Freshwater, Non-tidal
Wetland Loss
Lower Galveston Bay Watershed
1992-2002

A Rapid Assessment Method Using GIS and Aerial Photography

June 2005

Contract Report No 582-3-53336
For the Galveston Bay Estuary Program

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TEXAS COASTAL WATERSHED
PROGRAM

EXECUTIVE SUMMARY

The Lower Galveston Bay watershed lost at least 3.1% of its natural freshwater wetlands between 1992 and 2002. Most of the loss occurred in Harris County, which lost at least 13% of its natural freshwater wetlands in the same period, with over half of that loss occurring between 2000 and 2002. Rapid development in Galveston, Ft. Bend, and Brazoria Counties suggests losses on a par with Harris County in the next 2-5 years, and catastrophic losses for the entire area within the next two decades.

This analysis was the result of an innovative and inexpensive procedure to determine wetland loss. The results can in no way be considered precise, but they can reliably be considered as minimal estimates of wetland loss. As such, they reveal that impacts by development to freshwater wetland resources in the lower Galveston Bay watershed are extremely serious, with grave implications for the long term health of the Galveston Bay system.

The Texas Coastal Watershed Program is a joint effort of Texas Cooperative Extension and Texas Sea Grant, both part of the Texas A&M University System. The TCWP is affiliated with the Department of Recreation, Parks, and Tourism Science at Texas A&M University.

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Introduction

Accelerated development is occurring in the lower Galveston Bay watershed, particularly in and around Houston, with obvious impacts on wetland resources. But how many wetlands are actually being lost? Is this loss significant? Development in the Houston area occurs in a patchwork pattern over such a large area that it is not easy to get a feel for the overall rate and extent of wetland loss in the watershed.

Resource managers need quantitative data in order to make informed decisions about how to react to the loss of wetlands occurring in our area. Most sensitive observers sense that very significant wetland loss is occurring in the Lower Galveston Bay watershed. But only quantitative data can credibly inform the public policy debate about wetland loss and preservation. This project is an attempt to supply sorely needed data to insure that sound science informs the debate in our area.

Habitat protection and restoration is the number one priority of the Galveston Bay Plan, which the Galveston Bay Estuary Program is charged with implementing. This report will aid GBEP in understanding the magnitude of freshwater wetland loss in the lower Galveston Bay watershed.

This report deals strictly with freshwater wetland loss due to development. A companion report under the same contract addresses estuarine wetland loss due to development as well as subsidence and erosion. The terms “wetlands” in the remainder of this report refers to freshwater wetlands only (palustrine, lacustrine, and riverine).

The Tradeoff: Sampling versus Complete Inventory

A quantitative assessment of wetland loss requires a baseline on which to compare future trends. The National Wetland Inventory (NWI), conducted periodically by the U.S. Fish and Wildlife Service (USFWS) is the only area-wide wetland map that exists for our area. Several observers have suggested that a new NWI would be needed to quantitatively determine wetland loss in our area. The NWI was developed using high-altitude aerial photography, and while it is an excellent map of wetland resources at the scale at which it was designed, it is subject to a fairly high amount of error. The principal error of the NWI maps is that they consistently underestimate the true amount of freshwater wetlands on the ground (by as much as 30-70% by the senior author’s experience). A new NWI would also likely be subject to similar error. Improved methods might actually map more wetlands. A new NWI might be valuable for other purposes, but it would not provide a measure of wetland loss in this area, because the amount of error between the 2 NWIs would preclude quantitative comparisons.

A new NWI would thus only serve as a new baseline, since it could not be compared to the older NWI because of the inherent errors. And the next successive NWI could reveal other deficiencies in the previous baseline NWI, again invalidating comparisons. To be effective, consecutive NWIs would have to be extremely precise, and would thus be prohibitively expensive.

Although the NWI maps do underestimate actual wetlands, there is general agreement that the NWI in general does not misidentify wetlands. That is, areas that are identified as wetlands in the NWI are in fact wetlands with a high degree of reliability. If so, the NWI maps can be considered as a fairly reliable sample from which we can gauge the magnitude of wetland loss in our area. The wetland loss figures obtained from this exercise might not be as precise as we would like, but they represent a semi-quantitative, “least case” scenario that can be used to inform policy discussions.

With the method outlined here, we were able to provide a semi-quantitative assessment of wetland loss due to development in the lower Galveston Bay Watershed for a relatively nominal cost. We sacrificed the precision that might be obtained with a new NWI, but we quickly obtained reliable loss figures that managers and the public can immediately use to gauge the rate and magnitude of wetland loss in the area, and make decisions as appropriate.

Study Area

The study area comprises the lower Galveston Bay watershed (Figure 1). The watershed does not include areas above the Lake Houston dam that drain into the San Jacinto River, including the part of Harris County that drains into Spring Creek. The only county completely within the watershed boundaries is Galveston County. Because of the importance of Harris County in this region, and because a relatively small fraction is outside the watershed, we opted to include all of it in the study area. The rest of the counties in this report are only partially contained within the watershed.

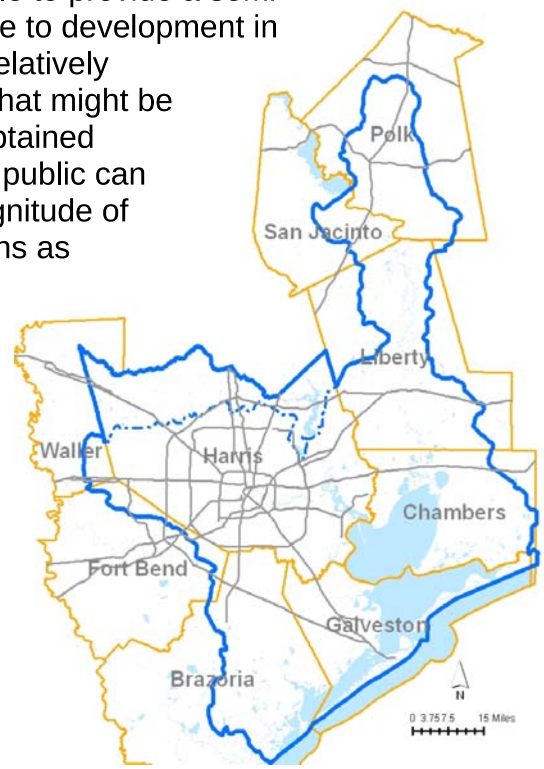

Figure 1. Project study area: the lower Galveston Bay watershed, including all of Harris County. Dashed line shows watershed boundary that clips Harris County.

Methodology (Brief)

Our methodology (described in detail in Appendix C) was simply to line up the digitized NWI lines from the latest year available (generally 1992 or 1993) on the latest digital aerial photography available (2000 or 2002 over most of the area) and determined whether or not any wetland areas as identified in the NWI had been lost to development (Figure 2).

The study period for the study area varies because there is not a uniform date for the latest NWI, and likewise for the most recent aerial photography. In general, the study period is from 1992-2002, with some significant exceptions noted in Figure 2.

There are no digital NWI maps for Polk County or most of San Jacinto County. Only older, 1982 NWI data was available for these counties. Methods for dealing with this portion of the study area are detailed in Appendix C. Wetland loss was minimal in these two counties.

This report deals with the loss of freshwater wetlands[1] to development. We were extremely cautious in our aerial-photo interpretation of development. The obvious cases of strip malls, residential developments, and the like posed no interpretive challenge. The more difficult cases involved vegetation removal and/or excavation without further development. Only in those cases where it was obvious that wetland hydrology had been destroyed did we classify a wetland as filled. Our assessment of wetland loss is thus a very conservative assessment. The losses reported here should be viewed as minimal rather than maximal estimates.

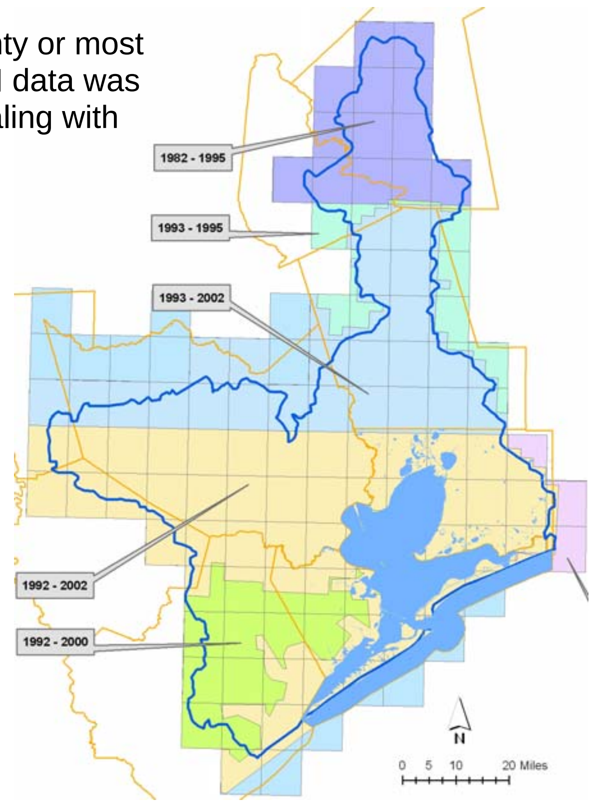

Figure 2. Aerial photography dates of NWI wetland mapping (first number in couplet) and latest photography for development (second number)

We further subdivided development into various categories (Table 1), although most of this report will focus on wetland loss as a result of development in general.

Table 1. Wetland loss categories

Category	**Description**
Residential	Generally residential, some light commercial, and roads
Commercial/industrial	Malls, strip malls, industrial and commercial facilities
Fill	Undefined fill; obvious removal of vegetation and excavation
Water	Wetlands have been replaced by an open water feature (e.g., pond or lake)

[1] P,L, and R by the NWI classification.

The Cowardin Classification

The Cowardin wetland classification (Cowardin et al., 1979) is in common use throughout the U.S. and is the system used by the National Wetland Inventory. It is a hierarchical system based primarily on hydrology and vegetation, and secondarily on the nature of the bottom or substrate. This report focuses on Palustrine, Lacustrine, and Riverine wetland systems. A companion report focuses on Estuarine and Marine systems. The System is the highest taxon in the Cowardin scheme.

Riverine wetlands are limited to river channels and occupy such a very small percentage of the study area. The Lacustrine or lake system is also of relatively small percentage. The Palustrine system, freshwater non-riverine, non-lacustrine wetlands, makes up the overwhelming majority of freshwater wetlands in the area, and their class taxa are given in Table 2. Only PEM, PFO, and PSS are significant in the study area. The location of Riverine and Lacustrine system wetlands is shown in Figure 3.

Subclasses are based on persistence of vegetation, nature of the vegetation, hydrology, and water chemistry. The subclasses are indicated by a series of letters or numbers after the class level. For example, PFO2T refers to a palustrine forested needle-leaved deciduous tidally influenced wetland (i.e., a cypress swamp near the mouth of a river). The entire Cowardin Classification is reproduced in Appendix D.

Table 2. Palustrine Wetlands Classes

Class ID	Name	Description
PEM	Emergent	Herbaceous vegetation—i.e., marshy
PSS	Scrub-shrub	Usually secondary growth (e.g., Chinese tallow tree or shrubby vegetation)
PFO	Forested	Wooded areas
PAB	Aquatic bottom	Submergent vegetation
PUS	Unconsolidated shore	
PUB	Unconsolidated bottom	

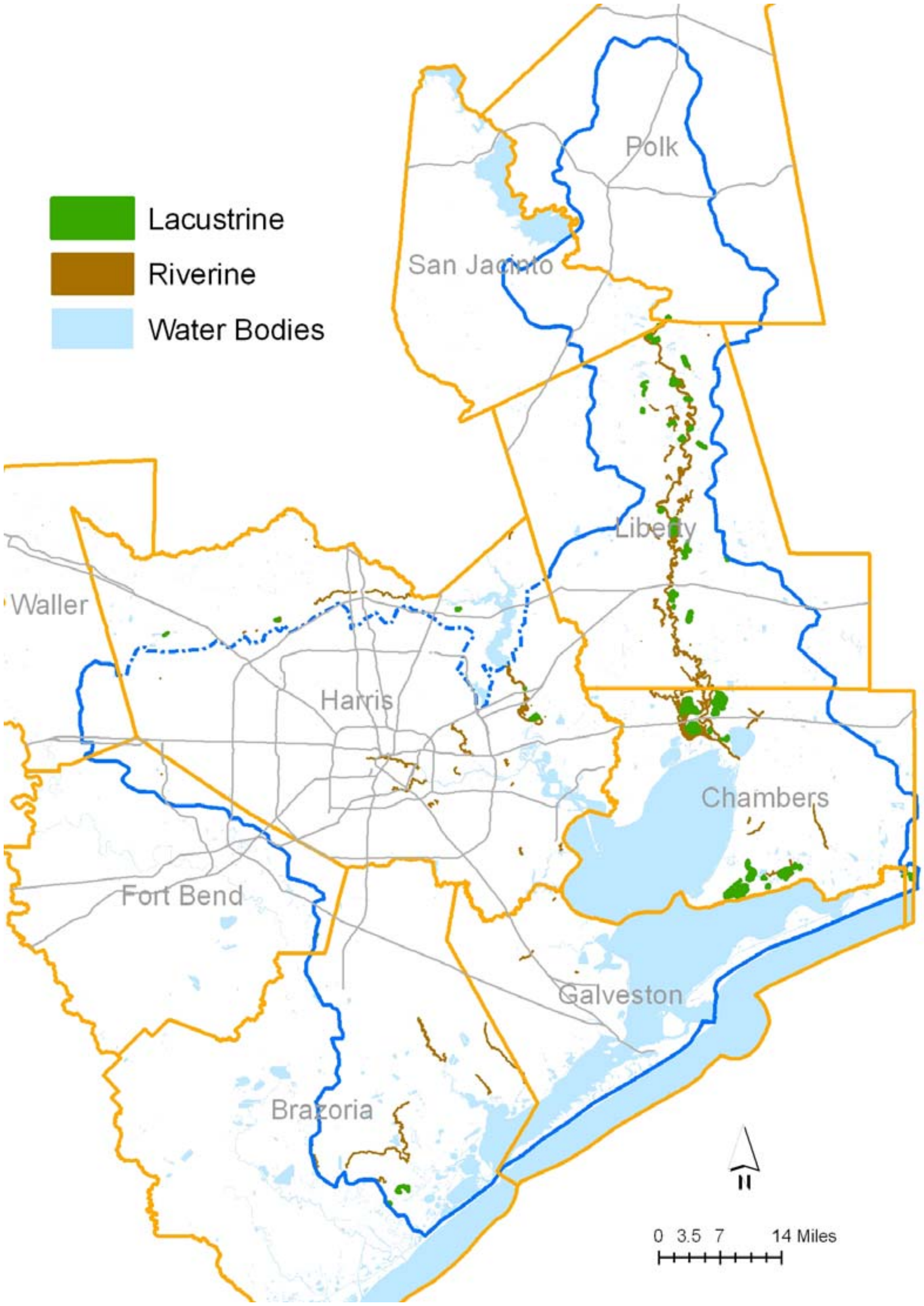

Figure 3. Location of Riverine and Lacustrine wetlands. The outline of these wetlands has been greatly exaggerated to aid to highlight their location

Man-made Wetlands

The classification system also includes provisions for human modifications. These modifications are coded as “special modifiers” in the system, represented by lower case letters at the end of the code. These include diking (h), excavation (x), spoil (s), artificial substrate (r), drained (d), and farmed (f). These wetlands for the most part are the result of human construction, except for the farmed and drained categories, which represent human modifications of natural wetlands.

The “farmed” wetland (f) is of special interest in this study, PEMf in particular. The PEMf category was used by the NWI in the lower Galveston Bay watershed to map both natural wetlands that were farmed as well as large areas that were diked off for rice or for temporary water fowl habitat. Figure 4 shows distinct wetland areas that form a fraction of the very large PEMf delineation. The entire polygon may have been under water when the 1992 NWI team performed the mapping. The diked/impounded category (h) probably should have been used for these large areas rather than the “f”, because the entire area is clearly not a permanent wetland, which is what the “f” should indicate.

The PEMf taxon covers large areas (132,130 acres, or 56% of the total PEM coverage) (Figure 5). Clearly, there are bona fide wetlands within each large PEMf polygon, but quantification of that amount was not within the scope of work of this project**.** The loss figures for PEMf and the other humanly modified wetlands are available in Appendix B and the database described in Appendix D. In this report we are concerned with the loss of natural wetlands and the numbers reported, unless otherwise specified, refer to natural wetlands. The natural wetlands include the special modifier “d” for drained wetlands. Most of these drains were temporary drains such as for draining rice fields. The wetland depression remains intact.

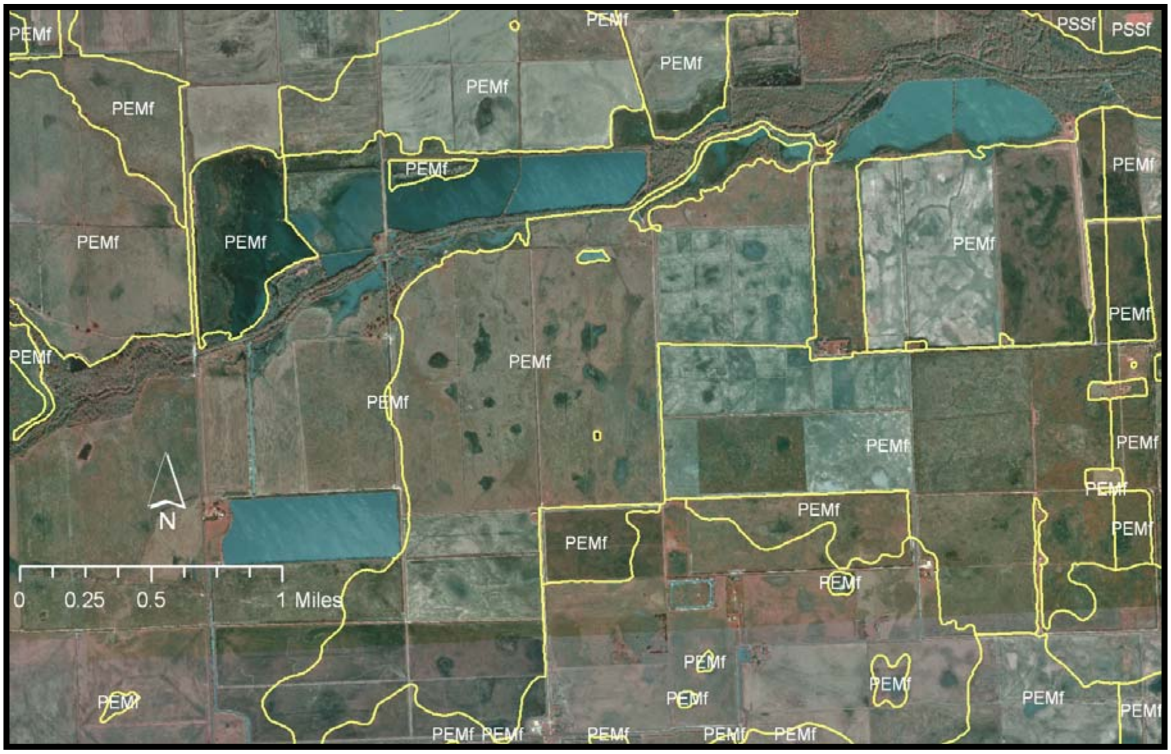

Figure 4. PEMf (palustrine emergent-farmed) delineation from the 1992 NWI (center of photo). Note the presence of distinct potholes or depressions throughout the polygon. The PEMf is clearly overextended—only a fraction of this area is truly wetland. The entire area may have been flooded in 1992 when the NWI was mapped (and should therefore have been mapped PEMh, or diked). The smaller PEMf delineations in the lower center of the photograph are more consistent with the Cowardin concept of a farmed wetland.

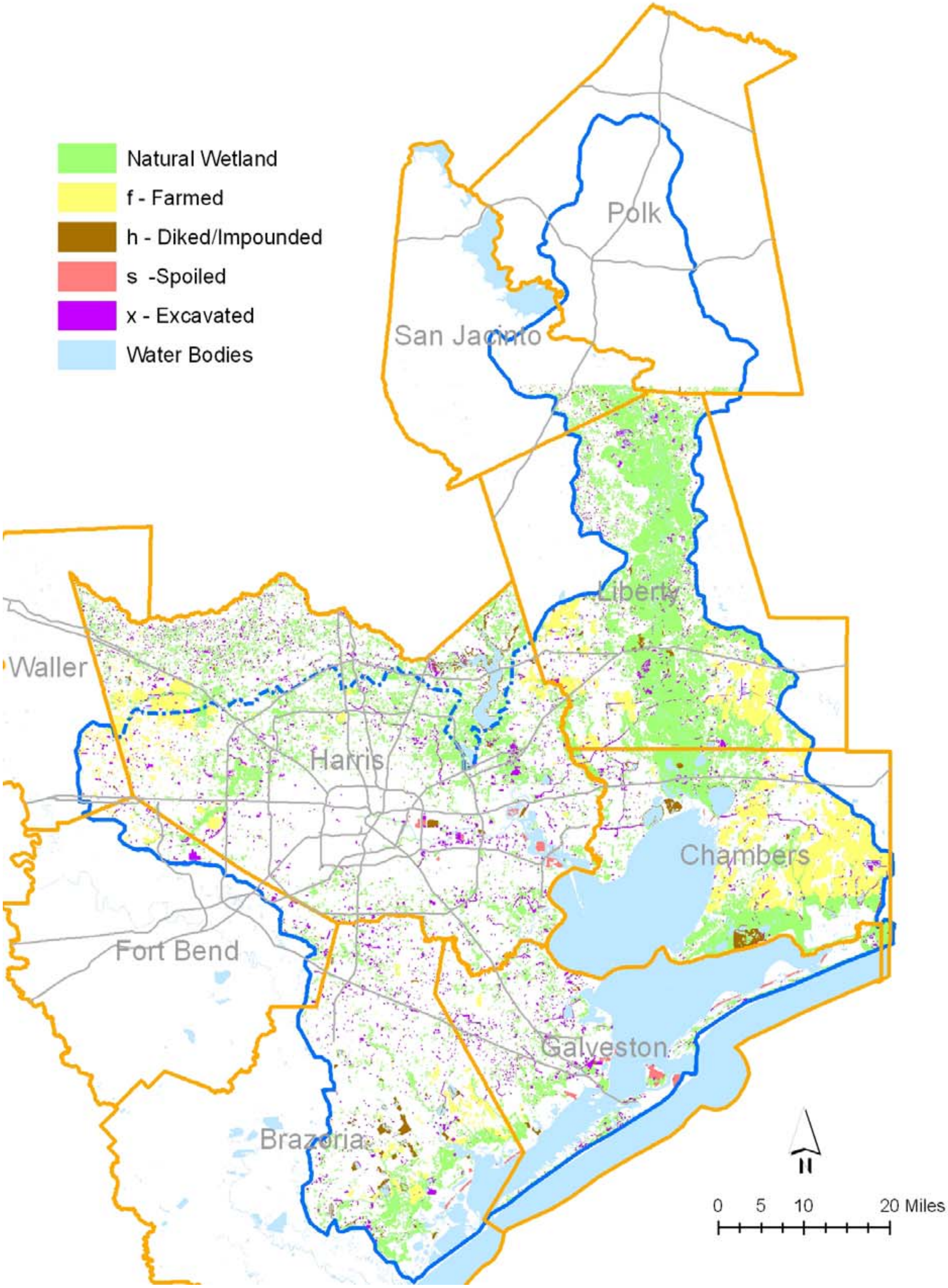

Figure 5. Location of human-modified wetlands. Outlines of wetland areas have been exaggerated to highlight their locations.

