CHAPTER FOURTEEN: ENGINEERING FOR SUCCESS

The tragedies of Hurricanes Katrina and Rita in 2005 have revealed to the world the enormous challenge Louisiana now faces. South Louisiana appears to have entered a period when the convergence of two powerful forces is working against its survival. Since the 1950's, the processes driving coastal loss have continued only slightly abated. Since 1990, meteorological and oceanic processes driving tropical systems have more frequently generated category 4 and 5 hurricanes. More destructive hurricanes are predicted for coming decades. ~ South Louisiana's ongoing peril is the continued overlap of weakened hurricane protection with more frequent and intense hurricanes.

In light of this predicament, how can the coast and culture of south Louisiana survive? The survival of a culture and a region is at stake. Hurricanes Katrina and Rita may have narrowed the field of discussion from what we might want, down to what we absolutely need. There is a growing consensus that what is needed is a pragmatic and effective strategy to integrate both coastal habitat restoration and engineered flood protection, such as levees. This strategy must be established soon and while under duress.

John Lopez (2006).
The Multiple Lines of Defense Strategy to Sustain Louisiana's Coast
Report to Lake Pontchartrain Basin Foundation, New Orleans.

14.1 Introduction

At the present time, the federal government is just completing a significant effort to re-establish the New Orleans Flood Defense System (NOFDS) to "pre-Katrina conditions" by a target date of June 1, 2006. The federal government has proposed to further improve the NOFDS to meet "100-year flood conditions" by 2010. Studies are currently underway by the Corps of Engineers to define an expanded and more reliable NOFDS (see Appendix G). In this Chapter we explore options for the engineering elements that could be provided in an improved long-term NOFDS.

The first question to be addressed in going forward is: "what should we do about providing adequate flood protection for the greater New Orleans area?" To the people who lived and continue to live in this area, this is not a question. These people are in the process of rebuilding their homes and lives. A majority of people who live in this area are committed to re-building and continuing the development of this area. Some have and will decide not to return; they will rebuild elsewhere.

The real question is about the '*we*'. The following thoughts on this question were advanced by former Speaker Newt Gingrich (2006):

Shortly after Hurricane Katrina devastated New Orleans, Speaker of the House Dennis Hastert wondered aloud whether the Federal Government should help rebuild a city much of which lies below sea level. The most tough-minded answer to that question demonstrates that rebuilding and protecting New Orleans is in *the national interest. Reason: The very same geological forces that created that port are what make it vulnerable to Category 5 hurricanes and also what make it indispensable.*

If engineering the Mississippi made New Orleans vulnerable, it also created enormous value. New Orleans is the busiest port in the U.S.; 20% of all U.S. exports and 60% of our grain exports, pass through it. Offshore Louisiana oil and gas wells supply 20% of domestic oil production. But to service that industry, canals and pipelines were dug through the land, greatly accelerating the washing away of coastal Louisiana. The state's land loss now totals 1,900 sq. mi. that land once protected the entire region from hurricanes by acting as a sponge to soak up storm surges. If nothing is done, in the foreseeable future an additional 700 sq. mi. will disappear, putting at risk port facilities and all the energy-producing infrastructure in the Gulf.

…Washington also has a moral burden. It was the Federal Government's responsibility to build levees that worked, and its failure to do so ultimately led to New Orleans' being flooded. The White House recognized that responsibility when it proposed an additional $4.2 billion for housing in new Orleans, but the first priority remains flood control. Without it, individuals will hesitate to rebuild, and lenders will decline too invest.

How should flood control be paid for? States get 50% of the tax revenues paid to the Federal Government from oil and gas produced on federally owned land. States justify that by arguing that the energy production puts strains on their infrastructure and environment. Louisiana gets no share of the tax revenue from the oil and gas production on the outer continental shelf. Yet that production puts an infinitely greater burden on it than energy production [from] other federal territory puts on any other state. If we treat Louisiana the same as other states and give it the same share of tax revenue that other states receive, it will need no other help from the government to protect itself. Every day's delay makes it harder to rebuild the city. It is time to act. It is well past time.

