBWPP) outlines a series of actions aimed at improving the overall health of the watershed and reducing the amount of pollutants entering the Bayou. These actions are based on the vision and goals proposed for the watershed by a broad group of stakeholders representing individual citizens, non-profit and commercial interests, and local, state, and federal government entities. The vision and goals entail leaving an environment and community for future generations that is much improved, or at least no worse than the present.

This plan sets forth specific goals and pollutant reduction targets in short-term (~5 years) and long-term (~20 years) frameworks. There are no intermediate goals (e.g., ~5-10 years) because this plan is intended to be a living document, frequently revisited by the stakeholders.

The Dickinson Bayou Watershed has changed markedly over the years, and not always for the better in terms of watershed health. Water quality in the Bayou has degraded, and what was once native prairie and farmland has been developed into subdivisions and shopping centers. Forecasts of increased growth and development only foretell further changes for the worse. The Partnership does not pretend it is possible to return the watershed to a pristine, pre-development state, but it does intend to insure that the water quality in the Bayou will not degrade much more, if at all.

First and foremost, this plan needs a champion, and preferably several; a champion who lives in the watershed and can dedicate sufficient time to building public support and gathering resources. There is no recipe for producing champions, but without a few homegrown supporters, success of this plan is unlikely. Secondly, dedicated staff is necessary to insure implementation of the plan. A full-time watershed coordinator is recommended, perhaps funded by watershed municipalities as part of their stormwater management programs. A watershed coordinator could provide stormwater education and outreach required of watershed cities under the Texas Pollutant Discharge Elimination System (TPDES) as well as coordination of DBWPP implementation, including the securing of additional outside funding.

For initial implementation phase of the DBWPP, the Partnership proposes modest short-term pollutant reduction targets of 23,394 lbs/yr of total nitrogen (6% reduction), 5,816 lbs/yr of total phosphorous (5% reduction), and 1.9 x 10^6 billion colonies/yr of bacteria (15% reduction), and 1,000 acres of preserved land[1]. A Clean Water Act Section 319 watershed implementation plan grant is already in place[2], and will be the main driver for accomplishing most of these short term goals. Several on the ground demonstrations of site specific BMPs are funded though this grant with the short-term goal of treating 250 acres with on the ground BMPs. This funding will also help install a demonstration stormwater wetland in the watershed and provide educational workshops for many different groups.

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[1] Preserving 1,000 acres will stop an additional 20,252 lbs/yr (4.3%) of total nitrogen, 4,797 lbs/yr (4.6%) of total phosphorus, and 6.2x10^5 billion colonies (4.7%) per year from entering Dickinson Bayou

[2] Granted to Texas Agrilife Extension through the Texas Coastal Watershed Program.

For the long term, the Partnership envisions much more substantial pollutant reductions and much improved watershed health compared to the present. Under this plan, watershed improvement would be based around three broad categories of actions: installation of stormwater best management practices (BMPs), land preservation, and channeling of a significant fraction of new development into "liveable centers."

The best stormwater BMP for this area is, in the Partnership's estimation, the stormwater treatment wetland (STW). Wetlands are a prominent part of our natural environment –they already work well here. Wetlands can easily be engineered into new detention basins or retrofitted into existing basins. If runoff from all existing development in 20 years were routed through STWs, a reduction in 267,968 lbs/yr of total nitrogen (32% reduction), 96,634 lbs/yr of total phosphorus (23% reduction) and 1.6 x 10^7 billion colonies/yr (46% reduction)[3] could be expected. The cost of implementing this goal would be substantial, but it would be a small fraction of total development costs. Not only would STWs provide a substantial pollutant load reduction, they would provide significant habitat for waterfowl and other fauna while beautifying local communities. Consideration should be given to regional management of stormwater detention, which would enable larger and ecologically more significant wetland complexes, as well as better treatment efficiency, versus subdivision-scale detention. A regional approach to wetlands would also put a government agency in charge of maintenance instead of individual businesses or home owners association offering a more unified approach to this issue.

The Plan calls for the preservation of some 4,200 acres of prime natural areas that still exist in the watershed. Preserving these acres in their natural state would result in substantial pollutant reductions over what would take place were that land developed[4]. The preserved natural areas would provide important natural services or infrastructure, such as floodwater detention, that would otherwise cost money. Beyond providing important habitat for native fauna, a large and ecologically intact fragment of Gulf Coast prairie and forest ecosystem would very importantly provide a strong sense of place and heritage for watershed residents, given the role this ecosystem has played in watershed history (see Appendix B). That sense of place could perhaps contribute more than anything else to a strong sense of ownership and stewardship on the part of watershed residents.

Lastly, liveable centers (also known as town centers) are emerging as an important regional development alternative. Development in walkable liveable centers is much more compact than, and therefore consumes much less land than, traditional development. In addition, walkable communities provide a much higher quality of life for many people. If 50% of new development were channeled into mostly small lot ($\leq$ about 3,000 sq ft) and townhome patterns, we could expect at least 20% reduction in what pollutant loads otherwise would have been. The

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[3] Reductions based upon projected 2029 loadings assuming full build out of the watershed at medium density, see Section 23 for full calculations

[4] If 4,200 acres were developed at medium density, they would contribute an additional 80,000 lbs/yr of total nitrogen[4], 20,000 lbs/yr of total phosphate, and some 2.4 billion colonies/year of bacteria.

impending creation of a commuter rail line along Hwy 3 will be a real opportunity for compact transit-oriented development, if appropriate planning takes place now.

This watershed plan is a list of potentially isolated actions. The fundamental principle of watershed management, however, is that everything is connected. This holds true for this plan as well. There is a synergy to be obtained by integrating as many actions as possible. Stormwater wetlands, for example, provide by water quality *and* habitat; liveable centers improve quality of life *and* result in pollutant loading reductions. This *watershed* plan seeks to integrate a diverse set of activities, and to find *watershed* wide benefits.

SUMMARY OF MILESTONES

Strategy	Milestone	Expected Completion Date	Cost
Organizational Continuity			
	Seek grant funding for coordinator & solicit funding from municipalities within the watershed	2009	No cost
	Hire watershed coordinator	2009	$70,000-100,000 annually
	Establish a 501(c)3 non- profit group	2010	$20,000 annually
Education and Outreach			
	Development of 3 key themes	2009	Cost listed under watershed coordinator
	Five watershed workshops held, and 10% of households/businesses reached	2014	Cost listed under specific strategies (i.e. habitat, stormwater management, etc.)
	Four outreach events attended by Watershed Partnership representatives	2010	Cost listed under specific strategies (i.e. habitat, stormwater management, etc.)
	Ten watershed specific publications produced	2010	Cost listed under specific strategies (i.e. habitat, stormwater management, etc.)
	Twelve demonstration sites (WaterSmart landscapes, rain gardens, construction site BMPs, LID BMPs)	2010	Cost listed under stormwater BMPs
	Implementation of full blown multimedia outreach campaign	Spring 2014	$2.5 million over 5 years

Strategy	Milestone	Expected Completion Date	Cost
Habitat Conservation			
	Hold 2 public workshops on preserving land though conservation easements	2010	$50,000 (also includes a landowner assistance program)
	Develop a watershed wide mitigation plan	2014	$30,000
	Develop a watershed wide habitat conservation plan	2014	$100,000
	Preserve 1,000 total acres of habitat in the watershed	2014	
	Preserve 2,500 total acres of habitat in the watershed	2019	
	Preserve 4,200 total acres of habitat in the watershed	2029	
Onsite Wastewater Facilities			
	On-site Sewage Facility (OSSF) Feasibility study	2010	$75,000
	OSSF Soil Evaluation Workshop	2009	$5,000
	Advanced Retrofit Workshop	dependent on feasibility study	$10,000
Permitted Wastewater			
	Complete conversion of clay sewer pipes	2016	$17 million
Stormwater Management			
	Creation of LID Technical Committee	2010	No cost

Strategy	Milestone	Expected Completion Date	Cost
	List of the best BMP's for Dickinson	2010	No cost
	Self guided tour map of demonstration sites in the watershed	2011	$5,000
	Adoption of a watershed stormwater ordinance by all communities within the watershed	2012	No cost
	Three construction site compost demonstration sites	2014	$1.1 million
	Three post construction site demonstration BMPs completed at highly visible sites (selected from technical committee list)	2010	
	100 LID BMP's installed at private homes	2014	
	50 LID BMP's installed at business, municipal offices, court houses, etc.	2014	
	Creation of (or retrofit) LID neighborhood	2014	
	10,000 acres treated by storm water BMPs	2029	
Stormwater Wetlands			
	Develop a retrofit manual/guidebook for landowners	Fall 2009	$10,000
	Complete 5 stormwater wetland treatment systems within the watershed	2014	$500,000
	All currently developed areas treated by stormwater wetlands	2029	

Strategy	Milestone	Expected Completion Date	Cost
Urban Growth			
	Ordinance changes to allow compact growth in select areas	2010	No cost
	At least 3 growth related workshops	2014	Cost listed under Watershed Coordinator
	Channel 50% of new growth into Liveable Centers	2029	No additional cost
Parks and Recreation			
	Additional 50 acres of park space open to the public, portion of which will be pocket parks	2013	Land acquisition costs listed under habitat conservation
	Installation of at least 5 educational signs throughout the watershed	2011	$7,500
	25% of parks managed organically (using WaterSmart Landscaping principles)	2014	No additional cost
	Hold 2 classes on boating safety and community stewardship	2010	No cost
	Additional 110 acres of park space open to the public	2019	Land acquisition costs listed under habitat conservation
	100% of parks managed organically (using WaterSmart Landscaping principles)	2019	No additional cost
Water Quality Monitoring			
	Clean Rivers Program surface water quality monitoring	2014	$22,000
	Installation of new continuous water quality monitoring station with flow meter	2014	$10,000 - $20,000 per year

FORWARD

Imagine an endless sea of thick, flowering prairie grasses, full of color and variety, disturbed only by segments of cloistered forests. Picture buffalo, wild mustangs, deer and a whole host of wildlife, roaming freely among the towering trees and grasses of this coastal lowland. Concealed between banks of majestic post oaks and aromatic cedars, discover a beautiful bayou, providing sustenance and life to all its inhabitants. Flowing modestly with tidal change, Dickinson Bayou resonates with an unassuming purpose when tasked with accepting storm-water from miles and miles of surrounding land. A vision captured only in the colorful past of this aged waterway, the Dickinson Bayou watershed has only small remnants of its once prevalent inhabitants and natural topography.

The watershed encompasses approximately 100 square miles of property that utilizes tributaries, drainage ditches and storm drains to move run-off into Dickinson Bayou. With the enormous influx of large commercial and housing developments, non-porous surfaces are rapidly changing the landscape within this watershed and having a negative effect on Dickinson Bayou and its populace. There is no question that the current appearance of this watershed is threatening the quality of water in Dickinson Bayou and Galveston Bay, and land use issues need to be addressed at the State and local level to prevent further degradation of Dickinson Bayou. The Dickinson Bayou watershed is a place for people to live and work, but it is also a place to connect with the natural heritage of this region.

*The Dickinson Bayou Watershed Plan presents the current state of the watershed, identifies concerns, provides recommendations on how to improve the watershed, devises an implementation schedule of those recommendations, and specifies who has the technical and financial framework for implementation to occur. All of these elements are important in achieving the mission of the Dickinson Bayou Watershed Partnership which is "**to protect, preserve and restore the quality of the Dickinson Bayou watershed and its communities."***

Julie Masters

Mayor, City of Dickinson

1. Introduction

The Dickinson Bayou Watershed

The Dickinson Bayou watershed lies between Houston and Galveston, Texas and encompasses a total area of 105 square miles (Figure 1). The watershed falls within Galveston and Brazoria Counties and includes portions of Alvin, Dickinson, Friendswood, Kemah, League City, Manvel, San Leon, Santa Fe and Texas City (Figure 2). The total population of the watershed is approximately 75,000[5]. Ethnically, the population is primarily white with significant Hispanic and African American populations and a small Asian population. The Dickinson Bayou watershed is about 50% developed, but there are still significant natural and agricultural areas.

Dickinson Bayou is a 22.7 mile long, slow moving coastal stream that drains into Dickinson Bay, a sub bay of the Galveston Bay system. The lower reaches of the bayou from 2.5 miles downstream of FM 517 to Dickinson Bay are tidally influenced, while the portion from the head waters to 2.5 miles downstream of FM 517 is not. (Figure 3) Dickinson Bayou has ten main tributaries: Oak Creek, Algoa Bayou and Hickory Bayou in the portion above tidal influence and Gum Bayou, Bensons Bayou, Giesler Bayou, Bordens Gully, Cedar Creek, Hulen Park Bayou and Arcadia Bayou in the tidal portion. The main channel of Dickinson Bayou has a significant deep section where the bottom of the channel dips below the level of the channel at the outlet to Dickinson Bay. This deep section effects the mixing of water in the bayou and flow to the Bay.

The climate in the Dickinson Bayou watershed is characterized by long hot, humid summers frequently cooled by sea breezes. Winters are warm and occasionally interrupted by incursions of cool air from the north. Rain occurs throughout the year, and precipitation generally averages 48 inches annually[6]. Snowfall is rare.

The Dickinson Bayou watershed is relatively flat with elevations ranging from zero to 60 feet above mean sea level. The westernmost portions of the watershed are generally higher and the land generally slopes downward toward Galveston Bay. Much of the tidal section of the watershed is below 30 feet (Figure 4). The soils throughout the watershed are moderately to very poorly drained loams, clays and clayey loams (Figure 5).

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[5] Houston-Galveston Area Council 2008. Population and Employment Forecasts. GIS dataset Format (1 mile grid).
[6] Galveston County Parks Department. Dickinson Bayou Watershed brochure. http://www.dickinsonbayou.org/watersheds/info/documents/DickinsonBrochure.pdf

Figure 1. Location of the Dickinson Bayou Watershed

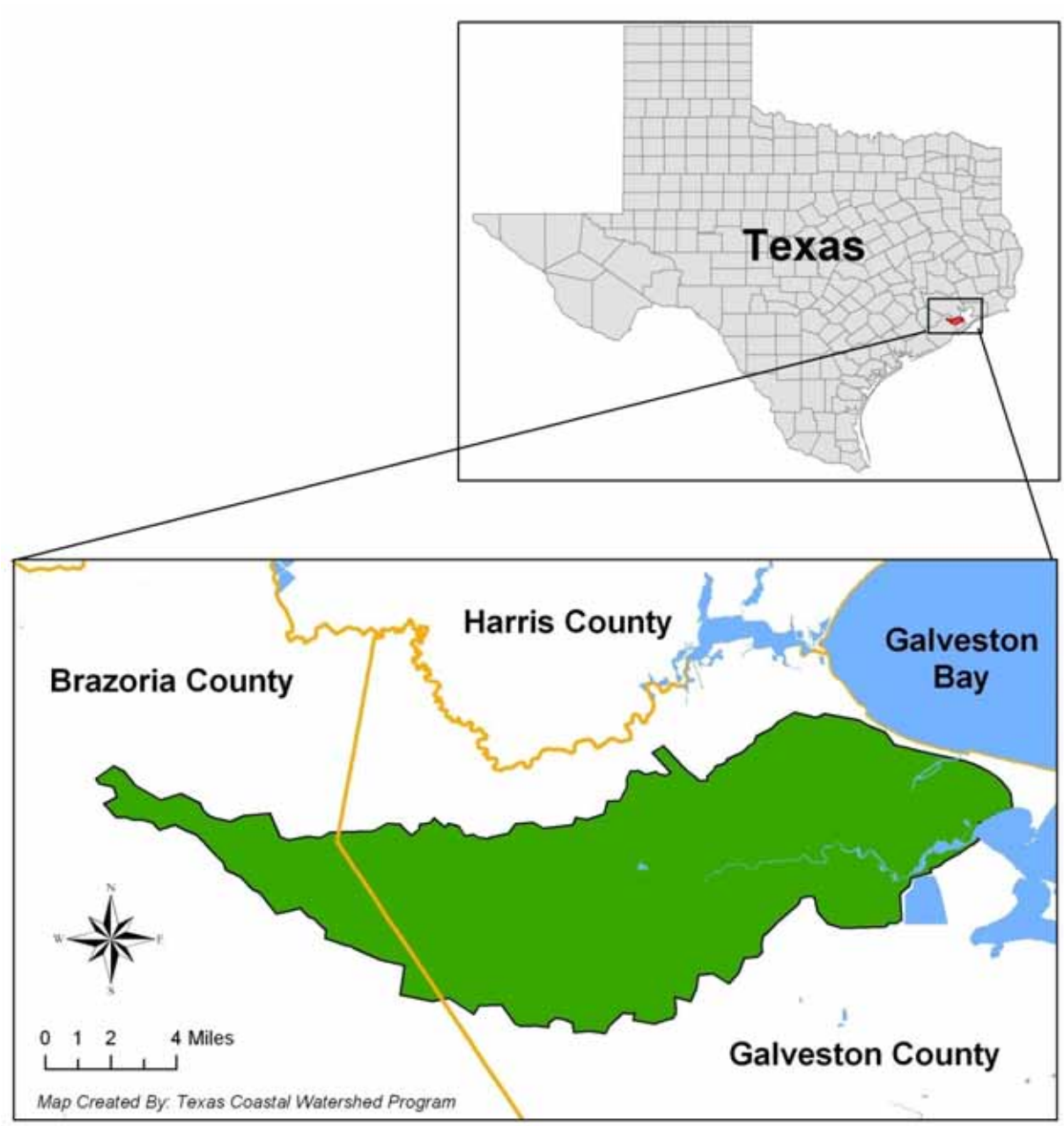


Figure 2. Cities in the Dickinson Bayou Watershed

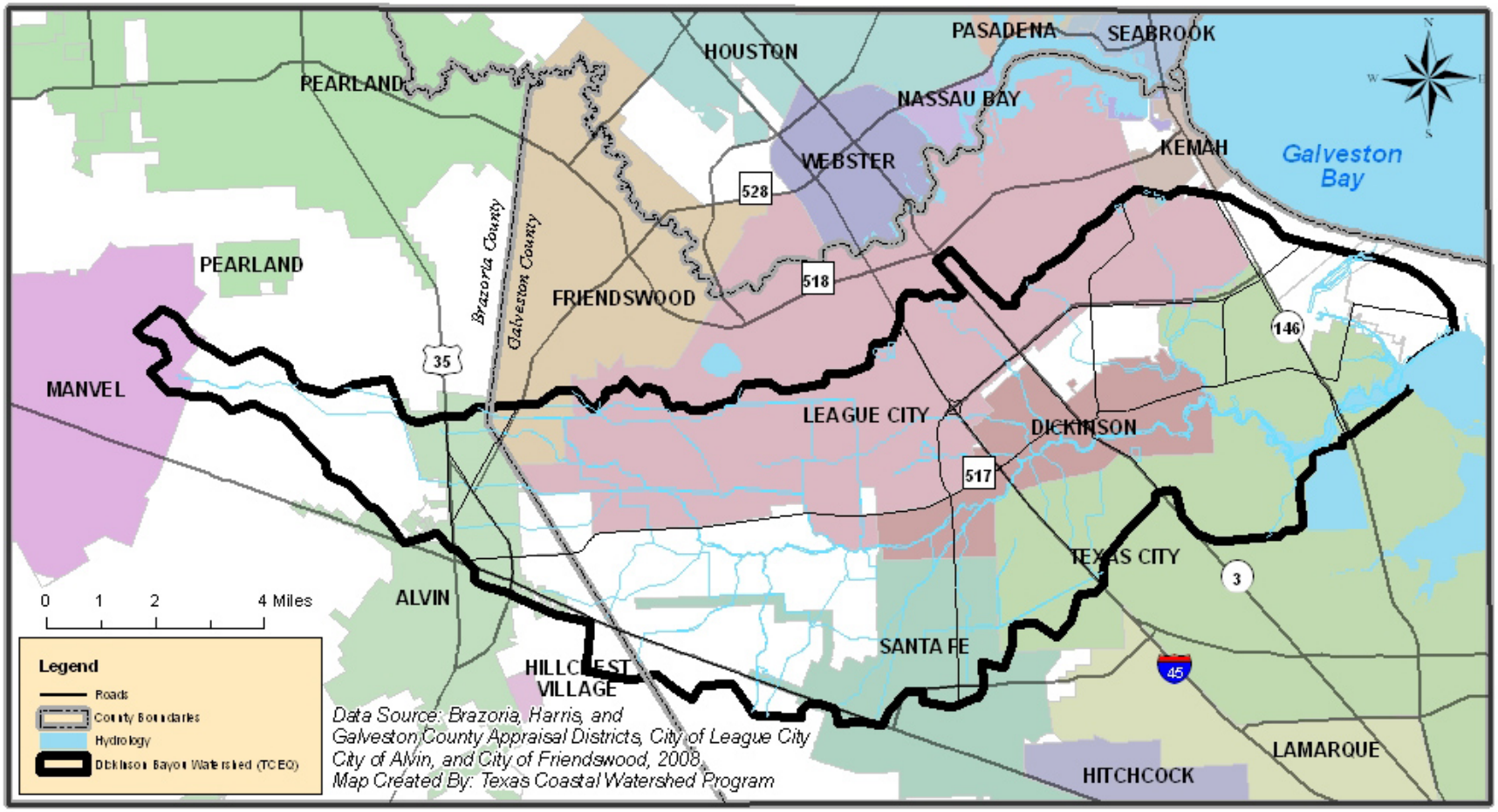


Figure 3. The tidal boundary of Dickinson Bayou

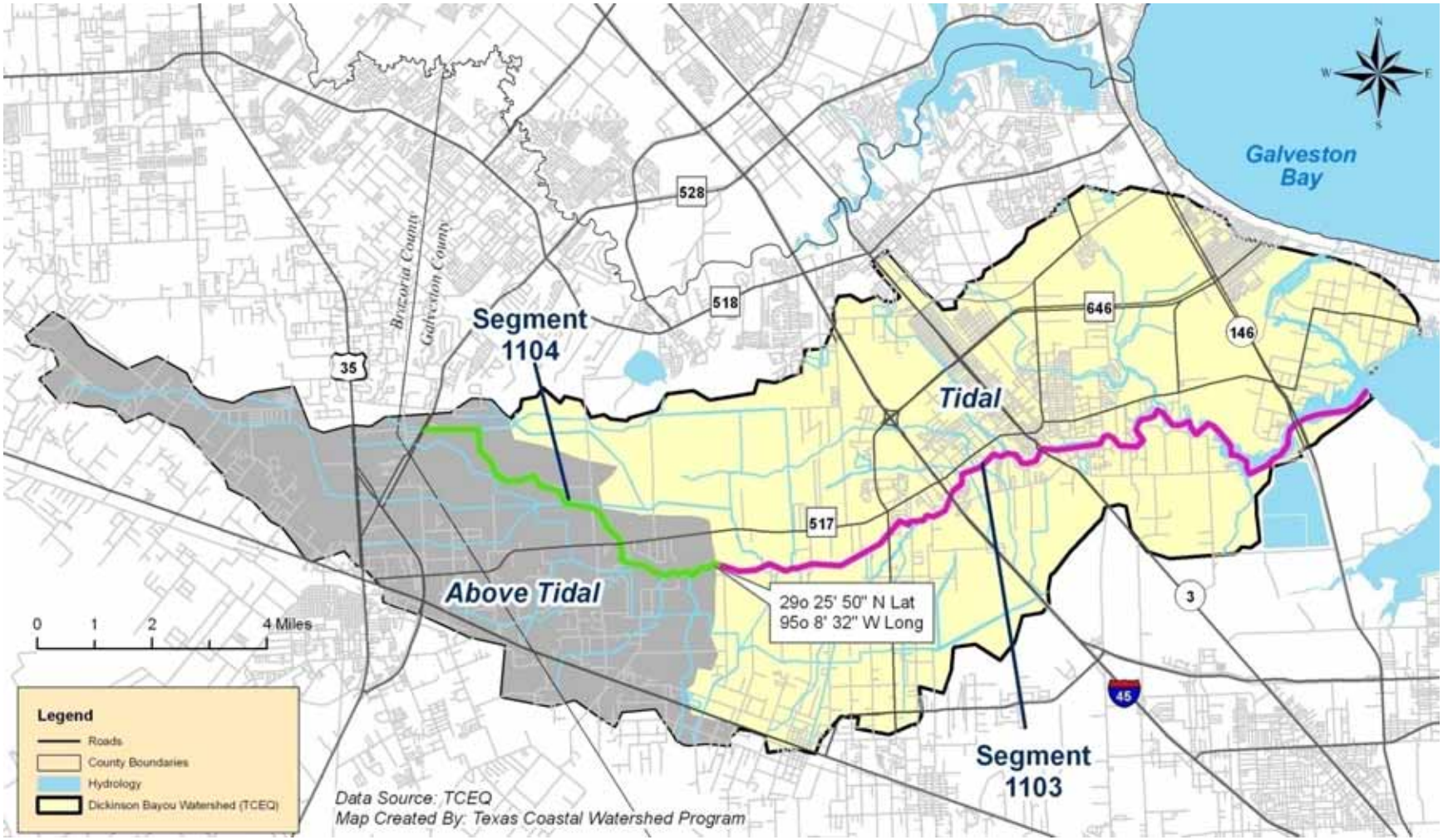


Figure 4. Dickinson Bayou Watershed Elevation

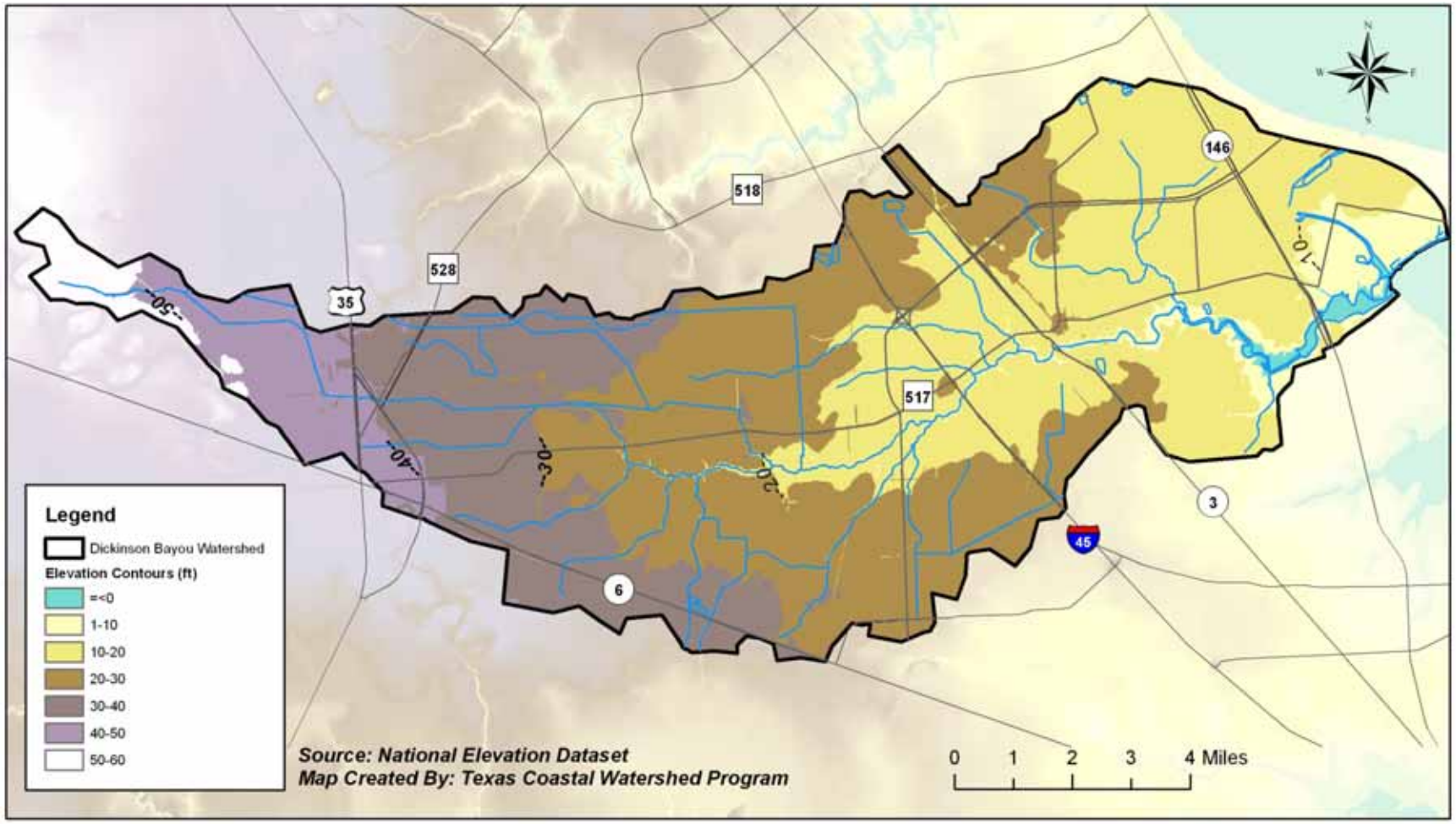


Figure 5. Dickinson Bayou Watershed Soils

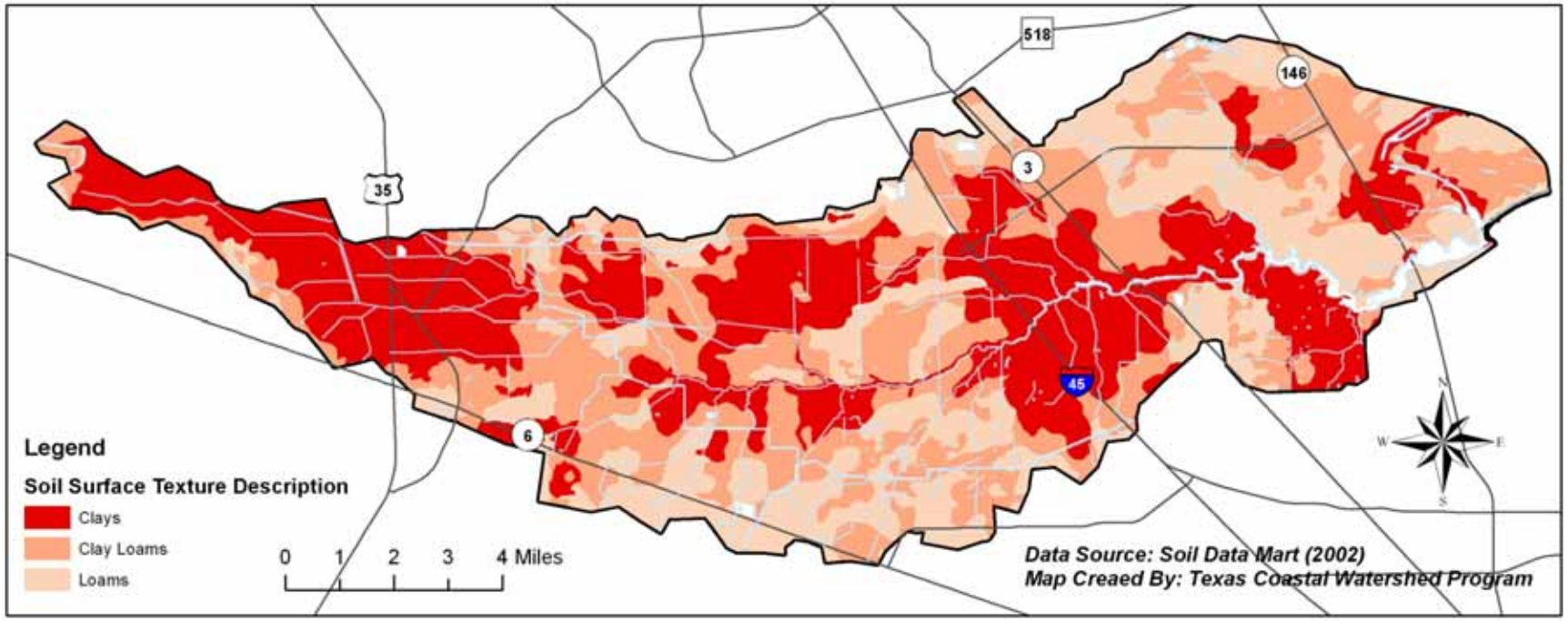
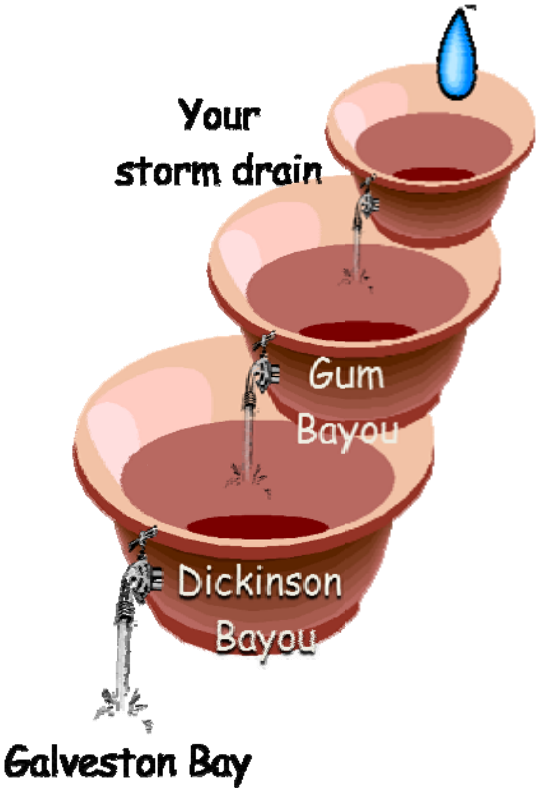


Figure 6. What is a watershed?

What is a watershed? A watershed is an area of land where precipitation drains into a single bayou, creek, river, lake, or bay. Watersheds include both natural elements such as prairies, marshes, and streams, and man-made elements such as homes, parks, schools and shopping centers.

Watersheds can be large or small. In addition, each watershed can be part of a larger watershed. For example, several sub-watersheds are part of the Dickinson Bayou watershed (Benson Bayou, Gum Bayou, etc), and the Dickinson Bayou watershed itself is part of the larger West Galveston Bay watershed.

Why are watersheds important? Everyone lives in a watershed. Even those who do not live near the water live on land that drains to a bayou, river, estuary or lake, and everyone's actions on that land affect water quality and quantity far downstream. Decisions made by homeowners and citizens can affect the quality of the water everyone uses for drinking, fishing, boating, or swimming. Individual actions—either negatively or positively impacting water quality—may not seem like much, but collectively, they can have a tremendous impact.



2. The Dickinson Bayou Watershed Partnership

The Dickinson Bayou Watershed Partnership (Watershed Partnership) formally came together in 2004 through a shared interest in preserving and enhancing the natural integrity of the watershed through the coordinated management of natural resources. The Watershed Partnership comprises stakeholders from state and federal agencies, nonprofit organizations, civic groups, academic institutions, local governments, business and industry groups, utility companies and citizens. The Dickinson Bayou Watershed Partnership worked as a group to establish their mission, vision, and goals. This was a consensus based process with the objective of maintaining and restoring the health of the Dickinson Bayou watershed.

The **Advisory Committee** is the main directive body of the Watershed Partnership and is made up of a cross section of stakeholders representing all areas mentioned above. The Advisory Committee meets to discuss issues that arise and votes to bring the most important points forward to the entire Watershed Partnership (Figure 7). All decisions are voted on, with no recommendations going forward that do not have full consensus of the Advisory Committee.

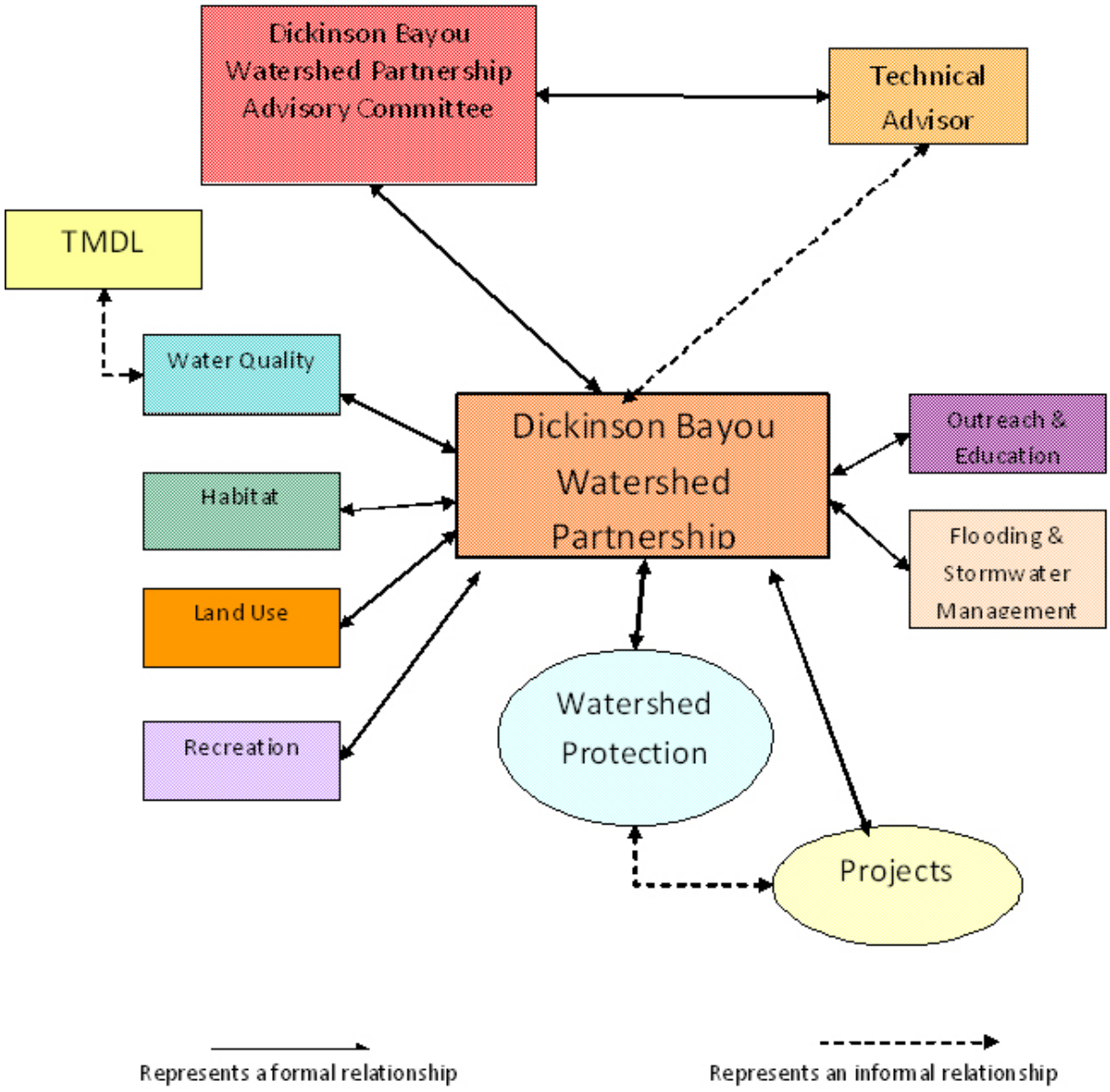
In addition to the Advisory Committee, there are six **Workgroups**: Land Use, Habitat, Education and Outreach, Flooding and Stormwater Management, Water Quality, and Recreation (Figure 7). These groups are open to any stakeholder and their members work to find realistic solutions to problems in the watershed. These work groups have all contributed to the writing of this watershed protection plan.

The Watershed Partnership is lead by a **chairperson** or two **co-chairs** elected by the partnership and by a watershed coordinator. The partnership meets at least twice each year for updates on advisory committee and workgroup happenings. All issues put forth by the Advisory committee are voted on at Watershed Partnership meetings and must be passed by a simple majority. All citizens of the watershed are invited and encouraged to attend these meetings.

The vision of the Watershed Partnership is a fully ecologically functioning bayou and a watershed that maintains the integrity of its natural resources. The vision also includes a watershed populace that is aware of the natural values of this watershed, and that makes choices accordingly. Implementation of this vision will involve improving education and stewardship, working to enhance water quality and protect habitat, and supporting a coordinated decision making process for activities that affect the watershed.

This watershed plan establishes the ***baseline conditions*** and an ***initial vision*** for the watershed. The plan also ***establishes priorities***, creates a detailed ***plan of management options***, and ***a plan to implement*** improvement projects. The Watershed Partnership will evaluate the progress of this process and repeat various stages as necessary, as part of an iterative process.

Figure 7. Organizational Structure of the Dickinson Bayou Watershed Partnership



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3. Definition of the Problem

Both Dickinson Bayou and its watershed have changed markedly over the years. Water quality in the Bayou is not what it once was. The watershed has changed from a pastoral collection of small towns and agricultural land far removed from Houston to a fast-growing suburb on the leading edge of growth spreading out from metropolitan Houston. The biggest changes ever in the character of the watershed, and probably the water quality of the bayou, will likely occur in the next two decades as suburban growth completely transforms the landscape.

The problems with Dickinson Bayou and its watershed are on two different levels. One is the regulatory level, defined by water quality standards set by the state. The second is a more general perception of declining environmental quality, in terms of loss of habitat, increased flooding, dramatic changes in quality of life, etc.

Dickinson Bayou does not meet the State water quality standards for dissolved oxygen (DO) or pathogen indicator bacteria. Low DO means that the bayou is not well aerated, and fish sometimes have problems breathing to such an extent that fish kills are not uncommon. **The Bayou also has high enough levels of bacteria, particularly fecal bacteria, that it does not meet state standards for contact recreation.** Depressed levels of DO are caused in part by relatively high levels of nutrients in stormwater runoff, likely associated with excessive use of fertilizers on residential and commercial landscape. The high levels of bacteria are caused mainly by organic waste from leaking, broken or otherwise malfunctioning sanitary sewer pipes, possible illicit (Illegal) discharges of untreated sewage, contaminated runoff from failing septic systems, and pet waste. These organic wastes also contribute substantially to the low DO condition.

Dickinson Bayou is naturally a poorly drained coastal stream. The bottom topography of a portion of the bayou is lower than the bottom topography of Galveston Bay, to which the bayou drains. This peculiar bottom topography means that Dickinson Bayou will naturally have some periods of low dissolved oxygen. It also means that **the Bayou has a fairly low threshold for low DO episodes**. In other words, it doesn't take much in terms of additional levels of the contaminants discussed above to trigger low DO episodes. This bottom topography also means that while low DO and high bacteria are well defined and easy to measure, a regulatory approach to solving the problem is neither straightforward nor easy.

Beyond the well defined regulatory issues, residents of the watershed have made it clear that the overall health of the watershed is not what it should be. **Too much of the original habitat has been lost to uncontrolled and unplanned growth.** Many, if not most, residents feel that **the small town quality of life in this area is rapidly being lost** to a high-traffic, uninterrupted sprawl of residential subdivisions and strip centers with little opportunity for contact with either farmland or natural areas. In addition, **there is a**

perception that the increase in developed areas is resulting in more flooding.

The Dickinson Bayou Watershed Plan is an attempt by the citizens and organizations in the watershed to tackle these problems. None of these problems occur in isolation from the other. This plan recognizes that an **integrated approach** is necessary to restore and improve the health of the Bayou and its watershed. This is not a regulatory plan, but the Watershed Partnership hopes that a regulatory approach can be devised by the State that is consistent with this plan.

There is no significant cropland left in the Dickinson Bayou watershed, and only limited cattle grazing. This plan does not address agricultural runoff; given that pollutant loadings from agricultural lands are minor compared to runoff from developed areas.

This plan explains in some detail the nature of the problems that afflict the watershed, and then lays out a program, developed by a broad-based group of stakeholders in the watershed, to put the bayou and its watershed on a path to health. This is a voluntary plan, and its **goals will not be achieved without the full participation of the counties, municipalities, businesses, organizations, and the citizens of the watershed.**

4. Water Quality

Water quality is the central issue around which this Plan is focused, mainly because there are regulatory limits associated with water quality (discussed below), and thus some legal imperatives are in place to improve water quality in Dickinson Bayou. In addition, the quality of the water in the Bayou is a reflection of the overall health of the watershed that contributes to the Bayou. The quality of the water in the Bayou can tell us what kinds of changes we need to be making in the watershed to improve the health of the system.

Water quality is a complex topic which comprises physical, chemical and biological components. In addition, Dickinson Bayou is a very slow moving coastal bayou with some complicating channel topography that further complicates the picture. (Figure 8) We do have a fair amount of data on the Bayou. This data, as well as our own senses and past history, tell us that the water quality in the Bayou is not as good as it was in the past nor as good as it could be today. This section describes in general terms what we know about the water quality of Dickinson Bayou.

Some studies have shown that sections of Dickinson Bayou have high concentrations of bacteria[7], which are unsafe for swimming. Other studies have shown that areas of Dickinson Bayou have low levels of oxygen in the water, which can be harmful to aquatic life, and in extreme cases have caused fish kills. Because of these findings, Dickinson Bayou has been listed on the Texas Water Quality Inventory and 303d List (for impaired water bodies).[8] As a result of this listing, more studies have been conducted to further understand the causes of the water quality problems and potential solutions. These studies are called "Total Maximum Daily Load" studies, or TMDLs. The Texas Commission on Environmental Quality (TCEQ) has been developing four TMDLs for Dickinson Bayou – two (one for tidal and one for non-tidal) to address the low dissolved oxygen and two to address the high bacteria levels[9].

Dissolved Oxygen

Dissolved oxygen , the concentration of oxygen in the water body as reported in milligrams per liter (mg/L), is a traditional measure of aquatic health and water quality because aquatic organisms need oxygen to survive, and is one of the simplest and most direct measures we have. There are some complications associated with DO, however, because it is variable in any water body throughout the day and over the seasons. Dissolved oxygen concentrations increase when aquatic plants and algae use sunlight and produce oxygen and decrease as oxygen gets used by living organisms, including plants, fish, shrimp, and especially bacteria, which breakdown organic matter and are abundant in the water column and in bottom sediments. Depending on salinity and temperature, dissolved oxygen concentrations at peak

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[7] Rifai, H. 2007. Total Maximum Daily Loads for Fecal Bacteria in the Dickinson Bayou Final Historical Data Review and Analysis Report Revision 1.

[8] http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/08twqi/twqi08.html

[9] Texas Commission on Environmental Quality. 2008. *Two Total Maximum Daily Loads for Dissolved Oxygen in Dickinson Bayou.*

levels in “healthy” waters are normally 7-10 mg/L. Many types of 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. In the worst case, fish kills can result from very low concentrations of dissolved oxygen, e.g., below 1mg/L. Dickinson Bayou has experienced several fish kills due to low dissolved oxygen, particularly in the area between I-45 and State Highway 3 (figure 9). These fish kills occur more often in warm weather because there is proportionally less oxygen in the water and oxygen consumption is higher.

For the time period 2000 – 2006, dissolved oxygen, in general, was lowest in the area between Cemetery Road and Gum Bayou, the zone of non-attainment[10] (Figure 9). The difference in DO levels in warm months (June to September) compared to cool months (October –to May) is apparent in Figure 9, where even the surface DO is low between Cemetery Rd and Benson Bayou. Also, in the warmer months, the DO was particularly low in the deeper layers.

The state of Texas requires the minimum dissolved oxygen level in a 24 hour period to be greater than 3mg/L and the average over 24 hrs to be above 4 mg/L in Dickinson Bayou in order to meet its aquatic life use designation.

Dissolved oxygen values are unquestionably low in Dickinson Bayou. But because Dickinson Bayou is naturally a slow moving coastal stream, there is some question as to just how high DO levels *could* be even if the watershed were in a pristine state. At present there is no consensus as to what that number might be. Clearly, DO is going to be lower than a faster flowing hill country stream. Dissolved oxygen values in Dickinson Bayou have improved over the years, as evidenced in the fish kill data below. There is a movement by some in the regulatory community to change the DO standard for coastal streams like Dickinson Bayou. This movement is resisted to some degree by many stakeholders in the Dickinson Bayou watershed, not because they don’t understand that the current standard may be inappropriate, but because of the uncertainty as to what the standard should be, and because they surmise that DO in the Bayou is not what it could be, even with the current amount of development in the watershed.

Low DO is not a direct pollutant that we can control; it is the result of a number of other factors. Unfortunately, we do not have enough data to quantitatively determine exactly how much each of these other factors contributes to the DO problem. We can, however, draw some conclusions from what we know about basic water quality principles.

Nutrients (especially nitrogen (N) and phosphorous (P)) are first on the list of concerns. Nitrogen and phosphorous feed algae in the water; excess N and P lead to algal “blooms”, or population explosions. High populations of algae in the water lead to a higher concentration of oxygen during the day, but very low levels in the night and early morning when the algae consume the oxygen. Water quality studies of Dickinson Bayou have not found excessively elevated

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[10] Texas Commission on Environmental Quality. 2008. *Two Total Maximum Daily Loads for Dissolved Oxygen in Dickinson Bayou.*

nutrients throughout the watershed or the length of the Bayou.[11] Total nitrogen concentrations ranged from 0.08 to 0.42 mg/L while total phosphorus values were in the range 0.09 to 0.25 mg/L[12] (Figure 10). Highest values were at Cemetery Road (nitrogen) and at SH 146 (phosphorus), and somewhat elevated nutrients levels were noted as a concern for additional locations (e.g., Benson Bayou at Dickinson Bayou), during some periods. Benson Bayou drains a heavily urbanized area suggesting polluted runoff associated with residential and commercial landscaping, among other sources. It is important to note that the thresholds where nutrients have an impact on water quality might be much lower for a slow-moving water body like Dickinson Bayou than they are for faster moving streams. In other words, it would not take as much nitrogen or phosphorous to cause an algal bloom as in faster moving stream. It appears that Dickinson Bayou, and other similar coastal bayous, are highly susceptible to low DO episodes resulting from relatively low concentrations of nutrients.[13]

Wastewater is also a prominent concern for low dissolved oxygen episodes. Oxygen is consumed as part of the normal bacterial decomposition processes when carbon-rich, or carbonaceous substances (e.g., wastewater), enter into water bodies. The recent TMDL study for DO in Dickinson Bayou[14] targeted these substances as a key factor in the low DO events in Dickinson Bayou.

Fish Kills

Dickinson Bayou has experienced many fish kills over the years, which are sudden die-offs of large numbers of fish. Fish kills indicate that the aquatic environment has become unsuitable and may be caused by low dissolved oxygen, spills or releases of toxic materials, and/or extreme temperatures. Low dissolved oxygen is the most common cause for fish kills along the Upper Texas Coast.

Since 1970, when data were first collected, 29 fish kills have been documented in Dickinson Bayou and 26 of those were thought to be caused by low dissolved oxygen (Table 1). More than 24 million fish have died in these kills; most of these were gulf menhaden. Catfish, mullet, and sand trout are the next most commonly reported fish in Dickinson Bayou fish kills. Many other species are also killed in small numbers, including largemouth bass, flounder, sunfish, carp, and croaker. The low DO conditions that lead to fish kills usually occur during the warmer months. In fact, 92% of the Dickinson Bayou fish kills due to low oxygen levels occurred between May and October (Table 2). Most of the fish kills in Dickinson Bayou have occurred in the reach between Cemetery Rd and State Highway 3, which is in the area where the DO impairment has also

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[11] Houston-Galveston Area Council Clean Basin Reports 2006: - Segment 1103 Dickinson Bayou Tidal, and Segment 1104 Dickinson Bayou Above Tidal. Both USGS reports

[12] Quigg, A., L. Broach, W. Denton, and R. Miranda. 2009. Water Quality in the Dickinson Bayou watershed (Texas, Gulf of Mexico) and health issues. Mar. Pollut. Bull, doi10.1016/j.marpolbul.2009.01.012

[13] Quigg, A., L. Broach, W. Denton, and R. Miranda. 2009. Water Quality in the Dickinson Bayou watershed (Texas, Gulf of Mexico) and health issues. Mar. Pollut. Bull, doi10.1016/j.marpolbul.2009.01.012

[14] Texas Commission on Environmental Quality. 2008. *Two Total Maximum Daily Loads for Dissolved Oxygen in Dickinson Bayou.*

been documented and also where the bayou is the deepest (Table 3). Overall there is a downward trend in the number of fish killed from the 1970's to the 2000's (Table 4). This downward trend corresponds to improving centralized wastewater treatment in the bayou over the years, and that improvement is the likely cause of reduced fish kills.

