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A new vision for New Orleans and the Mississippi delta: applying ecological economics and ecological engineering

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A new vision for New Orleans and the Mississippi delta: applying ecological economics and ecological engineering

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The restoration of New Orleans and the rest of the Mississippi delta after Hurricane Katrina can become another disaster waiting to happen, or it can become a model of sustainable development. Sea level is rising, precipitation patterns are changing, hurricane intensity is increasing, energy costs are predicted to soar, and the city is continuing to sink. Most of New Orleans is currently from 0.6 to 5 m (2–15 feet) below sea level. The conventional approach of simply rebuilding the levees and the city behind them will only delay the inevitable. If New Orleans, and the delta in which it is located, can develop and pursue a new paradigm, it could be a truly unique, sustainable, and desirable city, and an inspiration to people around the world. This paper discusses the underlying causes and implications of the Katrina disaster, basic goals for a sustainable redevelopment initiative, and seven principles necessary for a sustainable vision for the future of New Orleans and the Mississippi delta.

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The United States Government has pledged over $100 billion for rebuilding New Orleans and the Gulf coast region, following the terrible but predictable tragedy caused by Hurricane Katrina, estimated to be the largest natural disaster in US history (Figures 1 and 2). Billions more will go towards the restoration of the Mississippi delta. While some have argued that it does not make sense to rebuild New Orleans at all, given its highly vulnerable location (eg Kusky 2005), others have raised questions about how the city and region should be restored (Bohannon and Enserink 2005; Boesch *et al.* 2006). It is clear that enormous public resources are going to be spent and some form of rebuilding is going to occur, not least of all because the Mississippi River in the New Orleans region is home to the largest port in the nation and up to one-third of the nation's oil and gas is either generated or shipped through the north central Gulf. So the real question is not *if* but *how* the city should be rebuilt. There are two broad options: (1) essentially replace what was there before, or (2) use this tragedy as an opportunity to create something substantially different and better.

In a nutshell:

- While it is feasible to rebuild New Orleans to its former design, this is neither sustainable nor desirable
- What is required is a new vision of what the city could look like and how it could function in partnership with the surrounding delta, rather than in opposition to it
- Rebuilding New Orleans and the delta is a huge opportunity to put sustainability into practice and substantially improve the quality of life of all its residents
- The rebuilding must take into consideration global trends in climate change and energy scarcity
- To frame and achieve the new vision means moving away from conventional approaches to economics and engineering and towards the application of ideas from broader, more transdisciplinary fields such as ecological economics and engineering

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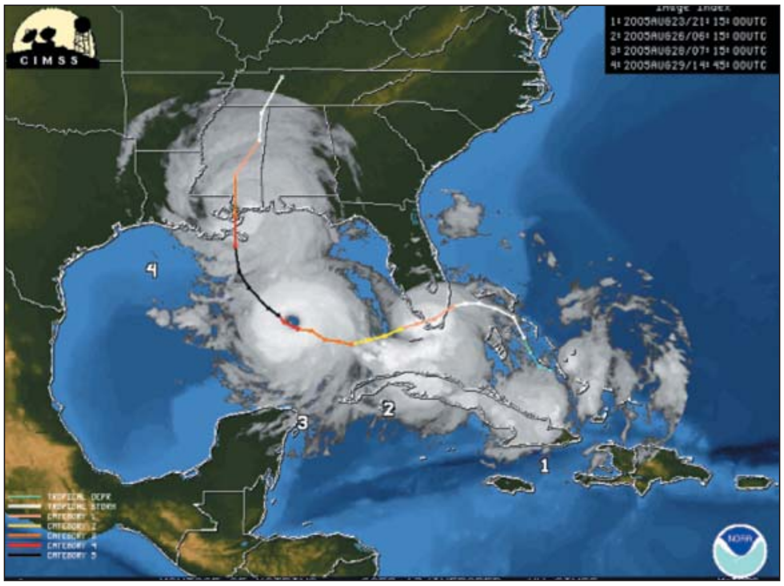
Option 1 seems to be largely the direction being taken so far. The Army Corps of Engineers has been actively working to rebuild the levees to their pre-storm status of being able to withstand a Category 3 hurricane. There is discussion of rebuilding all of the levees to withstand a Category 5 hurricane and even of building a Category 5 levee system across most of the Louisiana coast. However, there is already serious doubt as to whether a rapidly reconstructed levee will provide the needed protection (van Herndeen 2006); even if the rebuilding is successful, it will merely be setting up the pins to be knocked down again by a future, even larger hurricane. In addition, the increasing cost of energy will probably make such a levee system unsustainable. In the meantime, the city of New Orleans faces a combination of worsening problems, including: (1) likely more intense tropical storms due to global warming (Emanuel 2005; Webster *et al.* 2005; Hoyos *et al.* 2006); (2) continued land subsidence and sea level rise, albeit at a slower pace than in the past (Dixon *et al.* 2006); and (3) ongoing destruction of the coastal wetlands that serve as the city's storm protection barrier (in addition to the many other ecosystem services they provide).