Results

By 2002, the lower Galveston Bay watershed lost at least 3.1%, or 9,124 acres, of the 294,556 acres of natural freshwater wetlands[2] mapped by the NWI in 1992 (Table 3, Figure 6). By any standard, this loss is very significant. In less than 25 years, less than half of our existing wetlands will remain if the same rate of loss continued unchanged. Over 70% of this loss could be attributed to completed development projects (Table 4, Figure 7), with about 26% clearly filled and destroyed but with no obvious development (Figure 8), and less than 3% converted to water bodies, usually ponds or lakes (Figure 9).

The largest category of freshwater wetlands in the Galveston Bay system is the palustrine forested wetlands (PFO) (169,189 acres), which also suffered the largest number of acres lost (5,429 acres or 3.2% of the total) (Table 3). Emergent palustrine wetlands (PEM) are the second largest category (89,594 acres) with a similar percentage loss (2.8% or 2,538 acres).These two categories comprise the vast majority of non-tidal freshwater wetlands in the lower Galveston Bay watershed. A relative high percentage (7.7%) of scrub-shrub wetlands (PSS) were lost (1,085 of 14,091 acres). This last category appears to be made up primarily of Chinese-tallow infested wetlands.

Figure 10 shows the relative loss of freshwater wetlands across the entire study area. The unequal pattern of wetland loss in the study area is evident from this figure. Some very large, significant areas are lost 50-100% of their palustrine wetlands during the study period. The pattern of loss follows the pattern of development in the lower Galveston Bay watershed, with most of the loss occurring in Harris County.

Thirteen percent (7,195 acres) of all NWI-mapped freshwater wetlands in Harris County (56.533 acres) were lost between 1992 and 2002 (Table 5). Harris County alone accounted for nearly 80% of the total freshwater wetland loss for the entire lower Galveston Bay watershed. Significantly, over half of that loss occurred between 2000 and 2002[3] (Figure 12). The largest loss, percentage and acreage-wise, was from palustrine forested wetlands (Appendix A). Many of these forested wetlands are in the northeastern portion of Harris County, including many of the rapidly diminishing coastal flatwoods wetlands dominated by willow oak (*Quercus phellos*).

Much less development occurred in Galveston County during the study period (Table 5), but some significant losses did occur—a total loss of 1.8 percent or 257acres of NWI-mapped freshwater wetlands. Development is just beginning to take off in Galveston County. Wetland loss figures through 2004 would show a significantly larger number of acres lost.

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[2] P,L,and R wetlands by NWI classification.

[3] A separate effort not associated with this project quantified wetland loss in Harris County from 1992-2000.

Table 3. Total Wetland Loss, Lower Galveston Bay Watershed

System-Class	Description	Total Acres	Acres Lost	% Wet Loss
L1AB	Lacustrine - Limnetic - Aquatic Bed	121		0.0%
L1UB	Lacustrine - Limnetic - Unconsolidated Bottom	6,556	-	0.0%
L2AB	Lacustrine - Littoral - Aquatic Bed	191	-	0.0%
L2UB	Lacustrine - Littoral - Unconsolidated Bottom	507	-	0.0%
L2US	Lacustrine - Limnetic - Unconsolidated Shore	63	-	0.0%
	Subtotal	**7,438**	**-**	**0.0%**
PAB	Palustrine - Aquatic Bed	699	18	2.6%
PEM	Palustrine - Emergent	89,594	2,538	2.8%
PFO	Palustrine - Forested	169,189	5,429	3.2%
PSS	Palustrine - Scrub - Shrub	14,091	1,085	7.7%
PUB	Palustrine - Unconsolidated Bottom	2,586	22	0.9%
PUS	Palustrine - Unconsolidated Shore	143	4	2.5%
	Subtotal	**276,302**	**9,097**	**3.3%**
R1UB	Riverine - Tidal - Unconsolidated Bottom	3,927	-	0.0%
R1US	Riverine - Tidal - Unconsolidated Shore	20	-	0.0%
R2UB	Riverine - Lower Perennial - Unconsolidated Bottom	6,509	22	0.3%
R2US	Riverine - Lower Perennial - Unconsolidated Shore	351	4	1.0%
R4SB	Riverine - Intermitent - Streambed	9	2	23.5%
	Subtotal	10,816	27	0.3%
	Total	294,556	9,124	3.1%

All other counties in the study area are only fractionally contained within its boundaries. Nevertheless, the percentage loss figures likely reflect the magnitude of development and wetland loss in the respective areas (Table 5). Fort Bend County, in particular, shows a 17% loss in freshwater wetlands. The eastern side of the study area (Chambers, Liberty, Polk, and San Jacinto Counties) have had little development activity. Brazoria County has had a fair amount of development activity , but shows relatively little loss percentage wise because much of the development has been concentrated in the northern part of the county, and there are vast expanses of freshwater wetlands in the southern part of the county. No wetlands loss was observed in Polk or San Jacinto

Counties. Neither of these counties is included in the wetland loss atlas in Appendix C.

Table 4. Wetland loss by type of destruction.

Wetland Loss Type	NWI Lost (Acres)	NWI Lost %
Residential (includes roads)	5,745	63.0%
Industrial/Commercial (I)	759	8.3%
Filled (F)	2,357	25.8%
Water (W)	263	2.9%
SUBTOTAL	**9,124**	**100.0%**
Undeveloped	285,432	
TOTAL	**294,556**	
Total % Loss (SUBTOTAL/TOTAL)	**3.1%**	

Table 5. Wetland loss by county

	County Acres			NWI Acres			
COUNTY	**Total**	**in Study Area**	**% in Study Area**	**Total**	**% in Study Area**	**Lost in Study Area**	**%Loss in Study Area**
Brazoria	1,022,950	449,249	44%	21,863	5%	388	1.8%
Chambers	557,989	510,021	91%	64,178	13%	126	0.2%
Fort Bend	567,620	66,015	12%	1,592	2%	278	17.4%
Galveston	419,349	419,349	100%	14,449	3%	257	1.8%
Harris	1,138,320	1,138,317	100%	56,533	5%	7,195	12.7%
Liberty	752,738	473,130	63%	130,170	28%	879	0.7%
Polk	710,240	287,844	41%	612	0%	-	0.0%
San Jacinto	401,957	85,731	21%	5,099	6%	0	0.0%
Waller	332,246	31,563	9%	59	0%	0	0.7%
Total	**5,903,409**	**3,461,219**	**59%**	**294,556**	**9%**	**9,124**	**3.1%**

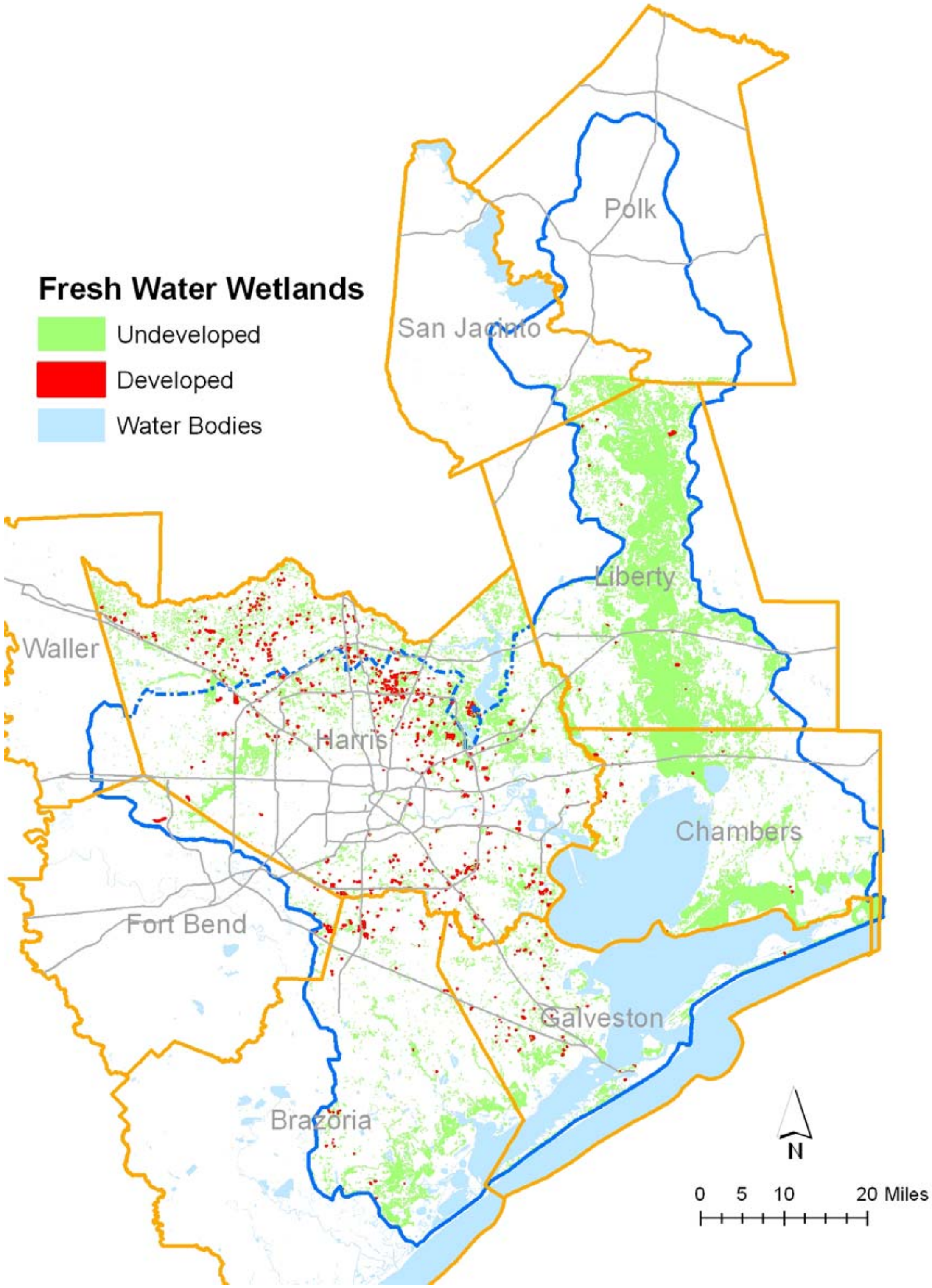


Figure 6. Total freshwater wetland loss in the study area. Green areas are undeveloped wetlands as of 2002. Red areas are developed or filled wetlands. Note extent of digital data to Polk County line.

Figure 7. Aerial photo on the left is from 1995 showing the NWI polygons superimposed on the photo. The photo on the right is from 2002 with the same superimposed NWI polygons. Developed polygons are shown in blue.

Figure 8.1995 photo on left shows NWI polygons which have been filled by 2002 photo on the right. Note that the wetland photographic signature has completely disappeared on the 2002 photo, but no obvious development has taken place.

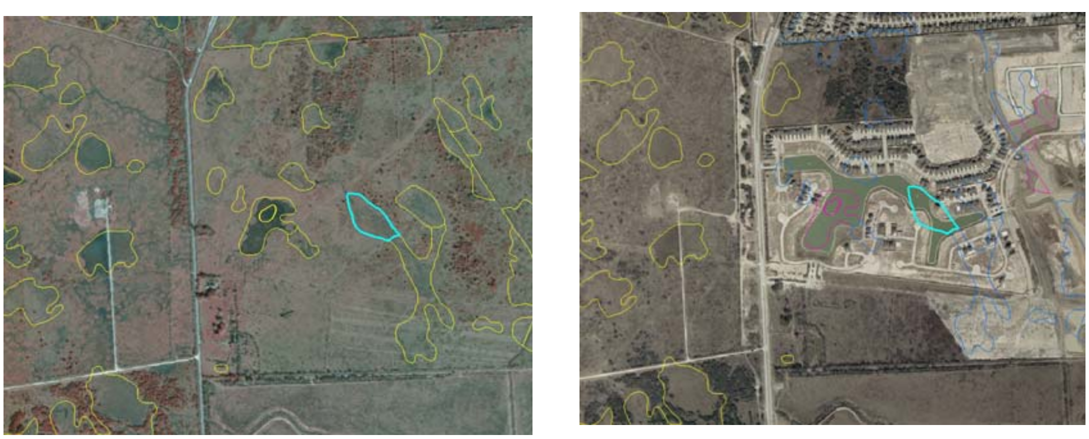


Figure 9. Wetland areas converted to water features. Note that these water features have no ecological value.

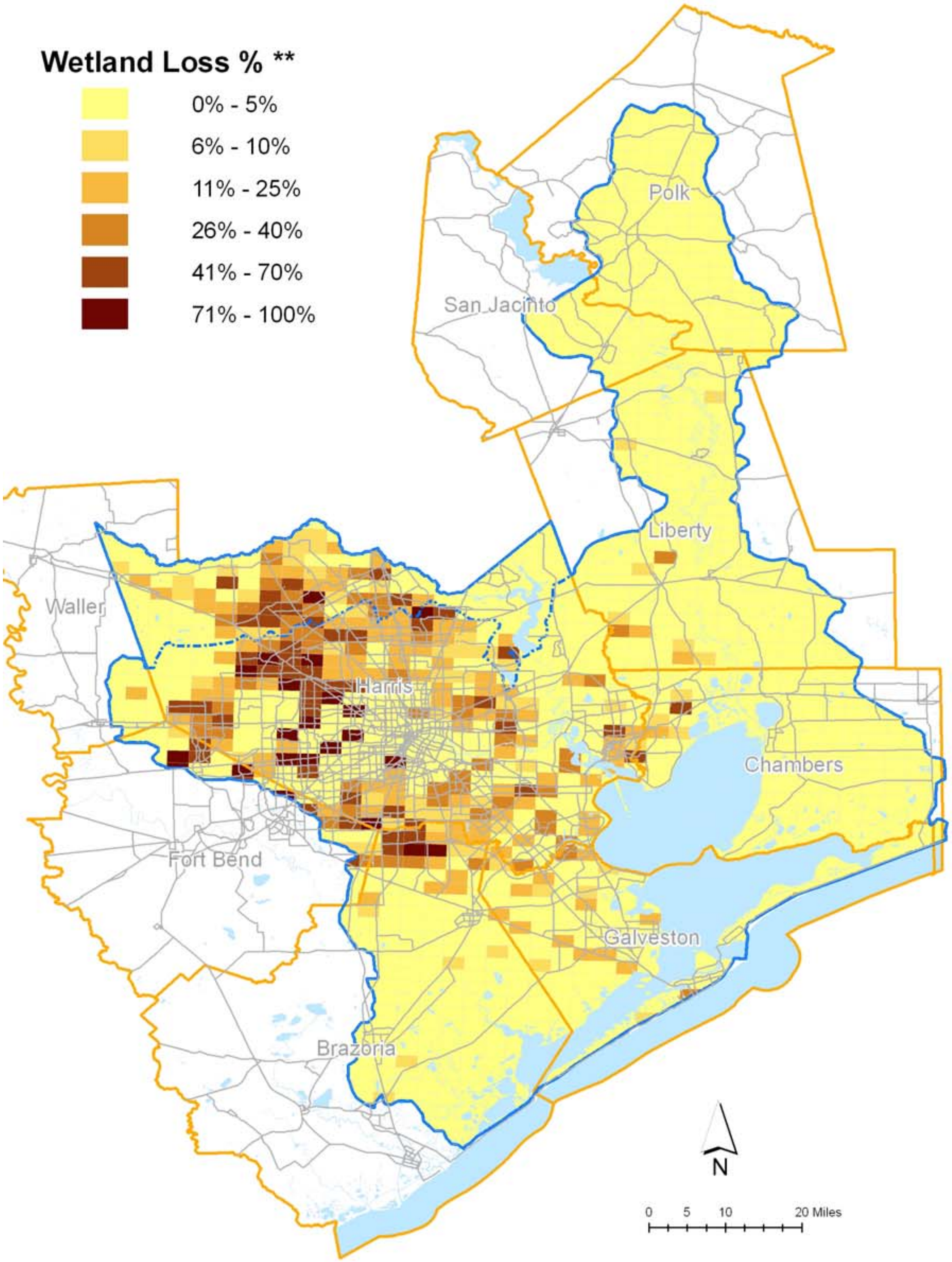


Figure 10. Wetland loss in the study area as a percentage of individual cell areas (2.5 by 1.6 mile cells).

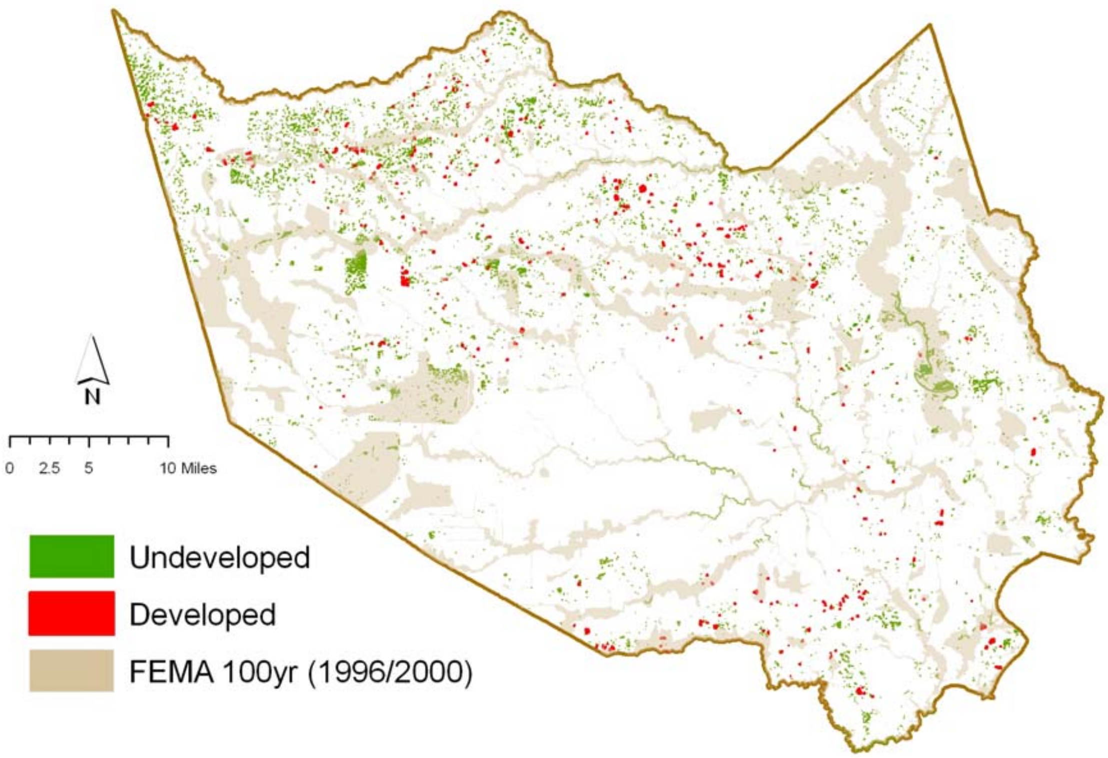


Figure 11. Wetland loss detail for Harris County, overlain on FEMA 100-yr floodplain)

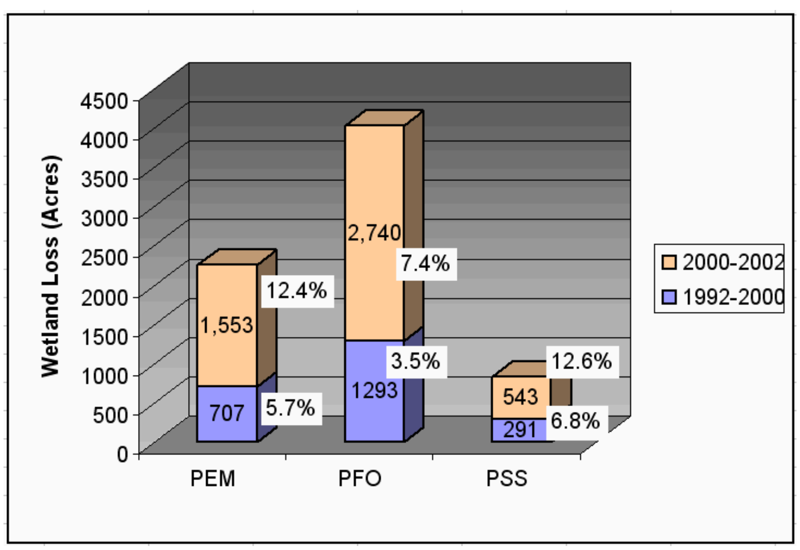


Figure 12. Wetland loss in Harris County from 1992 to 2000 and 2002. More than have the loss from 1992-2002 occurred between 2000 and 2002.

The Impact of SWANCC – adjacent and isolated wetlands.

The study period for this project straddles a major regulatory juncture with the U.S. Supreme Court Solid Waste Agency of Northern Cook County (SWANCC) ruling in January of 2001. The local U.S. Army Corps of Engineers Galveston District's narrow definition of hydrologically isolated wetlands following this decision rendered almost all wetlands outside of the FEMA 100-yr floodplain exempt from regulatory jurisdiction (except those very few wetlands outside the floodplain with a "bed and banks" connection—a virtual river bed – to a floodplain or a waters of the U.S.).

Can the accelerated expansion of wetland loss between 2000 and 2002 in Harris County (the only county where we have data from 2000) be attributed to the SWANCC decision? Probably not. A confounding factor is that development in general has been accelerating over the past few years across the area, driven by market forces unrelated to regulatory issues. The regulatory effects of the SWANCC decision took several months to take hold, so that if any acceleration of wetland loss did take place in the lower Galveston Bay watershed as a result of this decision, it would not have registered in this survey.

Figure 11 shows the distribution of palustrine wetlands and FEMA 100-year floodplains in Harris County, which gives a sense of the quantity of wetlands no longer under the Clean Water Act Section 404 protection (those outside of the 100-yr floodplain). The largest amount of wetland loss by far has occurred outside the 100-year floodplains (Table 6). But most development occurs outside of the floodplains anyway, so it is not possible to tell from this data whether or not SWANCC has had an impact on accelerating development. The key question is how much mitigation for wetlands developed in nonjurisdictional has been lost. This is some argument as to the effectiveness of enforcement and mitigations actions pre-SWANCC, but clearly whatever mitigation there was has been lost. Note that most of the palustrine emergent wetlands (marshy or "prairie pothole wetlands") are outside of the 100-year floodplains and for the most part therefore outside of Clean Water Act jurisdiction.

Eighty percent of PEM wetlands in the study area occur in the 100 year floodplain. This figure includes a large number of wetlands that occur in the Trinity bottoms. In Harris County, however, only 18% of the PEM wetlands occur in the floodplain, and thus over 80% of this class of wetlands falls outside of the stated jurisdiction of the USACE Galveston District.

Table 6. Distribution of wetlands and wetland loss with respect to the FEMA 100-yr floodplain

	NWI Wetlands -Total Freshwater						
	In 100 yr floodplain				outside 100yr floodplain		
Class	acres	% of total	acres lost	% Loss	acres	acres lost	% loss
L1AB	121	100%	-	0.0%	-	-	
L1UB	6,536	100%	-	0.0%	20	-	0.0%
L2AB	191	100%	-	0.0%	-	-	
L2UB	507	100%	-	0.0%	-	-	
L2US	12	19%	-	0.0%	51	-	0.0%
Subtotal	7,367	99%		0.0%	71		0.0%
PAB	554	79%	2	0.3%	145	16	11.2%
PEM	71,374	80%	301	0.4%	18,220	2,237	12.3%
PFO	119,391	71%	1,035	0.9%	49,798	4,394	8.8%
PSS	6,346	45%	194	3.1%	7,745	891	11.5%
PUB	2,362	91%	3	0.1%	224	20	8.8%
PUS	110	77%	-	0.0%	32	4	11.0%
Subtotal	200,138	72%	1,535	0.8%	76,164	7,562	9.9%
R1UB	3,927	100%	-	0.0%	-	-	
R1US	20	100%	-	0.0%	-	-	
R2UB	6,468	99%	22	0.3%	41	-	0.0%
R2US	347	99%	4	1.1%	4	-	0.0%
R4SB	9	100%	2	23.5%			0.0%
Subtotal	10,770	100%	27	0.3%	45		0.0%
TOTAL	218,276	74%	1,562	0.7%	76,280	7,562	9.9%

Table 7. Distribution of palustrine wetlands and wetland loss with respect to the FEMA 100-yr floodplain in Harris County.