Table 1. Number of fish killed in different types of fish kills in Dickinson Bayou from 1970 to present.[15]

SUSPECTED CAUSE	ESTIMATED NUMBER OF FISH KILLED
Brine Discharge	10
Low Dissolved Oxygen	24,100,000
Sewage	500
Unknown	4,000
TOTAL	**24,100,000**

Table 2. Timing of fish kills in Dickinson Bayou[11]

MONTH	FISH KILL EVENTS	ESTIMATED NUMBER OF FISH KILLED
April	1	10
June	3	500,000
July	5	5,100,000
August	7	13,300,000
September	7	5,200,000
October	2	4,000

[15] TPWD fish kill database and TCEQ unpublished files compiled by Linda Broach. Data has been rounded.

Table 3. Fish kills by reach of bayou[11]

APPROXIMATE NUMBER OF MILES EFFECTED	REACH DESCRIPTION	ESTIMATED NUMBER OF FISH KILLED
0 to 4	SH 146 to Gum Bayou	0
4 to 8	Gum Bayou to I-45	17,300,000
8 to 12	I-45 to Cemetery Rd	6,400,000
12 +	above Cemetery Rd	200,000

Table 4. Fish kills by decade[11]

Years	FISH KILL EVENTS	ESTIMATED NUMBER OF FISH KILLED
1970-1979	12	18,500,000
1980-1989	10	5,000,000
1990-1999	4	600,000
2000-2008	2	10,000

Bacteria

Bacteria levels are measured in Dickinson Bayou to determine if the bayou waters are suitable for “contact recreation” (e.g. swimming, boating, water skiing, wading). If bacteria levels are high, there is an increased chance that a person will get sick if they come in contact with the water, especially if any of the water is ingested. The bacteria that are measured are present in the intestines of warm-blooded animals and they are used as an indicator of the presence of human or animal waste in the water. These bacteria themselves do not typically cause illness in humans, but their presence indicates that other disease-causing microbes could be present.

Bacteria enter streams and bayous in several different ways. In dry weather, human waste can enter the water body through leaking sewer pipes, malfunctioning septic systems, poorly functioning wastewater treatment facilities, or discharge from a boat toilet. Animal waste can enter the bayou directly, if animals have access to the stream. This could include cows and

other livestock drinking from the stream or, more commonly, birds and small mammals that use the stream and stream banks as habitat. During wet weather, in addition to the above sources, runoff carries even more waste to the stream from people and animals in the watershed.

Escherichia coli (E. coli) and *Enterococcus* bacteria have been used as the main bacterial indicator organisms in the State of Texas since 2000. In freshwater, E. coli is used as the bacterial indicator. The *E. coli* criteria are 394 mpn/100 ml for a single sample[16], and 126 mpn/100 ml as a geometric mean. In tidal waters, *Enterococcus* is used as the indicator (n Dickinson Bayou, everything from Dickinson Bay to Cemetery Road is considered tidal). The criteria for *Enterococcus* are 89 mpn/100 ml in a single sample and 35 mpn/100 ml as a geometric mean. The relationship between the levels of these newer bacterial indicators in the water and the rates of illness in swimmers are stronger than those for fecal coliform bacteria, which were used as the indicator from before 1970 until 2000.

In Dickinson Bayou, bacterial levels measured with either indicator generally exceed the criteria from FM517 down to SH3 (Figure 11). The tributaries to Dickinson Bayou were generally higher in bacteria than the main-stem stations.

The TCEQ is working on a TMDL study in Dickinson Bayou to address these high bacteria levels, which were found throughout the main-stem and in four of the tributaries: Bensons Bayou, Bordens Gully, Geisler Bayou, and Gum Bayou (Table 5).

[16] MPN is the most probable number: A statistical estimate of the number of microbes in a known amount of water (usually 100mL); used when it is not feasible to count individual organisms.

Table 5. Bacterial data for Dickinson Bayou.[17] Highlighted cells exceed the geometric mean criterion for that indicator. Bold text indicates which indicator is used at that station to evaluate compliance with Texas Surface Water Quality Standards.

				Enterococcus (Tidal Indicator)			E. coli (Freshwater Indicator)		
Station	**Segment**	**Name**	**Station on Tributary?**	**# Samples**	**Geometric Mean (35)**	**% over 89 mpn/100ml**	**# Samples**	**Geometric Mean (126)**	**% over 394 mpn/100ml**
11467	1104	FM517	No	26	310	92%	**73**	**272**	**34%**
11465	1104	Jack Beaver Rd	No	22	321	86%	**19**	**271**	**26%**
11434	1103	Cedar Creek	Yes	1	1	0%	**26**	**123**	**19%**
11464	1103	Cemetery Rd	No	**85**	**130**	**61%**	92	189	22%
11462	1103	IH45	No	**82**	**60**	**29%**	88	200	27%
16469	1103	Bordens Gully	Yes	**38**	**240**	**74%**	48	711	69%
16470	1103	Geisler Bayou	Yes	**38**	**86**	**42%**	46	542	57%
16471	1103	Benson Bayou	Yes	**40**	**53**	**30%**	45	440	51%
11461	1103	At Benson Bayou	No	**44**	**110**	**52%**	44	252	34%
11460	1103	SH3	No	**121**	**40**	**28%**	110	188	27%
16679	1103	Mariners Mooring	No	**26**	**12**	**15%**	43	122	23%
16979	1103	Upstream of Gum Bayou	No	**43**	**31**	**30%**	42	144	33%
11436	1103	Gum Bayou	Yes	**41**	**33**	**17%**	44	252	34%
11455	1103	SH146	No	**42**	**11**	**10%**	43	45	12%

[17] Rifai, H. 2007. Total Maximum Daily Loads for Fecal Bacteria in the Dickinson Bayou Final Historical Data Review and Analysis Report Revision 1, Tables 13 and 14.

Total Maximum Daily Loads

Dissolved Oxygen

In 2008, the Texas Commission on Environmental Quality completed two draft Total Maximum Daily Load reports addressing depressed DO in Dickinson Bayou (one for each segment of the Bayou, tidal and above tidal). Released for public comment in May of 2008, the draft TMDL reports were not adopted by the TCEQ. They remain in draft form because the DO endpoint estimated in the TMDLs[18] could not be shown to reach the frequency of attainment currently required by the TCEQ (i.e., attainment frequency at the 90th percentile in terms of time).

The EPA requires that TMDLs adopted by a state be designed to meet the applicable water quality criteria specified in the state's water quality standards. The modeling results described in the draft Dickinson Bayou DO TMDL report showed that no reduction in oxygen-consuming organic matter, also known as biochemical oxygen demand (BOD), nutrients, or suspended solids could ultimately result in attaining the DO criteria, at the 90th percentile, in the tidally-influenced portion of the bayou. This is based on computer modeling scenarios simulating natural loading conditions and no wastewater discharges. The results of the TMDL analysis also showed that the natural bottom contours of Dickinson Bayou contribute significantly to the non-attainment of DO criteria and recommends a reassessment of these criteria for Dickinson Bayou or of the criteria assessment methodology used for the tidal portion of the bayou. The TMDL models showed that under periods of warm, dry weather, the sluggish estuarine hydrodynamics (water flow) in Dickinson Bayou influence the biochemical interactions occurring in tidal portions of the stream. This prevents the bayou from reaching the applicable DO criteria at the requisite frequency of 90%.

Two models were used to develop the draft Dickinson Bayou DO TMDLs:

1. A fully dynamic watershed model (HSPF) which simulated the loadings of constituents of concern from the watershed into the bayou and

2. A detailed hydrodynamic and water quality model (EFDC) which was used to simulate the physical and biochemical interactions of constituents of concern in the bayou and to determine the TMDLs.

This modeling approach was chosen because, like all available watershed models, the HSPF model lacks the ability to accurately depict the complexity of tidally influenced streams. The (HSPF) model was calibrated based on land use-specific event mean concentration data and export coefficients obtained from the scientific literature and with water quality data collected in the bayou. The loadings estimated by the HSPF model were used to develop and calibrate the EFDC model, which was, in turn, used to predict in-stream DO concentrations in both the tidal and non-tidal portions of the bayou.

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[18] The "endpoint" in these documents was defined as the expected DO levels if a 10% reduction of CBOD-causing pollutants were obtained.

The TCEQ is currently revising and refining the calibration of the existing HSPF watershed model of Dickinson Bayou with the objective of using it as a stand-alone model to develop TMDLs addressing low DO in the non-tidal portion of the Bayou, where the DO criteria is more likely to be achieved (i.e., attainment frequency at the 90th percentile). The DO impairment in the tidally-influenced portion of the bayou will be addressed separately at a later time, perhaps through a use attainability analysis (UAA).

Bacteria

Work is currently under way to collect data for a TMDL study for bacteria in Dickinson Bayou. A draft bacteria TMDL report is anticipated by the fall of 2010.

Figure 8. Dickinson Bayou Zone of Non-attainment and corresponding channel depth profile

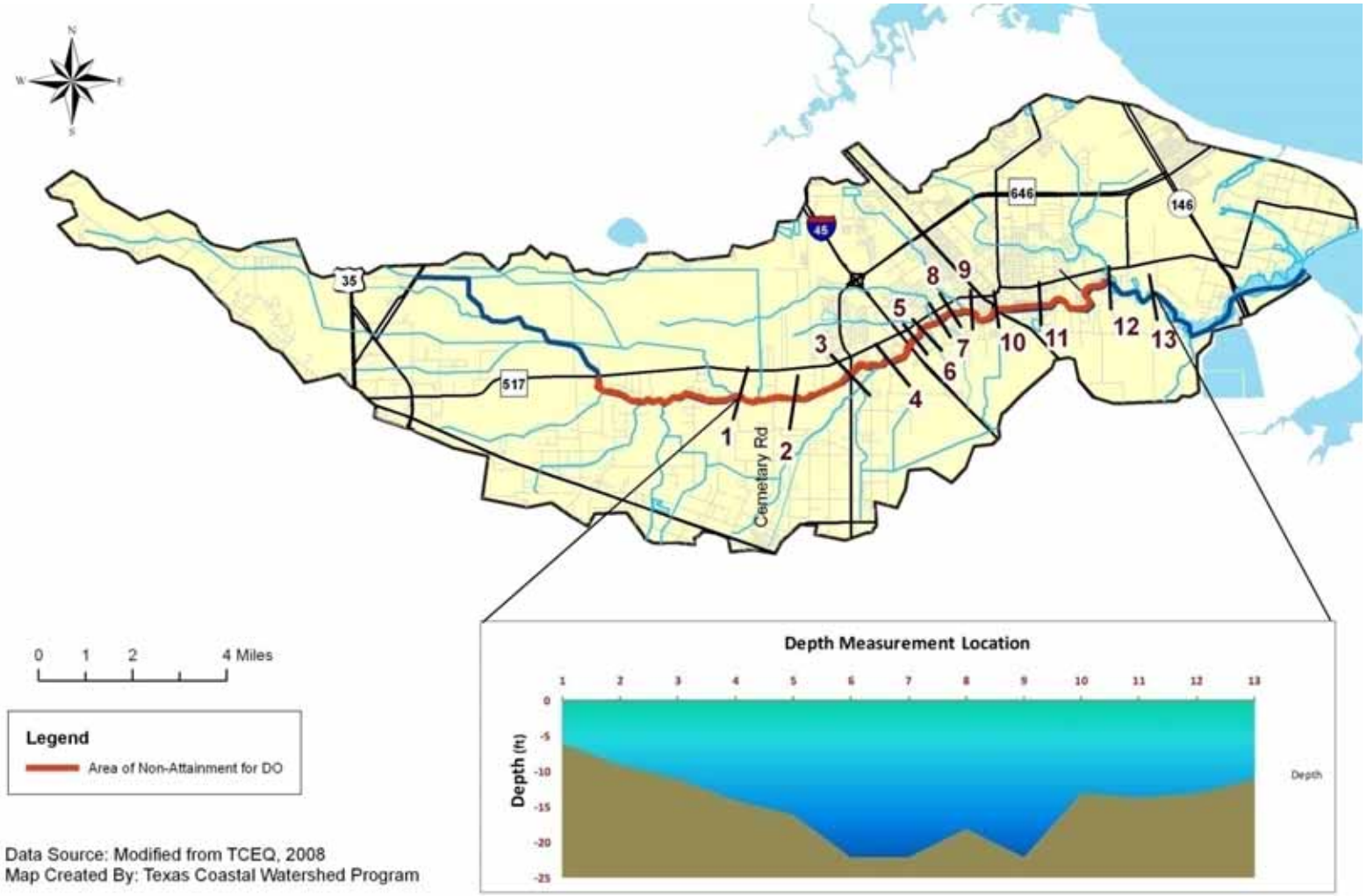
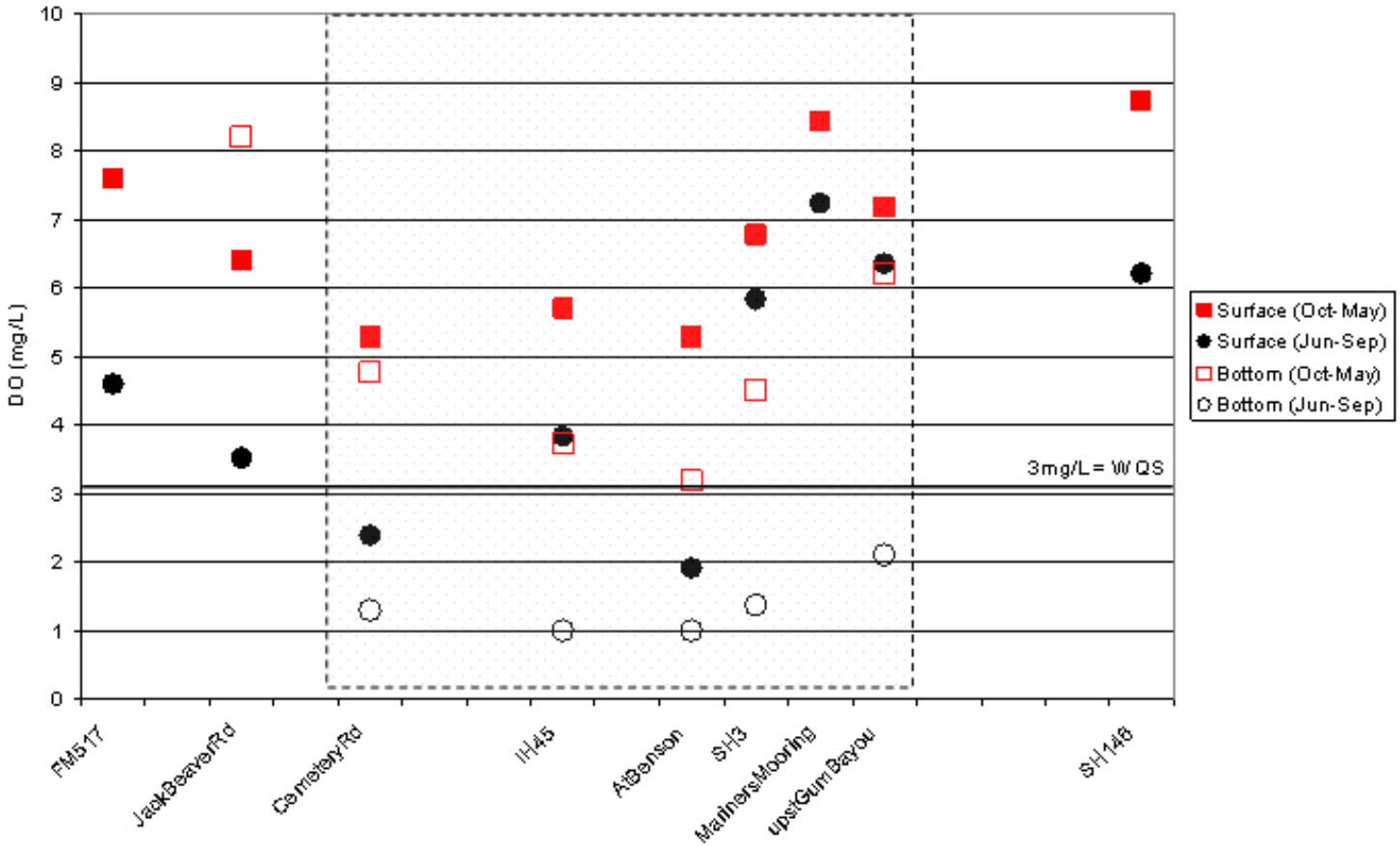
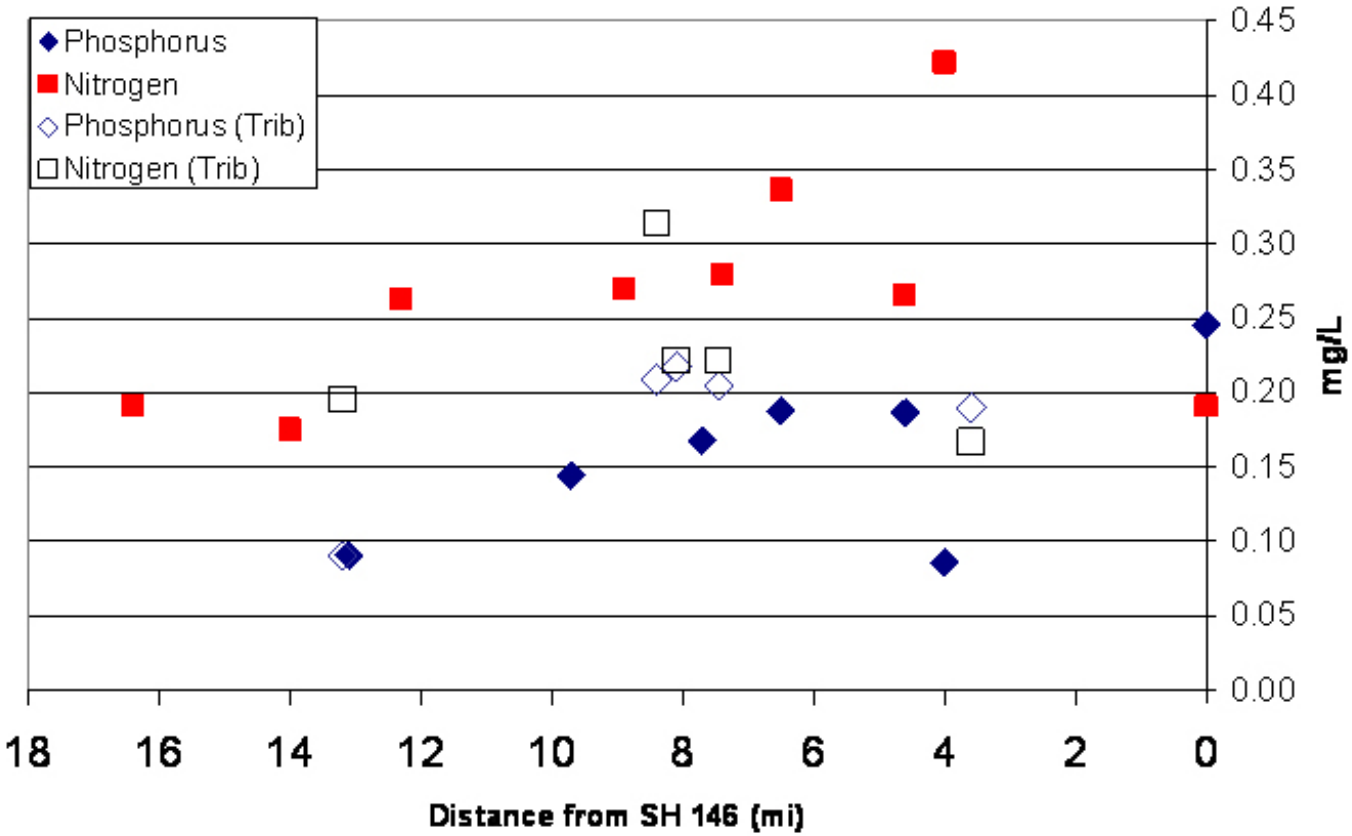


Figure 9. Average instantaneous dissolved oxygen levels in Dickinson Bayou from upstream (left) to downstream (right) in the warmer months (circles) and the cooler months (squares). Surface data (within 1 meter of water surface) is represented by the solid symbols, and bottom data is represented by open symbols. At some stations, only surface data was available.[19]



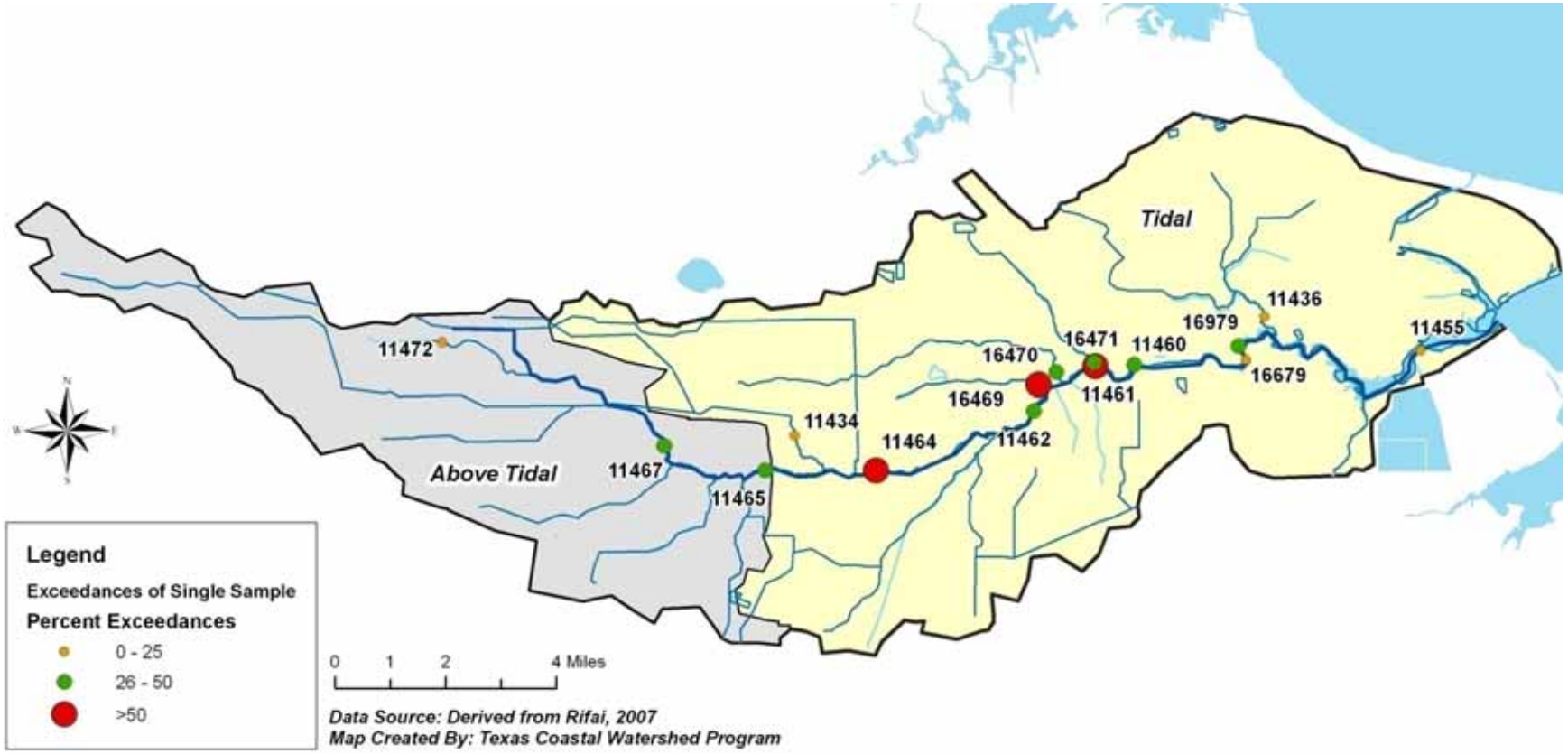
[19] Data from TCEQ database, from 2000 to 2006, compiled and graphed by Linda Broach

Figure 10. Nitrogen and Phosphorus concentrations in Dickinson Bayou and its tributaries (compiled from data collected from 2000 to 2006).[20]



[20] Data from TCEQ database, from 2000 to 2006, compiled and graphed by Linda Broach

Figure 11. Map of stations with relative exceedances for bacteria. (Above tidal indicator is E.coli, below tidal indicator is Enterococcus)



5. Waste-Water Discharges

Permitted Wastewater Treatment Facilities[21]

There are five active discharge permits[22] in Dickinson Bayou for domestic wastewater (sewage) treatment facilities and five active permits for discharge of industrial wastewater. The permit issued to Galveston County WCID #1 allows the largest discharge of wastewater into Dickinson Bayou at 4.8 million gallons per day (MGD). The next largest permitted discharge is for 0.95 MGD held by R. West Development Co., Inc. although this facility is not currently in operation. The remaining permitted domestic waste-water facilities currently in operation in the watershed each have permitted flows below 0.1 MGD (Table 6, Figure 12).

From approximately 1999 to mid-2002, the *reported* average daily domestic wastewater discharge to Dickinson Bayou was 2.88 MGD, which was at that time below the permitted daily flow of 3.82 MGD (Table 6, Figure 12). In 2007, average daily domestic wastewater discharge to Dickinson Bayou was 2.29 MGD, but the *permitted* daily domestic wastewater flow in Dickinson Bayou in 2007 had risen to 5.84 MGD, and with the addition of the 2 proposed new wastewater facilities in 2008, the *permitted* daily flow of treated domestic wastewater to Dickinson Bayou would be 7.29 MGD. Increasing discharge limits for some municipal permittees in recent years and current applications for new discharge permits in Dickinson Bayou indicate a projected increase in wastewater input of CBOD and nutrient loadings into the bayou, consistent with the observed trend toward increasing urbanization of the watershed.

Although the overall volume of treated wastewater permitted to discharge into Dickinson Bayou has increased over time, efforts to improve water quality problems in Dickinson Bayou have a long history and a number of significant changes and improvements have occurred over the recent past, which have likely improved water quality:

- Following a Waste Load Evaluation performed by the Texas Water Commission in 1986[23] all dischargers of domestic wastewater into Dickinson Bayou were required to achieve effluent water quality concentrations of 10 mg/L $CBOD_5$, 3 mg/L NH3-N, and 4 mg/L DO; all permit limits for industrial dischargers were held at their final permitted values and any new industrial discharge permits would be commensurate with those of domestic wastewater dischargers and would be considered on a case-by-case basis.
- Since 2000, effluent limits for the largest domestic wastewater treatment facility in the watershed (Galveston Co. WCID #1) have been reduced to a $CBOD_5$ limit of 7 mg/L and an NH3-N limit of 1.5 mg/L. Also, a significant wastewater facility (League City's

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[21] Much of the following was taken directly from Texas Commission on Environmental Quality. 2008. *Two Total Maximum Daily Loads for Dissolved Oxygen in Dickinson Bayou.*

[22] Under the Texas Pollutant Discharge Elimination System (TPDES) managed by the Texas Commission on Environmental Quality (TCEQ).

[23] Texas Water Commission. 1986. Waste Load Evaluation for Dickinson Bayou in the San Jacinto-Brazos Coastal Basin: Segment 1103-Dickinson Bayou Tidal, Segment 1104-Dickinson Bayou Above Tidal, September 1986.

Bayridge facility) was removed from service in 2002 and its outfall eliminated from Gum Bayou, a major tributary to Dickinson Bayou.

It is also important to note that, although the permitted wastewater volume has increased, the average volume of treated domestic wastewater entering Dickinson Bayou has actually decreased since 2002.

Not all of the wastewater generated in the watershed is discharged into Dickinson Bayou. For example, several Municipal Utility Districts (MUDs) in League City located in the Dickinson Bayou watershed discharge their sewage through a League City wastewater treatment plant into Clear Creek.

Parts of the sewered wastewater infrastructure are fairly old. Clay pipes, which are subject to cracking and leakage more than modern PVC pipes, are common in older parts of Dickinson.

Table 6. Permitted Waste Water facilities along Dickinson Bayou and its tributaries from "Two Total maximum Daily Loads for Dissolved Oxygen in Dickinson Bayou"[24]

TPDES Permit Number	Facility	Monthly Average Discharge 2007 (MGD)	Final Permitted Discharge Limit (MGD)	$CBOD_5$ (mg/L)	Total Suspended Solids (mg/L)	Ammonia-N (mg/L)	Dissolved Oxygen (mg/L)	Description of Discharge
WQ0013632-001	Meadowland Utility Corp	0.007	0.0234	10.0	15.0	3.0	4.0	Treated Domestic wastewater
WQ0012935-001	KC Utilities, Pine Colony Wastewater Treatment Facility	0.03	0.05	10.0	15.0	3.0	4.0	Treated Domestic wastewater
WQ0014440-001	R. West Development Co Inc	na	0.95	10.0	15.0	3.0	4.0	Treated Domestic wastewater
WQ0003416-000	West Management of Texas, Inc.	0.13	Report	na	na	na	na	Storm water/ground water
WQ0010173-001	Galveston Co. WCID1	2.26	4.8	7.0	15.0	1.5	6.0	Treated Domestic wastewater
WQ0000377-000	Penreco (outfall 001)	0.06	0.075	14.6 (lbs/day) BOD_5	20.0	na	na	Process water
WQ0014570-001	Marline Atlantis White	na	0.5	5.0	15.0	3.0	4.0	Treated Domestic wastewater
WQ0014326-001	CRVC Via Bayou LLC.	0.001	0.02	10.0	15.0	3.0	4.0	Treated Domestic wastewater
WQ0003749-000	Hillman Shrimp & Oyster Co	0.003	0.07	10.0	15.0	3.0	4.0	Process water
WQ0003479-000	Sea Lion Technology (outfall 201)	0.07	0.02	10 BOD_5	na	3.0	na	Treated Domestic wastewater
WQ0004086-000	Duratherm Inc.	0.08	Report	na	na	na	na	Treated stormwater
WQ0014804-001	South Central Water Co.	na	0.95	10.0	15.0	3.0	4.0	Treated Domestic wastewater

[24] Texas Commission on Environmental Quality. 2008. *Two Total Maximum Daily Loads for Dissolved Oxygen in Dickinson Bayou.*

On-Site Sewage Facilities

Failing septic systems (on-site sewage facilities or OSSFs) can be a major source of organic waste contributing to the depressed dissolved oxygen levels observed in Dickinson Bayou. We do not have any *direct* data to demonstrate a connection between failing OSSFs and poor water quality in the Bayou, but the data we do have points very strongly to OSSFs as a potential major source of poor water quality.

The largest concentration of houses with OSSFs is in sub-watersheds that drain directly into the "zone of impairment" (Figure 8). Before 1997, no evaluation of the site conditions was required before an OSSF was designed and installed on a site. Under the new regulations, a site evaluation is required to examine soil limitations such as high water tables and low-permeability clays, the two most common limitations in the soils of the Dickinson Bayou watershed. The identification of seasonal soil water tables is particularly problematic for non soil scientists, such that reliable identification, and thus proper design of OSSFs, has become more commonplace only relatively recently in Galveston County. Table 7 shows the relative change in OSSF permits granted in Galveston County, since 1995, for "advanced" OSSFs installed in accordance with soil limiting factors versus conventional leach-field systems appropriate for non-limiting soils[25]. It is only relatively recently that the more advanced systems have become the standard for Galveston County.

Table 7. Relative change in Galveston County new OSSF permits from selected years.[26]

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

[25] This table is of the number of permits *granted* in the indicated years, not the total number of systems in operation.

[26] from Martin Ettringer, Galveston County Health Department, 2008

It is highly likely that very many, if not most of the OSSFs in the Dickinson Bayou watershed are standard soil leach-fields, without any design elements adapted to high water tables or impermeable clays. Figure 13 shows the location of OSSFs in relation to the drainage pattern of the Dickinson Bayou watershed, and the location of soils with significant limitations for standard OSSFs. It is evident from the map that most of the soils in the areas with OSSFs have shallow water tables that would interfere with the proper functioning of a standard-design septic leach-field. During periods of extended wet weather, particularly from late fall through early spring, there is a high probability that many of these soils would be saturated to the surface. Sewage effluent can pass through saturated soils with very little treatment, and the surfacing of this raw sewage effluent will be quite common during periods of saturation, and the effluent can then easily be incorporated in stormwater runoff to the bayou. The fact that many of these soils are also relatively impermeable clays only worsens the situation in terms of increased probability for the surfacing of raw sewage effluent.

The timing of the depressed DO episodes in Dickinson Bayou does not correspond exactly to periods when the highest amount of runoff would be expected from saturated soils. The lowest episodes of observed low DO are in the middle of the summer. However, DO begins to decline in February, which is approximately the period of highest probability for saturated soils. There is definitely a need for further research into this problem and the impact of OSSF systems as remediation of failing OSSFs will likely play an important role in improving the water quality in Dickinson Bayou.

Figure 12. Permitted Discharges into Dickinson Bayou

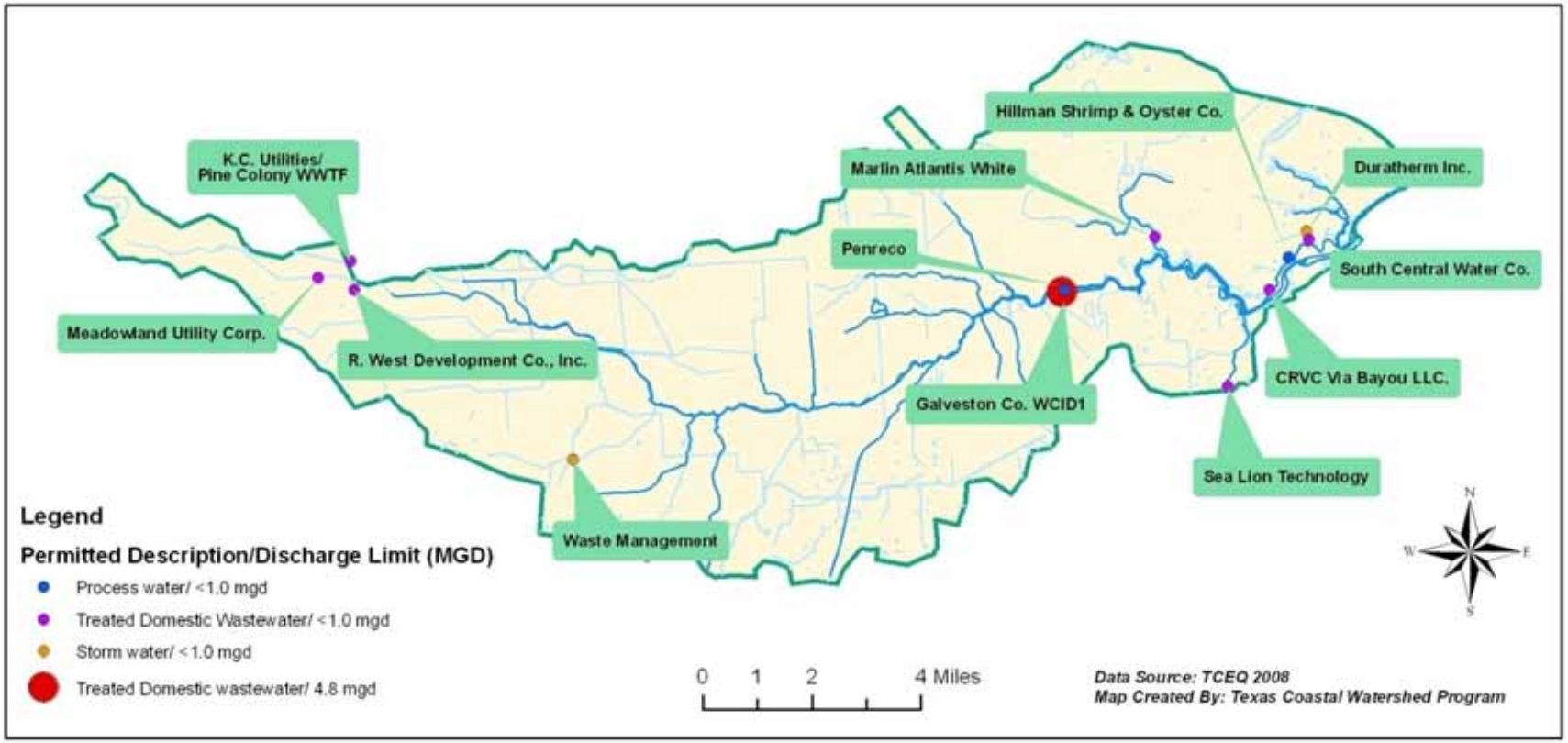
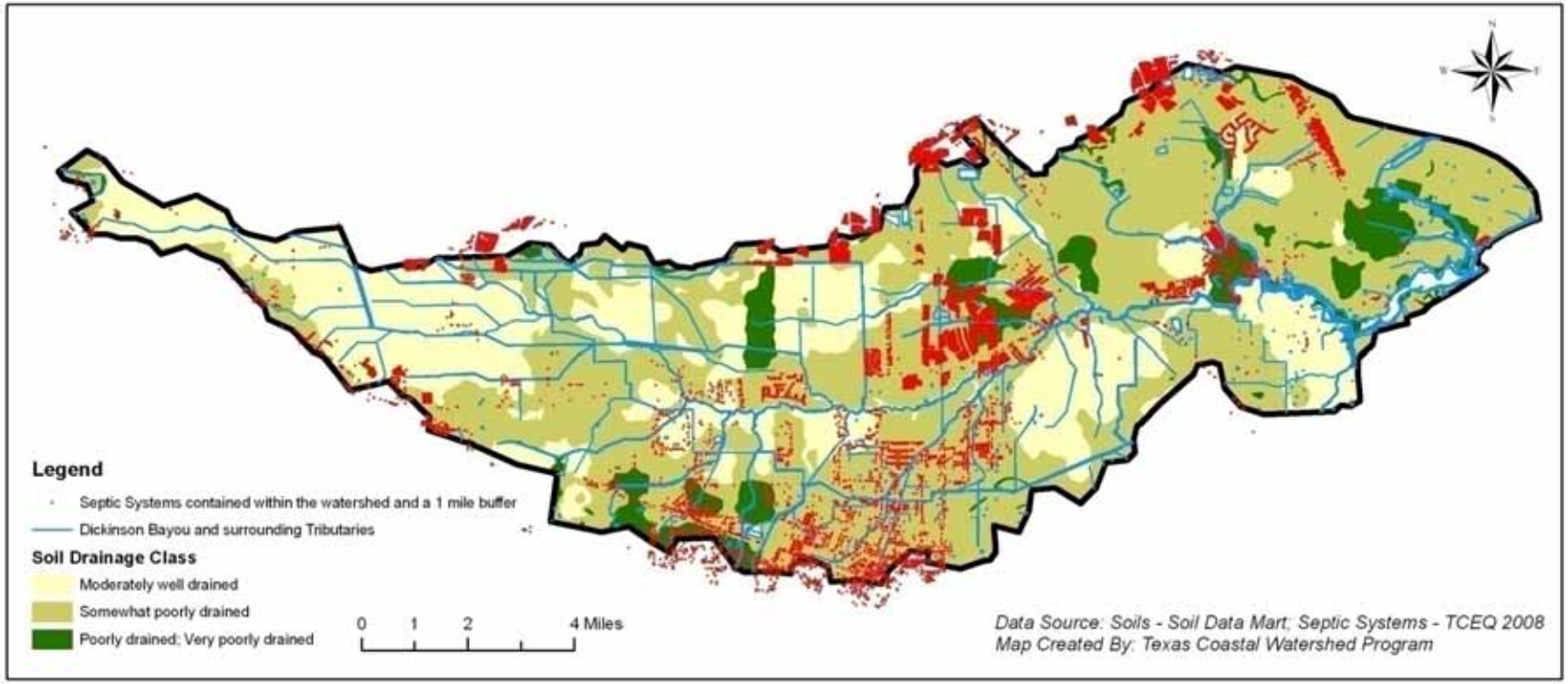


Figure 13. Location of households not connected to a centralized wastewater system, presumed to have septic systems, and the soils on which they are located in the Dickinson Bayou watershed



6. Land Use

Land use in the watershed is changing rapidly. Agricultural land, wooded riparian areas and open prairies with pockets of wetlands are being converted to residential and commercial suburban development.

Current Land Use

What once was considered "country living" is now becoming suburban. Private open space is quickly being sold to developers for suburban subdivisions. The Dickinson Bayou watershed, as of 2006, was approximately 50 percent developed, based on the land use classification developed by TCWP[27]. Within the developed areas, about 33 percent is considered low density (~600-800 people/sq mile) and 66 percent medium density (~2000 people/sq mile) development. There is little to no high density development within the watershed. The open space is composed mainly of pasture/prairie land with little agriculture.

There are currently thousands of homes being built and many new homes proposed to be built within the watershed. Many of the homes under construction are along FM 517 and FM 646 in Dickinson and League City. These new developments have raised concerns about the loss of open space, increased pollution, degraded stormwater runoff, flooding, and the decline of wildlife habitat.

Some of the cities in the watershed have master plans and zoning. Dickinson, for example, is in the process of developing a master plan and Alvin, Friendswood, Kemah, League City and Manvel all have master plans in place. Alvin, Friendswood, League City and Santa Fe have zoning ordinances. However, there are presently no *consistent* master plans, zoning ordinances, or municipal laws between the various municipalities and entities within the watershed to specifically promote environmental stewardship.

Development of New Land Use Map

A new land use classification was developed by the Texas Coastal Watershed Program based on 2006 aerial images (Figure 14). This land cover classification encompasses five main categories: medium density development, low density development, open space/agriculture, bare/transitional and open water (Table 8).

[27] Texas Coastal Watershed Program. 2008. Land Use Classification GIS layer. Available at www.urban-nature.org.

Table 8: Land use classification for the Dickinson Bayou watershed

Classification Type	**Square Miles**	**Acres**
Development– Medium Density *(Greater than ~2-3 dwelling units per acre or ≥40% impervious cover)*	30.10	19,267
Development – Low Density *(About 1 dwelling unit per 3 to 5 acres or 10% to 20% impervious cover)*	21.07	13,467
Open Space/Agriculture *(≤1 dwelling unit per 20 acres)*	52.40	33,536
Bare/Transitional	0.72	459
Open Water	0.26	167

The Houston-Galveston Area Council's Land Cover data (2002) and NOAA's Coastal Change Analysis Program (C-CAP) Classification (2005) were both evaluated and used to develop the new land cover classification. Areas that had an average of 1 dwelling unit per three to five acres, or 10-20 percent impervious cover were considered low density development. Areas that had greater than 2-3 dwelling unit per acre, and equal to or greater than 40 percent impervious cover were considered medium density development. Although there are some small areas of higher density development, such as downtown Dickinson, the majority of the development is medium to low density. Therefore, no areas were labeled as high density. Areas with approximately less than one dwelling unit per five acres and roughly less than 10 percent impervious cover were considered open space.

Based on the TCWP land use classification, developed areas (medium and low) and open space totaled 51.17 and 52.40 square miles respectively, with the remainder of the watershed being either bare/transitional or open water. Since agriculture is a minimal land use in the watershed (8.2 sq miles)[28] it was classified within the open space classification. Very little if any row crop agriculture remains in the watershed. The main agricultural activity is cattle grazing.

Within the Open Space land use classification, TCWP also identified (based on aerial and on-the-ground observations) certain areas of high habitat value or that could potentially be restored to high value habitat (Figure 17).

[28] Houston- Galveston Area Council. 2002. Land Cover Classification GIS Layer.

Land Use Projections

The Houston Galveston Area Council (HGAC) estimates that as of 2005 approximately 63,300 people live within the watershed and they project that the watershed will increase in population by approximately 50,000 by the year 2035. Based on the amount of land available for development, it is quite possible that the Dickinson Bayou watershed could increase in population by as much as 100,000 people within next 25 to 30 years.

Currently, about 51 sq miles are developed, 52 sq miles are undeveloped and three sq miles are open water. If it is assumed that there will be no additional future development in areas currently developed or within the 100 and 500 year floodplains (13.08 sq miles), then approximately 36 sq miles are left for future development and/or preservation (Figure 15).

The developed portions of the watershed average about 1,200 people per sq mile (63,300 people/51.73 sq miles)[29]. At this density, it would take about 43,000 people to completely develop the watershed. Newer developments are about 3000 – 4000 people per sq mile. As many as 100,000 new residents could fit into the watershed at this density. Current development code in all watershed municipalities ensures full development of the watershed, and demographic trends almost guarantee it.

Based on the Galveston County Consolidate Drainage District's Drainage Criteria Manual[30] for impervious surface values and the 2006 TCWP land use classifications (Table 15 on page 134), approximately 25 percent of the Dickinson Bayou watershed is covered by an impervious surface. According to the Stormwater Management Resource Center's Impervious Cover Model[3], once the watershed of a stream has greater than 25 percent impervious cover, the stream tends to become fairly degraded and biological diversity of the stream community declines (Figure 16). Also, bacteria levels can increase, causing the increased likelihood of illness in humans from recreating in the stream. Erosion, down cutting and widening of the stream channel usually occur due to increased stormwater runoff as well[31].

The Dickinson Bayou Watershed is currently at the "non-supporting" threshold for impervious cover. Some consideration needs to be given to a strategic plan for future land use to offset impacts from the projected increase in population.

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[29] Houston-Galveston Area Council 2008. Population and Employment Forecasts. GIS dataset Format (1 mile grid). ,http://www.h-gac.com/rds/forecasts/default.aspx.. Accessed June 2008.

[30] Galveston County Consolidated Drainage District. 2004. Drainage Criteria Manual.

[31] Stormwater Management Resource Center. 2008. Watershed Impervious Cover Model. < http://www.stormwatercenter.net/>. Accessed February 2009.

Figure 14. New TCWP Land Cover Classification

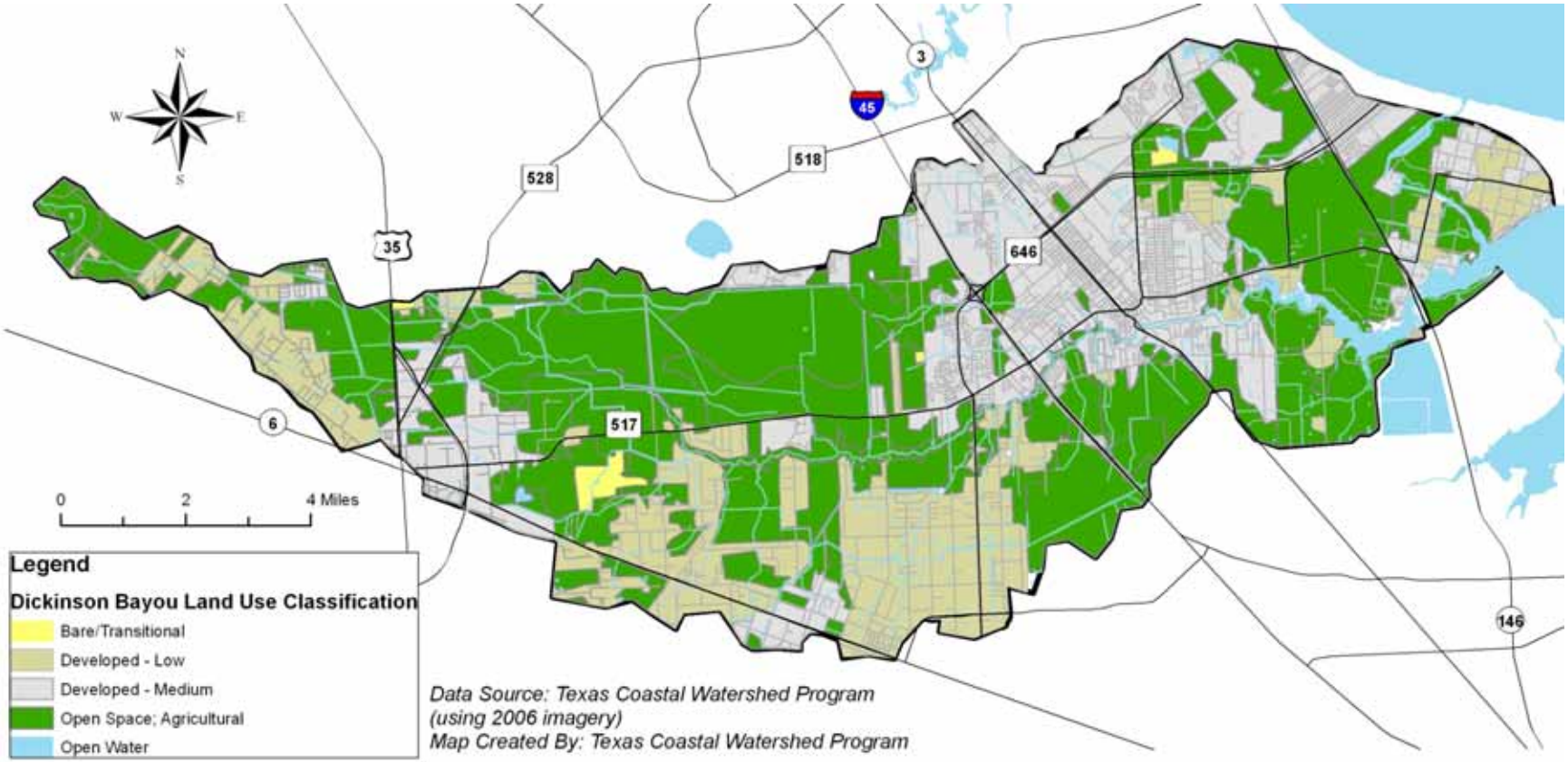


Figure 15. Projected areas of development in the Dickinson Bayou watershed in 2050 with the addition of 100,000 more people at 4,000 people/sq mile.

