Comprehensive Systems Analysis and Planning to Secure Water and Coastal Resources: Lessons Learned from Hurricanes Katrina and Rita

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Water is probably one of the most important resources that will define the economic, public health and environmental issues in the next century, certainly by 2050. Today, water resource quantity and quality across well-defined regional basins are largely defined by highly engineered landscapes linked to a changing global hydrologic cycle that will challenge our political will to provide for national priorities. Thus water resource planning through the development of public policy is arguably one of the most important features of our national security, sustainable natural resources, public health, and economic development. Ecosystem services derived from healthy natural resources support our national wealth, and our society will profit from policies that sustain the finite water resources of our continent, and our globe. Thus our national priorities and portfolio of water resource projects need to have a long-term perspective of providing for a safer, healthier and more sustainable society. And this is particularly true for our coastal resources that are inexplicably linked to our river basins.

The US Army Corps of Engineers has evolved into one of the most important federal agencies affecting the characteristics of our national water resources system. Thus the policies and priorities within the USACE planning and authorization guidelines define our future water resources capacity. Based on the assumptions of the significance of this agency responsibilities to future water conditions, the Committee on Environment and Public Works should not only consider issues associated with present or near-term water resource project portfolios, but must also look at the longer-term perspective of how the nation will prioritize this finite resource to achieve a more sustainable future giving the challenges of a changing climate. And these river resources must be factored into a priority system that properly accounts for the value that coastal resources provide our nation.

These fundamental principles of water resource planning and public work projects are very important to policies that address problems within coastal boundaries including: (1) wetland loss, (2) eutrophication (dead zones), and (3) coastal hazards. With 80% of the coastal land loss of the entire US, the largest seasonal hypoxic zone (nearly the size of

New Jersey), and now two devastating hurricanes in a single month during 2005, the Gulf Coast is a harbinger of what coastal communities throughout the US will face in the future. The issues and policies, by both federal and state entities, associated with rebuilding the Gulf Coast are those of national importance, which will require strong leadership in managing risks by more properly integrating engineering solutions with natural processes that more properly account for ecosystem goods and services – how do we build both structural and natural infrastructure in our coastal regions.

Coastal Louisiana has long been a landscape of rich natural resources and extensive human settlements that have tried to manage the **risks** of occupying an extremely dynamic coastal environment – the eight largest river delta in the world. Both environmental and social systems have tried to adapt to sea level, subsidence and hurricanes to accommodate sustainable development. Now the stakes are higher as we in Louisiana struggle with not only rebuilding our natural resources, 'America's Wetlands' of the Mississippi River delta, but also the social and business systems that have been devastated by two hurricanes, Katrina and Rita. So we are dealing with the challenge of promoting the **resiliency** of both natural and social systems by providing necessary natural and human resources. If **restored** properly, the Gulf Region will develop new paradigms as to how coastal communities deal with risks and hazards of the coastal zone. But we are developing this rebuilding process in a political environment of great urgency, which I advocate requires even greater commitment to a few fundamental principles of how to integrate protection and restoration of the ecological-social landscape within our coastal boundaries.

The loss of wetland resources in Louisiana has been occurring for over one hundred years, estimated at 1.2 million acres of coastal wetlands since the 1900's, and prior to Katrina was projected to lose another 300,000 acres by 2050. These wetlands relied on the distribution of water and sediment resources from the Mississippi River to keep the coastal landscape intact, to support a state known as 'sportsman paradise'. The underlying causes of losing 'America's Wetlands' include public work projects in navigation and flood control that reduced risks to social systems by 'controlling' river resources, fertile sediments and freshwater; causing them to be lost to the Gulf of Mexico rather than emptying into the deltaic floodplain. In addition, energy related industries built various canals and waterways through marsh landscapes that not only promoted access for oil and gas rigs, but also provided conduits for saltwater intrusion and storm surges. These artificial changes to the landscape to protect local communities and support a national economy worked against the **coastal processes** of the river delta causing risks to wetland vegetation. So while reducing the risks to human settlements and coastal infrastructure over the last 50 years has been very effective; it has been done at increased risks to ecosystems that rely upon river resources for survival.