	NWI Wetlands -Total Palustrine - Harris						
	In 100 yr floodplain				outside 100yr floodplain		
Class	acres	% of total	acres lost	% Loss	acres	acres lost	% loss
PAB	32	40%	2	5.7%	47	16	34.3%
PEM	2,293	18%	236	10.3%	10,181	2,024	19.9%
PFO	17,316	47%	686	4.0%	19,821	3,347	16.9%
PSS	1,201	28%	157	13.0%	3,109	678	21.8%
PUB	243	59%	1	0.5%	168	18	10.8%
PUS	45	65%	0	0.0%	24	4	14.9%
Subtotal	21,129	39%	1,081	5.1%	33,351	6,087	18.3%

Implications

Loss of natural freshwater wetlands in the lower Galveston Bay watershed over the 10 years of the study period (1992-2002) was massive and rapid. As shown in Table 3, we lost 2.8% of the most endangered category of wetlands in the overall area, the palustrine freshwater marshes (PEM, prairie potholes in the local parlance). In Harris County, however, a staggering 18% of its prairie marshes were lost (Appendix A), accounting for about 90% of the total loss of the prairie marshes in the entire study area. Indications are that development is proceeding apace if not quickening. The implications for freshwater wetland resources in the Lower Galveston Bay Waters are obvious.

Wetland loss in Harris County is proceeding so quickly that there may not be much that can be done except to try to save a few critical last pieces of ecologically significant real estate. Counties surrounding Harris County can expect a similar fate in the next few years.

If we remove from this analysis the large freshwater forested wetland system of the Trinity River bottom, the magnitude of wetland loss approaches catastrophic proportions. The Trinity River bottom is indeed a primary resource in our area. But our area is ecologically rich because of the diversity of wetland types that are found here. We are in serious danger of completely destroying some of the most valuable types altogether, such as the prairie pothole wetlands (PEM in the Cowardin system).

Wetland managers have rightly focused on managing the loss of estuarine habitat for the past few decades. While efforts to restore these valuable habitats should continue, natural resource managers should take note of the magnitude of freshwater wetland loss in the entire lower Galveston Bay watershed. Wetlands in the interior of the watershed are no less valuable than fringing estuarine wetlands. Freshwater wetlands provide critical ecological services to the Galveston Bay system, including water quality maintenance, stormwater buffering, and wildlife habitat, and the intangible sense of beauty and place that these wetlands play in the coastal prairies and forests.

It is important to recognize that much of what is being lost now is some of the most valuable habitat remaining on the entire upper Texas Gulf Coast. Vast acreages of land were land-leveled for agriculture during the Twentieth Century. Some of the best examples of undisturbed prairie-pothole, pimple-mound complexes are found in urban fringe areas yet to be developed and where agriculture had not penetrated. These are the areas now under the greatest threat.

It is imperative that coastal resource managers work with local citizens to educate them on the implications of wetland loss in our area. Without citizen support, little can be done to preserve critical areas on the scale that is needed. In addition, coastal resource managers should also take steps to identify remaining critical habitat, and work with local citizens to help preserve these areas.

Urban sprawl and development is the primary cause of the loss we have documented in this report. Sprawl is the result of a complex interplay of several factors, few of which may be responsive to the actions of natural resource managers. There is, however, a growing movement towards denser forms of development. Resource managers can aid that trend by making sure that policy discussions on urban development are informed by an understanding of the full impacts of diffuse development or sprawl on critical wetland resources, and particularly of the magnitude and rate of those impacts, and thus the need for a rapid reassessment of our current growth patterns.

REFERENCES

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. Biological Services Program. U.S. Fish and Wildlife Service. FWS/OBS-79/31. U.S. Government Printing Office. Washington, D.C.

APPENDIX A

WETLAND LOSS BY COUNTY

Wetland Loss by County by System-Class					
Wetland Class	**Number of NWI Polygons**	**Number of Polygons Lost**	**Total Acres**	**Acres Lost**	**% Wet Loss**
COUNTY: Brazoria					
L1AB	4	-	121.2	-	0.0%
L1UB	2	-	10.5	-	0.0%
Subtotal	**6**	**-**	**131.7**	**-**	**0.0%**
PAB	7	-	29.0	-	0.0%
PEM	1,968	46	15,845.5	44.5	0.3%
PFO	904	101	4,058.5	279.4	6.9%
PSS	304	27	895.1	64.0	7.2%
PUB	75	1	108.7	0.4	0.4%
PUS	2	-	0.4	-	0.0%
Subtotal	**3,260**	**175**	**20,937.2**	**388.4**	**1.9%**
R1UB	20	-	478.9	-	0.0%
R2UB	25	-	315.7	-	0.0%
Subtotal	**45**	**-**	**794.5**	**-**	**0.0%**
SUBTOTAL	**3,311**	**175**	**21,863.4**	**388.4**	**1.8%**
COUNTY: Chambers					
L1UB	36	-	5,091.4	-	0.0%
L2UB	20	-	485.6	-	0.0%
L2US	1	-	12.2	-	0.0%
Subtotal	**57**	**-**	**5,589.3**	**-**	**0.0%**
PAB	41	-	124.5	-	0.0%
PEM	1,977	12	39,722.1	20.2	0.1%
PFO	1,339	29	12,615.2	84.9	0.7%
PSS	450	11	2,276.7	20.4	0.9%
PUB	434	1	1,167.9	0.2	0.0%
PUS	21	-	26.1	-	0.0%
Subtotal	**4,262**	**53**	**55,932.5**	**125.7**	**0.2%**
R1UB	49	-	2,422.4	-	0.0%
R1US	1	-	2.7	-	0.0%
R2UB	24	-	230.8	-	0.0%
R2US	1	-	0.5	-	0.0%
Subtotal	**75**	**-**	**2,656.4**	**-**	**0.0%**
SUBTOTAL	**4,394**	**53**	**64,178.2**	**125.7**	**0.2%**
COUNTY: Fort Bend					
L1UB	1	-	9.2	-	0.0%
Subtotal	**1**	**-**	**9.2**	**-**	**0.0%**
PAB	4	-	8.2	-	0.0%
PEM	277	56	359.7	90.7	25.2%
PFO	219	66	927.9	157.9	17.0%

Wetland Loss by County by System-Class					
Wetland Class	**Number of NWI Polygons**	**Number of Polygons Lost**	**Total Acres**	**Acres Lost**	**% Wet Loss**
PSS	84	20	270.9	29.0	10.7%
Subtotal	**584**	**142**	**1,566.8**	**277.6**	**17.7%**
PUB	19	-	15.6	-	0.0%
PUS	1	-	0.2	-	0.0%
R2UB	1	-	0.3	-	0.0%
Subtotal	**21**	**-**	**16.1**	**-**	**0.0%**
SUBTOTAL	**606**	**142**	**1,592.1**	**277.6**	**17.4%**
COUNTY: Galveston					
L1UB	2	-	12.4	-	0.0%
Subtotal	**2**	**-**	**12.4**	**-**	**0.0%**
PAB	2	-	6.0	-	0.0%
PEM	1,800	75	11,123.7	96.5	0.9%
PFO	742	62	1,867.4	88.2	4.7%
PSS	363	27	1,187.4	70.6	5.9%
PUB	119	5	97.3	2.2	2.3%
PUS	36	-	34.8	-	0.0%
Subtotal	**3,062**	**169**	**14,316.6**	**257.5**	**1.8%**
R1UB	12	-	74.1	-	0.0%
R1US	2	-	4.9	-	0.0%
R2UB	9	-	41.2	-	0.0%
Subtotal	**23**	**-**	**120.3**	**-**	**0.0%**
SUBTOTAL	**3,087**	**169**	**14,449.3**	**257.5**	**1.8%**
COUNTY: Harris					
L1UB	11	-	169.0	-	0.0%
L2AB	2	-	19.5	-	0.0%
Subtotal	**13**	**-**	**188.4**	**-**	**0.0%**
PAB	66	10	78.6	18.0	22.8%
PEM	6,782	1,295	12,474.0	2,259.7	18.1%
PFO	7,419	1,061	37,137.5	4,033.0	10.9%
PSS	2,213	427	4,309.7	834.1	19.4%
PUB	424	23	411.0	19.4	4.7%
PUS	67	7	68.4	3.6	5.2%
Subtotal	**16,971**	**2,823**	**54,479.3**	**7,167.7**	**13.2%**
R1UB	32	-	940.6	-	0.0%
R1US	6	-	12.3	-	0.0%
R2UB	68	2	861.6	21.5	2.5%
R2US	85	5	47.5	3.7	7.7%
R4SB	4	1	3.4	2.1	63.2%
Subtotal	**195**	**8**	**1,865.3**	**27.3**	**1.5%**

Wetland Loss by County by System-Class					
Wetland Class	**Number of NWI Polygons**	**Number of Polygons Lost**	**Total Acres**	**Acres Lost**	**% Wet Loss**
SUBTOTAL	**17,179**	**2,831**	**56,533.0**	**7,195.0**	**12.7%**
COUNTY: Liberty					
L1UB	54	-	1,193.6	-	0.0%
L2AB	8	-	171.7	-	0.0%
L2UB	1	-	1.4	-	0.0%
L2US	2	-	51.0	-	0.0%
Subtotal	**65**	**-**	**1,417.7**	**-**	**0.0%**
PAB	101	-	423.2	-	0.0%
PEM	2,854	33	9,176.9	26.2	0.3%
PFO	8,642	116	108,451.0	785.8	0.7%
PSS	1,174	18	4,656.5	66.9	1.4%
PUB	299	1	776.3	0.1	0.0%
PUS	33	-	12.1	-	0.0%
Subtotal	**13,103**	**168**	**123,495.9**	**879.0**	**0.7%**
R1UB	1	-	10.9	-	0.0%
R2UB	81	-	4,944.7	-	0.0%
R2US	100	-	295.3	-	0.0%
R4SB	2	-	5.7	-	0.0%
Subtotal	**184**	**-**	**5,256.5**	**-**	**0.0%**
SUBTOTAL	**13,352**	**168**	**130,170.1**	**879.0**	**0.7%**
COUNTY: Polk					
L1UB	1	-	69.5	-	0.0%
Subtotal	**1**	**-**	**69.5**	**-**	**0.0%**
PAB	3	-	9.0	-	0.0%
PEM	49	-	110.3	-	0.0%
PFO	47	-	249.4	-	0.0%
PSS	47	-	128.0	-	0.0%
Subtotal	**146**	**-**	**496.7**	**-**	**0.0%**
R2UB	1	-	38.2	-	0.0%
R2US	1	-	7.8	-	0.0%
Subtotal	**2**	**-**	**46.0**	**-**	**0.0%**
SUBTOTAL	**149**	**-**	**612.2**	**-**	**0.0%**
COUNTY: San Jacinto					
L2UB	1	-	20.0	-	0.0%
Subtotal	**1**	**-**	**20.0**	**-**	**0.0%**
PAB	6	-	20.0	-	0.0%
PEM	328	-	727.8	-	0.0%
PFO	573	1	3,881.2	0.3	0.0%

Wetland Loss by County by System-Class					
Wetland Class	**Number of NWI Polygons**	**Number of Polygons Lost**	**Total Acres**	**Acres Lost**	**% Wet Loss**
PSS	102	-	364.7	-	0.0%
PUB	10	-	8.0	-	0.0%
PUS	2	-	0.8	-	0.0%
Subtotal	**1,021**	**1**	**5,002.5**	**0.3**	**0.0%**
R2UB	4	-	76.2	-	0.0%
Subtotal	**4**	**-**	**76.2**	**-**	**0.0%**
SUBTOTAL	**1,026**	**1**	**5,098.7**	**0.3**	**0.0%**
COUNTY: Waller					
PEM	31	2	54.1	0.4	0.8%
PFO	2	-	0.9	-	0.0%
PSS	1	-	2.1	-	0.0%
PUB	3	-	1.7	-	0.0%
Subtotal	**37**	**2**	**58.7**	**0.4**	**0.7%**
SUBTOTAL	**37**	**2**	**58.7**	**0.4**	**0.7%**
GRAND TOTAL	**43,141**	**3,541**	**294,555.7**	**9,123.9**	**3.1%**

APPENDIX B

WETLAND LOSS BY ALL ATTRIBUTES

Wetland Loss by Full NWI Attribute Code

Wetland Class	Number of NWI Polygons	Number of Polygons Lost	Total Acres	Acres Lost	% Wet Loss
L1: LACUSTRINE, LIMNETIC					
L1AB3H	3	0	92.2	-	0.0%
L1AB3Hh	3	0	40.5	-	0.0%
L1AB4Fh	6	0	16.9	-	0.0%
L1AB4H	1	0	29.0	-	0.0%
L1AB4Hh	3	0	42.6	-	0.0%
L1AB4Hx	2	0	178.7	-	0.0%
L1UBH	104	0	6,475.0	-	0.0%
L1UBHh	171	3	25,099.9	7.1	0.0%
L1UBHx	157	0	6,226.7	-	0.0%
L1UBKHx	6	0	99.1	-	0.0%
L1UBKh	1	0	185.3	-	0.0%
L1UBKhs	7	0	417.7	-	0.0%
L1UBV	3	0	80.6	-	0.0%
	467.0	**3.0**	**38,984.1**	**7.1**	**0.0%**
L2: LACUSTRINE, LITTORAL					
L2AB3Fh	2	0	109.4	-	0.0%
L2AB3Hx	1	0	2.0	-	0.0%
L2AB4F	5	0	152.1	-	0.0%
L2AB4Fh	6	0	79.9	-	0.0%
L2AB4Fx	3	0	82.6	-	0.0%
L2AB4H	5	0	39.0	-	0.0%
L2AB4Hh	5	0	5.0	-	0.0%
L2AB4Hx	7	0	10.4	-	0.0%
L2UBF	2	0	21.4	-	0.0%
L2UBFx	1	1	53.9	53.9	100.0%
L2UBHx	1	0	20.4	-	0.0%
L2UBT	20	0	485.6	-	0.0%
L2USAh	23	0	19.4	-	0.0%
L2USAx	2	0	2.8	-	0.0%
L2USC	3	0	63.2	-	0.0%
L2USCh	8	0	130.2	-	0.0%
L2USChs	2	0	42.2	-	0.0%
L2USCx	16	0	259.6	-	0.0%
L2USKhs	51	0	3,808.4	-	0.0%
L2USKs	1	0	69.0	-	0.0%
	164.0	**1.0**	**5,456.6**	**53.9**	**1.0%**
TOTAL LACUSTRINE	**631.0**	**4.0**	**44,440.7**	**61.0**	**0.1%**
PAB: PALUSTRINE, AQUATIC BED					
PAB3F	17	0	21.5	-	0.0%
PAB3Fh	4	0	14.8	-	0.0%
PAB3Fx	11	0	50.2	-	0.0%
PAB3H	5	0	6.8	-	0.0%
PAB3Hh	1	0	3.3	-	0.0%
PAB3Hx	4	0	4.1	-	0.0%
PAB3T	1	0	5.0	-	0.0%

Wetland Loss by Full NWI Attribute Code

Wetland Class	Number of NWI Polygons	Number of Polygons Lost	Total Acres	Acres Lost	% Wet Loss
PAB4F	179	8	567.2	17.0	3.0%
PAB4Fh	35	1	436.1	0.4	0.1%
PAB4Fx	181	12	303.9	8.8	2.9%
PAB4H	8	1	36.6	0.7	1.8%
PAB4Hh	17	0	50.5	-	0.0%
PAB4Hx	87	3	91.4	1.1	1.2%
PAB4Kx	6	3	4.1	2.9	72.1%
PAB4T	12	0	34.0	-	0.0%
PAB4Th	2	0	13.4	-	0.0%
PAB4Tx	1	0	5.7	-	0.0%
PAB4V	3	0	23.0	-	0.0%
PABF	5	1	4.6	0.3	5.8%
PABFh	2	0	5.0	-	0.0%
PABFx	9	1	9.6	2.3	24.5%
PABHh	1	0	3.0	-	0.0%
PABHx	1	0	5.9	-	0.0%
PABKx	5	4	9.6	9.0	93.7%
	597.0	**34.0**	**1,709.1**	**42.5**	**2.5%**
PEM: PALUSTRINE, EMERGENT					
PEM1A	7667	801	42,949.5	1,423.0	3.3%
PEM1A/U	20	0	353.0	-	0.0%
PEM1Ad	247	35	829.7	98.7	11.9%
PEM1Ah	68	3	743.3	7.8	1.0%
PEM1Ahs	18	0	216.6	-	0.0%
PEM1As	4	0	1.1	-	0.0%
PEM1Ax	146	15	468.7	26.2	5.6%
PEM1B	1	0	0.7	-	0.0%
PEM1C	6356	606	33,844.0	842.9	2.5%
PEM1C/U	14	0	471.0	-	0.0%
PEM1Cd	100	8	412.3	37.7	9.1%
PEM1Ch	185	7	5,768.6	40.2	0.7%
PEM1Chs	22	3	160.1	6.0	3.8%
PEM1Cs	12	0	8.7	-	0.0%
PEM1Cx	732	74	1,736.3	129.1	7.4%
PEM1F	1275	69	5,102.5	136.1	2.7%
PEM1Fh	196	5	2,865.8	6.4	0.2%
PEM1Fhs	3	0	21.6	-	0.0%
PEM1Fs	1	0	1.8	-	0.0%
PEM1Fx	659	42	1,462.5	54.5	3.7%
PEM1KCx	3	0	54.2	-	0.0%
PEM1Kh	4	0	331.7	-	0.0%
PEM1Khs	79	0	537.6	-	0.0%
PEM1Kx	9	1	120.4	2.5	2.1%
PEM1R	189	0	2,433.4	-	0.0%
PEM1S	35	0	145.2	-	0.0%
PEM1T	161	0	3,052.3	-	0.0%
PEMC	1	0	0.4	-	0.0%
PEMKx	2	2	4.1	4.1	100.0%

Wetland Loss by Full NWI Attribute Code

Wetland Class	Number of NWI Polygons	Number of Polygons Lost	Total Acres	Acres Lost	% Wet Loss
PEMf	2575	79	132,130.0	942.5	0.7%
	20,784.0	**1,750.0**	**236,227.0**	**3,757.5**	**1.6%**
PFO: PALUSTRINE, FORESTED					
PFO1/2A	1	0	4.5	-	0.0%
PFO1/2C	36	0	290.9	-	0.0%
PFO1/2F	686	1	10,885.5	7.9	0.1%
PFO1/2Fh	5	0	103.7	-	0.0%
PFO1/2R	3	0	10.1	-	0.0%
PFO1/2T	47	0	976.7	-	0.0%
PFO1/4A	294	31	1,982.5	143.3	7.2%
PFO1/4Ah	11	0	27.0	-	0.0%
PFO1/4C	16	0	104.8	-	0.0%
PFO1/5C	1	0	297.9	-	0.0%
PFO1A	12824	1166	114,713.1	4,679.8	4.1%
PFO1Ad	44	12	269.7	66.5	24.7%
PFO1Ah	190	1	888.6	10.3	1.2%
PFO1Ahs	7	4	128.2	70.9	55.3%
PFO1Ax	51	2	171.9	0.5	0.3%
PFO1B	1	0	1.3	-	0.0%
PFO1C	5092	186	32,630.8	384.8	1.2%
PFO1Cd	11	4	24.8	12.6	50.9%
PFO1Ch	108	1	438.4	90.1	20.6%
PFO1Chs	3	1	56.8	8.2	14.4%
PFO1Cx	98	3	179.1	10.4	5.8%
PFO1F	300	10	1,654.1	26.8	1.6%
PFO1Fh	18	1	105.4	16.6	15.8%
PFO1Fx	21	0	96.0	-	0.0%
PFO1R	137	0	3,384.5	-	0.0%
PFO1S	79	0	486.1	-	0.0%
PFO1Ss	8	0	33.8	-	0.0%
PFO1T	31	0	196.6	-	0.0%
PFO1Tx	1	0	0.9	-	0.0%
PFO2/EM1T	1	0	17.9	-	0.0%
PFO2A	3	0	5.5	-	0.0%
PFO2C	7	0	42.0	-	0.0%
PFO2F	51	0	196.9	-	0.0%
PFO2Fh	12	0	92.8	-	0.0%
PFO2Fx	1	0	6.1	-	0.0%
PFO2T	27	0	99.6	-	0.0%
PFO4/1A	42	7	364.5	43.5	11.9%
PFO4/1C	2	0	3.3	-	0.0%
PFO4A	146	19	524.6	64.1	12.2%
PFO4Ah	1	0	6.1	-	0.0%
PFO4Ax	1	0	3.1	-	0.0%
PFO4C	3	0	12.2	-	0.0%
PFO5C	1	0	7.9	-	0.0%
PFO5Hh	1	0	1.9	-	0.0%

Wetland Loss by Full NWI Attribute Code

Wetland Class	Number of NWI Polygons	Number of Polygons Lost	Total Acres	Acres Lost	% Wet Loss
PFO5V	1	0	0.8	-	0.0%
	20,424.0	**1,449.0**	**171,529.0**	**5,636.3**	**3.3%**
PSS: PALUSTRINE, SCRUB-SHRUB					
PSS1/2F	42	0	375.4	-	0.0%
PSS1/2Fh	3	0	10.7	-	0.0%
PSS1/2T	26	0	374.2	-	0.0%
PSS1/4A	11	0	31.4	-	0.0%
PSS1/4C	5	0	11.0	-	0.0%
PSS1A	2894	380	8,261.8	787.6	9.5%
PSS1Ad	28	5	126.8	6.4	5.0%
PSS1Ah	30	2	333.7	17.1	5.1%
PSS1Ahs	5	1	47.1	24.2	51.4%
PSS1As	1	0	2.8	-	0.0%
PSS1Ax	71	4	184.8	11.8	6.4%
PSS1C	1316	117	3,197.9	212.1	6.6%
PSS1Cd	6	2	7.4	1.5	21.0%
PSS1Ch	86	6	668.3	153.1	22.9%
PSS1Chs	3	1	121.5	9.5	7.8%
PSS1Cx	94	10	161.3	10.2	6.3%
PSS1F	152	8	486.3	15.5	3.2%
PSS1Fh	38	2	246.5	4.2	1.7%
PSS1Fx	35	1	56.2	0.6	1.0%
PSS1Khs	8	0	146.2	-	0.0%
PSS1Kx	4	1	37.7	1.3	3.5%
PSS1P	2	0	1.2	-	0.0%
PSS1R	30	0	123.4	-	0.0%
PSS1S	11	0	60.8	-	0.0%
PSS1Ss	3	0	15.0	-	0.0%
PSS1T	28	0	385.9	-	0.0%
PSS2A	37	5	47.7	0.5	1.1%
PSS2C	1	0	9.4	-	0.0%
PSS2F	9	0	13.3	-	0.0%
PSS2Fh	2	0	0.7	-	0.0%
PSS2T	1	0	2.2	-	0.0%
PSS3A	61	2	345.7	5.7	1.7%
PSS3Ah	3	0	13.6	-	0.0%
PSS3As	2	0	11.6	-	0.0%
PSS3C	4	0	18.0	-	0.0%
PSS3Khs	8	0	74.2	-	0.0%
PSS3P	5	0	12.8	-	0.0%
PSS4/1C	8	1	5.7	1.0	17.9%
PSS4A	59	10	182.9	54.7	29.9%
PSS4C	1	0	7.8	-	0.0%
PSSC	1	0	2.2	-	0.0%
PSSf	139	16	3,043.3	155.6	5.1%
	5,273.0	**574.0**	**19,266.3**	**1,472.8**	**7.6%**
PUB: PALUSTRINE, UNCONSOLIDATED BOTTOM					

