STATE OF THE WATERSHED

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

---

[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

[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

---

[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.

---

[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

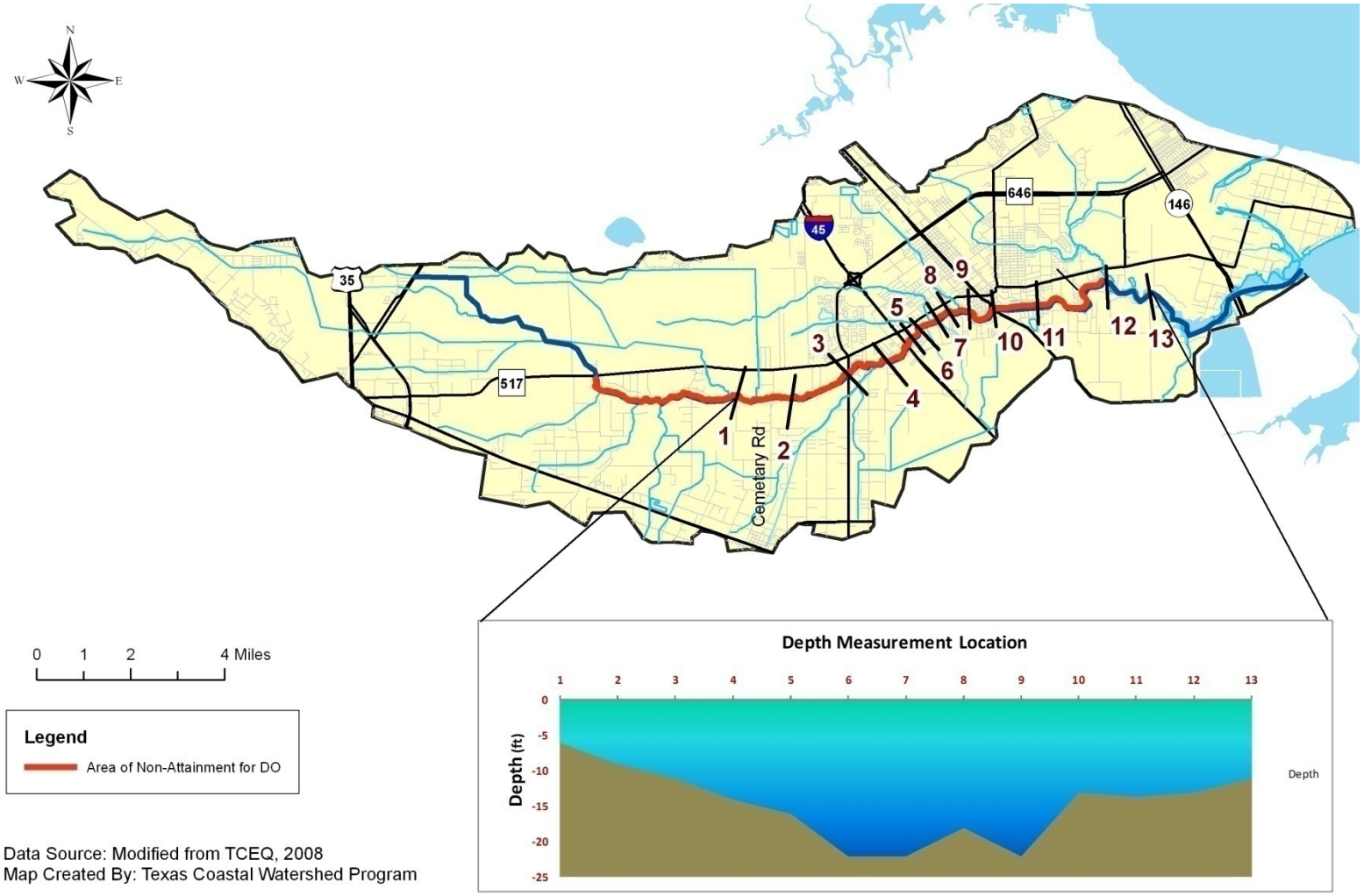
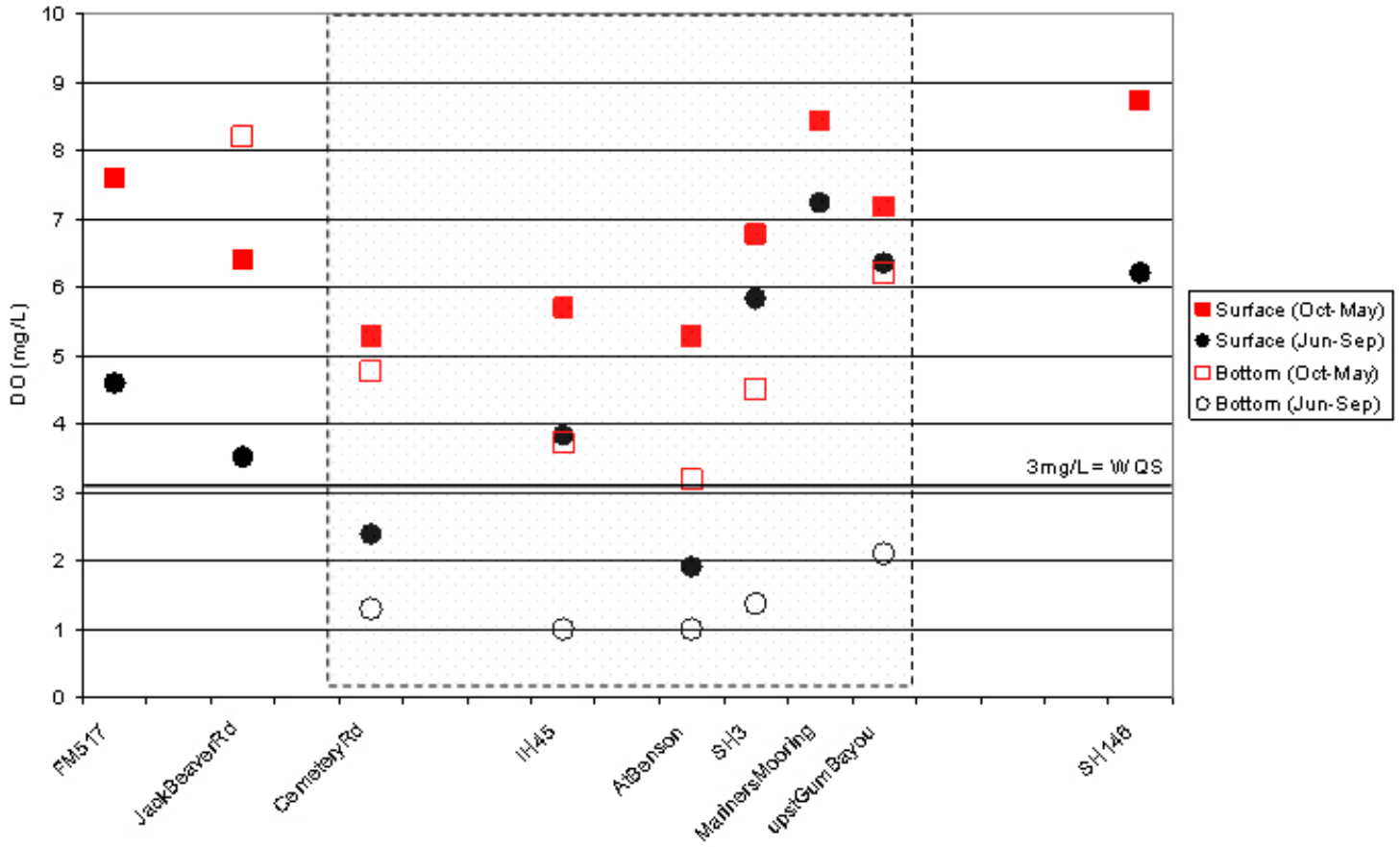
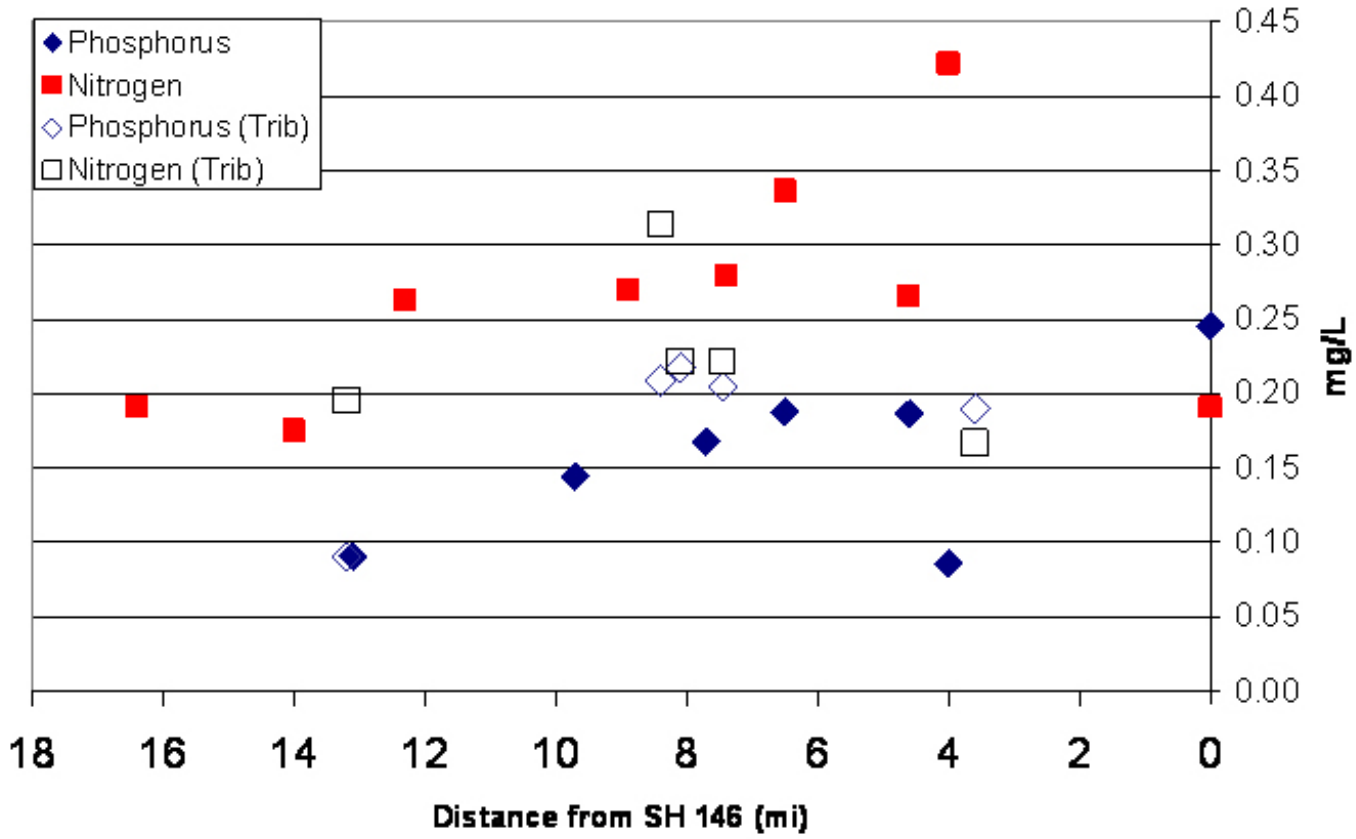