The coastal wetland landscape has been degrading for nearly 100 years, while the entire social system and industrial infrastructure along the coast was devastated in a month by hurricanes Katrina and Rita. There is an urgency to promote the resiliency of economic infrastructure that will rebuild social systems and provide protection and jobs to communities along the coast. This has to be done while we validate models and their

assumptions as to the proper combination of wetland resources and levee systems that are needed to secure and protect sustainable economic development. This validation process, with intense data collection and proper scientific review, will be instrumental in planning for risks in the future. This planning needs a science and engineering program that integrates the theories and practices of natural and social sciences to establish guidelines for engineering solutions that promote a sustainable and safe coastal landscape. This will require these three sciences (physical, social and engineering) to resolve the following three questions in a cooperative environment. **What is at stake? What processes are at work? What can be done to sustain economic and natural resources?** The continued isolation of these three issues by these three disciplines among existing institutions will amplify the continued increased risks of living in coastal communities of Louisiana and throughout the US. From now on, the public will demand accountability to the long-standing paradigm of public work projects with 'unintended consequences'.

So **what is at stake** if we do not properly rebuild both the social and natural capital of coastal Louisiana. More than 30% of the nation's fisheries catch comes from America's Wetland, and it provides one of the largest habitats in the world for migratory waterfowl. More than 25% of all the oil and gas used in the United States either originates from or passes through this working wetland, the distribution point for energy supplies to the entire eastern U.S. Louisiana's port system, including New Orleans, Port Fourchon, Baton Rouge, and related smaller ports connected by the Intracoastal Waterway, is the largest in the world, including greater tonnage that Rotterdam or Singapore, the next largest port systems. The coastal area currently provides a buffer from hurricane storm effects to approximately 2 million residents who live within the 19 coastal parishes (counties). Roughly half of the Louisiana coastal population resides outside of New Orleans and depends on the wetlands either directly or indirectly for employment in fisheries and the oil and gas industry.

So we cannot abandon either the economic or the natural resources of this region – this is a working coast that provides goods and services of tremendous national importance. At the same time, we have natural resources that also provide goods and services of equally national importance. The challenge is to find engineering solutions to risks and sustainability that consider the goods and services of both economic and natural resources of coastal regions.

So **what are the processes at work** in the Gulf coastal zone that can sustain a productive landscape (Boesch et al. 1994). Understanding the fundamental processes of the delta cycle is prerequisite to any policy that deals with geomorphic and ecologic features of this coastal system (Fig. 1). Transgressional sequences at the province and basin scales of coastal Louisiana govern smaller scale successional changes at the habitat scale of the marsh. The proximity of fluvial processes to marshes shift as distributaries of the Mississippi River migrate along the coast, changing the distribution of sediment, nutrients, and salt that control the type of habitat that colonizes the emergent zones of the basin. Thus there are continued changes not only from emergent to open water as part of the transgressional sequences, but the community composition of the emergent lands changes among fresh water, intermediate, brackish, and salt marsh vegetation (Fig. 2).

As fluvial processes decrease, there is a lack of fresh water discharge to control sea water encroachment, causing salt and brackish marshes to migrate landward, either replacing fresh water marshes or converting marshes to open water (Fig. 2). During active delta formation, such as observed in the Atchafalaya River basin, there is a migration of fresh water and intermediate vegetation toward the coast as salinity regimes decrease in the coastal zone. Processes at all three spatial scales including province, basin and habitat levels are coupled to produce a spatial mosaic of changes in wetland cover and composition that form very complex and dynamic patterns of coastal barrier system. The result of these processes across the Mississippi River Deltaic Plain is 6,177,610 acres (2,500,000 ha) of marshes that account for 60% of the coastal wetlands in the lower 48 states. These patterns of coastal processes have to be incorporated in any perspective of coastal restoration and rehabilitation.

The fundamental **processes** that the natural, social and engineering sciences will have to consider include a very dynamic landscape – which requires policies that promote adaptation rather than a philosophy of control. New Orleans, Louisiana's port and many coastal communities exist within a changing mosaic of barrier islands, salt marshes and freshwater swamps. Rebuilding after Katrina and Rita must address the ongoing and dynamic changes in this landscape – just as coastal restoration efforts did before these storms inflicted their damage, as described in our November 2004 LCA (Louisiana Coastal Area) report. For the last several thousand years, the land building or deltaic processes resulted in a net increase of more than 4 million acres of coastal wetlands, even with the occurrence of sea level rise, subsidence, and hurricanes.