Wetland Loss by Full NWI Attribute Code

Wetland Class	Number of NWI Polygons	Number of Polygons Lost	Total Acres	Acres Lost	% Wet Loss
PUBF	764	27	739.5	17.2	2.3%
PUBFd	2	0	0.8	-	0.0%
PUBFh	334	6	601.4	2.5	0.4%
PUBFhs	17	5	116.1	1.8	1.5%
PUBFs	4	0	0.9	-	0.0%
PUBFx	5206	223	4,403.1	233.4	5.3%
PUBFx/U	1	0	17.4	-	0.0%
PUBH	472	4	1,308.5	5.2	0.4%
PUBHh	448	8	2,485.8	6.4	0.3%
PUBHhs	1	0	0.7	-	0.0%
PUBHs	2	0	5.7	-	0.0%
PUBHx	3090	102	6,042.4	177.3	2.9%
PUBKHx	4	0	4.3	-	0.0%
PUBKh	14	0	303.5	-	0.0%
PUBKhs	30	0	105.5	-	0.0%
PUBKx	302	56	650.7	33.1	5.1%
PUBT	57	0	296.3	-	0.0%
PUBTx	2	0	1.8	-	0.0%
PUBV	87	0	224.0	-	0.0%
PUBVx	1	0	5.2	-	0.0%
	10,838.0	**431.0**	**17,313.5**	**476.9**	**2.8%**
PUS: PALUSTRINE, UNCONSOLIDATED SHORE					
PUSA	36	0	56.4	-	0.0%
PUSAh	1	0	3.9	-	0.0%
PUSAx	47	7	140.4	6.9	4.9%
PUSC	123	7	73.3	3.6	4.9%
PUSCh	7	0	43.7	-	0.0%
PUSChs	12	1	58.7	5.0	8.5%
PUSCx	591	77	757.5	60.6	8.0%
PUSKhs	33	0	116.2	-	0.0%
PUSKx	20	2	227.0	3.8	1.7%
PUSR	3	0	13.0	-	0.0%
	873.0	**94.0**	**1,490.1**	**79.9**	**5.4%**
TOTAL PALUSTRINE	**58,192.0**	**4,298.0**	**447,534.9**	**11,465.9**	**2.6%**
R1: RIVERINE, TIDAL					
R1UBH	2	0	14.2	-	0.0%
R1UBT	7	0	35.3	-	0.0%
R1UBV	105	0	3,877.4	-	0.0%
R1UBVx	27	0	137.3	-	0.0%
R1USR	4	0	9.4	-	0.0%
R1USS	5	0	10.5	-	0.0%
	150.0	**-**	**4,084.1**	**-**	**0.0%**
R2: RIVERINE, ;OWER PERENNIAL					
R2AB3Hx	9	0	78.3	-	0.0%
R2AB4Hx	8	0	42.9	-	0.0%
R2UBFx	1	0	0.5	-	0.0%

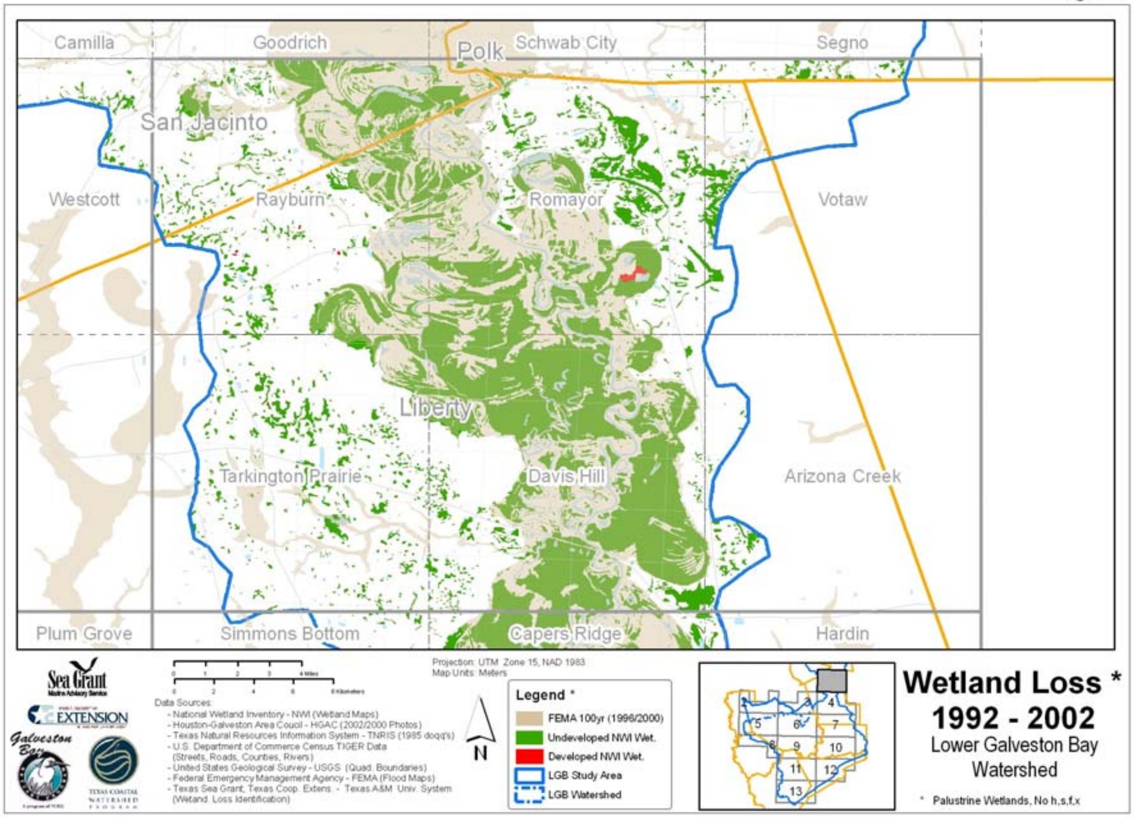
Wetland Loss by Full NWI Attribute Code

Wetland Class	Number of NWI Polygons	Number of Polygons Lost	Total Acres	Acres Lost	% Wet Loss
R2UBH	212	2	6,502.3	21.5	0.3%
R2UBHx	226	0	1,957.7	-	0.0%
R2UBV	1	0	6.4	-	0.0%
R2USA	161	1	327.3	0.3	0.1%
R2USC	26	4	23.8	3.4	14.1%
R2USCx	1	0	1.1	-	0.0%
			8,940.3	**25.2**	**0.3%**
R4: RIVERINE, INTERMITENT					
R4SBA	1	0	5.2	-	0.0%
R4SBC	5	1	3.8	2.1	55.2%
R4SBCx	23	0	38.9	-	0.0%
	29	**1**	**47.9**	**2.1**	**4.4%**
TOTAL RIVERINE	**179.0**	**1.0**	**13,072.3**	**27.3**	**0.2%**
TOTAL L, R, P	**59,002.00**	**4,303.00**	**505,048.00**	**11,554.12**	**2.3%**

APPENDIX C

ATLAS OF WETLAND LOSS

Page: 1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Polk
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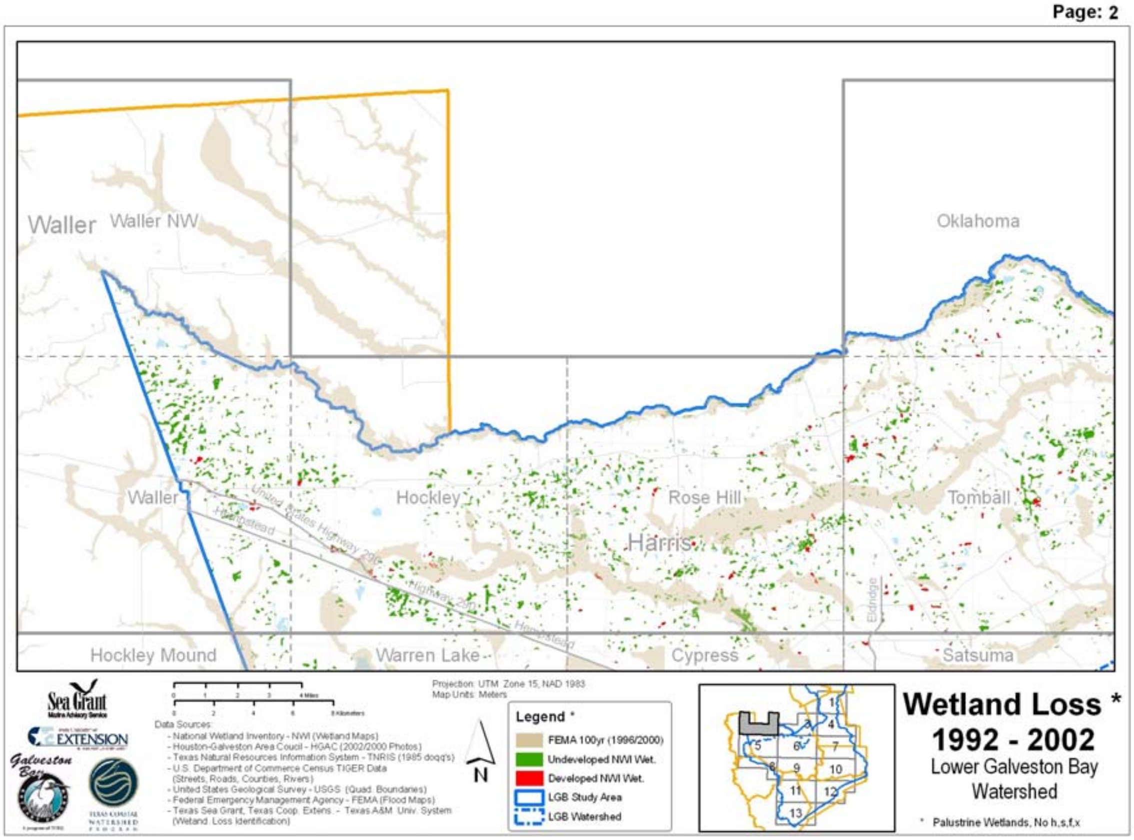
Segno
San Jacinto
Westcott
Rayburn
Romayor
Votaw
Liberty
Tarkington Prairie
Davis Hill
Arizona Creek
Plum Grove
Simmons Bottom
Capers Ridge
Hardin
0 1 2 3 4 Miles
0 2 4 6 8 Kilometers
Projection: UTM Zone 15, NAD 1983
Map Units: Meters
Data Sources:
- National Wetland Inventory - NWI (Wetland Maps)
- Houston-Galveston Area Coucil - HGAC (2002/2000 Photos)
- Texas Natural Resources Information System - TNRIS (1985 doqq's)
- U.S. Department of Commerce Census TIGER Data (Streets, Roads, Counties, Rivers)
- United States Geological Survey - USGS (Quad. Boundaries)
- Federal Emergency Management Agency - FEMA (Flood Maps)
- Texas Sea Grant, Texas Coop. Extens. - Texas A&M Univ. System (Wetland Loss Identification)
N
Legend *
FEMA 100yr (1996/2000)
Undeveloped NWI Wet.
Developed NWI Wet.
LGB Study Area
LGB Watershed
Wetland Loss *
1992 - 2002
Lower Galveston Bay Watershed
* Palustrine Wetlands, No h,s,f,x

Page: 2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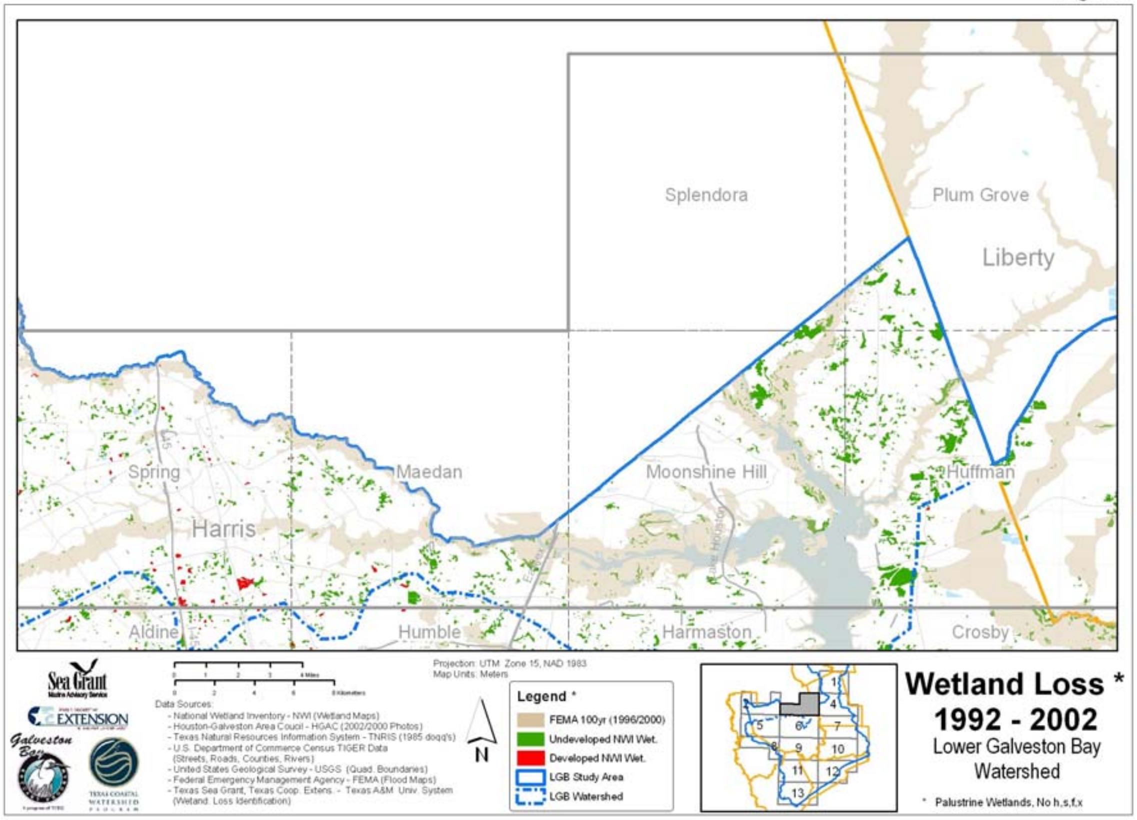
Waller NW
Oklahoma
Waller
Hockley
Rose Hill
Tomball
Harris
United States Highway 290
Hempstead
Eldridge
Hockley Mound
Warren Lake
Cypress
Satsuma
0 1 2 3 4 Miles
0 2 4 6 8 Kilometers
Projection: UTM Zone 15, NAD 1983
Map Units: Meters
Data Sources:
- National Wetland Inventory - NWI (Wetland Maps)
- Houston-Galveston Area Coucil - HGAC (2002/2000 Photos)
- Texas Natural Resources Information System - TNRIS (1985 doqq's)
- U.S. Department of Commerce Census TIGER Data (Streets, Roads, Counties, Rivers)
- United States Geological Survey - USGS (Quad. Boundaries)
- Federal Emergency Management Agency - FEMA (Flood Maps)
- Texas Sea Grant, Texas Coop. Extens. - Texas A&M Univ. System (Wetland Loss Identification)
N
Legend *
FEMA 100yr (1996/2000)
Undeveloped NWI Wet.
Developed NWI Wet.
LGB Study Area
LGB Watershed
Wetland Loss *
1992 - 2002
Lower Galveston Bay Watershed
* Palustrine Wetlands, No h,s,f,x


Splendora
Plum Grove
Liberty
Spring
Maedan
Moonshine Hill
Huffman
Harris
Aldine
Humble
Harmaston
Crosby
Sea Grant
EXTENSION
Galveston Bay
Projection: UTM Zone 15, NAD 1983
Map Units: Meters
Data Sources:
- National Wetland Inventory - NWI (Wetland Maps)
- Houston-Galveston Area Coucil - HGAC (2002/2000 Photos)
- Texas Natural Resources Information System - TNRIS (1985 doqq's)
- U.S. Department of Commerce Census TIGER Data (Streets, Roads, Counties, Rivers)
- United States Geological Survey - USGS (Quad. Boundaries)
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Legend *
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Developed NWI Wet.
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LGB Watershed
Wetland Loss *
1992 - 2002
Lower Galveston Bay Watershed
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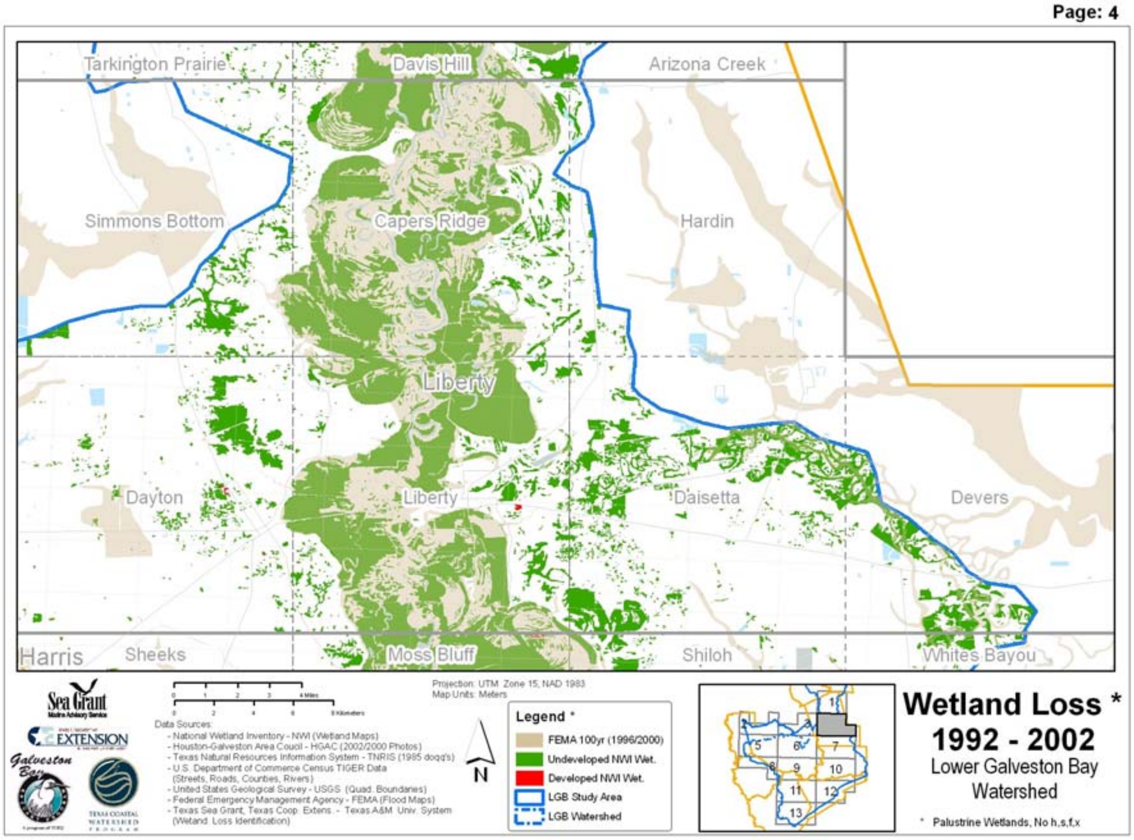
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Arizona Creek
Simmons Bottom
Capers Ridge
Hardin
Liberty
Dayton
Liberty
Daisetta
Devers
Harris
Sheeks
Moss Bluff
Shiloh
Whites Bayou
Sea Grant
EXTENSION
Galveston Bay
Projection: UTM Zone 15, NAD 1983
Map Units: Meters
Data Sources:
- National Wetland Inventory - NWI (Wetland Maps)
- Houston-Galveston Area Coucil - HGAC (2002/2000 Photos)
- Texas Natural Resources Information System - TNRIS (1985 doqq's)
- U.S. Department of Commerce Census TIGER Data (Streets, Roads, Counties, Rivers)
- United States Geological Survey - USGS (Quad. Boundaries)
- Federal Emergency Management Agency - FEMA (Flood Maps)
- Texas Sea Grant, Texas Coop. Extens. - Texas A&M Univ. System (Wetland. Loss Identification)
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Legend *
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Developed NWI Wet.
LGB Study Area
LGB Watershed
Wetland Loss *
1992 - 2002
Lower Galveston Bay Watershed
* Palustrine Wetlands, No h,s,f,x