Figure 9. Average instantaneous dissolved oxygen levels in Dickinson Bayou from upstream (left) to downstream (right) in the warmer months (circles) and the cooler months (squares). Surface data (within 1 meter of water surface) is represented by the solid symbols, and bottom data is represented by open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

[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

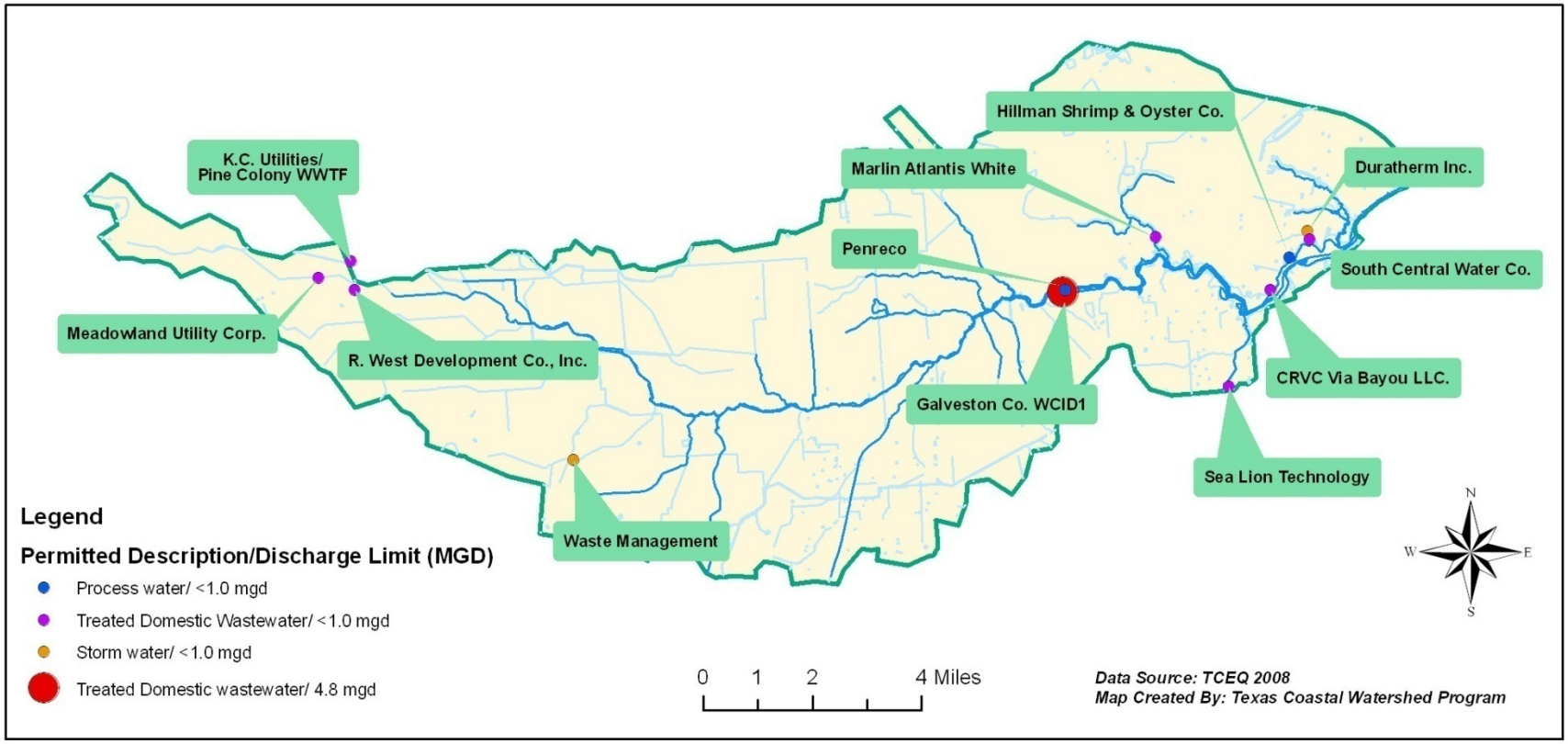
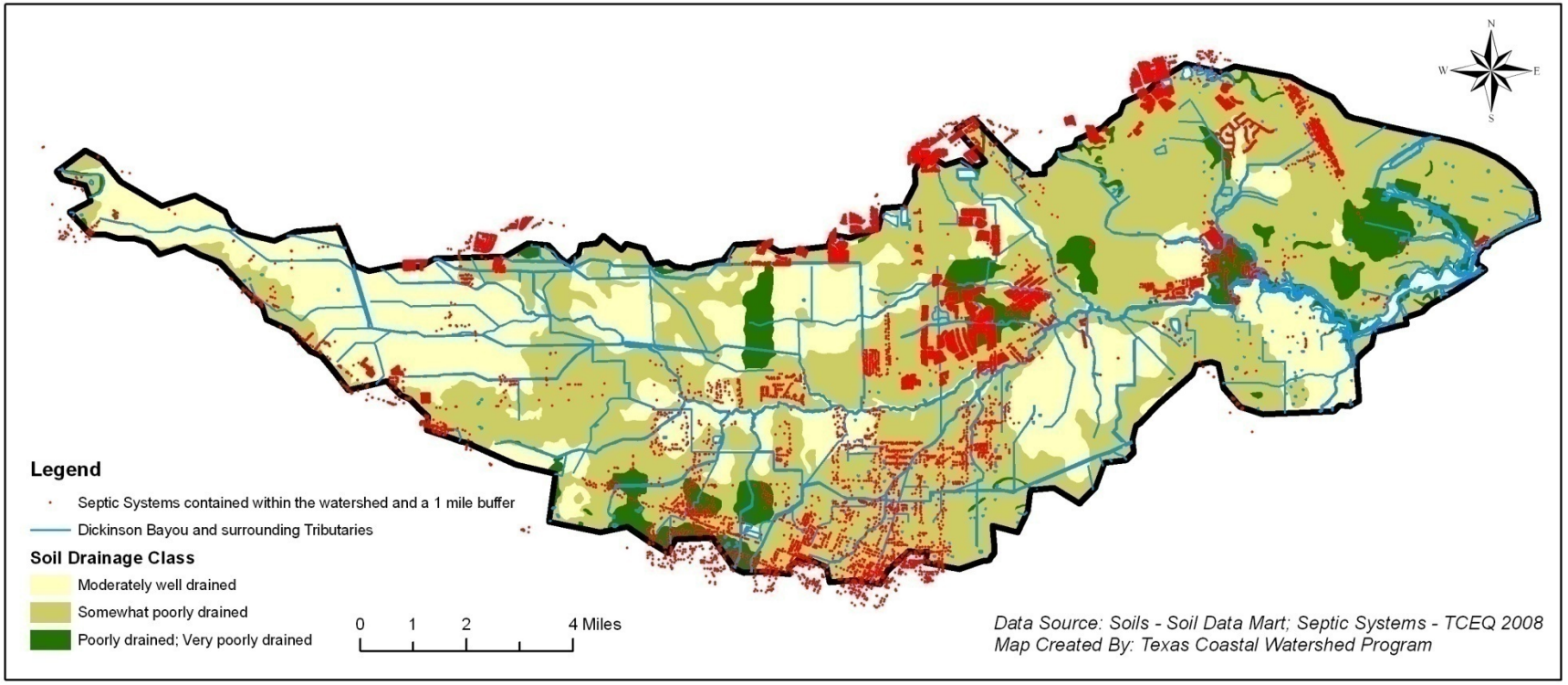