Courtesy of NOAA

Figure 1. *Track of Hurricane Katrina, 23–29 August 2005, showing spatial extent and storm intensity along its path.*

Option 2 seems to be the only viable and sustainable option, but it has so far received little serious attention. Our goal here is to elaborate on a substantially different vision of a truly *new* New Orleans – one that can provide a sustainable and high quality of life for all of its citizens, while working in partnership with (not in opposition to) the natural forces that shaped it. This New Orleans can also serve more generally as a model for sustainable development.

What happened in New Orleans?

The devastation of New Orleans by a major hurricane was, unfortunately, both predictable and predicted. A large number of reports in both the academic and popular press, including a special section in the *New Orleans Times-Picayune* (June 23–27, 2002), a National Public Radio series in October 2003, and an article in *Scientific American* (Fischetti 2001), depicted possible scenarios very close to what actually happened. While the immediate reaction to massive flooding caused by the levee breeching showed an apparent lack of disaster planning, the hurricane damage itself could only have been prevented by actions taken years in advance. It was clear from studies published in the past 50 years that New Orleans was becoming more vulnerable with each passing year. The wetlands surrounding New Orleans provide protection from storm surges. These wetlands, the result of 6 millennia of land building, have been lost at an average rate of 65 km^2 (~25 mi^2) per year since the turn of the century (Figure 3). The barrier islands are rapidly eroding as well. Almost 5000 km^2 (1800 mi^2) of coastal wetlands have been lost since the 1930s, and the situation has continued to deteriorate. Figure 4 shows the loss of coastal wetlands projected to occur by the year 2050. This forecast was made before Hurricane Katrina, and 100% of the projected loss actually occurred during the storm.

The cause of this dramatic land loss was a combination of natural and human forces. For millennia, the natural process of geologic subsidence was counterbalanced by riverine inputs into a deltaic plain characterized by natural hydrology. However, in the 19th and 20th centuries, there was a massive disruption of the hydrology of the delta. Riverine input was drastically reduced by the creation of levees and the closure of distributaries, and the internal hydrology of the delta were pervasively altered, mainly due to canal dredging for oil and gas exploration and extraction (Day *et al.* 2000). As a result, the blanket of freshwater, sediments, and nutrients from the Mississippi River basin that used to spread across the delta is no longer there. The heavily managed Mississippi River was forced to dump most of its load off the continental shelf into the deep waters of the Gulf of Mexico and the wetlands deteriorated due to canal dredging, subsidence, and salt water intrusion. Not only do the sediments from the Mississippi River help build coastal marshes, but the freshwater from the river counteracts salt water intrusion, the inflow of nutrients spurs organic soil formation (the major way that new soil is formed in the delta), and iron from the river precipitates toxic sulfides (Delaune *et al.* 2003; Delaune and Pezeshki 2003).

The Atchafalaya River, a branch of the Mississippi that now carries one-third of the

Figure 2. *Picture taken by an automatic camera at an electrical generating facility located on the Gulf Intracoastal Waterway (GIWW), where the Route I-510 bridge crosses the GIWW. This is close to where the Mississippi River Gulf Outlet enters the GIWW. The photo clearly shows the storm surge, estimated to be 5.5–6 m (18–20 ft.) in height.*