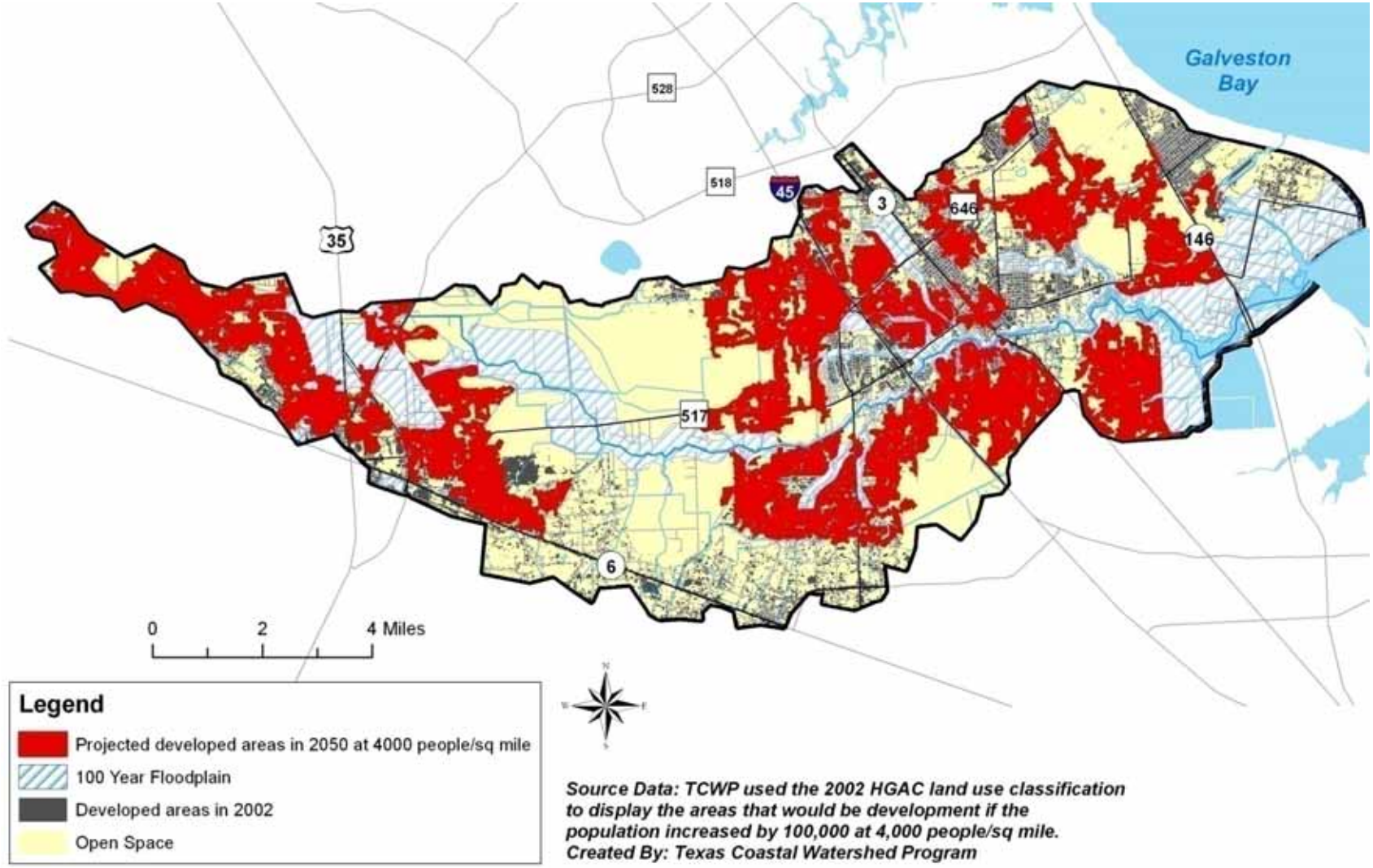
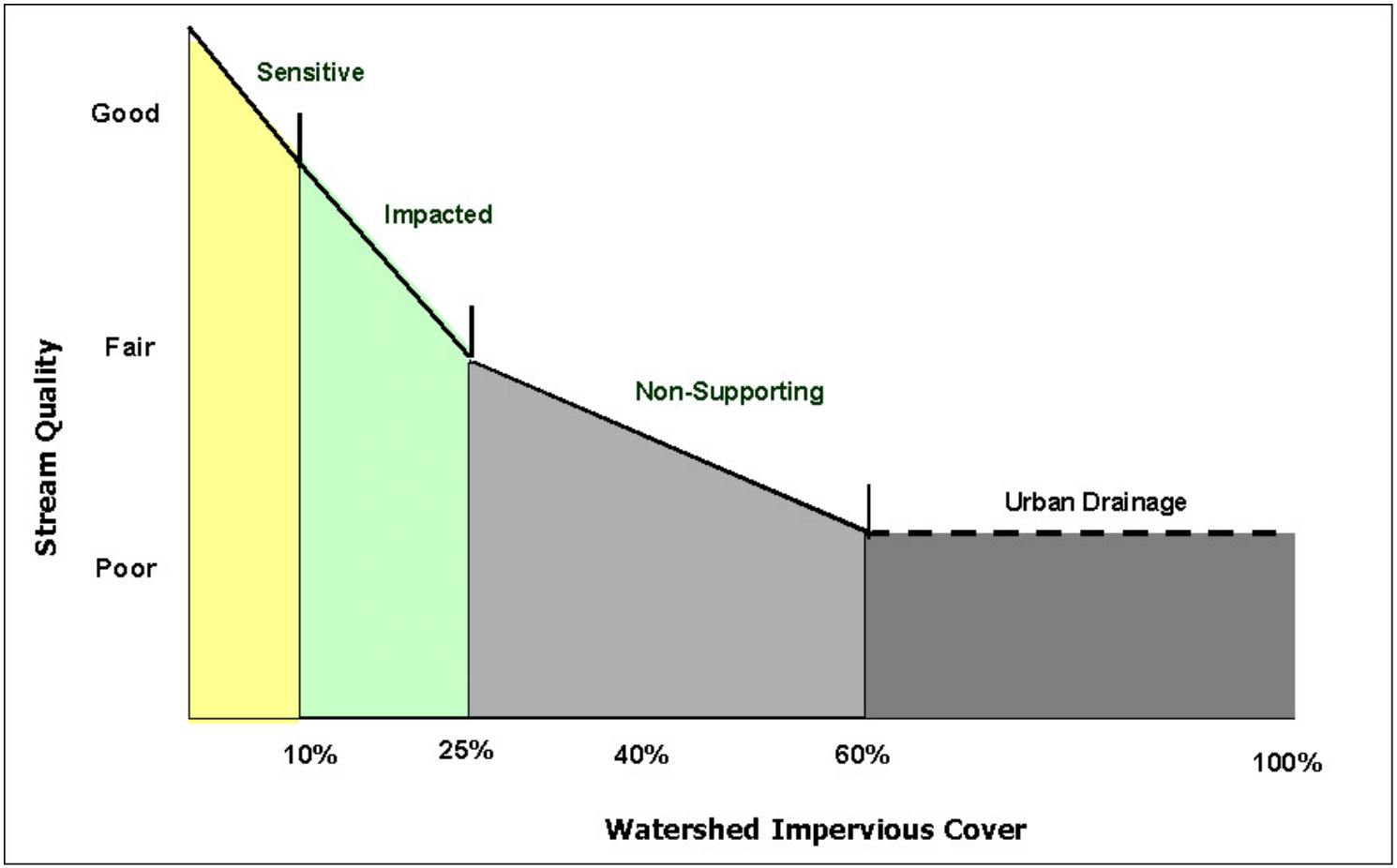


Figure 16: Watershed Impervious Cover Model[32]



[32] Stormwater Management Resource Center. 2008. Watershed Impervious Cover Model. <http://www.stormwatercenter.net/>. Accessed January 2009.

7. Habitat

The Dickinson Bayou watershed lies within the Gulf Coast Prairies and Marshes eco-region[33]. A lush cover of tall prairie grasses once covered the watershed, with mature coastal flatwoods along the bayou. It was a system that supported big bluestem, gulf muhly, and switchgrass on the prairie and large water oaks and sweetgum in the flatwoods. In spite of massive changes since settlement, particularly in the last few decades, a surprising amount of viable and valuable habitat remains in this watershed. But the next few decades will likely see what little remains disappear, if present trends continue.

A map of existing habitat (Figure 17) in the Dickinson Bayou watershed was constructed using historical and recent aerial photography. We identified estuarine marsh, coastal prairie, riparian forest and aquatic habitats (defined below). Coastal prairies account for a majority of the natural areas in the watershed. **Currently, almost 30% of land in the watershed is still valuable habitat** (Table 9) that plays a very significant role in improving and maintaining water quality and flood mitigation in Dickinson Bayou. These natural areas collect and store rain water and overland flow, and they clean the water as it flows through them.

A rough estimate of the "quality" of remaining prairie-pothole complexes (see Coastal Prairie Pothole Complexes) was attempted. A classification of "1" indicates that the pothole and mima-mound complex is pretty much intact, with no evidence of plowing or land-leveling. The vegetation may not be pristine, but, a significant number of important native species remain. An area of this type should be preserved. A classification of "3" means that some remnants of the original complex remain, perhaps enough to justify a restoration project. A quality of "2" is intermediate. Distinct potholes and pimple mounds remain, but some significant disturbance has occurred. Areas designated as a "2" have sufficient habitat value and warrant restoration.

[33] Calnan, Thomas R. and Cynthia A. Jennings, 1994. "Wetland Restoration and Creation in Dickinson Bay and Dickinson Bayou." Texas General Land Office publication.

Table 9. Acres of each habitat type remaining in the Dickinson Bayou watershed

Habitat Type	**Acres Remaining**	**Percentage of the Watershed**
Estuarine Marsh	46	> 0.01%
Coastal Prairie 1	5118	7.6%
Coastal Prairie 2	8156	12%
Coastal Prairie 3	5105	7.6%
Riparian Forest and Aquatic Habitats	838	1.2%
Total	**19,263**	**28.4%**

Coastal Prairie Pothole Complexes

The coastal prairie ecosystem of Texas and Louisiana is one of the most threatened habitats in the world. Once covering over 9 million acres of land, more than 99% of coastal prairies have been lost through conversion to agriculture, grazing land, and urban areas. Remaining coastal prairie parcels are highly fragmented and severely threatened by encroaching development and invasive, non-native species.

Coastal prairie pothole complexes consist of high, dry mima or pimple mound formations coupled with shallow (to sometimes deep) depressed areas (potholes). The native prairie pothole wetlands are often final holdouts for unusual plant species, like prairie arrowhead (*Sagittaria papillosa*), making them desirable refuges for migratory birds and local fauna.

Over a dozen plants in the ecosystem are considered rare, with two others considered "critically imperiled".[34,35] The coastal prairie is also the only place to find the federally endangered Attwater's prairie chicken, a rare subspecies of the Greater prairie chicken with fewer than 50 individuals remaining in the wild. Likewise, it is the only home in the watershed for the endangered plant prairie dawn (*Hymenoxys texana*) and Texas windmill grass (*Chloris texensis*).

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[34] Grace, et al. 2000. Vegetation associations in a rare community type – coastal tallgrass prairie. Plant Ecology (147) :105-115.

[35] Gould, Frank W. 1975. The Grasses of Texas. Texas A&M University Press. 635 pps.

Despite the widespread loss of much of these habitats and organisms of the coastal prairie ecosystem, there remains much biodiversity worth protecting. As of this writing, some of the best prairie remnants in the Galveston Bay can be found in the Dickinson Bayou watershed (Figure 17).

Estuarine Marshes

Estuarine wetlands are found along the fringes of Dickinson Bayou from its mouth up to about Interstate 45. These wetlands are brackish to saline areas which are affected by the tides. Plant communities are characterized by more salt-tolerant species including salt marsh cordgrass (*Spartina alterniflora*) in lower areas and marsh-elder (*Iva frutescens*) along higher areas of the bank. Estuarine marshes are critical wetland habitat which provides shelter and food for important animals and insects, including blue crabs, dragonflies and black drum fry. These wetlands were much more extensive in past decades, but subsidence, and a subsequent rise in water levels, destroyed well over half of existing salt marshes along the Bayou[36]. Restoration of these kinds of habitats is a priority throughout Galveston Bay.

Riparian Forest and Aquatic Habitats

The riparian forests of the Dickinson Bayou watershed contain significant complexes of upland forests intermingled with lower lying riparian forested wetlands or coastal flatwoods. The riparian forest corridor of **Dickinson Bayou is one of the last remaining unchannelized segments in the region, making it valuable and irreplaceable.**

These riparian corridors are dominated by a variety of vegetation, including cedar elm (*Ulmus crassifolia*), willow oak (*Quercus phellos*), and black willow (*Salix nigra*) along the banks. Upland forests along higher elevations in this same corridor are characterized by live oak (*Quercus virginiana*), loblolly pine (*Pinus taeda*), eastern red cedar (*Juniperus virginiana*) and green ash (*Fraxinus pennsylvanica*). Understory ground cover may include upland species like American beautyberry (*Callicarpa americana*) and yaupon holly (*Ilex vomitoria*) or wetland species such as spiderwort (*Tradenscancia ohiensis*) and palmetto (*Sabal minor).*

See Appendix D for a comprehensive list of tree species found within the watershed.

Aquatic habitats are found in and along the Bayou itself. The narrow, shallow channels of the headwaters of Dickinson Bayou are often blocked by fallen trees and scrub-shrub debris that create important habitat. Decaying plants and animal remains provide nutrients to the watershed. Plants along the waterway provide food and shelter for foraging fish, benthic invertebrates, and juvenile fish, which are in turn food for larger predators. Many of these larger predators are game fish that are recreationally fished for by the general public. Typical species found in these aquatic habitats include blue crabs (*Calinectes sapidus*), fingernail clams (*Pisidium compressum*), menhaden (*Brevoortia patronus*), striped mullet (*Mugil cephalis*) and spotted sea trout (*Cynoscion nebulosus)* (See Appendices E, and F for comprehensive lists).

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[36] Calnan, Thomas R. and Cynthia A. Jennings, 1994. "Wetland Restoration and Creation in Dickinson Bay and Dickinson Bayou." Texas General Land Office publication.

Juvenile brown and white shrimp (*Farfantepenaeus aztecus* and *Litopenaeus setiferus)* are also found in the lower estuarine portion of the Bayou, which is designated as a "protected nursery area" by Texas Parks and Wildlife Department (TPWD) and is closed to commercial and recreational fishing.

Fallen trees or snags in the channel provide worthwhile and even essential habitat, but, also create a problem for recreational access and by most accounts create barriers for the outflow of flood waters. Finding a balance that provides for both human and habitat needs will be part of any successful watershed plan. A balance that may prove difficult to find.

Protected Lands

For the purpose of this document, we are defining protected lands as areas that are set aside as parkland, nature preserves or lands utilized for boat ramps. There are many county, private and local parks within the watershed (Appendix G). These areas are included because each site has the potential for habitat restoration or additional preservation/conservation although, in general, park space is not considered valuable habitat.

Within the watershed, there are two preserves: the Marston Preserve and the Texas City Prairie Preserve.

> ***The Texas City Prairie Preserve*** is owned by The Nature Conservancy and features rare coastal prairie habitat. It is one of the last remaining sites that support wild Attwater's prairie chickens. Restoration of this 2,111 acre coastal prairie habitat is a primary stewardship activity on the preserve. Cattle grazing, which has occurred on the prairie since the late 1800s, continues to provide a substitute for the wandering herds of bison that are no longer present. Through the use of prescribed burning, Nature Conservancy staff is using natural fire to help restore the prairie. Chinese tallow trees, a non-native species that poses a serious threat to coastal prairies, are being eliminated.
>
> ***The Marston Preserve*** is one of the few remaining heavily forested, riparian land tracts along Dickinson Bayou, thanks to excellent care by current and previous private owners. This 14 acre property, formerly owned by Edgar Marston, was accepted into the Legacy Land Trust and has a permanent conservation easement associated with it. Although the property changed hands in 2002, the conservation easement remains no matter who owners the property, now or in the future. A large swimming pool on the tract has been converted to a functioning wetland and remains on the property as part of the conservation easement.

Invasive Species

There are a number of invasive and destructive exotic species in the Dickinson Bayou watershed. An invasive species is a species that is not native to an ecosystem and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. An invasive species may displace a native species by out-competing the native species for resources, and reproducing within the habitat.

There are several exotic animal and plant species in the watershed that have created challenges in habitat restoration efforts, including, but not limited to: Chinese tallow, nutria, and feral cat populations. Invasive aquatic plant species present within the watershed include elephant ear, water lettuce and alligator weed. Without existing biological control to check their growth and development, these species can dominate our natural aquatic areas, reducing the habitat and food resources necessary for our native fish, reptile, amphibian, bird and insect species.

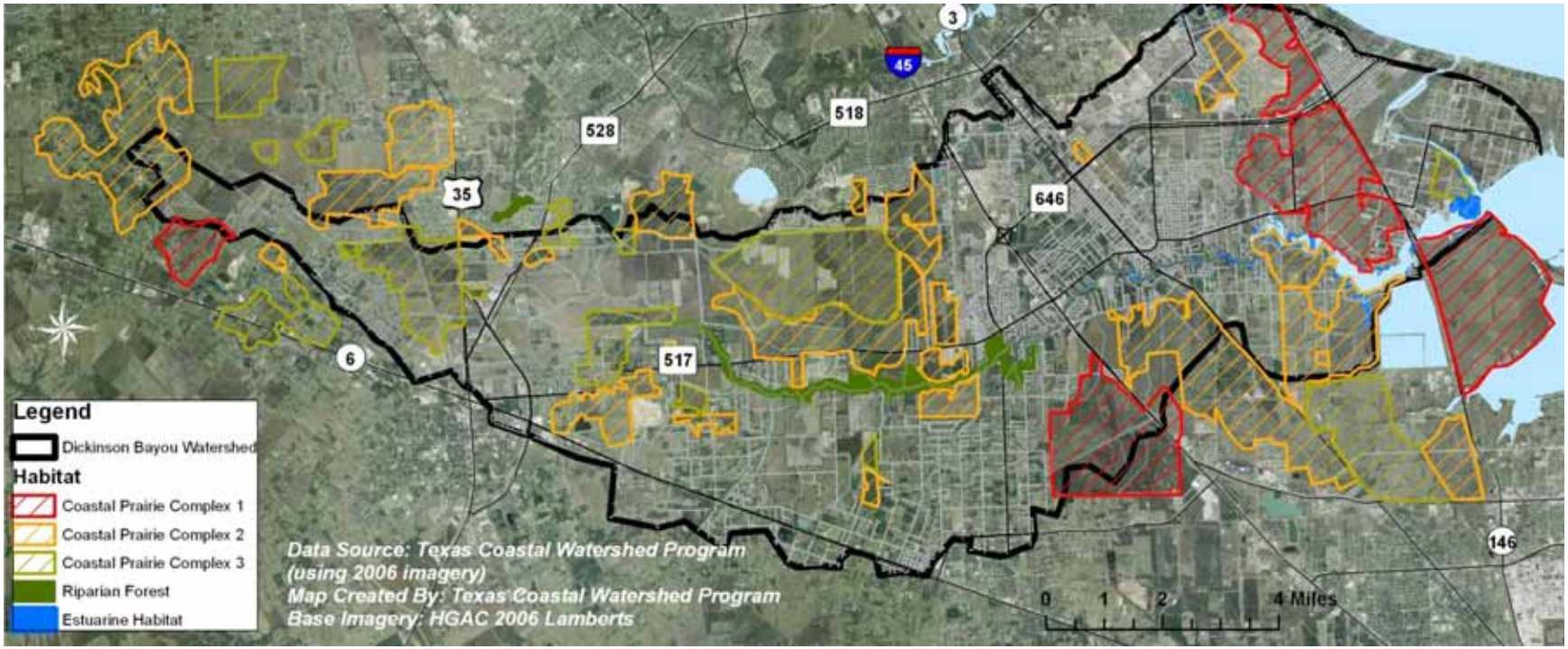
Ecological Services

The native habitats of the watershed provide much more than just food and shelter for wildlife. They provide many free functions that we must pay for when natural areas are lost. Natural areas such as wetlands and prairies absorb large amounts of rain fall, which moderate down stream flows and reduce flooding. Wetlands can also hold water for several days. During this time sediments and nutrients are removed from the water through a variety of physical and biogeochemical processes. This removal is important because sediments and nutrients in the bayou can lead to low levels of dissolved oxygen and it would cost hundreds of thousands of dollars to create a manmade system to accomplish this type removal. A slow release of water from the wetland system also helps to maintain stream flow. Instead of having one surge of water with each rain fall, water is collected in the wetland ponds and is slowly released into the bayou over several days maintaining a more consistent water level. All of these functions are essential to the health of Dickinson Bayou and its watershed. If we take away areas that provide these services for free, we will need to spend millions of dollars through taxes and fees to replace these functions, or see even further degradation of our watershed

Ecological Services of Native Habitats

- Reduced downstream flood peaks
- Maintenance of stream flows
- Maintenance of nutrient stocks
- Nutrient cycling (waste management)
- Sediment retention

Figure 17. Areas of high habitat value within the Dickinson Bayou watershed



8. Flood and Stormwater Management

Flooding concerns every citizen in the watershed; no one wants to see their property under water. The Dickinson Bayou watershed is very flat with poor natural drainage. And because it rains a lot, flooding is to be expected. Establishing good drainage has been necessary since the very first settlers arrived in this area. It is simply not possible to live in this watershed without some additional artificial drainage; managing drainage whether through drainage districts or through informal arrangements has always been an important part of life in this area.

A substantial artificial drainage network has been established for the watershed, but new development with its impervious surfaces results in ever greater amounts of stormwater runoff with its potential for flooding. The agencies actively managing drainage in the watershed (see "Stormwater Detention and Drainage") are always in a race to keep up with the effects of new development.

Many organizations within the Dickinson Bayou watershed have an interest in this issue and are working together to find appropriate, cost-effective solutions. Stormwater detention and conveyance is the primary method we currently use to avoid flooding. This practice also offers a realistic opportunity for water quality improvement through stormwater treatment wetlands, which will be an important step to cleaning up Dickinson Bayou.

Types of Flooding

Three types of flooding occur in the Dickinson Bayou watershed: stream flooding (overbank), outside the floodplain flooding, and coastal flooding (storm surge).

Stream Flooding occurs within the shallow floodplain which exists throughout much of the county and incorporates thousands of residences and businesses. Stream flooding begins when the channel capacity is exceeded. This kind of flooding is depicted on FEMA floodplain maps, with the risk of flooding shown in terms of a percent chance each year. A flood plain with a "one-percent" chance of flooding in any given year is the "100-year" floodplain. This is the floodplain that most people think about. Within the 1% floodplain is the "floodway", an area with a higher chance of flooding and much stronger flows (Figure 18). A 0.2% chance-in-a-year floodplain (or 500-year floodplain) is also frequently mapped.

Outside the Floodplain Flooding is caused by ponding and overland flow, and can occur almost anywhere. When intense local rainfall exceeds storm sewer or roadside ditch capacity, the water can pond in the streets and sometimes rise enough to flood residences that are not necessarily near a creek or bayou. The water will seek a path to the channel by flowing overland. When residences and other structures are in that path, additional flooding can occur. This type of flooding is not identified on the Flood Insurance Rate Maps.

Coastal Flooding occurs when unusually high tides or storm surges inundate low-lying land. A zone equivalent in risk in terms of occurrence to the 100-yr floodplain is mapped along the coast

by FEMA. Only a small portion of the watershed near the mouth of Dickinson Bayou is in the coastal flooding zone.

It is important to recognize that flooding can occur *anywhere* in the Dickinson Bayou watershed; it is just more likely in some places than others. No one in the watershed, therefore, should be without flood insurance. The risk of flooding is much less outside the 100-yr floodplain and flood insurance is much cheaper.

Subsidence

Subsidence is the sinking of the land surface due to the shrinking of clay layers deep in the ground. The primary cause of subsidence in the Dickinson Bayou watershed is groundwater withdrawal. Subsidence from 1906 to 1978 averaged 4 feet within the watershed. Some areas may have experienced more, especially near areas of industry (Figure 19). This subsidence decreased the stream gradient along Dickinson Bayou and most of its tributaries, and created more flooding. Ground subsidence can also result in more frequent and severe coastal flooding.

Subsidence is not reversible, but can be controlled, as illustrated by the actions of the Harris-Galveston Costal Subsidence District, created in 1975. Subsidence has been reduced to very low levels in the past few decades. Regulations implemented in 2001 for Galveston County, for example, limited permitted ground water withdrawals to 10% of the total permittee's water demand.

Historic Floods

Flooding is not a new problem to the Dickinson Bayou watershed. Historic records show the 1900 hurricane that destroyed much of Galveston Island also had a major impact on Dickinson. The Bayou reportedly rose 20 feet in 12 hours killing 11 people, and numerous head of livestock. Many buildings in Dickinson were inundated with water and all buildings were damaged. (See Appendix B for additional historic information)

Two additional floods of note occurred in March 1957 and September 1961. In 1957 over 13 inches of rain fell in Dickinson in a 24 hour period during a spring storm system that also spawned numerous tornados. This excessive rainfall caused the Bayou to crest 14 feet above the normal level. During Hurricane Carla in 1961, Dickinson Bayou reportedly crested 3.5 feet higher than in 1957, or over 17 feet above normal.[37]

Flood Plain Maps

The most recent flood plain map was produced using FEMA data.[38] This map shows much smaller flood plain areas than the map produced by the US Army Corps of Engineers in 1968, but this is not completely unexpected. New flood plain maps may reflect additional drainage ditches and management techniques used to mitigate the potentially catastrophic effects of a

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[37] US Army Corps of Engineers. 1968. Flood Plain Information: Dickinson Bayou, Dickinson, Texas.
[38] FEMA Map Service Center: http://msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1

large flood. However, the opportunity for flooding within the watershed is still very high, as 39% of the watershed is less than 20 feet above sea level. No part of the watershed is higher than 60 feet above sea level.

The Dickinson Bayou Watershed Steering Committee is working to produce a new flood plain map using the most up-to-date data possible. This will allow them to better plan for new development and stormwater needs, but this will NOT be an official FEMA map.

Who manages the floodplains?

Each City and County within the watershed has their own floodplain managers. The flood plain manager should be certified though the Texas Flood Plain Management Association. Each community follows FEMA directives and has adopted management recommendations, but there is still disparity in the ordinances between cities. Several cities prohibit encroachment into the floodway while many others do not specifically address this issue. (Table 10)

Table 10. Floodplain and Floodway ordinances in the Dickinson Bayou Watershed[39]

	Floodplain and/or Floodway Ordinance Language
Alvin	No specific mention
Dickinson	No specific mention
Friendswood	No construction or improvements unless compliant
Kemah	Preserve and enhance the water courses within the city
La Marque	Encroachment in the floodway prohibited unless certified by an engineer not to increase flood levels
League City	No increase in base flood elevation
Manvel	No encroachment into the flood way unless it will not increase base flood levels
Santa Fe	No specific mention
Texas City	Encroachment in the floodway prohibited unless certified by an engineer not to increase flood levels
Brazoria County	No specific mention
Galveston County	letter stating owner knows designation and will advise possible owners

Stormwater Detention and Drainage

Many different entities deal with stormwater detention and drainage throughout the Dickinson Bayou watershed. It is estimated that only 3-4% of detention is on a regional scale, meaning that 96-97% of detention basins serve only a neighborhood or small area of land. Thus, detention basins are owned by many different groups and follow no standard management practices. Basins are often maintained as mowed grassy areas, but sometimes they are never planted and rarely mowed allowing them to fill with weeds. Still other basins are dug so that they hold water year round and are marketed as a neighborhood "lake" often treated with

[39] Kultgen, P. 2007. Dickinson Bayou Watershed Ordinance Compilation Report to the Texas Coastal Watershed Program.

chemicals to maintain the look of pristine blue water. Generally, detention basins are fenced to keep the public out and are viewed as wasted space or a dangerous area instead of a potential amenity.

Some groups are already beginning to think about regional detention (Figure 20). The Dickinson Bayou Watershed Steering Committee is currently looking to build a large (approximately 100 acre) regional detention facility in the western portion of the watershed to manage *current* drainage needs. This project is not designed to address the detention needs of future development.

Currently, there are fourteen agencies within the Dickinson Bayou watershed that handle drainage, flooding, and stormwater. These are:

- Brazoria County
- Brazoria County Conservation and Reclamation District #3
- Brazoria County Drainage District #4
- Galveston County
- Galveston County Consolidated Drainage District
- Galveston County Drainage District #1
- Galveston County Drainage District #2
- City of Alvin
- City of Dickinson
- City of Friendswood
- City of League City
- City of Manvel
- City of Santa Fe
- City of Texas City

These groups came together and formed the **Dickinson Bayou Watershed Steering Committee** to address flood and drainage issues on a watershed scale. This group is currently working on several projects to address concerns within the watershed. These include a de-snagging project in Dickinson Bayou, clearing of non-native and invasive plants along the banks of Dickinson Bayou's upper reaches, and a master drainage plan for the watershed.

NPDES - TPDES

The National Pollutant Discharge Elimination System (NPDES) is a program overseen by the EPA which controls water pollution through permits. Industrial, municipal, commercial and other facilities must obtain a permit to discharge treated wastewater (either from treatment plants or industry) and/or stormwater into surface waters. Each state has an agency to administer these permits. In Texas, this agency is the TCEQ; they issue permits under the Texas Pollutant Discharge Elimination System (TPDES) and are held accountable by the EPA.

One important type of permit issued by the TCEQ is a **municipal separate storm sewer system (MS4) discharge permit**. This permit is a system to control municipal stormwater runoff. Phase I required large and medium cities to acquire permits, and Phase II required small cities (populations less than or equal to 100,000) in urbanized areas to acquire permits, this

means every city in the Dickinson Bayou watershed is required to obtain a permit. MS4 permits regulate the quality of stormwater released into surface waters and require six control measures:

1. Public education and outreach
2. Public involvement or participation
3. Detection and elimination of illicit (illegal) discharges
4. Controls for stormwater runoff from construction sites
5. Post-construction storm water management in areas of new development and redevelopment
6. Pollution prevention and “good housekeeping” measures for municipal operations

These measures go hand-in-hand with the goals of this watershed protection plan, and implementation of this plan will help cities meet their permit requirements.

Figure 18. Dickinson Bayou Watershed Floodplains

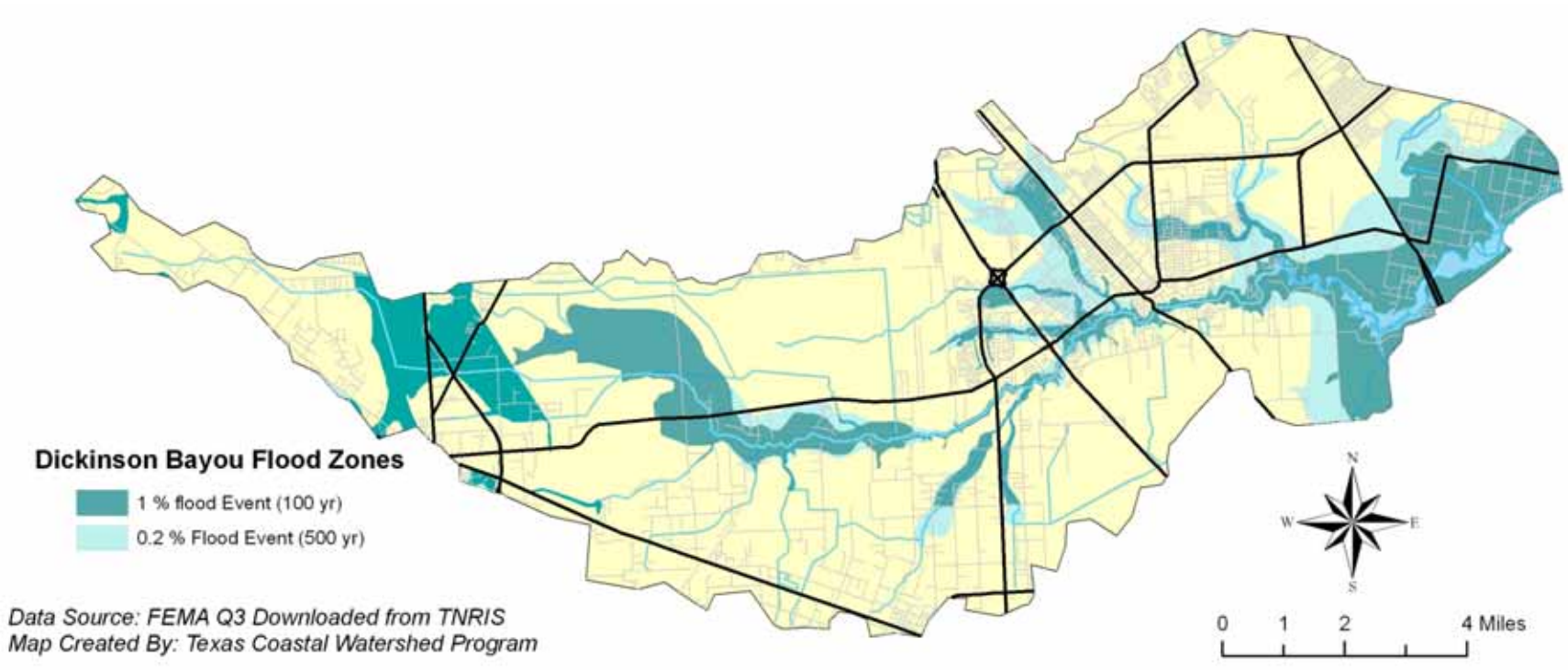


Figure 19. Subsidence for the Houston - Galveston Region

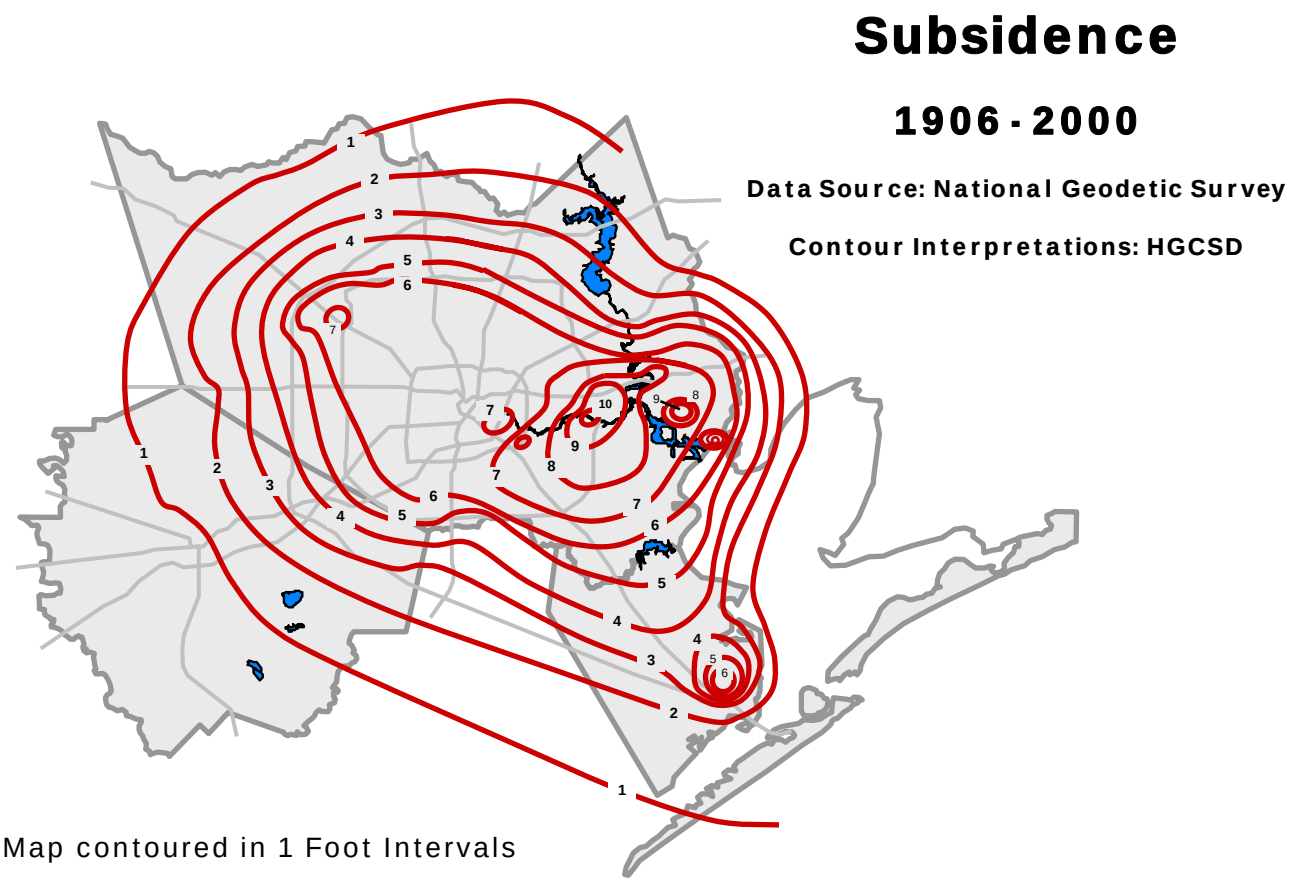
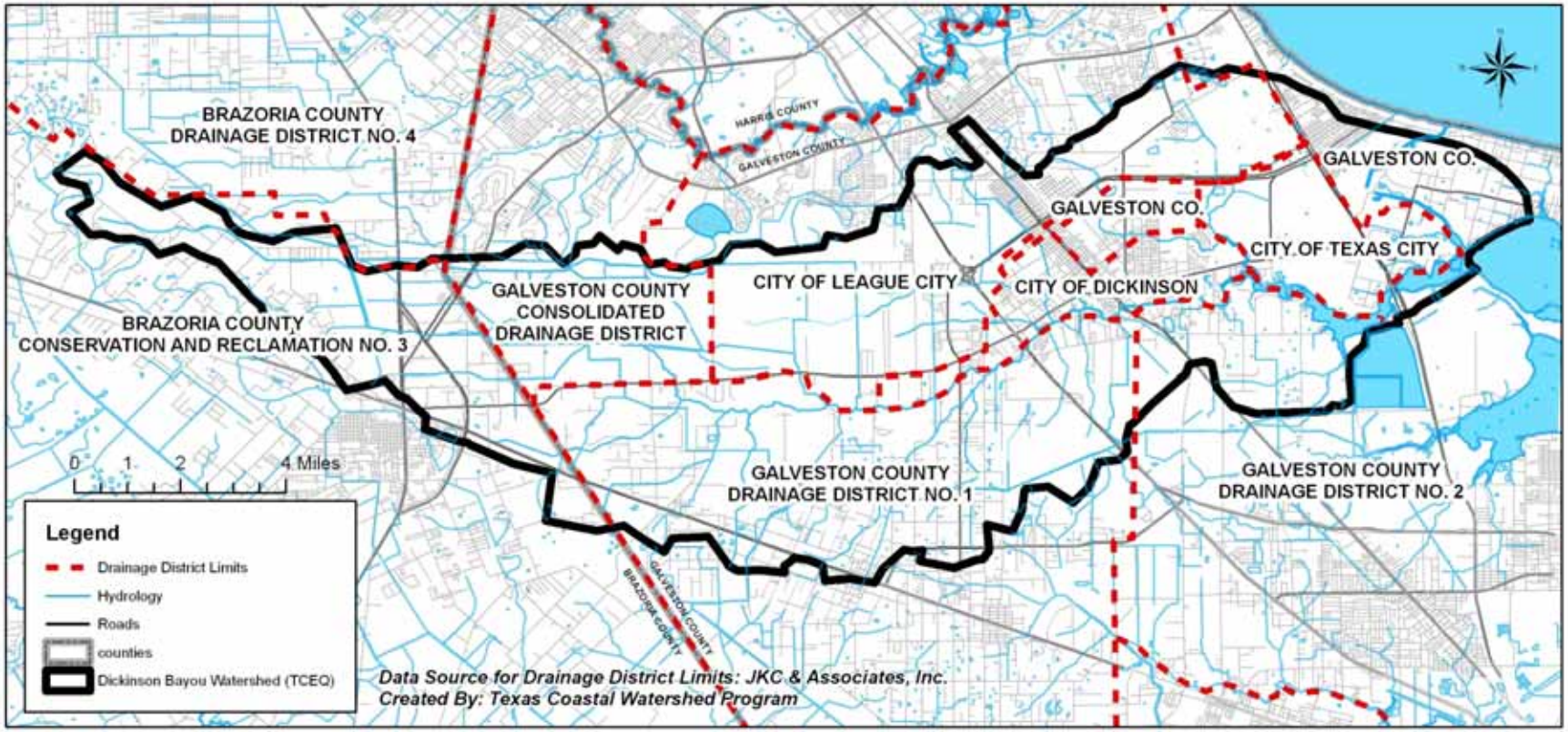


Figure 20. Drainage district boundaries in the Dickinson Bayou watershed



9. Outreach and Education

Many organizations are currently involved in environmental education programs throughout the Dickinson Bayou watershed. The focus of these efforts varies and the goals are specific to the entity organizing the activity. For example, Trash Bash works to clean the bayou and educate participants about litter and water quality. Master Naturalists work with school groups to teach youngsters about habitat and their surroundings. The Dickinson Bayou Watershed Partnership works to teach citizens ways to protect their watershed. Each of these is important and contributes to the health of the watershed, but coordination of the efforts would create a stronger, more powerful message. Organizations are working hard within the Dickinson Bayou watershed to spread awareness; however there are still gaps that need to be filled.

Awareness and Stewardship

Almost every citizen and visitor to Dickinson Bayou appreciates the beauty and value of the Bayou. However, they may not understand the connection between the Dickinson Bayou watershed and their everyday activities.

In this region, watersheds as a *system* are poorly understood; this is one of the main challenges facing the Dickinson Bayou watershed. Currently, there is no unified voice for the watershed. The Dickinson Bayou watershed covers a large area including parts of Alvin, Friendswood, Santa Fe, League City, Texas City, and all of the City of Dickinson. It is imperative to help citizens foster and develop an understanding of how watersheds work, so that they will value the Bayou and its watershed and become effective stewards.

Current Outreach Efforts

The greater Houston region has benefited from years of water quality outreach by organizations ranging from the Texas Commission on Environmental Quality, to the Galveston Bay Estuary Program, and the Houston-Galveston Area Council. There are also more localized efforts, including Keep Dickinson Beautiful and the Dickinson Bayou Watershed Partnership. Citizens are becoming aware that water quality affects them as well as the environment. They are also working to eliminate the obvious detrimental actions like dumping used car oil and yard clippings into the storm drain. Generally speaking, current outreach efforts can be categorized as one (or more) of the following:

- **Promotional Materials.** These publications have been printed or are online and are often readily available as are videos that can be borrowed or otherwise obtained for viewing. These are valuable to supplement presentations and to hand out at fairs and other outreach events with mass attendance. The material is standardized, and therefore the message is presented equally to all audiences. Printed materials help reinforce a message that may be lost, as they can be read and re-read at leisure. Because they have already been produced, these promotional items can usually be obtained free of charge, even in large quantities. Examples include the H-GAC

Dickinson Bayou Watershed brochure[40], Houston's Clean Water Clear Choice Campaign[41] materials, EPA[42] and TCEQ[43] brochures and Texas AgriLife Extension factsheets[44].

- **Workshop and Classroom Activities.** Many organizations offer workshops to provide a hands-on experience. These range from creating a wildlife-friendly habitat on school grounds to wading knee-deep into the bayou to collect and examine "bugs" (macroinvertebrates) to locally based ecology courses like those offered by Master Naturalists. In some cases, the participants enroll and attend at a specific organization's facility or educators go to schools and teach students in their classrooms as part of their school curriculum. In addition, the activities can be varied depending on the educator and the audience, for a more individualized lesson.
- **Public Participation Opportunities.** For those seeking a greater level of involvement, numerous opportunities for direct public participation exist: storm drain marking, water quality monitoring volunteers, local recycling programs, clean-up days, and other activities are organized by the municipalities and organizations in the area. These are often highly staff or volunteer intensive, yet regularly are reported to have the greatest impact upon participants. Such opportunities also have the ability to provide immediate, direct, and quantifiable impact upon the environment.

Public Participation

An important aspect of compiling this watershed plan was gathering community input. Three survey methods were employed to gather this information: a paper survey and two different polling techniques, one at a Dickinson Bayou Watershed Partnership meeting in April 2006 and the other at the Dickinson Bayou Watershed Planning Round Up & BBQ Bash in August 2008.

General Survey of Watershed Knowledge and Values

First, we conducted a traditional paper survey at the Dickinson Bayou Watershed Partnership meeting in April 2006 and 37 people responded. A slightly different version of this survey was given at the Dickinson Bayou Watershed Planning Round Up and BBQ bash in August 2008 and 51 people responded. (Appendix I)

A few combined survey results:

- 83% of respondents knew the correct definition of a watershed.
- 73% of respondents thought that Dickinson Bayou has environmental problems.
- The top four environmental problems were identified as:
    1. Illegal dumping and littering
    2. Habitat loss
    3. Polluted stormwater runoff
    4. Shoreline erosion

[40] http://www.dickinsonbayou.org/watersheds/info/documents/DickinsonBrochure.pdf
[41] http://www.cleanwaterways.org/
[42] http://www.epa.gov/owow/watershed/
[43] http://www.tceq.state.tx.us/compliance/monitoring/nps/mgmt-plan/index.html
[44] http://agrilifebookstore.org/

- The top three improvements that residents would like to see in the watershed are:
    1. Walking or biking trails
    2. Regular trash clean-ups
    3. Protection of forests along the creeks

Prioritization of Watershed Needs

For the second polling at the April 2006 Watershed Partnership Meeting, we asked attendees to complete a polling exercise. Prior to the meeting, each work group produced a series of questions about what the watershed needs and what is important to include in the Watershed Protection Plan. These related to the 5 workgroup topics (i.e. habitat, water quality, etc.); the recreation work group had not yet been established. Individuals attending the Watershed Partnership meeting ranked these questions according to what they felt were most important within each category. Then each participant ranked which of the questions were most important over all. (For full survey results see Appendix I)

The top five issues from the overall ranking were:

1. Need to examine building and development codes/ordinances
2. How does sprawl impact the watershed?
3. Developing protected areas within the watershed
4. Develop a list of laws that govern/impact uses of the bayou
5. Increase stewardship of citizens

The top issue for each category was:

- **Water Quality:** How does pollution impact Dickinson Bayou?
- **Habitat:** Developing protected areas within the watershed.
- **Land Use:** Examine building and developing codes/ordinances.
- **Flooding and Stormwater:** Examine flood control mechanisms and water storage techniques.
- **Education:** Develop a list of laws that govern impact/uses of the Bayou.

Planning Round Up Polling

The third polling took place at the Dickinson Bayou Watershed Planning Round Up and BBQ Bash in August of 2008. Information was presented at booths on topics relating to watersheds, water quality, and stormwater best management practices. Each booth featured an information poster about a given topic for review; attendees were presented with a series of statements and asked if they agreed or disagreed with each statement. (For full survey results see Appendix I)

Results from RoundUp Polling

Water Quality

- 100% of those surveyed were concerned about the water quality of Dickinson Bayou.

Habitat

- 100% believed that at least 30% of remaining habitat types in the watershed should be preserved and/or restored.
- 100% felt the watershed needs a plan to protect natural areas.

Land Use

- 97% felt watershed communities should use a the proposed new commuter rail system as a opportunity to build walkable communities.

Stormwater

- 45% felt Cities should charge a small stormwater utility fee to help pay for best management practices on both public and private land.
- 100% believed that tax incentives should be given for installing stormwater best management practices.
- 100% believed that cities and counties should work to limit the use of soluble fertilizers and pesticides.
- 100% felt stormwater wetlands should be required for all stormwater detention areas.

Recreation

- 97% felt everyone in the watershed should have at least a small park within walking distance of their home.
- 100% believed there should be more walking trails in the watershed.
- 89% felt there should be more public boat ramps or bayou access points.

Education

- 100% believe that Cities should work together to solve water quality problems in the watershed.
- 100% felt cities and counties should find a way to continue the Dickinson Bayou Watershed partnership as a long term group.

10. Recreation and Parks

The predominant recreational use of Dickinson Bayou is contact recreation: swimming, kayaking, water skiing, and more. This use of Dickinson Bayou is directly impacted by water quality, which affects the health and safety of all who use it. Recreational activities associated with Dickinson Bayou and the surrounding watershed have increased with population growth and development. A diversity of boating and water sports opportunities such as power boating, jet skiing, water skiing, canoeing, kayaking, fishing, swimming, hiking, and bird watching are available along the bayou.

Most power and deeper draft boats must launch from one of only two boat ramps on the lower reaches of the bayou between I-45 and Dickinson Bay. Deeper draft vessels have limited access points to the upstream portions of the bayou especially upstream of Cemetery Road where the waterway is narrow and often congested with fallen trees and snags.

Shallow water vessels such as canoes, kayaks and pedal boats can enjoy Dickinson Bayou's numerous tributaries. Upstream are pleasant wooded areas as well as interesting shallow bays and wetlands downstream. There are also limited access points for these smaller vessels but a wide variety of canoe-based opportunities exist, including birding, photography and fishing.

Several organized boating activities on the bayou are sponsored by the Dickinson Bayou Family Boaters' Association (DBFBA) to promote safe boating, as well as enjoyment and awareness of the entire bayou. An annual Christmas boat parade can be viewed from private docks along the waterway, the Highway 3 boat ramp, and Paul Hopkins Park. DBFBA also sponsors an annual "group boating" event to dine at a local restaurant or raft up at a popular anchorage like Redfish Island during the warmer months of the year.

Dickinson Bayou has been home to serious canoe racers since the mid-1960's. The Texas Canoe Racing Association (TCRA) was initiated in Dickinson in 1971, and has sponsored several race events in this area. Dickinson Bayou has been a popular location for fun canoe races as well as the more serious State Championship Series, which is now an annual race and was held in Dickinson in 1993 and 2007. Annual youth races are also held on the bayou in September and November. Long distance paddlers find that the Bayou offers an unimpeded four to five hour run between the downstream end of the bayou at Hwy 146 to the upper reaches of the bayou at Cemetery Road.

The City of Dickinson currently encourages many recreational activities on the bayou with support from Keep Dickinson Beautiful, the Dickinson Family Boaters' Association and the Dickinson Canoe Racing Association. TCEQ and Keep Dickinson Beautiful sponsor an Annual Trash Bash Clean-Up event every spring at the Highway 3 Boat Ramp in order to educate the public on preserving watershed values and to clean up the bayou. Keep Dickinson Beautiful with Texas Sea Grant assistance have sponsored multiple restoration plantings in local parks with Dickinson High School students to promote awareness of habitat restoration values within the watershed. During the annual sandhill crane migration, bird watching and photography may

be enjoyed at sunset when the birds land in local wetland areas after feeding in the fields in the western portion of the watershed.