Wetland loss is caused by soil accumulation insufficient to offset sinking of the land and rising sea levels. Human activities (canals, hydrologic modifications, failed reclamation, flood control measures) have caused wetland loss to accelerate; and prevented the natural processes to rebuild landscape features elsewhere along the coast. Without an aggressive ecosystem restoration effort, high rates of wetland loss will continue. The relative rise in sea level is an issue in coastal Louisiana; as it is in the Everglades, coastal Carolinas, Delmarva Peninsula, and New Jersey-New York coast. Given the high subsidence rates (land sinking) along with the seas rising, New Orleans is seeing now what many of these other coastal communities will see in about 4-5 decades. Given this condition, many proponents argue that we should give up on New Orleans. If that is the case, then we should also begin the systematic retreat of every coastal community in the U.S. Or we can reflect and think about a better partnership with nature; rather than viewing these situations as some sort of war with nature. This river delta experienced sea level rise three times it present level nearly 5000 years ago; and still was able to build wetland landscape given ample river resources.

As for nearly all river deltas in the world, to give up on the landscape and cultural heritage of an ecosystem that has such potential for 'ecosystem resilience' is a major statement in our political will to rehabilitate natural resources in this country. It is a statement of our stewardship of natural resources without a fight to overcome 'business as usual'. I have personally been involved in reconnecting sediment and freshwater resources from the Magdalena River in Colombia to a wetland floodplain consisting of

one the largest mangrove areas in the Caribbean Sea. Reconnecting these coastal processes, while maintaining several of the economic activities of the region, resulted in immediate and extensive response of wetland ecosystems. And in Louisiana, projects such as Caernarvon freshwater diversion, with the Caernarvon Interagency Advisory Committee, has effectively resolved conflict in ecosystem needs and stakeholder opportunities by developing ideas around the natural 'pulsing' of this landscape. Again, finding solutions by managing natural processes to sustain wetland resources that consider stakeholder use of coastal systems. There are trade offs, and realities of consequences must be clearly stated. But business as usual can be corrected to include partnerships among natural, social and engineering sciences to build more sustainable systems in such dynamic coastal landscapes. But the challenges of a changing climate means that such trade offs must consider 50 and 100 yr conditions of project landscapes, which will require even more river resources today to protect the future.

So **what can be done** to provide proper guidelines that balance the risks to social and natural resources to promote a more integrated restoration and protection of coastal resources along the Gulf coast (Fig. 3)? The key is to understand how to deal with uncertainty in such a dynamic landscape – and how that is factored into risk management. First, effective ecosystem restoration that will sustain coastal wetlands is to manage and use the natural resources that created the coastal area. The present waste of river resources each day is sufficient to mount a very aggressive, albeit energy intensive, campaign to artificially distribute sediments to recover some of the geomorphic features of this degrading landscape. This may take 5-10 years of aggressive use of long-distance conveyance of sediment slurries connected to present and proposed dredging activities. Then freshwater diversions, which are concrete structures in levees that allow river flow through gates to adjacent wetland floodplains, will sustain the landscape over longer several decades. These river resources are important to sustain wetland resources facing natural disturbances from relative rise in sea levels, storms, and subsidence. Along with rebuilding the deltaic floodplain, there must be an aggressive effort to restore shoreline protection and barrier islands. Many of these features will have to evaluate the negative effects of existing artificial features of the landscape, and think about reauthorizations and land-use practices that can provide opportunity of distributing water resources across the coast. Inventory of coastal barrier resources systems features, the coastal processes that sustain those features, and the free goods and services they provide are key elements of any restoration program.

The process of rebuilding coastal ecosystems as part of the social landscape will require new approaches to adaptive management strategies shared by natural, social and engineering sciences. And this new thinking will have to be adopted into our national priorities in public work projects. These strategies will have to deal with uncertainties, and establish methodologies to evaluate how services from both natural and social resources reduce risks to communities along the coast. There has to be conflict resolution in securing resources to support rebuilding the infrastructure of both ecosystems, urban, and industrial sectors of the coast. As restoration alternatives are developed to change the ecosystem and rebuild human settlements, system response must be monitored to incorporate learning as part of the process. We have to accept that not all the answers are

apparent in the initial investments in this joint enterprise of science and engineering, but there must be institutional commitment that financial resources will be held accountable to an adaptive management framework. It is the only way to deal with such uncertainties in a dynamic coastal setting. The only worst-case scenario is no action at all.