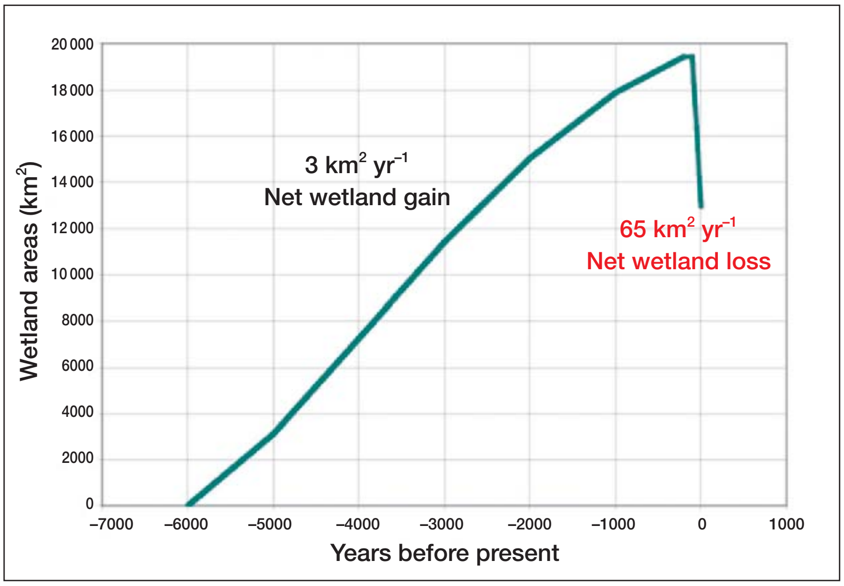


Figure 3. *History of coastal Louisiana wetland gain and loss over the last 6000 years, showing historical net rates of gain of approximately 3 km^2 yr^{-1} over the period from 6000 years ago until about 100 years ago, followed by a net loss of approximately 65 km^2 yr^{-1} since then.*

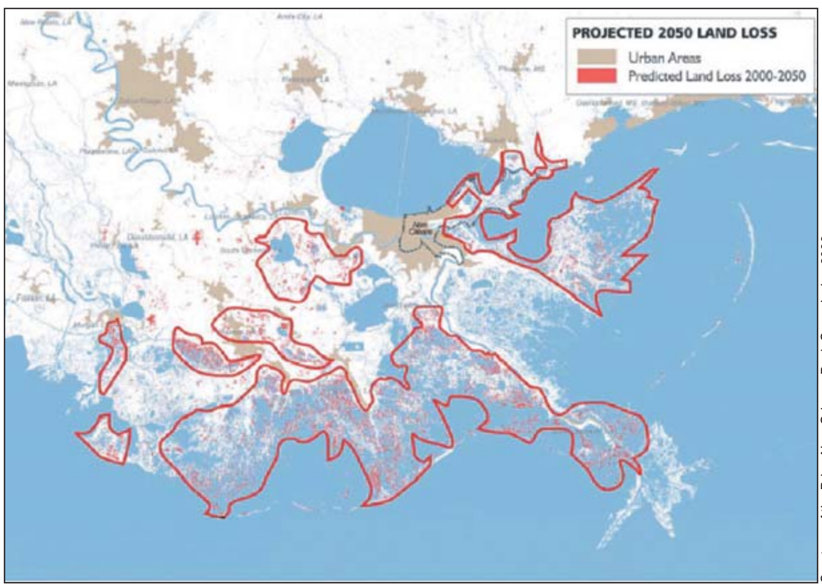
Mississippi's flow, discharges into shallow waters of the delta and has both built new deltaic lands and protected a large area of existing wetlands along the central Louisiana coast (Costanza *et al.* 1990; Day *et al.* 2000). The history of the Atchafalaya delta shows that appropriately managed river discharges and hydrologic restoration (by removing canal spoil banks) can result in net marsh creation and counteract the forces of land loss.

The mainstem Mississippi River was managed to allow deepwater shipping and commerce throughout the Mississippi basin and to impede flooding of developed areas. This management regime ultimately led to the situation that made New Orleans so vulnerable. The net result has been that the people who lived below sea level in New Orleans were in more danger every year from: (1) the potential for river flooding; (2) the disappearance of surrounding wetlands due to both restriction of river input and internal hydrological alterations; and (3) the deteriorating levees, which were under continued strain due to age and increasing hydrologic demands. Thus, what happened in New Orleans, while a terrible "natural" disaster, was also the cumulative result of excessive and inappropriate management of the Mississippi River and delta, inadequate emergency preparation, a failure to act in time on plans to restore the wetlands and storm protection levees, and the expansion of the city into increasingly vulnerable areas. Many of the areas that are now below sea level (Figure 5) were not always so. Up until the first quarter of the 20th century, most of the city was above sea level, either on the natural levee of the river or on older ridges formed by earlier courses of the river. However, the drainage of the wetlands between the natural levee along the Mississippi River and Lake Pontchartrain promoted soil oxidation and rapid subsidence (Figure 6) in many parts of the city.