For us it is not a question of *if* we go forward to provide an adequate and acceptable NOFDS. It is a question of *how* we go forward. Going forward will demand a lot of all involved including vision, commitment, responsibility, respect, organization, cooperation, leadership, knowledge, resources, preparations, time, and some good luck. While this Chapter examines the engineering aspects of providing long-term hurricane flood protection for the greater New Orleans area, it should be clearly understood that a PREREQUISITE to a successful venture must be re-engineering the Technology Delivery System (see Chapter 13) needed to develop such a system. History has clearly shown that without an effective and sustainable TDS, we can expect a deficient and defective long-term NOFDS. History will repeat itself if we let it.

During the next several decades, hurricane seasons are expected to produce greater numbers of more severe storms. Unnecessary delays in embarking on development and realization of a long-term NOFDS only increase our chances of failing. We learned this lesson during the 40-year period between the disastrous flooding of New Orleans in 1965 (hurricane Betsy) and the catastrophic flooding of 2005 (hurricane Katrina). Now is the time for careful and deliberate thought followed by effective and timely action. Another disastrous flooding of the greater New Orleans area should not be an option.

14.2 Engineering Considerations

The ILIT addressed two key aspects associated with the engineering considerations of going forward: (1) the NOFDS physical facilities, and (2) the engineering criteria and guidelines for these facilities.

14.2.1 Physical Facilities

Evaluation of the options for NOFDS physical facilities requires a basic understanding of the natural environmental - geological - ecological setting of this area, the commercial - industrial complex established in this area, and unique cultural - social - institutional - political elements. This is a very complex system whose future is shadowed by its past.

A systematic and integrated study needs to be performed of the options for provision of physical facilities so that informed choices can be made about how best to provide long-term flood protection for the greater New Orleans area. The NOFDS is part of an even larger challenge that involves other parts of the Gulf coast and the floodplain of the Mississippi River (Dean, 2006). The real threats of increased hurricane activity and intensity, coastal degradation, subsidence, and climate change (rise in sea level, increase in rainfall and flood potential) must be recognized and appropriate and effective preparations put in place to help protect life and property in this area.

The Mississippi River and the Gulf of Mexico have been interacting in this part of the United States for millions of years (Kelman, 2003). As a result of sediments transported and deposited by the Mississippi River during the past 100,000 years, a vast complex of delta lobes have developed where a succession of different river channels meet the Gulf of Mexico (Coleman, 1988). Sixteen of these lobes have been developed and abandoned during the past 20,000 years. The sediments deposited by these delta lobes dominate the geology of this area, and the recently deposited sediments reach thicknesses exceeding 500 feet (U.S. Army Corps of Engineers, 2004).

The Mississippi Delta is a broad wedge-shaped floodplain whose top is about where the Atchafalaya River branches off from the Mississippi River and whose broad curved base is the Gulf of Mexico coastline (about 150 miles wide) (Sparks, 2006). The coastline is delineated with a long line of barrier islands. The shape of this delta is determined by sediment accumulation, compaction, subsidence, growth faulting, changing sea level, and most recently by man's activities. Recent information indicates that since the sea reached its present level (about 6,000 years ago), six major lobes including a developing new one at the mouth of the Atchafalaya River have existed. The modern Birdsfoot Delta that lies to the southeast of New Orleans (Plaquemines parish) has existed for only about the last 1,000 years.

The river has been trying to change its course to the Atachafalaya River (100 miles to the west) as the length of the Mississippi River to the Gulf of Mexico has increased (now more than 200 miles). In order to maintain New Orleans as a deepwater port in the 1950s, the Corps of Engineers constructed the Old River Control Structure to help divert about 30% of the Mississippi River water down the Atachafalaya and keep the remainder flowing to the Gulf through its present course. In 1973, a flood on the Mississippi River almost caused failure of the Old River control Structure. The Corps completed a new auxiliary structure in 1985 to take some of the pressure off the Old River control Structure. At the present time, the Atachafalaya lobe is actively building toward the Gulf of Mexico and the lobe south of New Orleans is regressing.