Figure 13. Location of households not connected to a centralized wastewater system, presumed to have septic systems, and the soils on which they are located in the Dickinson Bayou watershed



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.

---

[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

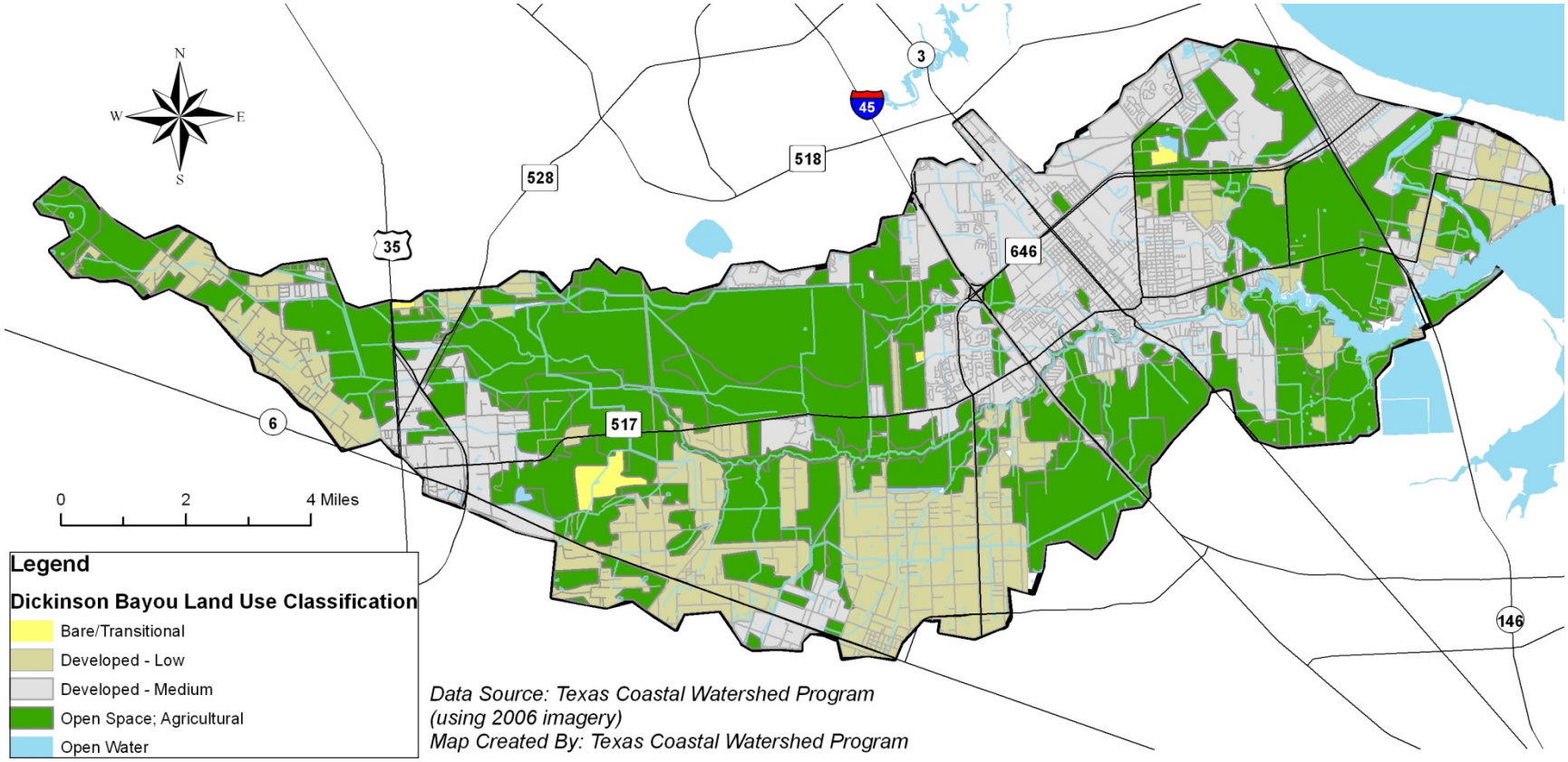
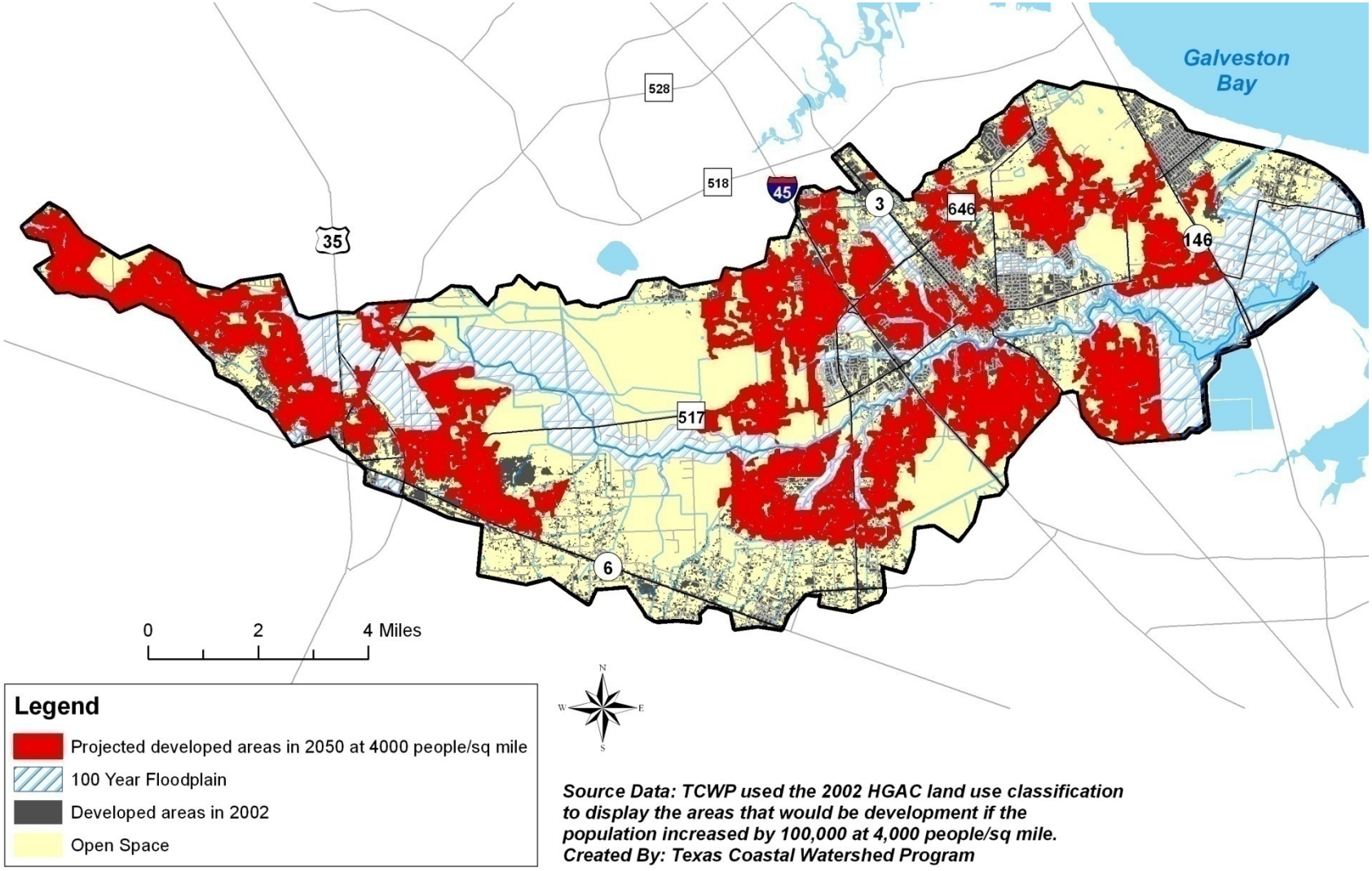
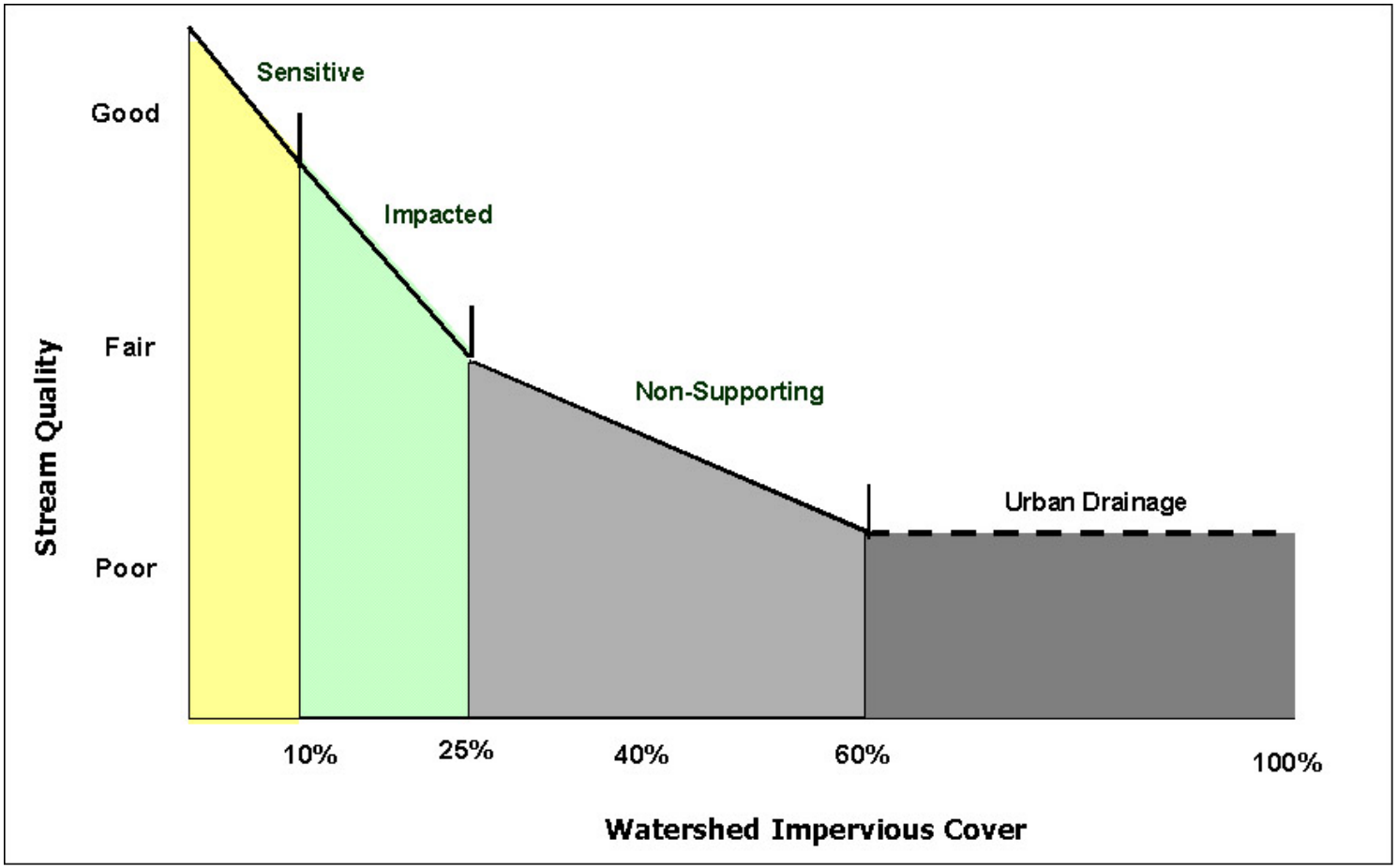