Recent engineering reviews of the levee systems have identified design and construction flaws that may have contributed to their failure (Warrick and Whoriskey 2006). It is now uncertain whether rebuilding the levees to their former design would even protect the city from a Category 2 hurricane. Ivor van Heerden, leader of a Louisiana-appointed team of engineers, is quoted by Warrick and Whoriskey (2006) as saying, "When asked, we have constantly urged anyone returning to New Orleans to exercise caution, because the system now in place could fail in a Category 2 storm. It has already failed during a fast-moving Category 3 storm that missed New Orleans by 30 miles."

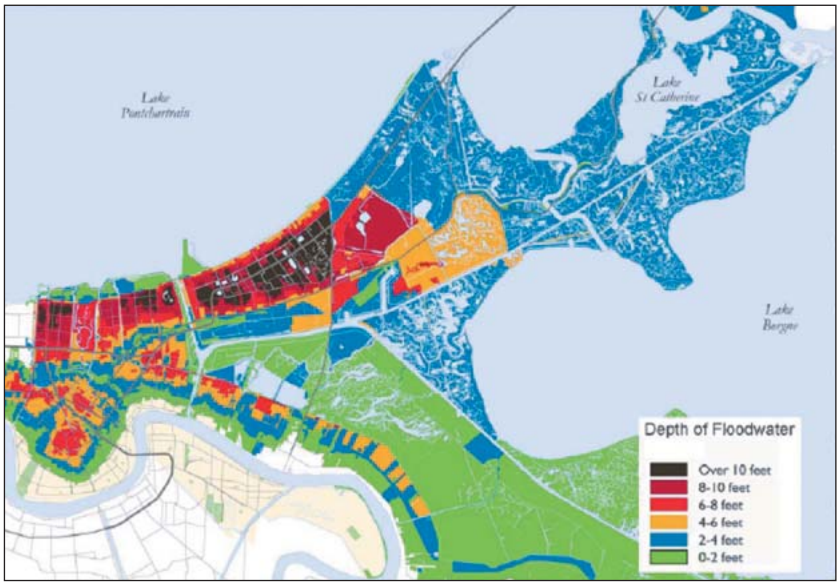
■ The restoration plan that never happened

A plan called the Louisiana Coastal Area (LCA) project (USACE 2004; Orth *et al.* 2005) would have slowed the trend of continuing wetland loss. Implementation of the plan was just beginning when Hurricane Katrina struck in August 2005. While some of the plan called for conventional engineering approaches (ie for barrier island restoration) a major element of the project also fit the



Courtesy of the Bring New Orleans Back Commission 2006

Figure 4. *Projected wetland loss by 2050 in coastal Louisiana. An estimated 100% of this projected loss occurred during Hurricane Katrina.*



Courtesy of the Bring New Orleans Back Commission 2006

Figure 5. *Map of areas flooded and flooding depths in New Orleans after Katrina.*

concept of ecological engineering, defined as the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both (Mitsch 1993, 1996, 1998; Mitsch and Jørgensen 2004). Some ecological engineering projects that were planned as part of the LCA were river diversions designed to reintroduce river water to delta wetlands (Mitsch and Jørgensen 2004). These diversions could also contribute, along with many similar actions throughout the basin, to a reduced hypoxic "dead zone" in the Gulf of Mexico (Mitsch *et al.* 2001, 2005; Day *et al.*, 2005). While the LCA plan was not sufficient to reverse coastal wetland loss, it was a step in the right direction.

Plans to restore coastal wetlands may now be in jeopardy as priorities shift to civil engineering solutions such as levees and pumps. The estimated $14 billion that was needed for this "natural engineering" may well be swallowed up by the reconstruction of the city to its former design and by a storm protection scheme for most of the Louisiana coast. Perhaps most importantly, from the standpoint of sustainability, the rebuilding of the city's hydrologic defenses is occurring when conventional energy sources are less available and more costly (Campbell and Laherrere 1988; Roberts 2004).

It is ironic that Louisiana and the rest of coastal America will probably be subjected to increased storm intensity and sea level rise due to a combination of climate change (partly the result of the burning of fossil fuels, a large fraction of which came from coastal Louisiana) and a degraded coastline, some of which is due to oil and gas exploration activity.