A variety of processes have altered the natural process of land building by the Mississippi River and its tributaries (Hallowell, 2005; Committee on the Restoration and Protection of Coastal Louisiana, 2006; Zinn, 2004, 2005a, 2005b). These include the building of upstream dams and flood control structures (decreased sediment supply), building of levees (which do not permit sediment transport to adjacent areas), building of canals and pipelines (oil and gas exploration and production), building of navigable waterways (e.g.: Gulf Inter-Coastal Water Way, Mississippi River Gulf Outlet), and configuration of the current mouth of the Mississippi river to "shoot" sediments out into the Gulf of Mexico, over the edge of the continental shelf, in order to reduce the need for active dredging to maintain navigability of the main river channel for shipping. All have had their effects on reducing replenishment of sediments to keep up with subsidence, on the balance coastal transport processes, and on providing nutrients to sustain freshwater wetlands.

With population and industrial growth along the Mississippi River and its tributaries (it drains about 40% the United States), influx of byproducts and waste products have also taken their toll on the wetlands. Exploration for and production (extraction, transport) of hydrocarbons have also taken their toll on wetlands and contributed to land loss. The rise of sea level has also taken its toll. The result is a rapidly degrading and regressing coastline. This coastline is projected to loose about 10 square miles of land per year during the next 50 years (Dean, 2006; Sparks, 2006). The rapidly regressing coastline has had important effects with regard to the increase in hurricane risk affecting the NOFDS.

The NOFDS is faced not only with the challenges associated with potential hurricane surges and waves, but also with potential floods from the Mississippi River, with subsidence and compaction, with reduction of the storm-buffering provided by coastal barrier islands and wetlands, and with potential water and saltwater ingress provided by man-made waterways. Oliver Houck (2006) addressed these challenges:

> *So here is the starting point: exactly what we do want the Louisiana coast to look like, to do for us, for say, the next century? …Earth to Louisianans: you really can't have this cake and eat it too. With all due respect, it is not just a matter of doing everything we want 'smarter.' It is a matter of getting straight what we want, and that comes first. What comes next is the hardest step for any American community to take, and shall be heresy in South Louisiana. A plan. The mere mention of planning raises blood pressures and brings on cries of Godless Communism. What we have had in the city of New Orleans and along the entire gulf coast is planning by default (local attorney Bill Borah calls it 'planning by surprise'). Planning takes place. It's just that we haven't taken part in it. Where water resources are concerned, it starts with real estate developers, port authorities, levee boards and other outside-the-ballot-box enterprises, their projects facilitated and funded by the Army Corps of Engineers. In their minds, the only question is a technical one: what kind of engineering do we need to get our project done? The system has produced the expected results: more rip-rap here, more drainage there, and levees to the horizon. The goal is - although it is never stated anywhere - to develop as much of the coast as possible. When you add the projects up, they determine the destiny of the city and South Louisiana.*
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> *What is apparent is that these levees, designed by engineers and approved by Congress, are the basic planning documents for the future of South Louisiana. What is north of these levees will be developed. What is south of them will be*

anyone's guess, although not for long; the map on global warming shows these coastal marshes gone within a century. De facto, we end up with a wall. Not all that adequate a wall, by the way. Only Category three, if that. Can you imagine the costs of maintaining even a Category three levee system winding back and forth to the Gulf from New Orleans to Texas" Can we imagine what will happen when development piles in behind it, and then gets flooded? Do we already know, from Lakeview and New Orleans East, what happens to land elevations behind levees once they are drained and paved?

Our choice is to start this process from the other end. If we do, another range of options open. There are a dozen major towns across the southern tier with thousands of homes and residents, and they deserve protection. But the way to provide it may be with the same kind of ring levee systems that protects (or should) New Orleans and its surrounding parishes, supplemented by flood gates at the mouths of the main canals. Or, it may mean peninsular levee systems down the historic ridges of the bayous, protecting what has always been the high ground. …Problem is, we have lacked the process - we have lacked even the language - for such a discussion. In addition to scientists and engineers, we may need some social workers. In saying this, I am most serious.

The ILIT examined two basic alternatives to develop a long-term NOFDS. The first was constructing levees, floodwalls, and pump stations capable of providing a long term NOFDS. At the present time, efforts are underway to provide "100-year" flood protection. But, the question is why "100-year" protection? Why not 1,000 year or 10,000 year protection (frequently posed as Category 4 or 5 hurricane protection)?

