Comprehensive Recommendations Supporting the Use of the Multiple Lines of Defense Strategy to Sustain Coastal Louisiana
2008 Report (Version I)

This report recommends integrated coastal projects and levee alignments for the entire coast of Louisiana with the overriding goal of improving hurricane flood protection and sustaining the coastal estuaries.

“\textquote{It may be hubris to think we could ever engineer our way out of this fix, when nature seems so aligned against us. It is certainly hubris to think we could do it without taking nature's assistance when it is offered.\textquote{}}

\textit{Quote from comments on the draft report by David Yeargin}

Funding provided by the McKnight Foundation
Report is available at MLODS.org, SaveOurLake.org, or CRCL.org
Multiple Lines of Defense Strategy

Flood protection and preservation of coastal habitats are the two essential features of the coast needed to sustain the people, natural resources, and economy of south Louisiana. These two broad features of the coast can primarily be addressed by a two-pronged strategy: (1) define and sustain Lines of Defense and (2) define and sustain Wetland Habitat Goals (Figure 1).

The MLODS encompasses both natural and manmade features that reduce hurricane impacts. The Wetland Habitat Goals define a gradient of wetland habitats and a corresponding salinity regime for surface waters of the coast. Planning and management of the coast should be proactive in order to sustain both. This is achievable because integration of the Lines of Defense and the Wetland Habitat Goals helps define the “where” and “how” of coastal restoration. The “how” is conventional methods appropriately selected for each habitat type, such as marsh creation through dedicated or beneficial fill material, river reintroductions, reef construction, rock armoring, etc. The “where” is focusing restoration on the geographic areas defined as “Lines of Defense.” The objective of this strategy is to coordinate and prioritize these conventional methods of restoration of coastal habitats for restoration and flood protection.

This report utilizes the MLODS and other sound science and engineering principles to define an ideal array of alternative Lines of Defense and statewide Wetland Habitat Goals. The report is geographically organized as in the Louisiana’s Comprehensive Master Plan for a Sustainable Coast and the United States Army Corps of Engineers’ (USACE) Louisiana Coastal Protection and Restoration Study (LACPR), which includes five planning units across the Louisiana coast (Figure 11).

![Coastal Louisiana](image)

**Figure 11:** Planning units used in this report are the same as those used in the *Louisiana’s Comprehensive Plan for a Sustainable Coast* and the USACE development of the LACPR Study.

Perhaps the most practical aspect of the MLODS is that it selects restoration projects which provide both direct ecologic and flood protection benefits. All restoration projects recommended here
should provide two benefits-for-the-price of one. For the cost of restoration, some sustainable threshold of the coast is to be achieved while providing the critical landscape features with the most flood protection benefit. For example, the total marsh creation acreage proposed in the plan is approximately 98,000 acres (153 square miles), which are strategically located on critical lines of defense as marsh buffers. This represents just 7.3% of the historical land loss of the coast. Nevertheless, the cost to construct 98,000 acres by pumping sediment will be at least $2.6 billion, which is all the more reason to be selective and strive to achieve the dual benefits. This is a significant challenge but is entirely achievable for the target date of completion of 2025 when the USACE has proposed completion of the higher LACPR level of flood protection for south Louisiana.

Similarly, diversions are strategically placed to sustain the marsh creation projects on these land bridges, wherever feasible, so that re-occurring expenses for marsh creation are minimized. Indeed, all the proposed elements are interconnected. Most projects could function alone, but the goal here is to maximize the benefits with as little investment as possible. It is anticipated that a future report will be released by this team detailing costs and priorities. Ultimately, life cycle economics of the projects and regional economy will determine the level of sustainability. Future work by this team may assist with this type of analysis, but, at this time, it is imperative to move toward implementation with priority projects.

It is important to clarify that this report is not intended to include all possible environmental restoration efforts for the coast; rather, it only recommends the critical measures to restore and sustain the coastal features which most appropriately compliment the flood protection system for target levels of flood protection. The report is not a complete environmental restoration plan. It is intended to comprehensively describe a flood protection system for coastal Louisiana. Because establishment of a flood protection system for the coast is the highest priority, the coastal restoration projects included here should, in general, be a higher priority than restoration without flood protection benefits.

**Sustainability**

In the United Nations’ “Brundtland Commission Report” (1987) and the United Nations Report (1987), sustainability is summarized in the following statement: “States shall conserve and use the environment and natural resources for the benefit of present and future generations.” The multi-generational vision is essential to any definition of sustainability; however, in the modern world, achieving this vision requires mutual support from the natural system and human economies. As it has been stated “there can be no conservation development without economic development”. Modern approaches to sustainability must recognize that we do NOT have dual independent systems composed of the “Environment” and “Development”; rather, we have one system. When we describe Louisiana’s coast as a “working coast,” we are recognizing that our coast is so intermeshed ecologically, economically and socially that these aspects cannot be considered independently and, therefore, are co-dependent.

Sustainability is NOT:

- An entirely self-sustaining ecosystem excluding use of economic capital
- An entirely self-sustaining economy excluding use of natural capital
Sustainability is a mutual exchange of natural and economic capital so that:
- A fundamental system of human economy and culture is indefinitely supportable
- A fundamental system of historic ecologic functions is indefinitely supportable

The proposed criteria for sustainability for coastal Louisiana as stated by the CRCL and adopted here is “A state of the wetlands, waters, and barrier shorelines of coastal Louisiana that achieves and maintains a dynamic and productive synergy of ecologic, economic and social capacities that are resilient*, adaptive**, and transformable*** to meet the needs of future generations with a minimal reliance on human intervention.”

*Resilience – the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks.
**Adaptability – the capacity of natural processes in the system to influence resilience.
***Transformability – the capacity to create a fundamentally new system when ecological, economical or social structures make the existing system untenable.

The bottom-line is that the Louisiana coast, upon which the local culture and economy is dependent, cannot be made to be entirely self-sustaining. The Louisiana barrier islands are naturally ephemeral and will likely require regular replenishments. However, a large portion of our coastline could be self-sustaining, or sustainable with minimal investment. It may be possible, by a short-term infusion of investment in wetland restoration and by limiting deliberate wetland destruction, that an acceptably low rate of wetland loss can be achieved.

By contrast, the Dutch have developed a system of dikes and storm surge barriers that offers a great level of protection, but are situated directly on the interface with the sea. This system is not self-sustaining and requires annual large-scale investments in order to sustain the level of protection desired. At any given point in time, there are great reaches of this system that are below standards. In the face of sea level rise and future uncertainties, these investments will have to continue to grow into the future. The goal of this report is to make these types of re-occurring restoration costs in Louisiana sufficiently low so that the economy may economically justify these or other necessary investments, therefore, making the coast mutually sustainable with the coastal economy.

**Types of Lines of Defense**

One of the basic assumptions of *Louisiana’s Comprehensive Master Plan for a Sustainable Coast* is that a “Multiple Lines of Defense” strategy (MLODS) should guide flood protection decisions (CPRA 2007). The eleven types of Lines of Defense are listed below in the order derived from the relative physical location to each other, moving inland from the Gulf of Mexico. The order is not intended to indicate the relative significance, but simply the relative physical position (Figure 12).

The Lines of Defense include natural landscape features, such as the offshore shelf, barrier islands, sounds, marsh land bridges, and natural ridges, as well as artificial features like levees and floodgates, that affect the propagation, storage, enhancement, and attenuation of storm surge and also affect wave impact. The wetlands’ capacity to reduce storm impact is a service naturally provided by the indigenous characteristics of these coastal habitats. Future restoration and
management of these natural Lines of Defense should expand or accentuate this service without compromising other services typically provided by these habitats. Wetland benefits have been well documented and include, at least, water quality enhancement, carbon sequestration, fisheries enhancement, aesthetic values, waterfowl habitat, rare and endangered species, etc. Many of these benefits extend well beyond the coastal zone. This report focuses on the flood protection benefit of wetlands but does not intend to undervalue these other services.

**Figure 12:** The Lines of Defense profile illustration is a diagrammatic profile of the general coast of south Louisiana, indicating the eleven types of Lines of Defense. Lines of Defense are natural or manmade features that contribute to the abatement of storm damage by reducing storm surge. One through five are natural landscape Lines of Defense. Six through eleven are manmade Lines of Defense, which may, through design or incidentally, provide a measure of reduction in storm damage. All eleven Lines of Defense may be influenced by human activities. Note that elevated homes are recommended both outside and inside levees.

Elevating businesses and homes as a Line of Defense should be applied both inside and outside levees. Even after Hurricane Katrina, not all areas of the coast have adjusted their approaches to implementing home elevation for new homes or existing homes. Base flood elevations required by FEMA are often not an acceptable minimum elevation for adequate protection of homes. FEMA base flood elevations have risen in the past and will continue to rise in the future. The standardized formulas do not consider all variables that might affect vulnerability to surge over time. Too often, home elevation is driven by local architectural styles and not by the actual need for home elevation over the life cycle of the home. Home elevation is the only Line of Defense which can be done individually (assuming homeowners have the financial assets to do so). Because home elevating can be done individually and can be implemented in months, this option is the most immediately implementable Line of Defense. Home elevation and subsidized home elevation programs are essential to the sustainability of our coast and are strongly recommended throughout this report.
The MLODS involves management of the hydrology of the coast under two fundamentally different meteorological conditions, that is, “fair weather” and “hurricane.” In fair weather, normal rainfall, tidal, and riverine processes are operative. During a hurricane, the coastal hydrology is dominated by surge effects and often higher rainfall amounts. Under the MLODS, the fair weather conditions are directly related to the habitat goals that are the result of fresh and saltwater inputs producing the estuarine gradient. Fair weather conditions can be reliably modeled regionally. Under hurricane conditions, the MLODS will achieve the recommended levels of protection (either 100 year or 400 year). The assessment of surge can be modeled with advanced modeling programs such as Advanced Circulation (ADCIRC) modeling, but with significant caveats. The effect of wetlands or other natural coastal features to modify surge is not well understood and is not fully accounted for in typical ADCIRC models. Nevertheless, the proposals here have been influenced by these models. Additional modeling and additional research must continue on surge behavior in the Louisiana coast and should be considered a key element of an adaptive management approach as coastal projects are designed, constructed and operated.