Figure 15. Projected areas of development in the Dickinson Bayou watershed in 2050 with the addition of 100,000 more people at 4,000 people/sq mile.



Source Data: TCWP used the 2002 HGAC land use classification to display the areas that would be development if the population increased by 100,000 at 4,000 people/sq mile.
Created By: Texas Coastal Watershed Program

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*).

[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).

[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.

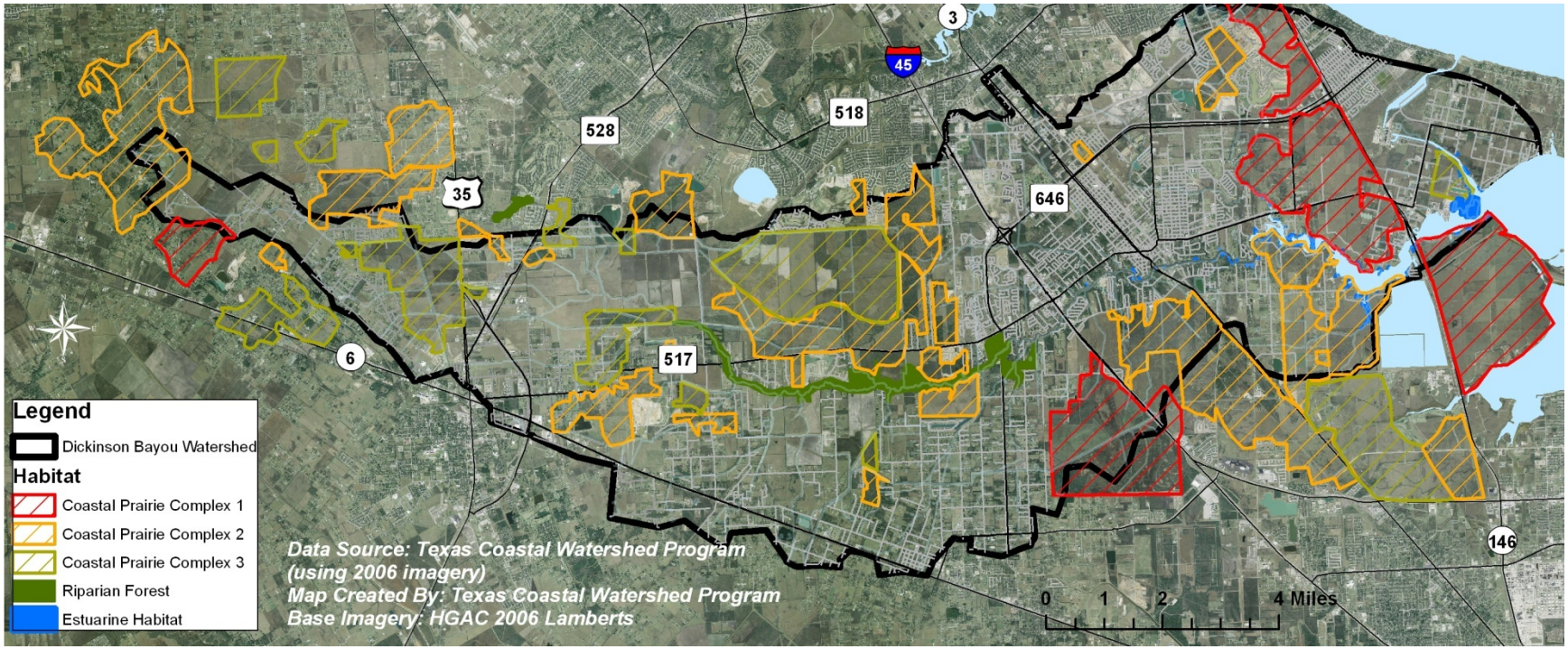
Ecological Services

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

[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.

