1.0 INTRODUCTION

Much of coastal Louisiana has been formed by a series of deltas of the Mississippi River that initially deposited riverine sediments, forming land and emergent vegetated habitat which then degraded when the river moved to a new course (Coleman and Gagliano 1964; Kolb and Van Lopik 1966; Frazier 1967). The cycle of a delta basically fills open-water habitat with sediment, producing wetland habitat of various types, which then degrades back to open water (van Beek and Meyer-Arendt 1981). Deegan and Thompson (1985) suggested that the cycle of delta growth and decay results in associated cycles of biological productivity and diversity. These changes follow well-established ecological concepts as noted by Marsden (1995), who stated "Biological systems are naturally subject to change due to the gain or loss of species. As a result of each change, food webs are altered, population balances are changed, and the ecosystem alters to incorporate the effects, whether minor or major". The establishment of new equilibria may take long periods of time, and, from a human perspective, everyone may not be satisfied with either the process or the end result. A system that is in constant change is one that may be difficult and frustrating to manage.

Important to understanding the biological cycles in coastal Louisiana are a few ecological concepts. Ricklefs (1973) defines 'carrying capacity' as the number of individuals that the resources of a habitat can support. This 'capacity' is never a fixed number and for most environments fluctuates with changing conditions. Changing conditions in coastal Louisiana associated with the cycle of delta growth and decay will constantly alter the carrying capacity of the system for many species. Loss of certain habitat types will reduce the success of many species, but, similarly, an increase of habitats such as open water, as predicted in the model for the Phase 1 study area (LADNR 1998a), will mean an increased carrying capacity for those species that thrive in these open water coastal areas. Use of these changes in abundance of coastal species may not always be made, as organisms that are currently targeted by various harvest groups are perhaps replaced with species that are found to be less desirable.

Over 25 years ago, the U.S. Environmental Protection Agency (EPA 1971) discussed the importance of estuarine habitat for many species important to commercial harvest. This relationship is also true for many species that have important ecological roles in coastal dynamics, so our focus should not be only on harvested species in our attempt at understanding the biological consequences of the decaying portion of our delta cycles. Most papers on coastal wetlands essentially agree that there is a strong functional relationship between wetlands and secondary production of aquatic organisms. Chew and Cali 1981; Fruge 1981; Browder and Moore 1981; Varnell 1981; Boesch et al. 1994, and Bowman et al. 1995 (among others) discuss this relationship of wetlands and secondary production, concentrating on important fishery species such as peneaid shrimp. Bowman et al. (1995) states "Louisiana's expansive wetlands are the reason it is one of the nation's leading states in fisheries production", noting the role wetlands play as a nursery for many young-of-the-year organisms. This functional relationship of coastal wetlands to secondary production is discussed in many studies, which suggest that as emergent habitats are lost (for example to open water), secondary production will decline, but there is still little direct quantitative information available, making specific predictive assessments illusory. As noted by Boesch et al. (1994), "Wetland fish, shellfish, and wildlife populations are both directly and indirectly vulnerable to the dramatic changes that have occurred and are predicted for the Louisiana coastal zone. Actual responses of particular communities and exploited stocks are often difficult to predict, however, and populations of some species may actually be enhanced by intermediate stages of wetland deterioration", recognizing that changing environmental conditions often lead to certain common species becoming more rare and being replaced by species that previously were themselves less common. But they also recognize that, in reference to the relationship of wetlands to secondary production, "Unfortunately, most of this evidence for such dependence is circumstantial, primarily because of the difficulty in documenting a quantitative link between its presence in Louisiana wetlands and commercial or recreational exploitation elsewhere".

The Mississippi River Coastal Wetlands Initiative Plan-Gulf Cost Venture (MRCWI-GCJV 1990) stressed the importance of the coastal wetland habitats in the study area for waterfowl and other wetland-dependent birds, noting: "The Louisiana coastal region serves waterfowl not only as a wintering area; it also supports many spring and fall transients enroute to their northern breeding grounds and their Central and South American wintering grounds." This study showed the largest duck migration corridor in North America reaching the coast in the Timbalier-Terrebonne and Barataria Basins.

The changes in habitats, using the methodology and projected land losses quantified in the Step G report (LADNR 1998a), are the criteria used to evaluate the no-action impacts to environmental resources. The interaction between emergent and open water habitats and aquatic and other fauna will be addressed here by examining three types of change between current status of the Phase 1 study area and the future physiographic predictions provided in the Step G report (LADNR 1998a). Section 2.0 of the report will deal with changes from current emergent (largely coastal wetland) habitats to projected open water. Section 3.0 will deal with changes in emergent habitat type based upon physical changes within the study area predicted by Step G. Section 4.0 will deal with changes in the habitat and faunal utilization of open water areas as these change from their current status to that projected for the future. In addition, there will be some consideration in Section 5.0 of the impacts of extreme events.

2.0 EMERGENT HABITAT TO OPEN WATER

2.1 Procedures and Data Sources

The land loss projections for 30 and 100-years were developed in Step G by dividing the study area into sections with similar recent loss patterns and projecting those losses into the future. The loss rates were obtained from the U.S. Army Corps of Engineers (USACE) land loss data base for 1974-1990 and only include land conversion to open water during that period. The data base does not include any conversion from open water to land. The land loss projection maps thus produced in Step G were superimposed, using a GIS system, upon habitat maps for the Barataria and Terrebonne basins for 1988/90 derived by Fuller et al. (1995). Fuller et al. (1995) provide details of how these maps were obtained. The overlay of projected land-open water over these 1988/90 habitat maps allowed the calculation of the areas of existing habitat which would be converted to open water under the projected land-water scenarios. This analysis did not account for any change in habitat type through time (except the increase in open water habitat). Such changes are considered in Section 3.0.

Condrey et al. (1995) characterized the current status, trends, and possible causes of change for many of the dominant fish, amphibians, reptiles, birds, mammals, and macroinvertebrates in the Barataria and Terrebonne basins, that include much of the Phase I study area. The Step C report, "Assessment of Resource Status and Trends" (LADNR 1998b) also lists many of the same species as Condrey et al. (1995) and these will not be repeated in this document. The reader should reference these two documents for information on individual species in the Phase I study area and for sources of data for the evaluation and more specific details of species life history and habitat.

2.2 Results of Land Loss Analysis

The results of application of the land loss projections to the 1988/90 habitat data are shown in Table 1 in terms of change in acreage of each habitat type. The change in relative proportions of each habitat type as land is converted to open water is shown in Figures 1a, 1b, and 1c. In these figures the submerged and floating aquatic vegetation habitat have been amalgamated with the open water category. These 'habitats' are poorly recognized by the habitat identification methodologies (J. Johnson, pers. comm.) and exist within open water. The analysis in Figures 1 a-c show them as open water in 1990 and any changes projected by the land loss are also included in open water. The continued existence or decline of floating or submerged vegetation depends upon a number of environmental factors such as salinity, turbidity, water velocities etc. and the land loss projections do not explicitly take into account the impact of these factors on floating and submerged habitats.

Table 2 shows the percentage change in open water and wetland habitat categories between 1990 and the 30 and 100-year projections. The increase in open water resulting from the projection of land loss 30-years into the future (13%) is accounted for by declines in all emergent marsh types and a small (2.5%) loss of wetland forest. Inspection of the raw data (Table 1) shows that this decline is fairly evenly distributed between cypress forests and bottomland hardwoods. Fresh marsh shows the lowest percentage loss by the 30-year projection (14.5%) and brackish marsh the highest (17.7%) although the spread is very small. All marsh types appear to be impacted to about the same relative extent.

The 100-year projection (Table 2) shows a slightly different pattern. Open water has increased 32% over 1990 acreages. The loss of fresh and intermediate marsh is 30.6% and 33% respectively indicating that these habitat types are continuing to decline. However, much greater relative changes occur in brackish and saline marsh categories which decrease by 39.4% and 46.7% respectively over the 100-years following 1990. Figure 1 shows that saline marsh accounts for over 8% of total project acreage in 1990 but only 4.3% by the 100-year projection. The parallel change in fresh marsh is from 13.5% of the total in 1990 to almost 9.4% in the 100-year projection. Wetland forests decline by almost 13% by the 100-year projection (Table 2) and Table 1 shows that more

Table 1 Acres of habitats for Present and future projections

	1990	30-year projection	100-year projection
Water	1212848	1388745	1625428
AB floating	11004	5140	3086
AB Submerged	10285	4068	2257
Fresh marsh	376008	321419	260852
Intermediate marsh	109144	92393	73124
Brackish marsh	192711	158450	116785
Saline marsh	226818	187540	120973
Cypress forest	157530	155704	136098
Bottomland forest	147611	144312	134885
Upland forest	16081	15112	13441
Dead forest	351	231	125
Bottomland scrub	57467	53604	44846
Upland scrub	12599	9058	5918
Shore/flat	1984	1288	858
AG/pasture	179693	176414	173541
Upland barren	674	600	548
Developed	73283	72080	70801
Other	96	29	17
TOTAL	2786187	2786187	2783583

Table 2. Percent change in selected categories.

% change from 1990	30-year projection	100-year projection
Water	13.27	32.14
Fresh marsh	-14.52	-30.63
Intermediate	-15.35	-33.00
Brackish	-17.78	-39.40
Saline marsh	-17.32	-46.67
Wetland forest	-2.48	-12.90

of this loss occurred in cypress forest than in bottomland hardwoods (change over 100-years being 13.6% and 8.6% respectively).

Figure 1a. Percent coverage by various habitats for present projections.

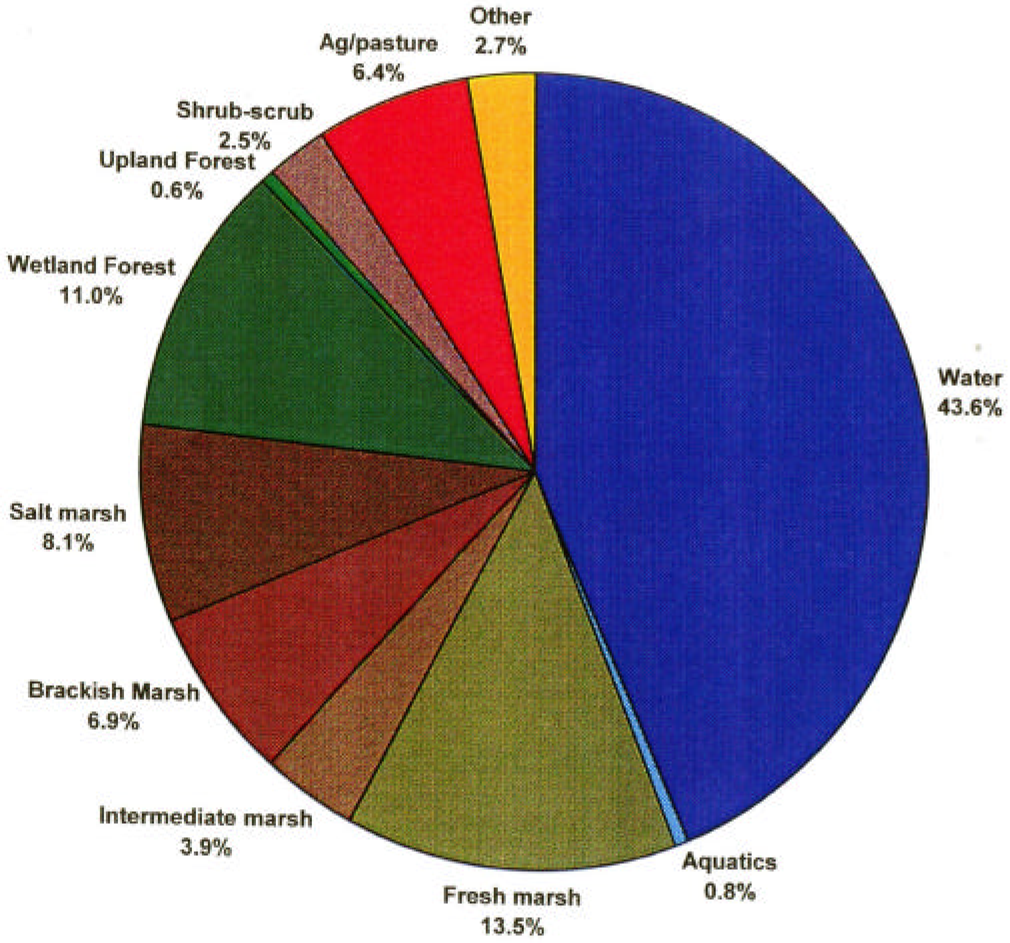


Figure 1b. Percent coverage by various habitats for 30-year projections.