It is only in the past few years since Hurricanes Katrina and Rita that ADCIRC modeling, the primary surge model used by FEMA and the USACE, has been refined sufficiently to allow quantification of the effects of low-lying coastal terrain and vegetation on storm surge and waves. Much additional research is needed for further verification, but this information is now allowing us to begin to think about “accommodation” hurricane surge along the same lines as floodplain managers responsible for addressing river flooding. The time frame is much shorter, of course, hours rather than weeks. However, we can still think of diverting surge away from population centers into prepared storage areas where it will do less damage or threaten less critical or fragile infrastructure. This “accommodation” of surge implies an integration of all elements of the landscape, whether natural, artificial or enhanced (restored) into the flood defense system. This is the fundamental concept at the heart of the MLODS approach.

Our long-term success to manage and accomodate storm surge on a subsiding coast ultimately depends upon restoring natural processes to build and maintain the deltaic landscape. Planners hope to bring back a restored coastal landscape that works synergistically with necessary and compatible levees and floodwalls to increase flood protection reliability over the long-term. They seek a landscape that, once restored, can become largely self-maintaining through reliance upon natural fluvial and wetland aggradation processes.

A sustainable coastal landscape that works for people will include a full complement of the elements that are identified as “Lines of Defense.” These elements can only be maintained in a healthy and flood-protection stance if the necessary river diversions and other marsh building projects begin to operate on that landscape at the scale required, either continuously or at suitable intervals, to achieve sustainability. Further, we recognize that if portions of estuaries are artificially severed from tidal processes by levee alignments, the estuary and its wetlands are damaged no less than when isolated from river influence and can no longer survive.

**Importance of Wetland Habitat Goals**

The Wetland Habitat Goals span from fresh to saline habitats and represent a gradient of habitat types from inland freshwater habitats to the Gulf of Mexico. Related to the habitat gradient, salinity
also varies across the estuary from fresh to seawater. More than any other variable, salinity
determines the basic wetland habitat type in south Louisiana (i.e., fresh, intermediate, brackish or
saline). The wetland habitat types are mapped by the vegetative cover, but they also strongly reflect
the land-animal and aquatic life present. The wetland habitat types (or goals), therefore, define the
natural resources of the landscape, including much of its economic potential. Because the
biological resources can be strongly influenced by salinity and salinity can be manipulated with
human intervention, the control of the estuarine salinity gradient of the coast should be a primary
management goal and not a random result nor simply the incidental result of a restoration project.

<table>
<thead>
<tr>
<th>Wetland Habitat Goals</th>
<th>are essential for Louisiana’s coastal planning because they:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Set a target for a sustainable estuary. Clear and measurable targets are increasingly recognized as a fundamental first step in any planning and restoration program.</td>
<td></td>
</tr>
<tr>
<td>2. Force the hydrologic integration of separate coastal projects, including levees, flood gates, river diversions, and marsh creation.</td>
<td></td>
</tr>
<tr>
<td>3. Forecast the natural resource allocation expected for resource users in areas including fisheries and forestry. This allows the state and commercial stakeholders to properly plan for resource use; for example, crawfishers or oysterfishers know where crawfish and oysters are to be located for future harvests with restoration.</td>
<td></td>
</tr>
<tr>
<td>4. Optimize use of funding, including fisheries management programs and coastal restoration programs. For example, the Louisiana Departments of Natural Resources and Wildlife and Fisheries can work much more effectively toward enhancing shrimp and oyster fisheries.</td>
<td></td>
</tr>
<tr>
<td>5. Shift the estuary toward a more natural and historic riverine system</td>
<td></td>
</tr>
<tr>
<td>6. Define areas where levees and freshwater habitat overlap, which can be targeted for restoration of cypress swamp buffers</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Wetland Habitat Goals

The five target Wetland Habitat Types are:

Swamp (0-3 ppt salinity)
Fresh Marsh (0-3 ppt salinity)
Intermediate Marsh (2-8 ppt salinity)
Brackish Marsh (4-18 ppt salinity)
Salt Marsh & Barrier Islands (8-29 ppt salinity)

(Note: Figure 13 does not distinguish between swamp and fresh marsh. Goals for maritime ridges are also shown where ridge restoration is recommended by this report.)
Geographic definition (mapping) of wetland habitats distribution is necessary for restoration and management. Table 1 lists the benefits of the Wetland Habitat Goals and Figure 13 depicts the location of the Wetland Habitat Goals along coastal Louisiana. (Note: Goals for maritime ridges are also shown where ridge restoration is recommended by this report). Figure 14 is a 1997 map of existing wetland habitats. The habitat goals map (Figure 13) defines the proposed future distribution of five basic coastal habitats and, therefore, potentially defines the natural resources to be derived from the coast when the goals are realized. The habitat map represents an average, long-term target around normal seasonal variations defining an estuarine gradient for the future hydrology of the coast. If all projects are forced to be designed to conform to this common vision of the hydrology, it assures that all projects will work in concert and result in a desirable estuarine gradient. Defining habitat goals is a method to minimize unintended hydrologic consequences of projects that include things such as levee alignments or flood gates.

It is recommended, but not required, that the distribution of the Wetland Habitat Goals is primarily based on consideration of a historical baseline and what is biologically and physically achievable with restoration, considering the already collapsed condition of the Louisiana coast. The overriding goal of development of the Wetland Habitat Goals is stabilization of land change and sustainability of the regional estuaries that compose coastal Louisiana. Ultimately, this goal may only be economically feasible through high organic productivity and efficient riverine sediment importation, which suggests allowing the estuaries to function as naturally as possible.

Figure 13 is the proposed Wetland Habitat Goals map for the Louisiana coast. This map is strongly influenced by reconstruction of habitats based on historical habitat data circa 1890 to 1932. The distribution reflects a more natural influence of overbank discharge by the Atchafalaya and Mississippi Rivers, resulting in the rivers being enveloped by fresh habitat. The intervening areas of Terrebonne Bay and St. Bernard Parish have more saline habitats, which is consistent with the historically inactive deltaic influence and less riverine influence. The historical reconstructions are based on historical documentation such as maps of oyster reefs and forest types in coastal Louisiana (Gunter, 1952; Wicker, 1979; Rossen et al., 1988; O’Neil, 1949; La. Board of Commissioners, 1912).

The Wetland Habitat Goals are the desired future habitat distribution proposed in this plan. This habitat distribution was selected because it complements other restoration proposals and represents potentially sustainable conditions for the coast. The wetland habitat distribution, in general, also corresponds to the historic distribution of habitats around 1900 before significant alteration by humans. One exception is in the area of Atchafalaya and Vermilion Bays where the habitat goals are fresher than the historic 1900 conditions. The post-1900 freshening in Atchafalaya Bay is due to the increase in discharge through the Atchafalaya River, starting as early as 1840 when logjams were cleared from the Atchafalaya River (Lopez, 2003). Vermilion Bay has seen an increase in freshwater due to the degradation and removal of large-scale oyster reefs which historically blocked the influence of the Atchafalaya River from entering East Cote Blanche Bay. Many of the wetlands in this area are experiencing the lowest rates of wetland loss across the coast due to the influence of freshwater and sediment of the Atchafalaya River. Because it is desirable to continue the land building of the active deltas, which also contribute to the western shore’s mud stream, it is not considered desirable to re-establish the more saline conditions of 1900 in this area of the coast. The
input of sediments into this area and land-building is a Line of Defense for coastal communities in this region. The need for protection for these communities along Highway 90, such as Franklin and Jeanerette, is justified. USACE (2006) reported the modeled storm still-water surge of 36 to 40 feet in this area along the GIWW alignment for a severe Category 5 storm (Table 2). Although the GIWW alignment is not recommended, the recommended alignment is just 6.5 miles further inland and would still be subjected to high surge. Maintaining or expanding the coastal buffer here is paramount to protecting the Highway 90 corridor.

Historical habitats, such as the cypress tupelo forests near Lake Maurepas (fresh habitat over 1,000 years old), and the oyster barrier reefs, such as in the Biloxi Marsh and Atchafalaya Bay (brackish habitat at least 100 years old), are ancient, stable habitats that attest to the coast being more stable prior to the induced state of collapse by anthropogenic impact during the industrialization of the coast. A goal of the strategy is to reduce the current instability of the coast by targeting the historic habitats and emulating the natural processes that sustained them.

Comparison of the proposed levee alignments (Figure 21) to the Wetland Habitat Goals (Figure 13) shows that most of the levees (77%) would have fresh habitat adjacent to them on the flood side. This creates an opportunity to restore extensive cypress swamps adjacent to the levees and provide a significant measure of protection by dampening surge’s energy (waves and currents), thereby reducing the chance of damage to the levee (Figure 22). This result is one of the natural outcomes of utilizing natural ridges for back levee alignments, recognizing that many of the ridges historically had fresh habitats adjacent to them. All other levee alignments, which do not have fresh habitat adjacent, are located in areas of intermediate habitat. In these areas, utilizing outfall management of storm water and treated wastewater may establish a cypress buffer that can provide significant additional protection benefit. None of the proposed levees are within brackish or saline marsh habitat goals where cypress trees will not grow.

Freshwater introduction and management is included in each of the Planning Units, and these measures are intended to be the tools to achieve the habitat goals while also allowing occasional pulsing events. Pulsing events may occur infrequently and may be opportunistic, such as diverting more water during a high water event on the Mississippi or Atchafalaya Rivers.