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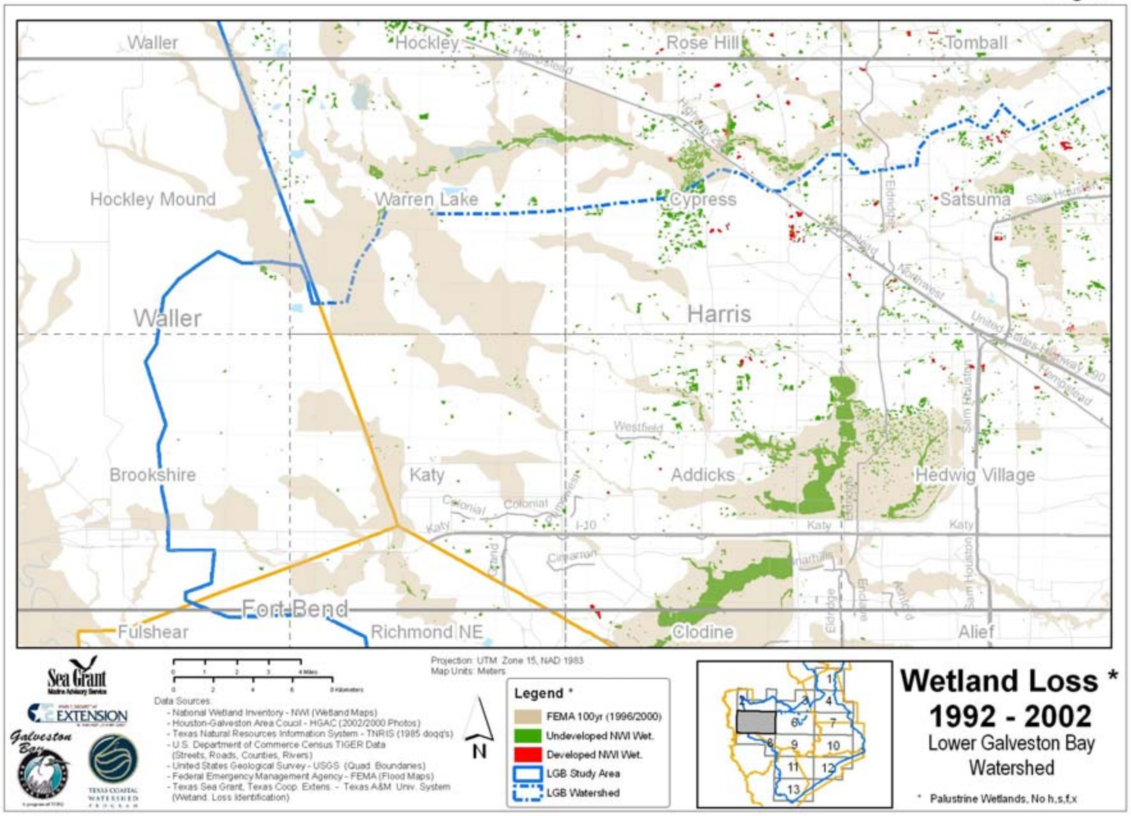
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Hockley
Rose Hill
Tomball
Hockley Mound
Warren Lake
Cypress
Satsuma
Waller
Harris
Westfield
Brookshire
Katy
Addicks
Hedwig Village
Fort Bend
Fulshear
Richmond NE
Clodine
Alief
Projection: UTM Zone 15, NAD 1983
Map Units: Meters
Data Sources:
- National Wetland Inventory - NWI (Wetland Maps)
- Houston-Galveston Area Coucil - HGAC (2002/2000 Photos)
- Texas Natural Resources Information System - TNRIS (1985 doqq's)
- U.S. Department of Commerce Census TIGER Data (Streets, Roads, Counties, Rivers)
- United States Geological Survey - USGS (Quad. Boundaries)
- Federal Emergency Management Agency - FEMA (Flood Maps)
- Texas Sea Grant, Texas Coop. Extens. - Texas A&M Univ. System (Wetland Loss Identification)
Legend *
FEMA 100yr (1996/2000)
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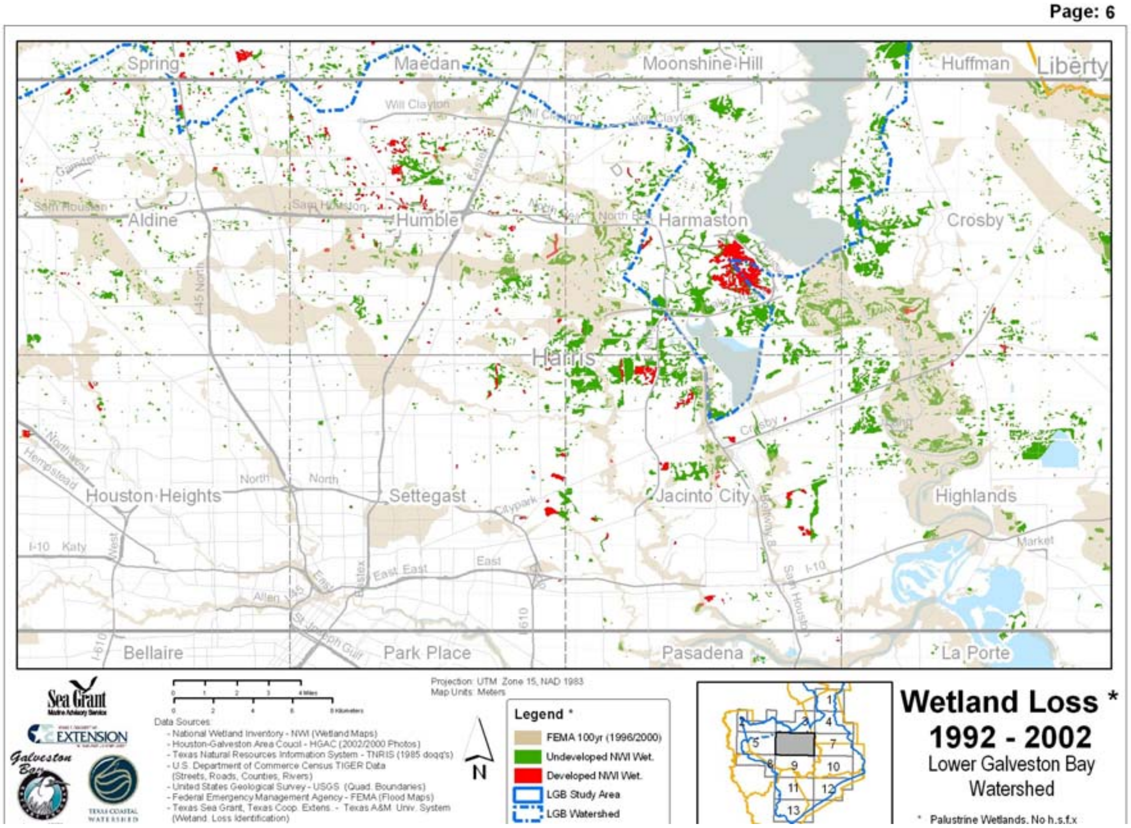
Developed NWI Wet.
LGB Study Area
LGB Watershed
Wetland Loss *
1992 - 2002
Lower Galveston Bay Watershed
* Palustrine Wetlands, No h,s,f,x

Page: 6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Maedan
Moonshine Hill
Huffman
Liberty
Aldine
Humble
Harmaston
Crosby
Harris
Houston Heights
Settegast
Jacinto City
Highlands
Bellaire
Park Place
Pasadena
La Porte
Projection: UTM Zone 15, NAD 1983
Map Units: Meters
Data Sources:
- National Wetland Inventory - NWI (Wetland Maps)
- Houston-Galveston Area Coucil - HGAC (2002/2000 Photos)
- Texas Natural Resources Information System - TNRIS (1985 doqq's)
- U.S. Department of Commerce Census TIGER Data (Streets, Roads, Counties, Rivers)
- United States Geological Survey - USGS (Quad. Boundaries)
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Lower Galveston Bay Watershed
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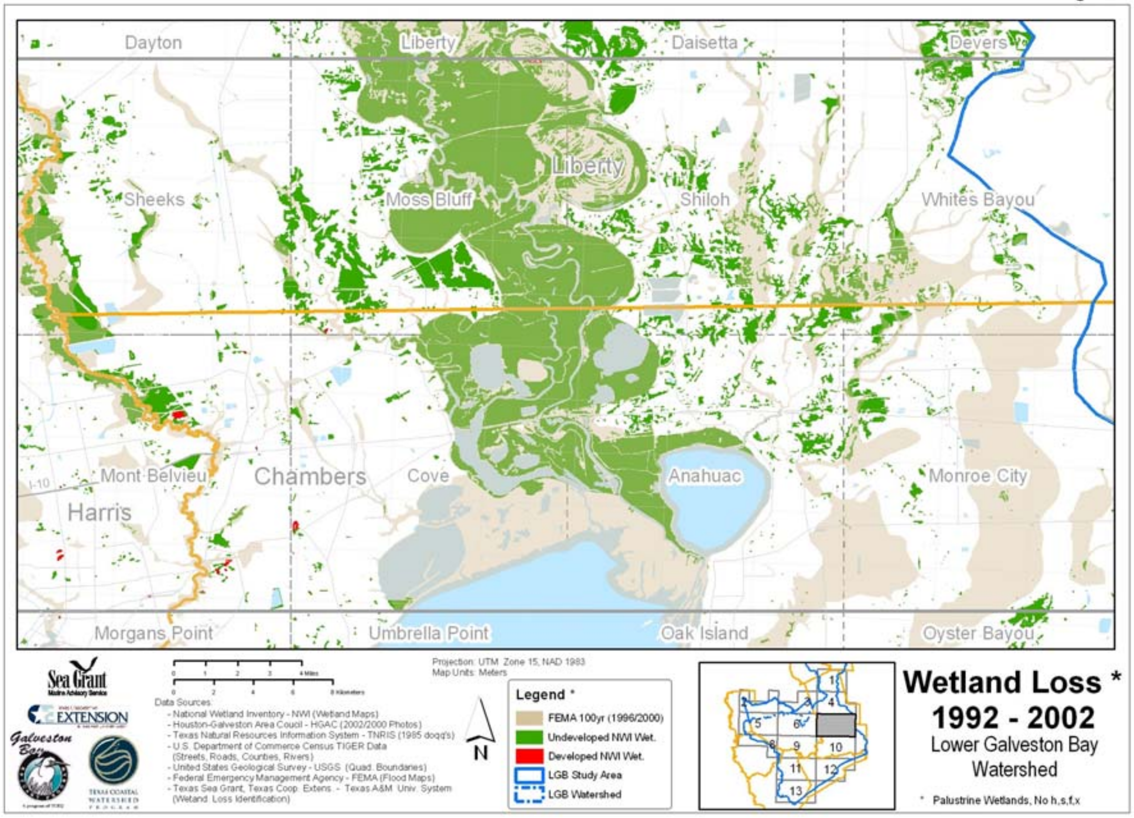
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Liberty
Daisetta
Devers
Liberty
Sheeks
Moss Bluff
Shiloh
Whites Bayou
Mont Belvieu
Chambers
Cove
Anahuac
Monroe City
Harris
I-10
Morgans Point
Umbrella Point
Oak Island
Oyster Bayou
Sea Grant
EXTENSION
Galveston Bay
TEXAS COASTAL WATERSHED PROGRAM
Data Sources:
- National Wetland Inventory - NWI (Wetland Maps)
- Houston-Galveston Area Coucil - HGAC (2002/2000 Photos)
- Texas Natural Resources Information System - TNRIS (1995 doqq's)
- U.S. Department of Commerce Census TIGER Data (Streets, Roads, Counties, Rivers)
- United States Geological Survey - USGS (Quad. Boundaries)
- Federal Emergency Management Agency - FEMA (Flood Maps)
- Texas Sea Grant, Texas Coop. Extens. - Texas A&M Univ. System (Wetland Loss Identification)
Projection: UTM Zone 15, NAD 1983
Map Units: Meters
N
Legend *
FEMA 100yr (1996/2000)
Undeveloped NWI Wet.
Developed NWI Wet.
LGB Study Area
LGB Watershed
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1992 - 2002
Lower Galveston Bay
Watershed
* Palustrine Wetlands, No h,s,f,x

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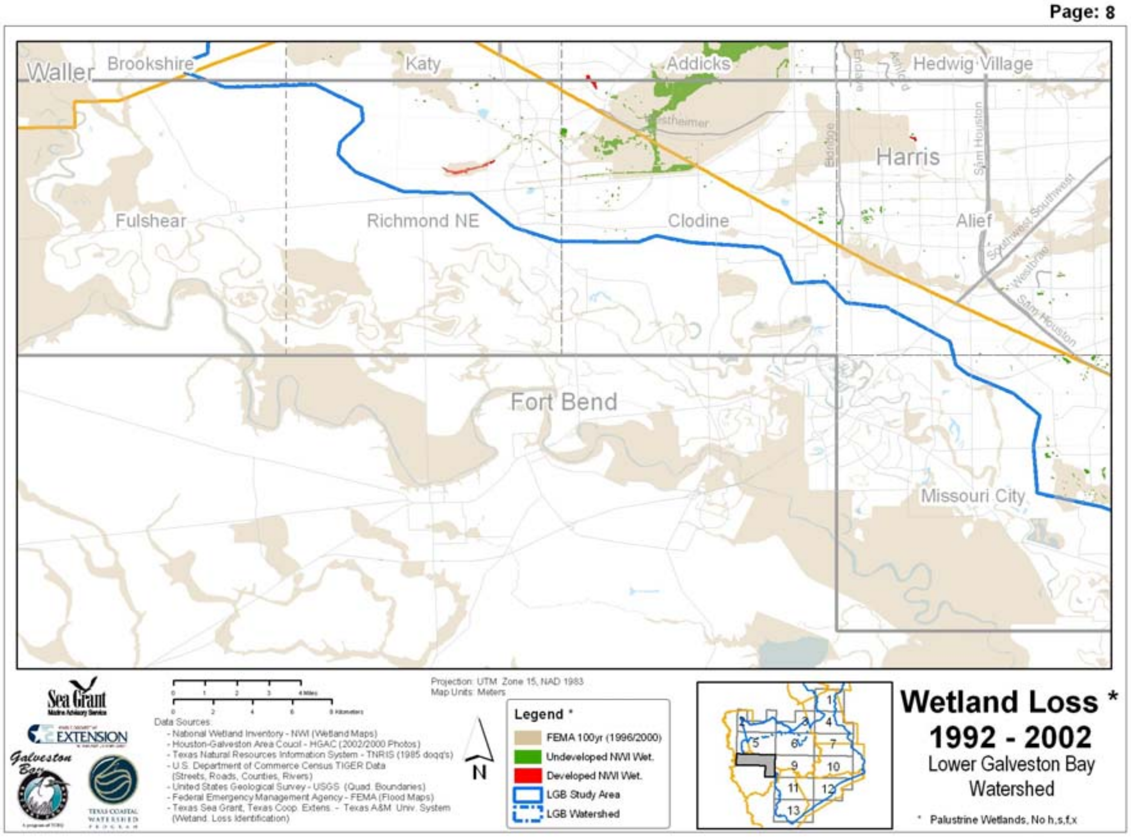
Waller
Brookshire
Katy
Addicks
Hedwig Village
Harris
Fulshear
Richmond NE
Clodine
Alief
Fort Bend
Missouri City
Sea Grant
EXTENSION
Galveston Bay
TEXAS COASTAL WATERSHED PROGRAM
Data Sources:
- National Wetland Inventory - NWI (Wetland Maps)
- Houston-Galveston Area Coucil - HGAC (2002/2000 Photos)
- Texas Natural Resources Information System - TNRIS (1995 doqq's)
- U.S. Department of Commerce Census TIGER Data (Streets, Roads, Counties, Rivers)
- United States Geological Survey - USGS (Quad. Boundaries)
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Projection: UTM Zone 15, NAD 1983
Map Units: Meters
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Legend *
FEMA 100yr (1996/2000)
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Developed NWI Wet.
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Watershed
* Palustrine Wetlands, No h,s,f,x

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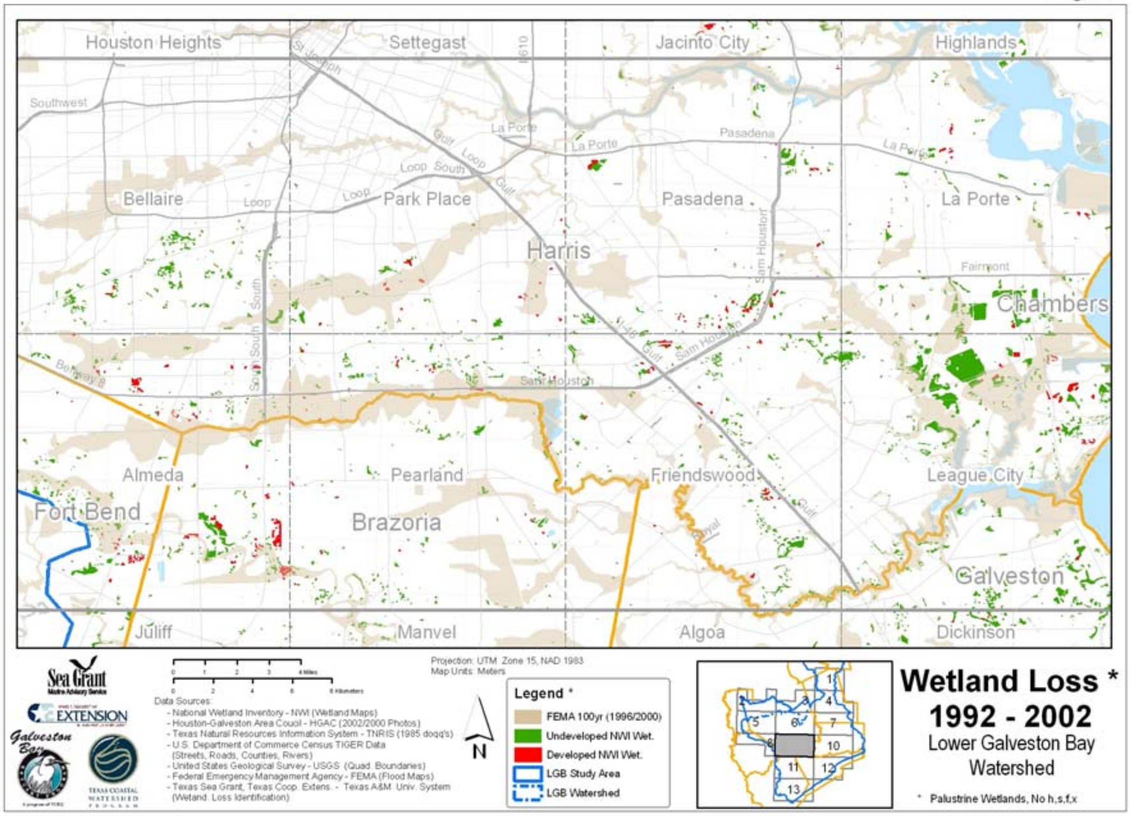

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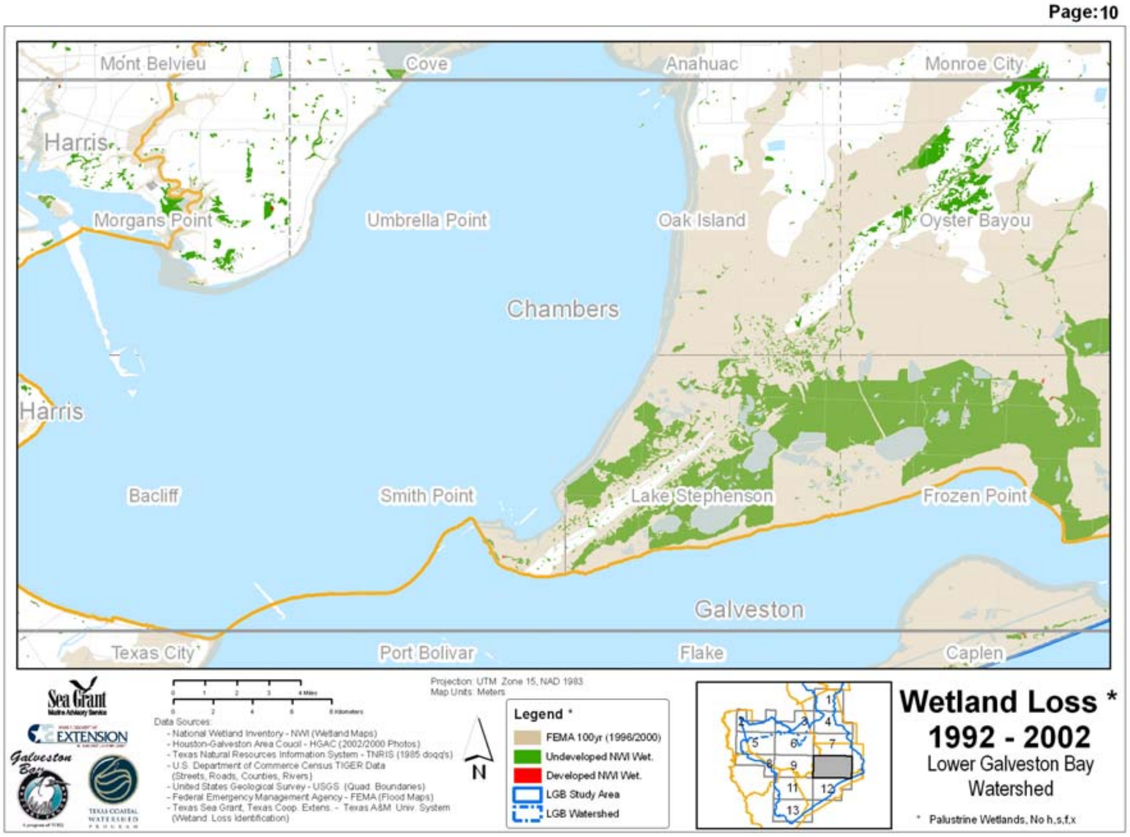

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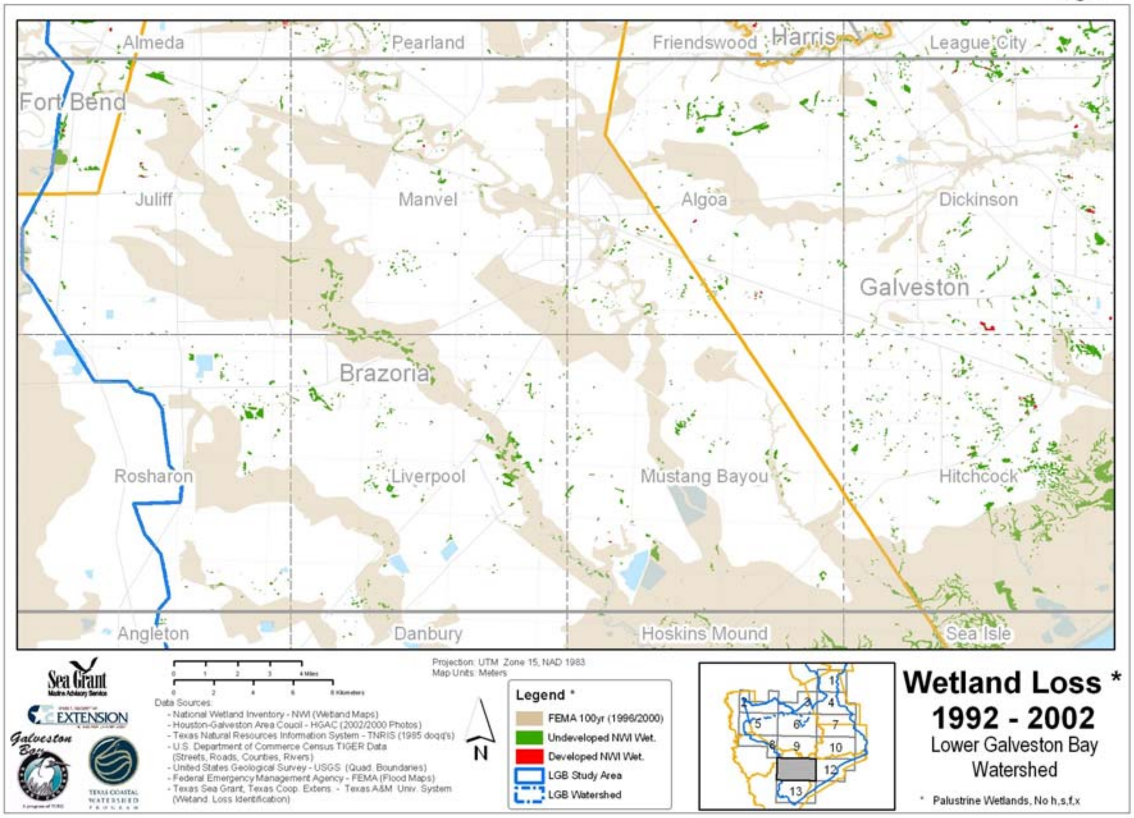