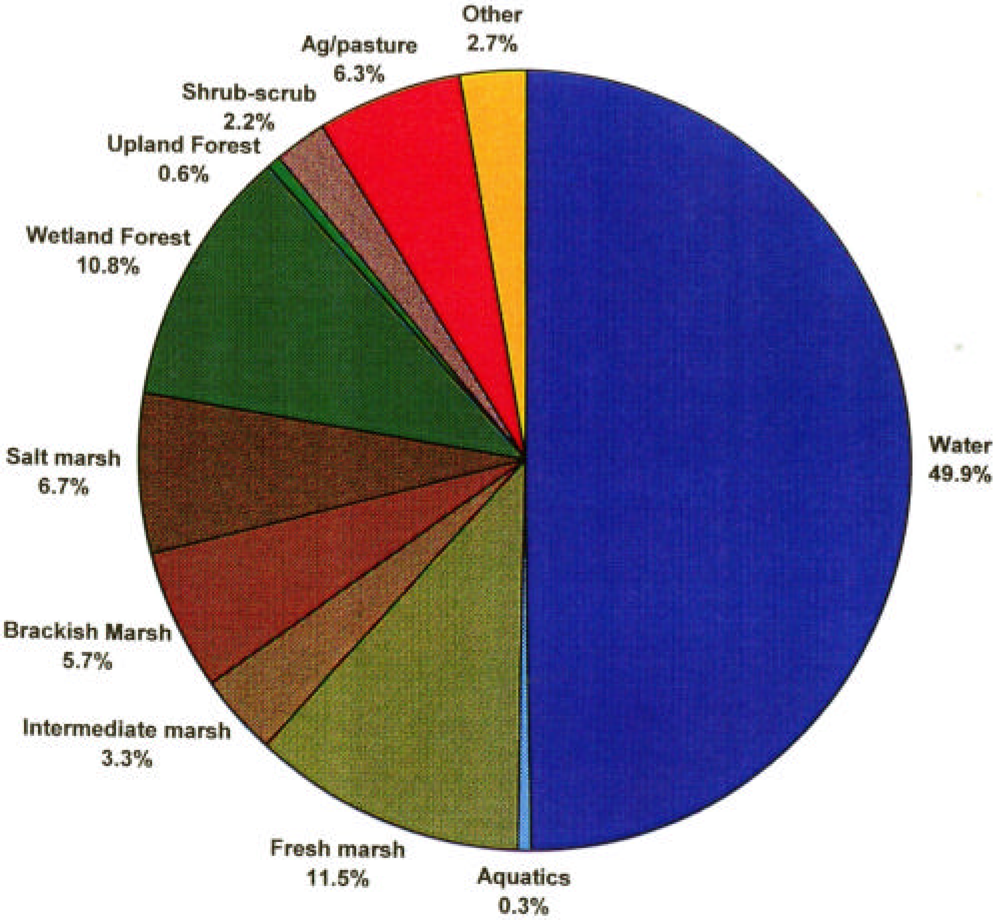
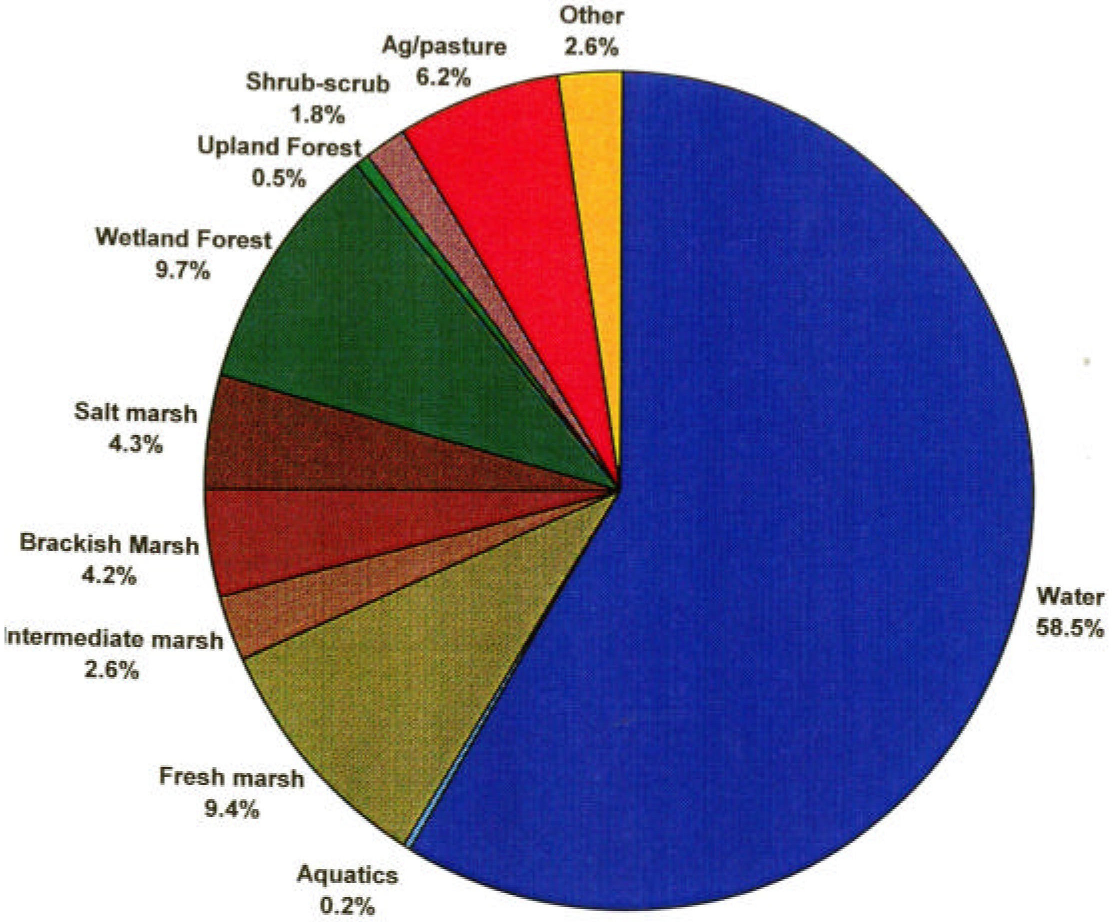


Figure 1c. Percent coverage by various habitats for 100-year projections.



The changes in habitat shown by these projections can be compared to historic changes in habitat types for part of the study area conducted by Fuller et al. (1995). Acreage data and percent change in habitat class between 1978 and 1990 from Fuller et al. (1995) are shown in Table 3. The acreages for 1990 are different from those shown in Table 1 as a smaller study area was available for the comparisons made by Fuller et al. (1995). Their comparisons were limited by the smallest project area available to them over their entire study. Even though these data apply to only part of the study area covered by Table 1 and other figures a similar pattern is found. The most dramatic changes between 1978 and 1990 occurred within non-fresh marshes (24% decline) and there was a notable decline in forested wetlands. The Fuller et al. (1995) study shows an historical increase in fresh marshes which is very different from the future projections shown here. This may be accounted for by the difference in the study areas as most of the area accounted for by this study but not by Fuller et al. (1995) is in the upper parts of the basins - areas which may be dominated by fresh marsh habitat.

Table 3. Habitat change data for Barataria and Terrebonne basins from Fuller et al., 1995.

Habitat	1978	1990
Water	1279360	1444480
Fresh marsh	217600	232960
Non fresh	700160	530560
Forested wetland	167680	156160

% change	1978-90
Water	12.91
Fresh marsh	7.06
Non fresh	-24.22
Forested wetland	-6.87

Some small changes do occur within non-wetland categories in Table 1. This is a reflection of the technique used to apply the land loss projections to the habitat maps where rates of loss are applied to polygons which include non-wetland habitat. As the original land loss rates were obtained from a land-loss study (Dunbar et al., 1992), rather than a habitat-specific wetland loss study, this type of change must be expected. However, as Table 1 shows, these changes are minimal compared to the conversion of wetland habitats to open water.

2.3 Spatial Distribution of Emergent Habitat Conversion to Open Water

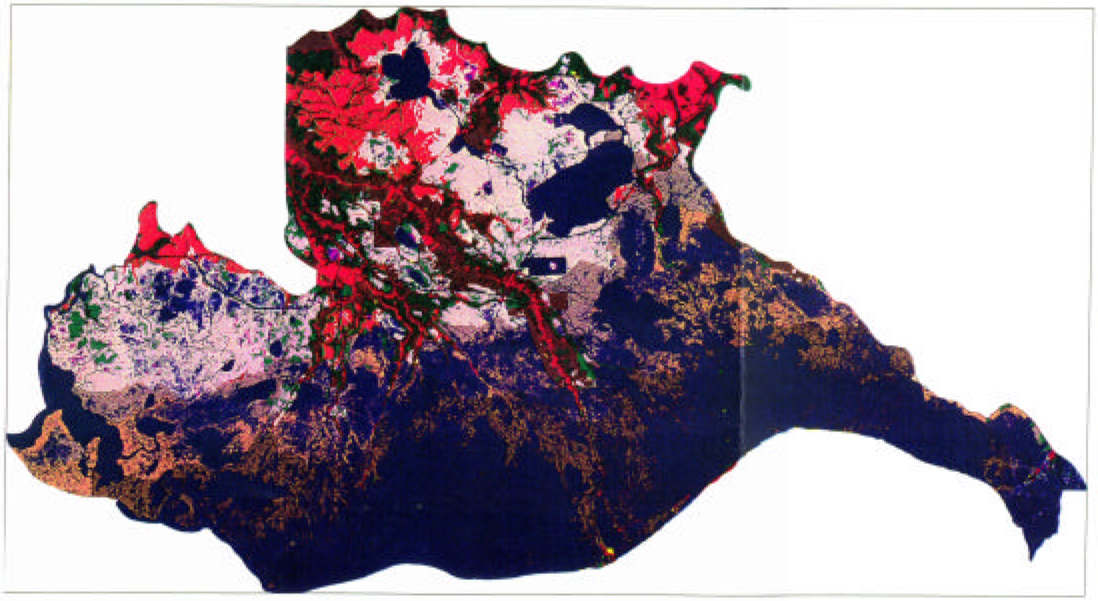
The 1990 habitat base map is shown in Figure 2. The application of the land loss projections to 1990 habitat maps is shown in Figure 3 and 4. Comparison of these images provides an indication of the spatial distribution of conversion of individual habitat types to open water.

2.3.1. 30-year projection

Almost 9000 acres of forested wetlands convert to open water in the 30-year projection. This represents 0.3% of the total area shown on the maps and it is difficult to identify focused areas of loss.

The change in fresh marsh is much greater. In the Penchant sub-basin, fresh marshes north of Four League Bay and south of Bayou Penchant show great loss. Further east within the Penchant sub-basin marshes south of Bayou Penchant and west of Lake Penchant show enhanced loss, as well as continued deterioration in the Turtle Bayou and in fresh marshes north of GIWW. Of these, few are identified by Fuller et al. (1995, Figure 3.15) as areas of marked land loss between 1956 and 1990. The area north of GIWW is not shown in Fuller et al. (1995) study and the Turtle Bayou area is shown as an area of high loss. In the Timbalier sub-basin, Figure 3 shows loss of fresh marsh in the Lake Boudreaux watershed and south of GIWW in the area west of Grand Bayou Canal. The former is shown as a loss area by Fuller et al. (1995) but the fresh marsh area west of Grand Bayou Canal did not show significant loss between 1978 and 1990. The fields sub-basin, which was not included in the Fuller et al. (1995) study, shows deterioration of fresh marsh both north of GIWW and east of Houma. The projected changes in fresh marsh in western Terrebonne do not seem to account for any potential stimulation of marsh growth in the area as Atchafalaya waters further penetrate into the area. The influence of the Atchafalaya seems to account for the low loss rates identified by Fuller et al. (1995) in this area. The land loss projections made here do not show that trend continuing. This is likely due to the techniques used to generate future projections of land-water in Step G. The loss rates were projected into the future for polygons

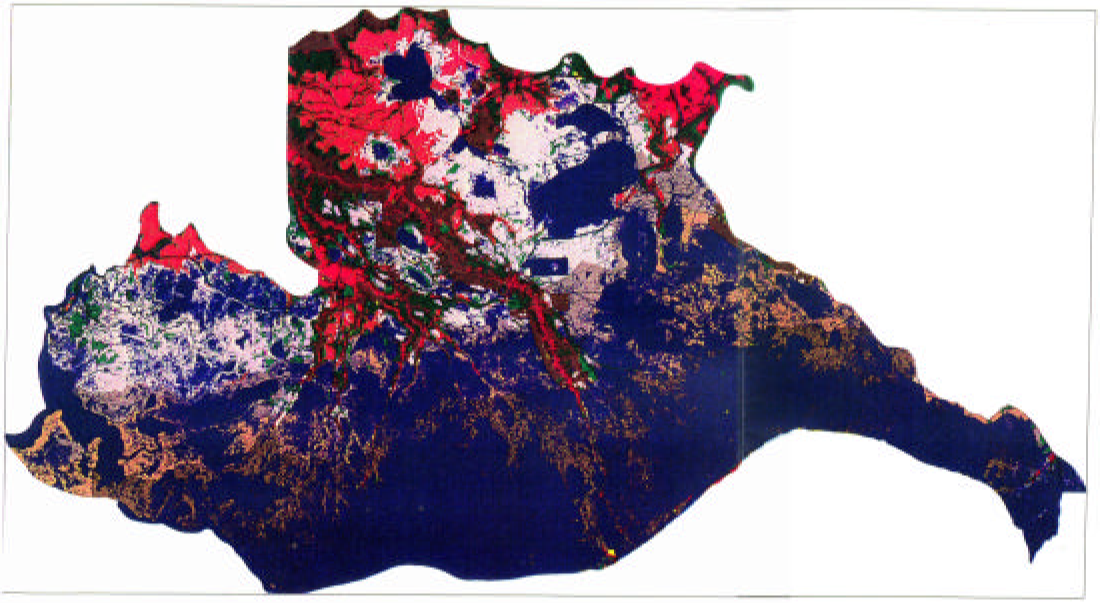
Figure 2. Present Coastal Habitat Image.