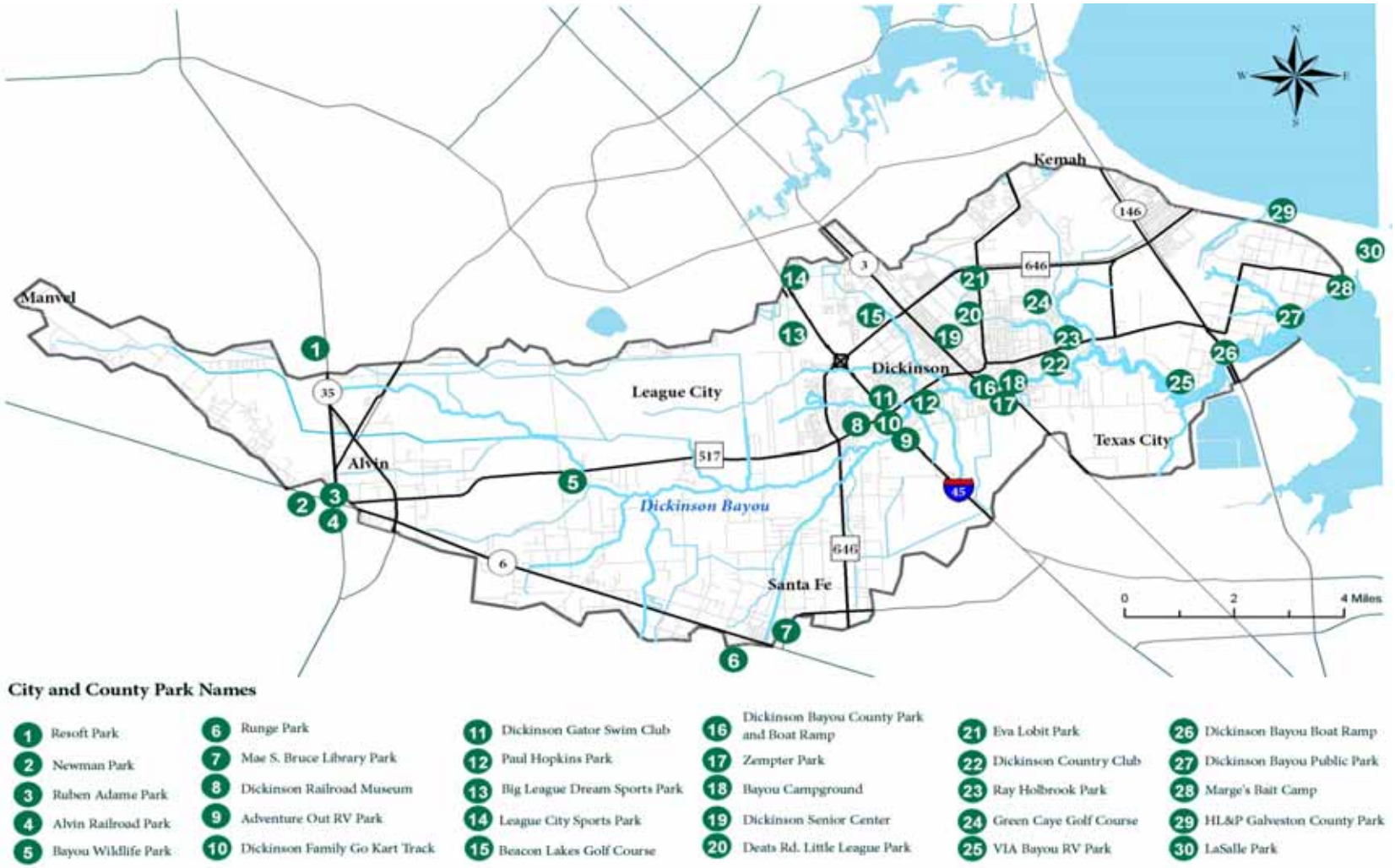
Parks

Many additional recreational opportunities exist throughout the watershed. Most of these are available at the 31 public access parks maintained or managed by Galveston or Brazoria County, as well as the Cities of Dickinson, League City, Santa Fe, and Alvin within the watershed (Figure 21). Currently these parks total 638.5 acres or 8.5 aces per 1,000 people. The National Recreation and Park Association recommends 10 acres of park space per 1,000 people.[45] Dickinson Bayou watershed falls short of this recommended standard.

Several private facilities and organizations provide both youth and adult team or club membership opportunities for participating in baseball, softball, basketball, soccer, volleyball, golf, swimming, skateboarding, camping and picnicking. There are small public properties within the City of Dickinson which have land access to the bayou but do not provide parking spaces or picnic areas. Other cities in the watershed provide some limited recreational opportunities but primarily serve as green space for local communities. A list of these public parks and private recreational opportunities is provided in Appendix G.

[45] http://www.nrpa.org/

Figure 21. Parks in the Dickinson Bayou Watershed



STRATEGIES AND GOALS

11. Overview of Management Strategies for a Better Dickinson Bayou Watershed

The stakeholders of the Dickinson Bayou watershed want to see a “better” watershed in their future. That “better” state is not a precisely quantifiable end point but it obviously means no further degradation. Stakeholders are clearly concerned about the impact of new development, particularly if it is “sprawl-like.” They would like to see new development shaped by codes and ordinances that protect and enhance natural resources. **Citizens of the watershed recognize that Dickinson Bayou water quality is not what it should be** and they would like to see less stormwater runoff with much higher water quality.

The State would ultimately like to see a more precise end point, that of meeting regulatory stands of the Clean Water Act. Bacteria levels are much higher than they should be, and dissolved oxygen is consistently lower than it should be. Because of the peculiar bottom contours and flow characteristics of the Bayou, meeting the DO standard is particularly difficult, and by some accounts may not be possible at all given the characteristics of the Bayou. The State is struggling to determine just how close, given both biophysical and financial constraints, the water quality in Dickinson Bayou can get to the current state standards.

This watershed plan is an attempt to map out a strategy for achieving both the broad goals of the citizen stakeholders as well as a closer approximation to the current State water quality standards for the Bayou. The following sections outline specific strategies and practices that can be put in place to help achieve these goals. Where appropriate, expected reductions in pollutant loading are detailed for each practice, as well as the cost of the practice and some suggested milestones for implementing the practices. We separated the goals and potential load reductions into short (~5 years) and long term (10-20 years) time frames. Rather than setting intermediate goals, it is recommended that these goals be revisited at least every 5 years and be reevaluated based on experience and changing conditions.

We have selected strategies that we know will make significant impacts in load reductions, or that in some cases at least minimize increases in loading (e.g., land preservation and liveable centers). We do not, however, have enough data to precisely quantify sources for every pollutant, nor can we precisely quantify exactly how much reduction we can expect from any given practice. We have taken the load reduction values from published studies, and while these are extensive, there is considerable variation in the expected efficiencies for any one practice. It should be remembered that these are estimates but, qualitative estimates should not be dismissed as less than useful. These estimates do give us a very good sense of the magnitude of the task ahead as well as where we can get the best result for the money.

This plan focuses on reductions in total nitrogen, total phosphorous, and bacteria. The recently completed draft TMDL reports for dissolved oxygen for both the tidal and non tidal portions of

the Bayou targets a 10-11% reduction in CBOD[46] loading from all sources. We do not directly target reductions in CBOD as part of this plan, because we have no way of directly estimating how effective the selected practices are in reducing this pollutant[47]. Given that CBOD appears for the most part to be associated with wastewater in one form or another, we are assuming that the practices this plan recommends for bacteria reduction will address CBOD as well.

The short term (~5 years) target for Total N and Total P is a reduction of 23,394 lbs/yr and 5,816 lbs/yr (5% and 6%), respectively. The long term goal is 267,968 lbs/yr for Total N and 86,634 for Total P. For bacteria, the short term goal is a reduction of 1.9×10^6 billion colonies/yr (15%) our goal will be sufficient reduction to achieve the state standards.[48] The long term goal is a reduction of 267,968 lbs/yr for Total N (32%), 86,624 lbs/yr for Total P (23%) and 1.6×10^7 billion colonies/yr for bacteria (46%).[49]

Short Term Loading Reductions

- 5% Total Nitrogen
- 6% Total Phosphorus
- 15% Bacteria

Long Term Loading Reductions

- 32% Total Nitrogen
- 23% Total Phosphorus
- 46% Bacteria

We begin by looking at ways to maintain our organizational structure and cohesion as a watershed partnership – a key to maintaining momentum and progress. The next section details an overall educational strategy to raise awareness of watershed issues amongst the general populace of the watershed. We then review options for preserving natural areas and enhancing the ecological services (e.g., clean water) that these areas provide us.

We evaluate options for improving wastewater discharges, from both permitted sewage systems and from potentially failing septic systems, perhaps the major contributor to low DO levels in the Bayou. There are no easy or cheap solutions for improvement in this area, particularly for septic systems.

The next few sections review practices that reduce stormwater runoff and pollutant loadings at the site level, from landscapes to pervious pavements to green roofs and more. Stormwater treatment wetlands are a larger scale approach that looks to be one of the most efficient ways to improve stormwater runoff water quality in our area, and we deal with this in a separate section.

Finally, we look at how building “livable centers” can provide some of the best opportunities for achieving pollutant load reductions while addressing some of the quality of life issues that concern so many of the citizens of the watershed.

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[46] Carbonaceous Biological Oxygen Demand

[47] The National Pollutant Removal Database Version 3 (2007) by the Center for Watershed Protection, for example, does not list CBOD amongst of the pollutants analyzed for best management practices.

[48] See Section 23 for calculations.

[49] Long term percent reductions are based on projections for 2009 with the full build out of the watershed at medium density, see Section 23 for full calculations

The strategies in this *watershed* plan look at the watershed as a whole, and recommend those management options that impact the most areas and provide the most improvement in water quality with the least expenditure of money. For example, stormwater treatment wetlands provide water quality treatment, habitat and add beauty to our environment.

12. Strategies for Organizational Continuity

A Permanent Watershed Coordinator

Of the top ten watershed lessons learned by the U.S. Environmental Protection Agency[50] (1997), the presence of a permanent watershed coordinator is ranked number 3. The many and differing entities operating in the watershed all have their own particular mandates and agendas. None of them has a specific mandate to collaborate (although it could be argued that there is an implicit public mandate for collaboration since the public does not expect agencies to work at cross purposes and the public also assumes agencies will work more efficiently without duplicating efforts). A watershed coordinator was in place for more than two years in the Dickinson Bayou watershed, funded through grants from the Galveston Bay Estuary Program. Without that coordinator, the watershed partnership would not have been formed, committees would not have been organized, and strategies and goals would not have been set. Given the present state of the partnership, at least a half-time watershed coordinator would be required to keep the momentum going that has been established so far. A full-time coordinator will be required to take the partnership to the next level.

A full-time watershed coordinator could serve the partnership municipalities in meeting their Phase II TPDES stormwater requirements, particularly in terms of education and outreach, as well as implementation. Any investment in a watershed coordinator position would thus have immediate benefits.

It is unreasonable to expect any one particular agency or entity to shoulder the full burden of the salary for a watershed coordinator. A pro-rata share based on population could be determined to spread the cost more evenly across the watershed.

Permanent Organization

The Dickinson Bayou Watershed Partnership has a fairly well defined organization, but has no formal structure or permanence. The Watershed Partnership needs to be an independent organization if it is to have any power or permanence. There are a number of organizational structures that could be explored. An independent 501(c)3 organization is one possibility, with a financial commitment from the member entities. A formal organizational structure does not mean the Partnership would have any regulatory power. It would simply mean that a formal structure exists for cooperation at the watershed scale.

Strategy

- Hire a permanent watershed coordinator
- Set up an independent entity for the Dickinson Bayou Watershed Partnership

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[50] USEPA. 1997. Top ten watershed lessons learned. EPA 840-F-97-001. National Center for Environmental Publications. Washington, D.C.

Financial requirements

- Watershed coordinator: $70,000-$100,000/year, inclusive of salary, benefits, and limited operating costs.
- Operating Costs 501(c)3: Perhaps $20,000/yr in addition to coordinator requirements listed above

Milestones

- Seek grant funding for coordinator: 2009
- Solicit member funding: 2009
- Hire coordinator: 2009
- Establish 501(c)3: 2010

13. Strategies for Publication Participation and Education

Education and outreach will be key components to the success of this watershed protection plan. Reaching out to citizens and municipal officials, showing them how to help, is essential. It will take a coordinated effort of many entities to make this happen. A full time watershed coordinator is essential to creating and maintaining watershed-wide education efforts. Also, many of the education programs suggested below will meet at least a portion of TPDES permit requirements for cities in the watershed. Incorporating permit needs will be an important way to help fund these programs. Cities will need to designate funds for stormwater education programs. Combining at least a portion of these resources will stretch limited funds and benefit everyone.

Strategies

Present a common unified message. The most important piece of the education puzzle is unity. A unified message must be presented across cities and throughout the watershed. This is especially important in terms of ordinances and implementation practices. One city should not undo the good work of another.

Targeted Outreach Campaign. A large scale campaign similar to Houston's *Clean Water Clear Choice* program should be developed for the watershed. This will require the cooperation of many organizations and a significant amount of funding. It should use all types of media available: television, radio, newspaper, magazines, signs, posters, brochures, handouts and the internet. All in an effort to reach every person in the watershed with the targeted message discussed above.

Brand Recognition for Dickinson Bayou Watershed. A logo has been developed for the Dickinson Bayou Watershed Partnership and this group needs to be marketed so it is a household name. Every person in the watershed should be familiar with the partnership and its mission.

Strategy Implementation Workshops. Most of the strategies for implementing the watershed plan will require a workshop component for education. The key is to target workshops to the most appropriate audience: homeowners, developers, public officials, etc.

Publications are still one of the best ways to reach a large audience. A well-designed, informative brochure, fact sheet or hand book can be pulled out for reference time and time again. These can be handed out at events and workshops or placed on display at local businesses and libraries. These can also be made available online to save on printing costs.

Programs for school children in the classroom and through extracurricular programs (Boy or Girl Scouts, science clubs, 4-H, etc) are a fun way to reach the youth of the watershed. Many simple, inexpensive and interesting activities exist for all age groups. Packaging these in a way

that teachers or volunteers can easily understand and present to groups and linking the relevance to our watershed are the keys to making these programs successful.

Targeted Goals and Actions

1. Establish a brand (logo) and develop a marketing plan for education and outreach for the watershed to include:
    - Signs- watershed entry signs, bacteria warning signs, information signs, etc.
    - Social Activities – to include attending conferences, providing town hall meetings, helping with Trash Bash, attending social events such as community fairs and festivals, etc.
    - Brochures – create 2-fold brochures for the adult population and a 3-fold brochure for youth and children. Create various posters and flyers.
    - Demonstrations – Create WaterSmart Landscaping BMP demonstration sites
    - Surveys & Polls – develop several surveys and polls within the context of a community planning and town hall meeting as well as the Watershed Partnership
    - Press releases and Public Service Announcements – Develop quarterly press releases of Watershed Partnership activities and goals achieved

2. Develop key themes to serve as core messages to be incorporated in promotional materials and classroom/workshop activities by jurisdictions and organizations in the watershed.

3. Develop partnerships with Education and Outreach organizations to engage the general public and share resources for common goals in volunteer water quality monitoring for the Dickinson Bayou watershed to include:
    - Texas Stream Team volunteer water quality monitoring
    - WaterSmart Landscaping
    - Keep Dickinson Beautiful
    - Service Clubs
    - Youth Groups and Scouts
    - Non-Government Organizations

4. Recruit influential spokespersons and friends of the Partnership to include:
    - Elected officials such as county judges and commissioners, city mayors and council members, state legislators or congressional representatives
    - Irrigation District Managers
    - Drainage District Managers
    - Media Personnel
    - Chamber of Commerce
    - Civic Organizations
    - Clergymen or women with a high community profile
    - Business or community leaders with a high profile in community affairs

5. Promote Stormwater Best Management Practices (BMPs) within the watershed.

6. Encourage municipalities within the watershed to actively participate as stewards of the watershed by:
    - Attending Meetings – Watershed Partnership representatives/members should attend City Council, Chamber, and civic group meetings
    - Reviewing rules, laws, and ordinances relating to the watershed – complete the "gap" analysis of various rules, laws, and ordinances as they relate to stewardship and management of the watershed
    - Promoting the Dickinson Bayou Watershed Protection Plan

Financial requirements

A big push is needed during the first several years to really begin implementation of this watershed plan. A proper multimedia campaign is key to kick starting this effort and will not be cheap. An investment of $2.5 million over the first five years would likely fund this effort and create the educational tools needed. A smaller investment, around $100,000, each year after that will keep programs operating and allow for expansion and growth.

However, impacts can be made for a smaller investment. Creating partnerships, developing key themes, writing press releases, recruiting influential spokespersons and encouraging municipalities to become watershed stewards are all FREE. Signs for BMP demonstration sites can be designed and installed for $1,500 each, watershed and BMP specific factsheets and brochures can all be produced for around $1,000 each, or less if they are not printed but made available solely on the internet.

Milestones

- Development of 3 key themes community partnerships– 2009
- Five watershed workshops held, and 10% of households/businesses reached – Fall 2010
- Four outreach events attended by a Watershed Partnership Representative– 2010
- Ten watershed specific publications produced - Fall 2014
- Twelve demonstration sites (WaterSmart Landscapes, rain gardens, construction site BMPs, LID BMPs) –2010
- Implementation of outreach campaign –2014

14. Habitat Strategies

Conservation

Natural areas provide huge benefits in terms of water quality and flood prevention (Figure 17). But we only reap these benefits if the land is in its natural state. While good habitat remains in the Dickinson Bayou watershed, it will all be gone in just a few years if present trends continue. **Conservation of high quality natural areas** is one of the most important things we can do to help maintain and improve the water quality in Dickinson Bayou.

In the best of circumstances, *all* high or medium quality habitats remaining in the watershed should be preserved, given the scarcity of virtually all of the remaining habitat types in the watershed. This would translate to over 13,000 acres and a price tag close to $1 billion! This aspiration, while noteworthy, is largely unattainable. Perhaps a more realistic preservation goal of 30% of the remaining habitat or 4,200 acres would be justifiable and attainable (Table 11). At current market prices, conserving 4,200 acres of land in the watershed would still cost $300 million—not a cheap price!

Table 11: Number of acres by habitat type targeted for protection within the Dickinson Bayou watershed

Habitat Type	**Acres Remaining**	**Targeted acres for Preservation**
Estuarine	46	46*
Prairie Pothole 1 (prime condition)	5,118	1,536
Prairie Pothole 2 (moderate condition)	8,156	2,447
Prairie Pothole 3 (somewhat degraded condition)	5,105	---
Riparian Forest	838	252
Total	**19,263**	**4,281**

* All estuarine land is considered preserved because current State of Texas permit requirements aim to protect these areas and make developing them difficult.

If habitat is to be preserved, it must be preserved in large-enough blocks to have some ecological significance. One hundred acres is considered a minimal amount of land for a single preservation parcel, with greater value gained as larger pieces are interconnected through corridors of one type or another.[51] A good example of land preservation, albeit mitigation through preservation, is the League City Prairie Park on Highway 96 near the intersection of Highway 146 and the Mar Bella subdivision. The City of League City purchased 44 acres of prime condition land and is preserving and managing this land as a nature park open for public use. This allows for education about and understanding of natural areas while preserving quality habitat for animals and the additional benefits of these areas. Mitigation, therefore, where appropriate and permitted may be a means of preserving prime habitat.

There are also ways to preserve land without purchasing it. *Conservation easements* allow the owner to maintain the property and makes them promise to keep the land in a natural state in perpetuity. These easements restrict development, commercial uses, industrial uses, and certain other activities on a property. Easements are agreements between the property owner and a government agency or land trust.

The Clean Water Act (CWA), Section 404, is the only federal law that protects a specific land category, namely wetlands. While municipalities do not have jurisdiction over wetlands under current federal and state law, they can require developers to comply with the federal statutes before granting any building permit within their jurisdiction. Simply requiring evidence of Section 404 compliance will yield more mitigation than is currently provided. Mitigation can include

$300 Million for Land
vs.
$300 Million for a Sports Stadium

The benefits of natural lands are not always easy to see because they have been there all of our lives. We don't realize these benefits until they are gone. Preserving natural land in the Dickinson Bayou watershed will likely cost around $300 million. *This is a lot of money.* But we must ask ourselves, how much is our history worth? How much are we willing to pay for our great grandchildren to reap the same benefits from the land that we do?

Minute Maid Park, home to the Houston Astros, cost $250 million to build. Reliant Stadium, home to the Houston Texans, cost $352 million to build. In 100 years what will be left of these stadiums? Crumbing piles of concrete and steel? Memories? Photographs?

In 100 years what will we see on natural lands? If they are protected, the same ecological and flood mitigation benefits we see today and have seen for tens of thousands of years. *They will still be a place to take our families and remember our heritage*. It will be the same untouched land of our ancestors.

*What is the best use of **your** money? Continues benefits or temporary benefits that leave behind piles of rubble?*

[51] Environmental Law Institute. 2003. Conservation thresholds for planners. Washington, D.C.

preservation and enhancement of existing wetlands. Insisting that this mitigation occur within the watershed could be a very significant way that important pieces of habitat get preserved at little or no cost to the municipality.

Restoration

Native lands in moderate condition offer many of the same benefits as land in prime condition. However, restoration efforts can rehabilitate this land back to a prime condition and *all* of its natural benefits. Many conservation agencies and organizations in the area are interested in habitat restoration projects but funding and labor is required to make them happen. Many grant programs exist to fund restoration projects and volunteers from master naturalists to Boy Scouts, can help with labor.

Habitat Management Plan

The development of a watershed-wide habitat management plan will be a collaborative effort between several agencies, counties, and cities. The watershed coordinator could help facilitate this process, by bringing groups together with knowledgeable professionals, helping to write portions of the plan, and working to make sure the goals of all groups and the watershed as a whole are met through this process.

An important component of a Habitat Management Plan is invasive species management. This ongoing issue if left unchecked often leads to degradation of native habitats. It is especially important to include non-chemical methods of control as these chemicals are adding to the poor water quality in Dickinson Bayou.

Education

Workshops should be held for land owners about conservation easements and the basics of entering into such an agreement. These short workshops should also include basic habitat information, ecological services information and examples of successful conservation easements.

Expected Pollutant Load Reduction

There is no load reduction set for the present time. Load reduction will be seen over time by not developing natural areas.

If the short term goal of preserving 1,000 acres is met. We will NOT see an additional 20,252 lbs/yr (4.3%) of total nitrogen, 4,797 lbs/yr (4.6%) of total phosphorus, and 6.2×10^5 billion colonies (4.7%) per year poured into Dickinson Bayou.[52] If the long term goal of preserving 4,200 is met, we will NOT see an additional 85,059 lbs/yr (18.1%) of total nitrogen, 20,147 lbs/yr (19.4%) of total phosphorous and 2.6×10^6 billion colonies/yr (19.7%) of bacteria enter the Bayou each year. [33] Thus, preserving this land will decrease the annual load by these amounts.

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[52] Complete calculations in Section 23

Targeted Goals and Actions

- Identify valuable natural habitats and develop a plan to preserve and/or restore these areas
- Identify wetland areas for restoration and develop a restoration plan
- Develop a mitigation plan to identify the most effective use of mitigation dollars to preserve habitat within the Dickinson Bayou watershed
- Estimate, in detail, the amount of remaining forested riparian habitat within the watershed
- Develop a habitat conservation management plan specific to each piece of preserved land
- Work with landowners to preserve land through conservation easements
- All municipalities within the watershed require full compliance with CWA Section 404 before granting any building permits, and insist that any mitigation be accomplished within the watershed.

Financial requirements

Purchasing land is not cheap, but must be done to protect our watershed and our bayous. At current market prices it will cost $300 million to purchase land. These costs could be shared by many groups, including cities, and counties, not-for-profit organizations, and private donors. Grants can be leveraged to purchase property, as well as bond issues or tax revenue; if cities choose to implement a stormwater fee, a portion of these funds could also be used. It will require a concerted effort of the Partnership for land preservation to be effective. CWA permitting and mitigation could yield land, easements and/or restoration opportunities in the watershed.

Minimal funding of $180,000 over several years would also be needed for additional projects. Fifty thousand dollars is needed for workshops on preserving private land with conservation easements and a homeowners program. A watershed wide mitigation plan would require funding of $30,000 and a habitat conservation plan would require funding of $100,000. This work and much of this cost could fall under the duties and funding of a watershed coordinator.

Milestones

- Hold 2 public workshops on preserving land though conservation easements: 2014
- Develop a watershed wide mitigation plan: 2014
- Develop a watershed wide habitat conservation plan: 2014
- Preserve 1,000 acres of habitat in the watershed: 2014
- Preserve 2,500 acres of habitat in the watershed: 2019
- Preserve 4,200 acres of habitat in the watershed: 2029

15. On-Site Wastewater Strategies

Establish a clear linkage between failing on-site sewage facilities (OSSFs) and water quality

A presumptive link has been identified between failing OSSFs and high levels of CBOD and bacteria in Dickinson Bayou. Given that remediation of failing OSSFs is an expensive project, a detailed investigation of the actual contribution of OSSFs to the water quality problem seems mandatory. Such a study would require multiple sampling events near areas with concentrations of OSSFs, sampling overland flow during periods of rainfall, and sampling tributaries after rainfall events as well as base-flow measurements.

OSSF enforcement and maintenance

Since 1997, state regulations require that OSSFs be designed to accommodate limiting factors in the soil and on the site. There are serious soil limitations for OSSFs in the Dickinson Bayou watershed, mainly shallow water tables and very clayey soils (see Figure 5). Standard soil leach-field systems do not treat and dispose of domestic wastewater to current standards. Advanced treatment and disposal systems are required for problematic soils. Table 8 shows considerable progress in the installation of advanced systems over the past decades, but as of 2006, 23% of all systems permitted in Galveston County were still standard leach-field systems. Flat-lying and adjacent Harris County, likely somewhat better drained than Galveston County on average, permits very few standard soil treatment systems. Galveston County should be permitting even less. Close attention should be paid to soil limitations, accepting as default drainage limitations unless proven otherwise.

Remediation of Failing OSSFs

Short of hooking up the affected neighborhoods to central sewer lines, there are remedies for some of the existing failing septic systems. For soils that are saturated to or near the surface, mounded systems can be constructed that elevate the leach-field above the native soil (usually no more than about 2 feet). A surface spray system or a subsurface drip system could then be installed in the mound. An advanced treatment system before distribution would also be a chlorination and aeration treatment for surface spray application, or UV, ozonation or similar disinfection for subsurface drip application.

The main limitation would likely be space in some of the smaller lots. However, many of the lots in these areas are quite large making this a viable option for most sites. The cost would also be a factor. Where space is not a limitation, upgrading a standard system as described above might cost $5,000 per house.

Strategy

- Detailed water sampling between failing OSSFs, tributaries, and Dickinson Bayou
- Hold a workshop (lecture and field exercise) on soil evaluation for Galveston County officials and OSSF installers and designers.
- Workshop on advanced retrofits for failing OSSFs

Expected Load Reduction

Significant load reductions could be expected from fixing failing OSSFs. There is not sufficient data at this time, however, to specify what kind of load reductions could be expected from repair and/or replacement of failing systems.

Financial requirement

- OSSF Feasibility study: $75,000
- OSSF Soil Evaluation Workshop: $5,000
- Advanced Retrofit Workshop: $10,000

Milestones

- OSSF Feasibility study: 2010
- OSSF Soil Evaluation Workshop: 2009
- Advanced Retrofit Workshop: dependent on feasibility study

16. Strategies for Centralized Wastewater Treatment Facilities

Current Infrastructure

The issue with permitted treatment facilities is not whether they are meeting their permit requirements as whether some of the older collection and treatment infrastructure is working as designed. In particular, some of the older sections of Dickinson are served by older pipes, such as clay pipes and asbestos-coated pipes that are subject to significant leakage, particularly in the high shrink-swell and wet soils that characterize much of this watershed. There is no data as to how much of the bacteria and CBOD problem in the Bayou might be attributed to faulty sewage infrastructure, there is no doubt that leakage from these older pipes is a significant problem to warrant attention. The principal wastewater treatment operator in the watershed, Water Control and Improvement District No. 1, is currently undertaking a program to upgrade all of the older pipes and several force mains[53]. The WCID #1 Board recently approved a nearly $17,000,000 improvement project to replace the older pipes within the next 8 years, largely financed through increased sewer rates. This replacement project will take place on a priority basis, addressing the areas with the greatest problems first. The areas of highest exfiltration or leakage appear to be between Gum Bayou and Hwy. 3.

Accidental Discharges

Wastewater treatment plants are subject to occasional failures. Most treatment plants report these immediately and repair the problem in short order. Vigilant watershed citizens should be aware of unusual or foul smelling discharges into the bayou and report these immediately to TCEQ by calling 1-888-777-3186 or sending an e-mail to cmplaint@tceq.state.tx.us. A force main failure near Hwy 3 about 2 years ago resulted in a significant discharge directly into the Bayou and was noted by many citizens. WCID #1 has replaced and significantly upgraded the protection of that force main and is scheduled to replace a similar force main soon.

Illicit Discharges

An illicit (illegal) discharge is defined as a discharge from a storm sewer system that is not entirely composed of stormwater. A discharge of domestic wastewater into a storm sewer system is perhaps the most common example of an illicit discharge Galveston County has an active monitoring program for illicit discharges, and published an important guidance manual on tracking illicit discharges[54].

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[53] Personal communication, David A Paulissen, General Manager, Galveston County WCID #1, January 29, 2009.
[54] A Guidance Manual for Identifying and Eliminating Illicit Connections to Municipal Separate Storm Sewer Systems (Galveston County (TX) Health District, 2002) http://www.gchd.org/pollution/GuideManual.pdf

The issue of fully permitted discharges and additional permits

How much more wastewater could be discharged into the Bayou? The recent draft version of the Dickinson Bayou TMDLs[55] recommends a loading level no greater than 90% of the already existing and permitted load, in terms of CBOD. This includes, of course, a very substantial nonpoint or runoff source of CBOD pollution, which we are assuming comes mainly from potentially failing on-site septic systems. What this means is that the stream could absorb more loading—in fact, something more than about twice as much of an increase in the existing point-source load, barring any increase in the OSSF load. But that is just to maintain status quo –not achieve any improvements in stream and water quality. Full development of the watershed would much more than double the waste load—whether permitted point source or runoff. Clearly some choices and tradeoffs need to be made to insure the integrity of the bayou and its watershed in the future.

Milestones

Complete conversion of clay sewer pipes: 2016 (sooner if additional funding is received)

[55] Texas Commission on Environmental Quality. 2008. *Two Total Maximum Daily Loads for Dissolved Oxygen in Dickinson Bayou.*

17. Site-Scale Strategies for Stormwater Management

Water quality issues for Dickinson Bayou are not only associated with permitted facilities such as municipal and industrial wastewater facilities but also derive from non-point source pollution. This pollution is caused by the everyday activities of watershed residents and is exacerbated by an increase in impervious surfaces (roads, parking lots, roof tops, driveways, etc.). Native soils in the watershed serve as a sponge that soaks up and filters rainwater and recharges ground water supplies. Paving over or building on open areas removes this natural sponge. Instead of soaking into the ground, water runs over concrete parking lots and, on to paved roads picking up pullutants as it flow over these surfaces; and into storm drains and into Dickinson Bayou and its tributaries, without the natural filtration of the soil.

Many of the tools listed below are referred to as Low Impact Development (LID) Best Management Practices (BMPs). They aim to mimic the natural hydrology of an area, allowing water to soak into the soil and as much as possible not run off. The design of these BMPs is site-specific and most are intended to be small scale projects that can easily be incorporated into a new or existing yard, parking lot or landscape.

Suggested Site Scale Stormwater Tools for the Dickinson Bayou Watershed

Rain Gardens: Rain gardens offer a landscaping technique that can be applied to a variety of situations whether it is a commercial, public or residential setting. They are designed to capture runoff from impervious surfaces such as compacted lawns, roofs, sidewalks, streets or parking lots. The water is allowed to slow down, become filtered, and is absorbed into the soil, recharging ground water. The design is typically a bowl shaped garden, excavated slightly, and the soil amended with sharp sand and compost. Water is directed from a surface, like a roof, and pools for a short time. Any excess runoff enters the storm drain system, but is cleaned of 80% of contaminates. Because rain gardens are composed of native plants, they also attract wildlife such as birds and butterflies, providing a beautiful and functional addition to any landscape.

WaterSmart Landscaping: These landscapes are planted with native and adapted non-invasive plants. These are well suited to our climate and soil conditions; therefore, they require less watering once they are established and do not need chemical fertilizers, pesticides or herbicides to thrive. This can result in a 90% reduction in the amount of polluted runoff entering the storm drain system and an equal reduction in the volume of water used for irrigation. As an added feature, native plants attract wildlife such as birds and butterflies to our landscapes.

Compost soil amendments: Use of compost on residential and commercial landscapes can greatly reduce the need for soluble fertilizers and pesticides, more than any other practice. Some care should be exercised with composts derived wholly or mostly from animal manures.

Bioswales: These open, vegetated drainage ways have gradual slopes and collect and slowly move water downstream giving it a chance to soak into the ground before reaching the bayou. These can replace curb and gutter systems and are especially useful along road ways and parking lots. Swales can be planted with grass and maintained by mowing, or planted with low

growing native wetland vegetation that can withstand both periods of moisture and drought and will not impede flow during large rain storms.

Construction Site Compost Filters: BMPs are not limited to post construction. Most construction sites are required to meet EPA standards for erosions and sediment control. Typically these sites employ silt fences and other structural practices, but there are better ways to address these issues. The best and, often times, most cost effective option is compost filters instead of control structures. After construction is completed, this compost can be spread out on site to help build healthy soil and establish lawns and flower beds.

Rain Water Harvesting: Water can be collected from roofs or hard surfaces (i.e. driveways or parking lots) and stored in small rain barrels or larger cisterns. This non potable water can be used to water plants and wash cars. Collecting water from hard surfaces keeps it from running into storm drains; by saving this water and distributing it during dryer times, it allows the water to soak into the soil and benefit from natural filtration before entering Dickinson Bayou.

Watershed wide stormwater ordinances: changing laws can make implementing BMPs more feasible in the watershed. This may simply mean changing the list of acceptable plants to include more natives (i.e. using native trees as street trees), allowing smaller driveways and parking lots to reduce impervious surfaces or allowing over flow lots to use pervious pavement. Especially as the communities within the watershed work to meet the requirements of MS4 permits. Small changes can make a large difference.

Ordinance

A key component to the success of LID and stormwater BMPs in the Dickinson Bayou watershed is support from local governments. A post-construction stormwater ordinance should be written or amended for each city to encourage or require installation of BMPs for specific kinds of development.[56] Ordinance language should allow for easy installation and retrofit of stormwater BMPs. An example ordinance form the Center for Watershed Protection is provided in Appendix J. This contains important language on BMP design, construction and maintenance, as well as measures to address violations in all of these areas. It also suggests ways to incorporate runoff reduction criteria, and water quality criteria, so BMPs will help improve the water quality in Dickinson Bayou.

It is imperative that all of the municipalities have continuity between their stormwater ordinances. This does NOT mean every ordinance should be identical; however these can be written to meet the specific needs and concerns of each community, while keeping the health of the Dickinson Bayou watershed, Dickinson Bayou, and ultimately Galveston Bay as a main focus.

[56] Alternatively, a city could enact an ordinance restricting total loadings from developed areas, and leaving it to the developer as to how those loading requirements would be met.

Education

Low impact development is a new concept to most citizens of the watershed including municipal officials and decision makers; therefore, a good educational program is essential for successful implementation of site specific BMPs. This program needs to reach stakeholders at every level within the watershed: students, homeowners, business owners, developers, elected officials and more. It will require different techniques and the efforts of many individuals and organizations to make this work. Efforts should include:

A **BMP Advisory Committee of technical experts will** be created. This committee will complete an informal survey of possible demonstration sites within the watershed and a list of recommended BMPs that are the most beneficial for the watershed. This group will also be available to local officials to answer questions and provide technical information about these strategies.

To reach the necessary individuals to make BMPs work, numerous **Workshops** are needed. These should focus on different groups including *municipal officials*, *developers* and *home owners*. It is essential to tailor each workshop to the audience and show them how they can implement site specific BMPs and how they can make a difference. These workshops should be held at appropriate times, to allow for optimal attendance. Also, it is best to schedule workshops for practices like rain gardens one to two months before optimal installation time so homeowners excited by the workshops are ready to implement these ideas at the correct time of year and will likely be more successful. The Texas AgriLife Extension Service will be a lead agency in holding workshops. Many additional groups, however, should also be involved, including but not limited to: All cities within the watershed, several branches of Galveston County government, Houston-Galveston Area Council, Master Naturalists, Master Gardeners, Galveston Bay Foundation, Galveston Bay Estuary Program, Texas Parks and Wildlife, local Universities, Texas Sea Grant, and Keep Dickinson Beautiful.

Publications are still one of the best ways to reach a mass audience. These can be distributed at community events, through schools or places of business. Publications can also be distributed electronically for very little cost. Publications explain the concept of BMPs are needed as well as a series of “How To” brochures for recommended BMPs so that developers, homeowners and business owners can “do it themselves.”

One of the best ways to inform people about site specific BMPs is through **Demonstration Sites,** or actual on the ground examples. The best way to teach someone is to show them. A demonstration of each BMP recommended by the advisory committee should be installed within the watershed. These should be in high profile, preferably public locations so they are easily accessed for viewing by anyone interested. Demonstration sites should also include interpretive signs explaining the site purpose, the techniques used, and why. These need to be colorful and inviting and use easily understandable language. Finally, once several of these demonstrations have been installed, a map and driving tour should be established and posted on local websites to facilitate tours for various groups.

Several **outreach programs** should be developed or implemented in the watershed. These could be spearheaded by any of the organizations mentioned in the workshop section above. Across the country the EPA, Extension Programs, Cities, Counties and States have put together excellent outreach campaigns targeting all types of non-point source pollution and use a variety of methods to reach the public. These should be implemented as is or tweaked to fit the needs of the Dickinson Bayou watershed. One such campaign should be targeted at *pet waste* as a source of bacteria and organic material. The Texas Commission on Environmental Quality and the EPA have developed some excellent information to work with and several additional pieces should be created to bring the necessary information to the watershed.

Expected Load Reduction

In the short term, we expect to treat 250 acres of medium density development with BMPs, including at least two neighborhoods (if 60% of the homes install some form of BMP) as well as commercial areas. BMPs range in effectiveness from 30% to 90% depending on the type and design, so we assume an effectiveness of 60%. At this level, we expect to see a reduction of 437 lbs/yr (0.47%) for total phosphorus, 1,885 lbs/yr (0.47%) for total nitrogen and 5.5×10^4 billion colonies/yr for bacteria.[57]

In the long term, we expect to treat 10,000 acres of medium density development with BMPs. For the purpose of calculations, we again assume 60% participation and 60% effectiveness. At this level, we expect to see a reduction of 17,466 lbs/yr (18.7%) for total phosphorus, 75,395 lbs/yr (18.7%) for total nitrogen, and 2.2×10^6 billion colonies/yr (18.3%) for bacteria.[58]

Financial Requirement

The cost to implement LID BMPs is very site specific; however it typically costs $5,000 to $10,000 per BMP. At an average of $7,500 per BMP it will cost around $1.1 million to install 150 BMPs in the Dickinson Bayou watershed. Below is a list of potential costs for each site as well as ways to minimize these costs.

The other costs are associated with education and production of publications. These will likely cost at least $250,000. Portions of these coats could be covered by local cities as part their compliance to MS4 permit guidelines.

[57] Complete calculations in Section 23
[58] Complete calculations in Section 23

Table 12. Ways to minimize installation costs for BMPs

Potential Costs	Ways to minimize costs
• Site for locations • Earth work • Supplies • Construction	• Volunteer labor • Partnerships/cost sharing between agencies • "Free" technical advice– through Extension Service and other programs

Milestones

- Creation of BMP Technical Committee: 2010
- List of the best BMP's for Dickinson: 2010
- Three construction site compost demonstration sites by: 2010
- Three additional BMP demonstrations completed at highly visible sites (selected from technical committee list): 2010
- Self guided tour map of demonstration sites in the watershed: early 2014
- Adoption of a watershed stormwater ordinance by all communities within the watershed: 2014
- 100 LID BMP's installed at private homes: 2014
- 50 LID BMP's installed at business, municipal offices, court houses, etc.: 2014
- Creation of (or retrofit) LID neighborhood: 2014
- 10,000 acres treated by BMPs: 2029

18. Strategies for Stormwater Detention and Wetlands

Wetlands are a key part of the Upper Texas Gulf Coast ecosystem and add to the subtle beauty of coastal prairies. They are also an integral part of the system that naturally cleans and detains stormwater as it makes its way to Galveston Bay. Engineers and biologists have found ways to design stormwater treatment wetlands into our stormwater detention and conveyance systems. These treatment wetlands are one of the very best options we have for cleaning polluted runoff. There are numerous sites in the watershed where engineered wetlands could be installed, and we know stormwater wetlands work in our area.[59]

Stormwater wetlands clean water much the same way as natural wetlands do. Wetland plants filter water as it passes through the marsh, and the chemical and biological processes unique to wetlands render many pollutants harmless, making the water exiting the wetland much cleaner than when it entered. A local example is the Mason Park Stormwater Wetland in Houston, Texas located along Brays Bayou. This wetland was designed to treat stormwater runoff from a 30 acre neighborhood while also providing habitat and beauty. The Mason Park wetland consistently removes 99% of bacteria from stormwater. This wetland has survived several severe floods and significant storm surge from a hurricane. It continues to provide all its design functions, especially improving water quality.

Stormwater wetlands can be incorporated in the Dickinson Bayou watershed in two ways. They can be retrofitted into existing stormwater detention ponds or they can be created from scratch in suitable locations.

Retrofit Wetlands

The Dickinson Bayou watershed has many small stormwater detention areas which are often seen as eyesores that provide basic detention and little else. These could be retrofitted into stormwater wetlands, which will enhance the appeal of a site, provide basic detention and improve water quality. Two primary considerations dictate the shape and cost of retrofitting a stormwater wetland. First, the amount of land readily available for the wetland must be enough to adequately treat the volume of stormwater produced. Secondly, the overall performance goals of the wetland within the landscape need to be established before the wetland is created.

Detention basins already exist for most residential and commercial development; these sites are ideal locations to retrofit stormwater wetlands. For retrofits, a pond will likely need to be excavated and re-sculpted, but since the basic pond design already exists, the cost for this work is minimal. After the pond has been re-sculpted, native wetland plants should be installed to insure the full benefit of a treatment wetland. A variety of plants provide greater water quality benefits as well as habitat that draws birds and other wildlife to the wetland site.

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[59] http://urban-nature.org/urbanwet/documents/e_coliarticle-master.pdf

New Construction Wetlands

There are also opportunities to place larger stormwater wetland systems (similar to the Mason Park Stormwater Wetland) on publicly-owned property (i.e. parks) serving larger subwatersheds within the Dickinson Bayou watershed. These endeavors would be more costly up front, but provide a greater service over time and offer the possibility of a multiuse space that combines a wetland with a park, and creates precious habitat for wildlife.

The creation of a stormwater treatment wetland presents its own set of challenges. First, a site must be purchased. The size of the wetland will be determined by the tract of land available. Additionally, construction costs will be more than for a retrofit project because a pond must be dug and contoured, and stormwater pipes may need to be redirected into the wetland. One of the most costly components of digging a pond is the removal of soil and associated off-site disposal costs. On-site disposal will significantly lower the overall project cost.

Financial Requirements

Cost per wetland can range from $30,000 to $50,000 per acre and up, exclusive of the land costs, depending on the site and size of the wetland. The first consideration starts with the land available for creation. Detention to compensate for runoff generated by a new development is required in this region. With planning, a typical dry detention basin could be replaced with a stormwater wetland. Choosing a stormwater wetland as both detention and treatment will require advance planning and design, and supplemental construction costs over and above what a simple detention basin would cost. A typical design can be produced for a retrofit or new construction for approximately $20,000 per wetland project. Additional costs may arise for engineering documents or plans, which will add approximately $10,000 to $20,000 to the total cost for design. Construction costs will vary by site depending on the location and whether disposal of fill material is on-site or off-site. Finally, the cost of vegetation and possibly water control structures need to be considered.

It is important to remember that the upfront cost needed to create a stormwater wetland treatment system will be recovered in long-term water quality improvement without additional expensive infrastructure.

Expected Load Reduction

The initial short-term goal of stormwater wetlands is to treat approximately 250 acres of developed watershed land, which represents 1.3% of this land use type for the watershed. Using documented median removal rates for total suspended solids and bacteria, the expected load reduction is 1,257 lbs/yr (0.31%) for total nitrogen, 582 lbs/yr (0.62%) for total phosphate and 1.2×10^6 billion colonies/yr (1.1%) for bacteria.[60]

The long term goal is for all currently developed land (both medium and low density) to be treated by stormwater wetlands. Using the same removal rates as for the short-term goal, the

[60] Complete calculations in section 23

expected load reduction is 267,968 lbs/yr of total nitrogen (32%), 96,634 lbs/yr of total phosphorus (23%) and 1.6 x 10^7 billion colonies/yr (46%).[61]

Milestones

- Develop a retrofit manual/guidebook for landowners: Fall 2009
- Complete 5 stormwater wetland treatment systems within the watershed: 2014
- All currently developed land treated by a stormwater wetland: 2029

[61] Reductions based upon projected 2029 loadings assuming full build out of the watershed at medium density, see section 23 for full calculations

19. Urban Growth Strategies

At full build out, an additional 100,000 new residents might be expected for the Dickinson Bayou watershed[62]. The current "recipes" for urban growth (the ordinances and codes that guide urban planning) allow and in fact insure that if growth continues unabated over the next 20-30 years, the entire watershed will be filled with suburban, automobile-dependent development, and, therefore, experience at least double the current pollutant loadings, given that the watershed is about 50% developed.

There are a couple of trends, however, that might slow this kind of growth. First is the rising cost of fuel. We can expect ups and downs in the price in the coming decades, but almost assuredly the overall price trend will be up, at times dramatically. People will be much less willing to drive long distances to work.

Second, changing demographics will result in large changes in demand for particular housing types over the next two decades. A majority of home buyers will be families without children—aging empty nesters or singles and young families. Many of these people will be looking for low-maintenance homes in walking distance of shopping and restaurants. A recent study[63] suggests that we are already overbuilt within most of the country in terms of the single-family detached homes that will be in demand in 2030. If true, that result would not bode well for long term appreciation of housing stock in places like the Dickinson Bayou watershed, where there are many more residents than there are jobs, and where there are few neighborhoods that would attract the largest demographics over the next two decades.

An awareness is emerging that walkable neighborhoods and commercial districts are much more than a passing fad. Major new "town centers" are springing up across the region, from The Woodlands to Sugarland and even Pearland. The main characteristics that make these developments walkable is proximity of the stores to each other and an urban pattern very much like older downtowns such as Galveston's The Strand or 6th Street in Texas City. Adjacent residential zones in a walkable community would have much smaller lots than are found in typical suburban developments, and much smaller setbacks to the street. The Woodlands is building denser residential neighborhoods close to their town center, and somewhat walkable neighborhoods are emerging even in places like LaMarque (e.g., the Borondo Pines development).

The proximity of houses to businesses, and other community structures and places is what makes a place walkable. The environmental benefit of this proximity is that much less land is consumed per capita, land that can be preserved in its undeveloped state. For example, the average density of medium-density residential areas in the Dickinson Bayou watershed is about 2,000 people per square mile (roughly 2-3 units to the acre). Residential areas a bit closer in to

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[62] A conservative estimate based on available land and current development densities.

[63] Nelson, A. C. 2006. Leadership in a new era. Journal of the American Planning Association, 72 (4):393-407.

Houston, for example in the Clear Lake area, have a density of about 4,000 people/ sq. mi. Eight thousand people per square mile (~8-10 units to the acre) is dense enough to yield a fairly walkable neighborhood, and still maintain detached single-family homes, although on relatively narrow lots (up to about 4,000 square feet). At 8,000 people/sq. mi., 100,000 people would occupy 12.5 square miles versus the 50 square miles occupied by development at 2,000 people/sq. mi. A denser development, of 12,000 people/ sq. mi., would result in further land savings. This would be similar to a townhome development.

Land savings are not the only environmental benefit to gain from walkable or compact development. Recent research[64] shows the total pollutant stormwater loads are much less for a given population at denser versus more spread out development. In fact, building a development at 8,000 people per square mile results in about the same reduction in pollutant loading that some of the best stormwater treatment practices (outlined in Section 18) could achieve treating runoff from a standard suburban development (4,000 people per square mile) for the same number of people.

Another benefit of compact traditional neighborhood development is the additional storm security associated with mixed-use developments.[65] Galveston's Strand, built in the classic mixed-use pattern of mixed commercial and residential, with compact residential neighborhoods within walking distance, survived the Great Storm of 1900 almost intact, and many more people could easily have taken refuge there had they known the extent of the approaching storm. Solidly-built mixed use commercial structures can act much like what FEMA calls a "safe-room", but at a community scale.

While the environmental benefits of small-town style compact development are considerable, the issue of community viability may be even more important to watershed residents. Many residents enjoy and will continue to demand larger-lot living, but every indication is that the very quality of life that drew them to this area will decay as the watershed builds out. The open spaces they enjoy will be gone, and strip malls will abound. Pockets of higher-density neighborhoods built around the small-town model could do more to preserve and even improve quality of life and the environment than just about any other practice. Figure 22 shows how a few select pockets could accommodate most of the forecast potential population increase, and Figures 23 shows what some of these density patterns might look like.

Compact growth in and of itself will not ensure that open space remains open. If there are areas worth preserving, then additional steps would need to be taken (discussed in Section 14).

Building at higher density might be the practice that could bring the highest total benefits for the watershed both in terms of environmental quality as well as quality of life, but it is clear that it is

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[64] Jacob, J.S. and R. Lopez. 2009. Is Denser Greener? An evaluation of higher density development as an urban stormwater best management practice, Journal of the American Water Resources Association. June 2009.

[65] Jacob, J.S. and S. Showalter.2008. The Resilient Coast: Policy frameworks for adapting the built Environment to climate change and population growth on the U.S. Gulf Coast. TAMU Sea Grant TAMU-SG-07-7401R. College Station.

also the most difficult practice to achieve. The current regulatory framework, for example, makes small-town density almost impossible to accomplish. A recent analysis of ordinances of all the municipalities in the watershed[66,67] revealed that a walkable, mixed-use development would require a series of variances, enough to discourage all but the most determined of developers.

A few simple changes, that would enable town-centered walkable development, could easily be made to most of the municipal ordinances in the watershed. Five simple changes are listed below. Changes in these areas would not require a major change in how development takes place, but could have a major impact on the shape that future development takes.

- *Smaller lots:* most municipalities in the watershed require 7000 sq. ft or more for single-family detached homes. Reducing the minimum to 3000-4000 sq ft would do more than just about anything else to improve walkability.
- *Greater density*: allowing more units to the acre is another way of expressing smaller lots. Eight to 12 dwelling units to the acre is dense enough to support a corner store or even light bus service, and still have single-family detached homes.
- *Mixed use*: Most modern zoning codes prescribe a separation of uses. Zoning can be a useful and powerful tool, but a too-strict separation of uses leads to auto-dependent development that is not at all walkable.
- *Reduce parking requirements*: recent studies have shown that most minimum parking requirements should probably be treated as maximum limits[68].
- *Greater street connectivity*: less cul de sacs and a higher number of intersections per square mile on a grid pattern enable higher density and much more walkability

There are many more areas that should be addressed to enable greener and more walkable development. The emerging LEED-ND standards provide a comprehensive list of areas to be addressed.[69]

An opportunity for denser, walkable development is presenting itself in the emerging I-45/ Hwy 3 commuter rail corridor. Transit-oriented-development is a special variety of town-centered development that occurs around transit stations. The rail stations could end up as large parking lots, but with a little foresight and some careful planning, these stations could be the location of some fairly vibrant urban neighborhoods that would contribute greatly to the overall quality of life in the area.

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[66] Kultgen, P. 2007. Dickinson Bayou Watershed Ordinance Compilation. Report to the Texas Coastal Watershed Program.
[67] Salzar, L. 2009. A Tool Kit for Texas Watershed Planning. An Analysis of Dickinson Bayou Watershed. Report to the Texas Coastal Watershed Program.
[68] Shoup, D.C. 2005. The High Cost of Free Parking. American Planning Association. Chicago, IL.
[69] Leadership in Energy and Environmental Design – Neighborhood Development; *www.usgbc.org/LEED/ND*

Educational Component

- Distribution of educational materials, including TCWP's Choices for Growth
- At least 3 growth related workshops, possibly related to HGAC's Liveable Centers concept, or Federal Highway Administration Context Sensitive Solutions workshops
- Preliminary public planning charrettes for transit stops if commuter rail discussion continues

Load reductions

Compact growth will afford no load reductions from existing loadings, but we can expect load reductions for a set number of people for compact versus conventional development. Communities in the watershed may elect any number of compact growth scenarios. For a long-term load reduction scenario, we estimate 50 percent of all growth in the next 20 years (perhaps comprising about 50,000 people) on average could be as compact as 12,000 people per square mile. If that density resulted in a 40% reduction in nutrient loading versus conventional suburban development[70], then the total load reduction would be about 20% of the future additional load

Financial requirements

No additional financing would be necessary. With appropriate development ordinances in place, compact development should not cost any more than conventional development, and in fact should be cheaper per unit of development.