An essential restoration objective is to maintain a salinity regime for the Wetland Habitat Goals and to promote the general health of the habitats, including high productivity and appropriate diversity. Once the habitat distribution is established and mutually accepted, a multitude of resources can focus on each of the habitat types, including both public and private restoration efforts and fisheries management. Greater diligence should be devoted to habitats that are also identified as a Line of Defense.

The recommended Wetland Habitat Goals have a reduced area of brackish and saline habitat. This reflects historic conditions but is also consistent with the strong scientific consensus that the Louisiana coast should increase the riverine influence to achieve sustainability. Fisheries will be re-distributed, but not necessarily reduced. The Caernarvon diversion has demonstrated that even though the oyster grounds were reduced in size, oyster productivity increased. With more riverine influence and habitat goals which align restoration and management, the quality of habitat, in general, should increase all over the coast and fisheries should thrive.
The wetland habitat goals are the desired future habitat distribution proposed in this report. This habitat distribution was selected because they complement other restoration proposals, and they represent potentially sustainable conditions for the coast. The wetland habitat distribution, in general, also corresponds to the historic distribution of habitats around 1900 before significant alteration by humans. One exception is in the area of Atchafalaya and Vermillion Bays where the habitat goals are fresher than historic 1900 conditions. The post-1900 freshening here is due to the increase in discharge through the Atchafalaya River. Since it is desirable to continue the land building of the active deltas which also contribute to the western shore’s mud stream, it is not considered desirable to re-establish the more saline conditions of 1900 in this area of the coast.

**Figure 13:** Proposed Wetland Habitat Goals for Louisiana (Note swamp and fresh marsh are mapped together and goals for maritime ridges are also shown where ridge restoration is recommended by this report).
Figure 14: Existing Wetland Habitat Types of Coastal Louisiana, circa 2007 (Source: National Wetlands Research Center, LA DWF & LSU).
Wetland Habitat Goals should be public, stated goals but with minimal legal impediment for adaptive management. For example, impacts described under the National Environmental Policy Act (NEPA) should acknowledge that wetland habitats may change to the habitat goal but also that habitat goals might need to be changed in the future. The state’s prerogative to change the habitat goals should not be impeded legally but be based on the best scientific information to select appropriate habitat goals to sustain the estuary and promote the Lines of Defense that provide flood protection. This goal is consistent with the State Supreme Court reversal of the Avenal oyster lawsuit brought against the State of Louisiana due to operation of the Caernarvon diversion (below).

“First, the right of the state to disperse fresh water from the Mississippi River over saltwater marshes in order to prevent coastal erosion is derived from a background principle of Louisiana law.”

“We find that the implementation of the Caernarvon coastal diversion project fits precisely within the public trust doctrine. The public resource at issue is our very coastline, the loss of which is occurring at an alarming rate. The risks involved are not just environmental, but involve the health, safety, and welfare of our people, as coastal erosion removes an important barrier between large populations and ever-threatening hurricanes and storms. Left unchecked, it will result in the loss of the very land on which Louisianans reside and work, not to mention the loss of businesses that rely on the coastal region as a transportation infrastructure vital to the region's industry and commerce. The State simply cannot allow coastal erosion to continue; the redistribution of existing productive oyster beds to other areas must be tolerated under the public trust doctrine in furtherance of this goal.”

Louisiana Supreme Court - 2003- C-3521 ALBERT J. AVENAL, JR., ET AL. v. THE STATE OF LOUISIANA AND THE DEPARTMENT OF NATURAL RESOURCES

It is the lack of unity on habitat goals by state agencies in the past which has caused significant management problems of the estuary in southeast Louisiana. The Avenal suit made this clear when one set of oyster lease claims considered (and rejected by the Supreme Court) was based on leases issued by the state not just after operation of the diversion began, but after the state was on notice of the oyster law suit. Wetland Habitat Goals can and should be used to empower the State and its agencies with a single vision of coastal resources.
Levee Alignments: Natural Ridges, Back Levees, Ring Levees

A critical element in the MLODS is the use of natural ridges as both Lines of Defense and as residential/commercial corridors. Natural ridges have low slopes and are vegetated with indigenous trees, whereas man-made levees have steeper slopes and have grass vegetation. Levee alignments that do not follow natural ridges invariably cut across basins and alter the natural hydrology. Such trans-estuary levee alignments are antithetical to an estuary and will likely confound the best intentions and engineering. Non-ridge levee alignments create serious engineering problems. The soft soil will have higher subsidence rates and, therefore, simultaneously weaken levees, increase costs, and require additional maintenance. Trans-estuary levees will promote the same problems that we are now desperately trying to solve, that is, critical loss of wetlands. Fortunately, the focus on ridges for development and protection in south Louisiana is the traditional pattern of land use (Figures 15 & 16).

Figure 15: Profile illustration of typical development on natural ridges in coastal Louisiana. This diagram is a conceptual profile view of elements of a ridge development corridor and an adjacent estuarine basin. The back levee allows compatibility between the development corridor and an estuarine basin. The estuary on the flood side is subject to storm surge, marine influence and elevated water levels from river diversions. Elevated causeways may connect ridges by crossing the estuarine basin between ridges. Back levees do require management of drainage and will likely require pump stations.

If one drives through south Louisiana, one finds that most highways are adjacent to a bayou with a continuous line of homes and businesses. What may not be as obvious is that the road is on the elevated bank of the bayou which is surrounded by the lower lying marsh. Although the difference in elevation between the ridge and the marsh may only be about 12 inches, the additional advantage of the soil foundation makes the ridges highly preferable for development. Our ancestors recognized the natural advantages of ridges and, therefore, the bayou/ridge pattern of development dominates our coastal landscape. This landscape legacy now affords us the opportunity to further utilize the advantages of natural ridges by building restoration and flood protection in concert with the ridge and basin landscape, utilizing back levee or ring levee alignments.
Traditional “back levees” near the outer edges of the ridges along developed corridors such as the Mississippi River, Bayou Lafourche, Bayou la Loutre, etc. are not just a pre-1900 cultural legacy. They are our own Louisiana style of “Smart Growth,” i.e. homes on high ground and wetlands on the low ground (Figure 17).

Figure 16: Map illustration of relation of natural ridges to the estuary. This diagram is a conceptual plan view of elements of a ridge development corridor and adjacent estuaries. The back levee allows compatibility between the development corridor and an estuarine basin. Ring levees (segmented back levees) may be appropriate in sparsely populated areas or areas in need of direct water access.

Definitions (as used in this report):

Natural ridges – ridges that have a naturally elevated land surface often vegetated with trees. In Louisiana, these are typically derived in at least three ways: as natural levees from overbank flow of a river (bayou), as a chenier by longshore transport of sand, or as a former barrier island.

Back levee – an artificial levee located on the wetland flank of a natural ridge designed to reduce flooding of the ridge by tides or storm surge.
Ring levee - levees that enclose a segment of a natural ridge, which would usually require flood gates to allow navigation and tidal flow though the bayou that may dissect the protected area enclosed by the levee.

Figure 17: Examples of back levees in South Louisiana along Bayou Lafourche and the Mississippi River. Both examples are relatively close to the ridge and have flanking wetlands. The levee in Jefferson Parish is located off the ridge in an area that was historically low-lying wetlands prior to development, and it follows the lake shoreline rather than the ridge.

The back levees are not just protecting the ridge-based assets but also allow for management of diversions within the wetlands to prevent backwater flooding, i.e. marsh water levels rising and moving into the adjacent developed uplands. This issue is acutely problematic for the existing Davis Pond Diversion in St. Charles Parish. Communities were allowed to develop in nearby wetlands and now are threatened by backwater flooding from Davis Pond. Davis Pond is now severely limited in use because higher discharge will flood these communities (specifically Willowridge development). The $135 million project generally is now operated at 10% of its capacity. Extensive use of back levees with development on the ridges not only avoids this conflict but allows better flood protection and more effective restoration. The post-construction improvements to the Davis Pond Diversion are expected to be completed in 2008 after which the structure may be able to run at full capacity.
Another important attribute of back levees along the Mississippi River is that the river is a potential source of sediment to build the levees, possibly reducing the sediment transportation costs. Soils of ridges will compact and subside less and, therefore, reduce costs of levee construction, as well as reduce future investments for maintenance. In addition, new levee alignments through wetlands will require expensive mitigation, adding to the total cost. With ridge alignments, it is more likely that treated waste water and storm water can be diverted to adjacent wetlands to establish robust marsh and wetland forest buffers directly in front of back levees reducing municipal cost for wastewater treatment.

Therefore, considering the natural landscape (ridges & basins) and the character of surge on the Louisiana coast, it is very advantageous for levees to flank natural ridges, i.e. back or ring levees. Wetlands should be located outside those levees to buffer surge. Levees can directly protect people and assets on ridges. The surrounding basin and estuary reduce surge heights and surge energy, thereby reducing risk of damage to levees and providing a higher level of protection.

*The more coastal area that our levees envelope, the less area there is left for surge to be dispersed or attenuated. Conversely, the smaller the areas behind levees, the more area is available to allow natural hydrology and estuarine wetlands to flourish.*

Louisiana’s *Comprehensive Master Plan for a Sustainable Coast* (State Master Plan) suggests that storage behind levees is desirable to address overtopping (CPRA, 2007, Appendix A page 31). However, this suggestion does not consider the tradeoff that an outer trans-estuary alignment will greatly increase surge height and, therefore, greatly increase the chance for overtopping and/or failure. Nor does this suggestion address the issue of storing surge water inside the levees, meaning that another interior level of protection is required to protect assets that are also inside the levee. The USACE is currently constructing hurricane protection levees in New Orleans with an overtopping allowance rate of 0.1 cfs per linear foot. This overtopping rate is minimal and the construction design does not take into account any greater rate of overtopping. Since current levee construction in coastal Louisiana is restricted to 1 in 100 year, the risk of overtopping from a large event, such as a 1 in 400 year event is high. Without overtopping protections, the risk of levee failures from any event greater than 1 in 100 year increases, thereby deeming the storage area inside the levee as much less effective in the event of a failure.