Habitat	Area (Acres)
🟦 Water------------:	1212848
🟪 AB Floating-------:	11004
🟪 AB Submerged------:	10285
Fresh Marsh-------:	376008
▨ Intermediate Marsh:	109144
🟧 Brackish Marsh----:	192711
🟫 Saline Marsh------:	226818
🟥 Cypress Forest----:	157530
🟩 Bottomland Forest-:	147611
🟩 Upland Forest-----:	16081
▨ Dead Forest-------:	351
🟩 Bottomland Shrub--:	57467
🟨 Upland Shrub------:	12599
🟨 Shore/Flat-------:	1984
🟫 AG/Pasture-------:	179693
🟨 Upland Barren-----:	674
🟥 Developed--------:	73283
🟦 Other Land--------:	96

Prepared by NSEL/LMRRI/LSU
November 13, 1996

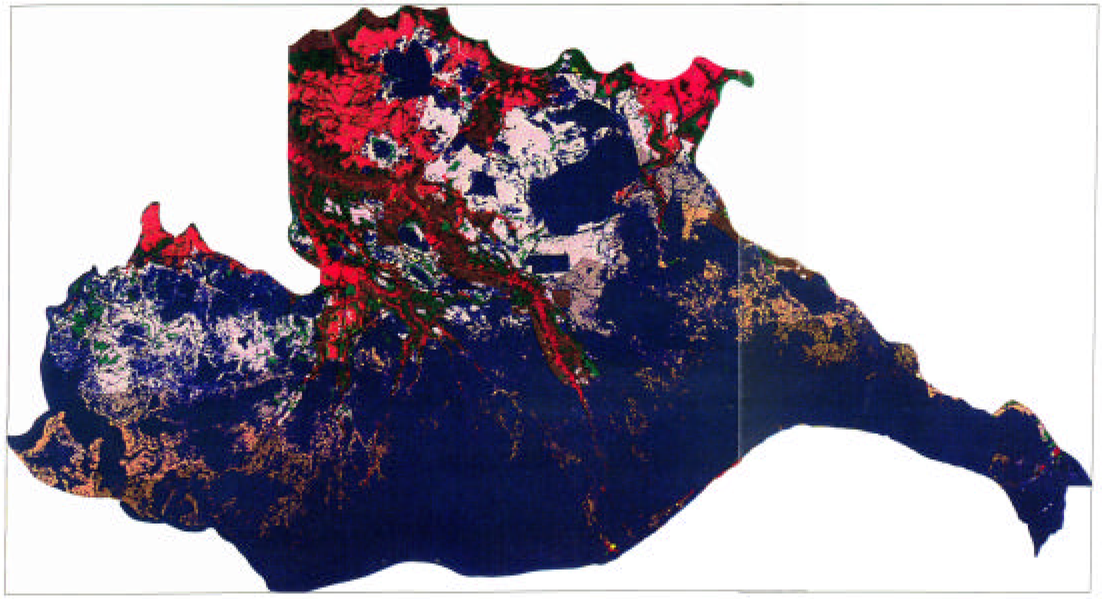
Figure 3. 30-Year Projection of Coastal Habitats.



Habitat	Area (Acres)
■ Water------------:	1388745
■ AB Floating-------:	5140
■ AB Submerged------:	4068
Fresh Marsh-------:	321419
■ Intermediate Marsh:	92393
■ Brackish Marsh----:	158450
■ Saline Marsh------:	187540
■ Cypress Forest----:	155704
■ Bottomland Forest-:	144312
■ Upland Forest-----:	15112
■ Dead Forest-------:	231
■ Bottomland Shrub--:	53604
■ Upland Shrub------:	9058
■ Shore/Flat-------:	1288
■ AG/Pasture-------:	176414
■ Upland Barren-----:	600
■ Developed--------:	72080
■ Other Land--------:	29

Prepared by NSEL/LWRRI/LSU
November 13, 1996

Figure 4. 100-Year Projection of Coastal Habitats



	Habitat	Area (Acres)
■	Water	1625428
■	AB Floating	3086
■	AB Submerged	2257
	Fresh Marsh	260852
■	Intermediate Marsh	73124
■	Brackish Marsh	116785
■	Saline Marsh	120973
■	Cypress Forest	136098
■	Bottomland Forest	134885
■	Upland Forest	13441
■	Dead Forest	125
■	Bottomland Shrub	44846
■	Upland Shrub	5918
■	Shore/Flat	858
■	AG/Pasture	173541
■	Upland Barren	548
■	Developed	70801
■	Other Land	17

Prepared by NEEL/LWRRI/LSU

considered to include similar land loss processes/rates. Where these polygons included shoreline erosion as a component of the loss rate, this loss was likely projected as interior loss as interior pixels were probably those closest to open water in brightness (see LADNR 1998a, for explanation of manipulation of thematic mapper image brightness). This has been rectified in the Step J report to more accurately reflect the spatial distribution of land loss and its projection into the future.

Loss of fresh marsh within the upper Barataria Basin is widespread. Focused areas appear to be in the Lake Boeuf area, both east and west of Lac des Allemands, west of Lake Salvador (south of Petit Lac des Allemands and north of Company Canal) and on the north shore of Lake Salvador. The fresh marshes south of Lake Salvador do not show significant change from fresh marsh to open water in Figure 3. Fuller et al. (1995) show very few areas of fresh marsh converting to open water between 1978 and 1990 (Figure 3.11). Some small areas are shown around Lake Catouache, but the area south of Lac des Allemands and west of Bayou des Allemands was not included in the Fuller et al. (1995) analysis.

Intermediate marsh declines by 15% between 1990 and the 30-year projection. Comparison of Figures 2 and 3 shows that most areas of this habitat type show loss. In the Penchant sub-basin, loss occurs across the intermediate marshes from Four League Bay to Bayou DuLarge, and the small areas of intermediate marsh in the Timbalier sub-basin continue to degrade. The intermediate marsh in the Barataria Basin appears to be more stable. The area north-west of Little Lake shows minor losses as do marshes north of Bayou Perot/Rigolettes and north of the Pen. These patterns in general are similar to those shown by Fuller et al. (1995).

Loss of brackish and saline marshes appears to be pervasive across the study area. Most areas of brackish marsh in 1990 show some change to open water after 30-years. More stable areas may be on Point au Fer and the area east of the Pen. Very few 'stable' areas of saline marsh can be identified. Areas east of Oyster Bayou in Terrebonne and south of West Point a la Hache (Bay Batiste to Bay Sansbois) seem to remain more intact than most study area saline marshes, which appear severely degraded after 30-years. These patterns in general are similar to those shown by Fuller et al. (1995).

Projections of geomorphic loss of barrier islands and shorelines have been specifically addressed in Step G. A summary of those findings is presented here to provide a context for assessment of habitat changes. It is assumed here that barrier islands and shoreline may consist of dune and saline marsh habitats. The 30-year projection for the Isles Dernieres shows fragments of barrier remain on all islands. These remnants are largely associated with implemented restoration projects. On Whiskey Island the relatively wide remaining area will likely include some saline marshes, while on Raccoon Island, Trinity Island and East Island the remaining thin islands will likely be dominated by low dune habitat. As Timbalier island is projected to continue lateral movement (G, Figure 2.9), it is expected that the remaining island area after 30-years will show a similar division of habitat between dune and saline marsh as in 1990. East Timbalier will likely consist of dune habitat and some saline marsh. Changes in the Caminada-Moreau Headland and on Grand Isle will result in maintaining a similar area of dune habitat as the shoreline migrates inland, or as the island rotates. There will be some loss of saline marsh on the backside of Grand Isle but the Caminada Moreau headland will still include saline marshes. Barrier beaches along the Plaquemines shoreline show considerable degradation by the 30-year projection and minimal dune habitat will remain in this area. The saline marshes behind the barriers are already highly degraded, and this habitat once exposed will be even more reduced in area.

2.3.2. 100-year projection

For the 100-year projection, no comparisons of these patterns to the historical data of Fuller et al. (1995) have been made as the time-scale of their analyses (1978-1990) is very small in relation to the 100-year projection and it seems likely that factors other than those incorporated in the Fuller et al. (1995) analysis may influence land loss.

Loss of forested wetlands is more significant after 100-years and Figure 4 shows conversion of cypress forest to open water in the upper Barataria basin, especially around Lac des Allemands and Lake Boeuf. The areas of cypress in northern and central Terrebonne remain fairly intact as does cypress forest north-west of Lake Catouache and south of Hwy. 90. There is also some marked loss of bottomland forest in upper Barataria, west of Lac des Allemands (west of Vacherie and north of LA Hwy. 20).

Areas of fresh marsh which deteriorated by the 30-year projection continue to lose land by the 100-year projection. The only fresh marsh areas in the Penchant sub-basin which remain intact are north of the Creole Bayou-Plumb Bayou area, along the margins of Bayou Penchant and between Lake Penchant and Lake Theriot. There is continued degradation of the limited fresh marsh in the Timbalier sub-basin but the upper Fields basin marshes remain intact. Within Barataria, marsh areas which showed high loss to open water after 30-years continue to lose land. However, there remain several large tracts of unbroken fresh marsh in the upper Barataria basin including south of GIWW and east of Delta Farms, north of Lake Salvador, west of Bayou des Allemands, and between Hwy. 90 and Lac des Allemands.

After 100-years, the only remaining areas of intact intermediate marsh in the study area are between Carencro Bayou and Creole Bayou in western Terrebonne, north east of Little Lake and north of the Pen in Barataria. All other areas are highly fragmented and the pattern appears to be a general continuation of loss during the 30-year projection. Saline and brackish marshes remain less fragmented in southwest Terrebonne and east of Barataria Bay, south of West Point a la Hache.

The projections for barrier island and shorelines show little remaining habitat after 100-years. A small area of likely dune habitat remains on east island in the Isles Dernieres and no barriers remain of the Timbalier system. The Caminada-Moreau headland has undergone considerable retreat but as the source of sand here is local reworking it is likely that a dune habitat remains along the shoreline, and on a the prograding section of Grand Isle. Projections in Step G suggest that no barrier habitat will remain along the Plaquemines shoreline (LADNR 1998a).

3.0 CHANGES IN EMERGENT HABITATS

3.1 Modeled Changes in Water Level

The hydrologic model described in Step G was used to derive water level data for 30 and 100-year projected conditions at 21 locations in the study area. These locations were selected to illustrate projected conditions across the basins and also at sites of interest because of the quality of existing data sets or the potential vulnerability of natural or economic resources in the area. The location of the sites corresponding to the names in Table 4 is shown in Figure 5. These data were generated for average conditions as described in Step G - a 0.2m tide in the Gulf of Mexico. The results are summarized in Table 4.