Why restore wetlands to protect New Orleans?

Increasing the area of coastal wetlands through ecological engineering provides a very cost-effective and sustainable approach for providing hurricane protection to human settlements in coastal Louisiana. Wetlands will provide an important and sustainable buffer against storm surges and wave action generated by tropical storms and hurricanes. Coastal ecosystems such as marshes and forested wetlands, whether naturally occurring or ecologically engineered, play a significant role in reducing the influence of hurricanes and even tsunami waves (Farber 1987; Mitsch and Gosselink 2000; Danielsen *et al.* 2005). The mechanisms involved include decreasing the area of open water (fetch) for wind to form waves, increasing drag on water motion and hence the amplitude of a storm surge, reducing direct wind effect on the water surface, and directly absorbing wave energy (Boesch *et al.* 2006).

While few experimental studies or modeling efforts have specifically addressed the effect of coastal marshes on storm surges, anecdotal data accumulated in Louisiana after Hurricane Andrew in 1992 suggested that storm surge was reduced about 4.7 cm km^{-1} of marsh (3 in $mile^{-1}$ of marsh; Louisiana Coastal Wetlands Conservation Task Force and Wetlands Conservation and Restoration Authority 1998). Extrapolating from this number, a storm tracking from the south

Figure 6. *Photo of a house in the Lakeview area near the University of New Orleans, showing the depth of flooding in this area. After the levees broke, the water level was at sea level, showing the depth of subsidence due to soil oxidation after drainage of the organic wetland soils in this area.*

of New Orleans through existing coastal marshes could have its surge reduced by 3.66 m (12 feet) if it crossed 80 km (50 miles) of marsh before reaching the city.

Since marsh plants hold and accrete sediments (Cahoon *et al.* 1995), often reduce sediment resuspension (Harter and Mitsch 2003), and consequently maintain shallow water depths, the presence of vegetation contributes in two ways: first by actually decreasing surges and waves and second by maintaining the shallow depths that have the same effect. Because wetlands indicate shallow water, the presence of wetland vegetation is also an "indicator" of the degree to which New Orleans and other human settlements are protected.

■ The goal for restoring New Orleans

Before discussing options for restoring New Orleans, we need to consider what we are trying to restore and why. The conventional approach to economic development focuses only on the market economy – the value of those goods and services that are exchanged for money. The purpose is usually taken to be to maximize the value of these goods and services – with the assumption that the more activity, the better off we are. Thus, the more GDP (which measures aggregate activity in the market economy), the better. However, the purpose of the regional economy should be broader – to provide for the sustainable well-being of people. That goal encompasses material well-being, certainly, but also anything else that affects well-being and its sustainability (Costanza *et al.* 1997a).

There is a substantial amount of new research that demonstrates the limits of conventional economic income and consumption in contributing to well-being (Easterlin 2003; Kasser 2003; Layard 2005). Easterlin (2003) has shown that well-being tends to correlate well with health, level of education, and marital status, and with income only up to a fairly low threshold of "enough", concluding that,

> "…most individuals spend a disproportionate amount of their lives working to make money, and sacrifice family life and health, domains in which aspirations remain fairly constant as actual circumstances change, and where the attainment of one's goals has a more lasting impact on happiness. Hence, a reallocation of time in favor of family life and health would, on average, increase individual happiness."

Layard (2005) points out that current economic policies are not improving happiness and that, "happiness should become the goal of policy, and the progress of national happiness should be measured and analyzed as closely as the growth of GNP".

There is also growing evidence that ecological systems produce a range of services that support human well-being (Costanza *et al.* 1997b; Daily 1997; Millennium Ecosystem Assessement 2005; National Research Council 2005; Farber *et al.* 2006). Ecosystem services occur at many scales, from climate regulation at the global scale, to flood and storm protection, soil formation, fisheries, nutrient cycling, recreation, and aesthetic services at the local and regional scales. It has been estimated that the annual non-market value of the Earth's ecosystem services is a great deal larger than global GDP (Costanza *et al.* 1997b; Boumans *et al.* 2002; Patterson 2002).

So if we want to assess the "real" economy – all the things which contribute to real, sustainable, human well-being – as opposed to only the "market" economy, we have to measure the non-marketed contributions to human well-being from nature, from family, friends, and other social relationships, at many scales, as well as from health and education. One convenient way to summarize these contributions is to group them into four basic types of capital that are necessary to support the real, human well-being-producing economy: built capital, human capital, social capital, and natural capital.