Levees that cross basins also interrupt the natural hydrology of storm surge attenuation. For example, the reported modeled surge levels generated for a levee constructed in Barataria Basin along the GIWW is 30 feet (USACE 2006). With a swamp alignment, which is essentially a back levee alignment, the 500 year surge levels are no more than 16 feet (USACE Plan Formulation Atlas, 2007). The GIWW levee alignment cuts the areal extent of the estuary in half, but in so doing, nearly doubles the surge height at the levees. Recent USACE modeling has also determined that storm surge from a 2,000 year storm event with a back levee alignment would not threaten communities northwest of Highway 90 (St. Charles and St. John the Baptist Parishes). This reduces the need for large protection levees into the entire Barataria Basin (USACE Personnel Communication, 2007). The GIWW alignment would require a much higher and much more expensive levee per mile. The alternative back levees, though longer, would be much lower and cheaper to build and maintain per mile. The protected areas behind back levees are long and narrow, which allows the protected area to be easily segmented into linear polders. If there was a
failure or overtopping of the back levee, the extent of flooding could be limited by the judicious use of polders (see following discussion).

Possibly most problematic is that an outer barrier levee such as a GIWW alignment in Barataria Basin would need to be built as high as 45 feet or more for a severe Category 5 storm (see Table 2, USACE, 2006). This alignment would be an unprecedented levee for Louisiana and would retain significant uncertainty of its performance. It would pose an enormous threat if failure of the levee occurred. The release of a 30-foot wall of water by failure of the levee would damage the landscape, regional assets, and the levee itself. It would also be a great life-threat to anyone remaining within the region. An even greater problem occurs further west along the GIWW alignment near Atchafalaya Bay where the combined surge and wave height is 55 feet (Table 2), nearly equivalent to a 6-story building!

![Summary of Waves and Water Levels for Alignment 1](image)

**Table 2**: Modeled Surge Levels and Wave Heights for a GIWW Alignment (Alignment 1). Table is from the USACE’s Preliminary Technical report for the LACPR project of reported still-water surge levels and wave heights for a GIWW alignment (Alignment 1) for an extreme Category 5 storm (possibly as great as a “3000 year” event). Locations 39 through 46 are located along the GIWW alignment in Planning Unit 2. Levees designed to not be overtopped would be required to be built in excess of 45 feet high (33 feet SWL & 12 feet for waves).

Proposed trans-estuary levee alignments, such as the GIWW alignment in the Donaldsonville-to-the Gulf project, are described as “leaky levees” with the suggestion that the levees will
allow the estuarine wetlands to remain healthy. However, there is an abundance of scientific documentation of the detrimental effect of impounding wetlands or “structural management” (Sanzone and McElroy, 1998). These effects include, at a minimum, reduction in sediment input, reduction of aquatic access for migratory species, alteration of the nutrient budget, increases in subsidence, and stranding of salt water leading to salt stress or plant mortality. Trans-estuary alignments interrupt natural distribution of sediment. Sediment moving gulfward is impounded. Sediment moving landward, such as deposition that may be triggered by a hurricane, is also interrupted (Turner, 2007). Levees within the estuary may restrict deposition on both the flood and protected side of the levee.

In Louisiana, there is a legacy of failed wetland reclamation in which estuarine-influenced wetlands were enclosed by levees. Examples include Delta Farms, The Pen, Guste Island, East New Orleans, Big Mar, Avoca Island, and more. The intent of these projects was to destroy the wetlands and create farmland, but they succeeded only in the destruction of wetlands. A particularly disturbing aspect of reclamation of wetlands in Louisiana is that, once the wetlands are brought under management, it seems very difficult to bring them back as estuarine wetlands. Often this outcome is due to land subsidence, especially if these areas are operated under a pump system. A casual look at a map of the Louisiana coast reveals many unnaturally “square lakes,” which were once wetlands. A large failed area of reclamation by levee impoundment is Avoca Island, which is now a lake (Figure 18).

Figure 18: Example of the historic impoundment and consequent land loss of Avoca Island. In the early 1900’s, the island was completely land and was used as a cattle ranch and farm. The levee was deliberately breached to relieve stranded flood water from the 1927 river flood, and the land never recovered, even though, for the past 80 years, the breach to Bayou Schaffer has remained open. Land loss has continued, and a CWPPRA project and beneficial-use projects have been authorized. Beneficial use of dredge material has rebuilt some land in the southern portion of the lake.

Marsh impoundments for the specific purpose of wetland management may be marginally successful, but often, over extended periods, they can be detrimental and, therefore, should be considered a measure of last resort to sustain emergent wetlands. In southwest Louisiana, numerous impoundments are managed, but often not for optimum wetland management. For
example many impoundments are managed for waterfowl for duck hunting. Management for ducks is a poor proxy for management of a marsh and may conflict with marsh restoration. Therefore, we suggest the reverse approach. Management for wetland productivity should be used as a proxy for waterfowl management. Although not often discussed, marsh management dikes are used to restrict access to private lands, and therefore may perpetuate impoundments even when other management might be pursued. Private landowners may have the right to restrict access but it should be recognized that using impoundments can compromise the habitat. Waterfowl management often attempts to maximize grass beds (SAV), which is sometimes at the expense of other wetland habitats. This is not always the case. Ducks Unlimited manages several marsh impoundments and specifically states the goal of expanding the emergent vegetation.

A significant and common problem of impoundments, even when being used optimally for wetland productivity, is the stranding of saltwater from hurricanes or tropical storms. Once salt water enters the impoundment, it is difficult to remove and may linger for years to the detriment of vegetation. The USGS documented that wetland recovery in southeast Louisiana after Hurricane Katarina was much more rapid than in southwest Louisiana due to the stranding of saltwater in marsh impoundments (Steyer, 2008).

These historic Louisiana examples are relatively small areas behind levees. However, some of the new proposed levee alignments in Louisiana’s Comprehensive Master Plan for a Sustainable Coast (CPRA, 2007) could enclose as much as 2,000 square miles, placing at risk an area equal to the cumulative land loss for the entire state since 1932. Although the stated intention for these proposals is to maintain these wetlands and not destroy them as historical land reclamation, the disrupted physical and biological processes are the same. That is, hydrologic exchange is severely modified with largely unknown consequences to the movement of water, sediment, and migrating aquatic species within and outside of the levee.

The use of leaky levees, especially at the scale in some proposed alternatives, has a high degree of scientific uncertainty and would place large areas of Louisiana’s wetlands at risk. Even if a leaky levee could be designed to reproduce the equivalent tidal exchange, this design does not equate to equivalence in migration of estuarine organisms or sediment movement. Modeling would also need to estimate the potential of the stranding of saltwater due to overtopping of a levee during a hurricane surge event. If management cannot adequately address the stranding of saltwater, significant mortality of any freshwater vegetation within the levee could result. Considering the historical wetland loss and the dire need for wetlands as a surge buffer, the risks posed by regional leaky levees is great and should be avoided. Finally, if the 2000 square miles of wetlands are located behind the leaky levees, and even if these wetlands survive, there will be 2,000 square miles less wetlands to buffer a storm surge in front of our levees.

Use of back levees or ring levees eliminates the need for “leaky levees”, and therefore, thousands of square miles of wetlands would not be placed at risk due to uncertain science and engineering of “leaky levee” design and operation.
One of the suggested weaknesses of back levee alignments is the potential to create a funneling effect of surge. Although St. Bernard Parish residents were well aware of the funneling effect near the MRGO (USACE, 2000), it was not until after Hurricane Katrina that the general public became acutely aware of this problem. Funnels can be any elevated features on the landscape that can focus surge into local areas and elevate surge higher than if the features were not present. Funnels are often formed from levees with an angular geometry with the open end facing the potential direction of surge. The infamous MRGO funnel is defined by the levees of the MRGO and GIWW, which face Lake Borgne. When considering levee alignments, local funneling geometries were avoided wherever possible. The back levee alignments proposed in places create regional angular alignments, but this scenario is often with the benefit of a large basin to accommodate surge. In addition, where the natural ridge and back levee alignments might create a funneling effect, surge spillways may be proposed to allow surge build-up against levees to be distributed across the ridge.

Back levees need to be carefully assessed for geotechnical properties. Because they are located near the boundary from ridge soils to wetland soils, it is possible that thin porous layers may extend across the levee alignment. This arrangement could allow piping of flood water and weakening of the levee. Sufficient geotechnical boring and engineering must assure that this will not happen on back levees or any other levees in coastal Louisiana.

**Implementation Criteria for Urban Polders**

The definition of a polder varies, but generally, definitions refer to a low-lying region completely enclosed by a levee designed to prevent water from the flood side from entering the protected side of the levee. This design often refers to polders for agricultural purposes, such as “land reclamation” of wetlands or of the sea. The often cited Dutch example refers to the land reclamation polders that encompass over half of the Netherlands.

In the aftermath of Hurricane Katrina, the use of polders within heavily urbanized municipalities has been heavily discussed and is hereby referred to as urban polders. The “Bring New Orleans Back Infrastructure Committee -Levees and Flood Protection Sub-Committee” has proposed a specific plan of polders or polder-enhancement throughout the New Orleans area (BNOBC, January 2006 report; see Figures 19 and 20). These polders would be pseudo-levees (such as train foundations) or other hydrologic barriers that compartmentalize the city with various in situ barriers inside the existing regional flood protection levee system. That is, these compartments would be polders within a “big polder,” i.e., the Lake Pontchartrain and Vicinities flood protection system. Some have suggested that the “urban polder, should be included as the 12th type of Line of Defense for coastal Louisiana.