Of most interest in Table 4 are those sites where there is a change from no flooding to flooding (X®V designation in Table 4). Although some change is detectable in the water level fluctuations at these sites, the magnitude of the change, and the amplitude of the variation in water level, is usually small (e.g., increase in tidal range at Sister Lake for 100-year projection is < 2 cm). This is also the case for some sites in the northern parts of the basins which show fluctuations in water level for all periods (i.e., NONE V designation in Table) such as Bayou Perot where the water level fluctuation due to tides at the 100-year projection is < 3 cm. Open water areas in the southern parts of the basins, e.g. Caillou island and St. Mary's Point show decreases in tidal range. Figures 6 a, b and c show time series plots of water level for the three model-runs for St. Mary's Point illustrating the small magnitude of these changes. Overall, the changes in water level projected for the sites shown in Table 4 do not appear to be of a magnitude that might cause ecological changes.

Figure 5. Water Level Projection Data Sites

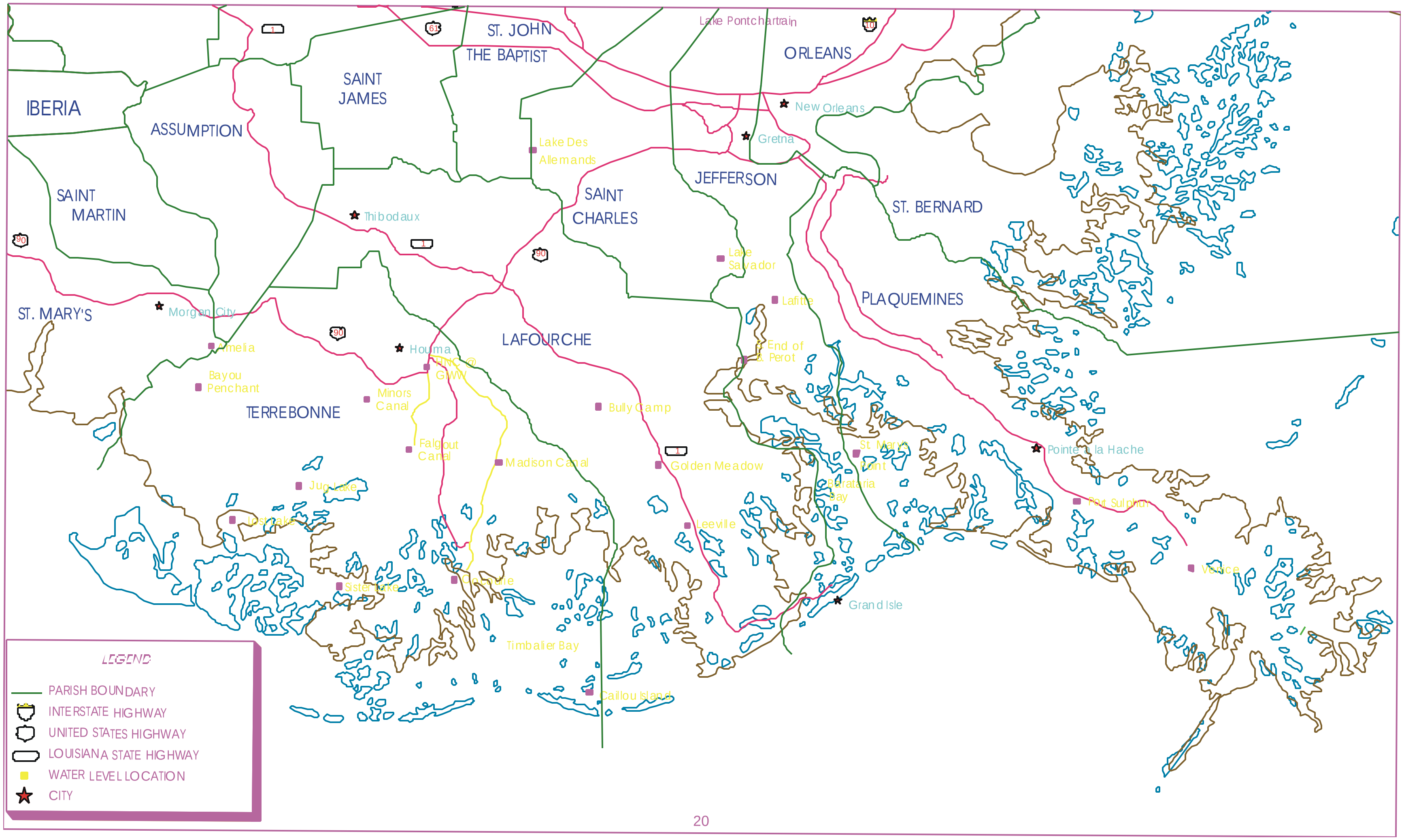


Figure 6a. Water Level Projections (Present).

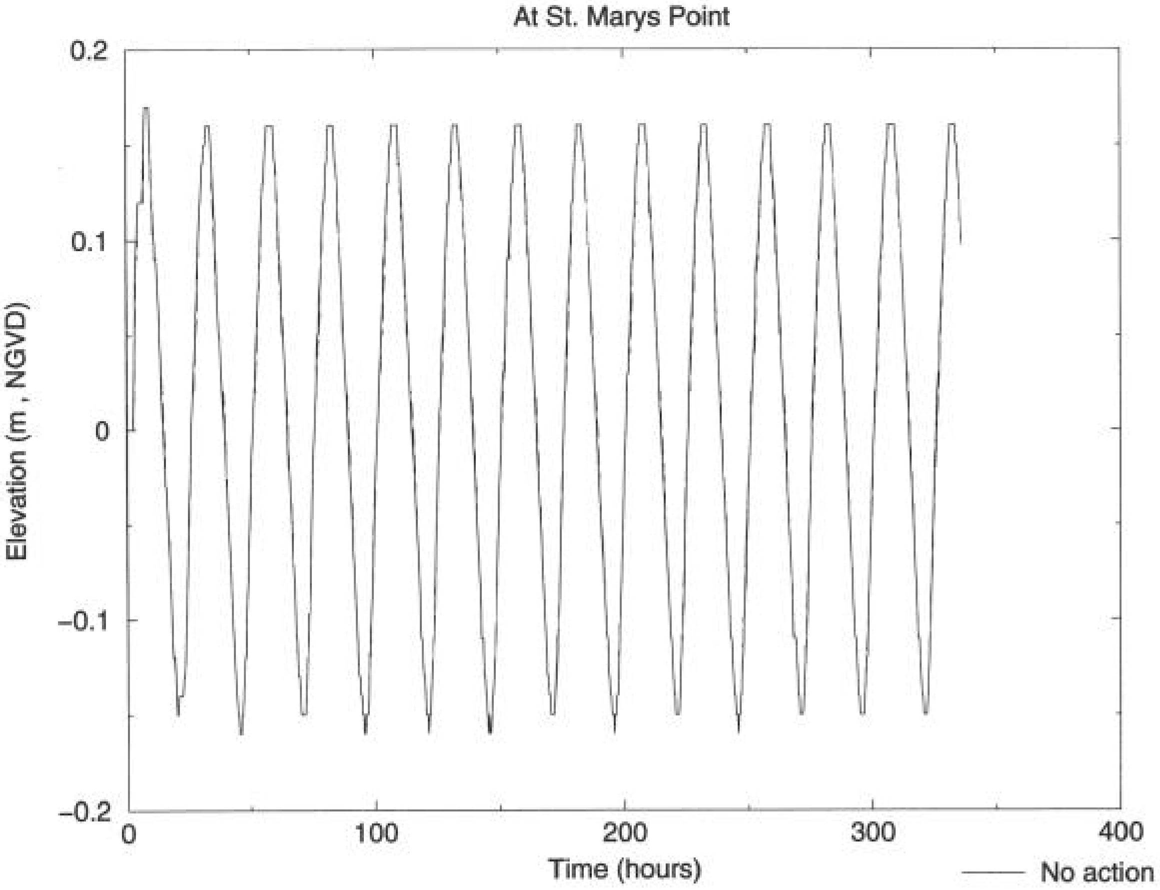


Figure 6b. Water Level Projections (30-Year)

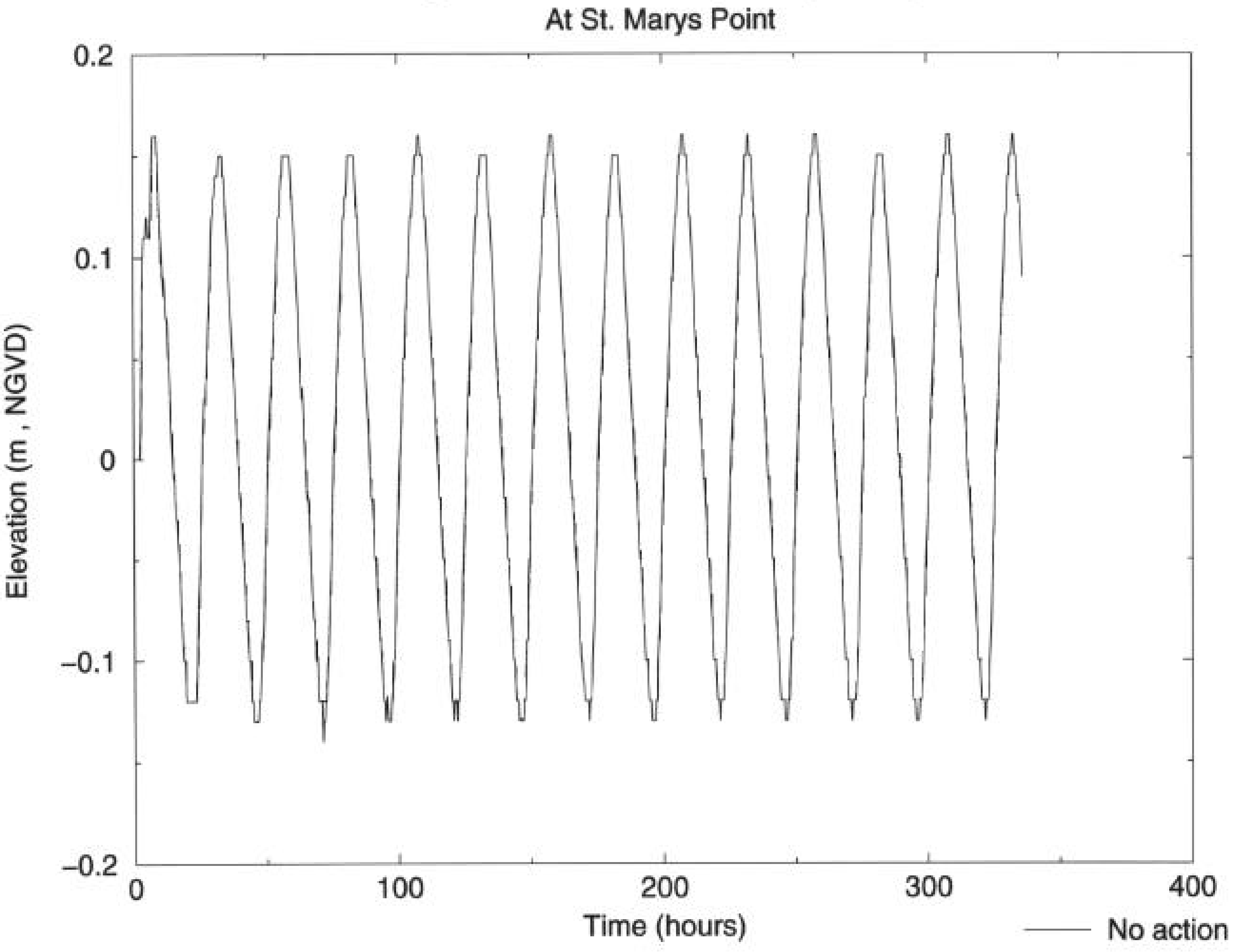


Figure 6c. Water Level Projections (100-Year)