Coastal wetlands in Louisiana have been estimated to provide \$940 ha^{-1} yr^{-1} (\$375 ac^{-1} yr^{-1} – these and all subsequent figures have been converted to 2004 US dollars) in storm and flood protection services (Costanza *et al.* 1989; Panel 1). Restoring Louisiana's coastal wetlands and New Orleans' levees has been estimated to cost about \$25 billion. Had the original wetlands and other natural features, such as barrier islands and natural ridges, been intact and the levees in better shape, a substantial portion of the \$100 billion plus damages from this hurricane would have been avoided. Prevention would have been much cheaper and more effective than reconstruction. In addition, the coastal wetlands provide other ecosystem services which, when added to the storm protection services, are estimated to be worth about \$12 700 ha^{-1} yr^{-1} (\$5200 ac^{-1} yr^{-1}; Costanza *et al.* 1997b). Restoring the 4800 km^2 (480 000 ha) of wetlands lost prior to Katrina would thus restore \$6 billion yr^{-1} in lost ecosystem services, or \$200 billion in present value (at a 3% discount rate).

■ What has been done so far?

New Orleans mayor Ray Nagin established the "Bring New Orleans Back" (BNOB) commission shortly after Hurricane Katrina, to develop and implement plans for rebuilding and repopulating the city. The Urban Planning Committee released its final report on January 11, 2006 (Bring New Orleans Back Commission 2006). They begin with a vision for the city:

> "New Orleans will be a sustainable, environmentally safe, socially equitable community with a vibrant economy. Its neighborhoods will be planned with its citizens and connect to jobs and the region. Each will preserve and celebrate its heritage of culture, landscape, and architecture."

This vision is consistent with the ideas about the components of quality of life and the importance of natural,

Panel 1. Storm protection value provided by coastal wetlands

The value of coastal wetlands for storm protection is obviously related to the amount and pattern of built capital that the wetlands are protecting. The design of coastal wetland restoration projects must take this into account in determining the most critical wetlands to restore. If New Orleans were partly or fully abandoned, the storm protection value of the wetlands would decrease accordingly. It is also true that there is an inverse correlation between the total area of coastal wetlands and their storm protection value per unit area. The fewer wetlands remaining, the higher their value per unit area.

social, human, and built capital elaborated in the previous section. To achieve this vision, the commission recommended a city-wide framework for reconstruction, consisting of four elements:

- A Flood and Stormwater Protection plan, including perimeter levees, pumping and gates, internal levees with separate pumps, and coastal wetland restoration.
- A Transit and Transportation plan, including city-wide high speed light rail with links to the airport, Baton Rouge, and the Gulf coast, and more emphasis on bicycles and pedestrian traffic.
- A Parks and Open Space plan, including multi-function parks that are also part of the internal stormwater management system that includes water cleansing.
- A Neighborhood Rebuilding plan, based on neighborhood centers that provide a high quality of daily life.

The BNOB Commission was the result of a broadly participatory process and represents a good start on the process of envisioning and creating a sustainable and desirable New Orleans. Nevertheless, the process and recommendations need to continue a great deal further.

A second set of recommendations (Boesch *et al.* 2006) called for levees to protect human settlements, including New Orleans, coupled with restoration of the coastal marshes and other wetlands. It concluded that planning, investment, and management decisions in coastal Louisiana needed to recognize the forces of nature and the values of natural capital in addition to the protection of life, property, and communities. It also concluded that an effective storm protection system is not possible without coastal restoration.

Seven principals for the restoration of New Orleans and coastal Louisiana

The natural, built, human, and social capital assets of New Orleans have been radically depleted and need to be rebuilt. We can recreate the vulnerable and unsustainable city that was there before, or we can reinvent New Orleans as a new model of a sustainable and desirable city of the future. To do this we need to redesign and restore not only the built infrastructure, but also the social, human, and natural capital of the region. How do we do this and what would a truly sustainable and desirable New Orleans look like? Certainly, the broad outlines of the BNOB commission report and the Boesch *et al.* (2006) report are good starting points. Here are some additional elements of a truly sustainable vision, based on ecological engineering and economics, that extend and amplify those recommendations (Costanza *et al.* 2006):

(1) Let the water decide. Building a city below sea level is always a dangerous proposition. While parts of New Orleans are still at or above sea level, much of it has sunk well below since the first quarter of the 20th century. It is not sustainable or desirable to rebuild these areas in the same way they were before. They should either be replaced with wetlands that are allowed to trap sediments to rebuild the land (see below), or replaced with buildings that are adapted to occasional flooding (ie on pilings or floats or with non-essential items on lower levels; Figure 7). Wetlands inside the levees can help clean waters, store short-term flood waters, provide habitat for wildlife, and become an amenity for the city.