The great attraction of the urban polder is analogous to a submarine or ship, which has many cabins that can be isolated with hatches. If the submarine springs a leak, the flooding can be isolated to a section of the submarine. The submarine may survive, and even all the crew may survive if they escape the flooded compartment. In the situation of New Orleans, urban polders have the potential to raise flood protection levels for some sections of the city but potentially at the expense of lowering flood protection levels for other sections of the city. Some have lightly referred to polders as “You flood and I don’t,” but it may be said as “You flood worse, and I don’t.” The use of urban polders is complex both hydrologically and socially and, therefore, requires careful consideration.
The hydrologic issue for urban polders is what modelers refer to as water storage. Storage is simply the available space for flood water to occupy during a flood. Storage is basically determined by the three sides of the container. The top boundary is the water level during the flood event, the bottom is the land surface, and the sides are lateral access of water to move into the area such as through overtopping or through a breach. Polders reduce storage capacity laterally by placing internal barriers in what otherwise has free movement of water. Reducing storage for storm surge, in general, has negative consequences. Because the water volume of surge is basically constant, lateral reductions in surge storage usually means that water is forced to go higher and may increase the damage to the flooded area.

In New Orleans, a 100 year flood protection system is being built along the Lake Pontchartrain lakefront. For a 100 year event, the designed levee height will allow a minimal rate of overtopping, and for larger storms and surges, the rate of overtopping is greater. The flood maps released by the USACE in 2006 illustrate flood levels throughout the city. Their assumption is that overtopping water enters at a certain rate and that the water is dispersed under existing conditions within the city, which provides wide access for water to move. Water might also enter through a breach in the flood protection system as happened in several locations during Hurricane Katrina. Even with several massive breaches from Hurricane Katrina, it required three days for the city to flood because of the widespread storage of water, which eventually flooded 80% of the city (IPET, 2006).

The critical fact that cannot be overlooked regarding polders in New Orleans is that, during the time that the city was flooding, Lake Pontchartrain was draining through its massive passes (Chef and The Rigolets), which resulted in lowering of the lake water level as the city was being flooded. When flooding stopped by reaching equilibrium, it was due to the rising water level in the city matching the lowered water level in Lake Pontchartrain. During those three days, water moved laterally through 80% of the city. If the city had been effectively compartmentalized with polders so that the water could only access 40% (rather than 80%), the water in the flooded polders would have risen more quickly and higher because the lake level would not have had the same time to lower by natural draining. In this scenario, the USACE current estimates of flooding in the city would change with some sections of city formerly shown as flooded becoming dry and other areas flooded to higher levels. This scenario could be significant enough to require changes to the current USACE assessment of the flood protection level provided by the Lake Pontchartrain and Vicinities flood protection system.

Urban polders can create acute trade-offs of one person’s enhanced flood protection being partially provided by another person’s reduction in flood protection. This situation is one aspect of urban polders that may create very challenging social decisions. The development of New Orleans has resulted in some coincidental and imperfect compartmentalization of the city (Figure 19). Figure 20 is proposed new or enhanced urban polders (compartments) by the Bring New Orleans Back Committee. The proposed compartments are significantly smaller than the existing ones. It is easy to visualize that these proposed polders would fill more quickly and that the flood levels would be higher in the flooded polders. A first step toward implementation of any proposed polders should be rigorous modeling of the hydrology under various storm surges, polder geometries, and outer levee alignments (Lake Pontchartrain and Vicinities and potential LACPR alignments).
Figure 19: Generalized existing incidental polders (bowls) in New Orleans as described by the Bring New Orleans Back Infrastructure Committee Levees and Flood Protection Sub-Committee (January 2006). Note: Original figure has mislabeled London Avenue (Street) and other features.

Figure 20: Proposed additional “urban polders” in New Orleans as described by the Bring New Orleans Back Infrastructure Committee Levees and Flood Protection Sub-Committee (January 2006). These additional polders are not recommended until further investigation (see discussion).
The social aspects and implementation of urban polders needs careful consideration. At first consideration, urban polders seem consistent with the MLODS, which promotes the use of multiple layers of protection and utilizes attempts to maximize use of varying types of protections, e.g., levees and coastal features. However, the MLODS is intended to be orchestrated around a regional flood protection system. It was the lack of a cohesive flood protection assessment or vision which greatly contributed to the catastrophic failure of the flood protection during Hurricane Katrina (USACE – IPET report, 2006 and 2007). The Hurricane Protection Chronology Report describes the forces tending to fragment the flood protection system over several decades (Wooley and Shabman, 2007). Since Hurricane Katrina, great emphasis has appropriately been placed on regionalizing the engineering, science, and implementation of future flood protection in south Louisiana. The regionalization of levee boards is intended to overcome the negative aspects of parochialism. Polders may greatly enhance parochialism and create inequity in flood protection even in spite of administrative changes because the general public who vote and pay taxes may view their flood protection needs locally rather than regionally. Urban polders can just as easily divide the people as it may divide the flood. Urban polders may have consequences even without a flood event, such as on property values within varying polders, which are perceived as good or bad polders.

Non-structural “Lines of Defense”, such as home elevating, may be applied very locally and is very parochial. However, elevating on piers or pilings does not increase the risk of flooding for others. Raising home elevations on soil foundation within a floodplain DOES increase the risk of flooding of others. The reduction of storage capacity within an un-impounded floodplain, as experienced from any fill placement, is a well established concept and for that very reason, there are laws or restrictions to address the negative aspects of fill in a floodplain. Polders that prevent internal water storage capacity have the same effect on the surge as if the polder were entirely filled. In this respect, polders are analogous to “fill in a floodplain”. Scientific or hydrodynamic data analyzing the impacts of polders within a levee must be conducted to begin a dialogue on the use of urban polders because they effectively reduce floodplain storage within a “protected” area.

The MLODS, as proposed by Lopez (2006) and as utilized here, also focuses on the regional flood protection system. Because urban polders tend to be antithetical to a regional flood protection system, it is not considered a Line of Defense contributing to the regional system. The flood protection levels proposed are intended to be the net result of the integration of the Lines of Defense without the use of polders. Polders may be used to increase flood protection or create redundancy beyond the regional standard as long as areas with reduced flood protection are somehow compensated or mitigated. Basically, several steps are suggested to move forward with urban polder implementation:

1. Hydrologic modeling and assessment of consequences for large-scale rain events and hurricane conditions.
2. Thorough vetting and dissemination to the affected public.
3. Consistency or compatibility to the regional flood protection system determined
4. Determination of no net reduction on flood protection to all proposed polders or mitigate those risk reductions.
5. Ultimate determination of the use of urban polders should not take priority over elements of a regional flood protection system and should be determined by elections in the effected

49 of 408
municipality approved by the Flood Protection Authority and the Coastal Protection and Restoration Authority (CPRA)

Structural Protection Features

Figures 21 and 22 depict the recommended levees and coastal restoration throughout coastal Louisiana (see individual Planning Unit maps and tables for more detail). Note that there is no single barrier levee across the coast. Instead, the regional levee alignments are interrupted by landward extending basins, allowing for maximum storage and attenuation of surge by both the areal extent and distribution of natural landscape features. The longest alignment east to west is about 50 miles long (New Orleans and Franklin area). The proposed alignments do have large scale V-shapes that can focus or funnel surge near the coast, but these re-entrants penetrate deeply into the coast (40 to 60 miles) so that surge should be diminished (Pontchartrain, Barataria, Atchafalaya, and Mermentau Basins) by the time it reaches these levee geometries. The geometry of these alignments largely mimics the natural landscape of the coast. Note on Figures 21, 22, and 23 the location of restoration features around the levee protected areas of the coast in relation to population centers to serve as additional protection features within the comprehensive protection system.

To offset the enhancement of surge by levees along these re-entrants, surge spillways are proposed (as being considered by the USACE for the LACPR) to disseminate the surge away from the levee system. This proposal includes three spillways along the Mississippi River, one along Bayou Lafourche, and two east and west of Morgan City. The spillways need to be carefully evaluated but should be seriously considered because they may offset the negative effect of levees to concentrate and amplify surge. The spillway proposals also include the potential to divert high-discharge pulse events during infrequent high-river floods through the spillway structures. One advantage of pulsing during a flood stage is that more sediment can be deposited in a shorter time period with a reduced long-term effect on salinities due to the much higher sediment concentration in river water during a flood event.

The levee alignments generally follow current levee alignments and take advantage of existing foundations for levee improvement while minimizing the mitigation needed for new levee alignments. Note that levees are tightly positioned around major municipalities and are generally on the perimeter of ridges or the upland-wetland interface where soil foundations are superior. Nearly all wetlands and virtually all wetland restoration projects are outside of any levee system. This arrangement allows for the highest chance of survival for estuarine wetlands and assures that any investment in restoration is part of the coastal buffer which is outside the levees. Therefore, all restoration provides both ecologic and flood protection benefits.

Coastal Restoration Features

Most of the proposed restoration measures in this report have been vetted through prior planning efforts and are included in Coast 2050 or the Louisiana’s Comprehensive Master Plan for a Sustainable Coast. The report includes restoration utilizing diversions, marsh creation, shoreline protection, barrier islands restoration, and oyster reef restoration (These
are described in more detail in the individual Planning Unit sections). Marsh management is avoided in all estuarine-influenced areas of the coast. Modest large-scale marsh management is necessary in the Chenier Plain to restore the historical hydrology and extent of freshwater marsh until long-term projects can address the intrusion of saltwater into the freshwater marshes.

Perhaps the most practical aspect of the MLODS is that it selects restoration projects which provide both direct ecologic and flood protection benefits. All restoration projects recommended here should provide two benefits-for-the-price of one. For the cost of restoration, some sustainable threshold of the coast is to be achieved, while providing the critical landscape features with the most flood protection benefit. For example, the total marsh creation acreage proposed in the plan (Figure 24) is approximately 98,000 acres (153 square miles), which are strategically located on critical Lines of Defense as marsh buffers. This acreage represents just 7.3% of the historical land loss of the coast. Nevertheless, the cost to construct 98,000 acres by pumping sediment will be at least $2.6 billion, which is all the more reason to be selective and strive to achieve the dual benefits. This challenge is significant but is entirely achievable for the target date of completion of 2025 when the USACE has proposed completion of the higher LACPR level of flood protection for south Louisiana.