At St. Marys Point

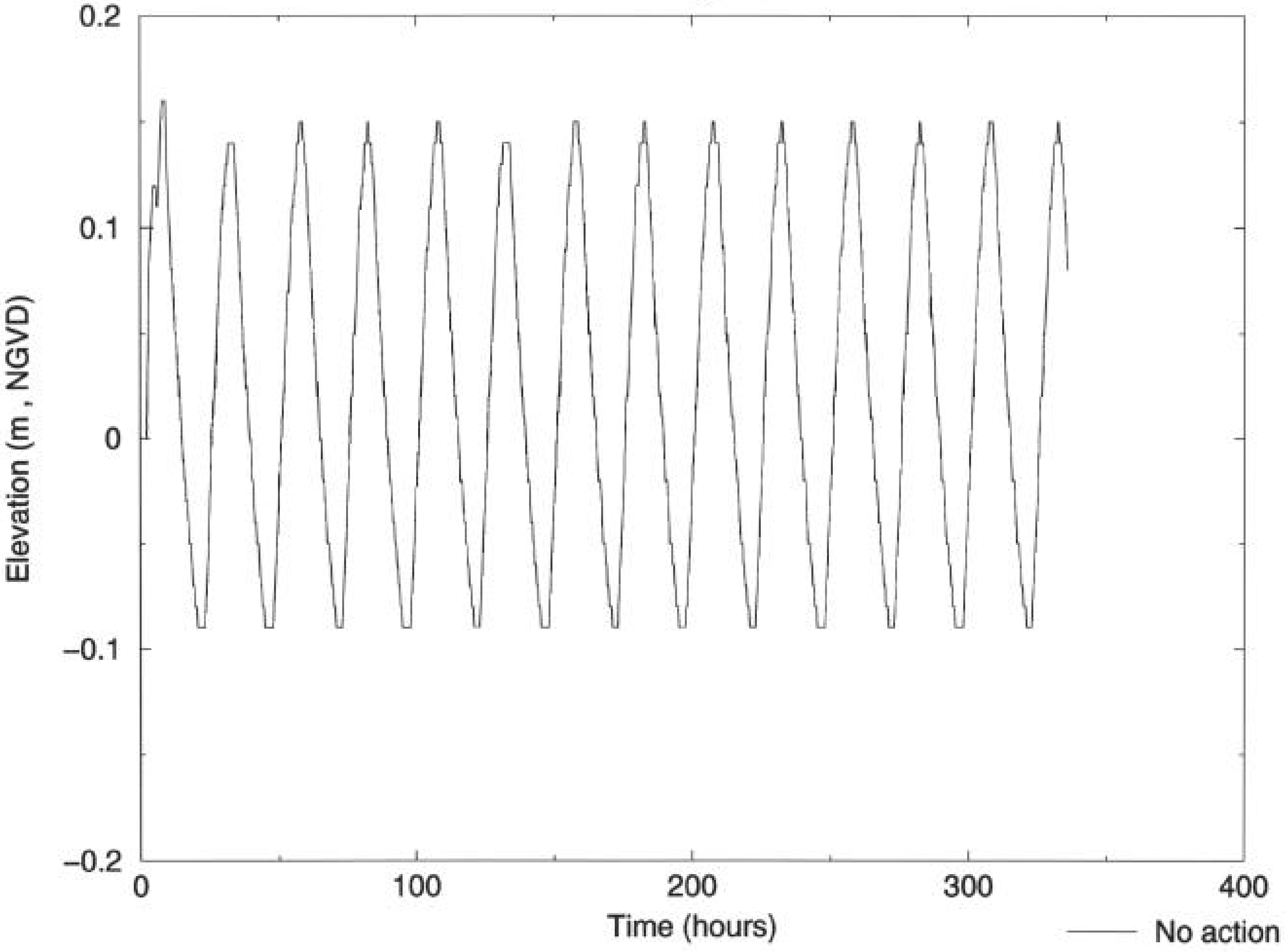


Table 4. Changes in water level for future projections. X = no change or not flooded. V = flooded and/or change in water level.

Station Name	Present	Water Level - 30-years	Water Level - 100-years	Type of Change
Venice	X	V	V	X→V
Port Sulphur	X	X	V	X→V
St. Mary's Point	V	V	V	NONE - V
Lafitte	X	X	X	NONE -X
Bayou Perot (S)	V	V	V	NONE - V
Lake Salvador	V	V	V	NONE - V
Leeville	V	X	V	X→V
Golden Meadow	X	X	X	NONE -X
Bully Camp	X	X	V	X→V
Caillou Island	V	V	V	NONE - V
Lac des Allemands	V	V	V	NONE - V
Madison Canal	X	X	X	NONE -X
Cocodrie	X	X	V	X→V
Falgout Canal1	X	V	X	NONE -X
HNC at GIWW	X	X	X	NONE -X
Minors Canal	X	X	V	X→V
Sister Lake	X	V	V	X→V
Jug Lake	X	V	V	X→V
Lost Lake	X	X	X	NONE -X
Bayou Penchant (W)	X	X	X	NONE -X
Amelia	X	X	X	NONE -X

1 Although water levels at Falgout Canal vary at the 30-year projection the flooding level for that scenario is less that 2 hours per cycle and may be within the error of the projection technique, especially as no flooding is identified for the 100-year projection.

However, the hydrologic model assumes that the marsh elevation relative to mean sea-level does not change through time (i.e., there is no accretion or elevation deficit and the marsh surface building at the same rate as relative sea level is rising). The changes in water level shown in the table are in addition to any changes which occur in basin marshes because of such deficits. The land loss projections assume that land will continue to be lost to open water throughout the two basins. One of the mechanisms for this loss is submergence of the marsh surface. This submergence usually occurs when either:

* marsh accretionary processes are unable to keep pace with rising relative sea-level, soil conditions become persistently anoxic and vegetation becomes stressed by the build-up of toxic sulphides (Koch and Mendelssohn, 1989)

* soil integrity and erosion of the marsh substrate. The cause of the stress may be salinity (e.g., McKee and Mendelssohn, 1989), herbivory , fungi, etc.

It is assumed that some changes in water level do occur over time in the project area marshes and that some component of the land loss within the area is a result of this factor. However, data are unavailable to quantify any effect of changes in water level on the quality or type of emergent habitats remaining in the basins.

3.2. Modeled Changes in Salinity

The two-dimensional hydrologic model used in Step G was ineffective at projecting salinity changes associated with future land loss scenarios at a temporal or spatial scale appropriate for projecting any associated modifications in habitat type. In addition, the magnitude of salinity change projected by the model (1-2 parts per thousand) is largely within the tolerance of many marsh vegetation types. For example, it is widely documented that Spartina alterniflora (dominant salt marsh vegetation) tolerates a wide range of salinities (Adams, 1963; Webb, 1983). Similarly, the variation in salinities found by Visser et al. (1996) in marshes dominated by Spartina patens was so wide (average salinity 10.4 (5.8 ppt), and overlapped with the zone dominated by Spartina alterniflora (average 17.5 (5.9 ppt) that it seems unlikely that 1-2 ppt increase in salinity over 100-years would result in a significant change in habitat types in the more saline marshes.

However, oligohaline and fresh vegetation types identified by Visser et al. (1996) showed narrower salinity ranges and some of these marsh types might be more susceptible to change with small changes in salinity. Table 5 shows the characteristics of these marsh types from Visser et al. (1996).

Table 5. Selected marsh type descriptions from Visser et al. (1996)

Marsh Type	Dominant Plant	Other plants	Salinity
Oligohaline Wiregrass	Spartina patens	Scirpus americanus	5.1 ± 3.2 ppt
Oligohaline Mix	Sagittaria lancifolia	Cyperus spp, Echinochloa spp	3.4 ± 1.1 ppt
Fresh Bulltongue	Sagittaria lancifolia	Panicum hemitomon	1.5 ± 1.0 ppt
Fresh Maidencane	Panicum hemitomon	Eleocharis spp.	0.5 ± 0.4 ppt
Fresh Spikerush	Eleocharis spp.	Hydrocotyle spp.	0.5 ± 0.4 ppt[1]

[1] salinity not provided by Visser et al. (1996) - assumed to be the same as Fresh Maidencane

Floating marshes in the study area have been examined by Sasser et al. (1994) and classified according to vegetation and substrate type. In this classification Type 1 floating marshes correspond to the fresh maidencane marsh type of Table 5, and Type 3 broadly correspond with fresh bulltongue. The vegetation assemblages are similar between floating marsh classes and these new marsh types. Not all the marshes in one type identified by Visser et al. (1996) will be floating but some of them will be as delineated on maps by Sasser et al. (1994). This correspondence allows the identification of areas of marsh in the Barataria basin which are particularly susceptible to changes in salinity because they both 1) include vegetation with limited salinity tolerance, and 2) are floating. Here floating marshes are considered to be worthy of particular attention as once they are disturbed and vegetation becomes stressed, no substrate will likely remain for recolonization by more salt tolerant species. There is little evidence that floating marshes can successfully transition to attached marshes (C. Sasser, pers. comm.). Because of these factors, it was felt the salinity changes in the Bayou Perot and Houma Navigation Canal areas deserved greater investigation.

3.2.1. Bayou Perot Area

This assessment of marsh types sensitive to small changes in salinity focused attention on marshes in and around Lake Salvador. In order to assess the potential for salinity changes associated with future no-action projections, a one dimensional model of salinity movement through the Bayou Perot region was used. This model allowed the projection of salinity penetration from Little Lake to Lake Salvador with changing land/water configurations. The model assumes constant boundary conditions for salinity in Little Lake (10 ppt) and Lake Salvador (1 ppt) and examines how the salinity gradient between these boundaries changes as land loss proceeded in the Bayou Perot areas. The projections for configuration of the width of open water are shown in Figure 7. For the base case, the maximum width to accommodate flow is 4 km with channels at each end which are 1 km wide (Little Lake end) and 1.5 km wide (Lake Salvador end). These widths were estimated from the land-water maps produced for Step G. The model area included part of Little Lake and part of Lake Salvador (hence km scale for distance shows 7 km through 23 km), however, the width of these water bodies did not change appreciably. The change in widths for 30-year and 100-year projections are shown in Figure 7.

Two types of conditions were modeled. One assumed little freshwater inflow to the upper part of Barataria basin (0.5 m3s-1). This represents conditions either without the Davis Pond diversion or during times of the year when the diversion is not operational. The second condition assumed an inflow of 142 m3s-1, with Davis Pond operational.

The results for the 'without David Pond' conditions are shown in Figure 8. It is clear that that channel at the south end reduces salinity penetration by 1-2 ppt and there is a small gradient along the wider, central section of the water body. Relatively high salinities penetrate as far as the entrance to the northern constriction and there is a steep decrease in salinity there. This steep decrease in salinity is likely a result of setting the boundary condition to 1 ppt in Lake Salvador. This model does not allow us to project salinities further to the north but suggests that during dry times of the year when there is little freshwater 'head' within Barataria Basin that higher salinities may influence Lake Salvador. However, the pattern described above varies little between the base case and the future projections. The differences in salinity penetration are less than 1 ppt . It is interesting to note that during the 30-year projection the northern constriction widens more than the southern constriction and the result of this is a decrease in salinities compared to the base case. This is because the wider northern opening allows the large

Figure 7. Projected Widths for Bayou Perot Model

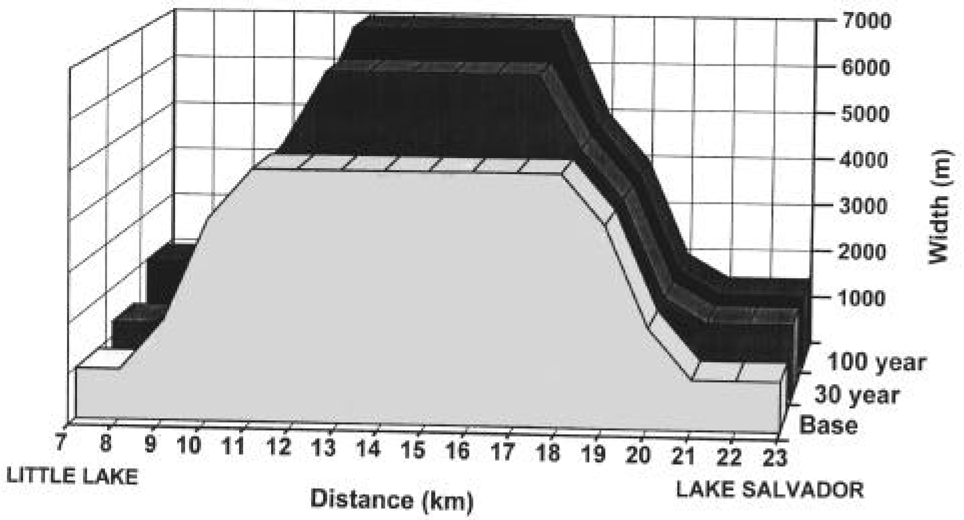
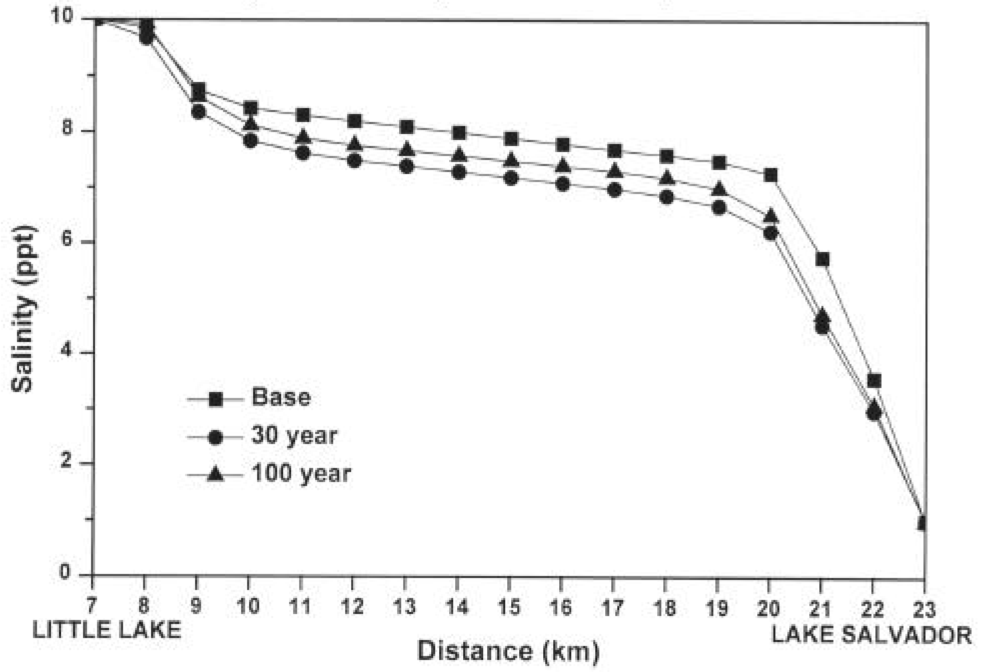


Figure 8. Results of Bayou Perot Model without Davis Pond.