Large-scale ecosystem restoration programs must begin immediately, in concert with the urgency to rebuild the urban and industrial infrastructure following major disturbances. Many coastal wetland landscapes, such as Louisiana, are reaching critical points and will become technically more challenging and certainly more costly to rebuild unless actions to stabilize them occur immediately. Following major disturbances, the rebuilding process has to look at opportunities that exist to improve protection of social systems – with stronger emphasis on how restoring natural resources can provide service to coastal communities. Coastal resources represent some of the most impacted and altered ecosystems worldwide and are sensitive to many hazards and risks, from floods to cyclones to disease epidemics (Adger et al. 2005, Science 309:1036-1039). Thus, management agencies need to explore 'linkages between ecosystems and human societies to help reduce vulnerability and enhance resiliency of these linked systems in coastal areas'.

Footnote:
"Every phenomenon and apparent eccentricity of the river …is controlled by law as immutable as the Creator, and the engineer need only to be insured that he does not ignore the existence of any of these laws, to feel positively certain of the results that he aims at. "
"If the profession of an engineer were not based upon exact science, I might tremble for the result, in view of the immensity of the interest dependent on my success."

From James B. Eads, USACE
taken from 'The Control of Nature' by John McPhee, 1989

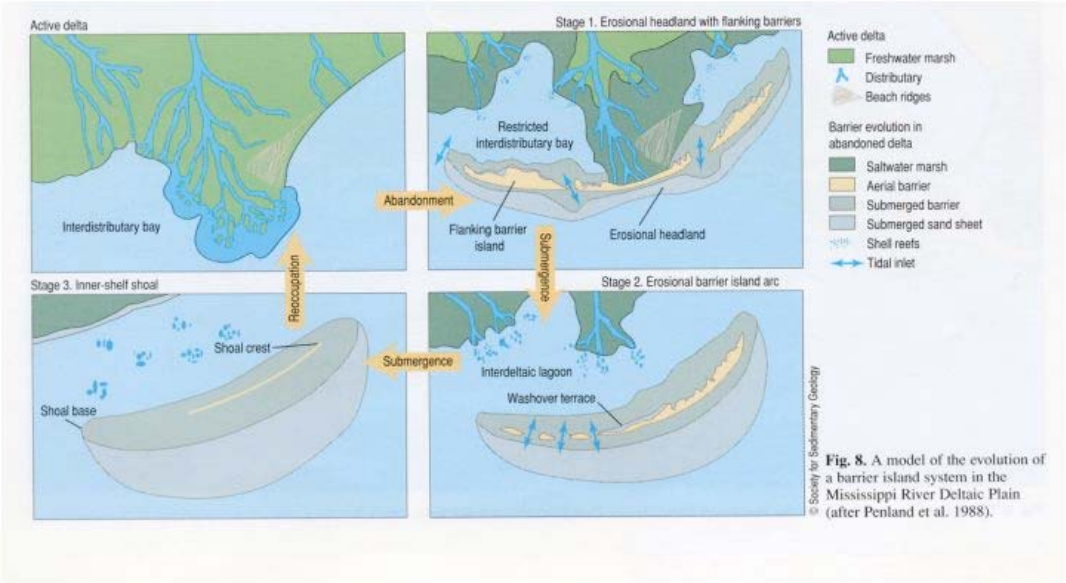


Figure 1. Model of the evolution of a barrier island system in the Mississippi River Deltaic Plain (Figure from Gosselink 1998; Original from Penland et al. 1988).