Diversions are strategically placed to sustain these protective land bridges and marsh creation projects wherever feasible so that re-occurring expenses for marsh creation are minimized. Indeed, all the proposed elements are interconnected. Most projects could function alone, but the goal here is to maximize the benefits with as little investment as possible.

The levee alignments are intended to be fully compatible with regular diversion flooding of the wetlands and also with more extreme pulsing events, which would raise water levels even higher. In all, twenty-eight diversions, three spillway-type pulsing diversions, and three land-building diversions are proposed. (This tabulation includes the Caernarvon and Davis Pond diversions, and the Wax Lake and Atchafalaya deltas.) Typical spring discharge on the Mississippi River (below Old River Control Structure) is 600,000 to 700,000 cfs (Gagliano and van Beek, 1976). The total spring-time capacity proposed for the diversions from the Mississippi River in this report is 436,050 cfs, which is roughly split east and west of the Mississippi River between Planning Units 1 and 2, but also discharge into Planning Unit 3a (Figure 24). The excess discharge of 200,000 to 300,000 cfs will flow through the one proposed remaining open pass in the delta below Head of Passes, which is recommended to be Pass a Loutre for restoration and navigation purposes (see PU-1 - # 29). With the remaining flow through Pass a Loutre, it is possible that sediment will be re-worked into the adjacent Delta National Wildlife Refuge (NWR) and the Pass a Loutre Wildlife Management Area (WMA). The total diverted discharge would be less than the informally suggested discharge availability for the river by the USACE (normal flow years as much as 525,000 cfs). The proposed discharge would also maintain at least 300,000 cfs flowing past New Orleans which is needed to prevent a salt water wedge from developing and contaminating the drinking water supply taken from the river (USFWS, 2006).

Discharge through the Atchafalaya River is proposed to be modified in two ways. It is recommended that a diversion with maximum design capacity of 140,000 cfs is constructed
into the Pochant Basin or Bayou Pochant (see PU-3b #10). In addition, through outfall management, it is recommended that an additional 2,000 cfs discharge be directed westward down the GIWW into Planning Unit 4 (#17). In the Atchafalaya River, during normal flow, approximately 10% of additional discharge would be diverted either east or west into wetlands for these two projects with the remaining discharge continuing to build the Atchafalaya and Wax Lake Deltas.

In high flood stage years, the Mississippi River discharge is over 1,000,000 cfs. The combined proposals of diversion and spillways could divert up to 1,300,000 cfs discharge into the wetlands and would probably only be limited by the anticipated discharge need to maintain Pass a Loutre. In the Atchafalaya River, 100% of the discharge in a flood year would flow through diversion spillways or into the existing active deltas.

It may be necessary to incorporate additional engineering elements to enhance the benefits of diversions or spillways. One proposed concept is to emplace temporary inflatable weirs just downstream of a diversion. The inflated weir will impede flow of water and sediment down river and enhance the potential for water and sediment to flow into the diversion. Another concept is to construct small diversions with caissons jacked into the ground and below the river levee to access water flowing near the base of the river channel (inverted siphon). This arrangement could reduce construction cost and capture coarser sediment from the river bed into the diverted water (Paul Kemp, pers. comm.). Finally, it may be necessary to re-establish some of the historic sediment load in the Mississippi River to benefit upriver reservoirs, which are rapidly infilling with sediment and to enhance the introduction of sediment to the Louisiana coast.

Restoration of natural ridges is limited to those ridges located at strategic locations that may mitigate or impede movement of surge water inland. Four ridges are proposed for restoration. In some cases, this restoration is simply re-forestation. Where soils need to be placed to rebuild elevation, borrow sites should not adversely affect wetlands. Ridges restored with public funds should have conservation easements so that the ridge habitat is protected and can function as a buffer to storm surge.

The habitat goals delineate the five traditional wetland habitat types in south Louisiana. This includes brackish habitat that is associated with the salinity regime conducive to oyster growth. The diversions and hydrologic modifications should be designed to re-establish this habitat objective. However, in addition there are recommendations to restore traditional three-dimensional oyster reefs. The loss of three-dimensional (barrier) reefs in Louisiana has contributed to the collapse of the coast. The area of brackish habitat is intended to accommodate a vibrant commercial fishery and restoration of barrier reefs. The barrier reefs may need to be augmented with hard stratum and should be placed in conservation to allow the reefs to fully develop into barrier reefs (possibly within state seed grounds). Areas of the coast heavily dependent on oysters to stabilize the shoreline, such as Marsh Island, should also have appropriate protection for oyster reefs. Mining of oyster shell material in critical oyster reefs or shoreline reaches should be severely limited. In addition, the few surviving ancient oyster reefs along the coast should be protected from further degradation or dredging.
Old River Control Structure

Under current legislation, the Atchafalaya River receives 30% of the Mississippi River discharge through the Old River Control Structure. The proposed diversions do not seem to require a change to this discharge allocation. Nevertheless, there are reasons to re-evaluate the operational goals of the Old River Control Structure and, therefore, the discharge allocation. There is uncertainty regarding changes to the “river regime” of the Mississippi River. As diversions become operational, the Mississippi River will be adjusting and developing different characteristics, such as aggradation or degradation of different channel reaches. Flexibility to control discharge through the Atchafalaya and Mississippi Rivers could prove to be extraordinarily useful for adaptive management, especially considering that navigation and drinking water requirements will always need to be met and uncertainties lie in the future, such as sea level rise. The flexibility to manage the Old River Control Structure may also facilitate adaptive management for wetlands. For example, with the use of proposed spillways at Morgan City, a storm surge could cause salt water to be stranded inland in freshwater basins, such as the Atchafalaya River Basin. Allowing more than the 30% allocation may allow sufficient discharge into the Atchafalaya Basin to flush saltwater out of the basin before stressing the freshwater habitat.

The Old River Control Structure itself has environmental impacts, such as preventing the natural migrations of anadromous fish. Considering the overriding priority to restore the coast and create high levels of flood protection, the management priorities need to be reconsidered for the Old River Control Structure.
Figure 21: Coastwide Map of Specific Proposed Lines of Defense Measures by Type. This map excludes evacuation routes, non-structural measures, and municipal drainage, which are considered an integral part of the comprehensive recommendations for each planning unit.
Figure 22: Coastwide Map of Generalized Proposed Lines of Defense Measures (in black) overlain over the habitat goals. Areas protected by levees are shown in red. Note the relation of restoration projects around the levee alignments. Levees are located in almost entirely all fresh habitats where bald cypress forest can be sustained or restored. The MLODS restores wetlands or other coastal habitats to supplement the natural coastal buffer in the critical areas in need of protection. Freshwater diversions (not shown) would sustain the marsh and forest wetlands buffers or build new marsh buffers.
Figure 23: Population map of south Louisiana from the USACE Planning Atlas. Note the population centers correspond with high levels of protection with levees and other Lines of Defense shown on Figures 16 and 17. The population closest to the coast also typically follows the ridges along bayous.
Figure 24: Proposed total discharges, through diversions and controlled crevasses, and marsh creation for each planning unit. This map depicts the typical river discharge for the Atchafalaya and Mississippi Rivers (AvAQ = average annual discharge, SpAvQ = spring average discharge; Max Q = maximum historical discharge). The map also depicts the proposed allocation of river discharge through diversions in normal years and through less frequent pulsed discharges through spillways and diversions.
River Flood Restoration Action Plan

The Mississippi and Atchafalaya Rivers inevitably have occasional “great floods.” The last great river flood was in spring 2008 (Figure 25) and prior to that in 1997, 1993, 1973, and 1927. Geological data show that even larger mega-floods have occurred regularly (Brown and Kennett, 1999). The occurrence of these flood events is driven by confluence of multiple high-precipitation events in the Mississippi River drainage basin. These events are considered threats for flooding but, in Louisiana, represent rare opportunities to have dramatic acceleration of restoration of our coastal wetlands because of the volume of sediment-rich water and the abnormal potential to flow large volumes of water into the wetlands.

In the spring of 2008, the Bonnet Carré spillway was opened to reduce flood stress on the Mississippi River levees in New Orleans. Louisiana witnessed the power of the river to restore our coastal boundary (Figure 26). Unfortunately, the Bonnet Carré Spillway directs the flow of sediment and nutrients directly into Lake Pontchartrain, causing more environmental harm than benefit.
The “River Flood Restoration Action Plan” would be an action plan to be implemented in the event of exceptionally high water on the Mississippi or Atchafalaya Rivers. The goal of the action plan is to maximize restoration benefits to the coast during a major flood event by introducing freshwater, sediment, and nutrients into the coastal estuaries. It should be anticipated that these great high water events will carry a disproportionally higher sediment load that may be two or three times as great as an average year sediment concentration (Figure 27: Gagliano and van Beek, 1976). Recent data suggests that at least in some years the increase in sediment volume between low water and high water may be even greater. When increase in discharge and increased in sediment concentrations are factored together, the suspended sediment mud volume may be as much as 11 times as great and sand 55 times as great (See Table 3).