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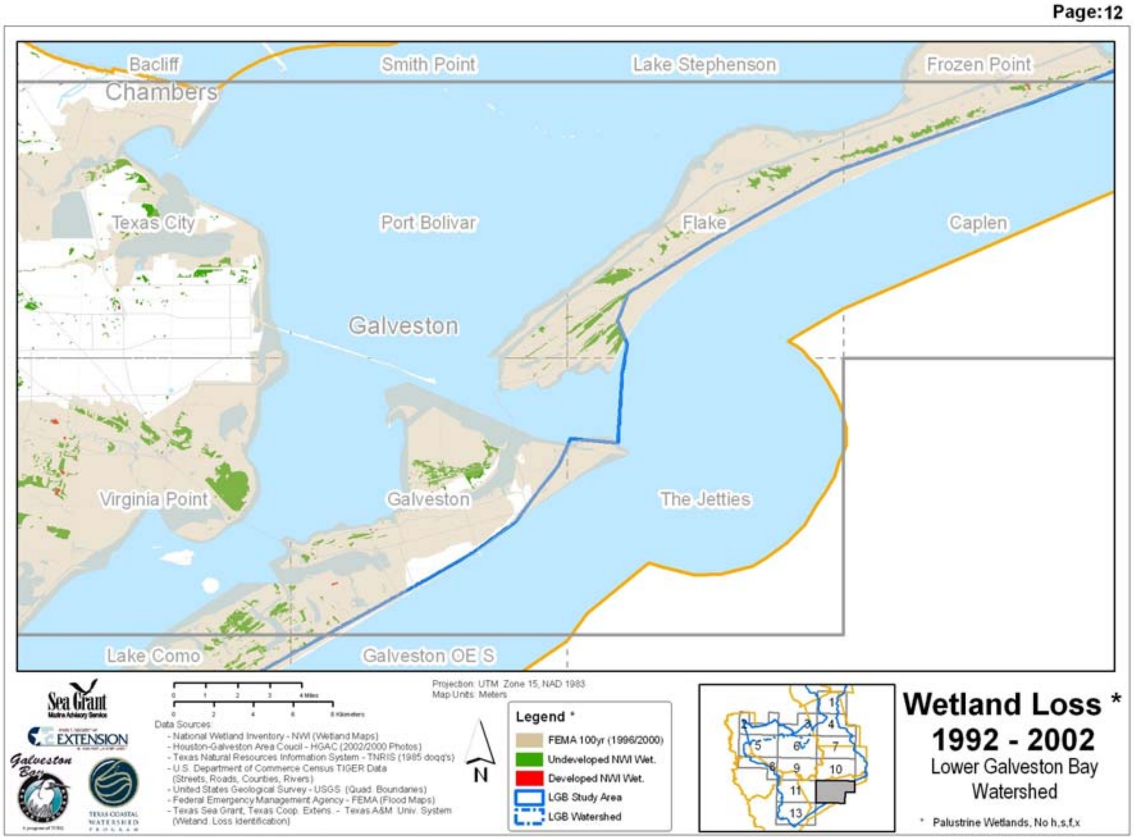

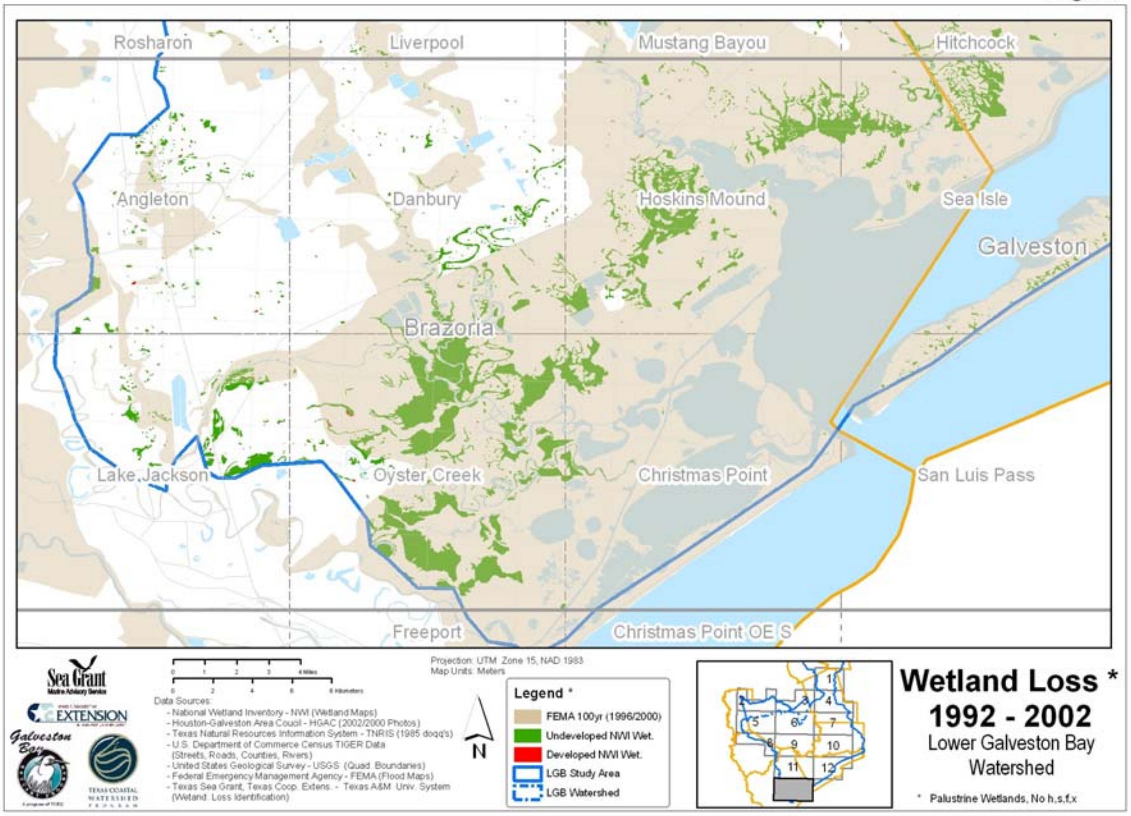
Rosharon
Liverpool
Mustang Bayou
Hitchcock
Angleton
Danbury
Hoskins Mound
Sea Isle
Galveston
Brazoria
Lake Jackson
Oyster Creek
Christmas Point
San Luis Pass
Freeport
Christmas Point OE S
Projection: UTM Zone 15, NAD 1983
Map Units: Meters
Data Sources:
- National Wetland Inventory - NWI (Wetland Maps)
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- U.S. Department of Commerce Census TIGER Data (Streets, Roads, Counties, Rivers)
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- Texas Sea Grant, Texas Coop. Extens. - Texas A&M Univ. System (Wetland Loss Identification)
N
Legend *
FEMA 100yr (1996/2000)
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APPENDIX D

METHODS AND META-DATA

GALVESTON BAY WETLAND LOSS

GEOSPATIAL DATA PROCESSING

The analysis and mapping of wetland loss due to development at its simplest level involves comparing the 1989-92 NWI polygons with the most recent aerial photography available. Development has a markedly different tonal pattern than undisturbed wetlands, such that it is a simple matter of delineating the developed area.

To perform the geospatial processing, 1995 CIR DOQQ photos and H-GAC 2002 aerial photography were used as backdrop imagery where 1989 NWI (National Wetland Inventory) maps in digital format were merged, overlaid and edited using heads-up digitizing (on-screen). NWI Polygon features were cut to reflect destruction of wetlands due to urban development or other causes. NWI attribute tables were modified to include a field that tracks polygon change. Other fields were added to individual NWI dataset's attribute tables before merging, to facilitate analysis and exporting detailed data at different levels: USGS Quads, County, Study Area or Lambert Grids. The entire processing is detailed in the sections below.

1- INPUT DATA

1.1 Study Area

The Lower Galveston Bay Watershed is covered by 108 USGS Quads. We extended the study area with 8 more quads, to include the entire Harris County, as shown in figure 1:

Figure 1: Study area with watershed boundary and USGS Quadrangles

Table 1 - USGS Quadrangle Names

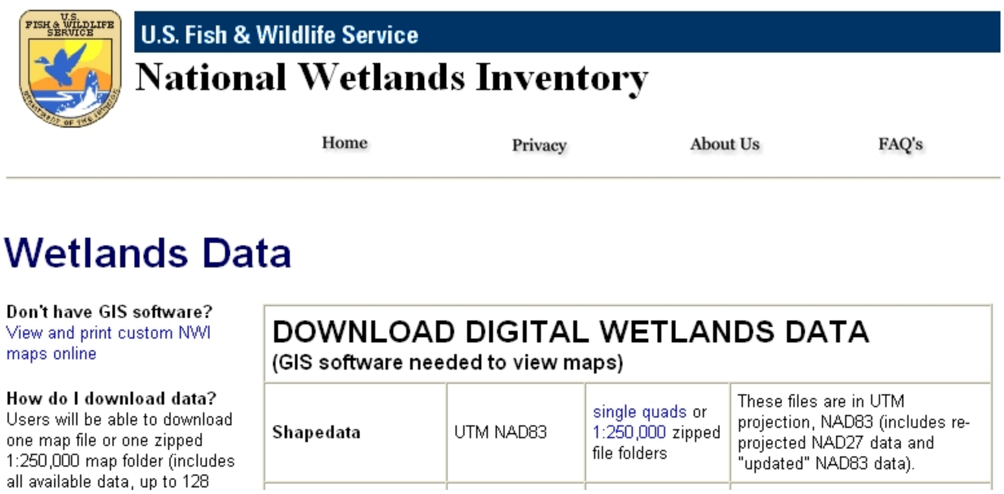
NAME	NAME	NAME
Addicks	Hedwig Village	Pearland
Aldine	High Island	Plum Grove
Algoa	Highlands	Port Bolivar
Alief	Hitchcock	Rayburn
Almeda	Hockley	Richmond NE
Anahuac	Hockley Mound	Romayor
Angleton	Hoskins Mound	Rose Hill
Arizona Creek	Houston Heights	Rosharon
Bacliff	Huffman	San Luis Pass
Bellaire	Humble	Satsuma
Blanchard	Jacinto City	Schwab City
Brookshire	Juliff	Sea Isle
Camilla	Katy	Segno
Capers Ridge	La Porte	Settegast
Caplen	Lake Como	Sheeks
Carmona	Lake Jackson	Shiloh
Christmas Point	Lake Stephenson	Simmons Bottom
Christmas Point OE S	League City	Smith Point
Clodine	Leggett	Soda
Coldspring	Liberty	Splendora
Corrigan	Liverpool	Spring
Cove	Livingston	Stanolind Reservoir
Crosby	Maedan	Stowell
Cypress	Manvel	Tarkington Prairie
Daisetta	Missouri City	Texas City
Danbury	Monroe City	The Jetties
Davis Hill	Mont Belvieu	Tomball
Dayton	Moonshine Hill	Umbrella Point
Devers	Morgans Point	Virginia Point
Dickinson	Moss Bluff	Votaw
Flake	Mud Lake	Waller
Freeport	Mustang Bayou	Waller NW
Friendswood	New Willard	Warren Lake
Frozen Point	Oak Island	Westcott
Fulshear	Oklahoma	Whites Bayou
Galveston	Onalaska	Whites Ranch
Galveston OE S	Oyster Bayou	
Goodrich	Oyster Creek	
Hardin	Park Place	
Harmaston	Pasadena	

1.2 Wetlands Vector Data

Vector datasets were downloaded in shapefile format from the official NWI website. All NWI datasets were merged using the same coordinate system, projection and datum (UTM (Universal Transverse Mercator) projection – zone 15 using NAD 83 datum, units: meters). Output vector datasets were reprojected and delivered using different projections, to allow users of ArcView 3.x to correctly overlay vector data to raster imagery stored in different coordinate systems (ArcView 3.x doesn’t allow raster data or projected vector data to be projected on-the-fly as ArcGIS 9.x does).

101 NWI quads were actually used in the project (see Table 2). From the original set of USGS quads, two of them (Freeport and Christmas Point OE s) didn’t have significant data. Finally, 13 quads from Polk and San Jacinto Counties (northern part of the study area) had not been released in digital vector format yet.

Website: http://www.nwi.fws.gov/downloads.htm



Zipped file folders (1:250,000 grid series – 1:24,000 scale): houston_104_files.zip - beaumont_64_files.zip

Unzipped shapefiles (UTM projection – zone 15, NAD83 datum)

Table 2 - NWI quad file names (shapefile vector format)

addick_p.shp	dayton_p.shp	jacinc_p.shp	oklaho_p.shp	splend_p.shp
aldine_p.shp	devers_p.shp	juliff_p.shp	oystby_p.shp	spring_p.shp
algoa_p.shp	dickin_p.shp	katy_p.shp	oyster_p.shp	stanor_p.shp
alief_p.shp	flake_p.shp	lakeco_p.shp	parkpl_p.shp	stowel_p.shp
almeda_p.shp	friend_p.shp	lakest_p.shp	pasade_p.shp	tarkip_p.shp
anahua_p.shp	frozen_p.shp	laport_p.shp	pearla_p.shp	texasc_p.shp
anglet_p.shp	fulshe_p.shp	league_p.shp	plumgr_p.shp	thejet_p.shp
arizcr_p.shp	galves_p.shp	libert_p.shp	portbo_p.shp	tombal_p.shp
baclif_p.shp	galvso_p.shp	liverp_p.shp	raybur_p.shp	umbrel_p.shp
bellai_p.shp	hardin_p.shp	lkjack_p.shp	richne_p.shp	virgin_p.shp
brooks_p.shp	harmas_p.shp	maedan_p.shp	romayo_p.shp	votaw_p.shp
caperr_p.shp	hedwiv_p.shp	manvel_p.shp	rosehi_p.shp	waller_p.shp
caplen_p.shp	highis_p.shp	missoc_p.shp	roshar_p.shp	wallnw_p.shp
christ_p.shp	highla_p.shp	monroc_p.shp	sanlui_p.shp	warrlk_p.shp
clodin_p.shp	hitchc_p.shp	montbe_p.shp	satsum_p.shp	westco_p.shp
cove_p.shp	hockle_p.shp	moonsh_p.shp	seaisl_p.shp	whiteb_p.shp
crosby_p.shp	hocklm_p.shp	morgan_p.shp	setteg_p.shp	whiter_p.shp
cypres_p.shp	hoskin_p.shp	mossbl_p.shp	sheeks_p.shp	
daiset_p.shp	housth_p.shp	mudlak_p.shp	shiloh_p.shp	
danbur_p.shp	huffma_p.shp	mustab_p.shp	simmob_p.shp	
davish_p.shp	humble_p.shp	oakisl_p.shp	smithp_p.shp	

1.3 USGS Quadrangles with no NWI digital data available

13 USGS quadrangles (see Figure 2) had no available wetland data in digital form (shapefiles), so we procured scanned copies of paper maps in TIF image format. These images were georeferenced to a projected coordinate system (UTM zone 15 – NAD83 datum) using the geo-referencing toolbar in ArcGIS.

These georeferenced images were made 50% transparent and overlaid on 1985 DOQQ aerial photographs. Only Palustrine wetlands clearly lost to development were digitized into vector polygons.

Figure 2 – USGS Quadrangles with no data id digital format (Vector format)

1.4 Aerial Photography

We used 2000/2002aerial photography (real color) procured from H-GAC (Houston-Galveston Area Council), and 1995 CIR DOQQ's (Color Infrared DOQQ's from the Texas Orthoimagery Program. These photos have the following projection and datum:

2002 H-GAC Photos: State Plane Coordinate System, Texas South Central Zone (FIPS 4204). Datum: NAD 1983. Units: feet.

1995 CIR DOQQ's: UTM (Universal Transverse Mercator) projection, zone 15. Datum: NAD 1983. Units: meters.

2- Geospatial processing

Included pre-processing individual NWI quads before merging them together into a single database, and other steps that are described as follows. ESRI ArcGIS 9.x (ArcEditor/ArcInfo) was used as main editing software to perform the entire processing.

2.1 Pre- processing

Before merging NWI polygons from all quads, certain pre-processing steps were followed so individual NWI quads could be later extracted successfully from the merged database. The Model Builder extension to ArcGIS was used to create a model (see Figure 3) to automate the process, as outlined below:

1. Four fields were added to each individual NWI quad shapefile: P_I (polygon unique ID field), QUAD (USGS quadrangle name), Dev (Identifies wetland loss or change to development) and EST (used to flag estuarine quadrangles around Galveston Bay)
2. Then, the algorithm updates the QUAD and EST fields based on user input using a dialog box. The P_I field is manually updated by copying the column that ends with the "P_I" text string (example, WESTCO_P_I). The "Dev" field is updated manually directly on the merged database.
3. The link between each polygon shapefile and the algorithm is recreated before each model run
4. Once the NWI quad polygons were edited, they were merged using a geo-processing tool from ArcGIS (Append).
5. The last step involves calculation of each polygon's areas, both in square meters and acres. Polygon areas in square meters are calculated using the ArcGIS field calculator and a VBA script. These areas are stored in a new field called "AREA_M2". Then, one more field is added (AREA_ACRE), whose values are derived from the previous calculation in square meters (AREA_M2 / 4047)

.

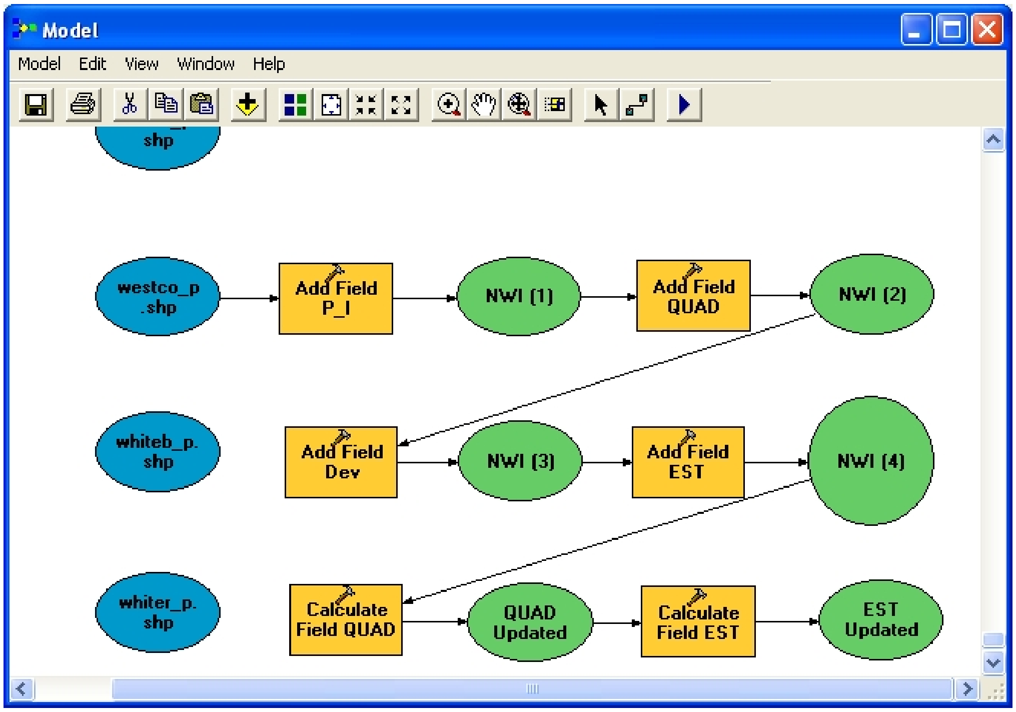


Figure 3 – Geoprocessing Model used to pre-process NWI Quads

2.2 NWI Polygon editing

This step included modifying (cutting) polygon features where urban development or other change was detected, based on backdrop aerial photographs (H-GAC 2002 photos). The NWI attribute table was edited at the same time, to reflect the reason of change (Figure 4). For that matter, an additional field (“DEV”)was added to the attribute table, which could take the following values:

R: Residential
I: Industrial/Commercial
F: Filled
W: Water

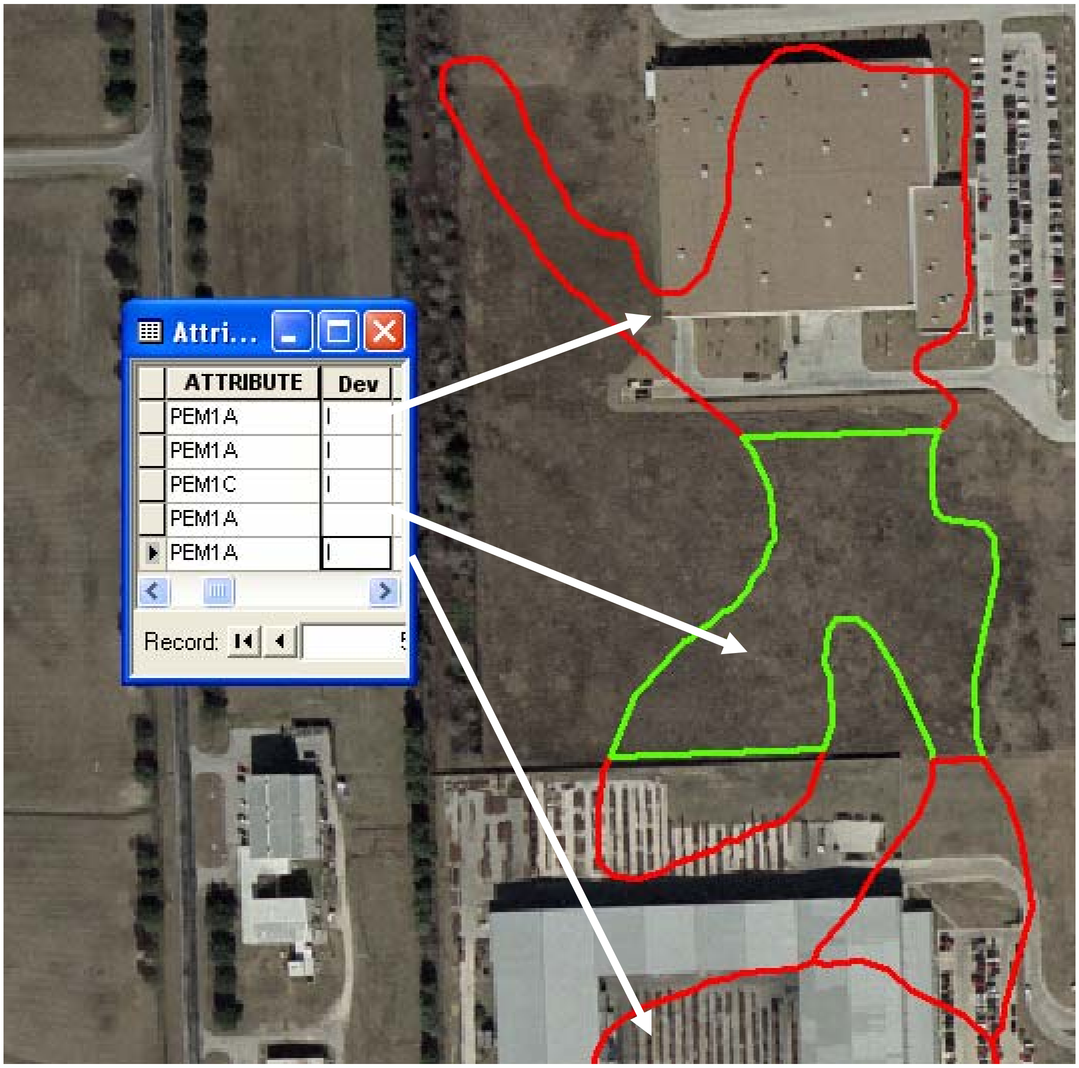


Figure 4. Wetland polygon from NWI overlain on 2002 color photo. *Developed area is cut out and reclassified as "I", which stands for "Industrial/Commercial" in the attribute table. The undeveloped area is left blank in the new field for 2002 status. A query method allows the "change" in 1990 habitats to be calculated.*

3 - Map output

3.1 Percent wetland loss by Lambert grid cell

This map (Figure 5) uses as display units the same grid used for the Lambert aerial photographs (2.5 mile x 1.6 mile approximate cell size):