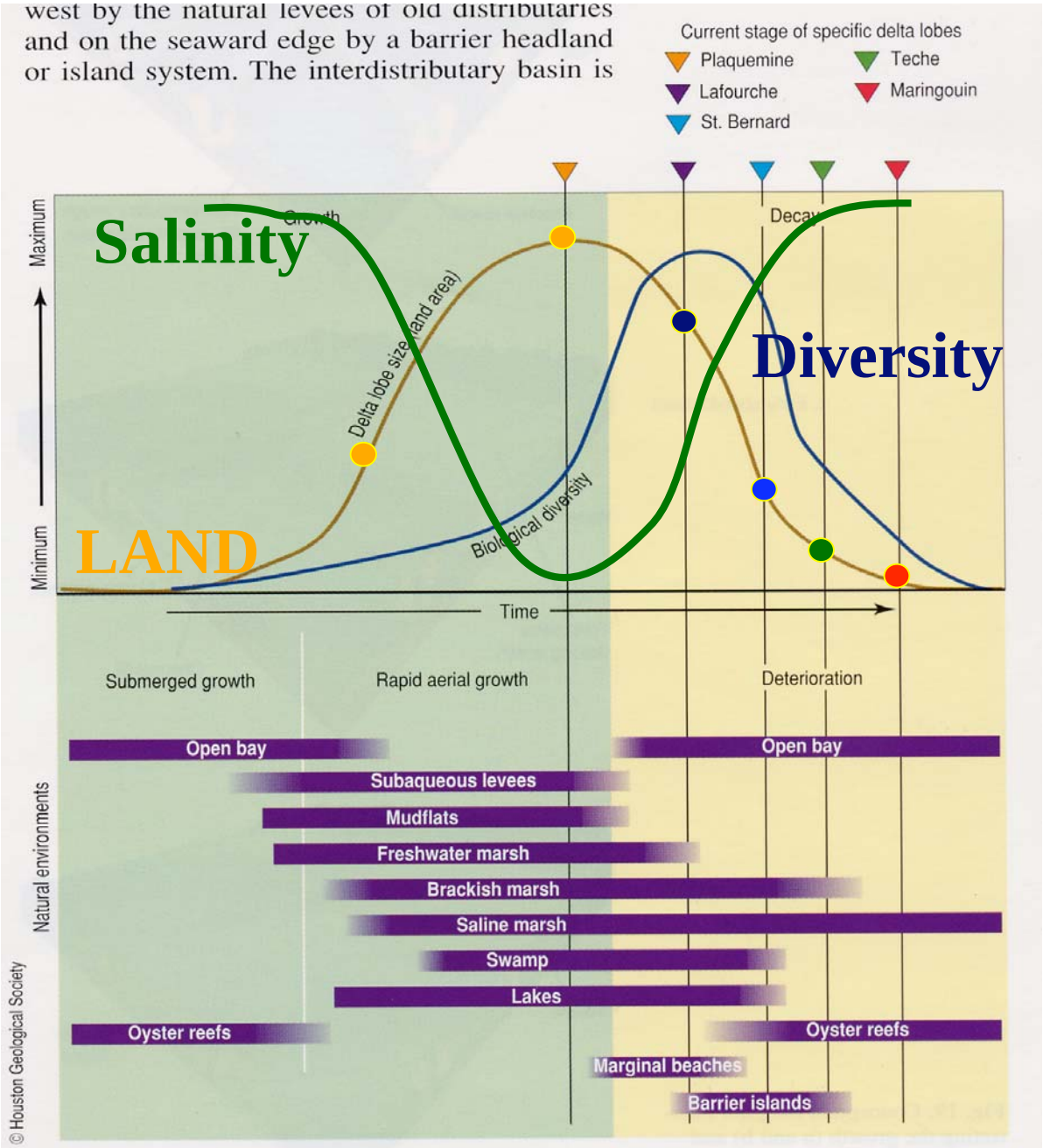


Fig. 18. Graphical depiction of the growth and decay of a delta lobe (adapted from Gagliano and Van Beek 1975; Neill and Deegan 1986). Habitat and biological diversity peak in the early to middle stage of the decay phase.

Figure 2. Conceptual model of the delta cycle depicting the growth and decay of a delta lobe (Figure from Gosselink 1998; modified from Gagliano and Van Beek 1975; Neill and Deegan 1986).