Milestones

- Ordinance changes to allow compact growth in select areas: 2010
- At least 3 workshops, as outlined above: 2014

[70] Jacob, J.S. and R. Lopez. 2009. Is Denser Greener? An evaluation of higher density development as an urban stormwater best management practice, Journal of the American Water Resources Association. June 2009.

Figure 22. Potential pockets of development with 100,000 additional watershed residents at 16,000 people per square mile (similar to the French Quarter of New Orleans)

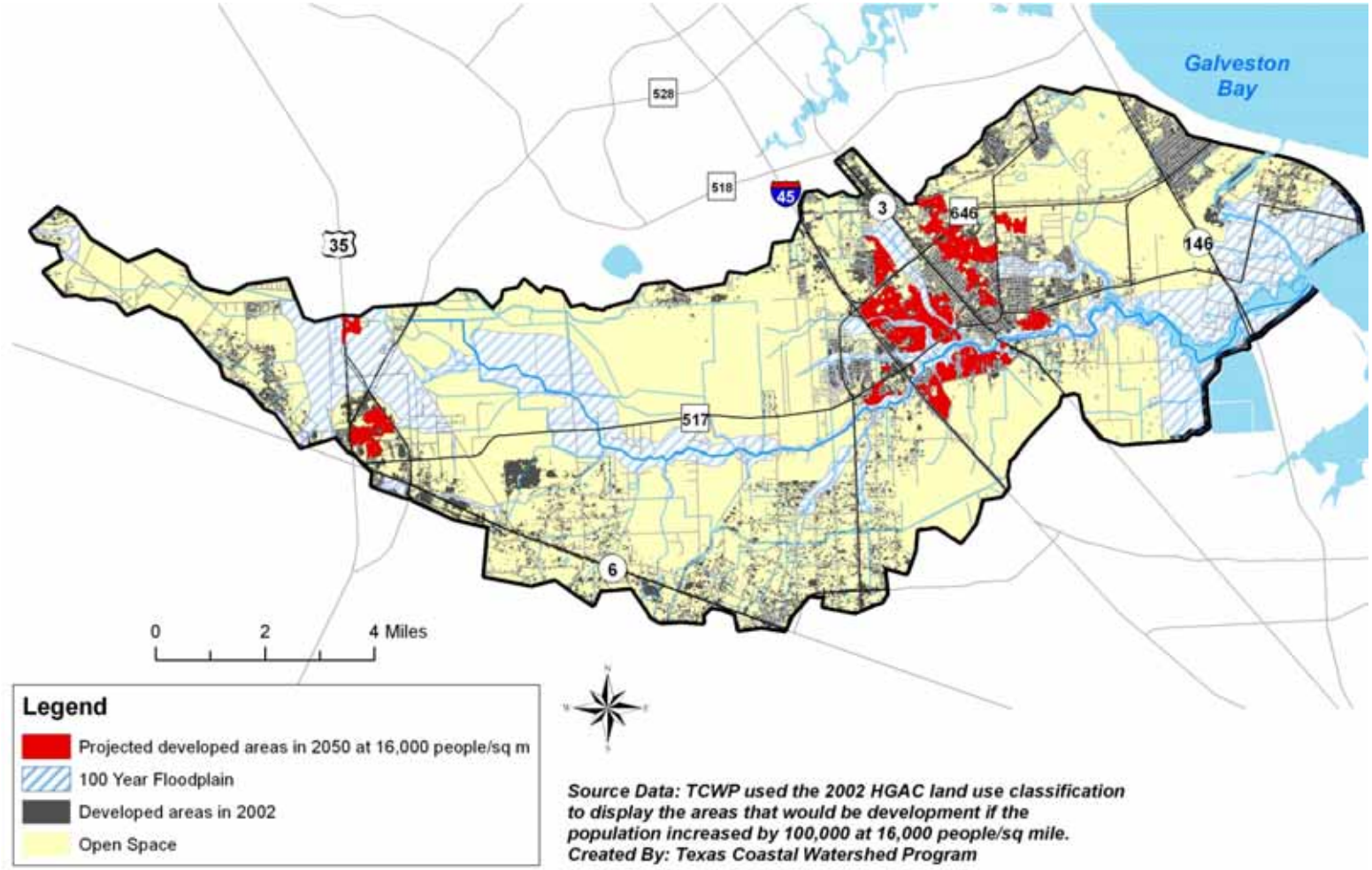

Figure 23. Examples of what high density development can look like. Photos courtesy of Urban Advantage

A typical modern mixed-use commercial district. Residential, commercial, and other uses are mixed and in close proximity. Cars are present, but this is not an “auto-dependent” neighborhood.

Single-family, detached homes dominate this compact, small-lot neighborhood. The greater concentration of houses enables some local retail within walking distance, and perhaps even some limited transit, not otherwise supportable in traditional larger lot communities.

20. Recreation and Parks Strategies

The Need for Parks

The Dickinson Bayou watershed currently has 8.5 acres of park space for every 1,000 people. The National Recreation and Parks Association recommends a minimum of 10 acres of park space for every 1,000 people. The watershed is close to meeting this standard but still needs over 110 acres of park space to reach this minimum. One way to provide this park space is to create pocket parks on small parcels of existing city or county property, especially on land with bayou frontage. These small parks would provide park space for individual neighborhoods and also offer the potential for canoe and kayak launches or trail heads for walking trails along the bayou.

Small local parks also fit into the concept of livable centers and a walkable community[71]. (See also Section 19).

Connection to Habitat

Adding park space, especially as nature parks, is a prime way to preserve habitat. This entails maintaining and managing land as it is and not creating mowed turf grass athletic fields. Parks can still be open for public use with walking trails, boardwalks, picnic tables and other amenities AND maintain the ecological function of the land.

This plan recommends preserving 4,200 acres of existing habitat in the watershed (See Section 14). Preserving habitat as nature parks allows for public access to these important natural resources and provides a framework for management of the property. These management techniques should strive to maintain ecological function and these parks should be dedicated through a land trust, conservation easement, or other agreement that will keep them as natural areas and not allow for the conversion to athletic fields or mowed turf areas.

Creating additional public access to the bayou is another multipurpose goal. Even small areas of water front property offer the opportunity for restoration of riparian (waters edge) habitat, either forest or marsh. The first priority for these areas should be as boat ramps, fishing piers, etc however we must consider multiple uses for all projects.

Regional detention basins offer another opportunity for parks. Centralizing detention (see Section 18) into large-scale (several hundred acres) sites offers another opportunity to access public lands. Instead of erecting fences and marking these areas as off-limits; walking trails, benches and even athletic fields can be worked into the design with the understanding that these areas will flood when necessary. The idea of a dual purpose facility is not new; Author Storey Park in Houston is a prime example of how, with planning, this is possible.

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[71] Shafer, S,, and Jacob, J. 2007. Urban Parks: The value of small urban parks, plazas, and other outdoor spaces. Department of Recreation, Parks, and Tourism Sciences, Texas A&M University, College Station. http://www.urban-nature.org/publications/documents/UrbanParks.pdf

Organic Landscaping Techniques for Park Management

The management of existing and new park spaces is essential to mitigating non-point source pollution. Excessive nutrients in Dickinson Bayou are thought to be responsible in part of the low levels of oxygen. One major contributor to excessive nitrogen levels is chemical fertilizer. Parks are often large expanses of manicured lawns managed by mowing and fertilizing. An organic approach to management will reduce the amount of excess nitrogen that runs off of the land after the application of fertilizer as well as exposure of children to these chemicals on athletic fields.

Targeted Goals and Actions

- Development of “pocket parks” for more accessibility to Dickinson Bayou.
- Improvement of existing public boat ramps.
- Clean up abandoned boats, barges and other debris in Dickinson Bayou
- Dredge the mouth of Dickinson Bayou to improve flow and oxygen exchange.
- Encourage greater water safety and boating safety measures in the local community in order to enhance local stewardship of the bayou.
- Encourage greater participation from local, state and federal authorities in enforcing water and boating safety measures on the bayou.
- Increase education on recreational activities and safety through signs and brochures on the watershed.

Financial Requirements

With current land costs, it would cost $770,000 to purchase 110 acres of land. This land could be part of the 4,200 acres of preserved habitat. The City of Dickinson currently owns several small pieces of property along Dickinson Bayou that could possibly be developed into pocket parks with a small investment (less than $50,000) for signs, picnic tables, benches, trash cans, play equipment, parking, etc. There are grant funds available for park amenities that could be pursued by the city to help offset these expenses.

With park space there is also additional costs for maintenance. This expense would fall to counties or cities already working on shoestring budgets. Properly managing all parks in the watershed would likely mean a small tax increase or park usage fee. Switching to organic management techniques will require some additional funding up front but over time parks could begin their own compost programs, convert little used lawn areas to wildflower meadows to reduce mowing and incorporate other changes which would reduce long term maintenance costs.

Milestones

- Add 50 acres of park space open to the public, portion of which will be pocket parks - 2013
- Installation of at least 5 educational signs throughout the watershed - 2011
- 25% of parks managed organically (using WaterSmart Landscaping principles) - 2014
- Hold 2 classes on boating safety and community stewardship - 2010
- Add 110 acres of park space open to the public – 2019
- 100% of parks managed organically (using WaterSmart Landscaping principles) - 2019

21. Water Quality Monitoring Plan

Historical and Current Monitoring

Historical water quality monitoring data for Dickinson Bayou is limited[72]. Monitoring did not begin until 1992, with only one station collecting data (Station ID: 11467 Figure 24). Since that time, the Texas Commission on Environmental Quality has added twelve surface water quality monitoring stations along the bayou as well as a continuous monitoring station located at the bridge on State Highway 3 (Station ID: C733).

The TCEQ's Clean Rivers Program (CRP) is currently scheduled to monitor ten sites along Dickinson Bayou and its tributaries during fiscal year 2008/2009 (September 1, 2008 to August 31, 2009) under the supervision of the Houston-Galveston Area Council, with data collection being performed by the Environmental Institute of Houston (Table 13). During this time, surface water-quality samples will be collected quarterly at each of the ten sites. Parameters being collected include: dissolved oxygen, pH, temperature, conductivity, salinity, turbidity, total suspended solids, bacteria and flow.

According to the CRP Coordinated Monitoring Schedule, all or most of the monitoring stations listed below were monitored either quarterly or bimonthly from 2003 to 2008[73]. The data collected from the monitoring stations can be downloaded from the TCEQ Website[74].

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[72] Houston-Galveston Area Council. 2006. Basin Summary Report. Media: Interactive CD.
[73] Texas Commission of Environmental Quality Clean Rivers Program Coordinated Monitoring Schedule. 2009. <http://cms.lcra.org/>. Accessed 2009 January 31.
[74] www.tceq.state.tx.us

Table 13: Frequency of Current Clean Rivers Program Surface Water Quality Sampling Fiscal Year 2009 (number of samples scheduled in Fiscal Year 2009)[75].

Station ID	Collection Agency*	Conventional	Bacteria	Flow	Field
Segment: 1103 – Dickinson Bayou Tidal					
11434	EIH	4	4		4
11436	EIH	4	4		4
11455	EIH	4	4		4
11460	EIH	4	4		4
11460	TCEQ	4	4		4
11462	EIH	4	4		4
11464	EIH/TCEQ	4	4		4
16469	EIH	4	4		4
16470	EIH	4	4		4
16471	EIH	4	4		4
Segment 1104 – Dickinson Bayou Above Tidal					
11467	EIH/TCEQ	4	4	4	4

**EIH – Environmental Institute of Houston*
**TCEQ – Texas Commission of Environmental Quality*

Dissolved Oxygen TMDL

As a result of the designation of non-attainment for DO criteria in the tidal portion of Dickinson Bayou in 1996, intensive monitoring was conducted as a part of the TMDL project to provide a baseline for TMDL model calibration. The TCEQ, in partnership with the Galveston County Health District, the Houston-Galveston Area Council and the U.S. Geological Survey conducted a series of monthly water quality monitoring events in 2000 and 2001. The effort consisted of 15 separate 48-hour DO surveys and water quality sampling events in seven locations and at two depths[76].

Intensive sampling conducted as part of the TMDL project confirmed that Dickinson Bayou is not meeting its assigned DO criteria and provided the detailed water quality information necessary to develop the TMDL[4].

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[75] *CRP Monitoring Schedule website.2008. <http://cms.lcra.org/schedule.asp?basin=11&FY=2009>*. Accessed February 2009.
[76] Texas Commission on Environmental Quality. 2008. Two Total Maxium Daily Loads for Dissolved Oxygen in Dickinson Bayou. Proposed for Public Comment.

Bacteria TMDL

The University of Houston–main campus (U of H) and the consulting company CDM were contracted by TCEQ to provide data and information to characterize water quality conditions and to verify or discount impairments of the designated water body uses. U of H and CDM produced two reports to address ongoing concerns about high bacteria levels and fulfill the requirements of the Bacterial TMDLs:

1. TMDL for fecal Bacteria in the Dickinson Bayou Final Historical Data Review and Analysis Report, October 2007.

2. TMDL for Fecal Bacteria in the Dickinson Bayou Sampling and Analysis Plan, February 2008.

Within the Sampling and Analysis Plan additional monitoring sites were established. These sites were strategically identified based on possible areas for increased pollutant loadings. Four components were established for additional research[77]:

1. Reconnaissance and pipe/source survey
2. Tributary monitoring
3. Bayou Wildlife Park monitoring
4. Waste water treatment plant monitoring

The Sampling and Analysis Plan (2008)[78] stated that they would sample at the outfalls of several unnamed tributaries to estimate tributary loadings, as well as locations surrounding the Bayou Wildlife Park and four waste water treatment plants.

The sampling locations were outlined in the TMDL for Fecal Bacteria in Dickinson Bayou Sampling and Analysis Plan. The sampling locations were proposed based on three main categories:

1. Proximity to tributaries to establish loadings from varying land uses
2. Potential loading from the Bayou Wildlife Park
3. The effect of waste water treatment plant effluent on water quality

All stations have been monitored for bacteria, water quality parameters (dissolved oxygen, pH, temperature, conductivity, salinity, and turbidity), instantaneous flow, nutrients (ammonia, total kjeldahl nitrogen, nitrite+nitrate, orthophosphorous, and total phosphorus), and conventional parameters (total suspended solids).

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[77] University of Houston and CDM. 2007. Total Maximum Daily Loads for Fecal Bacteria in the Dickinson Bayou Final Historical Data Review and Analysis Report: Revision 1. pgs 121.

[78] Rifai, Hanadi. 2008. Total Maxium Daily Loads for Fecal Bacteria in the Dickinson Bayou Sampling and Analysis Plan, Texas Commission on Environmental Quality.

Table 14: List of Monitoring Sites for the Bacteria TMDLs (Modified from Rifai, (2008).[79]

Component	Station	Description	# Events	Collection Agencies	Parameters
Tributary	11443	Unnamed Tributary at Rymal Rd.	Up to 2 dry and 2 wet with 3-6 samples per wet event	U of H	Field, Bacteria, Nutrients, Conventional Flow
	TBD3[a]	Unnamed Tributary at Cowan Rd.			
	TBD4[a]	Unnamed Tributary at Avenue L			
	TBD2[a]	Unnamed Tributary at Algoa Friendswood Rd.			
Bayou Wildlife Park	11464/11466[b]	Dickinson Bayou Near Arcadia/ Dickinson Bayou at Happy Hollow	Up to 2 dry and 2 wet (3-6 samples per wet event)	U of H	Field, Bacteria, BOD, Nutrients, Conventional Flow
	11467	Dickinson Bayou at FM517			
WWTP Sampling	4 WWTP[c]	See Table 7	1 event for a total of 4 WWTPs	To be determined	Field, Bacteria, Nutrients, Conventional Flow

[a] *To be Determined. The sampling locations along the tributaries were not described at the time of this report.*
[b] *Either station 11464 OR 11466 was sampled based on site access during storm events.*
[c] *Four WWTP selected from Table 6 and Figure 12 were sampled based on compliance history, ability to access outfall and reconnaissance findings. These site locations and data have not been released prior to the publication of this Plan.*

Proposed Monitoring

The Clean Rivers Program's surface water quality monitoring is scheduled to continue as stated in Table 14. No additional surface water quality monitoring is proposed other than the current CRP monitoring.

[79] Rifai, Hanadi. 2008. Total Maximum Daily Loads for Fecal Bacteria in the Dickinson Bayou Sampling and Analysis Plan, Texas Commission on Environmental Quality.

Targeted Goals

- Continue Clean Rivers Program surface water quality monitoring
- Monitor water quality in all new stormwater treatment wetlands
- Install a new continuous water quality monitoring station with flow monitoring on Dickinson Bayou (to further investigate the problem of flow rates contributing to pollutant loading)

Financial Requirements

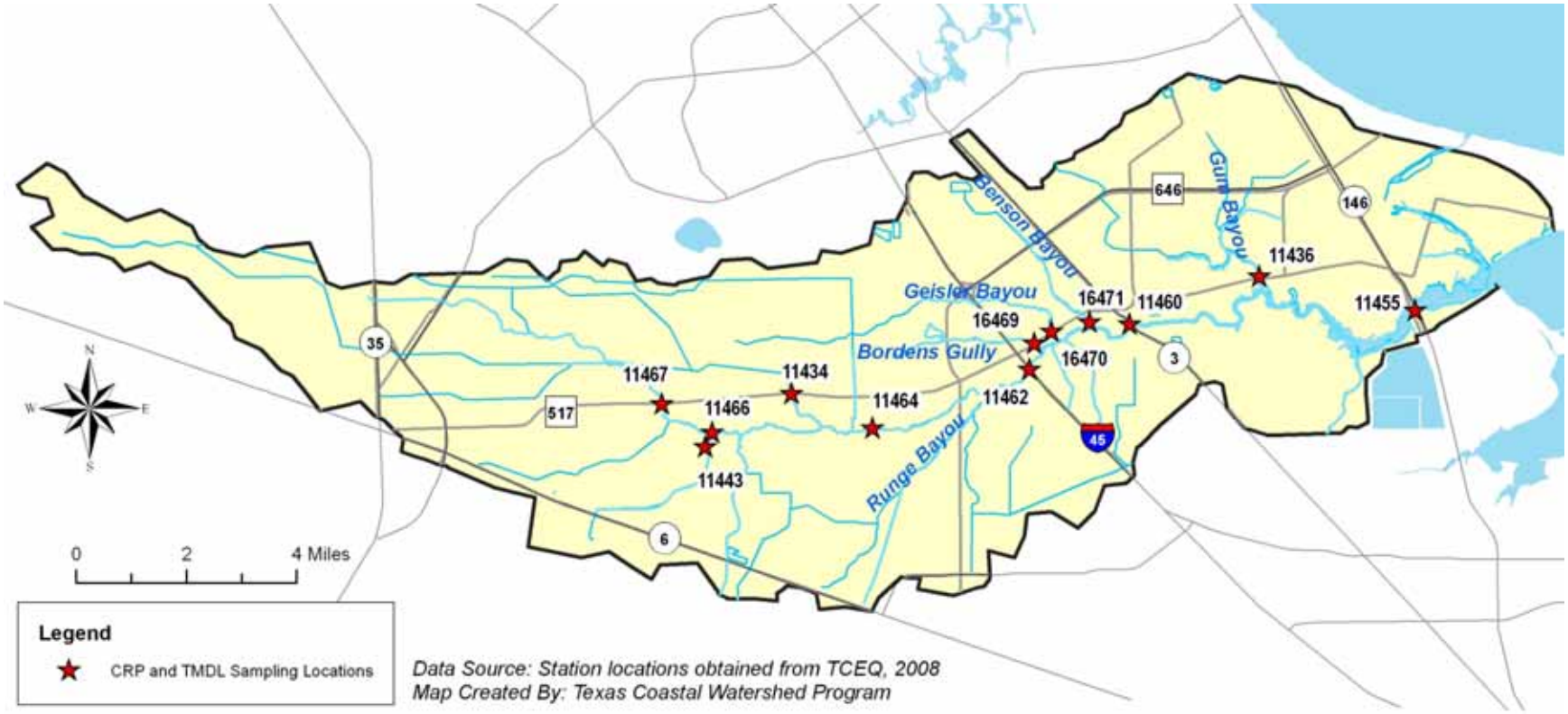
The Clean Rivers Program has already secured state funding of $22,000 to continue monitoring Dickinson Bayou. Stormwater wetland monitoring projects could potentially be integrated into the existing CRP monitoring program for minimal costs, about $1,000 per site, per year. However, it will provide more useful data to install automated monitors on at least some wetlands sites that cost upwards of $10,000 each.

The continuous water quality monitoring station will cost between $10,000 and $20,000 a year including installation and upkeep costs. The United States Geologic Survey and TCEQ have a co-op program that is a realistic option for funding this monitoring station.

Milestones

- Long term water quality data set from CRP: 2014
- Installation of continuous water quality monitoring station with flow monitor: 2014
- All stormwater treatment wetlands monitored though CRP or equipment: 2029

Figure 24. Current Clean Rivers Program and Bacteria TMDL Water Quality Sampling Stations



22. Pollutant Loadings

We developed a series of pollutant loading calculations to roughly quantify the impacts of the strategies selected in this plan on reducing existing and future pollutant loadings in the watershed. These calculations were based on the Simple Method developed by the Center for Watershed Protection. The Simple Method[80] for calculating loadings allows loads to be broken down by land use type. This method also allows the use of local data for pollutant concentrations, making the numbers more specific to the Dickinson Bayou watershed. The Simple Method is similar to the well-known Curve Number method, except that it uses impervious cover percentage values rather than curve numbers based on soil types. As input for the Simple Method calculations outlined here, we used imperviousness values from the Galveston County Consolidated Drainage District Drainage Criteria Manual[81] and EMC values from a detailed non-point source characterization done for the Galveston Bay National Estuary Program in 1992[82]. The 1992 study used the curve number rather than the Simple Method to calculate pollutant loadings for watersheds contributing to Galveston Bay, including that of Dickinson Bayou.

L = Annual Load (lbs/year) = 0.226 * R * C * A (for chemical constituents)

L = Annual Load (lbs/year) = 0.00103 * R * C * A (for bacteria)

0.226 = unit conversion factor (chemical constituents)

0.00103 = unit conversion factor (for bacteria)

R = annual runoff (inches) = P * Pj * Rv

P = Annual rainfall (45 inches)

Pj = Fraction of annual rainfall events that produce runoff (0.9)

Rv = Runoff coefficient (calculated as 0.05 + 0.9*Ia)

Ia = Impervious Cover (69% for medium density development, and 13% for low density development, 0% for open space, Table 15)

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[80] The Stormwater Managers Research Center, http://www.stormwatercenter.net (under “By Category”, then “Simple Method”

[81] Galveston County Consolidated Drainage District Drainage Criteria Manual, 2004.

[82] Values taken from Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.

C = Pollutant concentration/Event Mean Concentration (mg/l)[83]

A = Area (acres)

Current Loadings

Table 15. Impervious Cover for TCWP Land Use Loadings for the Dickinson Bayou Watershed (Taken from Galveston County Consolidated Drainage District Criteria Manual[84])

TCWP Classification	GCCDD Classification	Percent Impervious Value	Averaged Percent Value[85]
Medium Density	High Density	85	69
	Residential Small Lot	40	
	Isolated Transportation	90	
	Light Industrial	60	
Low Density	Residential Large Lot	20	13
	Residential Rural Lot	5	
	Developed Green Acres	15	
Open Space	Undeveloped	0	0

[83] Values taken from Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[84] Galveston County Consolidated Drainage District Drainage Criteria Manual, 2004.
[85] Value used in loading calculations below

Table 16. Current Total Phosphorus Loadings

	Medium Density Development	Low Density Development	Open Space	Entire Watershed
Unit Conversion Factor	0.226	0.226	0.226	---
R (annual runoff, inches)	27.18	6.76	2.03	---
C (pollutant concentration, mg/l)	0.79[a,b]	0.42[a,c]	0.12[a,d]	---
A[e] (area, acres)	19,267	13,467	33,563	66,270
L (annual load, lbs/year)	**93,482**	**8,646**	**1,842**	**103,969**
L (annual load, kg/year)	**34,891**	**3,227**	**687**	**38,805**

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as “Residential” Table 5.11 pg 93
[c] Average of “Residential,” “Agricultural,” and “Open/Pasture” values in Table 5.11 pg 93
[d] Value labeled as “Open/Pasture” in Table 5.11 pg 93
[e] From TCWP land use map (Figure 14)

Table 17. Current Total Nitrogen Loadings

	Medium Density Development	Low Density Development	Open Space	Entire Watershed
Unit Conversion Factor	0.226	0.226	0.226	---
R (annual runoff, inches)	27.18	6.76	2.03	---
C (pollutant concentration, mg/l)	3.41[a,b]	2.16[a,c]	1.51[a,d]	---
A[e] (area, acres)	19,267	13,467	33,563	66,270
L (annual load, lbs/year)	**403,510**	**44,464**	**23,175**	**471,149**
L (annual load, kg/year)	**183,194**	**20,186**	**10,521**	**213,902**

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as "Residential" Table 5.11 pg 93
[c] Average of "Residential," "Agricultural," and "Open/Pasture" values in Table 5.11 pg 93
[d] Value labeled as "Open/Pasture" in Table 5.11 pg 93
[e] From TCWP land use map (Figure 14)

Table 18. Current Bacteria Loadings

	Medium Density Development	Low Density Development	Open Space	Entire Watershed
Unit Conversion Factor	0.00103	0.00103	0.00103	---
R (annual runoff, inches)	27.18	6.76	2.03	---
C (pollutant concentration, mg/l)	22,000[a,b]	9,000[a,c]	2,500[a,d]	---
A[e] (area, acres)	19,267	13,467	33,563	66,270
L (annual load, billion colonies/year)	**1.1×10^7**	**8.4×10^5**	**1.7×10^5**	**1.3×10^7**

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as "Residential" Table 5.11 pg 93
[c] Average of "Residential," "Agricultural," and "Open/Pasture" values in Table 5.11 pg 93
[d] Value labeled as "Open/Pasture" in Table 5.11 pg 93
[e] –TCWP land use map (Figure 14)

1992 Loadings

As a cross check on our Simple Method calculations, we calculated loadings for Dickinson Bayou in 1992 using the 1992 input values. Except for bacteria, our calculated values were within rough agreement with the values developed with curve numbers and published in the 1992 report.

Table 19. Total Phosphorus Loadings using 1992 data

	Medium Density Development	Low Density Development	Agriculture	Entire Watershed
Unit Conversion Factor	0.226	0.226	0.226	---
R (annual runoff, inches)	27.2	16.6	2.0	---
C (pollutant concentration, mg/l)	0.37[a,b]	0.790[a,c]	0.36[a,d]	---
A[a,e] (area, acres)	3,200	5,760	12,800	---
L (annual load, kg/year)	**3,301**	**7,753**	**957**	**12,011**
GBNEP Calculated Load[a,f] (kg/year)	**---**	**---**	**---**	**21,000**

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as high density urban in Table 5.11 pg. 93
[c] Value labeled as residential in Table 5.11 pg. 93
[d] Value labeled as Agricultural Table 5.11 pg.93
[e] Values taken from table E.2 pg 9
[f] Table III.3 page196

Table 20. Total Nitrogen Loadings using 1992 data

	Medium Density Development	Low Density Development	Agriculture	Entire Watershed
Unit Conversion Factor	0.226	0.226	0.226	---
R (annual runoff, inches)	27.2	16.6	2.0	---
C (pollutant concentration, mg/l)	2.1[a,b]	3.41[a,c]	1.56[a,d]	---
A[a,e] (area, acres)	3,200	5,760	12,800	---
L (annual load, kg/year)	**18,737**	**33,464**	**4,149**	**56,350**
GBNEP Calculated Load[a,f] (kg/year)	**---**	**---**	**---**	**130,000**

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as high density urban in Table 5.11 pg. 93
[c] Value labeled as residential in Table 5.11 pg. 93
[d] Value labeled as Agricultural Table 5.11 pg.93
[e] Values taken from table E.2 pg 9
[f] Table III.3 page196

Table 21. Bacteria Loadings using 1992 data

	Medium Density Development	Low Density Development	Agriculture	Entire Watershed
Unit Conversion Factor	0.00103	0.00103	0.00103	---
R (annual runoff, inches)	27.2	16.6	2.0	---
C (pollutant concentration, mg/l)	22,000[a,b]	22,000[a,c]	2,500[a,d]	---
A[a,e] (area, acres)	3,200	5,760	12,800	---
L (annual load, billion colonies/year)	**2.0×10^6**	**2.2×10^6**	**6.7×10^4**	**4.2×10^6**
GBNEP Calculated Load[a,f] (billion colonies/year)	**---**	**---**	**---**	**6×10^6**

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as high density urban in Table 5.11 pg. 93
[c] Value labeled as residential in Table 5.11 pg. 93
[d] Value labeled as Agricultural Table 5.11 pg.93
[e] Values taken from table E.2 pg 9
[f] Table III.3 page196

Projected Load Reductions

Stormwater Best Management Practices

Table 22. Projected load reductions for installation of site specific BMPs; this includes residential and commercial areas. We assume 60% participation and 60% BMP effectiveness.

	Projected Load Reductions for Short Term Goals (5 years)			Projected Load Reductions for Long Term Goals (20 years)		
	Total Phosphorus	**Total Nitrogen**	**Bacteria**	**Total Phosphorus**	**Total Nitrogen**	**Bacteria**
Unit Conversion Factor	0.226	0.226	0.00103	0.226	0.226	0.00103
R (annual runoff, inches)	27.18	27.18	27.18	27.18	27.18	27.18
C[a] (pollutant concentration, mg/l)	0.79	3.41	22,000	0.79	3.41	22,000
A (area, acres)	250	250	250	10,000	10,000	10,000
Percent participation	0.60	0.60	0.60	0.60	0.60	0.60
Percent effectiveness	0.60	0.60	0.60	0.60	0.60	0.60
Annual Load Reduction	**437 lbs**	**1,885 lbs**	**5.5×10^4 billion colonies**	**17,466 lbs**	**75,395 lbs**	**2.2×10^6 billion colonies**
Annual Percent Load Reduction	**0.47%**	**0.47%**	**0.5%**	**18.7 %**	**18.7%**	**18.3%**

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX. Value labeled as “Residential” Table 5.11 pg 93
[b] Center for Watershed Protection. 2007. National Pollutant Removal Performance Database, Version 3.

Stormwater Wetlands

Table 23. Projected load reductions for installation of storm water wetlands. Short term load reductions are calculated for treatment of 250 acres of medium density development. Long term reductions are calculated for treatment of all currently developed lands (both medium and low density).

	Projected Load Reductions for Short Term Goals (5 years)			**Projected Load Reductions for Long Term Goals (20 years)**		
	Total Phosphorus	**Total Nitrogen**	**Bacteria**	**Total Phosphorus**	**Total Nitrogen**	**Bacteria**
Unit Conversion Factor	0.226	0.226	0.00103	---	---	---
R (annual runoff, inches)	27.18	27.18	27.18	---	---	---
C[a] (pollutant concentration, mg/l)	0.79	3.41	22,000	---	---	---
A (area, acres)	250	250	250	32,734	32,734	32,734
Percent effectiveness	0.48	0.24	0.78	0.48	0.24	0.78
Annual Load Reduction	**582 lbs**	**1,257 lbs**	**1.2×10^6 billion colonies**	**49,021 lbs**	**107,514 lbs**	**1.0×10^7 billion colonies**
Annual Percent Load Reduction	**0.62%**	**0.31%**	**1.1%**	**48%**	**24%**	**78%**

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX. Value labeled as “Residential” Table 5.11 pg 93
[b] Value taken from Center for Watershed Protection. 2007. National Pollutant Removal Performance Database, Version 3.

Habitat

Table 24. Projected load reductions from preserving land in a natural state, preventing this land from being developed. Calculations assume land would be developed at Medium Density, the most common density in the watershed. Stopping development would stop loadings from increasing by these amounts each year.

	Projected Load Reductions for Short Term Goals (5 years)						Projected Load Reductions for Long Term Goals (20 years)					
	Total Phosphorus		Total Nitrogen		Bacteria		Total Phosphorus		Total Nitrogen		Bacteria	
	Open Space	Medium Density	Open Space	Medium Density	Open Space	Medium Density	Open Space	Medium Density	Open Space	Medium Density	Open Space	Medium Density
Unit Conversion Factor	0.226	0.226	0.226	0.226	0.00103	0.00103	0.226	0.226	0.226	0.226	0.00103	0.00103
R (annual runoff, inches)	2.03	27.18	2.03	27.18	2.03	27.18	2.03	27.18	2.03	27.18	2.03	27.18
C[a] (pollutant concentration, mg/l)	0.12[a,b]	0.79[a,c]	3.41[a,b]	3.41[a,c]	2,500[a,b]	22,000[a,c]	0.12[a,b]	0.79[a,c]	3.41[a,b]	3.41[a,c]	2,500[a,b]	22,000[a,c]
A (area, acres)	1,000	1,000	1,000	1,000	1,000	1,000	4,200	4,200	4,200	4,200	4,200	4,200
Load	55	4,852	691	20,943	5.2×10^3	6.2×10^5	231	20,381	2,902	87,961	2.2×10^4	2.6×10^6
Annual Load Reduction	4,797 lbs		20,252 lbs		6.2×10^5 billion colonies		20,147 lbs		85,059 lbs		2.6×10^6 billion colonies	
Annual Percent Load Reduction	4.6%		4.3%		4.7%		19.4%		18.1%		19.7%	

[a] Newell, C.J., H.S. Rifai, and P.B. Bedient. 1992. Characterization of non-point sources and loadings to Galveston Bay. The Galveston Bay National Estuary Program. Publication GBNEP-15. Houston, TX.
[b] Value labeled as “Open/Pasture” in Table 5.11 pg 93
[c] Value labeled as “Residential” Table 5.11 pg 93

23. Summary of Plan Strategies and Milestones

Strategy	Responsible Party	Total Cost	Funding Mechanism	Indicator	Milestone Short term (~5 years)	Long term (~20 years)
Strategies for Organization Continuity						
Establish a permanent watershed coordinator	Watershed communities	$70,000-100,000 per year	Pro-rata share for each city in watershed	Years of service	3	20
Set up independent entity for DBWP, 501(c)3	Watershed Coordinator	$20,000 per year in addition to Watershed coordinator	Pro-rata share for each city in watershed	Years in existence	3	20
Strategies for Education and Outreach						
Establish a DBWP logo and a full blown multimedia outreach campaign	Watershed Coordinator and Education/ Outreach Workgroup	$2.5 million over 5 yrs	GBEP funding (for logo), various foundations, grants, and cost shares for media campaign	% of households reached	5%	100%
Develop key themes to serve as key message	TCWP	$0	--	# of meetings held	Key themes	
Recruit influential spokespersons for DBWP	Watershed Coordinator	$0	--	# of people recruited	2	12

Strategy	Responsible Party	Total Cost	Funding Mechanism	Indicator	Milestone Short term (~5 years)	Long term (~20 years)
Develop partnerships with key E/O organizations	Watershed Coordinator	$0	--	# of partnership letters signed	5	15
Strategies for Habitat Conservation						
Preserve 4,200 acres of prime or moderate condition habitat	Watershed communities	$300 million	Cities, counties, grants, conservation easements	# of acres preserved	1,000	4,200
Education/Outreach Workshops on conservation easements and land owner assistance program	Education/ Outreach Workgroup	$50,000	State and federal grants (i.e. Coastal Management Program)	# of workshops held	4	--
Develop a watershed wide mitigation plan	TCWP	$30,000	State and federal grants (i.e. Coastal Management Program)	Status of plan	Completed plan	--

Strategy	Responsible Party	Total Cost	Funding Mechanism	Indicator	Milestone Short term (~5 years)	Long term (~20 years)
Develop a watershed wide habitat conservation plan	Watershed communities	$100,000	State and federal grants (i.e. Coastal Management Program)	Status of plan	Completed plan	--
Strategies for Onsite Waste-Water Facilities						
Detailed water sampling to investigate the extent of the possible OSSF problem	DBWP	$75,000	State and local grants	Completion of report	Completion of report	--
Education /Outreach Workshop (lecture and field exercises) on soil evaluation for OSSF	TCWP	$5,000	State and local grants	# of workshops held	2	--
Education/Outreach Workshop on advanced OSSF retrofits	TCWP	$10,000	State and local grants	# of workshops held	1	--
Strategies for Centralized Waste Water Treatment Facilities						
Conversion of clay sewage pipes to a non-porous pipe	WCID #1		Wastewater fees	% of pipes replaced	--	100% (by 2016)

Strategy	Responsible Party	Total Cost	Funding Mechanism	Indicator	Milestone Short term (~5 years)	Long term (~20 years)
Site Scale Strategies for Stormwater Management						
LID Technical committee	TCWP	$0	--	# of meetings held	20	--
Install 150 stormwater BMPs	DBWP	$1.1 million (for short term goal)	Grants, private funds and cost share programs	# of acres treated	250	10,000
Education/Outreach Install 3 construction site BMP demonstrations including signage	TCWP	$15,000	Section 319 funding, community match	# BMPs installed	3	--
Education/Outreach Install 3 post construction BMP demonstrations including signage	TCWP	$15,000	Section 319 funding, community match	# of BMPs installed	3	--
Education/Outreach Public relations campaign promoting demonstrations including a self guided tour map of the sites	TCWP	$1,500	Section 319 funding, community donations	Web site hits digital tour map	1,000	--

Strategy	Responsible Party	Total Cost	Funding Mechanism	Indicator	Milestone Short term (~5 years)	Long term (~20 years)
Strategies for Stormwater Wetlands						
Install stormwater wetland treatment systems	TCWP and partners	$50,000 per acre	Section 319 funding, community match, state and local and private funding	# acres treated by wetlands	250	32,734 (All currently developed areas)
Education/Outreach Stormwater Wetland retrofit manual/guidebook for homeowners	TCWP	$10,000	Coastal Management Funding	Completion of Manual	Completion of Manual	--
Strategies for Urban Growth						
Ordinance revisions to allow for compact growth in select areas	Cities	$0	--	# of cities with ordinances	all	--
Channel 50% of new growth into compact Liveable Centers	Cities	$0	--	% development denser than 8 dwelling units/acre	--	50%
Education/Outreach workshops on liveable centers	TCWP	$0	--	# of workshops held	3	--
Strategies for Parks and Recreation						
Additional 110 acres of park space in watershed	Watershed Communities	$770,000	Cities, counties, NGOs	Acres of park space added	50	110

Strategy	Responsible Party	Total Cost	Funding Mechanism	Indicator	Milestone Short term (~5 years)	Long term (~20 years)
Education/Outreach Educational signage	DBWP	$10,000	State and local grants	Number of signs	5	--
Education/Outreach Community stewardship and boater ethics classes	TCWP	$0	--	# of workshops held	2	--
Implement organic techniques for park management	Galveston County Parks Department	No additional funds	County and City Parks	Portion of parks transitioned	25%	100%
Monitoring Activities						
Surface Water Quality Monitoring	Clean Rivers Program	$22,000	State funds	Decrease in total Nitrogen Decrease in total Phosphorus Decrease in Bacteria	23,394 lbs/yr 5,816 lbs/yr 1.9×10^6 billion colonies/yr	267,968 lbs/yr 96,634 lbs/yr 1.6×10^7 billion colonies/yr
Continuous water quality monitoring station with flow meter		$10-20,000 per year	USGS Co-op program	Installation of station	2014	--

APPENDICES

24. Appendix A: Entities Active in the Dickinson Bayou

Local

Bayou Preservation Association (BPA) is a citizens' group whose mission is to "protect and restore the richness and diversity of our waterways". BPA facilitates collaborative projects and public awareness about the region's streams and bayous in order to foster watershed management, conservation, and recreation along Houston's defining natural resource. (http://www.bayoupreservation.org/)

Dickinson Bayou Watershed Partnership The (Watershed Partnership) is a collaborative of stakeholders from state agencies, nonprofit organizations, civic groups, academic institutions, local governments, business and industry groups, and utilities. It is developing and implementing a watershed plan for the purposes of protecting, preserving, and restoring the quality of the Dickinson Bayou watershed and its communities. (www.dickinsonbayou.org)

Dickinson Bayou Watershed Steering Committee is a group formed by all the entities dealing with storm water removal in the Dickinson Bayou watershed. This group includes representatives from: Brazoria County, Brazoria County Conservation and Reclamation District #3, Brazoria County Drainage District #4, Galveston County, Galveston County Consolidated Drainage District, Galveston County Drainage District #1, Galveston County Drainage District #2, City of Alvin, City of Dickinson, City of Friendswood, City of League City, City of Manvel, City of Santa Fe, City of Texas City

Galveston Bay Area Master Naturalists. The Texas Master Naturalist program develops local teams of "master volunteers" to provide educational and outreach services aimed at the better management of natural resources and natural areas within their communities. The Texas Master Naturalist program is a partnership between the Texas Cooperative Extension Service, Texas Parks & Wildlife, and other local partners. (http://www.gbamasternaturalist.org/)

Galveston Bay Eco-Paddle Association (GBEPA) is a troop that surveys wildlife and habitat quality in the bay system, increases public awareness of the bay's natural resources, and records and monitors the effects of human impact on the bay's fragile eco-system. (http://www.ecopaddle.org/)

Galveston Bay Foundation (GBF) Restoration and conservation of valuable Galveston Bay habitats are primary activities of the Galveston Bay Foundation. Conservation of Bay resources ranges from smooth cordgrass planting to create marshes to woodland plantings, mitigation planning, and land acquisition. In all these activities, GBF relies on countless volunteer hours. Another priority, protecting wetlands through acquisition and management, will provide a legacy of productivity within the Bay for future generations. (www.galvbay.org)

Harris-Galveston Coastal Subsidence District (HGCSD) was created by the Texas legislature in 1975. It acts as a groundwater district for this region, and has developed and

implemented a plan to regulate groundwater withdrawal and encourage the use of alternate sources, such as surface water. This regulation of ground water pumping has helped to significantly slow subsidence in the Armand Bayou area, one of the major contributing factors of habitat loss and degradation in the watershed. HGSCD provides extensive water conservation educational materials. (http://www.subsidence.org)

Houston Advance Research Center (HARC) is a 501(c)(3) not-for-profit organization based in The Woodlands, Texas dedicated to improving human and ecosystem well-being through the application of sustainability science and principles of sustainable development. (http://www.harc.edu/)

Houston Audubon Society is a nonprofit organization that promotes the conservation and appreciation of birds and wildlife habitat. Houston Audubon acquires and maintains critical habitat as bird sanctuaries. It conducts education programs and field trips for children and adults. It readily offers its expertise to efforts to promote conservation of birds and their habitats. (http://www.houstonaudubon.org/)

Houston-Galveston Area Council is an association of counties, cities, and school districts in the Gulf Coast Planning Region. It is involved with community and environmental planning, land use planning, air and water quality, and quality of life issues throughout the Houston-Galveston area. (http://www.h-gac.com/)

Keep Dickinson Beautiful (KDB) works to create partnerships to make Dickinson a cleaner, more beautiful place to live, work and play, and to preserve our heritage of tall Pines, natural beauty and rich culture. (http://www.ci.dickinson.tx.us/dbweb/intro.html)

Legacy Land Trust (LLT) is the principal land trust operating in the area. LLT will provide assistance in obtaining conservation easements, and can act as holder of an easement. In some cases, LLT may actually accept title to the land. (http://www.legacylandtrust.org/)

Texas Coastal Watershed Program (Texas Sea Grant Program /Texas AgriLife Extension Service) County and marine agents associated with the AgriLife Extension Service program of both Texas Sea Grant (TSG) and Texas AgriLife Extension Service (TAES) are active in the Armand Bayou area and available to assist with a variety of water quality education programs and demonstrations in the watershed. The Texas Coastal Watershed Program (TCWP) is a regional program of TSG and TAES and has an active watershed education program in the area. (http://www.urban-nature.org)

The Trust for Public Land (TPL) works with local communities to develop and implement projects to meet parks and open space needs. TPL also provides assistance through their legal and real estate specialists to help locate and finance public green space. In the Houston-Galveston region, TPL is working specifically to increase public access to Galveston Bay and its tributaries and to save critical habitats in the watershed. (http://www.tpl.org/)

University of Houston-Clear Lake and Environmental Institute of Houston (EIH) at the University of Houston/Clear Lake helps people in the Houston region participate more effectively

in environmental improvement. Information and technology is obtained and disseminated from research supported by EIH in critical areas including pollution prevention, natural resource conservation, public policy, and societal issues. EIH seeks to expand balanced environmental education based on objective scholarship to empower the entire community to make sound decisions on environmental issues. (http://www.eih.uh.edu/)

State Government

Coastal Coordination Council (CCC) is the policy board for the Coastal Management Program (CMP). The Council is made up of representatives from state resource agencies, local governments, small business, citizens, agriculture, as well as gubernatorial appointees. It adopts uniform goals and policies to guide decision-making by all entities regulating or managing natural resource use within the Texas coastal area. The Council reviews significant actions taken or authorized by state agencies and subdivisions that may adversely affect coastal natural resources to determine their consistency with the CMP goals and policies. In addition, the Council oversees the CMP grants program and the Small Business and Individual Permitting Assistance Program. (http://www.glo.state.tx.us/coastal/ccc.html)

Galveston Bay Estuary Program is a program of the TCEQ that coordinates efforts to implement The Galveston Bay Plan, the Comprehensive Conservation and Management Plan for Galveston Bay. The Estuary Program works with local stakeholders to develop projects and programs to protect and restore Galveston Bay habitats, ensure adequate freshwater inflows to maintain a healthy estuarine system, manage fish and wildlife species, control invasive species, protect and improve water quality, particularly through addressing non-point source pollution, compile and analyze resource data to determine ecosystem health, conduct necessary research, and conduct public outreach and education to promote conservation of bay resources. The Galveston Bay Council, a management committee made up of representatives of state and federal agencies, local governments, citizens, commercial and recreational fishing interests, business and industry, and conservation organizations, is charged with guiding Estuary Program activities to ensure the best use of available resources in implementing The Galveston Bay Plan. (http://gbep.state.tx.us)

Texas Coastal Management Program (CMP), administered by GLO, provides a framework for coordinating state, local, and federal programs for the management of Texas coastal resources. The CMP was created in the late 1980s to provide for a more coordinated, comprehensive approach to coastal resource management. (http://www.glo.state.tx.us/coastal/cmp.html)

Texas Commission on Environmental Quality (TCEQ) is responsible for regulating the discharge of contaminants to surface water, groundwater, soil, and air through a wide variety of programs, and conducts public outreach and education in support of these programs. The TCEQ also conducts monitoring and assessment of surface waters to determine compliance with water quality standards. TCEQ conducts Section 401 certification reviews of U.S. Army Corps of Engineers Section 404 permit applications for the discharge of dredged or fill material into waters of the U.S., including wetlands. These certification reviews determine whether a

proposed discharge will comply with state water quality standards. TCEQ also administers the Supplemental Environmental Project Program, an innovative approach to resolving enforcement actions and improving environmental quality. Supplemental Environmental Projects are comprised of a wide variety of activities including wetland protection and restoration. TCEQ hosts the Galveston Bay Estuary Program and also provides extensive outreach materials. (http://www.tceq.state.tx.us/index.html)

Texas General Land Office (GLO) In Texas, nearshore waters below the mean high-tide mark belong to the state. Texas state law delegates regulation of activities conducted in coastal areas on state-owned lands such as the construction of marinas, piers, docks, etc., to the Texas General Land Office (GLO). Although federal regulations also apply in most of these circumstances, GLO review provides an additional level of scrutiny of impacts to state waters and the public. Any lands that accumulate as a result of activities within waters over state-owned lands generally revert to the State. The General Land Office administers several coastal conservation programs, including the Coastal Management Program and the Coastal Erosion Planning and Response Act Program. (http://www.glo.state.tx.us/)

Texas Parks and Wildlife Department (TPWD) provides outdoor recreational opportunities by managing and protecting fish and wildlife and their habitat and acquiring and managing parklands and historic areas. Responsibilities include hunting and fishing, wildlife management areas, law enforcement, state parks and historic areas, conservation and resource protection, and hunter and boater education. In the Galveston Bay watershed, TPWD operates several state parks, historic sites, and wildlife management areas, and has coordinated several large habitat restoration projects. Locally, TPWD leases the Armand Bayou Coastal Preserve from the General Land Office. Also of local interest is TPWD's Recreation Grants Program, which offers matching funds for communities wishing to construct recreational facilities. The Private Lands Initiative and the Wildscapes Program are available to assist landowners in managing their property in an ecologically friendly manner. (http://www.tpwd.state.tx.us/)

Texas State Soil and Water Conservation Board (TSSWCB) administers Texas' soil and water conservation law and coordinates conservation and pollution abatement programs throughout the state. One program is the Water Quality Management Plan (WQMP) program. Also known as the 503 program, the WQMP program is a voluntary mechanism by which site-specific plans are developed and implemented on agricultural and silvicultural lands to prevent or reduce nonpoint source pollution from these operations. Plans include appropriate treatment practices, production practices, management measures, technologies, or combinations thereof. Plans are developed in cooperation with local SWCDs, cover an entire operating unit, and allow financial incentives to augment participation. (http://www.tsswcb.state.tx.us)

Federal Government

U.S. Department of Agriculture is active in natural resource management, particularly through the Natural Resource Conservation Service and the U.S. Forest Service. Both organizations

provide resources for natural resource conservation, public land management for conservation purposes, and educational programs. (http://www.usda.gov)

Environmental Protection Agency (EPA) works to develop and enforce regulations that implement environmental laws enacted by Congress, such as the Clean Water Act and Clean Air Act. EPA is responsible for researching and setting national standards for a variety of environmental programs, and delegates to states and tribes the responsibility for issuing permits and for monitoring and enforcing compliance. Where national standards are not met, EPA can issue sanctions and take other steps to assist the states and tribes in reaching the desired levels of environmental quality. The EPA also sponsors several initiatives and grant programs to provide assistance to organizations involved in watershed management, pollution prevention, education, and sustainable development. (http://www.epa.gov/)

Federal Emergency Management Administration (FEMA) has undertaken a massive effort of flood hazard identification and mapping to produce Flood Hazard Boundary Maps, Flood Insurance Rate Maps, and Flood Boundary and Floodway Maps. The maps identify Special Flood Hazard Areas (SFHAs), which are regulated to minimize potential loss of life and property and the economic benefits to be derived from floodplain development. Development may take place within the SFHA, provided that development complies with local floodplain management ordinances, which must in turn meet the minimum Federal requirements. Flood insurance is required for insurable structures within the SFHA to protect Federal financial investments and assistance used for acquisition and/or construction purposes within communities participating in the National Flood Insurance Program. (http://www.fema.gov/)

National Oceanic and Atmospheric Administration (NOAA) NOAA Fisheries is a division of the National Oceanic and Atmospheric Administration. NOAA Fisheries works to restore and maintain sustainable fisheries, promote the recovery of protected species, and to protect and maintain the health of coastal marine habitats. The agency conducts research to restore and create fish habitat, reviews coastal development and water projects that may alter or destroy habitat, and recommends measures to offset development and use impacts. NOAA works to achieve its goals by its own actions in cooperation with other resource protection agencies, conservation organizations, and local communities, and by sponsoring national programs such as the Coastal Management Program and Community-Based Restoration Program. (http://www.noaa.gov/)

U.S. Army Corps of Engineers (USACE) administers regulatory programs and issues permits under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. In addition to its military role, it leads efforts in planning, designing, building, and operating water resources and other civil works projects, such as navigation, flood control, environmental protection, and disaster response. Locally, the Galveston District of the Corps of Engineers leads the Interagency Coordination Team, which was created to address key environmental issues and concerns associated with the widening and deepening project for the Houston-Galveston Navigation Channel. The Beneficial Uses Group is a subcommittee of the Interagency Coordination Team and identifies environmentally and economically responsible ways to utilize the material dredged from the ship channel expansion project. Efforts include

several recent and ongoing efforts to create new islands and restore historic islands that provide important upland, intertidal, and submerged habitats for water birds and aquatic species. (http://www.usace.army.mil)

U.S. Fish and Wildlife Service (USFWS), part of the Department of the Interior, protects America's diverse fish and wildlife resources. Locally, its Texas Coastal Program focuses on restoring and protecting economically, recreationally and ecologically important coastal fish and wildlife habitats through partnerships. By sharing biological knowledge, offering technical assistance in identifying and designing restoration projects, identifying habitat protection opportunities, and providing federal matching funds to implement projects, USFWS Texas Coastal Program biologists play a vital role in supporting and implementing coastal conservation initiatives that succeed through partnerships. (http://www.fws.gov/)

25. Appendix B: History of Dickinson Bayou and Bay

A Historical Perspective of the Dickinson Bayou Watershed

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The source of the earliest known habitat information for the Dickinson Bayou watershed was the journal of a young surveyor named Mr. Lewis who traveled on the schooner "*Lively*" from New Orleans in November of 1821. The *Lively* was transporting immigrants to Stephen f. Austin's first colony on the Brazos River. Bad weather prevented them from finding the entrance to the Brazos River resulting in their return to the Bolivar-Galveston Island entrance. They proceeded into Galveston Bay to replenish their food and water supplies. A hunting party sailed up the bay and landed on the western shore of the bay at a location that was still in sight of Galveston Island. The masts of the schooner were visible. The descriptions of the area and the distance traveled showed the landing of the yawl on the Dickinson Bay shore of the San Leon peninsula near Eagle Point. The hunting party camped near shore overnight and headed west in the morning. "…we set a west course over a dense prairie covered with nothing but grass, which was generally as tall as a man… the thirst of the party was intense…" Mr. Lewis thought they party traveled approximately five or six miles before they saw a line of timber. Some water was found in a hole in a "buffalo path" and a signal was given for the whole party to regroup before heading for the timber. From the descriptions of the timber of small oaks and the distance traveled it is likely that they were in the small post oak forest area of Salt Lake.