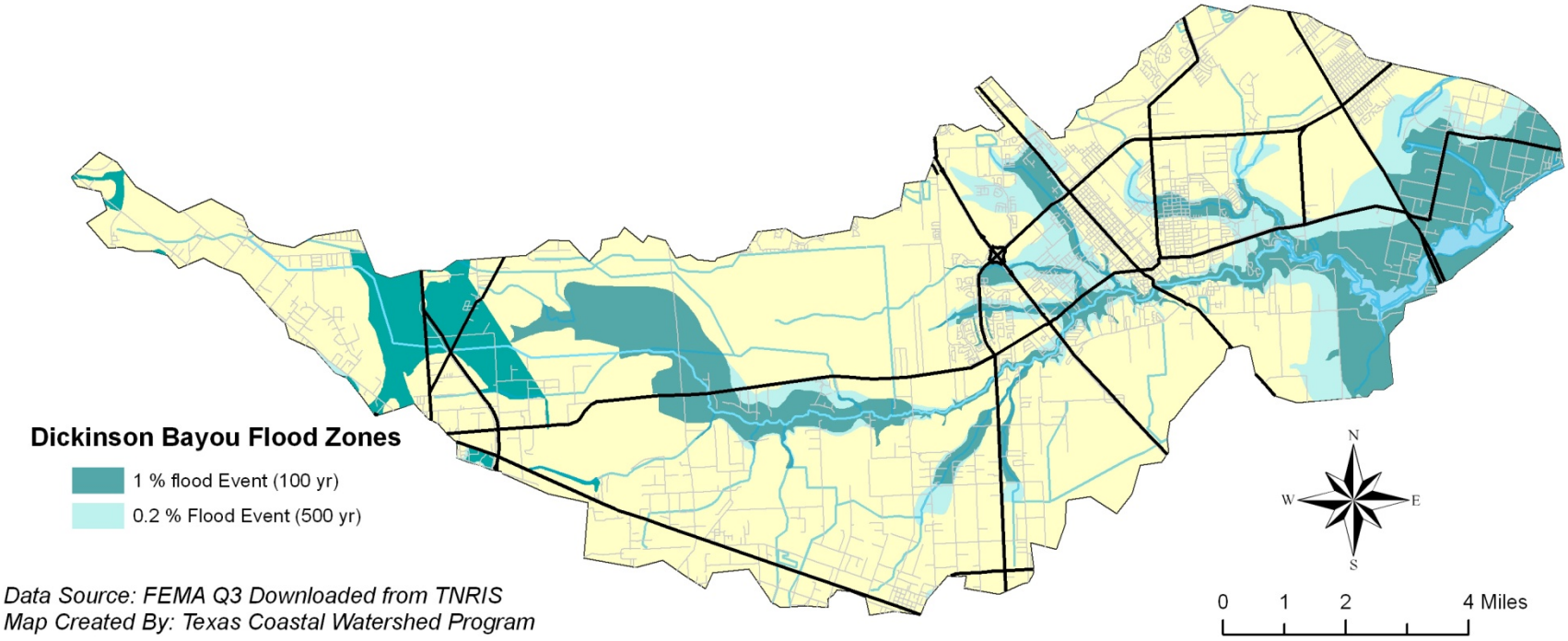
One important type of permit issued by the TCEQ is a **municipal separate storm sewer system (MS4) discharge permit**. This permit is a system to control municipal stormwater runoff. Phase I required large and medium cities to acquire permits, and Phase II required small cities (populations less than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



Data Source: FEMA Q3 Downloaded from TNRIS
Map Created By: Texas Coastal Watershed Program