Our studies of economic cost-benefit guidelines, and historic and current standards of practice for public facilities in the United States and elsewhere indicated that protection against disastrous flooding of the greater New Orleans area should be for conditions having average return periods <u>much</u> more demanding than the present goal of "100-year" flood protection. This issue was addressed by another very similar region that must defend its population and commercial enterprises at elevations up to 23 feet below sea level - the Netherlands (Netherlands Water Parternership, 2005):

Our standards are accepted risks related to the design-criteria of our dikes. Those standards are laid down in the Flood Defense Act. For the economically most important and densely populated part of the country, we design our dikes and dunes to be strong enough to withstand a storm-situation with a probability of 1 to 10,000 a year. That means, that a Dutchman - if he should live a 100 years - has a chance of 1 percent to witness such an event. For our parliament, these odds became the acceptable standard. For the less important coastal areas we calculate the probability of 1 to 4,000 and along the main rivers 1 to 1,250.

This background was developed largely after the Netherlands suffered catastrophic flooding of the country in 1953. This flooding was comparable to the flooding of the greater New Orleans area in the wake of hurricane Katrina (approximately 1,800 dead, 50,000 destroyed homes, 350,000 acres of flooded land). It was also preceded by a history that included a large number of malfunctions that included poor organization, bad maintenance, warnings not heeded, poor communications, underestimation of the danger, negligence, lack of preparedness (Jurjen

Battjes, personal communication; Dec. 30, 2005). This same history was repeated in the catastrophic failure of the NOFDS.

Following the 1953 catastrophe, the Dutch vowed "never again" and developed a system that is today a model of advanced engineering and water resource management. It also provides a model for the organizational re-engineering required to realize the system they have in place today, and that they continue to maintain and improve. This organization is a centralized Rijkswaterstaat which is the national public works department in charge of all flood defense works. This department has direct ties and interfaces with the local agencies responsible for continued development, maintenance, and improvement of flood defense work (including evacuation and disaster recovery). However, the Dutch have learned the sad lessons of trying to overwhelm nature with engineered works. They have seen many unintentional consequences from such an approach surface as very severe negative environmental and quality of life impacts. And, they learned from these mistakes and gone on to remediate the mistakes and develop new strategies (Netherlands Water Partnership, 2005):

> *Climate changes are increasing the likelihood of flooding and water-related problems. In addition population density continues to increase, as does the potential for economic growth, and consequently, the vulnerability to economic and social disaster. Two undesirable developments that, in terms of safety, exacerbate one another - a grown risk with even larger consequences. As such, the safety risk is growing at an accelerated pace (safety risk - chance multiplied by consequence).*
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> *The Netherlands is changing its approach to water. This change involves the idea that the Netherlands will have to make more frequent concessions. We will have to relinquish open space to water, and not take back existing open spaces, in order to curb the growing risk of disaster due to flooding, We will also need to limit water-related problems and be able to store water for expected periods of drought. By this we do not mean space in terms of the height of ever taller levees or depth through continued channel dredging, but space in the sense of flood plains. This approach will require more area, but in return we will increase our safety and limit water related problems. Safety is an aspect that must play a different role in spatial planning. Only by relinquishing our space can we set things right; if this is not done in a timely manner, water will sooner or later reclaim the space on its own, perhaps [in a] dramatic manner.*

The Dutch continue to be challenged by their countrymen not to become conceited or complacent - they are devoted to a culture of continuous improvements in their flood protection.

Our consideration of this background indicated that the most attractive option for provision of an acceptable and sustainable long-term NOFDS *is one of re-establishing and enhancing selected natural defenses supplemented with engineered works as necessary to provide long-term flood protection*. Guidelines and many useful insights are provided by John Lopez (2006) in the report *The Multiple Lines of Defense Strategy to Sustain Louisiana's Coast* about how such an option might be developed. Additional background for development of this option is also provided in the reports *Coast 2050: Toward a Sustainable Coastal Louisiana* (Louisiana Coastal Wetlands Conservation and Restoration Task Force 1998), *Ecosystem Restoration Study* (U.S. Army Corps of Engineers 2004), *Drawing Louisiana's New Map* (National Research Council 2006), and *A New Framework for Planning the Future of Coastal*

Louisiana after the Hurricanes of 2005 (Working Group for Post-Hurricane Planning for the Louisiana Coast 2006). Results contained in these studies provide a coherent and substantial basis for development of a long-term NOFDS. Lopez (2006) proposes eleven *Lines of Defense* (see Figure 14.1):