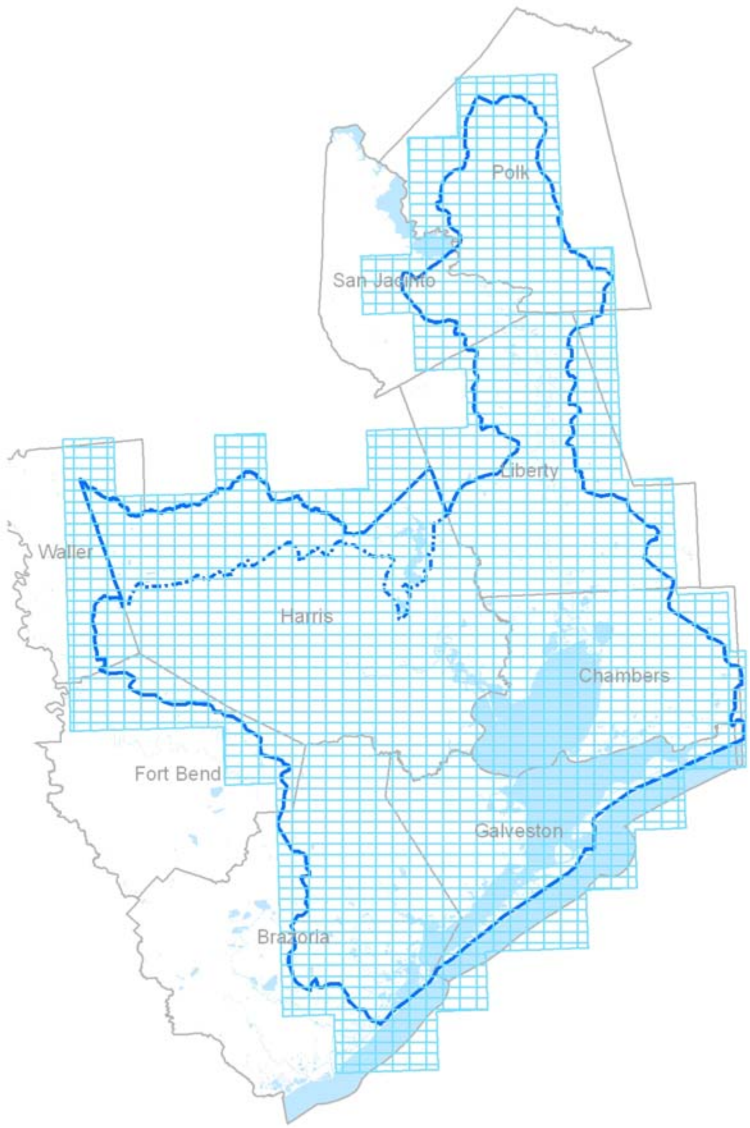


Figure 5 – Lambert grid used to create relative wetland loss map

To create this wetland percent loss map (Figure 6), one extra field was added to the merged NWI wetland file (WETLOSS_AC). This field stores areas for lost wetlands only. The merged NWI wetland file was then spatially joined to the Lambert grid shown above, summarizing wetland area fields per Lambert cell (Area_acres and wetloss_ac). The final symbolization for the map was created in graduated colors, normalizing lost areas (wetloss_ac) by total wetland area (area_acre), after filtering the layer (definition query) by wetland type (example, Palustrine wetlands, without h, s, and x, special modifiers), as shown below:

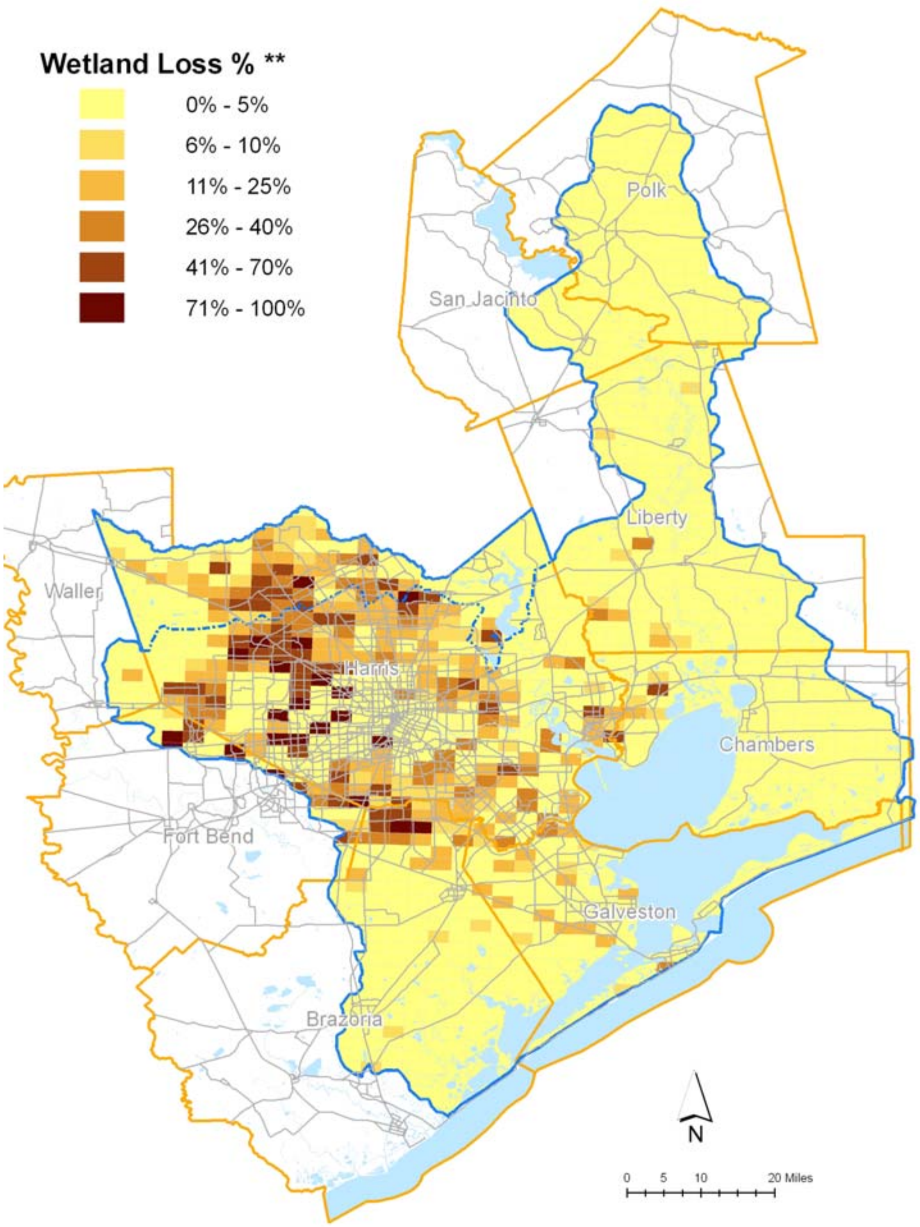


Figure 6 – Relative Wetland Loss by Lambert grid cell

3.2 Detailed Wetland Loss Map Atlas

To create this 13-page map atlas, we downloaded and installed a sample from the ESRI Developer's Website (*DSMapBook*). Each page covers up to 8 NWI quads. See sample page in Figure 7 below.

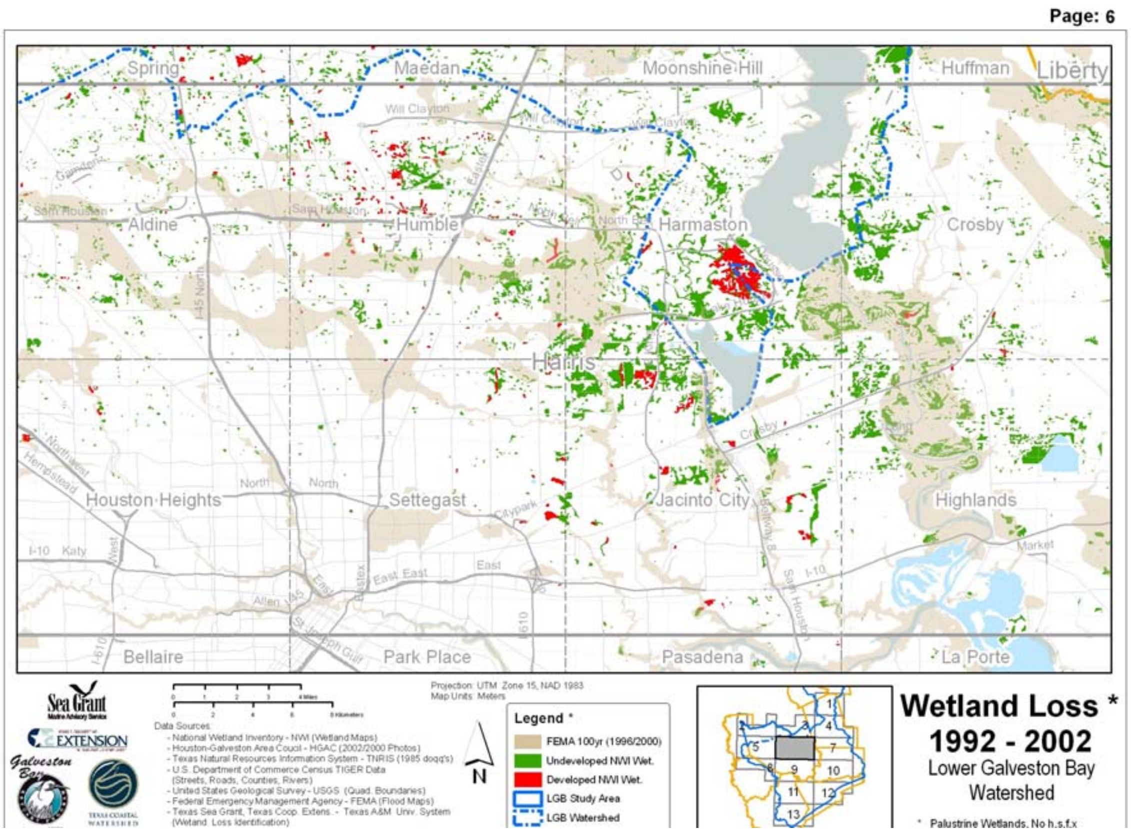


Figure 7 – Sample page form Wetland Loss Map Atlas

3.4 - Tabular Output Data

Two main formats were used to produce tabular reports: MS Excel files and MS Access database format.

MS Excel

MS Excel files were first created by exporting the merged Attribute table into a DBF file and then reading and converting this file into an MS Excel worksheet file format. Further calculations were performed using Excel's embedded mathematical functions. (See appendix with tabular results)

MS Access Database

A simplified database application was developed to facilitate querying the wetlands database using different criteria. For example, wetland loss can be queried and summarized by System, Class and full NWI attribute code. Besides, wetland loss can be summarized by USGS quad, County or total Study Area, and classified into Natural or man-made wetlands. Figures 8 to 15 show selected screen shots taken from the application:

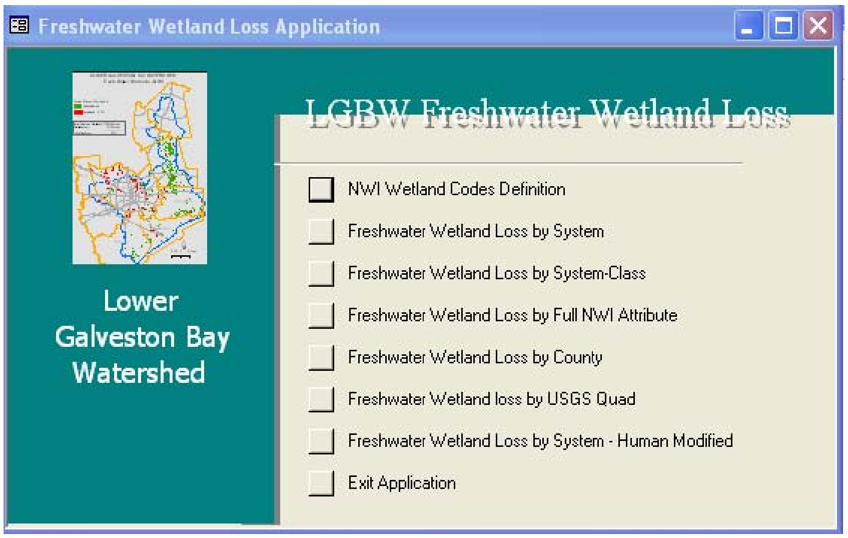


Figure 8 – Wetland Loss Application – Main Menu

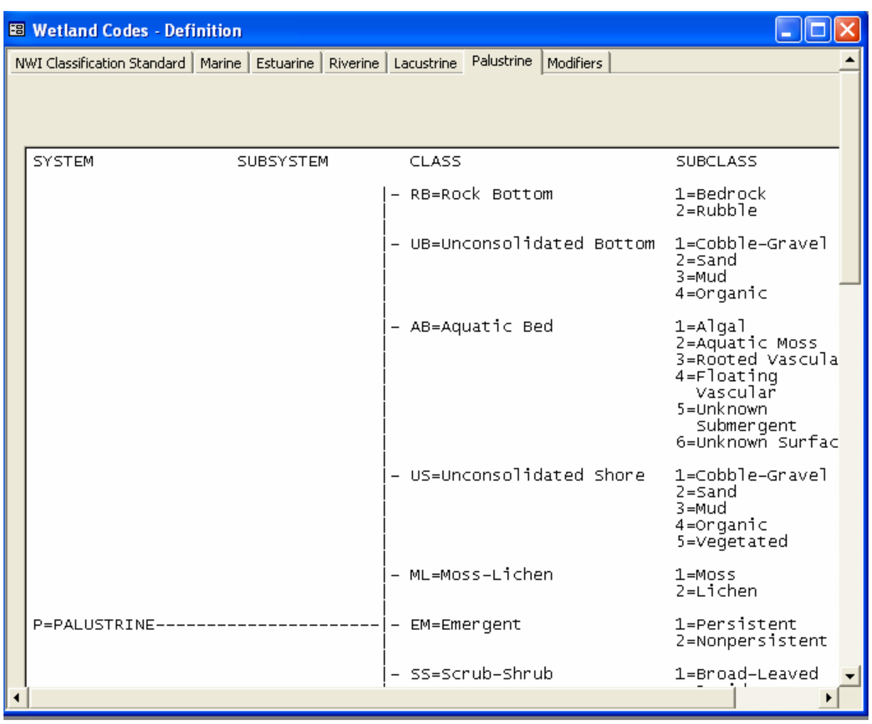


Figure 9 – Wetland Loss Application – NWI Codes Definition

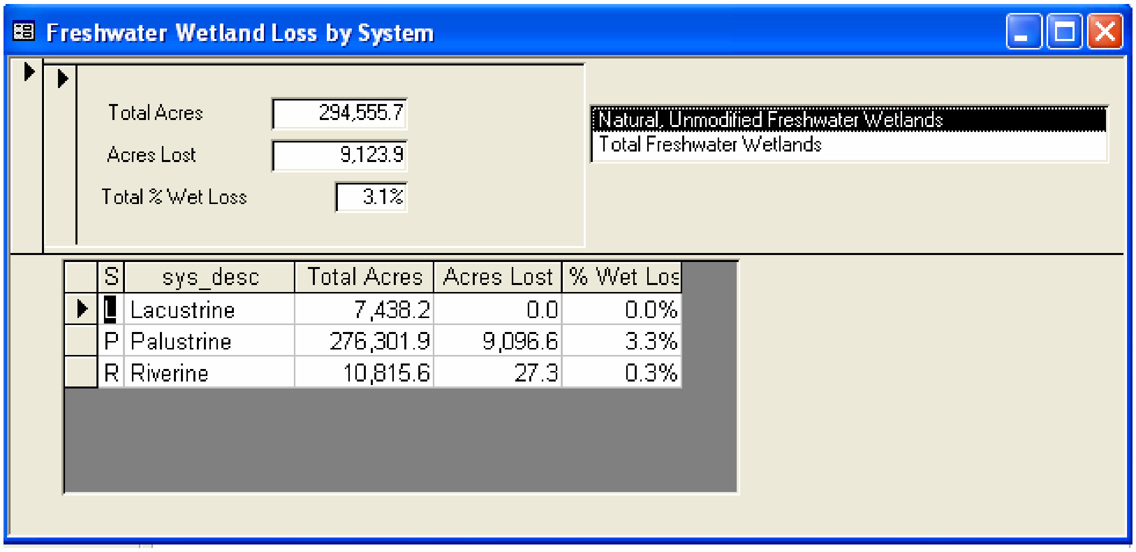


Figure 10 – Wetland Loss Application – Wetland Loss by System

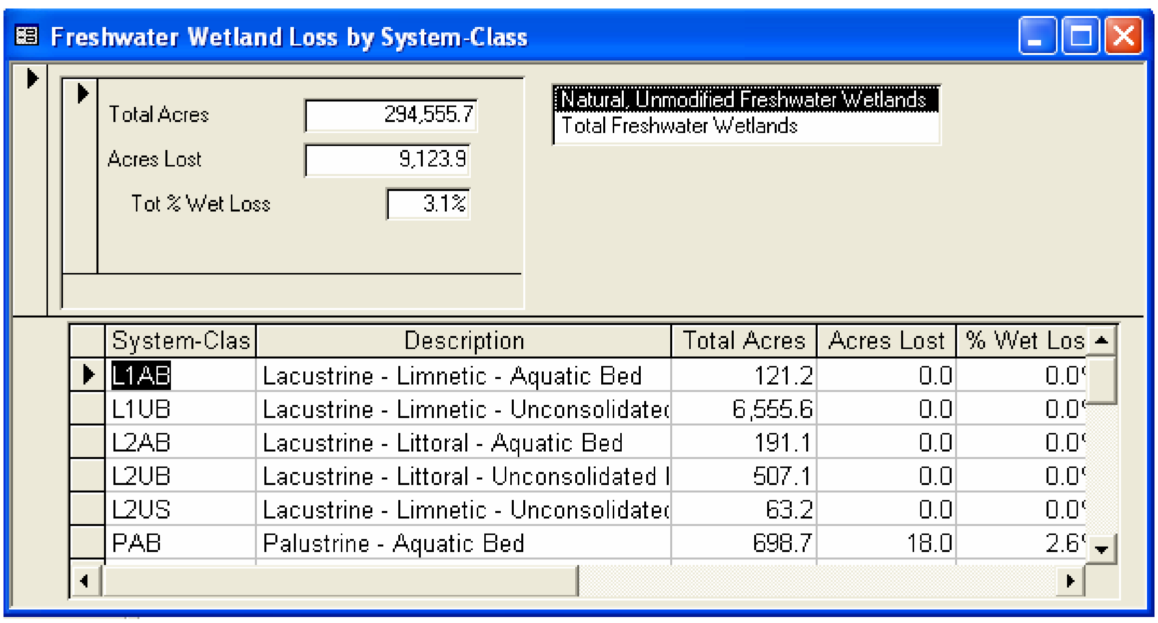
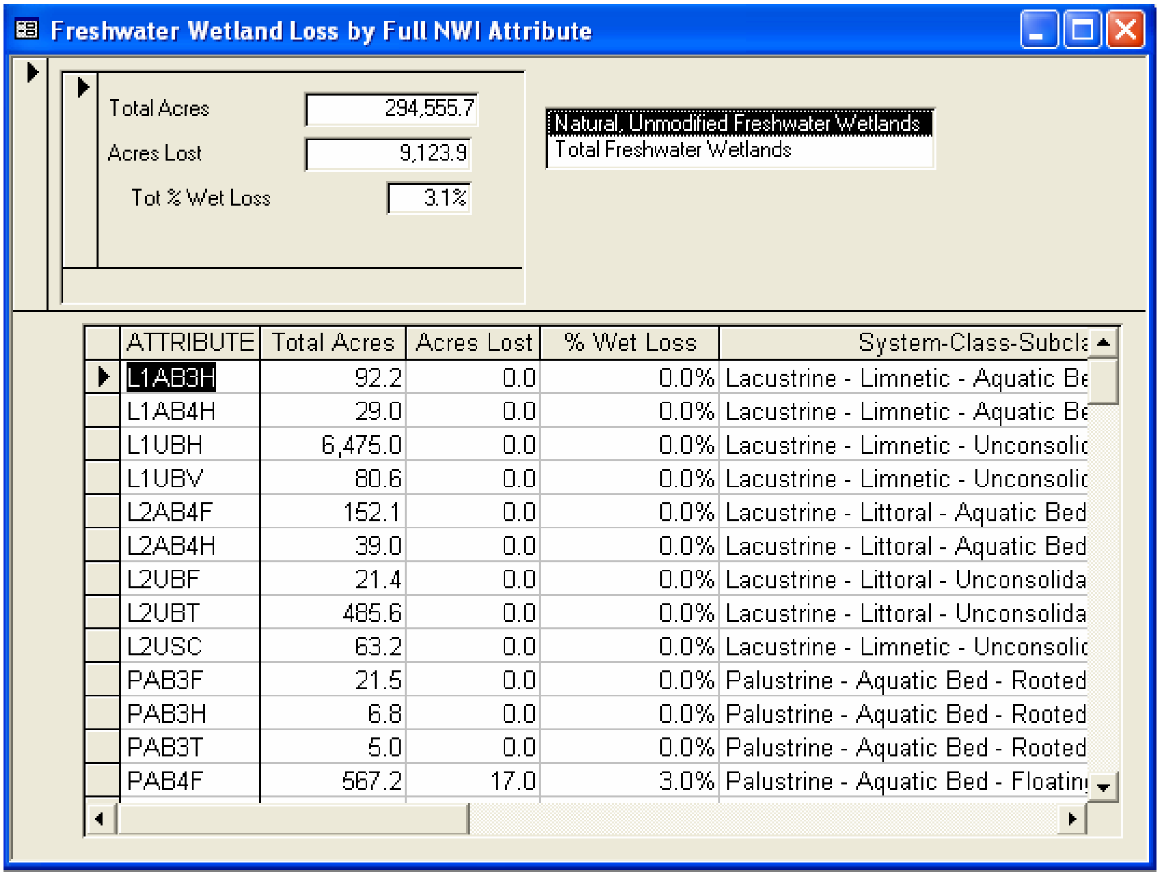


Figure 11 – Wetland Loss Application – Wetland Loss by System-Class



Freshwater Wetland Loss by Full NWI Attribute

Total Acres 294,555.7

Acres Lost 9,123.9

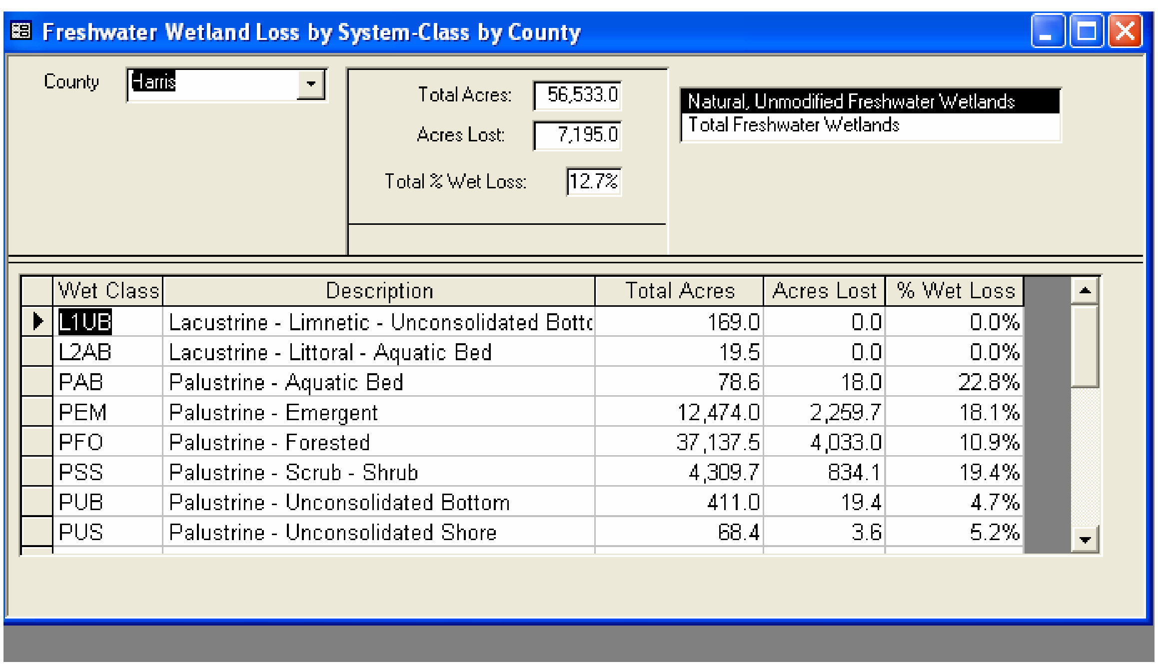
Tot % Wet Loss 3.1%

Natural, Unmodified Freshwater Wetlands

Total Freshwater Wetlands

ATTRIBUTE	Total Acres	Acres Lost	% Wet Loss	System-Class-Subcla
L1AB3H	92.2	0.0	0.0%	Lacustrine - Limnetic - Aquatic Be
L1AB4H	29.0	0.0	0.0%	Lacustrine - Limnetic - Aquatic Be
L1UBH	6,475.0	0.0	0.0%	Lacustrine - Limnetic - Unconsolic
L1UBV	80.6	0.0	0.0%	Lacustrine - Limnetic - Unconsolic
L2AB4F	152.1	0.0	0.0%	Lacustrine - Littoral - Aquatic Bed
L2AB4H	39.0	0.0	0.0%	Lacustrine - Littoral - Aquatic Bed
L2UBF	21.4	0.0	0.0%	Lacustrine - Littoral - Unconsolida
L2UBT	485.6	0.0	0.0%	Lacustrine - Littoral - Unconsolida
L2USC	63.2	0.0	0.0%	Lacustrine - Limnetic - Unconsolic
PAB3F	21.5	0.0	0.0%	Palustrine - Aquatic Bed - Rooted
PAB3H	6.8	0.0	0.0%	Palustrine - Aquatic Bed - Rooted
PAB3T	5.0	0.0	0.0%	Palustrine - Aquatic Bed - Rooted
PAB4F	567.2	17.0	3.0%	Palustrine - Aquatic Bed - Floatin