"We went down the patch of low scrubby brush oak wood, and as we advanced the timber increased in size and widened. We then turned to the edge for a camping place where we could have wood and water… I had turned toward the heart of the timber, for it was not more than two or three hundred yards wide. I stopped to see if I could hear the noise of the company, but instead I heard the flutter of turkeys going to roost. [at camp] I told them I found plenty of good water, but better than that I heard a gang of turkeys flying to roost…We were up a little before day. I proceeded to a place that I had marked out where I struck the prairie, and there I went direct to where I had heard the turkeys". Lewis wrote that two turkeys were killed. They continued the hunt. "I had observed a good deal of fresh deer sign in the woods and I went again to the bayou and down it some distance without finding anything; but in attempting to return, I became a little bewildered and had rather lost my reckoning until they fired a gun… They had all started back… The growth of timber around me was in the shape of a crescent, the two points extending in the direction of our boat".

"Now for sixty or a hundred feet next to the edge of the forest it was free from some cause or the other of high grass and afforded easier walking than in the tall thick prairie grass, and I concluded to take the latter as some blind buffalo and deer paths pointed to the upper point of the crescent where I intended to join the rest of the party. I think I had not gone more than two hundred yards on my route, when I heard the report of a gun from them. I of course looked to see the cause, and saw that they were looking at right

angles from my direction. I kept my eyes busy to see the object they appeared to be following with their eyes. Most of them soon started on… when turning my eyes in the direction of my intended route, I discovered from the motion of the high grass that, whatever the object at which they were looking might be, it was making its way toward me. I took it to be a deer or panther or wolf. I soon learned what it was, for I saw at a distance of some eighty or a hundred yards that it was a bear…" The hunting party returned to the "Lively" with a good supply of meat, two turkeys, a black bear, and a "mule-eared" rabbit.

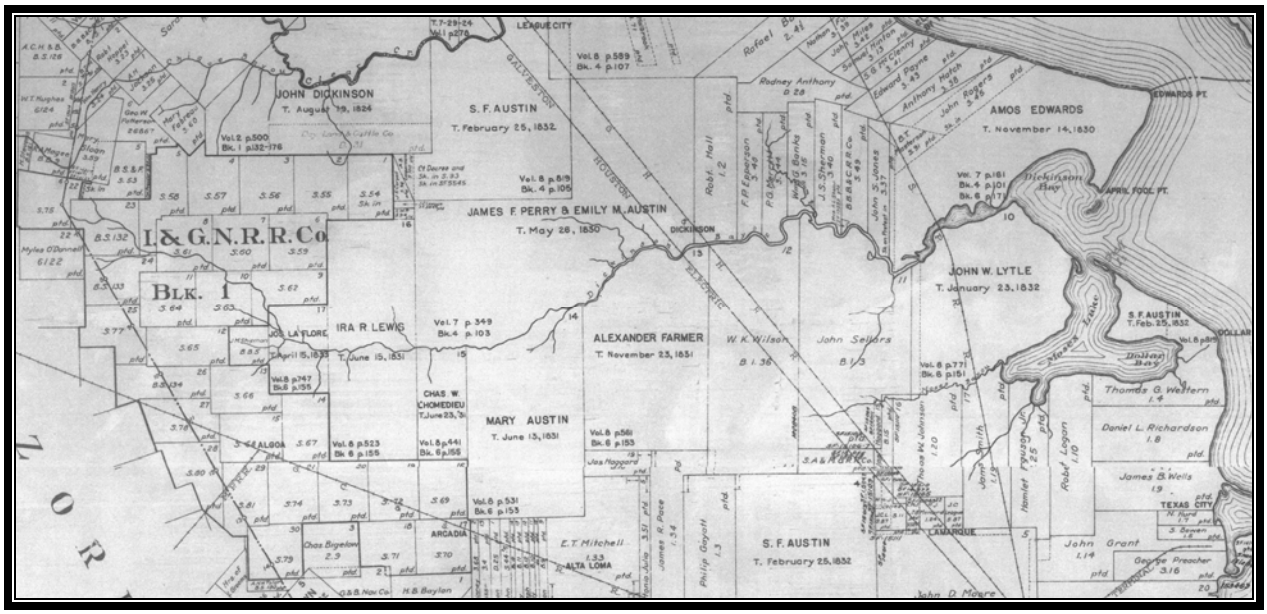
Today there is still a forest of oaks identified as the Sand Post Oak, Quercus stellata var. margaretta (Ashe) Sarg., on the old Houston Light and Power/Reliant Energy property, but Salt Lake which was a storm water run-off lake that fed into Salt bayou is now part of the cooling tower channel that was dredged from Dickinson Bay to Galveston Bay for the Bacliff HL&P Robinson Plant during the mid 1960s. These oaks have been able to regenerate from root sprouts when destroyed by storms and were once found along the Dickinson Bayou riparian corridor into San Leon and across the bay in Smith Point and Chambers and Jefferson counties. Several good examples of native tallgrass coastal prairie still survive in San Leon near the cooling canal.

Photo by Alecya Gallaway 1999

Looking Across the Salt Lake Intake Canal to the Remnant Post Oak Forest

The riparian corridor of Dickinson Bayou was aptly described by the Spanish with the name Arroyo de Cedros (River of Cedars). The watershed was part of the “Littorial Zone” of Texas, comprised of lands touched by the tides and ten leagues inland that were restricted from settlement by the Mexican Government. In 1828, this restriction was repealed and Stephen F. Austin was allowed to bring in colonists. It became Stephen F. Austin’s fourth colony. Dickinson Bayou land was highly prized by Stephen F. Austin as cattle range and herds of wild Spanish cattle had been reported in the area by his surveyors. Austin chose two leagues mid-stream on the north side of the bayou for his sister Emily and her new husband, James Perry (1830), and one league directly across the bayou on the south side for his cousin Mary Austin [Holley] (1831). The other league (4,428 acres) land grants made by Austin were to: Amos Edwards (1830) on the north side of Dickinson Bay at Galveston Bay (now San Leon), J.W. Lytle (1833) on the south side of Dickinson Bay across from Edwards, Alexander Farmer (1831) south side of the bayou on the east border of Mary Austin’s league, J.R. Lewis whose league straddled the bayou west of the Austin and Austin-Perry leagues, and the last grant in 1833 was 640 acres to J. Laftere on land where the bayou headwaters forked west of the Lewis league. After the Texas Revolution some of the vacant land was given to veterans and by the early 1840s portions of the original grants began to be sold.

While the Austin-Perry and Mary Austin leagues were being processed by the Mexican Government, a famous historical Texas entrepreneur, David G. Burnet, was looking at the same land as a site for a large steam-driven sawmill. In a letter to Samuel May Williams, he describes the timber as being “mixed oak and cedar along both banks the length of the bayou with a wide stretch of pine timber located mid-stream”. In order to establish a sawmill on the bayou, Burnet wanted the rights to all of the timber the entire length and on both sides of the bayou. Austin would not consent to granting Burnet the rights so the large saw mill was never established on the bayou possibly saving the pines that are found mid-stream.



Dickinson Bayou Watershed Clip of a 1939 League Map of Galveston County, Texas GLO Historical Map #1835

Historical letters and journals document more information about the habitat and wildlife. In 1838, Mary Austin Holley wrote that the surveyor for Galveston County saw a herd of 30 buffalo, numerous wild mustangs and innumerable deer in the tall grass prairie on her Dickinson Bayou league. In 1841, John G. Tod purchased most of the Mary Austin League and immediately set up a small saw mill on the property. That same year he negotiated with James Perry to trade milled cedar timber, and to purchase some of his pine timber across the bayou. A letter in 1842, from Tod to Perry, tells of a considerable amount of destruction to Perry's pine timber by worms which had defoliated acres of his trees, and about whole sections of his pine timber that had been poached.

In 1852 John Tod increased his land on the bayou by buying 3,728 acres of the league granted to William K. Wilson by the State of Texas in 1849. The Galveston, Houston & Henderson Railroad was chartered in 1853 and by 1856 the tracks were laid through the Tod land and a tresle bridge 343 feet in length was built across Dickinson Bayou. By 1860 the number of cattle ranging the watershed had grown to support a tannery and slaughterhouse. These were the enterprise of John Tod and were located on the bayou east of the railroad. Cattle were slaughtered mainly for their tallow used for candles, horns used for buttons, combs, jewelry and decorative items, hides for leather, hooves for glue and bones for charcoal to refine sugar.

Dickinson Bayou Map #104 "Captain Todd's Packing House" Overlay Courtesy Jan Culberson TPWD Dickinson

Captain Todds Slaughter and Packing House on Dickinson Bayou

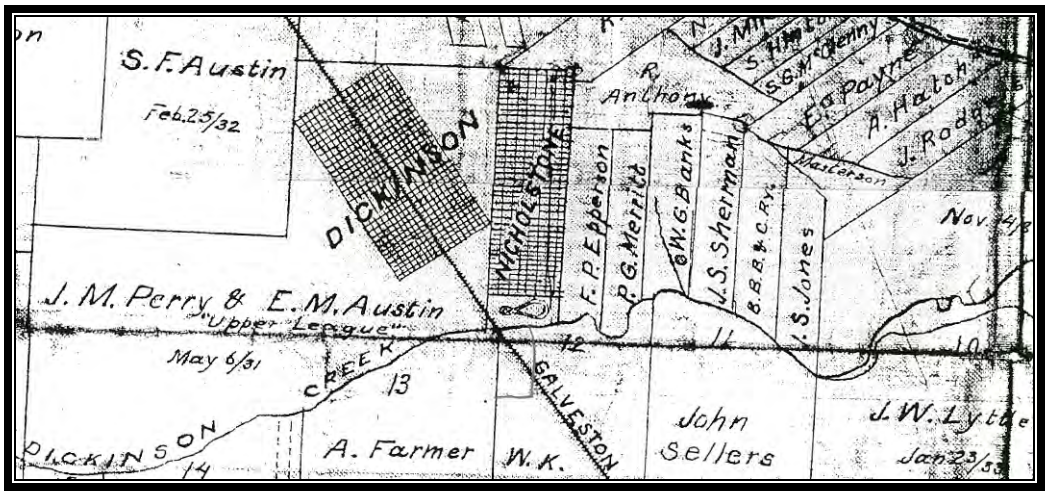
Located at end of Starboard Lane in Dickinson

John G. Tod ran the packing house through the Civil War years and for some years afterwards. In 1862 one of the buildings was used for the first anniversary ball in celebration of the 26th annual anniversary of the Battle of Galveston. The packery also supplied meat and candles for General Magruder's army stationed in the seven forts protecting the railroad and Galveston Island. Cattle brought to Tod's came from all areas of Galveston, Harris and Brazoria counties. Herds were even trailed across the width of Galveston Bay across Red Fish Bar from Chambers and Liberty counties. The Dickinson Bayou watershed was primarily open range cattle country from the 1830's until the Italian farmers settled in the area in 1890 and after 1900, but from the first settlement most of the land owners did sustenance farming and sold or bartered their extra produce.

In 1873, John Hanson Beadle's book, *The Undeveloped West or, Five Years In The Territories*, was published. In the book he gives a brief description of the habitat as seen from his train window during his ride on the GH&H from Houston to Galveston "The road runs nearly straight southeast, apparently over a perfectly level plain, sloping so gently down to the Gulf that the eye can not perceive the decline. For a mile or two from Houston we run through a heavy grove, then out into an open prairie and for ten miles see not a house or rod or fence… and between Houston and Galveston one does not see fifty houses… Herds of Texas cattle are seen in every direction from our train, and grazing appears to be the only use made of this fertile prairie extending for thirty miles from the coast."

E. B. Nichols, a director of the GH&H Railroad purchased land on Dickinson Bayou in the mid-1850s. He built a summer home on a Native American midden that was reputedly the highest ground along the bayou (at the end of California). The midden sites along Dickinson Bayou are accumulations of rangia shells deposited by the Akokisa, a nomadic Atakapan speaking tribe, as they camped along the bayou in related groups and gathered the clams, one of their staple foods, for thousands of years. In 1862, during the Civil War, Nichols became a member of General Magruder's staff and his summer home became Magruder's headquarters on Dickinson Bayou.

In 1890, Fred McKinney Nichols, one of E.B. Nichol's seven sons bought the Nichols' Dickinson estate and began investing in land on Dickinson Bayou. Nichols, along with eight other investors, organized the Dickinson Land and Improvement Association. They promoted "Nicholstone" a platted farming community, on unoccupied lands north east of the town of Dickinson and across the bayou from the Wilson/Tod league, as prime land for fruit farms and homes. His biographical sketch in 1894 stated that for "nearly forty years, sweet and Irish potatoes, ribbon cane of the variety of which the celebrated New Orleans molasses is made, pears, peaches, plums, grapes, and all kinds of berries, and that in profusion and of the finest quality", have grown on his land. Fred Nichols designated forty acres on Dickinson Bayou as a public park called the "Dickinson Picnic Grounds". He also established a harness race track at the park. In 1896 the "Texas Coast Fair" was held at the Dickinson Picnic Grounds.



1890s League Map Courtesy Gallaway Collection

The 1900 Storm hit the coast near Galveston County on September 9th, 1900. Dickinson was one of the areas to suffer extensive destruction. The Houston Post reported: September 10th, "At Dickinson all buildings were damaged. The fairgrounds were completely destroyed. The exposition buildings destroyed and pavilion blown flat onto the ground. The trees at the fairgrounds were splintered and uprooted. The livelihood of the community, its crops and livestock have been totally decimated, the town outlook is "dark and cheerless." Five members of the Clarke family drowned at their home on Dickinson Bayou. The bayou rose twenty feet in twelve hours. It overflowed its banks and spread out over the prairie. All of the trees throughout the town were damaged or destroyed. All of the crops and fruit trees are gone. September 13th, "The total dead is eleven". September 16th, "Dickinson Bayou rose 20 feet and the wind blew the trees and shrubbery out of the ground. The loss of cattle is very heavy". On September the 19th the Galveston Daily News reported: "List of more fatalities at Dickinson, Chris Otterside, wife and two children, Sallie Northcut, A. Zollern, John Mees Sr., Mr. Northcut, and three unidentified bodies. Cattle on the lowlands were lost. The Major Hotel wrecked, Mrs. H. Benson's house unroofed. Mr. H. Benson's house blown off blocks. Dr. Garner's office heavily damaged. Captain Nicolini's cottages blown off their blocks.

From Clara Barton's 1900 Storm Red Cross report we find information on how the Dickinson watershed became noted for its fields of strawberries. Clara Barton had made a great effort to administer to the needs of all the storm victims on Galveston Island and the mainland. She sent her own associates out to survey the widespread destruction and see how the victims could be best helped. From page 20 of the report: "They found some six storm-swept counties… The winds had swept over them and leveled their buildings and destroyed their homes. The sea had rolled over them and washed away not only every growing plant, but also the soil it grew upon. All small animals, such as hogs, sheep, and fowls were destroyed. The heavy cattle, mules and horses that survived had nothing left to eat… By close inquiry, our agents found that if [strawberry] plants could be obtained and set within two weeks, there was a reasonable hope of at least one-third of a crop of strawberries for the coming April and the fields would be left in full bearing for the following year. Without the loss of another day, I directed further inquiry as to the

probable number of plants required, the varieties best suited to their soil and where they had been accustomed to purchase them.

Agents were directed to open negotiations with their accustomed dealers, for one million plants, to be delivered as rapidly as they could be set…letters of appreciative thanks and blessings commenced to pour in from all quarters, stating that new life had been infused among the inhabitants… new plants were in bloom in middle December, thus giving a crop market in February.

The Red Cross had 1,428,000 Strawberry Pants sent to: Genoa, Webster, Dickinson, League City, Hitchcock, Alta Loma, Arcadia, Alvin, Manvel, Arcola, and Pearland. According to the GH&H Agent's Log for 1908, strawberry season opened March 15th and went to May 31st and 30,062 crates of strawberries were shipped. In 1909, 47,984 crates of strawberries, 15,000 bushels of beans, 1,000 bushels of okra, 500 boxes of tomatoes, 1,000 bushels of sweet peppers, 1,500 boxes of mixed vegetables and 100 boxes of oranges were shipped from the Dickinson Station. The watershed was now agricultural with both open cattle range and farms.

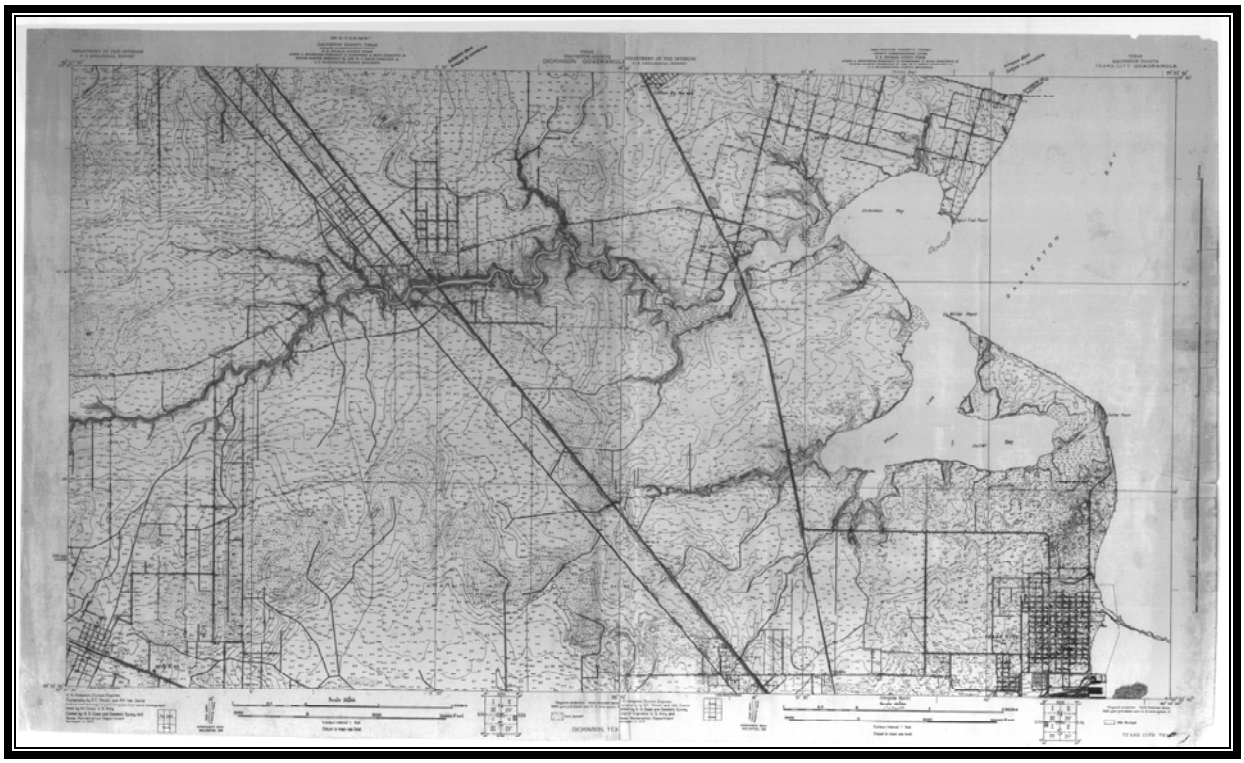
The watershed now had three rail lines crossing through it. The Galveston, Houston and Henderson was built mid-stream between 1854 and 1860. The Galveston to Richmond section of the Gulf, Colorado & Santa Fe at the head of the watershed was started in 1875 and reached Richmond in 1879. The North Galveston, Houston & Kansas City ran between Galveston into North Galveston (San Leon) and then into Houston along the western shore of the Bay. It crossed Dickinson Bayou where it meets Dickinson Bay, and was built between 1893 and 1895.

In 1911, the fourth rails crossed the watershed. The Galveston-Houston Interurban Electric Train was finished. The tracks crossed Dickinson Bayou west of the GH&H tracks. The Oleander Clubhouse was built by a group of prominent Galvestonians in 1912. According to Jim Hudson's book, *Dickinson, Taller Than The Pines,* the club house was located "on the north or Bayou side of the 90 degree curve just before Oleander veers abruptly westward, while Palm Drive proceeds to the South. The lands lying generally to the South and West of the club site were at that time the club's golf course". Unfortunately the club burned to the ground in 1918. The interurban ran until 1936 when it lost its funding and closed.

Oleander Club House and Golf Links, Photos courtesy of Clint Wolston

The Dickinson Bayou waterway itself remained virtually untouched until the late 1930s when dredging, land development, oil exploration, groundwater removal, sewage and subsidence gradually took its toll.

In 1938, the Rivers and Harbors act adopted the Dickinson Bayou navigational channel Project. It provided for a channel 6-feet deep at Mean Low Tide and 60-feet wide along the present route from the natural 6-foot depth in Galveston Bay through Dickinson Bay and Dickinson Bayou to the GH&H Railroad bridge at Dickinson, a length of channel about 11.4 miles. The project was finished in 1940. Before this project the bayou had lush marsh with a small channel through the middle with what the locals called “lakes” where the water was deep enough to swim. This is illustrated by the 1929 topographical map below.



COE, USGS 1929 Topographical Map, GLO #9087

1940s Map of Dickinson Bay, Gallaway Collection

The tallgrass prairies of the watershed were prime Attwater's Prairie-Chicken habitat. In 1978, J. D. Woodham of Dickinson gave an oral history of his involvement with these birds during the 1960s to a College of the Mainland student for the humanities publication "Firewheel." Mr. Woodham told how he lured the birds to food and observed their activities. His observations were published in a World Wildlife Association book. Sam Saunders was interviewed in 1991. He grew up in San Leon, and was 13 years old when the 1915 Storm hit Galveston Bay. He said that according to his dad, Tom Saunders, the 1900 Storm washed the prairie-chickens out of the San Leon prairies into the Dickinson prairies. Sam and his brother Tom said that the 1915 Storm washed over Texas City and into San Leon and a new population of Prairie-chickens came with the debris from Texas City. During an interview in 1996 with Frank Dick, of Dickinson, and Coy Robinson, of the Hillman area of Texas City, prairie chickens were remembered roosting on the roof of a house on Hwy 517 between Gum Bayou and Hwy 1266.

The historical accounts of the habitat of Dickinson Bayou watershed give a good perspective of the habitat that has been lost over time. It also illustrates the uniqueness of the watershed, and illustrates the value of any habitat that can be saved.

26. Appendix C: Fish Kill Data

Documented fish kills from Texas Parks and Wildlife Department and Texas Commission on Environmental Quality files.

Date	Estimated Total Killed	Location	Major Species	Cause
9/14/1970	219,648	Dickinson Bayou	gulf menhaden	Low Dissolved Oxygen
6/13/1971	200	Magnolia Bayou	mullet, shad	Low Dissolved Oxygen
7/7/1971	3,000,000	Dickinson Bayou from FM 646 to 1.5 miles below IH 45	gulf menhaden	Low Dissolved Oxygen
8/16/1971	4,000,000	Dickinson Bayou near Hwy 3	gulf menhaden	Low Dissolved Oxygen
8/23/1971	240,000	Magnolia Bayou near FM 517	gulf menhaden	Low Dissolved Oxygen
9/3/1971	1000000	Dickinson Bayou near IH 45	gulf menhaden	Low Dissolved Oxygen
7/14/1972	4,000	Dickinson Bayou, 2 miles West of IH 45	multiple species	Unknown
7/31/1972	2,000,253	Dickinson Bayou btwn Magnolia and FM 646	gulf menhaden	Low Dissolved Oxygen
4/23/1974	12	Dickinson Bayou, 5 miles NE of Alvin	Catfish	Brine Discharge
4/21/1976	12	Dickinson Bayou at FM 646	bullhead catfish	Low Dissolved Oxygen

7/29/1978	2,058	Dickinson Bayou and Captain's Drive (btwn SH 3 and SH 146)	gulf menhaden	Low Dissolved Oxygen
8/29/1978	8,000,038	Dickinson Bayou between IH-45 and Gum Bayou	gulf menhaden	Low Dissolved Oxygen
9/7/1980	3,000,008	Dickinson Bayou - between SH 3 and 1/4 mile West of the IH 45 bridge	gulf menhaden	Low Dissolved Oxygen
8/30/1981	51,000	Dickinson Bayou - 1 mile East of IH-45 bridge upstream 2 miles West of IH-45 bridge.	gulf menhaden	Low Dissolved Oxygen
8/8/1982	20,058	Dickinson Bayou near IH 45	gulf menhaden	Low Dissolved Oxygen
9/1/1982	100,000	Dickinson Bayou from IH 45 upstream about 3 miles	gulf menhaden	Low Dissolved Oxygen
10/8/1982	3,000	Dickinson Bayou between IH 45 and FM 646	gulf menhaden	Low Dissolved Oxygen
10/30/1982	1,000	Dickinson Bayou near SH 3	gulf menhaden	Low Dissolved Oxygen
8/26/1983	2,650	Dickinson Bayou between SH 3 and IH 45	gulf menhaden	Low Dissolved Oxygen
7/19/1984	88,660	Dickinson Bayou between SH 3 and FM 646	gulf menhaden	Low Dissolved Oxygen
9/4/1984	730,000	Dickinson County Club Bayou Bend canal that drains into		Low Dissolved Oxygen

		Dickinson Bayou.		
8/11/1988	1,000,037	Dickinson Bayou - Above and below SH 3 crossing	gulf menhaden	Low Dissolved Oxygen
9/13/1993	10,000	Dickinson Bayou from SH 3 to IH 45	gulf menhaden	Low Dissolved Oxygen
6/20/1996	500,000	Dickinson Bayou, between SH 3 and IH 45	gulf menhaden	Low Dissolved Oxygen
7/30/1997	500	Dickinson Bayou - One mile west of I-45 and 517	gulf menhaden	Low Dissolved Oxygen
9/10/1997	100,050	Dickinson Bayou and IH 45	gulf menhaden	Low Dissolved Oxygen
11/17/1999	Unknown	Dickinson Bayou north of IH 45 to Cemetery Road		Low Dissolved Oxygen
3/27/2003	500	Trib to Dickinson Bayou off FM 517	gulf menhaden	sewage
6/4/2003	10,000	Dickinson Bayou between SH 3 and IH 45	gulf menhaden	Low Dissolved Oxygen

27. Appendix D: Common Trees found in the Dickinson Bayou Watershed

Common Name	Scientific Name
Ash, Green	*Fraxinus pennsylvanica*
Basswood	*Tilia caroliniana*
Beauty-Berry, American	*Callicarpa americana*
Birch, River	*Betula nigra*
Buckthorn, Carolina	*Rhamnus caroliniana*
Cedar, (Eastern) Red	*Juniperus virginiana*
Centaury, Branched	*Centaurium pulchellum*
Cypress, Bald	*Taxodium distichum*
Elm, American	*Ulmus americana*
Elm, Cedar	*Ulmus crassifolia*
Elm, Winged	*Ulmus alata*
Greenbriar, Saw	*Smilax bona-nox*
Hackberry, Sugar	*Celtis levigata*
Hawthorn, Parsley	*Crataegus marshallii*
Hercules Club / Tickle Tongue	*Zanthoxylum clava-herculis*
Hickory, Bitternut	*Carya cordiformis*
Hickory, Pignut	*Carya glabra*
High Tide Bush / Iva	*Iva frutescens*
Holly, Deciduous / Possum-Haw	*Ilex decidua*
Huisache	*Acacia farnesiana*
Ligustrum, Wax-Leaf	*Ligustrum licidum*

Locust, Honey	*Gleditsia triacanthos*
Mulberry, Red	*Morus rubra*
Mulberry, White	*Morus alba*
Oak, Cherrybark	*Quercus falcata*
Oak, Live	*Quercus virginiana*
Oak, Post	*Quercus stellata*
Oak, Water	*Quercus nigra*
Oak, Willow	*Quercus phellos*
Onion, Wild	*Allium canadense*
Orange, Trifoliate	*Citrus trifoliata*
Osage Orange	*Maclura pomifera*
Palmetto, Dwarf	*Sabal minor*
Pear, Callery	*Pyrus calleryana*
Pecan	*Carya illinoensis*
Pine, Loblolly	*Pinus taeda*
Pine, Slash	*Pinus elliottii*
Privet, Chinese	*Ligustrum sinense*
Privet, Japanese	*Ligustrum japonica*
Privet, Upland	*Forestiera ligustrina*
Privet, Upland	*Mimosa strigillosa*
Rattlebox, Drummond	*Sesbania drummondii*
Rattlesnake Master	*Eryngium yuccifolium*
Rose-Mallow, Halberd-Leaved	*Hibiscus militaris*
Wood Sage	*Teucrium canadense*
Shrubby Seedbox	*Ludwigia octovalvis*

Sweetgum	*Liquidambar styraciflua*
Sycamore, American	*Platanus occidentalis*
Chinese Tallow	*Triadica sebifera*
Wax Myrtle	*Myrica cerifera*
Willow, Black	*Salix nigra*
Willow, Lance-Leaved Water	*Justicia ovata*
Yaupon	*Ilex vomitoria*

28. Appendix E: Common Fish Found in Dickinson Bayou/Dickinson Bay

Common Name	Scientific Name
Lined Sole	*Achirus lineatus*
Bowfin	*Amia calva*
Sea Catfish	*Arius felis*
Gafftopsail Catfish	*Bagre marinus*
Inland Silversides	*Menidia beryllina*
Tidewater Silversides	*Menidia peninsulae*
Bay Whiff	*Citharichthys spilopterus*
Southern Flounder	*Paralichthys lethostigma*
Blue Runner	*Caranx crysos*
Leatherjack	*Oligoplites saurus*
River Carpsucker	*Carpiodes carpio*
Creek Chubsucker	*Erimyzon oblongus*
Smallmouth Buffalo	*Ictiobus bubalus*
Blacktail Redhorse	*Moxostoma poecilurum*
Green Sunfish	*Lepomis cyanellus*
Warmouth	*Lepomis gulosus*
Orangespotted Sunfish	*Lepomis humilis*
Bluegill / Bluegill Sunfish	*Lepomis macrochirus*
Dollar Sunfish	*Lepomis marginatus*
Longear Sunfish	*Lepomis megalotis*
Redear Sunfish	*Lepomis microlophus*
Largemouth Bass	*Micropterus salmoides*

Yellow Bass	*Morone mississippiensis*
White Crappie	*Pomoxis annularis*
Black Crappie	*Pomoxis nigromaculatus*
Gulf Menhaden	*Brevoortia patronus*
Gizzard Shad	*Dorosoma cepedianum*
Threadfin Shad	*Dorosoma petenense*
Blackcheek Tonguefish	*Symphurus plagiusa*
Grass Carp	*Ctenopharyngodon idella*
Common Carp	*Cyprinus carpio*
Golden Shiner	*Notemigonus crysoleucas*
Sheepshead Minnow	*Cyprinodon variegatus*
Gulf Killifish	*Fundulus grandis*
Bayou Killifish	*Fundulus pulverous*
Rainwater Killifish	*Lucania parva*
Ladyfish	*Elops saurus*
Bay Anchovy	*Anchoa mitchilli*
Diamond Killifish	*Adinia xenica*
Violet Goby	*Gobioides broussonetti*
Naked Goby	*Gobiosoma bosc*
Clown Goby	*Microgobius gulosus*
Blue Catfish	*Ictalurus furcatus*
Black Bullhead	*Ictalurus melas*
Yellow Bullhead	*Ictalurus natalia*
Channel Catfish	*Ictalurus punctatus*
Flathead Catfish	*Pylodictis olivaris*

Spotted Gar	*Lepisosteus oculatus*
Longnose Gar	*Lepisosteus osseus*
Shortnosed Gar	*Lepisosteus platostomus*
Alligator Gar	*Lepisosteus spatula*
Striped Mullet	*Mugil cephalus*
White Mullet	*Mugil curema*
Mosquitofish	*Gambusia affinis*
Sailfin Molly	*Poecilia latipinna*
Freshwater Drum	*Aplodinotus grunniens*
Sand Seatrout	*Cynoscion arenarius*
Spotted Seatrout (Speckled Seatrout)	*Cynoscion nebulosus*
Spot	*Leiostomus xanthurus*
Atlantic Croaker	*Micropogonias undulatus*
Black Drum,	*Pogonias cromis*
Red Drum	*Sciaenops ocellatus*
Hogchoker	*Trinectes maculatus*
Sheepshead	*Archosargus probactocephalus*
Pinfish	*Lagodon rhomboides*
Gulf Pipefish	*Syngnathus scovelli*
Southern Puffer	*Sphoeroides nephelus*
Bighead Searobin	*Prionotus tribulus*

29. Appendix F: Common Reptiles and Amphibians of Dickinson Bayou/Dickinson Bay

Reptiles - Snakes	Scientific Name	Comments
Eastern Yellow-bellied Racer	*Coluber constrictor*	
Great Plains Rat Snake	*Elaphe guttata emoryi*	
Texas Rat Snake	*Elaphe obsoleta*	
Western Mud Snake	*Farancia abacura reinwardtii*	
Eastern Hognose Snake	*Heterdon platyrhinos*	
Prairie Kingsnake	*Lampropeltis calligaster*	
Speckled Kingsnake	*Lampropeltis getulus*	
Eastern Coachwhip	*Masticophis flagellum*	
Yellowbelly Water Snake	*Nerodia erythrogaster favigaster*	
Gulf Saltmarsh Snake	*Nerodia clarkii*	Threatened
Blotched Water Snake	*Nerodia erythrogaster transversa*	
Broad-banded Water Snake	*Nerodia fasciata confluens*	
Diamondback Water Snake	*Nerodia rhombifer rhombifer*	
Rough Green Snake	*Ophyodrys aestivus*	
Graham's Crayfish Snake	*Regina grahamii*	
Marsh Brown Snake	*Storeria dekayi limnetes*	
Texas Brown Snake	*Storeria dekayi texana*	
Flathead Snake	*Tantilla gracilis*	
Western Ribbon Snake	*Thamnophis proximus proximus*	
Rough Earth Snake	*Virginia striatula*	

Texas Coral Snake	*Micrurus fulvius*	
Southern Copperhead	*Agkistrodon contortix*	
Western Cottonmouth	*Agkistrodon piscivorus*	
Western Pygmy Rattlesnake	*Sistrurus miliarus*	
Reptiles - Alligator	**Scientific Name**	**Comments**
American Alligator	*Alligator mississippiensis*	
Reptiles - Turtles	**Scientifc Name**	**Comments**
Red-eared Slider	*Chysemys scripta elegans*	
Western Chicken Turtle	*Deirochelys reticularia miaria*	
Texas Cooter	*Pseudemys texana*	
Three-toed Box Turtle	*Terrapene carolina triunguis*	
Ornate Box Turtle	*Terrapene ornata ornata*	
Mississippi Mud Turtle	*Kinosternon subrubrum hippocrepis*	
Common Musk Turtle	*Sternotherus odoratus*	
Common Snapping Turtle	*Cholera serpentina serpentina*	
Alligator Snapping Turtle	*Macroclemys temminckii*	State Threatened
Pallid Spiny Softshell	*Trionyx spiniferus pallidus*	
Texas Diamondback Terrapin	*Malaclemys terrapin littorlis*	State Threatened
Reptiles – Lizards, Anoles and Skinks	**Scientific Name**	**Comments**
Green Anole	*Anolis carolinensis*	
Western Slender Glass Lizard	*Ophisaurus attenuatus attenuatus*	
Texas Horned Lizard	*Phrynosoma cornutum*	State Threatened
Five-lined Skink	*Eumeces fasciatus*	

Broadhead Skink	*Eumeces laticeps*	
Ground Skink	*Scincella lateras*	
Mediterranean Gekko	*Hemidactylus turcicus*	
Amphibians – Frogs and Toads	**Scientific Name**	**Comments**
Cricket Frog	*Acris crepitans*	
Blanchard's Cricket Frog	*Acris crepitans creptians*	
Cope's Gray Treefrog	*Hyla chrysoscelis*	
Green Treefrog	*Hyla cinerea*	
Squirrel Treefrog	*Hyla squirella*	
Gray Treefrog	*Hyla versicolor*	
Northern Spring Peeper	*Pseudacris crucifer crucifer*	
Upland Chorus Frog	*Pseudacris triseriata feriarum*	
Sheep Frog	*Hypopachus variolosus*	
Bullfrog	*Rana catesbeiana*	
Leopard Frog	*Rana sphenocephala*	
Eastern Narrow-mouth Toad	*Gastrophryne carolinensis*	
Gulf Coast Toad	*Bufo valliceps vaiilcpes*	
Amphibians – Salamanders and Aquatic Salamanders	**Scientific Name**	**Comments**
Smallmouth Salamander	*Ambystoma texanum*	
Three-toed Amphiuma	*Amphiuma tridactylum*	
Western Lesser Siren	*Siren intermedia nettingi*	
Gulf Coast Waterdog	*Necturus beyeri*	

30. Appendix G: Parks in the Dickinson Bayou Watershed

GALVESTON COUNTY PARKS

Nine recreational Galveston County Parks including three boat ramps are located within the Dickinson Bayou watershed. Galveston County Parks may be contacted via:

Galveston County Park Administration

(409) 934-8100

(409) 934-8140 (fax)

info.parks.seniors@co.galveston.tx.us .

To review more park information, visit the:

http://www.galvestonparks-seniors.org/locations/ls_overview.asp

Paul Hopkins County Park, in the center of Dickinson provides public access to Dickinson Bayou and one of its tributaries, Benson's Bayou. Recent efforts by local citizens and the county park department have brought major improvements to the park for walking trails, birding, and canoeing and kayaking access to the bayou. This park hosts the Texas State Canoe Championship Series annually. Each year the City of Dickinson, Dickinson Beautiful and Galveston County host the "festival of lights" in the Park between the Thanksgiving and New Year's holidays. This event features an arrary of lights throughout the park and provides entertainment while strolling through the park to view the lights and special activities for small children. The property around this park was historically restricted for exclusive residential use, creating a park like atmosphere well beyond the actual boundaries of the park. This surrounding area retains many pines, post oaks and other native tree species providing crucial habitat for birds, possum, squirrel and raccoons.

Elva Lobit County Park, in the northeast portion of the watershed, offers baseball and soccer fields along with basketball and picnic facilities. The baseball field is used by private citizen groups and by a Dickinson youth baseball organization. Families gather for sports events as well as outdoor cookouts. Two wetland creation sites in the park provide additional stormwater detention and habitat for waterfowl and wildlife.

Ray Holbrook County Park on Gum Bayou offers softball fields, picnic areas, walking and jogging space, and preserves crucial green space for local residents. The park remains open only during daylight hours and is primarily used by the Dickinson Girls' Softball League. There is also a potential canoe and kayak launching site within this Park as it also provides parking space for vehicles and trailers. Shallow draft vessels may access Dickinson Bayou from this launching site during high tides. This park is located between Dickinson High School and recently completed Barber Middle School.

Two Galveston County boat ramps are located at State Highway 3 and at State Highway 146. These boat ramps provide access for recreational boating and sport fishing, as well as picnic areas for families fishing along the banks and piers of Dickinson Bayou. Construction of a second bridge at State Highway 146 will eventually provide more parking spaces for trailers and a paved surface over the existing parking lot and ramp.

DICKINSON CITY PARKS

The city of Dickinson maintains two public parks and several undeveloped pocket parks. **Village Green Gazebo Park** is located across from the Hwy 3 Boat Ramp and is adjacent to City Hall. The Dickinson Historic Society maintains the **Dickinson Historic Train Depot** on FM 517 W. The City also owns many undeveloped street "right of ways" or access points to Dickinson Bayou and its tributaries that are currently not readily accessible to the public but are suitable for developing pocket parks on the bayou. Some of these access points are limited due to minimal parking spaces available in a private residential community, or have set up informal agreements to maintain these "green spaces" for neighborhood use only. However, some of the City's potential pocket parks provide access points to the Bayou that are of sufficient size to develop canoe or kayak launching facilities, nature trails, picnic tables, and bird watching areas, with five to eight parking spaces. The city also owns several residential neighborhood properties that are suitable for developing future green spaces or pocket parks not directly located on Dickinson Bayou

In addition to potential City pocket parks at undeveloped access points along Dickinson Bayou, several community churches have recreational areas they are willing to share with the local community. The Pine Drive Community Church has expressed interest in partnering with other community groups to develop a park open to the public on a large portion of their land with Bayou frontage off Hughes Road.

For additional Information on City of Dickinson Parks contact:

City of Dickinson

2716 FM 517 East

Dickinson Texas 77539

281-337-2489

http://www.ci.dickinson.tx.us/

SANTA FE CITY PARKS

There are two parks located in City of Santa Fe which are located within the Dickinson Bayou watershed.

Runge Park is located in Santa Fe along the southern boundary of the watershed. Approximately 11 acres of parkland were given to the county in 1942. The park amenities were given to the county in 1942; these include Little League and Pony Colt baseball fields, riding arenas, a community center, and an open air pavilion.

Mae S. Bruce Park, located downtown on Hwy 6, provides an informal atmosphere where the community can enjoy the park's simple and intimate surroundings for the purpose of public and private small group gatherings

For additional information on Santa Fe city parks contact:

City of Santa Fe Parks Department

(located in City Hall)

12002 Hwy. 6

P.O. Box 950

Santa Fe, TX 77510-0950.

409-925-6412

http://www.ci.santa-fe.tx.us/

LEAGUE CITY PARKS

League City manages two large parks within the Dickinson Watershed. Each park features multiple soccer, baseball, and softball fields, basketball courts, skateboarding, and other activities. **Big League Dream Sports** Park, which is located on the west side of I-45 off of Calder Road at 1150 Big League Dreams Parkway, League City, TX 77573. This park also features a lighted skate board area and multiple ball fields within the sports complex. A complete list of recreational opportunities for this park is available at **http://www.bigleaguedreams.com, via email info@bigleaguedreams.com or telephone at (281) 316-3400.**

League City also manages the large Sports Park on Link Road which also provides lighted recreational sports fields, restrooms and picnic areas.

BRAZORIA COUNTY PARKS AND BOAT RAMPS

One Brazoria County Park is located in the Dickinson Bayou watershed. **Resoft County Park** located just north of Alvin off of CR 281 and Hwy 35 is an 80 acre day use only park. This park offers both large and small covered pavilions, with picnic tables and outdoor grills that are available for a small rental fee. The park has a freshwater lake for recreational fishing or just

playing by the water. It also features one of the county's largest custom designed playgrounds along with softball and soccer fields, horseshoe pits, basketball and volleyball courts.

Additional information on Brazoria County Parks may be obtained at:

Brazoria County Parks Department Administration

313 W. Mulberry

Angleton, TX 77515

(979) 864-1541

http://www.brazoriacountyparks.com/day_use/index.asp

ALVIN CITY PARKS

There are three Alvin City Parks located within the watershed.

Newman Park provides baseball and softball fields, and basketball courts in addition to a playground and covered pavilion for picnics. The **Ruben Adame Park** provides baseball, softball, basketball and a covered pavilion for picnics. The **Alvin Railroad Depot** provides a unique facility with a historic railroad depot building. It provides air-conditioned and heated restrooms throughout the year. It also is the beginning of the **Tom Blakeney Jr. Hike and Bike Trail,** a paved trail that is located in the downtown area of Alvin.

For additional information on Alvin City Parks contact:

City of Alvin Parks and Recreation Department

800 Dyche Lane

Alvin, Texas 77511

281-388-4299

281-388-4350 (fax)

http://www.alvin.tx.citygovt.org/deptdtl.asp?Dept=130

PRIVATE PARKS AND RECREATIONAL FACILITIES

There are several privately owned but open to the public recreational parks, swimming pools, golf courses, and camping facilities in the Dickinson watershed.

Dickinson Gator Swim Club is located on Spruce Drive in Dickinson near I-45 Highway between Deats Road and FM 517. This privately owned swim club features a heated lap lane

pool that is open to private members. Additional information including membership fee is available at: **www.dickinsongatorswim.org.**

The Dickinson Bayou watershed is home to three private golf courses. **Chaparral Recreation Association Inc.** is located along the south side of Dickinson Bayou on Avenue J, and features an unlighted 9-hole course with a swimming pool for members. **Green Caye Golf Course** is located near Gum Bayou and Dickinson High School on Caroline Avenue in Dickinson, and features a lighted 9-hole course with a driving range and putting green for both day and night use by the public. **Beacon Lakes Golf Course** is located on FM 646 and features a lighted 8-hole course open to the public.

Zempter Park is located on the south side of Dickinson Bayou adjacent to Highway 3. Although it is privately owned by Little League of Dickinson, it offers recreational access to Dickinson Bayou for bank fishing as well as multiple baseball fields for youth sports in the evenings and weekend.

Bayou Campground is located in the City of Dickinson with access to Dickinson bayou. This campground has rental facilities for canoes and pedal boats, as well as 100 primitive camping sites, and 15 electrical hook-up camping sites. It also features 40 RV camp sites with full hook ups. This campground is conveniently located on Hwy 3 just south of the Dickinson Bayou State Hwy 3 Boat Ramp.

Via Bayou RV Park is located in Texas City with water frontage access to Dickinson Bayou. This park has 81 RV camp sites with full hook up service. The park features a five boat slip marina and access to fishing and boating opportunities in Dickinson Bayou. Additional information is available at: **www.viabayourv.com**

Meadowlark RV Park is located on South Street in Alvin and has a freshwater lake with fishing, canoeing, swimming and 37 RV camp sites. Additional information is available at: **http://www.gocampingamerica.com/campgrounds/default.aspx?state=TX&id=8245&dynamic=0/ or call (281) 331-5992 or email mjour77542@aol.com.**

Valentino's Marina off of Hwy 146 on the south side of Dickinson Bayou features covered boat slips for privately owned boats. This site has a boat ramp and fuel facilities.

The **Bayou Zoo** located in Alvin at 5050 FM 517 on banks of Dickinson Bayou. It features walking trails and special tram rides to see the 40 species of animals and 400 species of birds that roam freely through the park's open wooded and prairie habitats. There are picnic areas and animal petting areas for small children. **To contact the park owner Clint Wolson call 281-337-6376.**

31. Appendix H: GIS Dataset Sources

2006 Aerial Imagery. 2006. Obtained from the H-GAC via personnel communication, June 2007.

City Boundaries. 2008. Obtained via email from Brazoria, Galveston, and Harris Appraisal District and local City data.

Coastal Change Analysis Program (CCAP). 2007. Downloaded from the NOAA Coastal Services Center. <http://www.csc.noaa.gov/crs/lca/gulfcoast.html>. Accessed January 2008.

County Boundaries. Unknown. Obtained from Tiger files. May 2008.

FEMA Q3 Floodplains. Unknown. Galveston and Brazoria FEMA Q3 floodplains layers were downloaded from the TNRIS website in May of 2008. FEMA is the original created of the data. http://www.tnris.state.tx.us/datadownload/county.jsp?Name=GALVESTON> Accessed unknown.

Habitat Dataset. 2008. Created by the Texas Coastal Watershed Program, September 2008. Metadata available upon request. www.urban-nature.org.

H-GAC Land Cover. 2002. Obtained from H-GAC via email, December 2007.

H-GAC Population Forecast Data 1 Mile Grid. 2008. Obtained from the H-GAC's website. < http://www.h-gac.com/rds/forecasts/default.aspx>. Accessed March 2008.

Hydrology data. Unknown. Obtained from the Texas General Land Office and TCEQ, January 2008.

Onsite Sewage Systems. 2007. GIS layer obtained from Roger Miranda at the Texas Commission of Environmental Quality (TCEQ). Mr. Miranda retrieved this data from the Houston Galveston Area Council (Date Unknown).

Permitted Waste Water Treatment Facilities Location and data. 2008. Obtained from Roger Miranda at TCEQ via email, June 2008.

Recreational Areas in the Dickinson Bayou Watershed. 2008. Developed by Jan Culbertson and the Dickinson Bayou Watershed Partnership Parks and Recreation Subcommittee.

Roads data. Unknown. Obtained from the Texas General Land Office and Tiger files in January 2008.

Soil data. Unknown. Obtained from the Natural Resource Conservation Service's (NRCS) Soil Survey Geographic Dataset (SSURGO), March 2008.

Watershed Boundary. 2008. The Watershed Boundary was constructed by the Texas Commission of Environmental Quality.

Water Quality Sampling Sites. Obtained from TCEQ, January 2008.

32. Appendix I: Public Surveys

Dickinson Bayou Watershed Survey

Combined Results from May, 2006 And August, 2008. A total of 90 persons took this survey.

The first set of questions focuses on your use and knowledge of Dickinson Bayou and your opinions about the local environmental quality. Please answer these questions to the best of your ability.

1. What is a ***watershed***?

   < 1% A small building used to store water

   83% An area of land that drains to one body of water

   15% A generic name for a bayou, river, stream or creek

2. Do you know generally the boundaries of the Dickinson Bayou watershed?

   46% Yes

   28% No

   26% Not sure

3. With what portions of Dickinson Bayou, if any, are you familiar (please check all that apply)? *Please see the map at the back of the survey for reference*

   33% The upper (above tidal) portion of Dickinson Bayou

   58% The lower (tidal) portion of Dickinson Bayou

   9% I am not familiar with any portion of Dickinson Bayou

4. Which of the following outdoor activities **do you** participate in on Dickinson Bayou? *(Please check all that apply)*

   50% Fishing

   22% Swimming

   17% Skiing/Jet Skiing

   31% Exploring by walking/hiking along the bayou

   26% Kayaking or canoeing

   40% Wildlife viewing

   16% Boating

   22% None of these

5. Do you **still** participate in those outdoor activities listed in Question 4?

   71% Yes

   29% No

6. If you answered ***No*** to the previous question, why did you decide not to participate in outdoor activities on the Dickinson Bayou?