> ***1st Offshore shelf within the Gulf of Mexico:*** *The offshore shelf ranges in depth from 300 feet at the shelf edge to zero depth at the gulf shoreline. Its width vanes from a few miles to hundreds of miles. The primary benefit of the shallow shelf is to dramatically reduce wave height and wave energy from an approaching tropical system. A negative aspect of the shelf is that it will promote higher storm surges inland. The variable influences storm surges due to the geometry of the shelf needs to be considered for storm surge analysis. Also, dredging activities on the shelf should avoid increasing shoreline erosion by wave refraction around dredge holes. The gulf fisheries and the oil and gas industry are key economic aspects of the shelf. Examples: Narrow shelf at the mouth of Mississippi River & Wide shelf offshore from Cameron Parish*

> ***2nd Barrier Islands****: The Louisiana barrier island shoreline is characterized by fragmented barriers or shoals with low vertical profiles and low sand content. However, barrier islands provide an important wave barrier for interior sounds and coastal marsh. The primary benefits of barrier islands are the near-complete reduction in wave height and the slight reduction in storm surge further inland. A negative aspect of barrier islands is their ephemeral nature and unpredictable local impacts to them from hurricanes. Barrier islands also have significant recreational aspects such as fishing and birding. Examples: Chandeleur Islands and Grand Isle*

> ***3rd Sounds****: The primary benefit of the sounds is to provide a relatively shallow water buffer to deep water currents. Sounds do have a negative aspect during storms by allowing waves to re-generate on the sound side of barrier islands. Also, sounds may cause storm surge and wave erosion on the back side of barrier islands.*

> ***4th Marsh Landbridges****: Marsh landbridges are areas of emergent marsh with relative continuity compared to adjacent bays, sounds or areas of significant marsh/land loss. Ideally, landbridges connect other elevated landforms such as natural ridges. Since some ridges are developed and have adjacent levees, marsh landbridges may also bridge adjacent levee systems and economic corridors. Marsh landbridges compose much of the residual internal framework of the coast which reduces fetch and shoreline erosion of interior marshes and lagoons. Landbridges impede storm surge movement inland and protect other emergent marsh areas that may perform the same function. Some landbridges are threatened themselves by various processes of marsh loss and need to be sustained through restoration and maintenance. The landbridges represent an increasing fraction of the remaining emergent marsh of the coast and provide typical high productivity and fishery benefits typical of coastal wetlands. Examples: East Orleans landbridge, Biloxi Marsh landbridge, Barataria Basin landbridge, Upper Terrebonne Bay landbridge, Grand Lake-White Lake landbridge, Western Marsh Island landbridge, south Calcasieu Lake landbridge*

5th Natural Ridges*: In southeast and central Louisiana, most natural ridges are the natural levees of abandoned distributary channels. These channels now act as tidal channels and are often colloquially named bayous or rivers. In southwest Louisiana, most natural ridges are chenniers running parallel to the Gulf coastline. Natural ridges may have continuous elevation of several feet and, therefore, will impede overland flow across the ridge and potentially reduce storm surge. Natural ridges often define (at least historically) the hydrologic basins of the coast. Natural ridges are most effective when they have at least 6 feet of elevation and well drained soils to maintain upland forests. Forests will also slow the movement of overland flow and may also provide a wind barrier. Natural ridges tend to be the economic corridors across the coast including primary state highways and coastal communities. These highways are also likely to be evacuation routes. Examples: Bayou la Loutre, Bayou Lafourche*

6th Manmade Soil Foundations*: Manmade soil foundations for transportation may provide incidental benefit to storm surges. Railroads, highways and spoil banks may run parallel to the coast and locally provide a manmade ridge several feet [high]. These foundations may have settled and may need improvement to provide reliable transportation routes without chronic flooding. If highway improvements are contemplated, the effects 011 storm surge may be considered. Examples: Highway 90, Hwy 82*

7th Flood Gates*: Flood gates are typically designed to withhold flood water and, therefore, remain open under most conditions. Flood gates are generally open so as not to impede navigation or natural ebb and flow of tides and aquatic organisms. Flood gates would be closed during a threat of flooding and to reduce flood tides in channels. Because of the generally low elevation of the coast, the effectiveness of flood gates may depend on the nearby topography or constructed features such as levees or spoil banks. Examples: Bayou Bienvenue, Bayou Dupre*