Figure 19. Subsidence for the Houston - Galveston Region

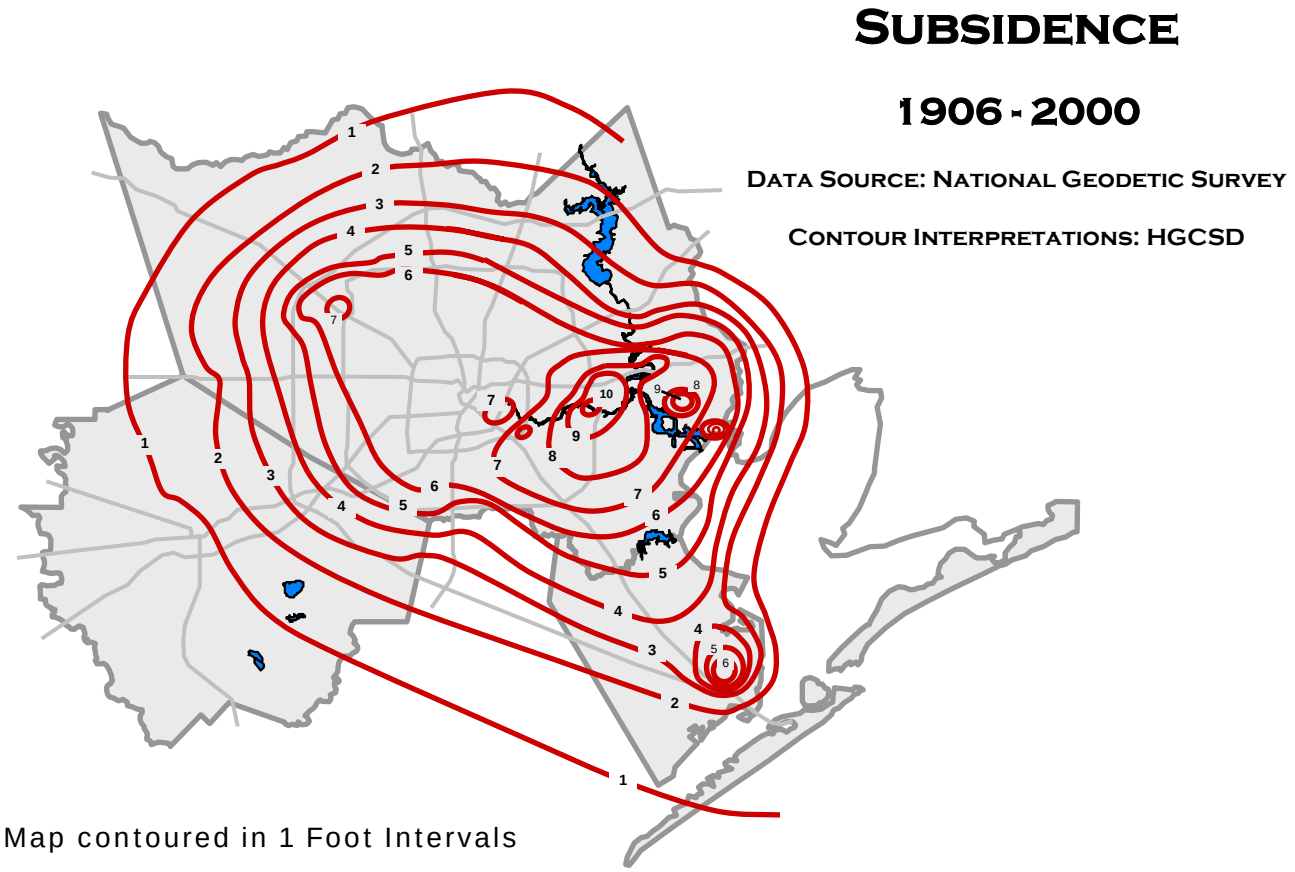
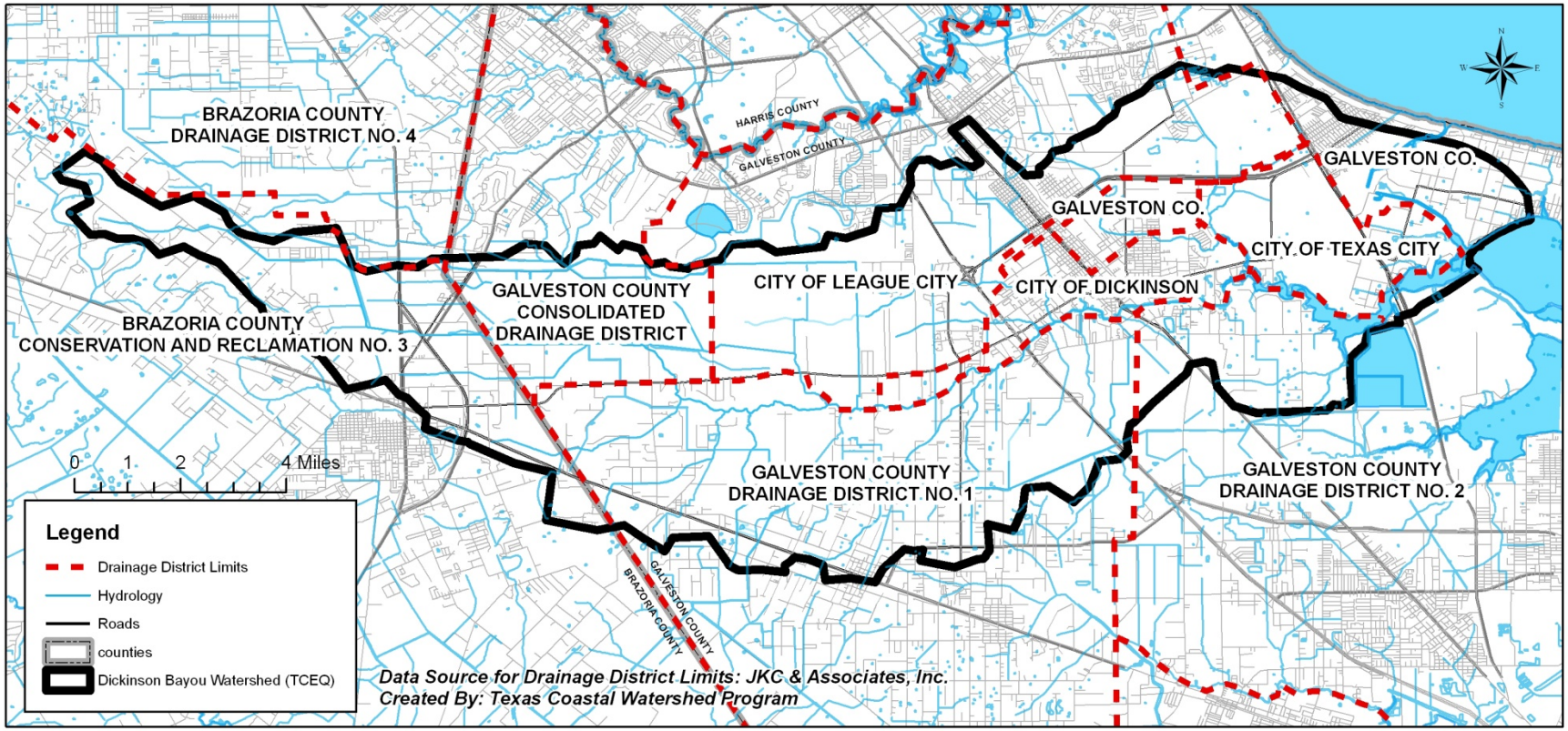


Figure 20. Drainage district boundaries in the Dickinson Bayou watershed



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