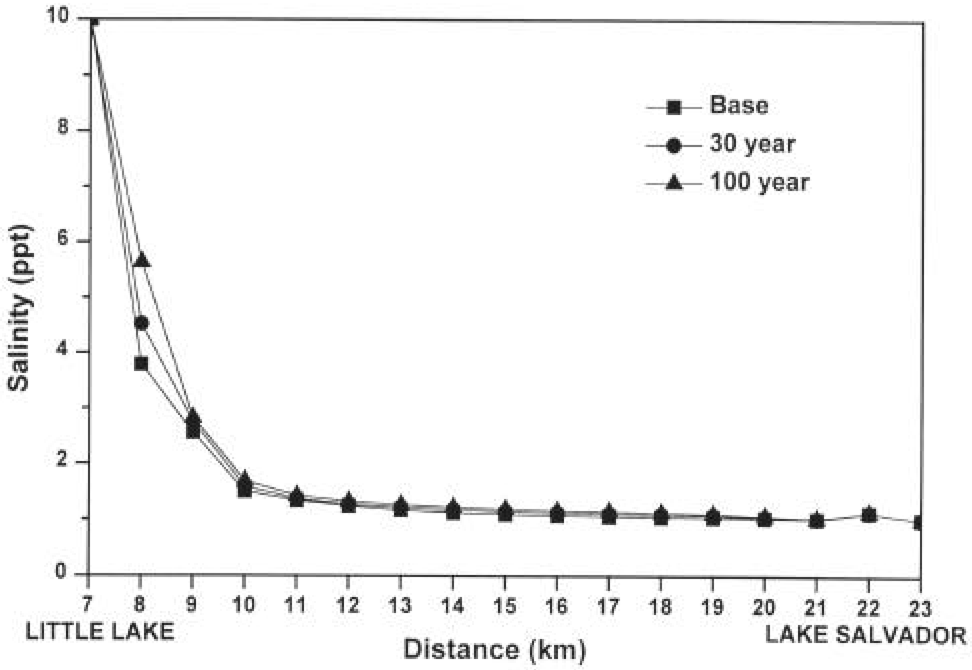
body of relatively fresh water to the north (i.e., Lake Salvador) to mix to the south. When the southern constriction also widens (in the 100-year projection) salinities increase slightly but not as far as the base case. These data indicate the importance of these 'constrictions' not only in preventing salt water from penetrating up into the basin but also in increasing freshwater retention in the northern part of the basin. This may have implications for the effect of extreme events on sensitive marshes but not for average conditions. Overall, this analysis shows that the small fluctuations in salinity associated with changing land-water configurations in the Bayou Perot area are unlikely to impact the relatively sensitive marshes around Lake Salvador.

The results for 'with Davis Pond'; conditions are shown in figure 9. As described above, the opening of the southern constriction in the 100-year projection allows more saline water to penetrate into the main body of Bayou Perot but this has minimal effect on the large amount of freshwater inflow associated with the diversion. Under these conditions, no salinity penetration will threaten the sensitive low-salinity, floating marshes.

3.2.2. Houma Navigation Canal

The same model used for Bayou Perot was applied to the Houma Navigation Canal. This was considered important because of existing problems with salinity penetration in the area which affect water supply as well as the wetland environment. The evaluation of land loss showed no perceptible loss of forested wetlands in the vicinity of the Houma Navigation Canal. However, this salinity analysis was conducted to assess the type of salinities prevailing in the region between Falgout Canal and Houma and the type of emergent habitat which might occur under future conditions (i.e., is there likely to be a change in habitat type?).

Figure 9. Results of Bayou Perot Model with Davis Pond.

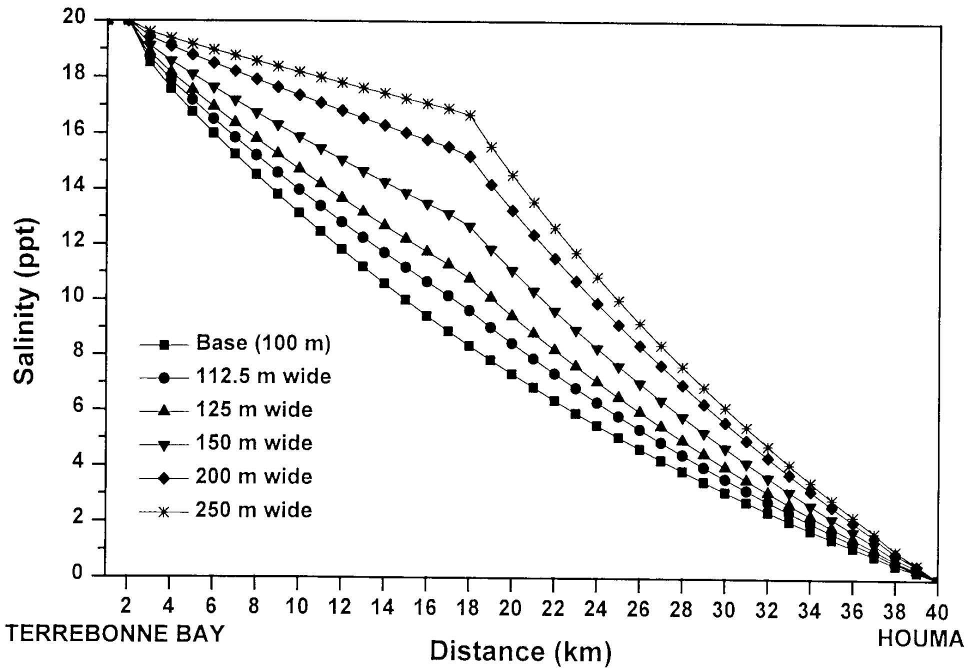


The model was configured for the stretch of the Houma Navigation Canal between the north side of Terrebonne Bay and Houma - a stretch of 40 km. The boundary conditions for salinity were set at 20 ppt at the south end and 0 ppt in the GIWW at Houma. A minimal freshwater inflow of 0.5 m3s-1 was assumed to represent conditions prevailing when the Atchafalaya River is low and local rainfall is low (e.g., fall). The depth was held constant at 5m along the channel and the width of the southern part of the channel varied to represent changing land-water conditions as land loss occurs south of HNC-Bayou Grand Caillou. This intersection is 17 km from the start of the model channel in Terrebonne Bay. The northern part of the channel remained at 100 m wide for all model runs.

In the base case, there is a conservative mixing of the salt and fresh water bodies along the length of the channel producing an even salinity gradient (Figure 10). When the southern part of the channel is widened salinities increase in the wider channel section, and more salt penetrates north into the still narrow (100 m) channel section. The wider the lower channel becomes, the smaller the change in salinity. Most change in salinity is associated with a width increase of 25-50 m. Increasing the width beyond this results in proportionately less increase in salinity. As the model holds salinity in Houma at 0 ppt, it is not possible to use this model to show salinity increases as Houma. However, should there be sufficient freshwater to maintain 0 ppt in Houma, an increase in channel width to 200 m would increase salinities by 3-4 ppt 10 km south of Houma. This may be sufficient to cause a change in habitat types.

Figure 4 shows that the area surrounding HNC between the Bayou DuLarge and Bayou Grand Caillou ridges and north of Bayou Provost remains largely intact land in the 100-year projection of land-water. However, the base habitat type in that area is a combination of cypress-tupelo swamp and bottomland hardwood forest. These are the only remaining habitats of this type remaining south of GIWW in the 100-year projection. In addition, Figure 4 shows a lack of bank integrity for the HNC south of Cocodrie, between Cocodrie and Four Point Bayou, and between Bayou Grand Caillou

Figure 10. Results of Houma Navigation Canal Model.



and Falgout Canal (especially on the western margin), showing potential for large increases in channel width in those areas (the resolution of the image is insufficient to allow accurate measures of projected channel width). The width of HNC exceeds 100 m already in many stretches between Grand Caillou and Terrebonne Bay. In this area a change in habitat type is therefore expected, associated with greater salinity penetration along the HNC. In the 100-year projection this wetland forest habitat will be replaced by a combination of oligohaline wiregrass and oligohaline mix marsh types (Visser et al., 1996).

3.2.3. Impacts to Fauna

The magnitude of salinity change projected by the model is within the tolerance of most animals using the Barataria-Terrebonne estuaries, so it seems unlikely that salinity changes will be the prime cause of any changes in local faunal assemblages.

Rounsefell (1964), in eastern Louisiana marshes, found some shift of fish species from higher salinity marsh (14 ppt) through intermediate salinities (11-14 ppt) to lower salinities (<5 ppt), but there was considerable overlap among species in all three areas, and some species such as southern flounder, Atlantic croaker, silver perch, bay anchovy, pinfish, and spotted/sand sea trout were common over the entire salinity range. Low salinity marsh species were mostly freshwater and estuarine species, with a few migratory estuarine/marine species. Intermediate salinity marshes had a wide range of species, from true estuarine residents, some estuarine/marine species, to several marine species. Marshes with the highest salinity were dominated, not surprisingly, by marine fishes and secondarily by estuarine/marine species. He also concluded that brown shrimp, white shrimp, and adult blue crabs showed no salinity preference.

Small blue crabs (<100 mm) were more abundant in lower salinity regions and very scarce in the highest salinity. He concluded that the effect of the projected salinity change in the study region (Lake Borgne marsh) of 2 to 5 ppt on the vertebrate fauna "will not necessarily be drastic". The only invertebrate thought to be impacted by the rise in salinity would be the oyster, primarily by increased predation by the oyster drill. Overall, in the 30-years since these predictions were made, there has been no substantial alteration of the aquatic vertebrate (mostly fishes) assemblages in this marsh region, helping to substantiate the suggestion that salinity will probably not have a major influence on the fish assemblages in the Phase I study area over this 100-year prediction period, although there may be alterations of the relative abundance of many or some coastal aquatic species.

The estuarine fauna of the coastal region of Louisiana has survived several previous cycles of delta growth and decay, so the predicted salinity changes during the projected 100 period are most likely smaller than the overall range of salinity during an entire delta cycle. In fact, the life history patterns of many of the species that use the estuaries have evolved over long periods of geological time so it is suggested that the relatively "short" span of 100-years will not produce dramatic interruptions of the basic life cycles of most of the aquatic species using the Barataria-Terrebonne estuaries.

Some previous reports on coastal organisms suggest salinity has impacted certain species. Van Sickle et al. (1976) reported that salinity in lower Barataria had increased and that as a result, over the previous 30-year period, oyster production moved inland in the system, resulting in the concern that oyster production would be negatively impacted by pollution. This increase in salinity was attributed to land loss and changes in the flow of the Mississippi River, but no data were presented. This study stated that "Perhaps the single most important environmental factor affecting oyster populations is salinity". However, they also pointed out that being physiologically euryhaline, oysters can live in a wide range of salinity. Increased salinity can, however, leave oyster beds more vulnerable to predation from the oyster drill. Chatry et al. (1983) arrived at similar conclusions in an examination of optimal salinities for Louisiana oysters.