8th Flood Protection Levees*: Flood protection levees are designed and constructed for flood protection of municipalities or other coastal infrastructure features. Levees are generally designed to be an absolute barrier defining a flood side and a protected side. The intent is to have zero storm surge flooding on the protected side, but an unintended consequence may be to increase water levels on the flood side. Levees are generally not designed to be overtopped or to withstand significant wave erosion. Exceptions include "potato levees" or other low relief levees designed to reduce flooding from non-storm tides. Typical hurricane protection levees protect limited portions of the coast with intense economic development. Examples: St. Bernard levee, Jefferson and Orleans Parish levees on Lake Pontchartrain*

9th Flood protection pumping: *Pumping stations are generally within leveed areas and are used to reduce flood risk from rainfall and are not designed to pump out flood water in the case of a levee breach. Most pumping stations are not prepared with fuel, staff or other requirements to be effective to pump out flood water from a significant levee breach. Generally, these are large capacity pumps which displace water vertically above the water level on the flood side of the levee. Pumping stations are generally to protect areas of intense development. Examples: Orleans and Jefferson Parish's pumping stations.*

10th: Elevated Homes and Businesses: *All homes and businesses in south Louisiana are subject to being flooded if they are not elevated above the normal land elevation. Even those behind levees are not 100% safe. Hurricanes Katrina and Rita made this painfully clear. All attempts to reduce storm surge height or its extent are limited by the intensity and attributes of particular storm events. Since there will always be the potential of a storm exceeding the limits of protection from storm surges, immovable assets such as homes and businesses should be elevated to the appropriate flood elevation risk. This is the last line of defense for immovable assets. Elevated homes also provide important side benefits such as improved protection from termites and more economic capacity to re-level or raise the houses due to settlement or increased flood risk. Example: pre-1940 housing in New Orleans, LUMCON, Marina del Ray in Madisonville*

11th Evacuation*: Evacuation routes are typically highways, but could also include other means of transportation such as railroads, air transportation, etc. Evacuation routes are the last line of defense for people or moveable assets. Evacuation routes and procedures should be established for the coast. Ideally, evacuation routes may also serve as re-entry routes for first responders and as routes to re-populate after a storm event. Evacuation routes are generally selected based capacity to move a large number of people to safer areas as a storm approaches the coast. Some routes may be subject to flooding quickly and need to be improved. Examples: Regional contra-flow evacuation plan for southeast Louisiana.*

The Corps of Engineers and other organizations are continuing work to develop an advanced and more reliable NOFDS that is more compatible with the natural, industrial and social environments of southern Louisiana. The Working Group for Post-Hurricane Planning for the Louisiana Coast recently concluded (2006):

In the long term, hurricane protection for larger population centers, including the New Orleans region, can only be secured with a combination of levees and a sustainable coastal landscape. This will require adapting to changing conditions by re-establishing the constructive processes associated with distributing Mississippi River water and sediments across the coastal landscape, as well as alleviating the other destructive effects of past or future human activities.

With presently observed subsidence rates and anticipated acceleration of sea-level rise, most - although not all - of the coastal landscape could be maintained through the 21st century. And with efficient management of the river's resources, this landscape could be expanded in some places. However, this result can only be achieved with very aggressive, strategic, and well-informed restoration efforts, varying in size and objective but integrated within a landscape management plan.

The challenges associated with rehabilitation and improvement of the NOFDS need to be addressed in an integrated way combining public and social, organizational and institutional, natural and environmental, and commercial and industrial considerations. This is a "systems problem" that has many parts which are interactive, interdependent, and highly adaptive. We need to understand potential impacts, positive and negative, on the parts of this system so that wise choices and informed decisions can be made on how best to proceed. This is a different kind of "engineering problem" in which the Technology Delivery System used to address that problem is of utmost importance. Gerald Galloway (2006) summarized these issues:

> *Since 1983, when the Water Resources Council was effectively abolished, there has been no central direction to or coordination of federal water efforts, among the many departments that deal with water issues. Congress remains locked in a turf-conscious committee system that does not encourage coordination. Except for enforcing water quality standards there is little federal guidance, other than budgetary or ad hoc initiatives, on other water issues.*
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> *Given the present policy vacuum and the reluctance on the part of Congress and the administration to support comprehensive planning, New Orleans and coastal Louisiana will have to develop, in coordination with federal agencies, their own vision for the future and move ahead in a way that brings together solutions to the many water challenges facing the region. this comprehensive plan must address all aspects of coastal Louisiana's water challenges.*

Each of the alternatives for development of a long-term NOFDS has its pluses and minuses, costs and benefits. It is clear that these alternatives need to be continually examined in an integrated and systematic way. The fundamental technology exists to develop an adequate long-term NOFDS. The question is not “can we do it?” The question is “will we do it?”

14.3 Engineering Criteria and Guidelines

The basic technology exists to develop an effective and efficient NOFDS. A major challenge is timely and proper application of this technology. The following recommendations are made to facilitate such application.

Recommendation 1: Develop an integrated and coherent Flood Defense System for the greater New Orleans area (NOFDS) to provide desirable and acceptable levels of flood protection throughout its life-cycle. Particular attention must be paid to interfaces and interdependencies in this system. The NOFDS should be balanced, complete, cohesive, clear, consistent, and have controls and continuity. The NOFDS should be based on the best available and safest technology and most up-to-date legal standards. Risks should be properly identified, contained and compartmentalized. The system must recognize the unique natural environmental setting including its geology, meteorology, oceanography, the Mississippi River floodplains, deltas and wetlands, subsidence, and the rise in sea level and frequency and intensity of hurricanes. The system must also recognize and accommodate the unique societal and cultural environments of this area.

Recommendation 2: Develop a NOFDS based on enhancing natural defenses supplemented with engineered defenses that incorporate concepts of defenses in depth, robustness or resilience, and fail-safe performance. Selective re-establishment of natural coastal defenses and wetlands and restored floodplains to provide for river floods should be supplemented with engineering works that together have the capabilities of providing desirable and acceptable levels of flood protection. Coastal management must be focused on providing safety from flooding and environmental protection. Water should be given space. Some areas will have to be returned to nature and judicious and wise decisions must be reached on which areas will be populated and developed and the levels of protection that will be provided to these areas. Engineering works should include raising, strengthening and defending levees, providing floodgates and storm surge barriers, positioning and defending modern pump stations. Engineering must also address compartmentation to limit potential flooding and adequate and effective evacuation measures to help limit effects on people and their possessions. A robust NOFDS will require a combination of appropriate configuration of engineered elements and components, ductility or an ability to deform and stretch and not loose important performance characteristics, excess capacity so that if some elements or components are overloaded or do not perform desirably, desirable protection can be maintained, and appropriate correlation or mutual relationships so that desirable protection is realized. Fail safe characteristics should be provided in all of the important elements of the NOFDS so that when the design and ultimate performance conditions are exceeded, the performance characteristics are not appreciably compromised.

Recommendation 3: Develop a NOFDS founded on advanced Risk Assessment and Management principles for all phases in the life-cycle including concept development, design, construction, operation, and maintenance. These principles should address natural, analytical modeling, human and organizational performance, and knowledge acquisition and utilization uncertainties and be based on proactive, reactive, and interactive risk assessment and management approaches. These approaches should be based on reductions in likelihoods of failure, reduction in the consequences associated with potential failures, and increases in detection and correction of developments that can lead to failures. Advanced Risk Assessment and Management approaches should be used to provide decision makers with information to define what levels of protection should be provided for which areas to be protected and how much can and should be spent for those purposes.

Recommendation 4: Develop updated engineering guidelines and procedures for all elements and components to be incorporated in the FDS for all life-cycle phases based on proven state-of-practice and state-of-art technology. Where technology gaps are identified, substantial development programs should be implemented to fill them with existing research results. Where technology gaps can not be filled with existing research results, research should be undertaken or sponsored to enable their timely filling.

Recommendation 5: Develop, implement, and enforce advanced Quality Assurance and Quality Control methods and procedures for all life-cycle phases of the NOFDS. Quality Assurance (proactive) and Quality Control (interactive) measures are of particular importance to help disclose 'predictable surprises' and variances in the desirable quality characteristics of the elements and components in the NOFDS. These methods and procedures should be used in all life-cycle phases of the NOFDS including concept development, design, construction, operation, maintenance, and continued improvement. These procedures and measures need to assure that the best available and safest technology is used and used properly.