<table>
<thead>
<tr>
<th>SCOFIELD EXPERIMENTAL TRANSECT</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>WATER DISCHARGE (m³/sec)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Discharge (Jan 2008)</td>
<td>9,433</td>
<td>2,054</td>
<td>54,739</td>
</tr>
<tr>
<td></td>
<td>MUD</td>
<td>MUD</td>
<td>MUD</td>
</tr>
<tr>
<td></td>
<td>2,054</td>
<td>11.6X</td>
<td>53.2X</td>
</tr>
<tr>
<td>High Discharge (Apr 2008)</td>
<td>31,592</td>
<td>104,287</td>
<td>634,357</td>
</tr>
<tr>
<td></td>
<td>MUD</td>
<td>MUD</td>
<td>MUD</td>
</tr>
<tr>
<td></td>
<td>11.6X</td>
<td>53.2X</td>
<td>55.4X</td>
</tr>
</tbody>
</table>

Table 3: Increased sediment load on the Mississippi River during 2008 high water (Source: Mead Allison, 2008).
The River Flood Restoration Action Plan might include maximum use of controlled freshwater diversions in which the normal salinity/habitat targets are not used to limit flow. Because the flood river condition will likely create greater maintenance dredging of navigation channels, the action plan could include an emergency beneficial use of dredge material for sites along the Mississippi River.

Figure 27: Graph of Mississippi River Discharge Frequency and Relation to Sediment Load and Sediment Concentration. High-water events on the river carry higher sediment load and represent opportunities for significant restoration (Gagliano and van Beek, 1976).
The use of “pulsing” is a well established scientific concept and has been conducted with the normal river stages, such as at the Caernarvon Diversion (Keddy, 2000; Day et al., 2003). Exceptionally high water on the Mississippi River represents a multi-generational opportunity that should be considered within the 100 year planning horizon of this planning effort. Since some fisheries may experience short-term negative impact, the Action Plan should include short-term impact assistance for commercial fisheries. The flood year cannot be predicted and could occur in just the next six months; therefore, this should be a standing plan of action that should be developed as soon as possible. It is likely that such an action plan could be utilized several times within the 100 year time frame and have a dramatic influence toward sustaining the coastal wetlands. Other smaller rivers such as the Pearl, Vermilion, Amite, and Sabine Rivers, could also have their own individual action plans.

The individual Planning Units have proposed elements, such as diversions and spillways, to create the mechanical opportunity to occasionally have large pulses of river water flow into the estuary. However, a regional action plan for high water should be developed to utilize the diversion and spillways in a coordinated way to best utilize the river resources while also achieving the goal of avoiding flooding of coastal municipalities from the high water of the Mississippi or Atchafalaya Rivers.

In high flood stage years, the Mississippi River discharge is 1,000,000 cfs to 2,000,000 cfs. The combined proposals of diversion and spillways could divert up to 1,300,000 cfs discharge into the wetlands and would probably only be limited by the anticipated discharge needs to maintain Pass a Loutre. In the Atchafalaya River, 100% of the additional discharge in a flood year would flow through diversion spillways or into the existing active deltas.
Evacuation Routes

The MLODS proposes that evacuation routes are Lines of Defense and that the routes need to be geographically integrated with other Lines of Defense to anticipate their performance and evaluate the requirements to be effective evacuation routes. Figure 28 is the official evacuation route map of Louisiana. On Figure 29, these official routes are superimposed on the map of other proposed Lines of Defense for the coast (a few routes are not depicted where the scale does not allow detail).

The MLODS recommendations include the evaluation of evacuation routes throughout the coast and integration of these state evacuation routes into the Comprehensive Protection Plans for each Planning Unit. In addition, state and local authorities should coordinate evacuation planning to facilitate quick and uncomplicated evacuation of residents in the path of a potential threat. Every effort should be made to educate the public on the evacuation plans and risks associated with the protection system at the time of the threat.

A few specific recommendations for evacuation routes are included below:

Interstate 10 in Eastern New Orleans (Irish Bayou area) has a few miles of roadway outside the levee and too low for safe evacuation and should be elevated.

Louisiana Highway 1 from Larose south to Port Fourchon is a vital industrial corridor and evacuation route. The section below Larose should be entirely elevated or, at least, have sections elevated. An elevated earthen foundation is probably not desirable because this arrangement may focus surge moving inland on either east or west flank of the highway. This is consistent with the current plan for an elevated causeway being constructed by the Louisiana Department of Transportation and Development (LDOTD).

Highway 90 and Interstate 49 (I-49) replacement across the Barataria Basin needs to be considered as an important evacuation route. The new I-49 roadway should be an elevated causeway outside of the levee system. This concept is under consideration as a design alternative by LDOTD.

Highway 82 should have a more consistently elevated earthen foundation and be armored on the seaward side, which will enhance usefulness as an evacuation route, act as a Line of Defense, and impede storm surge.

Highway 3124 to Lafitte, Highway 315 to Theriot, and Highway 57 to Dulac should be elevated to allow extended evacuation opportunity and to allow rapid re-entry to these municipalities isolated with ring levees. Improvement should be made for evacuation from ring levees surrounding Dulac and Theriot.

If controlled crevasse structures are built along the Mississippi River, such as those proposed in Plaquemines Parish, elevated causeways should be constructed.
Figure 28: Official evacuation Route Map for the State of Louisiana. Black circles indicate critical areas in need of improvements.
Figure 29: Evacuation Routes Superimposed on other Lines of Defense measures map. Note that most evacuation routes have high levels of protection from levees and the coastal landscape. Some major evacuation routes outside of levee protection are discussed in the above section.
Non-structural Measures & Municipal Drainage

For all communities in coastal Louisiana, non-structural flood mitigation measures need to be considered as an essential Line of Defense Strategy and an integral part of the Comprehensive Protection Plan for each Planning Unit. Non-structural mitigation measures such as elevating homes or businesses are extremely important Lines of Defense. Elevating assets protects from flood water whatever the source – rain, surge, river flood, etc.

Slabs built-on-grade are a very poor choice for south Louisiana because they are low or require fill in the floodplain, and they are also very expensive to elevate subsequently. With the almost certainty of flood threat in south Louisiana due to so many variables, slab homes should be avoided within the 1,000 year surge floodplain (see Figures 21, 22, 33 or 34). The Unified New Orleans Plan for recovery of the City encourages homeowners to build above the required base flood elevations and to demolish flooded slab-on-grade homes. This “Elevate New Orleans” program estimates 85,000 homes should be elevated at a cost of $1.2 billion. If the most urban center in coastal Louisiana is demolishing slabs-on-grade, is there any other coastal Louisiana city which should allow new construction of slab-on-grade homes? The inappropriateness of slab-on-grade in coastal Louisiana is a “lesson learned” only if we act on the knowledge.

Figure 30 is a photograph of two camp/homes in St. Bernard Parish, which survived Hurricanes Katrina and Rita with minor damage even though they are located outside of any levee protection. Figure 31 is a photograph of elevated homes within New Orleans inside of levee protection. Figure 32 is a photograph of homes being elevated within the New Orleans levee protection system.

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide any residence or small business in the City of New Orleans with “gap financing” to fund the gap between the FEMA/Road Home funds and the actual costs of elevating a structure. Elevations must be performed in accordance with new FEMA BFEs and design guidelines. Incentives will be available for at least 5 years. More details are provided in Project Sheet #02.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. Provide incentives for the voluntary reconstruction of slab-on-grade houses.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide homeowners whose slab-on-grade homes flooded during Katrina, or any other flood event, with “gap financing” to voluntarily demolish the home and rebuild a new house on-site in accordance with the new FEMA BFEs and design guidelines. The new structure must be designed and constructed in a more traditional New Orleans style, either on piers, with chain walls, or with first floor basements, in order to elevate the first floors above flood waters. Incentives will be available for at least 5 years. This program will be implemented differently across recovery planning areas in the City. More details are provided in Project Sheet #03.</td>
</tr>
</tbody>
</table>

Unified New Orleans Plan, 2007
Figure 30: Elevated St. Bernard Parish camps/homes that Survived Hurricanes Katrina and Rita outside of levee protection in St. Bernard Parish (near Delacroix) with relatively minor damage. Many other elevated camps were destroyed, which indicates adequate elevation, high quality construction, and some good fortune may be necessary to survive severe surge conditions such as Hurricane Katrina. (Photograph: January 2006 by John Lopez).

Figure 31: Elevated Broadmoor home in New Orleans that survived Hurricane Katrina flooding due to flood wall breaches. Flood water was approximately 6 feet deep and did not extend into upper living area. The ground level “basement” is unfinished and used for non-living purposes such as workshop, storage of replaceable items, etc. Wood construction is exposed and on concrete piers. The house was re-painted after Hurricane Katrina. (Photograph taken October 2007 by John Lopez, who lived in the house in the 1980’s).
Although requirements for elevation of new homes is currently managed through FEMA and local parish authorities, such as local zoning, the State could affect elevation requirements through statewide building codes. After Hurricane Katrina, the state legislated new building codes for the entire state, but these much-needed code standards primarily addressed wind hazard and not flood related hazard. This situation can and should be changed so that statewide building codes address home elevation that exceeds federal guidance and should include strong disincentives for slab-on-grade buildings within the 1000 year surge floodplain (Figure 33 and 34). The American Society of Civil Engineers’ (ASCE) latest guidance on construction (ASCE 24-05) encourages building codes that use elevation above federal requirements.

**Figure 34** illustrates the importance of elevating homes within a levee. Because the flood level due to overtopping is lower than the flood level outside the levee, the incremental value of elevating inside a levee is actually greater than outside a levee. Considering flooding from just overtopping, a slight elevation increase inside a levee may provide dramatic increase in flood protection level.

Non-structural approaches are an integral element of flood damage reduction and an additional measure of redundancy or security. **Table 4** lists the basic non-structural approaches that should be considered.