62% Polluted water

8% Snakes, gators, or other creatures

15% Boat traffic

15% Other, Specify_____

7. Are you concerned about your children or family swimming in the Dickinson Bayou?

59% Yes

27% No

14% Have not decided

8. Do you believe there are enough public access sites on Dickinson Bayou for outdoor recreational enjoyment?

32% Yes

48% No

20% Not sure

9. Where do you usually access the bayou?

41% Public boat ramp

27% Private dock

23% Public park

9% Private backyard

10. Habitats are natural areas suitable for wildlife and that retain at least some of their natural character. Some examples include wetlands, salt marshes, shallow open water bays, and tall grass prairies. Do you believe any of these habitats should be protected in the Dickinson Bayou watershed?

96% Yes

4% No

11. Based upon what you know about Dickinson Bayou, do you think there are environmental problems associated with it? *(Please check one)*

73% Yes => Please answer Question 12

7% No } Please skip to Question 13

20% Don't know

12. If you answered "**Yes**" in Question 11, what environmental problems are you aware of on Dickinson Bayou? *(Please check all that apply)*

83%	Illegal dumping and littering	**68%**	Shoreline erosion
71%	Habitat loss	**26%**	Livestock
33%	Lack of recreational opportunities	**36%**	Flooding
71%	Polluted stormwater runoff	**53%**	Sewage
42%	Dirt or sediment in water	**26%**	Fish kills
75%	Other, please specify _____		

13. How concerned are you about the ability of fish and other aquatic life to survive in Dickinson Bayou? *(Please check one)*

61% Very concerned

34% Some what concerned

5% Not concerned at all

14. Are you aware that Dickinson Bayou is impaired and is currently being studied to find ways to correct the pollution problem? *(Please check one)*

78% Yes

22% No

15. Who do you believe is responsible for providing this study on the Dickinson Bayou watershed?

28% County Health District

3% University of Houston

16% Each city works together on the study

27% Texas Commission on Environmental Quality

15% Texas A & M University

11% Federal Government

16. When you think about the thousands of new homes being constructed in the Dickinson Bayou watershed how do you feel about:

	Very Positive	Somewhat positive	Neutral	Somewhat negative	Very negative
The impact it will have on the bayou?	**6%**	**16%**	**22%**	**18%**	**38%**
The effect will it have on public services?	**6%**	**11%**	**25%**	**29%**	**29%**
The effect will it have on crime?	**6%**	**14%**	**35%**	**20%**	**25%**

17. Would you be willing to live in a house with a very small yard if you also had access, within easy walking distance, of a small grocery store or convenience store and other shops such as cleaners and coffee shops, restaurants, etc.?

17% Very willing
24% Somewhat willing
25% Neutral
14% Somewhat unwilling
20% Not at all willing

18. I would like to walk more and drive less.

27% Very willing
30% Somewhat willing
27% Neutral
8% Somewhat unwilling
8% Not at all willing

19. When you think about the increasing growth/development in and around your community, how do you feel about:

	Very Positive	Somewhat positive	Neutral	Somewhat negative	Very negative
The possibility of more jobs?	**40%**	**31%**	**19%**	**8%**	**2%**
The possibility of increased congestion?	**14%**	**10%**	**16%**	**26%**	**34%**
The possibility of more shopping and entertainment opportunities?	**32%**	**22%**	**24%**	**12%**	**10%**
Additional environmental challenges?	**8%**	**19%**	**26%**	**19%**	**28%**
The need to manage growth to protect quality of life?	**39%**	**35%**	**12%**	**12%**	**2%**
Increased tax burdens on existing residents?	**15%**	**10%**	**33%**	**23%**	**19%**

The following four questions are all hypothetical (made up); the purpose of these questions is to gauge the public's willingness to financially support environmental projects along the bayou. There are **NO** plans to tax citizens to fund a Dickinson Bayou clean-up or purchase land. The Dickinson Bayou Watershed Partnership has no authority to impose any type of taxes or fees.

20. Would you be willing to pay an extra few dollars a month, for example on your utility bill, to help cities and non-profits organizations purchase, and set aside, important natural areas so they can be enjoyed by all citizens?

25% Very likely

45% Somewhat likely

18% Neutral

4% Somewhat unlikely

8% Very unlikely

21. Assume that you are asked to vote on a project that would provide the funding required to clean-up Dickinson Bayou. In approximately five years, this clean-up would make Dickinson Bayou safer for contact recreation (swimming/wading) by improving the water quality. This project would raise local taxes over a five year period in order to pay for the clean-up project. Would you support, oppose, or remain neutral about this project? *(Please check one)*

38%	Very supportive
25%	Somewhat supportive
27%	Neutral
0%	Somewhat unsupportive
10%	Very unsupportive

22. If you **support** the proposed project, what is the highest level of taxation that you would be willing to pay each year for five years to clean-up Dickinson Bayou?

37%	$0-20	**17%**	$80-100
9%	$20-40	**6%**	$100-150
9%	$40-60	**6%**	$150-200
8%	$60-80	**9%**	Over $200

23. If you **oppose or remain neutral** about this clean-up project, which statement best reflects why you would **not** be willing to provide financial support for clean-up of Dickinson Bayou? *(Please check one)*

41%	I support the clean-up of Dickinson Bayou, but cannot afford higher taxes at this time.
12%	I support the clean-up project, but I think someone else should pay for it.
27%	I support the clean-up project, but I don't think taxes are the best way to pay for it.
7%	I support the clean-up project, but I don't think it can be accomplished.
5%	I support the improvement of Dickinson Bayou, but I think that bacteria and low dissolved oxygen levels are not environmental problems in the bayou.
3%	I think Dickinson Bayou is okay the way it is.
5%	Other, please specify _____

24. What other improvements, if any, would you like to see along Dickinson Bayou? *(Please check all that apply)*

61% Walking or biking trails

39% Public access for fishing and recreation

26% Additional Parks and Open Space

58% Regular trash clean-ups

36% Fish stocking

52% Protection of forests along the creeks

30% Additional flood control mechanism installed

3% None

8% Other, please specify_____

25. Are you concerned about flooding or storm surges along Dickinson Bayou and in the watershed in general?

38% Very concerned

48% Somewhat concerned

10% Neutral

2% Not very concerned

2% Not concerned

We would like to finish up this survey with some questions about you. These questions are for research purposes only. The information that you provide will remain confidential and will not be shared with any business or other institution.

26. What is your zip code?

56% Dickinson, **14%** League City, **10%** Galveston, **2%** La Marque, **4%** La Porte, **2%** Liverpool, **2%** Deer Park, **2%** Channelview, **4%** Baclif, **2%** Alvin, **2%** Sugarland

27. What type of land do you own in the **watershed** (a watershed is the land that drains into a river system or body of water, in this case the land that drains into Dickinson Bayou)

(Please check all that apply)

71% Home or residential

3% Commercial

18% None

2% Agricultural

4% Riparian (stream side) land

0% Other, please specify_____

28. How long have you been a resident of the **watershed**? *(Please check one)*

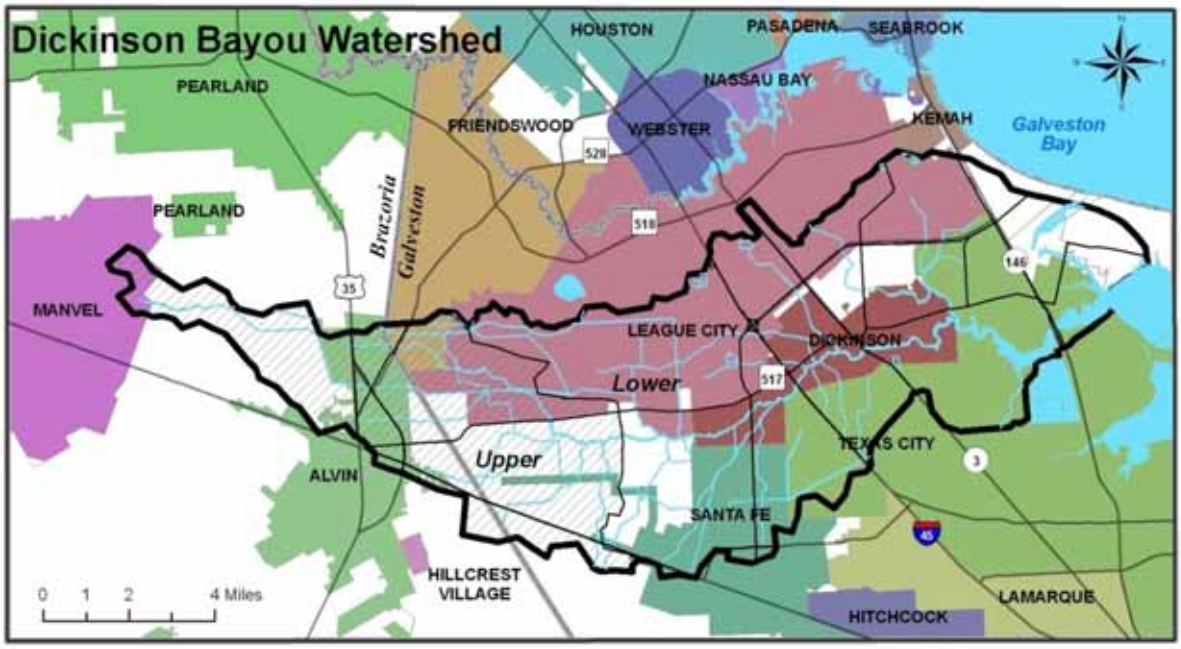
13%	Less than 1 year	**30%**	Between 1 and 10 years
28%	Longer than 10 years	**7%**	All my life
22%	I live outside the watershed		

29. What is your highest level of education? *(Please check one)*

1%	Less than a high school diploma
11%	High school diploma or GED
29%	Some college/technical school
35%	College degree
24%	Graduate school

30. What year were you born?

11%	20-30 yrs. old	**26%**	51-60 yrs. old
26%	31-40 yrs. old	**13%**	61-70 yrs. old
17%	41-50 yrs. old	**7%**	71+ yrs. Old



Results from Community Voting at May 2006 Watershed Partnership Meeting

Water Quality

Statement	Example questions	Rank within category	Overall rank
How does pollution impact Dickinson Bayou		1	12 (tie)
	What impacts do point and non-point source pollution have on how Dickinson Bayou is used for fishing and swimming?		
	What are the primary sources of point and non-point source pollutants in Dickinson Bayou?		
What are the water quality standards for Dickinson Bayou		4	8 (tie)
	Does Dickinson Bayou meet the State of Texas water quality criteria?		
	How are state standards set?		
	How can Dickinson Bayou meet the designated uses for water bodies in Texas?		
Examine water quality monitoring on Dickinson Bayou and it's tributaries		3	12 (tie)
	Where does current monitoring take plane and what kind of data is gathered?		
	Are additional monitoring sites needed and where?		

	Can citizens participate and serve as volunteer monitors?		
Flow of water and how it effects Dickinson Bayou		2	10 (tie)
	What are the current flow levels of Dickinson Bayou?		
	How can the flow of water affect the water quality of the bayou?		
	Does the shape of the bayou affect the flow and quality of the water?		

Flooding and Stormwater

Statement	Example questions	Rank within category	Overall rank
Examine flood control mechanisms and water storage techniques			
	Compare and contrast the different flood control mechanismsn: non structural controls (wetland, detention/retention basins) versus structural controls (channelization).	**1**	9 (tie)
Develop bayou maintenance guidelines		2	**4 (tie)**
	Should fallen trees/snags be removed from the bayou?		
	How would snag removal affect landowners downstream?		
	Will snag removal improve navigation and safety?		
	Do the snags provide important habitats?		
Compile regulations on building in and along the flood plain		4	12 (tie)
	How do different cities handle development along the bayou?		
Examine reducing and managing stormwater		3	7
	How can stormwater quantities be reduced?		
	How is stormwater currently managed within the watershed?		

Land Use

Statement	Example questions	Rank within category	Overall rank
Increase And Improve Recreational Opportunities On And Along The Bayou		3	6
	Does the public have enough access to Dickinson Bayou?		
	Would you like to hike/bike along Dickinson Bayou?		
	Are there enough parks in the watershed?		
	Do you enjoy skiing/jet skiing on Dickinson Bayou?		
How Does Sprawl Impact The Watershed		2	**2**
	Can there be too much development occurring in the Dickinson watershed?		
	Do you believe there has been a significant loss of natural open spaces in the watershed?		
	Are developers currently creating communities that require longer car trips?		
	Are newly developed communities lacking in character and charm?		
	Is a walkable community important to you?		
Examine Building And Developing Codes/Ordinances		**1**	**1**

	Do or should current building ordinances for new developments take into account enhancing and protecting natural resources (forest, wetlands and prairies)?		
	Should developers/builders be given incentives to maintain, protect and preserve natural resources when possible?		

HABITAT

Statement	Example questions	Rank within category	Overall rank
Examination Of The Loss Of Habitat In The Watershed		6	11
	Has there been a significant loss of habitat in the watershed?		
	What types of habitats have been lost?		
	Where in the watershed has a significant amount of habitat been lost?		
	What does habitat fragmentation do to the wildlife?		
Shoreline Erosion Management		2	8 (Tie)
	Is it possible to decrease shoreline erosion by using alternative means i.e. no bulkheads?		
	Should motorized boat traffic be reduced to decrease shoreline erosion?		
Habitats Role In Reducing The Impacts Of Flooding		3	10 (Tie)
	How can habitats also serve as flooding/stormwater retention?		
	Which types of habitat have the greatest benefits to flooding/stormwater retention?		
Management Of Plant And Animal Species In The Watershed		5	13
	What impact do invasive species have on the bayou and the watershed?		

	Which invasive species are located in the watershed?		
	Can invasive species be eradicated?		
	What type of biodiversity exists in the watershed?		
Developing Protected Areas Within The Watershed		**1**	**3**
	Should there be an effort to increase the number of acres of land for the preservation of wildlife and plant communities?		
	Should and if so where within the watershed should land be designated as protected (no development can ever occur).		
	Are there existing programs available to landowners who want to preserve their land forever?		
Examination Of The Regulations And Laws Regarding Disturbing Land Along The Bayou		4	9 (Tie)
	Should there be a central location where the public can find out what developments will be occurring or any permits were applied for along Dickinson Bayou?		
	What are the regulations or laws regarding building along the bayou?		

Outreach and Education

Statement	Example questions	Rank within category	Overall rank
Increase Stewardship Of Citizens		2	5
	Should there be a greater effort to get the public more involved with land preservation (natural spaces)?		
	Should individuals be guided to take more personal responsibility for their actions (littering/dumping)?		
	Is the public educated about their personal impact on Dickinson Bayou?		
	What does the public know about the bayou and the watershed?		
Educate Students About The Bayou And The Watershed		3	9 (Tie)
	Students should be made aware of how they impact the bayou.		
	It is important to teach students about how the Dickinson Bayou watershed fits into the greater Galveston Bay watershed.		
	Students need to know what non-point and point source pollutants are and how they affect the water quality of Dickinson Bayou.		
	Educating students about the types of flora and fauna that exists in the watershed is needed.		

Develop A List Of Laws That Govern Impact/Uses Of The Bayou		**1**	**4 (Tie)**
	Develop a guide that assists in determining where building can and can't take place along the bayou.		

Public Polling at the Dickinson Bayou Watershed Planning Round Up & BBQ Bash, August 2008

Stormwater Management (Low Impact Development)		**AGREE**	**DISAGREE**
1	Businesses should be required to use best management practices for their parking lots and land.	96%	4%
2	Home owners should be required to install best management practices on their property.	17%	29%
3	Developers should be required to use install best management practices on all newly developed properties.	95%	5%
4	Tax incentives should be given to businesses and homeowners for installing best management practices.	100%	0%
5	Cities should charge a small storm water utility fee to help pay for best management practices on both public and private land.	45%	55%

WATER QUALITY		**AGREE**	**DISAGREE**
1	I am concerned about the water quality in Dickinson Bayou.	100%	0%
2	I believe that my everyday behaviors effect the water quality of Dickinson Bayou.	100%	0%
3	Waste water treatment plants should be monitored more often.	97%	3%
4	Septic system owners should be forced to upgrade to sanitary sewers (waste water treatment plants).	91%	9%
5	Public funds should be used to help upgrade septic systems.	77%	23%

RECREATION		AGREE	DISAGREE
1	Everyone in the watershed should have at least a small park within walking distance of their home.	97%	3%
2	The tidal section of Dickinson Bayou should be dredged to allow for more and larger boat access.	68%	32%
3	Barges and other abandoned vessels should be removed from the bayou.	100%	0%
4	The watershed should have more: Athletic (soccer, softball, etc) fields	63%	37%
	Nature Parks	100%	0%
	Public boat ramps/access points	89%	11%
	Walking trails	100%	0%
	Marinas	75%	25%
	Signs telling about the bayou and the watershed	98%	2%

WATERSHED PLAN AND PARTNERSHIP		AGREE	DISAGREE
1	Cities within the Dickinson Bayou watershed should work together to solve water quality problems.	100%	0%
2	Cities and Counties within the watershed should find a way to continue the Dickinson Bayou Watershed Partnership as a long term group.	100%	0%

WATERSMART & RAIN GARDENS		AGREE	DISAGREE
1	Landscape ordinances should include recommended plant lists.	100%	0%
2	Homeowners should be able to plant more garden beds and less lawn.	100%	0%
3	Conservation landscaping should be a part of city and county policy.	95%	5%
4	All city and county landscapes should follow WaterSmart principles.	100%	0%
5	Cities and counties should work to limit the use of soluble fertilizers and pesticides.	100%	0%

HABITAT		AGREE	DISAGREE
1	The preservation of all the native habitats in the Dickinson Bayou watershed is essential to the future of the watershed.	100%	0%
2	The Dickinson Bayou watershed, as a whole, needs a plan to protect natural areas.	100%	0%
3	The Dickinson Bayou watershed must designate specific areas for conservation and develop site-specific plans to preserve and protect those areas.	100%	0%
4	At least 30% of remaining habitat types in the watershed should be preserved and/or restored.	100%	0%

STORMWATER WETLANDS		AGREE	DISAGREE
1	Stormwater wetlands should be required for all stormwater detention areas.	100%	0%
2	Incentives should be given to groups (developers, home owners associations, businesses) who install stormwater treatment wetlands.	100%	0%
3	Public funds should be used to help defray the cost of installing stormwater wetlands.	73%	27%

Livable Centers		AGREE	DISAGREE
1	Barriers to town-centered development should be removed.	93%	7%
2	Watershed communities should use commuter rail to build walkable communities.	87%	13%
3	Liveable centers can help preserve the small town character many value in this area.	93%	7%

33. Appendix J: Model Stormwater Ordinance

This ordinance is excerpted from the Center for Watershed Protection's Stormwater Management Post-Construction Guidance Manual and Tools. Additional guidance and language is available in the full document available on line at:
http://www.cwp.org/Resource_Library/Center_Docs/SW/pcguidance/Tool3.pdf

Post-Construction Stormwater Model Ordinance

For more information on the Post-Construction Guidance Manual, contact the Center for Watershed Protection, 8390 Main Street, 2nd floor, Ellicott City, MD 21046, 410-461-8323

center@cwp.org

www.cwp.org.

Post-Construction Stormwater MODEL Ordinance

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Section 1. General Provisions

1.1. Findings of Fact

It is hereby determined that:

(1) Land development activities and associated increases in site impervious cover often alter the hydrologic response of local watersheds and increase stormwater runoff rates and volumes, flooding, stream channel erosion, or sediment transport and deposition;

(2) This stormwater runoff contributes to increased quantities of water-borne pollutants, including siltation of aquatic habitat for fish and other desirable species;

(3) Improper design and construction of stormwater best management practices (BMPs) can increase the velocity of stormwater runoff thereby increasing stream bank erosion and sedimentation;

(4) Impervious surfaces allow less water to percolate into the soil, thereby decreasing groundwater recharge and stream baseflow;

(5) Substantial economic losses can result from these adverse impacts on the waters of the municipality;

(6) Stormwater runoff, soil erosion and nonpoint source pollution can be controlled and minimized through the regulation of stormwater runoff from land development activities;

(7) The regulation of stormwater runoff discharges from land development activities in order to control and minimize increases in stormwater runoff rates and volumes, stream channel erosion, and nonpoint source pollution associated with stormwater runoff is in the public interest and will minimize threats to public health and safety.

(8) Regulation of land development activities by means of performance standards governing stormwater management and site design will produce development compatible with the natural functions of a particular site or an entire watershed and thereby mitigate the adverse effects of stormwater runoff from development.

(9) Clearing and grading during construction tends to increase soil erosion and add to the loss of native vegetation necessary for terrestrial and aquatic habitat;

(10) Illicit and non-stormwater discharges to the storm drain system can contribute a wide variety of pollutants to waterways, and the control of these discharges is necessary to protect public health and safety and water quality.

1.2. Purpose

The purpose of this ordinance is to establish minimum stormwater management requirements and controls to protect and safeguard the general health, safety, and welfare of the public residing in watersheds within the [**JURISDICTION**]. This ordinance seeks to meet that purpose through the following objectives:

(1) To inhibit the deterioration of water resources resulting from development.
(2) To protect the safety and welfare of citizens, property owners, and businesses by minimizing the negative impacts of increased stormwater discharges from new land development and redevelopment.
(3) To control the rate, quality <u>and volume</u> of stormwater originating from development and redevelopment sites so that surface water and groundwater are protected and flooding and erosion potential are not increased.
(4) To control nonpoint source pollution and stream channel erosion.
(5) To maintain the integrity of stream channels and networks for their biological functions, drainage, and natural recharge of groundwater.
(6) To protect the condition of state (and U.S.) waters for all reasonable public uses and ecological functions.
(7) To provide long-term responsibility for and maintenance of stormwater BMPs.
(8) To facilitate the integration of stormwater management and pollution control with other ordinances, programs, policies, and the comprehensive plan of [**JURISDICTION**].
(9) To establish legal authority to carry out all the inspection and monitoring procedures necessary to ensure compliance with this ordinance.

Specific to the MS4

(1) To regulate the contribution of pollutants to the MS4 by stormwater discharges from development, redevelopment.
*(2) To enable [**JURISDICTION**] to comply with the National Pollution Discharge Elimination System permit and applicable federal and state regulations.*
*(3) To facilitate compliance with state and federal standards and permits by owners of construction sites, developments, and permanent stormwater BMPs with [**JURISDICTION**].*

Other Special Resources

- *To preserve the natural infiltration of groundwater to maintain the quantity and quality of groundwater resources.*
- *To protect against and minimize the pollution of public drinking water supplies resulting from development and redevelopment.*
- *Impaired Waters*
- *Lakes*
- *Cold-Water Fisheries*
- *Coastal Areas*
- *Wetlands*

1.3. Applicability

This ordinance shall be applicable to all land development, including, but not limited to, site plan applications, subdivision applications, and grading applications, unless exempt pursuant to Section 1.4. These provisions apply to any new development or redevelopment site within [**JURISDICTION**] that meets one or more of the following criteria:

(1) Land development that creates [**FIVE-THOUSAND (5,000) SQUARE FEET OR MORE**] of impervious cover.

(2) Redevelopment that creates, adds, or replaces **[FIVE-THOUSAND (5,000) SQUARE FEET OR MORE]** of impervious cover.

(3) Land development activities that are smaller than the minimum applicability criteria set forth above if such activities are part of a larger common plan of development, even though multiple, separate and distinct land development activities may take place at different times on different schedules.

1.4. Exemptions

The following activities are exempt from this ordinance:

(1) Individual single-family or duplex residential lots that are not part of a subdivision or phased development project that is otherwise subject to this ordinance.

(2) Additions or modifications to existing single-family or duplex residential structures.

(3a) Projects that are exclusively for agricultural and silvicultural uses. Agricultural or silvicultural roads that are used to access other land uses subject to this ordinance are not exempt. Agricultural structures that are also used for other uses subject to this ordinance are not exempt.
OR
*(3b) Any agricultural or silvicultural activity that is conducted according to an approved farm conservation plan or timber management plan prepared or approved by [**APPROPRIATE STATE AGENCIES**].*

(4) Maintenance and repair to any stormwater BMP deemed necessary by the [**STORMWATER AUTHORITY**].

(5) Any emergency project that is immediately necessary for the protection of life, property, or natural resources.

(6) Linear construction projects, such as pipeline or utility line installation, that do not result in the installation of any impervious cover, as determined by the **[STORMWATER AUTHORITY]**. Such projects must be designed to minimize the number of stream crossings and width of disturbance, and are subject to **[APPLICABLE CONSTRUCTION STORMWATER OR EROSION & SEDIMENT CONTROL ORDINANCE].**

(7) Any part of a land development that was approved by **[JURISDICTION'S PLAN APPROVING AUTHORITY]** prior to the effective date of this ordinance.

1.5. Legal Authority

This ordinance is adopted pursuant to authority conferred by and in accordance with **[APPLICABLE STATE AND/OR FEDERAL REGULATIONS].**

1.6. Compatibility with Other Permit and Ordinance Requirements

This ordinance is not intended to interfere with, abrogate, or annul any other ordinance, rule or regulation, stature, or other provision of law. The requirements of this ordinance should be considered minimum requirements, and where any provision of this ordinance imposes restrictions different from those imposed by any other ordinance, rule or regulation, or other provision of law, whichever provisions are more restrictive or impose higher protective standards for human health or the environment shall be considered to take precedence.

1.7. Severability
If the provisions of any article, section, subsection, paragraph, subdivision or clause of this ordinance shall be judged invalid by a court of competent jurisdiction, such order of judgment shall not affect or invalidate the remainder of any article, section, subsection, paragraph, subdivision or clause of this ordinance.

1.8. Liability
Any person who undertakes or causes to be undertaken any land development shall ensure that soil erosion, sedimentation, increased pollutant loads and changed water flow characteristics resulting from the activity are controlled so as to minimize pollution of receiving waters. The requirements of this ordinance are minimum standards and a person's compliance with the same shall not relieve such person from the duty of enacting all measures necessary to minimize pollution of receiving waters.

By approving a plan under this regulation, [**JURISDICTION**] does not accept responsibility for the design, installation, and operation and maintenance of stormwater BMPs.

1.9. Designation of Stormwater Authority: Powers and Duties

*The [**STORMWATER AUTHORITY**] shall administer and enforce this ordinance, and may furnish additional policy, criteria and information including specifications and standards, for the proper implementation of the requirements of this ordinance and may provide such information in the form of a Stormwater Design Manual.*

*The Stormwater Design Manual may be updated and expanded from time to time, at the discretion of the [**STORMWATER AUTHORITY**], based on improvements in engineering, science, monitoring and local maintenance experience.*

Representatives of the [**STORMWATER AUTHORITY**] shall have the right to enter upon any land for the purposes of making an inspection or acquiring information to determine whether or not the property conforms to the requirements of this ordinance.

Section 2. Definitions

"Applicant" means a property owner or agent of a property owner who has filed an application for a stormwater management permit.

"Building" means any structure, either temporary or permanent, having walls and a roof, designed for the shelter of any person, animal, or property, and occupying more than 100 square feet of area.

"Channel" means a natural or artificial watercourse with a definite bed and banks that conducts continuously or periodically flowing water.

"Dedication" means the deliberate appropriation of property by its owner for general public use.

"Detention" means the temporary storage of storm runoff in a stormwater BMP with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

"Easement" means a legal right granted by a landowner to a grantee allowing the use of private land for conveyance or treatment of stormwater runoff and access to stormwater practices.

"Erosion and Sediment Control Plan" means a plan that is designed to minimize the accelerated erosion and sediment runoff at a site during construction activities.

"Fee in Lieu Contribution" means a payment of money in place of meeting all or part of the stormwater performance standards required by this ordinance.

"Groundwater Management Area" means a geographically defined area that may be particularly sensitive in terms of groundwater quantity and/or quality by nature of the use or movement of groundwater, or the relationship between groundwater and surface water, and where special management measures are deemed necessary to protect groundwater and surface water resources.

"Groundwater Recharge Volume (Rev)" – The portion of the water quality volume (WQv) used to maintain groundwater recharge rates at development sites.

"Impaired Waters" means those streams, rivers and lakes that currently do not meet their designated use classification and associated water quality standards under the Clean Water Act.

"Impervious Cover" means those surfaces that cannot effectively infiltrate rainfall (e.g., building rooftops, pavement, sidewalks, driveways, etc).

"Industrial Stormwater Permit" means a National Pollutant Discharge Elimination System permit issued to a commercial industry or group of industries that regulates the pollutant levels associated with industrial stormwater discharges or specifies on-site pollution control strategies.

“Infill Development” means land development that occurs within designated areas based on local land use, watershed, and/or utility plans where the surrounding area is generally developed, and where the site or area is either vacant or has previously been used for another purpose.

"Infiltration" means the process of percolating stormwater into the subsoil.

"Infiltration Facility" means any structure or device designed to infiltrate retained water to the subsurface. These facilities may be above grade or below grade.

"Jurisdictional Wetland" means an area that is inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions, commonly known as hydrophytic vegetation.

“Land Development” means a human-made change to, or construction on, the land surface that changes its runoff characteristics.

"Land Disturbing Activity" means any activity that changes the volume or peak flow discharge rate of rainfall runoff from the land surface. This may include the grading, digging, cutting, scraping, or excavating of soil, placement of fill materials, paving, construction, substantial removal of vegetation, or any activity that bares soil or rock or involves the diversion or piping of any natural or man-made watercourse.

"Landowner" means the legal or beneficial owner of land, including those holding the right to purchase or lease the land, or any other person holding proprietary rights in the land.

"Maintenance Agreement" means a legally recorded document that acts as a property deed restriction, and that provides for long-term maintenance of stormwater BMPs.
“Municipal Separate Storm Sewer System (MS4)” means publicly-owned facilities by which stormwater is collected and/or conveyed, including but not limited to any roads with drainage systems, municipal streets, gutters, curbs, catch basins, inlets, piped storm drains, pumping facilities, retention and detention basins, natural and human-made or altered drainage ditches/channels, reservoirs, and other drainage structures.

“National Pollutant Discharge Elimination System (NPDES) Stormwater Discharge Permit” means a permit issued by the EPA, or by a State under authority delegated pursuant to 33 USC § 1342(b), that authorizes the discharge of pollutants to waters of the State, whether the permit is applicable on an individual, group, or general area-wide basis.

“Non-Stormwater Discharge” means any discharge to the storm drain system that is not composed entirely of stormwater.

“Non-Structural Measure” means a stormwater control and treatment technique that uses natural processes, restoration or enhancement of natural systems, or design approaches to control runoff and/or reduce pollutant levels. Such measures are used in lieu of or to supplement structural practices on a land development site. Non-structural measures include, but are not limited to: minimization and/or disconnection of impervious surfaces; development design that reduces the rate and volume of runoff; restoration or enhancement of natural areas such as riparian areas, wetlands, and forests; and on-lot practices such as rain barrels, cisterns, and vegetated areas that intercept roof and driveway runoff.

"Nonpoint Source Pollution" means pollution from any source other than from any discernible, confined, and discrete conveyances, and shall include, but not be limited to, pollutants from agricultural, silvicultural, mining, construction, subsurface disposal and urban runoff sources.

"Off-Site Facility" means a stormwater BMP located outside the subject property boundary described in the permit application for land development activity.

"On-Site Facility" means a stormwater BMP located within the subject property boundary described in the permit application for land development activity.

"Owner" means the owner or owners of the freehold of the premises or lesser estate therein, a mortgagee or vendee in possession, assignee of rents, receiver, executor, trustee, lessee or other person, firm or corporation in control of a piece of land. As used herein, owner also refers to, in the appropriate context: (i) any other person authorized to act as the agent for the owner; (ii) any person who submits a stormwater management concept or design plan for approval or requests issuance of a permit, when required, authorizing land development to commence; and (iii) any person responsible for complying with an approved stormwater management design plan.

"Permanent Stormwater BMP" means a stormwater best management practice (BMP) that will be operational after the construction phase of a project and that is designed to become a permanent part of the site for the purposes of managing stormwater runoff.
"Private Inspector" means an independent agency or private entity that is retained by the applicant to conduct inspections and submit documentation to the [**STORMWATER AUTHORITY**] in accordance with this ordinance, and that is certified by the [**STORMWATER AUTHORITY**] to conduct such inspections.

"Pro-Rata Share" means the proportional amount to be paid by an applicant to contribute to the construction of a regional stormwater BMP, as determined by the [**STORMWATER AUTHORITY**].

"Receiving Stream or Channel" means the body of water or conveyance into which stormwater runoff is discharged.

"Recharge" means the replenishment of underground water reserves.

"Redevelopment" means a change to previously existing, improved property, including but not limited to the demolition or building of structures, filling, grading, paving, or excavating, but excluding ordinary maintenance activities, remodeling of buildings on the existing footprint, resurfacing of paved areas, and exterior changes or improvements that do not materially increase or concentrate stormwater runoff or cause additional nonpoint source pollution.

"Regional Stormwater" means stormwater BMPs designed to control stormwater runoff from multiple properties or a particular land use district, and where the owners or developers of the individual properties may participate in the provision of land, financing, design, construction, and/or maintenance of the facility.

"Responsible Party" means any individual, partnership, co-partnership, firm, company, corporation, association, joint stock company, trust, estate, governmental entity, or any other legal entity; or their legal representatives, agents, or assigns that is named on a stormwater maintenance agreement as responsible for long-term operation and maintenance of one or more stormwater BMPs.

"Stop Work Order" means an order issued that requires that all construction activity on a site be stopped.

"Stormwater Authority" means the department or agency, and its authorized agents, which is responsible for coordinating the review, approval, and permit process as defined by this ordinance.

"Stormwater Design Manual" means an engineering and/or project review document maintained by the **[STORMWATER AUTHORITY**] containing technical standards and specifications, policies, procedures, and other materials deemed appropriate by [**STORMWATER AUTHORITY**] to assist with compliance with the provisions of this ordinance.

"Stormwater Hotspot" means an area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

"Stormwater Management" means the use of structural or non-structural practices that are designed to reduce stormwater runoff pollutant loads, discharge volumes, peak flow discharge rates and detrimental changes in stream temperature that affect water quality and habitat.

"Stormwater Pollution Prevention Plan" means a plan, usually required by a permit, to manage stormwater associated with industrial, commercial, institutional, or other land use activities, including construction. The Plan commonly describes and ensures the implementation of practices that are to be used to reduce pollutants in stormwater and non-stormwater discharges.

"Stormwater Best Management Practice (BMP)" means a measure, either structural or nonstructural, that is determined to be the most effective, practical means of preventing or reducing point source or nonpoint source pollution inputs to stormwater runoff and water bodies.

"Stormwater Retrofit" means a stormwater BMP designed for an existing development site that previously had either no stormwater BMP in place or a practice inadequate to meet the stormwater management requirements of the site.

"Stormwater Runoff" means flow on the surface of the ground, resulting from precipitation.

"Stream Buffer" means an area of land at or near a streambank, wetland, or waterbody that has intrinsic water quality value due to the ecological and biological processes it performs or is otherwise sensitive to changes which may result in significant degradation to water quality.

"Water Quality Volume (WQv)" means the storage needed to capture and treat 90% of the average annual stormwater runoff volume. Numerically (WQv) will vary as a function of long term rainfall statistical data.

"Watercourse" means a permanent or intermittent stream or other body of water, either natural or man-made, which gathers or carries surface water.

"Watershed or Subwatershed Management Plan" means a document, usually developed cooperatively by government agencies and other stakeholders, to protect, restore, and/or otherwise manage the water resources within a particular watershed or subwatershed. The plan commonly identifies threats, sources of impairment, institutional issues, and technical and programmatic solutions or projects to protect and/or restore water resources.

"Wetland Hydroperiod" means the pattern of fluctuating water levels within a wetland caused by the complex interaction of flow, topography, soils, geology, and groundwater conditions in the wetland.

Section 3. Permit Procedures and Requirements

3.1. Stormwater Management Concept Plan and Consultation Meeting

*Each owner subject to this ordinance shall submit to the [**STORMWATER AUTHORITY**] for review and approval a stormwater management concept plan as provided herein:*

(1) ***Stormwater Management Concept Plan:*** *All preliminary plans of subdivision and site plans shall provide a stormwater management concept plan describing, in general, how stormwater runoff through and from the development will be treated and conveyed. The concept plan shall also identify important natural features identified though a Natural Resources Inventory conducted in accordance with Section 4.1(17). All other land development projects subject to this ordinance shall submit a stormwater management concept plan prior to preparation of the stormwater management design plan.*

(2) ***Application Requirements:*** *The stormwater management concept plan submittal shall contain a completed application form provided by the [STORMWATER AUTHORITY], the fee required by Section 3.10, and a stormwater management concept plan that satisfies the requirements of this section and the Stormwater Design Manual.*

(3) ***Concept Plan Prior to Design Plan****: The stormwater management concept plan must be approved prior to submission of a stormwater management design plan (as part of the construction or final site plan) for the entire development, or portions thereof.*

(4) ***Meetings with [STORMWATER AUTHORITY]:*** *All applicants are encouraged to hold a pre-submittal consultation meeting with the [**STORMWATER AUTHORITY**] to discuss potential approaches for stormwater design and opportunities to use design techniques to reduce runoff rates, volumes, and pollutant loads. In addition, the applicant or his representative shall meet on-site with a designee of the [**STORMWATER AUTHORITY**] prior to approval of the stormwater management concept plan for the purposes of verifying the conditions of the site and all receiving channels.*

(5) ***Maximize Use of Techniques to Reduce Runoff by Design:*** *The stormwater management concept plan shall utilize to the maximum extent practicable site planning and design technique that reduce runoff rates, volumes, and pollutant loads. Such techniques include, but are not limited to, minimization and/or disconnection of impervious surfaces; development design that reduces the rate and volume of runoff; restoration or enhancement of natural areas such as riparian areas, wetlands, and forests; and distributed practices that intercept and treat runoff from developed areas.*

3.2. Stormwater Management Design Plan

Each owner subject to this ordinance shall submit to the [**STORMWATER AUTHORITY**] for review and approval a stormwater management design plan as provided herein:

Stormwater Management Design Plan: A stormwater management design plan containing all appropriate information as specified in this Ordinance shall be submitted to the [**STORMWATER AUTHORITY**] in conjunction with the final subdivision plat, final site plan, construction plan, or any other land development plan subject to this ordinance.

Application Requirements: The stormwater management design plan submittal shall contain a completed application form provided by the [**STORMWATER AUTHORITY**], the fee required by Section 3.10, a stormwater management design plan that satisfies the requirements of this section and the Stormwater Design Manual, a stormwater maintenance plan, and a certification stating that all requirements of the approved plan will be complied with. Failure of the owner to demonstrate that the project meets these requirements, as determined by the [**STORMWATER AUTHORITY**], shall be reason to deny approval of the plan.

Consistency between Concept & Design Plans: A copy of the approved stormwater management concept plan shall be submitted with the stormwater management design plan. The [**STORMWATER AUTHORITY**] shall check the design plan for consistency with the concept plan and may require a revised stormwater management concept plan if changes in the site development proposal have been made.

Stormwater Management Design Plan Content: The stormwater management design plan shall contain maps, charts, graphs, tables, photographs, narrative descriptions, explanations, citations to supporting references, a record of all major permit decisions, and other information as may be necessary for a complete review of the plan, and as specified in the latest version of the Stormwater Design Manual.

3.3. Stormwater Management Design Plan: Review Procedures

Preliminary Review for Completeness of Plan: The [**STORMWATER AUTHORITY**] shall have a maximum of ten (10) calendar days from the receipt of an application for preliminary review to determine if the application is complete. During this period, the application will be accepted for review, which will begin the thirty (30) day review period, or rejected for incompleteness. The applicant will be informed in writing of the information necessary to complete the application.

Review Period: The thirty (30) day review period begins on the day the complete stormwater management design plan is accepted for review by the [**STORMWATER AUTHORITY**]. During the thirty (30) day review period, the [**STORMWATER AUTHORITY**] shall either approve or disapprove the plan and communicate the decision to the applicant in writing. Approval or denial shall be based on the plan's compliance with this Ordinance and the Stormwater Design Manual.

Modifications Needed for Approval: In cases where modifications are required to approve the plan, the [**STORMWATER AUTHORITY**] shall have an additional thirty (30) days to review the revised plan from the initial and any subsequent resubmission dates. If the plan is approved, one copy bearing certification of such approval shall be returned to the applicant. If the plan is disapproved, the applicant shall be notified in writing of the reasons.

Appeal Decisions of [STORMWATER AUTHORITY]: The applicant or any aggrieved party authorized by law may appeal the [**STORMWATER AUTHORITY'S**] decision of approval or disapproval of a stormwater management design plan. The appeal shall be made to the [**GOVERNING BOARD OF JURISDICTION**], must be in writing, and must be submitted within thirty (30) days after the [**STORMWATER AUTHORITY**] renders its decision to approve or disapprove the plan.

Substantive Changes to Plan: No substantive changes shall be made to an approved plan without review and written approval by the [**STORMWATER AUTHORITY**]. The [**STORMWATER AUTHORITY**] may request additional data with a plan amendment as may be necessary for a complete review of the plan and to ensure that changes to the plan will comply with the requirements of this ordinance.

Expiration of Plan Approval: The stormwater management design plan's approval expires in one year from the date of approval unless a final plat is recorded or unless work has actually begun on the site. The recordation of a final plat for a section of a subdivision (or initiation of construction in a section) does not vest the approval of the stormwater management design plan for the remainder of the subdivision. If the stormwater management design plan expires, the applicant shall file with the [**STORMWATER AUTHORITY**] for reapproval of the stormwater management design plan.

3.4. Plan Preparation and Certification

(1) **Certification by Plan Preparer:** The stormwater management design plan shall be prepared by a licensed landscape architect, certified professional surveyor, or professional engineer and must be signed by the professional preparing the plan, who shall certify that the design of all stormwater BMPs meet the requirements in this local law.

(2) **Certification by Owner:** The owner shall certify that all land clearing, construction, land development and drainage will be done according to the approved plan.

3.5. Coordination with Other Approvals and Permits

(1) ***Approval of Other Permits:*** *No grading or building permit shall be issued for land development without approval of a stormwater management design plan.*

(2) ***Coordination with Other Plans:*** *Approval of the stormwater management design plan shall be coordinated by the [**STORMWATER AUTHORITY**] with approval of an erosion and sediment control or construction stormwater plan with regard to the location, schedule, and/or phasing for temporary and permanent stormwater management measures. If natural drainage features or other natural areas are to be preserved, then these areas must be shown and measures provided for their protection on both the erosion and sediment control plan and the stormwater management design plan. If other elements of the stormwater management design plan utilize soils, vegetation, or other natural features for infiltration or treatment, then these areas must be shown on the erosion and sediment control plan and measures provided for their protection during construction*

(3) ***Other Permits or Approvals May Be Needed:*** *Approvals issued in accordance with this ordinance do not relieve the applicant of responsibility for obtaining all other necessary permits and/or approvals from other federal, state, and/or local agencies. If requirements vary, the most restrictive shall prevail. These permits may include, but are not limited to: construction stormwater discharge permits, applicable state and federal permits for stream and wetland impacts, and applicable dam safety permits. Applicants are required to show proof of compliance with these regulations before the [**JURISDICTION'S PLAN APPROVING AUTHORITY**] will issue a grading, building, or zoning permit.*

(4) ***Stormwater Measures within Flood Plain:*** *Construction of stormwater measures or facilities within a Federal Emergency Management Agency (FEMA) designated floodplain shall be avoided to the extent possible. When this is unavoidable, all stormwater BMP construction shall be in compliance with all applicable requirements of the [**JURISDICTION'S FLOOD PLAIN CODE**].*

3.6. Maintenance Agreement and Plan

Prior to approval by the [**STORMWATER AUTHORITY**] of a stormwater management design plan, each owner shall submit a maintenance agreement and maintenance plan in accordance with the following:

(1) **Responsible Party:** The owner shall be responsible for the operation and maintenance of such measures and shall pass such responsibility to any successor owner, unless such responsibility is transferred to [**JURISDICTION**] or to another governmental entity in accordance with Section 3.12.

(2) **Requirement for Maintenance Agreement & Plan:** If a stormwater management design plan requires structural or nonstructural measures, the owner shall execute a stormwater maintenance agreement prior to the [**STORMWATER AUTHORITY**] granting final approval for the plan, or any plan of development or other development for which a permit is required under this Ordinance. The agreement shall be recorded in the office of the clerk of the circuit court for [**JURISDICTION**] and shall run with the land.

(3) **Required Elements for Maintenance Agreement & Plan:** The stormwater maintenance agreement shall be in a form approved by [**JURISDICTION**], and shall, at a minimum:

(a) **Designate Responsible Party:** Designate for the land development the owner, governmental agency, or other legally established entity (responsible party) which shall be permanently responsible for maintenance of the structural or non-structural measures required by the plan.

(b) **Pass Responsibility to Successors:** Pass the responsibility for such maintenance to successors in title.

(c) **Right of Entry for Stormwater Authority**: Grant the [**STORMWATER AUTHORITY**] and its representatives the right of entry for the purposes of inspecting all stormwater BMPs at reasonable times and in a reasonable manner. This includes the right to enter a property when the [**STORMWATER AUTHORITY**] has a reasonable basis to believe that a violation of this Ordinance is occurring or has occurred and to enter when necessary for abatement of a public nuisance or correction of a violation of this Ordinance.

(d) ***Maintenance Plan:*** *Ensure the continued performance of the maintenance obligations required by the plan and this ordinance through a maintenance plan (which may be an attachment to the actual maintenance agreement). The plan shall include a list of inspection and maintenance tasks, a schedule for routine inspection and maintenance, actions to be taken when maintenance is required, and other items listed in the Stormwater Design Manual.*

3.7. Easements

Storm drainage easements shall be required where the conveyance, storage, or treatment of stormwater is identified on the stormwater management design plan, or where access is needed to structural or non-structural stormwater measures.

The following conditions shall apply to all easements:

(1) Dimensions: Easements shall be of a width and location specified in the Stormwater Design Manual.

(2) Easements Approved Before Plat Approval: Easements shall be approved by the [JURISDICTION'S PLAN APPROVING AUTHORITY] prior to approval of a final plat and shall be recorded with the [JURISDICTION] and on all property deeds.

(3) Deeds of Easement: A deed of easement shall be recorded along with the final plat specifying the rights and responsibilities of each party to the easement.

3.8. Performance Bond or Guarantee

*(1) **Performance Bond or Guarantee Required:** No permits shall be issued unless the applicant furnishes a performance bond or guarantee. This is to ensure that action can be taken by [**JURISDICTION**], at the applicant's expense, should the applicant fail to initiate or maintain those measures identified in the approved stormwater management design plan (after being given proper notice and within the time specified by the [**STORMWATER AUTHORITY**]). If [**JURISDICTION**] takes such action upon such failure by the applicant, [**JURISDICTION**] shall collect from the applicant the difference should the amount of reasonable cost of such action exceed the amount of the security held.*

*(2) **Term of Performance Bond or Guarantee:** The performance bond or guarantee furnished pursuant to this section, or the unexpended or unobligated portion thereof, shall be returned to the applicant within sixty (60) days of issuance by the [**STORMWATER AUTHORITY**] of a Stormwater Certificate of Completion in accordance with Section 5, OR the final acceptance of the permanent stormwater BMP by the [**STORMWATER AUTHORITY**].*

*(3) **Term Extended for Initial Maintenance**: At the discretion of the [**STORMWATER AUTHORITY**], the performance bond or guarantee may be extended beyond the time period specified above to cover a reasonable period of time for testing the practices during storm events and for initial maintenance activities. For the purposes of this section, the time shall not exceed 2 years.*

*(4) **Partial Release of Bond:** The [**STORMWATER AUTHORITY**] shall have the discretion to adopt provisions for a partial pro-rata release of the performance bond or guarantee on the completion of various stages or phases of development.*

3.9. As-Built Plans

*All applicants are required to submit as-built plans for any permanent stormwater management facilities located on-site after final construction is completed. The plan must show the final design specifications for all stormwater management facilities, meet the criteria for as-built plans in the Stormwater Design Manual, and be sealed by a registered professional engineer. A final inspection by the [**STORMWATER AUTHORITY**] is required before any performance bond or guarantee will be released.*

3.10. Fees

The [**STORMWATER AUTHORITY**] has the ability to require a fee to support local plan review, inspection and program administration. Each owner seeking approval of a stormwater management concept plan or stormwater management design plan shall pay a fee upon submittal of such plan, and shall pay a fee for each inspection, in amounts according to the schedule set forth below.

(1) *Stormwater Management Concept Plan: $*
(2) Stormwater Management Design Plan: $
(3) Amendment to a Stormwater Management Concept or Design Plan: $
(4) Request for a Waiver: $
(5) Each Inspection: $

3.11. Fee-In-Lieu Payment

The [**STORMWATER AUTHORITY**] may maintain a Fee-In-Lieu and/or Pro-Rata Share program in accordance with an approved watershed or subwatershed plan or stormwater master plan. Such a program shall follow the general conditions of **Section 4.9.**

3.12. Dedication of Stormwater BMPs

The owner of a stormwater practice required by this Ordinance may offer for dedication any such stormwater practice, together with such easements and appurtenances as may be reasonably necessary, as provided herein:

(1) **Preliminary Determination by [STORMWATER AUTHORITY]**: Upon receipt of such offer of dedication by [**JURISDICTION**], the [**STORMWATER AUTHORITY**] shall make a preliminary determination that the dedication of the practice is appropriate to protect the public health, safety and general welfare, and furthers the goals of [**JURISDICTION'S**] stormwater management program and/or associated watershed plans. The [**STORMWATER AUTHORITY**] shall forward its determination to [**GOVERNING BOARD OF JURISDICTION**]. Prior to making its determination, the [**STORMWATER AUTHORITY**] shall inspect the practice to determine whether it has been properly maintained and is in good repair.

(2) **Acceptance by [GOVERNING BOARD]:** [**GOVERNING BOARD OF JURISDICTION**] may accept the offer of dedication by adoption of a resolution. The document dedicating the stormwater BMP shall be recorded in the office of the clerk of the circuit court for the [**JURISDICTION**].

(3) **Owner to Provide Documentation**: The owner, at his sole expense, shall provide any document or information requested by the [**STORMWATER AUTHORITY**] or the [**GOVERNING BOARD OF JURISDICTION**] in order for a decision to be reached on accepting the practice.

Section 4. Post-Construction Performance Criteria for Stormwater Management

4.1. General Post-Construction Stormwater Management Criteria

(1) **Stormwater BMP Maintenance:** All stormwater BMPs shall be maintained in accordance with the approved and deeded stormwater maintenance agreement and stormwater maintenance plan. The design of stormwater facilities shall incorporate maintenance accommodation and long-term maintenance reduction features in accordance with the latest version of the Stormwater Design Manual.

(2) **Overland Flood Routes:** Overland flood routing paths shall be used to convey stormwater runoff from the 100-year, 24-hour storm event to an adequate receiving water resource or stormwater BMP such that the runoff is contained within the drainage easement for the flood routing path and does not cause flooding of buildings or related structures. The peak 100-year water surface elevation along flood routing paths shall be at least one foot below the finished grade elevation at the structure. When designing the flood routing paths, the conveyance capacity of the site's storm sewers shall be taken into consideration.

(3) **Velocity Dissipation:** Velocity dissipation devices shall be placed at discharge locations and along the length of any outfall to provide non-erosive flow velocity from the structure to an adequate receiving stream or channel so that the natural physical and biological characteristics and functions of the receiving stream are maintained and protected.