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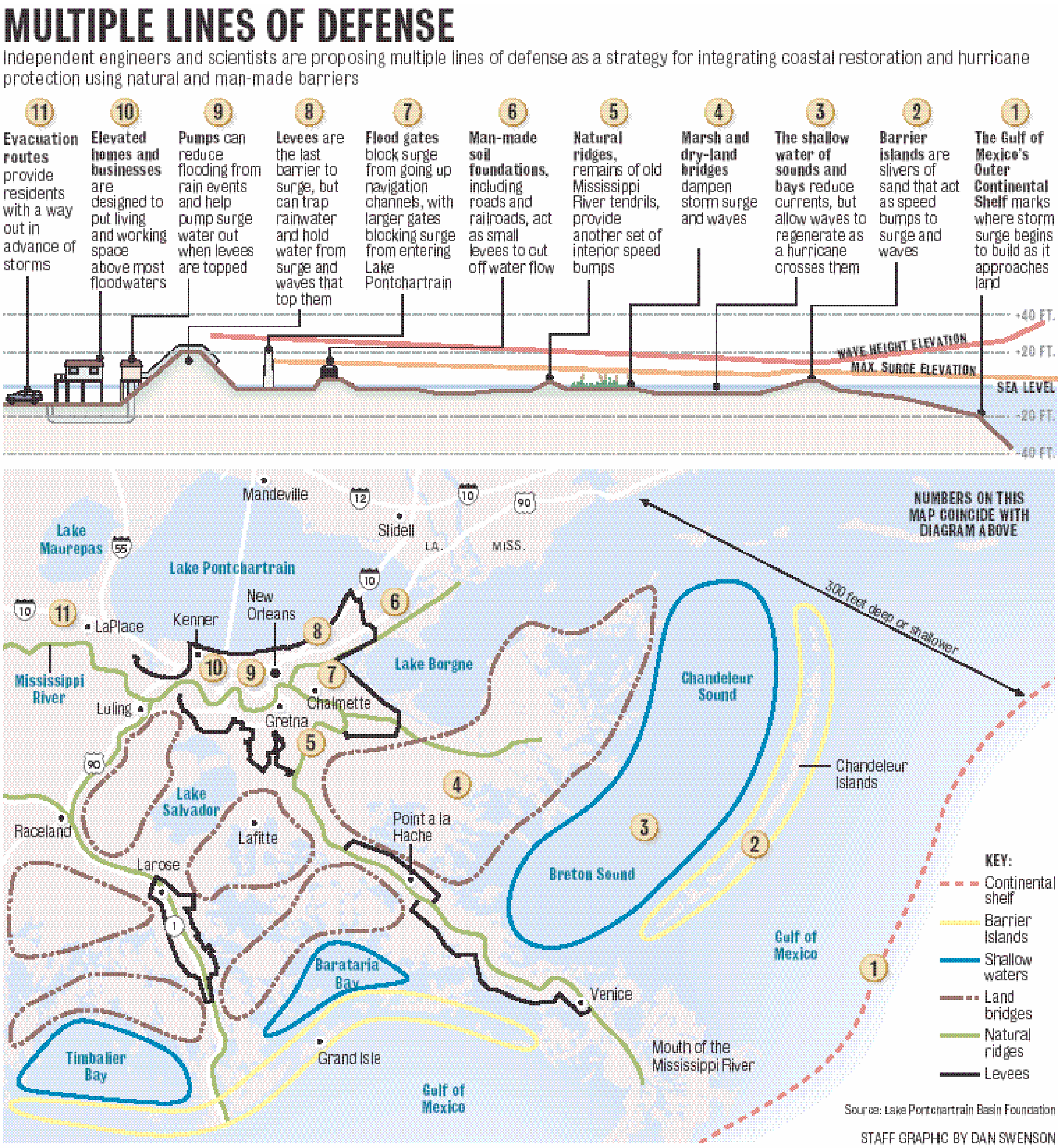

Figure 14.1: Eleven Lines of Defense (Lopez, 2006; graphic provided by the New Orleans Times Picayune)