Figure 12 – Wetland Loss Application – Wetland Loss by Full Attribute Code



Freshwater Wetland Loss by System-Class by County

County Harris

Total Acres: 56,533.0

Acres Lost: 7,195.0

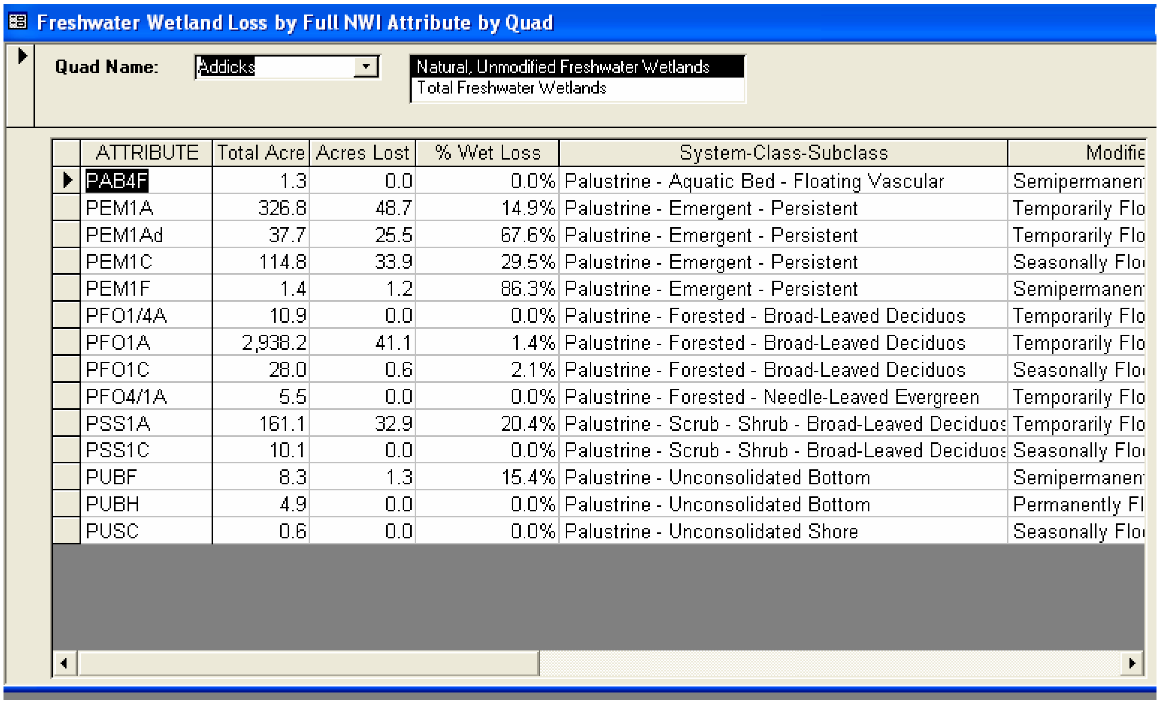
Total % Wet Loss: 12.7%

Natural, Unmodified Freshwater Wetlands

Total Freshwater Wetlands

Wet Class	Description	Total Acres	Acres Lost	% Wet Loss
L1UB	Lacustrine - Limnetic - Unconsolidated Botto	169.0	0.0	0.0%
L2AB	Lacustrine - Littoral - Aquatic Bed	19.5	0.0	0.0%
PAB	Palustrine - Aquatic Bed	78.6	18.0	22.8%
PEM	Palustrine - Emergent	12,474.0	2,259.7	18.1%
PFO	Palustrine - Forested	37,137.5	4,033.0	10.9%
PSS	Palustrine - Scrub - Shrub	4,309.7	834.1	19.4%
PUB	Palustrine - Unconsolidated Bottom	411.0	19.4	4.7%
PUS	Palustrine - Unconsolidated Shore	68.4	3.6	5.2%

Figure 13 – Wetland Loss Application – Wetland Loss by System by County



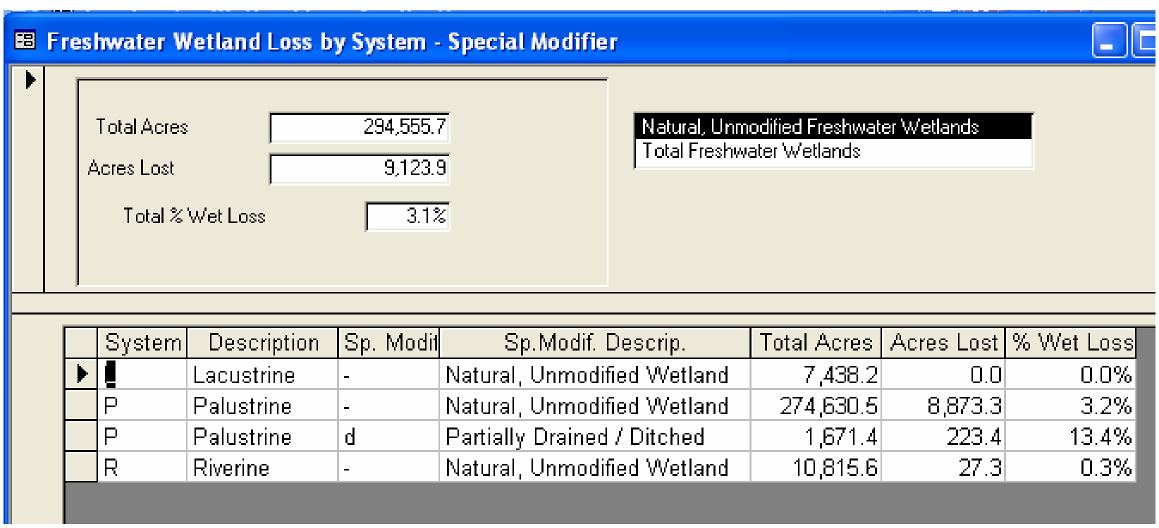
Freshwater Wetland Loss by Full NWI Attribute by Quad

Quad Name: Addicks

Natural, Unmodified Freshwater Wetlands
Total Freshwater Wetlands

ATTRIBUTE	Total Acre	Acres Lost	% Wet Loss	System-Class-Subclass	Modifie
PAB4F	1.3	0.0	0.0%	Palustrine - Aquatic Bed - Floating Vascular	Semipermanen
PEM1A	326.8	48.7	14.9%	Palustrine - Emergent - Persistent	Temporarily Flo
PEM1Ad	37.7	25.5	67.6%	Palustrine - Emergent - Persistent	Temporarily Flo
PEM1C	114.8	33.9	29.5%	Palustrine - Emergent - Persistent	Seasonally Flo
PEM1F	1.4	1.2	86.3%	Palustrine - Emergent - Persistent	Semipermanen
PFO1/4A	10.9	0.0	0.0%	Palustrine - Forested - Broad-Leaved Deciduos	Temporarily Flo
PFO1A	2,938.2	41.1	1.4%	Palustrine - Forested - Broad-Leaved Deciduos	Temporarily Flo
PFO1C	28.0	0.6	2.1%	Palustrine - Forested - Broad-Leaved Deciduos	Seasonally Flo
PFO4/1A	5.5	0.0	0.0%	Palustrine - Forested - Needle-Leaved Evergreen	Temporarily Flo
PSS1A	161.1	32.9	20.4%	Palustrine - Scrub - Shrub - Broad-Leaved Deciduos	Temporarily Flo
PSS1C	10.1	0.0	0.0%	Palustrine - Scrub - Shrub - Broad-Leaved Deciduos	Seasonally Flo
PUBF	8.3	1.3	15.4%	Palustrine - Unconsolidated Bottom	Semipermanen
PUBH	4.9	0.0	0.0%	Palustrine - Unconsolidated Bottom	Permanently Fl
PUSC	0.6	0.0	0.0%	Palustrine - Unconsolidated Shore	Seasonally Flo

Figure 14 – Wetland Loss Application – Wetland Loss by Full Attribute Code by Quad



Freshwater Wetland Loss by System - Special Modifier

Total Acres 294,555.7
Acres Lost 9,123.9
Total % Wet Loss 3.1%

Natural, Unmodified Freshwater Wetlands
Total Freshwater Wetlands

System	Description	Sp. Modif	Sp.Modif. Descrip.	Total Acres	Acres Lost	% Wet Loss
L	Lacustrine	-	Natural, Unmodified Wetland	7,438.2	0.0	0.0%
P	Palustrine	-	Natural, Unmodified Wetland	274,630.5	8,873.3	3.2%
P	Palustrine	d	Partially Drained / Ditched	1,671.4	223.4	13.4%
R	Riverine	-	Natural, Unmodified Wetland	10,815.6	27.3	0.3%

Figure 15 – Wetland Loss Application – Wetland Loss by Special Modifier (Human-modified)

APPENDIX E
COWARDIN CLASSIFICATION

National Wetlands Classification Standard

Map codes of wetland habitat types used in this application follow the classification system in this Service publication: *Classification of Wetlands and Deepwater Habitats of the United States*, 1979, by Cowardin, Lewis M. et al.

According to this publication, the code structure is hierarchical, progressing from Systems and Subsystems, to Classes, Subclasses and Dominance Types. Modifiers for water regime, water chemistry and soils are applied to Classes, Subclasses and Dominance Types. Special modifiers describe wetlands and deepwater habitats that have been either created or highly modified by man or beavers.

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

```
SYSTEM              SUBSYSTEM        CLASS                      SUBCLASS

                                  |- RB=Rock Bottom             1=Bedrock
                                  |                             2=Rubble
                                  |
                                  |- UB=Unconsolidated Bottom   1=Cobble-Gravel
                                  |                             2=Sand
                                  |                             3=Mud
                                  |                             4=Organic
                                  |
                |-- 1=SUBTIDAL----|- AB=Aquatic Bed             1=Algal
                |                 |                             3=Rooted Vascular
                |                 |                             5=Unknown
                |                 |                               Submergent
                |                 |
                |                 |- RF=Reef                    1=Coral
                |                 |                             3=Worm
                |                 |
                |                 |- OW=Open Water/Unknown Bottom (used on older
                |                                                   maps)
M=MARINE--------|
                |
                |
                |                 |- AB=Aquatic Bed             1=Algal
                |                 |                             3=Rooted Vascular
                |                 |                             5=Unknown
                |                 |                               Submergent
                |                 |
                |                 |- RF=Reef                    1=Coral
                |-- 2=INTERTIDAL--|                             3=Worm
                                  |
                                  |- RS=Rocky Shore             1=Bedrock
                                  |                             2=Rubble
                                  |
                                  |- US=Unconsolidated Shore    1=Cobble-Gravel
                                                                2=Sand
                                                                3=Mud
                                                                4=Organic
```

```
SYSTEM              SUBSYSTEM        CLASS                      SUBCLASS

                                  |- RB=Rock Bottom             1=Bedrock
                                  |                             2=Rubble
                                  |
                                  |- UB=Unconsolidated Bottom   1=Cobble-Gravel
                                  |                             2=Sand
                                  |                             3=Mud
                                  |                             4=Organic
                                  |
                |-- 1=SUBTIDAL----|- AB=Aquatic Bed             1=Algal
                |                 |                             3=Rooted Vascular
                |                 |                             4=Floating
                |                 |                               Vascular
                |                 |                             5=Unknown
                |                 |                               Submergent
                |                 |                             6=Unknown Surface
                |                 |
                |                 |- RF=Reef                    2=Mollusc
                |                 |                             3=Worm
                |                 |
                |                 |- OW=Open Water/Unknown Bottom (used on older
                |                                                   maps)
E=ESTUARINE-----|
                |
                |
                |                 |- AB=Aquatic Bed             1=Algal
                |                 |                             3=Rooted Vascular
                |                 |                             4=Floating
                |                 |                               Vascular
                |                 |                             5=Unknown
                |                 |                               Submergent
                |                 |                             6=Unknown Surface
                |                 |
                |                 |- RF=Reef                    2=Mollusc
                |                 |                             3=Worm
                |                 |
                |                 |- SB=Streambed               3=Cobble-Gravel
                |                 |                             4=Sand
                |                 |                             5=Mud
                |                 |                             6=Organic
                |                 |
                |                 |- RS=Rocky Shore             1=Bedrock
                |                 |                             2=Rubble
                |                 |
                |-- 2=INTERTIDAL--|- US=Unconsolidated Shore    1=Cobble-Gravel
                                  |                             2=Sand
                                  |                             3=Mud
                                  |                             4=Organic
                                  |
                                  |- EM=Emergent                1=Persistent
                                  |                             2=Nonpersistent
                                  |
                                  |- SS=Scrub-Shrub             1=Broad-Leaved
```

```
SYSTEM              SUBSYSTEM        CLASS                      SUBCLASS

                                 |                            Deciduous
                                 |                          2=Needle-Leaved
                                 |                            Deciduous
                                 |                          3=Broad-Leaved
                                 |                            Evergreen
                                 |                          4=Needle-Leaved
                                 |                            Evergreen
                                 |                          5=Dead
                                 |                          6=Indeterminate
                                 |                            Deciduous
                                 |                          7=Indeterminate
                                 |                            Evergreen
                                 |
                                 |-  FO=Forested            1=Broad-Leaved
                                                              Deciduous
                                                            2=Needle-Leaved
                                                              Deciduous
                                                            3=Broad-Leaved
                                                              Evergreen
                                                            4=Needle-Leaved
                                                              Evergreen
                                                            5=Dead
                                                            6=Indeterminate
                                                              Deciduous
                                                            7=Indeterminate
                                                              Evergreen



                                 |-  RB=Rock Bottom         1=Bedrock
                                 |                          2=Rubble
                                 |
                                 |-  UB=Unconsolidated Bottom  1=Cobble-Gravel
                                 |                          2=Sand
                |--1=TIDAL--------|                          3=Mud
                |                 |                          4=Organic
                |                 |
                |                 |-*SB=Streambed            1=Bedrock
                |                 |                          2=Rubble
                |                 |                          3=Cobble-Gravel
                |--2=LOWER        |                          4=Sand
                |    PERENNIAL----|                          5=Mud
                |                 |                          6=Organic
                |                 |                          7=Vegetated
                |                 |
                |                 |-  AB=Aquatic Bed         1=Algal
R=RIVERINE------|--3=UPPER        |                          2=Aquatic Moss
                |    PERENNIAL----|                          3=Rooted Vascular
                |                 |                          4=Floating
                |                 |                            Vascular
                |                 |                          5=Unknown
                |                 |                            Submergent
                |--4=INTERMITTENT-|                          6=Unknown Surface
                |                 |
                |                 |-  RS=Rocky Shore         1=Bedrock
```

```
SYSTEM              SUBSYSTEM        CLASS                     SUBCLASS

                |                 |                            2=Rubble
                |                 |
                |                 |- US=Unconsolidated Shore   1=Cobble-Gravel
                |--5=UNKNOWN      |                            2=Sand
                |    PERENNIAL----|                            3=Mud
                  (used on older  |                            4=Organic
                   maps)          |                            5=Vegetated
                                  |
                                  |-**EM=Emergent              2=Nonpersistent
                                  |
                                  |- OW=Open Water/Unknown Bottom (used on older
                                  |                                   maps)
                                  |-*STREAMBED is limited to TIDAL and
                                  | INTERMITTENT SUBSYSTEMS, and comprises
                                  | the only CLASS in the INTERMITTENT SUBSYSTEM.
                                  |
                                  |-**EMERGENT is limited to TIDAL and LOWER
                                  | PERENNIAL SUBSYSTEMS.


                                  |- RB=Rock Bottom             1=Bedrock
                                  |                            2=Rubble
                                  |
                                  |- UB=Unconsolidated Bottom  1=Cobble-Gravel
                                  |                            2=Sand
                                  |                            3=Mud
                                  |                            4=Organic
                                  |
                |-- 1=LIMNETIC----|- AB=Aquatic Bed            1=Algal
                |                 |                            2=Aquatic Moss
                |                 |                            3=Rooted Vascular
                |                 |                            4=Floating
                |                 |                              Vascular
                |                 |                            5=Unknown
                |                 |                              Submergent
                |                 |                            6=Unknown Surface
                |                 |
                |                 |- OW=Open Water/Unknown Bottom (used on older
                |                                                     maps)
L=LACUSTRINE----|
                |
                |
                |                 |- RB=Rock Bottom            1=Bedrock
                |                 |                            2=Rubble
                |                 |
                |                 |- UB=Unconsolidated Bottom  1=Cobble-Gravel
                |                 |                            2=Sand
                |                 |                            3=Mud
                |                 |                            4=Organic
                |                 |
                |                 |- AB=Aquatic Bed            1=Algal
                |                 |                            2=Aquatic Moss
                |                 |                            3=Rooted Vascular
                |                 |                            4=Floating
```

```
SYSTEM              SUBSYSTEM        CLASS                     SUBCLASS

                |-- 2=LITTORAL----|                              Vascular
                                  |                            5=Unknown
                                  |                              Submergent
                                  |                            6=Unknown Surface
                                  |
                                  |- RS=Rocky Shore            1=Bedrock
                                  |                            2=Rubble
                                  |
                                  |- US=Unconsolidated Shore   1=Cobble-Gravel
                                  |                            2=Sand
                                  |                            3=Mud
                                  |                            4=Organic
                                  |                            5=Vegetated
                                  |
                                  |- EM=Emergent               2=Nonpersistent
                                  |
                                  |- OW=Open Water/Unknown Bottom (used on older
                                                                   maps)


                                  |- RB=Rock Bottom            1=Bedrock
                                  |                            2=Rubble
                                  |
                                  |- UB=Unconsolidated Bottom  1=Cobble-Gravel
                                  |                            2=Sand
                                  |                            3=Mud
                                  |                            4=Organic
                                  |
                                  |- AB=Aquatic Bed            1=Algal
                                  |                            2=Aquatic Moss
                                  |                            3=Rooted Vascular
                                  |                            4=Floating
                                  |                              Vascular
                                  |                            5=Unknown
                                  |                              Submergent
                                  |                            6=Unknown Surface
                                  |
                                  |- US=Unconsolidated Shore   1=Cobble-Gravel
                                  |                            2=Sand
                                  |                            3=Mud
                                  |                            4=Organic
                                  |                            5=Vegetated
                                  |
                                  |- ML=Moss-Lichen            1=Moss
                                  |                            2=Lichen
                                  |
P=PALUSTRINE----------------------|- EM=Emergent               1=Persistent
                                  |                            2=Nonpersistent
                                  |
                                  |- SS=Scrub-Shrub            1=Broad-Leaved
                                  |                              Deciduous
                                  |                            2=Needle-Leaved
                                  |                              Deciduous
                                  |                            3=Broad-Leaved
                                  |                              Evergreen
```

```
SYSTEM               SUBSYSTEM        CLASS                     SUBCLASS

                                   |                            4=Needle-Leaved
                                   |                              Evergreen
                                   |                            5=Dead
                                   |                            6=Indeterminate
                                   |                              Deciduous
                                   |                            7=Indeterminate
                                   |                              Evergreen
                                   |
                                   |-  FO=Forested              1=Broad-Leaved
                                   |                              Deciduous
                                   |                            2=Needle-Leaved
                                   |                              Deciduous
                                   |                            3=Broad-Leaved
                                   |                              Evergreen
                                   |                            4=Needle-Leaved
                                   |                              Evergreen
                                   |                            5=Dead
                                   |                            6=Indeterminate
                                   |                              Deciduous
                                   |                            7=Indeterminate
                                   |                              Evergreen
                                   |
                                   |-  OW=Open Water/Unknown Bottom (used on older
                                                                    maps)


                                    MODIFIERS

                                   |- A=Temporarily Flooded
                                   |- B=Saturated
                                   |- C=Seasonally Flooded
                                   |- D=Seasonally Flooded/Well Drained
                                   |- E=Seasonally Flooded/Saturated
                                   |- F=Semipermanently Flooded
                  |--Non-Tidal------|- G=Intermittently Exposed
                  |                |- H=Permanently Flooded
                  |                |- J=Intermittently Flooded
                  |                |- K=Artificially Flooded
                  |                |- W=Intermittently Flooded/Temporary (used on
                  |                |                                 older maps)
                  |                |- Y=Saturated/Semipermanent/Seasonal (used on
                  |                |                                 older maps)
                  |                |- Z=Intermittently Exposed/Permanent (used on
                  |                |                                 older maps)
WATER REGIME----|                |- U=Unknown
                  |
                  |
                  |
                  |
                  |                |- K=Artificially Flooded
                  |                |- L=Subtidal
                  |                |- M=Irregularly Exposed
                  |                |- N=Regularly Flooded
                  |--Tidal----------|- P=Irregularly Flooded
```

```
                                 |-*S=Temporary-Tidal
                                 |-*R=Seasonal-Tidal
                                 |-*T=Semipermanent-Tidal
                                 |-*V=Permanent-Tidal
                                 |- U=Unknown
                                 |
                                 |-*These water regimes are only used in
                                 |  tidally influenced, freshwater systems.


                                 |- 1=Hyperhaline
                                 |- 2=Euhaline
                |--Coastal       |- 3=Mixohaline (Brackish)
                |  Halinity------|- 4-Polyhaline
                |                |- 5=Mesohaline
                |                |- 6=Oligohaline
                |                |- 0=Fresh
                |
                |
                |
WATER CHEMISTRY-|
                |                |- 7=Hypersaline
                |--Inland        |- 8=Eusaline
                |  Salinity------|- 9=Mixosaline
                |                |- 0=Fresh
                |
                |
                |
                |
                |--pH Modifiers  |- a=Acid
                   for all       |- t=Circumneutral
                   Fresh Water---|- i=Alkaline


SOIL-----------------------------|- g=Organic
                                 |- n=Mineral


                                 |- b=Beaver
                                 |- d=Partially Drained/Ditched
SPECIAL MODIFIERS----------------|- f=Farmed
                                 |- h=Diked/Impounded
                                 |- r=Artificial Substrate
                                 |- s=Spoil
                                 |- x=Excavated

U = Uplands
```