4.0 CHANGES IN OPEN WATER HABITATS

4.1 Physiography and Salinity

The value as faunal habitats of open water areas created as a result of land loss in part depends upon their physiography (shape, size, depth, relation to other open water bodies) and the salinity of the water. With the conversion of wetland habitat to open water, an important function of these habitats, that being feeding areas and predator refuges, would be greatly diminished or lost entirely. These changes will be assessed by habitat type for the wetland components of the system base upon the habitat images described in Section 2. Trends in the following landscape parameters will be assessed:

* fragmentation/interspersion
* depth
* connectivity to open bay

Some literature (see Boesch et al. 1994) suggests that some fragmentation of estuarine wetlands may provide additional access and nutrients for organisms and may result, for an unpredictable period of time (see Figure 15, Boesch et al. 1994), in increased secondary production, but ultimately a decline in production and long-term loss of fishery production would be seen (Browder et al. 1989). Some predictions were that this downturn in secondary production would be soon Deegan and Thompson (1985) suggested that such an increase in production might result from utilization of detritus that has built up in estuarine environments but will eventually collapse because the dynamics of the system will ultimately be using the detritus faster than the eroded system can produce it. They discussed what mixture of marsh/meanders/open water ratios might provide for high secondary production. Whether the 30-year or 100-year predictions of marsh loss could result in enhanced production or an imbalanced production ratio cannot be determined at this time, but with 33% to 46% marsh loss being projected, there is a likely possibility that the systems will be using more detritus than they will be able to produce. Functionally, this is similar to the conclusions of Browder et al. (1989).

4.1.1. Barrier islands

The loss of the barrier islands results in a change from dune/marsh habitats to open water habitats where the open water type is similar to that existing on the shoreface and within the coastal bays. There will be no increase in salinity. The trends are:

* fragmentation/interspersion - maximized as islands disappear completely
* depth - increases
* connectivity - maximized as becomes part of the bay/gulf system

Shore and flat habitat is critical to many species of fish and birds in the region. Projections estimate only 65% and 43% of this habitat existing after 30 and 100-years, respectively. Visser and Peterson (1994) discussed the importance of barrier islands (beach habitat) to shore and seabirds, and Wiedenfeld et al. (1996) noted that "these islands provide important nesting habitat for seabirds, which sometimes nest in colonies of thousands;" a function that will be lost as the barrier islands continue to disappear. Thompson (1988) listed species of fish that specifically use beach habitat, agreeing with Ruple (1984), that for some species such as Florida pompano and Gulf kingfish, this habitat is their main nursery area so loss of over 50% of this environment would almost certainly have a strong negative impact on the population. Wiedenfeld et al. (1996) also document the importance of 'wooded, chenier areas', listing the habitat on Grand Isle as particularly important. Our projections show that some of this habitat will remain after both 30 and 100-years, but that much of the barrier islands will be gone and it is doubtful as to whether any of the remaining fragments could still function in meeting the habitat needs of bird species, for example, brown pelicans, black skimmers, and sandwich, royal, and least terns. Certainly, there would not be the carry capacity for these species that we have today.

Visser and Peterson (1994) report that barrier island (beach) restoration was very successful in maintaining habitat for colonies of many Louisiana's seabirds. They document the preferred use of marsh sites for only two species of seabirds, habitat that is projected to diminish by 20% to 40% over 30 and 100-years, respectively.

Condrey et al. (1995) reviewed the species in the Barataria-Terrebonne estuaries that are presently on the federal list of threatened or endangered animals, noting that several species of birds (e.g. brown pelican) make essential use of coastal habitats associated with barrier islands, so continued loss of this habitat would further threaten these animals. Overall, the entire barrier island ecosystem shows collapse along much of the study area over the 100-year period.

4.1.2. Open bays

The open bay environments expand through time at the expense of adjacent barrier island and salt marsh habitats. There is no change in their physiography. There may be a slight 1-2 ppt increase in salinity at the northern margins of the bays. No change in salinity will occur close to the Gulf margin. There is little change predicted in average depth of the open bays, except in those areas of receding shoreline.

The increased acreage of open water may actually result in an increased number of aquatic species. In comparison to estuaries, a large number of aquatic species live in the open waters of the Gulf of Mexico. Gunter (1967) felt that salinity was the main influencing factor for the observation that the largest number of species were found in the shallow waters of the Gulf of Mexico, declining as you move up through the estuary into lower salinity waters. Sheridan (1983), agreeing with Gunter, reported the highest diversity of fishes in his Texas study occurred in the shallow Gulf of Mexico just offshore from Galveston estuary. Of the 208 fish species recorded from the Barataria-Terrebonne estuaries, 121 are marine, 26 are estuarine/marine, 24 are true estuarine residents, and 37 are freshwater (Deegan and Thompson 1985, Condrey et al. 1995, LADNR 1998b). There are several hundred additional marine fish species not known presently from these estuaries that may move into these habitats if erosion ultimately makes them open bays of the Gulf of Mexico. This same pattern is also true for marine macroinvertebrates. This, however, may be at the expense of many preferred recreational and commercial fish and macroinvertebrates that use protected estuarine habitats to complete their life cycles. McHugh (1967) suggested that these same factors would produce the pattern often found in estuaries of increasing numbers and numbers of species in estuaries during an annual cycle.

With 100-year projections of 33% to 46% loss of intermediate, brackish, and saline marsh habitat, the resident estuarine species of fish and macroinvertebrates may be the assemblage component that suffers the sharpest drop in population, since they would lose, to open water, important habitat needed for successfully completing all stages of their life history. Also, migratory estuarine-marine species (e.g., blue crab, red drum, southern flounder, etc.) will have their marsh nursery areas replaced by open water, thus losing an important habitat component of their life cycle. The loss of marsh may result in species that use this habitat as a nursery (e.g.

spotted seatrout) being replaced by similar or closely related species that are more dependent on open waters as their nursery (e.g. sand seatrout). Any of the species that make use of the open waters for all or a major part of their estuarine life history would be predicted to become more abundant than they are at present, for example, the hardhead catfish.

Hypothetically, oysters may be one of the estuarine organisms that might be enhanced by the erosion of marsh in the Barataria-Terrebonne systems, if the increased acreage of open water proves suitable for the establishment of new oyster beds. This possibility was discussed in Condrey et al. (1995) who recommended that the shallow-water habitats being formed by the erosion of marsh be examined for their potential as new oyster leases.

4.1.3. Salt marsh

Within the salt marsh zone, areas which are already fragmented in 1990 (e.g., Leeville to Fourchon area, marshes north of Lake Barre) appear to make the transition to large open water areas by the 100-year projection and appear as marsh islands within open water areas at the 30-year mark. Salt marsh areas which remain at the 100-year projection are all fragmented. The trends are:

* fragmentation/interspersion - increases
* depth - increases (to 30 cm in new small ponds, to 2 m in bays)
* connectivity - increases as all marsh becomes fragmented to some extent

Saline marsh is projected to lose 17% and 47% of the total acreage in the Barataria and Terrebonne estuaries over the 30 and 100-year time spans. This marsh type is already fragmented, so the marsh makes a major transition to open water. Much of the function of this type of marsh will be lost, particularly as feeding and predator refuge areas. Rozas et al. (1988) postulate that many young-of-the-year transient species or small marsh residents make important use of shallow rivulets and meanders to quickly reach the marsh surface where they feed and at the same time avoid predation among the thick vegetation. This function would be greatly diminished in the small remaining fragments of saline marsh in the system as the rivulets and meanders are lost to erosion. With close to half of the total acreage lost, any potential enhancement from edge heterogeneity will most likely have come and gone. Estuarine residents such as gobies and killifish will have lost much of their lower bay habitat; for example, Fundulus jenkinsi, the saltmarsh killifish, a marsh resident, is presently a candidate for inclusion on the

Federal Endangered Species Act, uses these rivulets and meanders to gain access to flooded marsh surfaces for feeding and spawning. Estuarine/marine transitory migrants such as penaeid shrimp, spotted seatrout, and red drum use the saline marsh as nursery areas and this function will be greatly impaired. Overall, secondary fishery production in saline marsh will greatly decline. Fewer marine species enter the estuary to use saline marsh, so this group will not be as severely impacted.

Although salt marsh is not essential habitat for most furbearers, waterfowl, and alligators (Palmisano, 1973), it is important nesting habitat for many wading and seabirds, such as the Louisiana heron, snowy and great egret, white ibis, Forster's tern and others. Fragmentation of the marsh and conversion to open water of close to half the present acreage of salt marsh would result in a greatly diminished carrying capacity for these species unless these species are able to increase their utilization of less saline habitats farther inland.

4.1.4. Brackish marsh

Much of the brackish marsh zone has already degraded to large open water areas by 1990 (e.g. Montegut, Madison, Wonder lake area). The remaining brackish marsh areas increase in fragmentation. The only large open water areas which are not present in 1990 are on Point-au-Fer. Salinities in this zone may increase by 1-2 ppt. Relatively intact brackish marsh areas remain at the 100-year projection at Blue Hammock Bayou, and west of West Pointe a la Hache. The trends are:

* fragmentation/interspersion - increases
* depth - increases to 30 cm in new ponds and 1 m in larger ponds (not bays)
* connectivity - increases but not direct

The dynamics of biological use of brackish marsh can be very similar to that of saline marsh. The utilization of this marsh type as a nursery grounds by estuarine/marine fish and macroinvertebrates does not differ significantly from saline marsh and Condrey et al. (1995) does not distinguish these two types of marsh as habitat for birds. Smith (1979) actually included both marsh types in his discussion of "brackish-water" habitats as nursery for penaeid shrimp. The projected fragmentation of this marsh will probably result in some loss of its nursery function, but may enhance its use by birds as feeding areas due to the more open nature of the eroded marsh, since Roberts et al (no date) considered brackish marsh as important wintering and feeding sites for many wading, sea, and shore birds. The slight increase in projected salinity and depth will probably have little biological consequences. Roberts et al. (no date) reported that fairly large areas of marsh in the Barataria estuary changed both from intermediate to brackish and brackish to saline, so the question of marsh loss and marsh "transition" is complex. Palmisano (1973) noted "Brackish marsh has long been recognized as the most productive fur habitat along the northern Gulf coast"; emphasizing that this was the preferred habitat for Louisiana muskrat. Loss of 40% of this habitat as shown in the 100-year projection could be devastating to local muskrat populations.

4.1.5. Intermediate marsh

Intermediate marshes remain relatively stable in the Barataria basin, presumably because of the influence of Davis Pond. There will be no increase in salinity here. Changes there are largely increases in the size of existing open water bodies rather than widespread fragmentation. Within Terrebonne, intermediate marshes in both the west and east become more fragmented. There will be a change in salinity of approximately 1 ppt in these areas with the prevailing salinity still less than 3 ppt. The trends are:

* fragmentation/interspersion - increased in Terrebonne, stable in Barataria
* depth - new open water bodies less than 0.5 m deep
* connectivity - still large areas of marsh isolated from direct connection to bays, low drainage density remains, despite increase in channel size.

Intermediate marsh, the transition between more saline habitat and freshwater marsh, is projected to decline by about one-third over 100-years, with the Terrebonne Basin suffering more decline than Barataria. Chambers (1980) and Simoneaux (1979) characterized the fish assemblages utilizing intermediate marsh.

Roberts et al. (no date) showed change from fresh to intermediate marsh in northern Barataria Bay, but felt this was sampling artifact. Intermediate marsh is important habitat for alligators and historically many of Louisiana's most valuable furbearers such as muskrat and mink (Palmisano 1973). Palmisano (1973) documented the importance of intermediate marsh as "puddle duck" waterfowl habitat. The MRCWI-GCJV (1990) stressed the necessity of having acreage of intermediate marsh to support North American waterfowl populations. The projected loss over 100-years of one-third of this habitat is cause for serious concern since conservation efforts elsewhere in North America to stabilize and enhance waterfowl populations could fail from lack of acreage along coastal Louisiana.