(2) Avoid abrupt boundaries between deepwater systems and uplands. Gentle slopes with barrier islands, shallow waterbodies, wetlands, and natural ridges are the best division, and avoid putting humans, particularly those who have few resources to avoid hydrologic disasters, in harm's way. The abrupt boundaries of the levees are necessary, since natural features such as wetlands and barrier islands alone cannot protect the city, but we need to use both, as appropriate. The idea of avoiding abrupt boundaries is included in the idea of multiple lines of defense, where all of these features are integrated into a comprehensive flood protection system (Lopez 2006)

(3) Restore natural capital. A healthy economy requires a balance of built, human, social, and natural capital. Because of its enormous size (about 25 000 km^2) and productivity, the Mississippi delta is perhaps the most concentrated area of natural capital in North America. This is reflected in the largest fishery and most important flyway terminus in the US, abundant fish and wildlife, high water cleansing ability, and high storm protection services. As discussed earlier, restoring the 4800 km^2 of wetlands lost prior to Katrina would provide a host of valuable ecosystem services, worth roughly \$6 billion yr^{-1}, or \$200 billion in present value (at a 3% discount rate).

(4) To do this we should use the resources of the Mississippi River to rebuild the coast, changing the current system that constrains the river between levees. Diversions of water, nutrients, and sediments, such as those envisioned in the LCA plan, should be greatly expanded in order to allow more rapid restoration of the coastal wetlands. Levees are necessary in some locations, but where possible the levees should be breeched by structures in a controlled way, to allow marsh rebuilding. Reopening old distributaries and allowing crevasse formation are

two additional ways to reconnect the river to the deltaic plain. The reconnection of the river should be integrated with other features, such as barrier island restoration, wise use of dredged sediments, and extensive canal and spoil bank removal, to develop a comprehensive restoration plan. Other restoration resources, such as treated municipal effluent and upland runoff, should also be used (eg Day *et al.* 2004).

(5) Restore the built capital of New Orleans to the highest standards of high-performance green buildings and a car-limited urban environment, with high mobility for everyone. New Orleans has abundant renewable energy sources in the form of sun, wind, and water. The energy issue is absent from the BNOB commission report, but is critical for any design claiming to be sustainable. What better message than to build a 21st century sustainable city, running on renewable energy, on the rubble of a 20th century oil and gas production hub.

(6) Rebuild the social capital of New Orleans to 21st century standards of diversity, tolerance, fairness, and justice. New Orleans has suffered long enough with social capital dating from the 18th (or even the 15th) century. To do this the planning and implementation of the rebuilding must maximize participation by the entire community. This will certainly be difficult for a number of reasons, including the historical antecedents of racism and classism in the region, and the fact that much of the population has been forcibly removed from the city (Cutter *et al.* 2003). Yet it is absolutely essential if the goals of a sustainable and desirable future are to be achieved. The BNOB commission has made a good start in the direction of broad participation, but much more needs to be done.

(7) Finally, we should restore the Mississippi River Basin to minimize coastal pollution and the threats of river flooding in New Orleans. Upstream changes in the 3 million km^2 Mississippi drainage basin have substantially changed nutrient and sediment delivery patterns to the delta. Changes in farming practices in the drainage basin can improve not only the coastal restoration process, but also improve the nation's agricultural economy by promoting sustainable farming practices in the entire basin (Mitsch *et al.* 2001; Mitsch and Day 2006).

Figure 7. *One possible future development pattern for areas at risk for flooding, with non-essential activities (such as garages and parking) on the ground floor.*

The restoration of New Orleans and the rest of the Mississippi delta can become another expensive disaster waiting to happen, or it can become a model of sustainable development. If it is the latter, it could be a truly unique inspiration to billions of people around the world. What better way to say to the world "look at what can be accomplished" than to create a sustainable and desirable city, shining like a jewel on the Mississippi, where all the streetcars run on renewable energy and are named "Desirable".

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