(4) **Discharges to Adjacent Property:** Concentrated discharges from land development, including from stormwater practices, shall not be discharged onto adjacent developed property without adequate conveyance in a natural stream or storm sewer system. The [STORMWATER AUTHORITY] may require drainage easements where stormwater discharges must cross an adjacent or off-site property before reaching an adequate conveyance.

(5) **Individual Lots Not Separate Land Development:** Residential, commercial or industrial developments shall apply these stormwater management criteria to land development as a whole. Individual residential lots in new subdivisions shall not be considered separate land development projects, but rather the entire subdivision shall be considered a single land development project.

(6) **Location of Stormwater Facilities on Lots:** Stormwater facilities within residential subdivisions that serve multiple lots and/or a combination of lots and roadways shall be on a lot owned and maintained by an entity of common ownership, unless an alternative arrangement is approved by the [STORMWATER AUTHORITY]. Stormwater practices located on individual lots shall be maintained by the lot owner, or, at the discretion of the [STORMWATER AUTHORITY], be placed within an easement and maintained by an entity of common ownership.

(7) **Hydrologic Computation Assumptions:** Hydrologic parameters shall reflect the ultimate land development and shall be used in all engineering calculations. All pre-development calculations shall consider woods and fields to be in good condition, regardless of actual conditions at the time of application.

(8) **Authorization to Discharge to MS4:** If runoff from a land development will flow to a municipal separate storm sewer system (MS4) or other publicly-owned storm sewer system, then the applicant shall obtain authorization from the system’s owner to discharge into the system. The

[**STORMWATER AUTHORITY**] may require the applicant to demonstrate that the system has adequate capacity for any increases in peak flow rates and volumes.

(9) **Compliance with Federal & State Regulations:** All stormwater facilities and conveyance systems shall be designed in compliance with all applicable state and federal laws and regulations, including the Federal Clean Water Act and all applicable erosion and sediment control and flood plain regulations. To the extent practical, stormwater facilities shall not be located in areas determined to be jurisdictional waters through Section 404 of the Federal Clean Water Act and/or applicable state regulations.

(10) **Protect Public Health, Safety & General Welfare:** The design of stormwater BMPs shall consider public health, safety, and general welfare. These considerations include, but are not limited to: preventing flooding of structures and travelways; preventing standing water in facilities, manholes, inlets, and other structures in a manner that promotes breeding of mosquitoes; preventing attractive nuisance conditions and dangerous conditions due to velocity or depth of water and/or access to orifices and drops; and preventing aesthetic nuisances due to excessive slopes, cuts and fills, and other conditions.

(11) ***Adherence to Stormwater Design Manual:*** *All stormwater BMPs shall be designed to the standards of the most current version of the Stormwater Design Manual, unless the [**STORMWATER AUTHORITY**] grants the applicant a waiver or the applicant is exempt from such requirements.*

(12) ***Treat Entire Land Development:*** *The stormwater design shall provide for treatment of runoff from the entire land development, to the extent practical.*

(13) ***Landscape Plan:*** *The design of stormwater BMPs shall include a landscape plan detailing both the vegetation to be in the practice and how and who will manage and maintain the vegetation. The landscape plan shall be prepared in accordance with the Stormwater Design Manual.*

(14) ***Pretreatment:*** *Each stormwater BMP shall have an acceptable form of water quality pretreatment, in accordance with the pretreatment requirements found in the current Stormwater Design Manual.*

(15) ***Stormwater Authority Discretion:*** *If hydrologic, geologic, topographic, or land use conditions warrant greater control than that provided by the minimum control requirements, the [**STORMWATER AUTHORITY**] may impose additional requirements deemed reasonable and necessary to control the volume, timing, rate and/or quality of runoff. The [**STORMWATER AUTHORITY**] may restrict the use of certain stormwater BMPs, require pretreatment above the minimum standards in the Stormwater Design Manual, and/or require a stormwater pollution prevention plan in certain circumstances. These include, but are not limited to: stormwater generated from stormwater hotspots, stormwater discharges that are conveyed with non-stormwater discharges, and stormwater discharged in important groundwater management areas or areas where geologic conditions are conducive to groundwater contamination (e.g., karst).*

(16) ***Replicating Pre-Development Hydrology:*** *Stormwater management designs shall preserve the natural hydrologic functions, stream channel characteristics, and groundwater recharge of the pre-developed site, to the extent practical. This shall be accomplished by treating runoff at the source, disconnecting impervious surfaces, preserving or enhancing natural flow paths and vegetative cover, preserving or enhancing natural open spaces and riparian areas, and other measures that replicate pre-development hydrologic conditions. The [**STORMWATER AUTHORITY**] shall exercise*

discretion in the application of this standard, especially in cases of infill development, redevelopment, or other unique circumstances.

(17) ***Natural Resources Inventory:*** *Stormwater management designs shall include an inventory of important natural resources features on the site, and these features shall be shown on the Stormwater Management Concept Plan that may be prepared in accordance with Section 3.1. Protection and/or conservation of the site's natural features may, at the discretion of the [**STORMWATER AUTHORITY**], be used and given credit as "Non-Structural Measures" in accordance with Section 4.8. The natural resources inventory shall include, but not be limited to the following: natural drainage features, riparian buffers, wetlands, steep slopes, soils with high infiltration capacity, significant forest or prairie patches, and significant trees and natural communities.*

(18) ***Treatment of Off-Site Stormwater:*** *Off-site stormwater conveyed through a land development shall be placed within an easement and conveyed in a manner that does not increase upstream or downstream flooding. Off-site stormwater shall be conveyed around on-site stormwater BMPs, unless the facilities are designed to manage the off-site stormwater. The [**STORMWATER AUTHORIT**Y] may allow credits for treating off-site stormwater.*

(19) ***Stream & Wetland Crossings:*** *All stream and wetland crossings subject to Section 404 and/or state stream and wetland regulations shall minimize impacts on streams and wetlands, to the extent practical and achievable, by crossing streams and wetlands at a right-angle, reducing the footprint of grading and fill, and utilizing bridges, open bottom arches, spans, or other structures that do not restrict or alter stream or wetland hydrology. If culverts are placed within stream and wetlands, at least one culvert shall be countersunk or otherwise placed to allow the formation of a natural channel or wetland bottom to allow movement of aquatic organisms.*

4.2 Runoff Reduction Criteria

In order to replicate pre-development hydrologic conditions, and to promote baseflow to streams and wetlands, some portion of the post-development runoff shall be permanently reduced by disconnecting impervious areas, maintaining sheetflow to areas of natural vegetation, infiltration practices, and/or collection and reuse of runoff. The applicant shall use either (1) (2) or (3) below to comply with these criteria:

(1) Groundwater Recharge/Infiltration
Replicate the pre-development recharge volume, based on regional average recharge rates for hydrologic soil groups

- *Residential Sites: Post-development recharge = 90% of pre-development recharge*
- *Non-Residential Sites: Post-development recharge = 60% of pre-development recharge*

(2) Overall Runoff Reduction (Option 1)
No increase in the overall runoff volume compared to the pre-development condition for all storms less than or equal to the 2-year, 24-hour storm.

(3) Overall Runoff Reduction (Option 2)
Capture and remove from the site hydrograph the volume of water associated with the 80th percentile storm event (or other storm event deemed appropriate by the STORMWATER AUTHORITY).

*(4) This criterion shall be met using practices outlined in the **Stormwater Design Manual** that provide for the infiltration, evapotranspiration, and/or storage and reuse of runoff.*

(5) The volume of water needed for Runoff Reduction shall be considered part of the overall Water Quality Volume (WQv) required in Section 4.3, and shall not be in addition to the Water Quality Volume.

*The [**STORMWATER AUTHORITY**] may waive some or all of the requirements of this section as specified in (6) and (7) below:*

*(6) **Risk of Groundwater Contamination:** Stormwater hotspots, contaminated soils, and sites in close proximity to karst or drinking water supply wells may not be subject to groundwater recharge/infiltration requirements, as determined by the [STORMWATER AUTHORITY]. The [STORMWATER AUTHORITY] may impose reasonable conditions in granting such a waiver.*

*(7) **Site Constraints:** Areas characterized by high water table, shallow bedrock, clay soils, contaminated soils, and other constraints may be subject to reduced volume control requirements, as determined by the [STORMWATER AUTHORITY]. The [STORMWATER AUTHORITY] may impose reasonable conditions in granting such a waiver.*

*(8) **Documentation for Waiver:** When seeking a waiver in accordance with either (6) or (7) above, the applicant shall demonstrate that no reasonable alternatives for compliance exist through site and stormwater management design, and that stormwater discharges will not unreasonably increase the extent, frequency, or duration of flooding at downstream properties and structures or have an unreasonable adverse effect on streams, aquatic habitats, and channel stability. In making its determination to allow full or partial waivers, the [**STORMWATER AUTHORITY**] shall consider cumulative impacts and also the land development's adherence to the land use plans and policies of [**JURISDICTION**], including the promotion of infill and redevelopment in particular areas.*

4.3. Water Quality Criteria

Post-development runoff that is not permanently removed through the application of the runoff reduction criterion shall be captured and treated in a water quality BMP to prevent or minimize water quality impacts from land development. The applicant shall use (1) below to comply with this criterion:

(1) **Water Quality Volume Standard:** Structural and non-structural practices shall be designed to capture and treat the Water Quality Volume (WQv). The WQv shall be computed as follows, unless another volume is specified in the **Stormwater Design Manual**.

$WQv = [P \times Rv \times A]/12$, where:

P = rainfall depth generated by the 90% storm event (inches)

Rv = Site Runoff Coefficient = $Rv_I \times \%I + Rv_T \times \%T + Rv_F \times \%F$

Where:

Rv_I = runoff coefficient for impervious cover

%I = percent of site with impervious cover (fraction)

Rv_T = runoff coefficient for turf cover and disturbed soils
%T = percent of site with turf cover or disturbed soils (fraction)
Rv_F = runoff coefficient for forest cover or natural open space
%F = percent of site with forest cover or natural open space (fraction)

A = Area draining to stormwater BMP (acres)

Value for Rv_I, Rv_T, and, Rv_F shall be determined from the following table based on hydrologic soil groups present on the site.

Rv Coefficients				
	A soils	**B Soils**	**C Soils**	**D Soils**
Forest Cover & Natural Open Space	0.02	0.03	0.04	0.05
Turf Cover & Disturbed Soils	0.15	0.20	0.22	0.25
Impervious Cover	0.95	0.95	0.95	0.95

(2) This criterion shall be met using practices from the Stormwater Technology Table in the **Stormwater Design Manual**. BMPs or combinations of BMPs should be selected that achieve the highest pollutant load reduction for the pollutants of concern.

(3) All runoff removed through the runoff reduction criterion counts towards treating the WQv.

(4) ***Additional Criteria for Stormwater Hotspots:*** *In addition, stormwater discharges from stormwater hotspots may require the use of specific structural, non-structural, and/or pollution prevention practices, including enhanced pre-treatment. Discharges from a stormwater hotspot shall not be infiltrated without enhanced pre-treatment, as approved by the [**STORMWATER AUTHORITY**].*

4.4. Channel Protection Criteria

The stormwater system shall be designed so that post-development discharges will not erode natural channels or steep slopes. This will protect in-stream habitats and reduce in-channel erosion. The applicant shall use Tier 1 or Tier 2 performance standards, as applicable, to meet this criterion.

*(1) At each discharge point from the site, if the on-site drainage area is **less** than 10% of the total contributing drainage area to the receiving channel or waterbody, the following Tier 1 performance standards shall apply:*

<u>Tier 1 Performance Standards</u>

(a) Wherever practical, maintain sheetflow to riparian buffers or vegetated filter strips. Vegetation in buffers or filter strips must be preserved or restored where existing conditions do not include dense vegetation (or adequately sized rock in arid climates).
(b) Energy dissipaters and level spreaders must be used to spread flow at outfalls.
(c) On-site conveyances must be designed to reduce velocity through a combination of sizing, vegetation, check dams, and filtering media (e.g., sand) in the channel bottom and sides.
(d) If flows cannot be converted to sheetflow, they must be discharged at an elevation that will not cause erosion or require discharge across any constructed slope or natural steep slopes.

(e) Outfall velocities must be non-erosive from the point of discharge to the receiving channel or waterbody where the discharge point is calculated.

*(2) At each discharge point from the site, if the on-site drainage area is **greater** than 10% of the total contributing drainage area to the receiving channel or waterbody, then the Tier 1 performance standards in subsection (1) shall apply in addition to the following Tier 2 performance standards:*

<u>Tier 2 Performance Standards</u>

*(a) Sites greater than 10 acres (or a site size deemed appropriate by the [**STORMWATER AUTHORITY**]) must perform a detailed downstream (hydrologic and hydraulic) analysis based on post-development discharges. The downstream analysis shall extend to the point where post-development discharges have no significant impact, and do not create erosive conditions, on receiving channels, waterbodies, or storm sewer systems.*

(b) If the downstream analysis confirms that post-development discharges will have an impact on receiving channels, waterbodies, or storm sewer systems, then the site must incorporate some or all of the following to mitigate downstream impacts:

- *Site design techniques that decrease runoff volumes and peak flows.*
- *Downstream stream restoration or channel stabilization techniques, as permitted through local, state, and federal agencies.*
- *24-hour detention of the volume from the post-development 1-year, 24-hour storm. The [**STORMWATER AUTHORITY**] may give credit for the application of Runoff Reduction (Section 4.2) and WQv measures (Section 4.3) toward meeting storage requirements. Discharges to cold water fisheries should be limited to 12-hour detention.*

*(c) Sites less than 10 acres (or a site size deemed appropriate by the [**STORMWATER AUTHORITY**] shall verify that stormwater measures provide 12- to 24-hour detention of the volume from post-development 1-year, 24-hour storm. The [**STORMWATER AUTHORITY**] may give credit for the application of Runoff Reduction (Section 4.2) and WQv measures (Section 4.3) toward meeting storage requirements. A detailed downstream analysis is not required unless the local program identifies existing downstream conditions that warrant such an analysis.*

4.5. Flood Control Criteria

Downstream overbank flood and property protection shall be provided by controlling the post-development peak discharge rate to the pre-development rate. This criterion shall be met for the 10-year, 24-hour storm event, or other design storm(s) listed in the **Stormwater Design Manual.**

Stormwater BMPs that impound water shall demonstrate that the 100-year storm can safely pass through the structure without overtopping or creating damaging conditions downstream.

The [**STORMWATER AUTHORITY**] may waive some or all of the requirements of this section as specified in (1), (2), (3) and (4) below:

(1) **Discharge to Large Waterbody:** The land development discharges directly to a flood plain, ocean, or major river or waterbody, and the [STORMWATER AUTHORITY] determines that waiving the flooding criteria will not harm public health and safety. The applicant shall secure drainage easements from any downstream property owners across whose property the runoff must flow to reach the flood plain, ocean, or major river or waterbody. The applicant shall also demonstrate that

any piped or open-channel system in which the runoff will flow has adequate capacity and stability to receive the project's runoff plus any off-site runoff also passing through the system.

(2) **Insignificant Increases in Peak Flow:** The land development results in insignificant increases in peak flow rates, as determined by the [**STORMWATER AUTHORITY**].

(3) **Alternative Criteria Provided:** The land development is subject to a floodplain study that recommends alternative criteria for flood control.

(4) **Increases in Downstream Peak Flows or Flood Elevations:** The [**STORMWATER AUTHORITY**] determines that complying with the requirements of this section will result increases in peak flows or downstream flooding conditions due to coincident peaks from the site and the contributing watershed or another factor.

(5) **Documentation for Waiver:** When seeking a waiver in accordance with either (1), (2), (3) or (4) above, the applicant shall demonstrate that stormwater discharges will not unreasonably increase the extent, frequency, or duration of flooding at downstream properties and structures or have an unreasonable adverse effect on streams, aquatic habitats, and channel stability. In making its determination to allow full or partial waivers, the [**STORMWATER AUTHORITY**] shall consider cumulative impacts and also the land development's adherence to the land use plans and policies of [**JURISDICTION**], including the promotion of infill and redevelopment in particular areas.

4.6. Redevelopment Criteria

Land development that qualifies as redevelopment shall meet one of the following criteria:

(1) ***Reduce Impervious Cover:*** *Reduce existing site impervious cover by at least 20%.*

(2) ***Provide Treatment:*** *Provide Runoff Reduction and water quality treatment for at least 30% of the site's pre-development impervious cover and any new impervious cover through stormwater BMPs designed in accordance with the criteria in* ***Sections 4.2 through 4.3*** *and the* ***Stormwater Design Manual****.*

(3) ***Apply Innovative Approaches:*** *Utilize innovative approaches to reduce stormwater impacts across the site. Examples include green roofs and pervious parking materials. The local program can exercise flexibility with regard to sizing and design standards for sites that are fitting practices into existing drainage infrastructure.*

(4) ***Provide Off-Site Treatment:*** *Provide equivalent stormwater treatment at an off-site facility*

(5) ***Address Downstream Issues:*** *Address downstream channel and flooding issues through channel restoration and/or off-site remedies*

(6) Contribute to Watershed Project: *Contribute to a watershed project in accordance with* ***Section 4.9.***

(7) ***Combination of Measures:*** *Any combination of (1) through (6) above that is acceptable to the [****STORMWATER AUTHORITY****].*

4.7. Sensitive Waters and Wetlands: Enhanced Criteria

*Land development that discharges to sensitive waters and wetlands, as designated in the **Stormwater Design Manual**, shall meet enhanced criteria. These may include, but are not limited to:*

*(1) **Nutrient-Sensitive Waters:** Enhanced control of nutrients and sediment for discharges to drinking water reservoirs, lakes, estuaries, and/or coastal waters.*

*(2) **Cold-Water Fisheries:** Control of temperature increases for discharges to designated cold-water fisheries.*

*(3) **Groundwater:** Enhanced recharge and pre-treatment requirements to protect groundwater supply.*

*(4) **Wetlands**: The control of impacts to wetland hydrology, including limiting fluctuations to the natural or pre-development wetland hydrology.*

*(5) **Impaired Waters:** Enhanced bacteriological or pollutant controls for discharges to impaired waters, as designated in the most recent 303(d) list produced by EPA or the appropriate State agency.*

*In these cases, the [**STORMWATER AUTHORITY**] may require additional storage, treatment, filtering, infiltration, or other techniques. The use of non-structural practices shall be used to the maximum extent practical to meet enhanced criteria.*

*In making its determination to apply enhanced criteria, the [**STORMWATER AUTHORITY**] shall consider cumulative impacts and also the land development's adherence to the land use plans and policies of [**JURISDICTION**], including the promotion of infill and redevelopment in particular areas.*

4.8. Non-Structural Measures

*The use of nonstructural measures is encouraged to reduce sole reliance on structural stormwater management measures. The applicant may, if approved by the [**STORMWATER AUTHORITY**], take credit for the use of nonstructural measures as a means to comply with the criteria in **Sections 4.2 through 4.7**. For each potential credit, there is a minimum set of design criteria that identify the conditions or circumstances under which the credit may be applied. The site design practices that qualify for this credit and the criteria and procedures for applying and calculating the credits shall be included in the **Stormwater Design Manual**.*

4.9. Contribution to a Watershed Project: Fee-in-Lieu & Pro-Rata Share

The [**STORMWATER AUTHORITY**] shall establish the criteria and conditions by which a project is eligible for a fee-in-lieu payment for off-site and watershed enhancements. The [**STORMWATER AUTHORITY**] may allow a fee-in-lieu payment, according to the established criteria and conditions, in lieu of partial or full on-site compliance with the requirements of this Ordinance.

Provided that the [**STORMWATER AUTHORITY**] implements a program in accordance with **Section 3.11**, land development projects that are within the target or drainage area of a watershed or subwatershed management plan adopted by the **[STORMWATER AUTHORITY**], [**JURISDICTION**], and/or another appropriate local, regional, or state agency or program, shall comply with the following:

(1) **On-Site Projects**: If the watershed or subwatershed management plan identifies specific projects on the applicant's property, the [**STORMWATER AUTHORITY**] may allow implementation of some or all of these projects as part of the stormwater management design plan to satisfy, in part or in whole, the criteria in Sections 4.2 through 4.7.

(2) **Fee-in-Lieu Contribution for Off-Site Projects:** The [**STORMWATER AUTHORITY**] may allow a fee-in-lieu contribution to off-site watershed project(s) identified in the management plan to satisfy, in part or in whole, the criteria in Sections 4.2 through 4.7. The fee-in-lieu contribution shall be in accordance with the fee schedule adopted by [**JURISDICTION**] and maintained by the [**STORMWATER AUTHORITY**].

(3) **Regional Stormwater Management:** If the land development is within the drainage area of an existing or planned regional stormwater BMP identified in the management plan, the applicant shall pay a pro-rata share of the cost of implementing the practice. The pro-rata share contribution shall be in accordance with the fee schedule adopted by [**JURISDICTION**] and maintained by the [**STORMWATER AUTHORITY**]. If a project is eligible for a fee-in-lieu and pro-rata share contribution, then the [**STORMWATER AUTHORITY**] shall determine one or the other fee or contribution for the project to pay.

(4) **Other Off-Site Projects:** In certain circumstances dictated by the [**STORMWATER AUTHORITY**], the applicant may propose an off-site watershed solution as a means to comply, in part or in whole, with the criteria in **Sections 4.2 through 4.7**. In these cases, the [**STORMWATER AUTHORITY**] shall require submission of a comprehensive watershed study that includes sufficient information to evaluate impacts of the proposed solution on runoff rates, water quality, volumes and velocities, and environmental characteristics of the affected areas. The [**STORMWATER AUTHORITY**] may approve the watershed solution as a means to comply with **Sections 4.2 through 4.7**, in part or in whole, if the watershed solution provides better overall protection for water resources than strict application of the on-site criteria. In all cases, land rights, access agreements or easements, and a maintenance agreement and plan shall be provided to ensure long-term maintenance of any off-site watershed project.

Nothing in the subsection shall compel the [**STORMWATER AUTHORITY**] to approve a plan that, in its determination, may pose a threat to public health, safety, or the environment. In approving a contribution to a watershed project, the [**STORMWATER AUTHORITY**] may apply conditions necessary to protect downstream property and environmental resources.

4.10. Waivers

Every applicant shall provide for stormwater management as required by this Ordinance, unless a written request for a waiver is filed and approved by the [STORMWATER AUTHORITY]. Prior to applying for a waiver request, the applicant must demonstrate that all reasonable options to comply with Ordinance have been exhausted, including the use of non-structural measures (**Section 4.8**) and/or construction or contribution to a watershed project (**Section 4.9**).

The request for a waiver must be in writing and must include waiver fee specified in **Section 3.10**. The [**STORMWATER AUTHORITY**] shall respond in writing by granting or denying the waiver in full, or granting the waiver with any necessary conditions or mitigation measures to protect public health, safety, and the environment. The applicant shall note any full or partial waivers, and conditions imposed by the [**STORMWATER AUTHORITY**], on the stormwater management design plan.

Section 5. Construction Inspection for Permanent Stormwater BMPs

5.1. Notice of Construction Commencement

The applicant must notify the [**STORMWATER AUTHORITY**] before the commencement of construction. In addition, the applicant must notify the [**STORMWATER AUTHORITY**] in advance of construction of critical components of the stormwater practices on the approved stormwater management design plan. The [**STORMWATER AUTHORITY**] may, at its discretion, issue verbal or written authorization to proceed with critical construction steps, such as installation of permanent stormwater practices based on stabilization of the drainage area and other factors.

5.2. Construction Inspections by [STORMWATER AUTHORITY] or its Representatives

The [**STORMWATER AUTHORITY**] or its representatives shall conduct periodic inspections of the stormwater practices shown on the approved stormwater management design plan, and especially during critical installation and stabilization steps. All inspections shall be documented in writing. The inspection shall document any variations or discrepancies from the approved plan, and the resolution of such issues. Additional information regarding inspections can be found in the **Stormwater Design Manual**. A final inspection by the Stormwater Authority is required before any performance bond or guarantee, or portion thereof, shall be released.

5.3. Inspection by Certified Inspector

At its discretion, the [**STORMWATER AUTHORITY**] may authorize the use of private inspectors to conduct and document inspections during construction. Such private inspectors shall submit all inspection documentation in writing to the **[STORMWATER AUTHORITY**]. All costs and fees associated with the use of private inspectors shall be the responsibility of the applicant.

If the use of private inspectors in authorized, the [**STORMWATER AUTHORITY**] shall maintain a training and certification program, or authorize another entity to maintain such a program. All private inspectors shall be certified prior to conducting any inspections or submitting any inspection documentation to the [**STORMWATER AUTHORITY**].

If private inspectors are utilized, then inspections by the [**STORMWATER AUTHORITY**] or its representatives, as provided in **Section 6.2**, may be reduced in frequency. However, the [**STORMWATER AUTHORITY**] shall remain the responsible entity for ultimate inspection, approval, and acceptance of all stormwater BMPs, and for issuance of the Certificate of Completion in accordance with **Section 5.5**.

5.4. Stormwater Certificate of Completion

Subsequent to final installation and stabilization of all stormwater BMPs shown on the stormwater management design plan, submission of all necessary as-built plans, and final inspection and approval by the [**STORMWATER AUTHORITY**], the [**STORMWATER AUTHORITY**] shall issue a Stormwater Certificate of Completion for the project. In issuing such a certificate, the [**STORMWATER AUTHORITY**] shall determine that all work has been satisfactorily completed in conformance with this Ordinance.

Section 6. Ongoing Maintenance for Stormwater BMPs

6.1. Maintenance Responsibility

The responsible party named in the recorded stormwater maintenance agreement (**Section 3.6**) shall maintain in good condition and promptly repair and restore all structural and non-structural stormwater BMPs and all necessary access routes and appurtenances (grade surfaces, walls, drains, dams and structures, vegetation, erosion and sedimentation controls, and other protective devices). Such repairs or restoration and maintenance shall be in accordance with the approved stormwater management design plan, the stormwater maintenance agreement, and the stormwater maintenance plan.

6.2. Maintenance Inspection by [STORMWATER AUTHORITY] or its Representatives

The [**STORMWATER AUTHORITY**] or its representatives shall conduct periodic inspections for all stormwater practices for which a Stormwater Certificate of Completion has been issued in accordance with Section 5.5. All inspections shall be documented in writing. The inspection shall document any maintenance and repair needs and any discrepancies from the stormwater maintenance agreement and stormwater maintenance plans.

6.3. Maintenance Inspection by Certified Inspector

At its discretion, the [**STORMWATER AUTHORITY**] may authorize the use of private inspectors to conduct and document ongoing maintenance inspections. Such private inspectors shall submit all inspection documentation in writing to the [**STORMWATER AUTHORITY**]. All costs and fees associated with the use of private inspectors shall be the responsibility of the responsible party.

If the use of private inspectors is authorized, the [**STORMWATER AUTHORITY**] shall maintain a training and certification program, or authorize another entity to maintain such a program. All private inspectors shall be certified prior to conducting any inspections or submitting any inspection documentation to the [**STORMWATER AUTHORITY**].

If private inspectors are utilized, then inspections by the [**STORMWATER AUTHORITY**] or its representatives, as provided in **Section 6.2**, may be reduced in frequency. However, the [**STORMWATER AUTHORITY**] shall remain the responsible entity for ultimate inspection of stormwater practices and any enforcement actions necessary under **Section 7 of this Ordinance**.

6.4. Records of Maintenance Activities

The responsible party shall make records of the installation and of all maintenance and repairs, and shall retain the records for at least five (5) years. These records shall be made available to the [**STORMWATER AUTHORITY**] during inspection of the practice and at other reasonable times upon request.

6.5. Failure to Provide Adequate Maintenance

In the event that the stormwater BMP has not been maintained and/or becomes a danger to public safety or public health, the [**STORMWATER AUTHORITY**] shall notify the responsible party by registered or certified mail. The notice shall specify the measures needed to comply with the maintenance agreement and the maintenance plan and shall specify that the responsible party has thirty (30) days or other time frame mutually agreed to between the [**STORMWATER AUTHORITY**] and the responsible party, within which such measures shall be completed. If such measures are not completed, then the [**STORMWATER AUTHORITY**] shall pursue enforcement procedures pursuant to Section 7 of this Ordinance.

If a responsible person fails or refuses to meet the requirements of an inspection report, maintenance agreement, or maintenance plan the [**STORMWATER AUTHORITY**], after thirty (30) days written notice (except, that in the event the violation constitutes an immediate danger to public health or public safety, 24 hours notice shall be sufficient), may correct a violation of the design standards or maintenance requirements by performing the necessary work to place the practice in proper working condition. The [**STORMWATER AUTHORITY**] may assess the responsible party of the practice for the cost of repair work which shall be a lien on the property, or prorated against the beneficial users of the property, and may be placed on the tax bill and collected as ordinary taxes by [**JURISDICTION**].

Section 7. Violations, Enforcement and Penalties

7.1. Violations

Any action or inaction which violates the provisions of this Ordinance, the requirements of an approved stormwater management design plan or permit, and/or the requirements of a recorded stormwater maintenance agreement may be subject to the enforcement actions outlined in this Section. Any such action or inaction is deemed to be a public nuisance and may be abated by injunctive or other equitable relief. The imposition of any of the penalties described below shall not prevent such equitable relief.

7.2. Notice of Violation

If the [**STORMWATER AUTHORITY**] or [**JURISDICTION**] determines that an applicant or other responsible person has failed to comply with the terms and conditions of a permit, an approved stormwater management design plan, a recorded stormwater management maintenance agreement, or the provisions of this ordinance, it shall issue a written notice of violation to such applicant or other responsible person. Where a person is engaged in activity covered by this ordinance without having first secured a permit therefore, the notice of violation shall be served on the owner or the responsible person in charge of the activity being conducted on the site.

The notice of violation shall contain:

(1) The name and address of the owner or the applicant or the responsible person;

(2) The address or other description of the site upon which the violation is occurring;

(3) A statement specifying the nature of the violation;

(4) A description of the remedial measures necessary to bring the action or inaction into compliance with the permit, the stormwater management design plan, the stormwater maintenance agreement, or this ordinance and the date for the completion of such remedial action;

(5) A statement of the penalty or penalties that may be assessed against the person to whom the notice of violation is directed; and,

(6) A statement that the determination of violation may be appealed to **[GOVERNING BOARD OF JURISDICTION]** by filing a written notice of appeal within thirty (30) days after the notice of violation (except, that in the event the violation constitutes an immediate danger to public health or public safety, 24 hours notice shall be sufficient).

7.3. Penalties

In the event the remedial measures described in the notice of violation have not been completed by the date set forth for such completion in the notice of violation, any one or more of the following actions or penalties may be taken or assessed against the person to whom the notice of violation was directed.

(1) **Stop Work Order:** The **[STORMWATER AUTHORITY]** or **[JURISDICTION]** may issue a stop work order which shall be served on the applicant or other responsible person. The stop work order shall remain in effect until the applicant or other responsible person has taken the remedial measures set forth in the notice of violation or has otherwise cured the violation or violations described therein, provided the stop work order may be withdrawn or modified to enable the applicant or other responsible person to take the necessary remedial measures to cure such violation or violations.

(2) **Withhold Certificate of Occupancy:** The **[STORMWATER AUTHORITY], [JURISDICTION'S PERMIT ISSUING AUTHORITY]**, or **[JURISDICTION]** may refuse to issue a certificate of occupancy for the building or other improvements constructed or being constructed on the site until the applicant or other responsible person has taken the remedial measures set forth in the notice of violation or has otherwise cured the violations described therein.

(3) **Suspension, Revocation or Modification of Permit:** The **[STORMWATER AUTHORITY]** or **[JURISDICTION]** may suspend, revoke or modify the permit authorizing the land development project. A suspended, revoked or modified permit may be reinstated after the applicant or other responsible person has taken the remedial measures set forth in the notice of violation or has otherwise cured the violations described therein, provided such permit may be reinstated upon such conditions as the **[STORMWATER AUTHORITY]** or **[JURISDICTION]** may deem necessary to enable the applicant or other responsible person to take the necessary remedial measures to cure such violations.

(4) ***Civil Penalties:*** *In the event the applicant or other responsible person fails to take the remedial measures set forth in the notice of violation, the* ***[STORMWATER AUTHORITY]*** *or* ***[JURISDICTION]*** *may impose a penalty not to exceed $1,000 (depending on the severity of the violation) for each day the violation remains unremedied after receipt of the notice of violation. A schedule of civic penalties is outlined in the table below.*

Violation	Penalty
Failure to submit and receive approval of a stormwater management design plan prior to construction	**[$ 1,000]**
Failure to submit and receive approval of a stormwater maintenance agreement and plan prior to construction	**[$ 500]**
Failure to install stormwater BMP(s) as indicated on the approved stormwater management design plan	**[$ 750]**
Failure to notify Stormwater Authority before commencement of construction	**[$ 500]**
Failure to maintain stormwater BMP within 30 days of notification (See Section 6.5 for more detail)	**[$ 750]**

(5) **Criminal Penalties**: For intentional and flagrant violations of this ordinance, the **[STORMWATER AUTHORITY]** or **[JURISDICTION]** may issue a citation to the applicant or other responsible person, requiring such person to appear in **[APPROPRIATE MUNICIPAL, MAGRISTRATE, OR RECORDERS]** court to answer charges for such violation. Upon conviction, such person shall be punished by a fine not to exceed $1,000 or imprisonment for 60 days or both. Each act of violation and each day upon which any violation shall occur shall constitute a separate offense.

7.4. Appeals

The decisions or orders of the **[STORMWATER AUTHORITY]** or [**JURISDICTION]** shall be final. Further relief shall be to a court of competent jurisdiction.

7.5. Remedies Not Exclusive

The remedies listed in this Ordinance are not exclusive of any other remedies available under any applicable federal, state or local law.

Approved by: _____ Date _____

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34. Appendix K: Watershed Partnership Groups

Dickinson Bayou Watershed Partnership Advisory Committee
Armand Bastein, Larry Bigelow, Heather Biggs, Linda Broach, Brian Craig, Jan Culbertson, Kevin Cunningham, Michael Cunningham, Gabi DelaRosa, Winston Denton, Meredith Fant, Rebekah Gano, George Guillen, Mike Hogan, Ken Hoffstetler, John Jacob, Rick Johnson, Steven Johnston , Scott Jones, Jared Judy, Jim Keese, Brian Koch, Julie Masters, Carl Masterson, Jim McBride, Jack Murphy, Wes Padgett, George Regmond, Sean Rosenberry, Ronnie Schultz, Marissa Sipocz, Elsie Smith, Sara Snell, Jessica Stephens, Holli Swick, Mary Alice Trumble, Aaron Wendt, Berna Dette Williams, Jean Wright, Peggy Wright

Dickinson Bayou Watershed Partnership Chairs
Rick Johnson (Current Co-Chair)
Wes Padget (Current Co-Chair)
Sara Snell (Past Chair)

Dickinson Bayou Watershed Partnership Workgroups

Flooding and Stormwater: Aaron Wendt, Al Louviere, Brain Craig, Brett Bercher, Carl Masterson, Heather Biggs, Ivan Langford, Jack Murphy, Jason Christain, Jim McBride, Ray and Sherrie Jones

Habitat: Charriss York, George Regmond, Jan Culbertson, Jared Judy, Jim Keese, Marissa Sipocz, Mary Alice Trumble, Pat Windstar, Wes Padgett

Land Use: Armand Bastein, Berna Dette Williams, Brian Koch, Heather Biggs, Holli Swick, John Jacob, Julie Masters, Laura Bowers, Laura Sykes, Meredith Fant, Rebekah Gano, Steven Johnston

Outreach and Education: Elsie Smith, Heather Biggs, Kevin Cunningham, Mary Villareal, Rebekah Gano, Sara Snell, Scott Jones

Recreation: Elaine Britcliffe, Jan Culbertson, Joe Privat, Joel and Pat Christie, Kathie Derrick, Kathleen Kirst, Ken Hufstetler, Mary Dunbaugh, P. Robinson, Ray and Sherry Jones, Rick Johnson, Sam Reichek

Water Quality: Antonietta Quigg, George Guillen, Jean Wright, Linda Broach, Steven Johnston, Winston Denton, Michael Cunningham, Roger Miranda

35. EPA 9 Elements Summary and Crosswalk

The EPA has identified nine specific items that should be present in a watershed protection plan[86]. They are:

A. Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be indentified at the significant subcategory level along with estimates of the extent to which they are present in the watershed.
B. An estimate of the load reductions expected from management measures.
C. A description of the nonpoint source management measures that will need to be implemented to achieve load reductions, and a description of the critical areas in which those measures will be needed to implement this plan.
D. Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.
E. An information and education component used 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.
F. Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.
G. A description of interim measureable milestones for determining whether nonpoint source management measures or other control actions are being implemented.
H. A set of 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.
I. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item 8 above.

These nine elements are incorporated throughout the watershed plan, where most appropriate. Below is a table summarizing these elements for the Dickinson Bayou Watershed Protection Plan.

[86] U.S. EPA. 2008. Handbook for Developing Watershed plans to Restore and protect Our Waters. EPA 841-B-08-002.

EPA Element	Location in Plan
Element A Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be indentified at the significant subcategory level along with estimates of the extent to which they are present in the watershed.	Chapter 3
Element B An estimate of the load reductions expected from management measures.	Chapter 22: Table 22, Table 23, and Table 24
Element C A description of the nonpoint source management measures that will need to be implemented to achieve load reductions, and a description of the critical areas in which those measures will be needed to implement this plan.	Chapter 14, Chapter 15, Chapter 17, Chapter 18, and Chapter 19
Element D Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.	Plan Strategies & Milestones table page 128, "Funding Mechanism" column Also in Chapter 14, Chapter 15, Chapter 17, Chapter 18, and Chapter 19 under the heading "Financial Requirements"
Element E An information and education component used 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.	Chapter 13 Also mentioned in Chapter 14, Chapter 15, Chapter 17, Chapter 18, and Chapter 19 under the heading "Education and Outreach"

Element F Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.	Summary of Milestones Table, pages 13-16
Element G A description of interim measureable milestones for determining whether nonpoint source management measures or other control actions are being implemented.	Plan Strategies & Milestones table page 128 "Milestones, short term" column
Element H A set of 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.	Criteria are listed as short term load reductions in the "Plan Strategies & Milestones" table, page 128 "Milestones, short term" column
Element I A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item H above.	Chapter 21

36. Glossary

303(d). Refers to section 303(d) of the Clean Water Act. Every two years, states must assess the quality of their water and submit a report to the EPA detailing the extent to which each water body in the state meets water quality standards. The TCEQ publishes this assessment as the Texas Water Quality Inventory and 303(d) List. The Inventory gives the status of all surface water bodies of the state that were evaluated for the given assessment period. The 303(d) List is an important management tool produced as part of the assessment. It identifies waters for which preventive measures are not sufficient to achieve established water quality standards. These waters are often referred to as “impaired” water bodies.

Best Management Practice (BMP). Structural and nonstructural techniques that store or treat stormwater runoff to reduce flooding, remove pollutants, and provide other amenities.

Biological Oxygen Demand (BOD). The amount of oxygen consumed by the natural decomposition of biological matter or chemical reactions in the water column. BOD is often used as a measure of organic pollutants discharged into streams. BOD loadings tend to deplete oxygen water in the receiving body as the organic material is decomposed, lowering dissolved oxygen content.

Chlorophyll-a. The primary photosynthetic pigment of plants that gives them their green color. Measured as an indicator of water quality. High levels of chlorophyll-a may indicate an algal bloom.

Coastal floodplain flooding. (Also called “storm surge flooding.”) When the storm surge associated with a hurricane or tropical disturbance pushes water onshore and inundates low lying coastal areas.

Conservation easement. A legally enforceable agreement between landowner(s) and a conservation group or government body, allowing the landowner(s) to continue ownership and most/all current uses while devoting the land to specified long-term conservation uses.

Conductivity. The ability of a water sample to conduct electricity. Conductivity is related to salinity, and is a measure of the concentration of dissolved solids or salts in the water.

Cone of Subsidence. The cone-shaped subsidence of the water table caused by over withdrawal (overpumping) of groundwater, which lowers the water table.

Dissolved Oxygen (DO). The concentration of oxygen dissolved in the water column, and available for biochemical activity. The amount of water that can dissolve in water varies with salinity and temperature, such that cold, fresh water can hold more oxygen when fully saturated than warm, salt water.

Ecological footprint. The extent and breadth of impacts that an activity has on the surrounding ecosystem. For example, the placement of a wide, well-maintained utility easement through the middle of a contiguous, pristine forest would be considered to have a much larger ecological

footprint than the clearing of a few trees at the forest's edge for a road sign. The easement would bisect a previously intact ecosystem, create extensive forest edge, and provide opportunities for penetrations of new species such as the Brown-headed Cowbird, all of which can significantly alter the system's ecology, while removing a few trees at the forest's edge would not likely have serious ecological impacts.

Estuary. A semi-enclosed system comprising a transition from freshwater to marine environments, where freshwater from rivers, bayous and tributaries mixes with salt water from an ocean. This mixing provides a unique environment that houses diverse flora and fauna. The Galveston Bay estuary is a highly productive, nutrient rich ecosystem that provides critical nursery areas for juvenile marine organisms such as shrimp, oysters, crabs, and numerous fish species.

Estuarine. Adjective, of or relating to an estuary. Example: estuarine ecology.

Eutrophic. Characterized by an excess accumulation of nutrients, increased algal production, and low dissolved oxygen levels.

Fecal coliform bacteria. Bacteria found in the intestinal tracts of warm-blooded animals. These organisms are used as indicators of fecal pollution and the possible presence of waterborne pathogens.

Flood Damage Reduction Plan (FDRP). Map developed to lessen the damages to an area caused by flooding that can include a combination of structural and non-structural elements.

Flood Insurance Rates Map (FIRM). Map showing the areas subject to flooding from a primary flooding source, typically major rivers, channels and their tributaries, and are meant to help determine the risk of flooding for a property. The FIRMs show floodplains based on a 1% flood, and sometimes floodplains based on a 2% flood

Floodplain. A strip of relatively level land bordering a stream, built of sediment carried by the stream and dropped in the slack water beyond the influence of the swiftest current. It is called a living floodplain if it is overflowed in times of high water, or a fossil floodplain if it is beyond the reach of the highest flood.

Habitat. (Also called "natural area.") Habitat refers to natural areas that are suitable for wildlife, and that retain at least some of their natural character.

Impaired waterbody. A waterbody is impaired when it does not support the uses established for it by the Texas Surface Water Quality Standards. Impaired waterbodies are listed on the Texas 303(d) list.

Impervious cover. Groundcover, natural or manmade, that does not allow storm water to infiltrate into the ground. Examples of impervious cover include pavement, buildings and rock.

Indicator. Measurable quantity of a chemical (i.e., elements or compounds) or biota (i.e., organisms, species, or communities) that can be used to evaluate the relationship between pollutant sources and their impact on environmental conditions.

Low Impact Development (LID). A technique to maintain or mimic predevelopment runoff conditions through a variety of small landscape features that infiltrate, filter, store, evaporate, and detain runoff close to its source. LID addresses stormwater through small, cost-effective landscape features located at the lot level.

Macroinvertebrate. Macroinvertebrates are invertebrate animals, animals without vertebral columns or spinal chords, which are visible to the naked eye. Those that inhabit the bottom of water bodies are referred to as benthic macroinvertebrates, or benthos. Macroinvertebrates are critical links in the food webs of aquatic systems. As many are sensitive to pollutants, and are often fairly immobile compared to fish species, they are useful indicators of water quality.

Main stem. The major channel of a waterbody into which tributaries flow.

Microgram (µg). One one-millionth of a gram; 10-6 gram.

Mima mound (Also called “pimple mound.”) Circular to elliptical mounds up to 150 feet in diameter and two to four feet in height from the general ground level. These features are often found in association with freshwater depressional wetlands in prairie pothole complexes.

Most Probable Number. A statistical estimate of the number of microbes in a known amount of water (usually 100mL); used when it is not feasible to count individual organisms.

Natural area. (Also called “habitat.”) Habitat refers to natural areas that are suitable for wildlife, and that retain at least some of their natural character.

Nitrates. Nitrates are compounds containing the nitrate ion (NO3-). Nitrates are important nutrients for green plants.

Nitrites. Nitrates are compounds containing the nitrite ion (NO2-), often produced by bacterial processing of ammonia. Nitrites are toxic to many animal species, as they bind to hemoglobin and interfere with respiration.

Non-point source (NPS). Pollution originating from many diffuse sources rather than one specific, identifiable source. Non-point source pollution is caused by rainfall or snowmelt. As the runoff moves, it picks up and carries away natural and man-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and groundwater.

Non-point source pollution. Pollution originating from many diffuse sources rather than one specific, identifiable source.

Nutrient. Any substance used by living things to promote growth. This term is usually applied to nitrogen and phosphorous in water and wastewater, but can also be applied to other essential

and trace elements. Excess quantities of nutrients can contribute to water quality problems and eutrophication.

Open space. Any undeveloped area, and includes natural habitat as well as parks, pastures, and water.

Overbank flooding. (Also called “shallow floodplain” flooding). Occurs when water level in stream or channel rises to a level higher than the channel bank, inundating the area adjacent to the channel.

Pervious cover. Groundcover, natural or manmade, that allows storm water runoff to infiltrate into the ground.

Phosphorus (Total P). Phosphorus is an essential nutrient in plant growth. Total phosphorus is a measure of all the various forms of phosphorus that are found in a water sample. Excess phosphorus can contribute to algal blooms and eutrophication.

Photosynthesis. The process by which many plants and algae convert energy in sunlight to chemical forms of energy that can be used by biological systems.

Phytoplankton. Photosynthetic aquatic organisms carried about by water motion. Phytoplankton are primary producers and form the foundation of the food chain in many ecosystems.

Pimple mound. (Also called “mima mound.”) Circular to elliptical mounds up to 150 feet in diameter and two to four feet in height from the general ground level. Pimple mounds are often found in association with freshwater depressional wetlands in prairie pothole complexes.

Point source. Any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, discrete fissure, or container. It also includes vessels or other floating craft from which pollutants are or may be discharged. By law, the term “point source” also includes concentrated animal feeding operations, which are places where animals are confined and fed.

Point source pollution. Pollutants that come from a concentrated, discernable originating point, such as a pipe from a municipal wastewater treatment plant or factory or a large registered feedlot with a specific point of discharge.

Prairie pothole. Circular to irregular, undrained depressions scattered on the ground surface. These features are most often remnants of ancient river channels, partially filled with sediments, and abandoned by natural migration of the river channels. These potholes seasonally fill with water and are important in retaining water during rain events, processing pollutants and retaining sediments to improve the quality of water that eventually winds up in streams, and provides important habitat for a diversity of plant and animal species, notably waterfowl.

Rain Garden. A garden used to capture water during rainfall events. These gardens are usually planted with wetland or bog plants, which help in processing pollutants and trapping sediments, resulting in cleaner water runoff.

Respiration. In this document, reference is made to cellular respiration. Cellular respiration is the use of oxygen by living organisms during metabolic processes that generate energy.

Riparian. Pertaining to the banks of a stream.

Runoff. See Stormwater Runoff.

Salinity. The concentration of dissolved salts in water.

Secci Depth. The depth at which a standard black-and-white disc is indistinguishable from the surrounding water. Secci depth is used as a measure of water clarity, or turbidity (see definition below).

Sediment. Particles of sand, clay, silt, and plant matter deposited in slow moving areas of streams and rivers and in reservoirs and estuaries.

Smart growth. a compact, efficient, and environmentally sensitive pattern of development that preserves open spaces and agricultural lands by creating walkable pedestrian and transit-oriented communities that enable a high degree of social interaction and cohesion.

Storm surge flooding. (Also called “coastal floodplain” flooding.).Occurs when the storm surge associated with a hurricane or tropical disturbance pushed water onshore and inundates low lying coastal areas.

Shallow floodplain flooding. (Also called “overbank” flooding.) Occurs when water level in stream or channel rises to a level higher than the channel bank, inundating the area adjacent to the channel.

Stormwater. Runoff from land and impervious areas such as paved streets, parking lots, and building rooftops during rainfall and snow events.

Stormwater runoff. (Also called “runoff.”) Rainfall that does not evaporate or infiltrate into the ground but instead flows across land and into waterbodies.

Total Maximum Daily Load (TMDL). Maximum amount of pollutant loading that a waterbody segment can receive and still support water quality standards/designated uses.

Toxicity. The degree to which a substance is harmful to the health of humans or other organisms.

Trophic. Trophic state of a waterbody refers to its nutritional status. Various classification schemes exist that group waterbodies into discrete trophic (quality) states along a continuum from oligotrophic (poorly nourished) to mesotrophic to eutrophic to hypereutrophic (overnourished).

Turbidity. A measure of the cloudiness of water, which is a function of the amount of suspended material, both organic and inorganic. Typically turbidity is measured by determining the extent to which light is attenuated in passing through water.

Water column. Refers to the vertical region in a water body anywhere between the surface and the bottom, but not inclusive of the surface or bottom.

37. Acronyms

BFE	Base Flood Elevation Base Flood Elevation
BMP	Best Management Practice
CBOD	Carbonaceous Biological Oxygen Demand
CCC	Coastal Coordination Council
CWA	Clean Water Act
DO	Dissolved Oxygen
EA	Environmental Assessment
EFDC	Environmental Fluid Dynamics Code
EIH	Environmental Institute of Houston
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act Endangered Species Act
FBFM	Flood Boundary and Floodway Map
FEMA	Federal Emergency Management Agency
FHBM	Flood Hazard Boundary Maps
FIRM	Flood Insurance Rate Map
GBEP	Galveston Bay Estuary Program
GBF	Galveston Bay Foundation
GBIC	Galveston Bay Information Center
GLO	Texas General Land Office
H-GAC	Houston-Galveston Area Council
HGCSD	Harris-Galveston Coastal Subsidence District
HHW	Household Hazardous Waste
HMGP	Hazard Mitigation Grant Program
HSPF	Hydrologic Simulation Program - Fortran

KDB	Keep Dickinson Beautiful
LID	Low Impact Development
LIDAR	Light Detection and Ranging
LLT	Legacy Land Trust
mg/L	Milligrams (1/1,000 gram) per liter, a unit of measure for concentration
MS4	Municipal separate storm sewer systems
MPN	Most Probable Number
NEPA	National Environmental Protection Act
NFIP	National Flood Insurance Program
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NRCS	Natural Resources Conservation Service
NWF	National Wildlife Federation
OSSF	On-site Sewage Facility
OWOW	EPA's Office of Wetlands, Oceans, and Watersheds
PPT	Parts Per Thousand
SAV	Submerged Aquatic Vegetation
SEP	Supplemental Environmental Project Program of the Texas Commission on Environmental Quality
SFHA	Special Flooding Hazard Area
SWMP	Stormwater Management Program
SSURGO	Soil Survey Geographic
TCEQ	Texas Commission of Environmental Quality
TCWP	Texas Coastal Watershed Program (Texas Sea Grant / Texas AgriLife Extension Service)
TGLO	Texas General Land Office

TNC	The Nature Conservancy
TNRIS	Texas Natural Resources Information System
TPDES	Texas Pollution Discharge Elimination System
TPL	The Trust for Public Land
TPWD	Texas Parks and Wildlife Department
TSARP	Tropical Storm Allison Recovery Project
TSG	Texas Sea Grant College Program
TSS	Total Suspended Solids
TWDB	Texas Water Development Board
TWPC	Texas Water Policy Council
UHCL	University of Houston - Clear Lake
USACE	U.S. Army Corps of Engineers
USDA NRCS	Natural Resources Conservation Service, of the U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service, of the U.S. Department of the Interior
USGS	U.S. Geological Survey

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