Intermediate marsh is often important habitat for seasonal estuarine-marine fish and macroinvertebrates penetrating farther inland, and the cumulative impact of large losses of saline, brackish, and intermediate marsh acreage almost certainly would result in population decline of these species. Many fishes considered to be freshwater species can usually live in the salinities found in intermediate marsh (5 ppt +/-), so this habitat is important for channel and blue catfish, largemouth bass, and many species of sunfish such as warmouth and redear. Condrey et al. (1995) reviewed the literature for selected freshwater fish species in the Barataria-Terrebonne estuary, suggesting causes for possible changes in their abundance. Increased fragmentation of the intermediate marsh in the Terrebonne system will be detrimental to species of fish such as sunfish and killifish that prefer protected edge habitats, with loss of spawning areas for many of these nest-building sunfish a distinct possibility.

4.1.6. Fresh marsh

There is a large difference between Barataria, with Davis Pond, and Terrebonne. In Barataria fresh marshes remain relatively stable and open water bodies will remain fresh. New small ponds will be shallow and isolated. In Terrebonne already fragmented areas of western Terrebonne marshes coalesce to form large bodies of open water (e.g., Turtle Bayou, and west of Grand Bayou canal) with some large tracts of marsh remaining (e.g., between Creole and Willow Bayous, and north of Lake Penchant). There will be no change in salinity in these systems (< 1 ppt). The trends are:

* fragmentation/interspersion - increased in Terrebonne, stable in Barataria
* depth - new open water bodies less than 0.5 m deep
* connectivity - still large areas of marsh isolated from direct connection to bays, low drainage density remains, despite increase in channel size.

Similar to the projected changes in intermediate marsh, there is a large difference between losses of freshwater marsh in Barataria Bay (smaller) and Terrebonne Bay (larger). Tidally influenced fresh marsh can be important habitat for young of certain seasonal estuarine-marine species (for example: southern flounder and Gulf menhaden) that normally use the upper reaches of estuaries as preferred nursery/refuge habitat. These species would lose habitat, particularly in Terrebonne Bay where a greater percent of freshwater marsh is predicted to be lost, but this may be difficult to document in the overall population along coastal Louisiana. Freshwater marshes are used by a fairly wide range of fishes and although some species can tolerate low levels of salinity, Carver (1965) reported that salinity was one of the main limiting factors impacting eight species of freshwater centrarchids (bass and sunfish) in freshwater marshes near the mouth of the Mississippi River. Important commercial species of catfish tolerate a wide range of habitat conditions (salinity, turbidity, etc.) so they will probably be relatively unaffected by the projected changes in freshwater habitats. Amphibians will also probably be unaffected by the projected changes since it is suggested that there will not be any salinity increases which would have a strong negative effect on this group of animals. Freshwater marsh is important alligator and snapping turtle habitat, but changes seem likely to not affect these species. Roberts et al. (no date) reported that freshwater marsh is important habitat for furbearers and large numbers of birds such as migratory waterfowl (various species of ducks and geese), and wading birds (herons and egrets) that use the habitat for nesting. Although there is a projected 30% loss of freshwater marsh, over 250,000 acres will remain in the two systems, but this is far short of the projected acreage of the North American Waterfowl Management Plan (MRCWI-GCJV 1990) that has the objective of "providing, through preservation, restoration, creation, and enhancement approximately 509,000 acres of fresh marsh" in the Mississippi Deltaic Plain Region. The creation of new small, shallow ponds within the marsh may provide valuable habitat for spawning and nesting for amphibians and certain fishes (sunfish and bass). These ponds may serve as feeding stations for many of the birds and these small aquatic organisms.

4.1.7. Wetland Forest

There are few areas of wetland forest remaining in Terrebonne. Those that do remain as wetland forest show some increase in fragmentation by the 100-year projection, with increase in size of existing open water bodies (e.g., area between Bayou Black and Bayou Cocodrie). In Barataria there is some fragmentation of wetland forest areas south-west of Lac des Allemands with most new ponds being connected to the existing drainage network. There will be no increase in salinity in either Terrebonne or Barataria wetland forest areas (although some wetland forest areas south of Houma may change to other habitat types as outlined in Section 3). The trends are:

* fragmentation/interspersion - increased

* depth - new open water bodies less than 0.5 m deep, up to 1.5 m where connected to existing channels
* connectivity - increase in connectivity especially in Barataria..

Again, the Terrebonne system will have a greater loss of wetland forests compared to the Barataria system. Any loss of forest habitat may result in loss of nesting trees for the species of birds utilizing this habitat. Of critical concern is the potential loss of nesting trees for bald eagles, a species presently on the federal list of threatened and endangered species (although it is projected to be removed from Endangered Species Act protection in the near future). Waterfowl such as wood ducks and mallards make important use of this habitat, as well as many species of wading birds that may abandon the area if the die-off of trees produces too many large open spaces. The wetland forests are valuable habitat for several species of furbearers (mink, raccoon, nutria), deer, rabbit, and squirrel. A die-off of trees would certainly lower the carrying capacity of this habitat for these species, resulting in a population decline.

5.0 IMPACT OF EXTREME EVENTS

5.1 Hydrology of Extreme Events

The Step G report outlines the maximum water levels across the study area associated with two category 5 hurricane storm tracks (Figures 4.5 - 4.10). For the eastern-most track (Track 1) most wetland areas in the Barataria basin are flooded although some isolated areas close to Hwy. 90 and Raceland appear to remain subaerial. the pattern is similar in the 30-year scenario and the 100-year scenario shows a larger extent of flooding with only minor changes in the depth distribution. Barataria basin is flooded with 1-2 m of water. In the Terrebonne basin, flooding is shallower (generally < 1m) with some wetlands in western Terrebonne, south of GIWW, remaining emergent as well as areas along the ridges south of Houma. The pattern is similar after 30-years but after 100-years most ridges south of Houma are flooded and the western Terrebonne areas remain emergent. The western track (Track 2) shows extensive flooding (< 1.2 m) over both basins with the exception of the barrier shoreline in Barataria basin. There is an increase in water depth in some areas by the 100-year scenario but parts of the Barataria barrier shoreline remain sub-aerial. Model simulations of waves associated with the waves (LADNR 1998a) shows that the coastline is overtopped with waves approx. 2 m high while in bays and flooded wetland areas waves are generally limited to 1 m in height.

5.2 Habitat Susceptibility

Recent studies of the effect of Hurricane Andrew on the Phase 1 Study Area have allowed assessment of the effects of hurricane storm surge on coastal wetlands. This provides the best context for projection of the effects of the Category 5 hurricanes described in Step G. Although the no-action projections and model scenarios indicate few significant changes through time (30- and 100-year scenarios) in the hydrology of these hurricane events, the potential impact of these on various habitat types needs to be assessed in order that any changes in these impacts associated with barrier shoreline restoration scenarios can be adequately identified in Step J.

5.2.1. Barrier Island Habitat

Barrier beaches suffer most during hurricane impacts. Stone et al. (1995) note that the breaker wave height during hurricane Andrew was greater than the foredune elevation along much of the Grand Isle to Point au Fer section of the coast allowing opportunities for breaching and overwash. Both these processes remove sand from the beach and redistribute those sediments onto back-barrier marshes and adjacent bays. Dingler and Reiss (1995) note that Hurricane Andrew was powerful enough to strip all the sand from the beach face along portions of Trinity island, Isles Dernieres, as well as some mud from the marsh core of the island. Dingler and Reiss (1995) also note that the impact was so severe that sand was largely transported to the back of the island and post-storm recovery processes, which normally move sand back to the beach from the nearshore, did not operate in the year following the storm. The pace of recovery of the beach habitat after severe hurricane impacts is determined by the magnitude of the impact and the time for recovery before the next storm impact. The low elevation of the foredunes along the Louisiana coast makes overwash, and transport to the back of the island, a more likely consequence of hurricane impact. Lower intensity events and/or higher dune elevations can result in sand eroded from the beach being deposited in the nearshore, as was the case during Hurricane Hugo's impact on Myrtle Beach and Debidue Beach (Birkemeier et al., 1991). Overall, it is likely that beach habitat will at least temporarily disappear after the impact of a major hurricane.

The back barrier marsh habitat is less exposed to erosion during the hurricane tracks used in Step G than the Gulf-facing shoreline. Vegetated marshes may be covered with overwash deposits from beaches and this will result in a transition to the dune/beach habitat if the deposits are thick. Where thin veneers of sand are deposited on back barrier marshes, marsh vegetation will continue to grow. Soils of back barrier marshes are typically more sandy than those of mainland marshes (D. Reed, unpublished data) probably due to both aeolian and storm inputs of sand from the beach. DeLaune et al. (1986) identified sandy storm deposits in backbarrier marshes on Grand Terre and Grand Isle up to 10 cm in thickness. Such deposits would be unlikely to cause a transition in habitats and the marsh would grow through the sand as was apparently the case at the locations sampled by DeLaune et al. (1986). During the phase of storm passage where back-barrier marshes are directly exposed to wave attack, marginal erosion of the marshes is likely. This type of erosion diminishes the area of marsh on the island and is exemplified in McBride et al. (1992) where retreat of back barrier marshes is evident along most Louisiana barrier islands. Overall, hurricane impacts will cause some direct marginal erosion of back barrier marshes and some marshes may be covered with sand, although the marsh vegetation will normally continue to grow through the cover.

5.2.2. Saline Marsh Habitat

The effect of hurricanes on saline marshes in the Phase 1 study areas has been examine by Cahoon et al. (1995a, 1995b) and Nyman et al. (1995). There is little evidence of direct physical removal of marsh substrate in these environments and the main effects appear to be beneficial via the deposition of relatively thick sediment layers which can enhance the ability of some marshes to keep pace with relative sea-level rise. However, Cahoon et al. (1995a) identify an alternative effect of Hurricane Andrew on some saline marshes which are in a 'stressed' condition before hurricane impact. In their study, comparison of marsh surface elevation measures at Bayou Chitigue before and after the passage of the storm show a significant lowering of the marsh surface. The mechanisms causing this lowering are unclear but it may be associated with loading of weak soils with storm flood waters and a loss of soil structural integrity caused by waterlogging stress and plant deterioration.

Such lowering of the marsh surface may result in a change from vegetated to open water habitats as a result of the storm but these effects will likely be localized and a broader effect will be the vertical building of the marsh soil surface. The further opening of coastal bays under future no-action scenarios may increase the potential for sediment supply to the marshes under storm conditions. These marsh types will not be adversely affected by any short-term changes in salinity associated with storm impacts.

5.2.3. Brackish, Intermediate and Fresh Marsh Habitats

These habitat types are treated together as they are susceptible to catastrophic disturbance by hurricane flooding and waves. Data from Hurricane Andrew (Guntenspergen et al., 1995) show that these marshes can experience physical fragmentation and movement as a result of hurricane flooding. They are particularly susceptible in areas of floating substrate (Sasser et al., 1994) where relatively rapid increases in water level and wind stress on the mat surface can result in tearing and lateral movement and compression of the marsh surface (e.g., Jackson et al., 1995; Guntenspergen et al., 1995). Some disturbance may be caused by salt spray and thick sediment deposits but these marshes types can recover from such saline exposure (R. Howard, pers. comm.) and in brackish marshes sediment inputs may be as beneficial as in saline marshes. Lateral compression may result in ridge and trough topography as well as open water areas. Ridges may convert from wetlands to upland habitats while open water areas are likely to persist in the landscape. Should barrier shoreline restoration in the Phase 1 study areas reduce flooding by extreme events, these impacts may be reduced.

5.2.4. Wetland Forests

The main effect of extreme events on wetland forests is via wind damage which, although important, will not be altered by barrier shoreline deterioration or restoration. Therefore, the storm impact to these habitats will not be considered in this study.

6.0 SUMMARY

The no-action projections for 30- and 100-years show the largest land loss for fresh-, saline-, brackish-, and intermediate marshes. In all, 144,879 acres (226 mi2) and 332,947 acres (520 mi2) of these four habitat types are predicted to be lost in 30- and 100-years respectively.

The water level fluctuations vary throughout the study area as the land loss occurs in the future. In general, the water levels are not ecologically significant. The changes in landscape will produce some changes in salinity patterns within the bay marsh systems. However, none of these changes are considered to be of sufficient magnitude to result in habitat shifts in the emergent marsh areas.

Changes to the faunal communities are associated with the amount of habitat of a certain type rather than a change in habitat type. Specifically, the projected loss of the barrier islands is significant to many species of birds that utilize the islands as either nesting areas (e.g., shorebirds, seabirds), or as a migratory stop over habitat for songbirds and other trans-Gulf migrators. In addition, high-energy beach habitat that currently serves as a nursery ground for many species of fish that have no alternate nursery habitat is projected to be lost. The loss of the barrier island marsh will eliminate nursery habitat for many species of young-of-the-year estuarine marine fish and macroinvertibrates that move inland to mainland marshes.

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