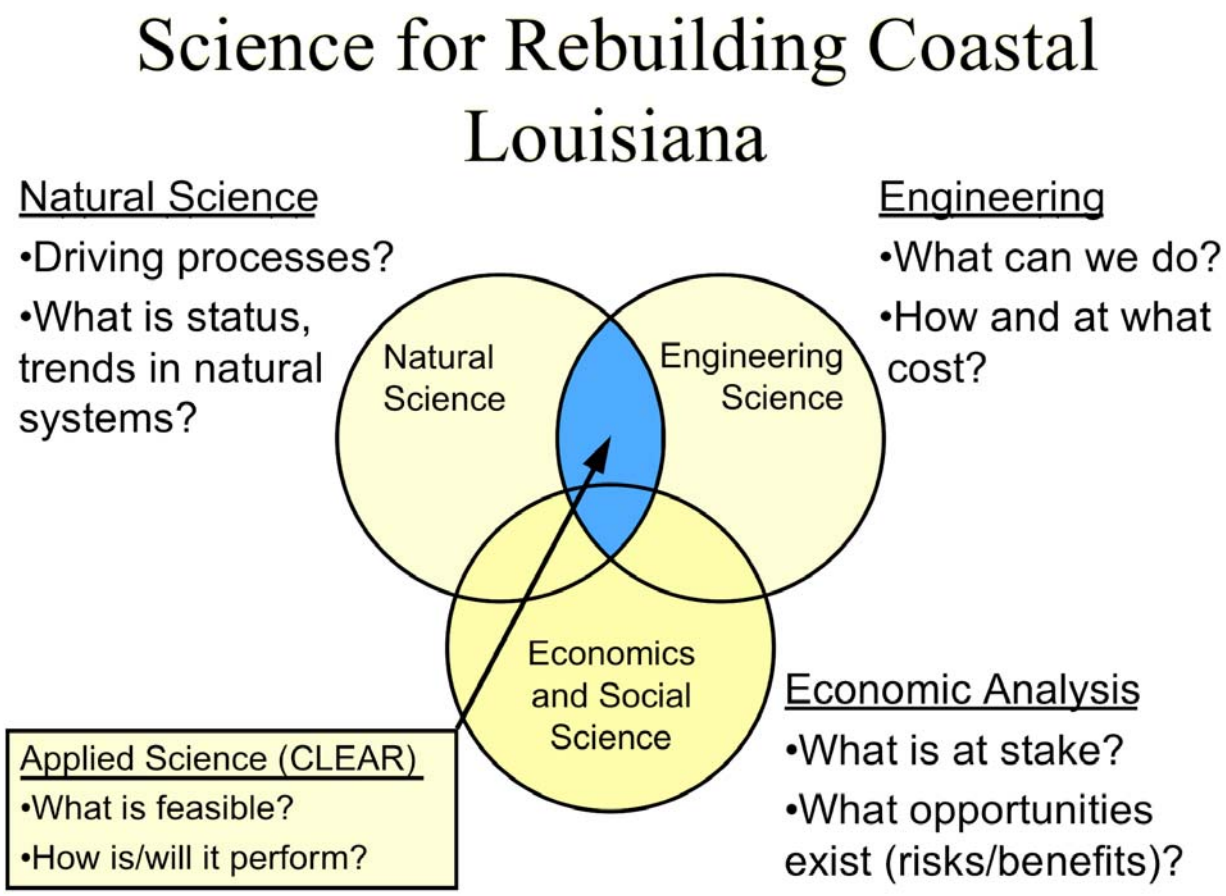


Fig. 3. Integration of the natural, social and engineering sciences to guide public work projects in coastal barrier resources systems such as coastal Louisiana. The Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) program (www.clear.lsu.edu) has developed some of the modules to accomplish this integrated framework.

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c. Publications

(i) Related to project

1. Twilley, R. R. et al. 2003/2004. Louisiana Coastal Area Ecosystem Model. Louisiana Department of Natural Resources File Report, Volumes I/II, 578 pp.
2. Bianchi, T., J. Pennock, and R.R. Twilley (eds). **1999.** Biogeochemistry of Gulf of Mexico Estuaries. John Wiley and Sons, New York. 428 pp.
3. Twilley, R.R., E. Barron, H.L. Gholz, M.A. Harwell, R.L. Miller, D.J. Reed, J.B. Rose, E. Siemann, R.G. Welzel and R.J. Zimmerman. 2001. Confronting Climate Change in the Gulf Coast Region: Prospects for Sustaining Our Ecological Heritage. Union of Concerned Scientists, Cambridge, MA and Ecological Society of America, Washington, DC. October 2001.
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6. Twilley, R. R. and V.H. Rivera-Monroy. **2005**. Developing Performance Measures of Mangrove Wetlands Using Simulation Models of Hydrology, Nutrient Biogeochemistry and Community Dynamics. Journal of Coastal Research 40:79-93.
7. Perez, Brian C., John W. Day, Jr., Dubravko Justic, Robert R. Twilley. 2003. Nitrogen and Phosphorus Transport Between Fourleague Bay, Louisiana and the Gulf of Mexico: The Role of Winter Cold Fronts and Atchafalaya River Discharge. Estuarine, Coastal and Shelf Science Vol 57/56: 1065-1078. .

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