![Figure 32: Two historic Broadmoor Homes in New Orleans being raised post-Hurricane Katrina after being inundated with floodwater due to flood wall breaches.](image)

Many non-structural measures are actions that can be undertaken by an individual, family, or a small business on their own initiative with less need for governmental processes of authority although measures must still meet or exceed local codes and regulations. Non-structural measures can often be a more appropriate solution to a flood threat, in which the private owner has more control. It is expected to take, at least, several years to many decades to complete 100 year level of protection with structural means. For instance, to achieve 100 year level of protection for the Morganza to the Gulf alignment, with timely appropriations, will take over 20 years. Many non-structural measures, such as elevating a home, can be completed by an individual within a year.
Figure 33: Modified FEMA illustration of stillwater level and V-zone (wave effects) with the additional recommendations of this report (in red) to exceed the 100 year standard both vertically and laterally. New slab-on-grade construction should be strongly discouraged or simply eliminated within the entire 1,000 year surge flood plain including construction both inside and outside of levee protection. Excess elevation above required BFEs is desired to address a multitude of issues, such as higher surge, subsidence, sea level rise, etc.

Figure 34: Modified FEMA illustration showing the Stillwater level and v-zones with levee overtopping (without breaching). Elevation of homes within a levee may have high incremental benefits because a small elevation increase may provide dramatic improvement in flood protection levels.
Table 4: Non-structural options (source: Rod Emmer, Ph.D. Training course).

Non-structural measures must be placed in a geographic context of the other Lines of Defense measures. Most fundamentally, assets are either within a levee protected area or outside. Assets outside the levee system may expect the direct impact of storm surge including waves and currents. Non-structural standards may be guided by this geographic delineation as shown in Figure 33.

In Figure 33, the orange area delineates the area where assets within the levee system may expect the direct impact of storm surge or precipitation. Therefore, non-structural standards may be guided by this geographic delineation as shown in Figure 35. Areas shown in yellow depict the non-levee protected coast that requires non-structural approaches. These areas have the natural coast as the primary Line of Defense but typically require additional protection through non-structural approaches, such as elevating homes. This protection should be commensurate to the life-threat and economic exposure expected from flooding with waves and currents by direct interaction with storm surge and precipitation. Areas shown in orange depict the levee protected areas that require non-structural approaches commensurate with the exposure of life and assets due to risk of overtopping and the risk of failure of a levee, flood gates, flood wall, etc. Areas in orange also need adequate capacity for drainage, which will generally require pump capacity to pump water to the flood side of the levee.

The non-levee protected coast is subject to direct inundation from storm surge and precipitation. Figure 36 is the inundation map of high water for both Hurricanes Katrina and Rita (compiled from FEMA Inundation Maps for coastal parishes). Note the similarity between Figures 33 & 34. The yellow area also corresponds with the coastal buffer. The coastal buffer allows surge to dissipate. Individual parish FEMA inundation and Advisory Base Flood Elevation (ABFE) maps are available on line for most coastal parishes in Louisiana.

We strongly advise that all significant assets in the yellow areas of Figure 35 should be re-located or appropriately elevated with supplemental mitigation measures (Table 4). Additional areas in orange that do not yet have constructed levees should also strongly consider non-structural measures immediately. FEMA issued ABFE maps for most of the Louisiana coast after Hurricanes

<table>
<thead>
<tr>
<th>Modify susceptibility to flooding</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Floodplain regulations – discourage construction in flood prone areas</td>
</tr>
<tr>
<td>b. Development and redevelopment – relocate to areas less prone to flooding</td>
</tr>
<tr>
<td>c. Warning and preparedness – early warning, evacuation, move assets from harm</td>
</tr>
<tr>
<td>d. Flood proofing – elevating, water-tight structures</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modify impact of flooding</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Flood insurance -- adequate insurance</td>
</tr>
<tr>
<td>b. Relief and recovery – Clean-up incentives, pre-storm contracting for clean up</td>
</tr>
</tbody>
</table>
Katrina and Rita. These should be considered a minimum standard (note Figure 36 is not the ABFE map but rather the actual flood elevations from these specific storms). New modeling and new analysis is ongoing. It is probable that new and higher elevations will be justified, and revised FEMA maps will be issued. Also it is important to understand that these are parish and community maps. Local conditions may decrease or increase local inundation under various storm conditions.

Studies have shown that elevating above the required elevation is cost effective and actually “pays back” more than the initial investment through reduced damage and reduced flood insurance rates. Incremental cost to elevate above the base flood elevation is estimated to generally be 0.25% to 0.5% per foot of the cost for a new home. A new $400,000 home would cost $3,000 to $6,000 to elevate three feet. Outside of the levee system, flood insurance can be reduced as much as 66% by elevating three feet above the base flood elevation. In flood zone A (100 year floodplain), flood insurance can be reduced by 50%. (Jones et al., 2006 – American Institute for Research) Just as the USACE adds 2 to 3 feet of freeboard to every levee design, residents are encouraged to add freeboard to the home elevation designs, to ensure a level of protection in the face of sea level rise and future uncertainties. It is better to err on the high side when elevating or otherwise implementing mitigation measures (Table 4) to assets such as homes and businesses.

FEMA reports recommend exceeding their own BFE standards:

“It is highly recommended that building be constructed to survive flood levels that exceed the base flood design conditions”

Mitigation Team Report -Hurricane Katrina in the Gulf Coast
FEMA 549/ July 2006

Freeboard is also recommended in the State’s Hazard Mitigation Plan – 2008

“Establish a state freeboard requirement for construction in areas with significant (to be defined) subsidence rates, such that during the useful life of a building (e.g., as defined by FEMA BCA standards) no increased risk should be encountered.”

As noted from the recent storms, very few structures can withstand the direct impact of moving water. Areas in the yellow on Figure 35 should expect the possibility of moving flood water with waves. Figure 36 demonstrates the extent of coastal flooding from Hurricanes Katrina and Rita and the minimum extent of the need for non-structural measures. The revised Flood Insurance Rate Maps (FIRMs) will show V-zones where enhanced National Flood Insurance Program (NFIP) requirements apply. Extensive information is available for building and recovery in an exposed coastal environment. For example, FEMA has a comprehensive “Coastal Construction Manual” available to download free on the FEMA website (fema.gov; do a search for the Coastal Construction Manual, FEMA 55). In addition, books, publications, and fact sheets have been available since the early 1980s from parish or community floodplain administrators domiciled in the local government complex, the state floodplain section, LDOTD, in parish and community libraries, and free on the Louisiana State University (LSU) Agriculture Center website. (http://www.lsuagcenter.com/en/family_home/hazards_and_threats/recovery_assistance/list.htm). The new revised state building code and local building codes should be followed and enforced.
In terms of mitigating effects of moving surge water, the first choice is to relocate. In terms of coastal construction, the #1 rule in areas subject to moving water is to elevate above the expected still water plus wave elevation assuming at least a 100 year storm.

The levee protected coast is subject to indirect inundation from storm surge. Due to levee and flood wall failures, 80% of New Orleans, 100% of St. Bernard Parish, and most of Plaquemines Parish were flooded by Hurricane Katrina. Structures near the failures were severely damaged or demolished by moving water. Structures not adjacent to the levee or floodwall failures were inundated by rising water, which remained for weeks. This occurrence often results in a need to replace wiring, floors, finishing, appliances, etc, but it can also lead to structural damage, especially if flood waters remain for more than a few days. The flooding within a levee is generally from three possible scenarios:

1. Precipitation in combination with inadequate drainage,
2. Surge height and waves sufficient to overtop levees or floodwalls (hurricane surge or river flood event),
3. Failure of the structural protection system.

Therefore, elevating assets (homes and businesses) or flood-proofing non-residential structures within levee protection should also be seriously considered. A 100 year level of protection levee has a much higher chance of overtopping than a 400 year protection levee, but in both cases, there is still a need for assets to be elevated or for the property to be covered by a flood insurance policy. Another factor to consider is the value of the assets.

In New Orleans, pre-1930 architecture reflected the wisdom of two centuries of persistent occupation of a region surrounded by water. Old homes were often elevated above a storage area in what are locally referred to as (ground level) basements. Often, the lower structure walls are built on small concrete or brick piers. The wisdom of this design is immense. Valuables are elevated and less likely to be damaged by flood water. Even without flooding, all structures in south Louisiana are subject to damage by local subsidence. This elevated structure with exposed structural members allows leveling of the house (or re-elevating) to be done at a much lower cost when compared to raising a slab-on-grade structure. Finally, this type of structure is a better strategy to minimize damage by termites. The concrete pier is a termite buffer and the exposed structural members allow ease of inspection, treatment, and repair of wood. The Louisiana House Checklist for south Louisiana home construction recommends for termite resistance that homes be constructed with wood floor joists a minimum of 18 inches off the ground (see www.LouisianaHouse.org).

The three totally independent reasons, which justify elevated homes in south Louisiana:

- Flood protection
- Cost efficiency to re-level a house because of land subsidence
- Termite resistance
Anyone one of these reasons is a strong argument or compelling reason for home elevation. In most areas all three are applicable and make an overwhelming argument for home elevation in coastal Louisiana.

In south Louisiana, elevated structures within or outside of levee protection, in general, are much more likely to be sustainable. Considering the combined long-term threats of subsidence damage, flood damage, and termite damage, the wisdom of slab homes or businesses built on grade anywhere in coastal Louisiana is seriously questioned.

Don’t Wait, Elevate!

Key References regarding Non-structural Measures:


LSU AgCenter - “Build Safer, Stronger, Smarter”

Figure 35: Non-structural measures. This map delineates two geographic areas of different approaches to non-structural measures superimposed on Lines of Defense Measures. Non-structural measures are an integral part of the Comprehensive Protection Plan for each planning unit.
Figure 36: Coastwide Inundation Map from Hurricanes Katrina and Rita by FEMA (2006). Note the concentrations of surge in St. Bernard Parish, the Orleans Land Bridge, Terrebonne Parish, the Highway 90 corridor near Vermilion Bay, and along the Chenier ridges in southwest Louisiana. Also, note the similarity of this map and the previous map (Figure 35) in the overlap of coastal inundation to the “non-levee” protected regions of the coast. In some local areas in PU-1 and 2, surge was actually higher for Hurricane Rita than Hurricane Katrina. (This map is not the FEMA BFE map but rather the actual flood elevations to these specific storms).