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Changes in Victoria Harbour, Hong Kong, 1969-2003

The above image was produced from the Corona photo collected in 1969 and the Landsat-7 image acquired in 2003 (Back cover). The blue colour indicates the area of reclaimed land over the period, 1969-2003.

The Earth From Afar: Image Review

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New Orleans Awaits the "Big One"

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In Southern Louisiana, the "Big One" is a catastrophic hurricane with storm surges that would swallow up the entire city of New Orleans and the surrounding environs. In 1969 hurricane Camille, as a Category 5 storm with winds of 200 mph (322 kph), came ashore only 60 miles (97 kilometers) east of the city in Mississippi as the strongest hurricane on record. It sent a twenty-four foot sea surge through the coastal sections of southern Mississippi. If Camille had landed within 20 or 30 miles (32 or 48 kilometers) of New Orleans, it would have most likely destroyed the city and resulted in a great number of deaths. In the last 120 years, 12 or 13 major hurricanes with winds over 111 mph (178.6 kph) have hit within 85 miles (137 kilometers) of the city. This averages to one major storm per decade. Since the last major storm to reach near New Orleans was over 35 years ago, the city is ripe for a large hurricane.

Mark Fischetti states in *Scientific American*, that:

> "New Orleans is a disaster waiting to happen...If a big slow-moving hurricane crossed the Gulf of Mexico on the right track, it would drive a sea surge that would drown New Orleans under 20 feet of water...Scientists at LSU [Louisiana State University] who have modeled hundreds of possible storm tracks on advanced computers predict that more 100,000 people could die."

New Orleans, a city with over 400,000 people and another one million living in its immediate environs, sits between the Mississippi River and Lake Pontchartrain, constantly struggling to endure against floods and hurricanes (Figure 1). Nearly half of the city ranges between 8 and 10 feet (2.4 and 3.0 meters) below sea level. The city is surrounded by levees to protect it from floodwaters, and huge pumping stations to keep the area dry. The city is a large "bowl" waiting to be flooded. It is located on one of the worst sites for any big city in the United States.

Vast and Rich Situation

Why would a city develop and grow here? Pierce Lewis describes New Orleans as the "inevitable city on an impossible site." It was inevitable that a large city would be built in southern Louisiana where the Mississippi River flows into the Gulf of Mexico. The Mississippi River and its tributaries drain two-thirds of the United States. This arrangement provides the city with a vast and rich situation or hinterland. However, the potential of this exceptional situation did not materialize immediately when the French and Spanish controlled the city. It took the expansion of the United States from the Atlantic to the Pacific to provide political and economic unity to this vast river system, and thereby, bring about the development of the city as a major port. Today, New Orleans receives and distributes by water millions of tons of products, making it one of the busiest ports in the world.

Nearly 400,000 river barges that carry a vast range of cargo throughout the Mississippi River system arrive at New Orleans each year. A modern day barge is frequently joined together with several other barges to form a single elongated vessel, which is pushed by a river boat. Some of these assemblages can reach lengths of 1200 feet (365 meters), the surface size of a large aircraft carrier. Cotton, rice and soybeans from the Mississippi Lowlands, corn and soybeans from the Mid-West, wheat from the Great Plains, and coal from the Appalachian Mountains are among just a few of the products carried by these barges to New Orleans.

Inhospitable Site

This outstanding situation almost dictates the need for a major port city on the Mississippi delta in southern Louisiana; however, determining the exact site for such a city has not been an easy task, let alone maintaining it. The delta is an extremely flat environment, covered mainly by marsh and watery muck and laced by bayous and distributaries, sometimes making it very difficult to find paths through the region. It has been described as "a land between earth and sea, belonging to neither." The region is also prone to excessive heat and high humidity, frequent floods, heavy downpours of rain, numerous disease and health problems, and hurricanes.

In determining the location of a port it was apparent that the city had to be on the river. However, in geological time, the Mississippi River has fluctuated frequently back and forth across the delta, not allowing the river to establish a fixed course for long periods. At New Orleans, the Mississippi's present riverbed is only about 1,000 years old. Once the city developed as a major port, steps had to be taken to make sure that the river maintained its existing course. If in the 1950s the U.S. Army Corps of Engineers had not intervened by building a series of huge spillways called the Old River Control Structures located above Baton Rouge, the river would have diverted its course sometime during the latter half of the 20th century and taken the path of the current Atchafalaya River. This almost happened in 1973 when a major flood nearly destroyed the control structures. This course change would have reduced the river's distance to the Gulf of Mexico by half and would have left New Orleans stranded. Even now thirty percent of the Mississippi River's water is diverted into the Atchafalaya River in order to reduce the pressure on New Orleans' levees. With this volume the Atchafalaya is one of the largest rivers in North America.

Figure 2 is a true-color MODIS image taken on March 5, 2001. It shows the murky brown water of the Mississippi mixing with the dark blue water of the Gulf of Mexico. New Orleans appears in light gray near the center of the image, just below Lake Pontchartrain. The second large murky brown water concentration on the west side of the image is the Atchafalaya River discharging sediment into the Gulf. If the Atchafalaya became the main course of the Mississippi, a new port city would have to be established and much of the capital investment in New Orleans would be lost.

Even though it is evident that a port city had to be established on the river, one might ask, "Why couldn't the port be developed much farther up-river where better sites exist?" Based on the depth and size of the river, ocean going ships are limited to how far they can navigate inland. As ships have become larger over the years, the size and depth of the river at New Orleans has become more of a problem. At Canal Street, the river is 2200 feet (670 meters) across with a mid-stream depth of 100-180 feet (30-54 meters). Due to the depth of the river New Orleans has become a break-in-transportation point between ocean going ships and river boats that require less depth and can carry goods throughout the river network. With all of the goods being transported and exchanged at New Orleans the city has never developed a major industrial base. It is a "through port," not a "terminal port." It handles a large amount of raw goods but fails to do much with the goods in terms of manufacturing, and thereby, add value to the products and wealth to the city.

Levees

During floods, silt is deposited along the river's banks.

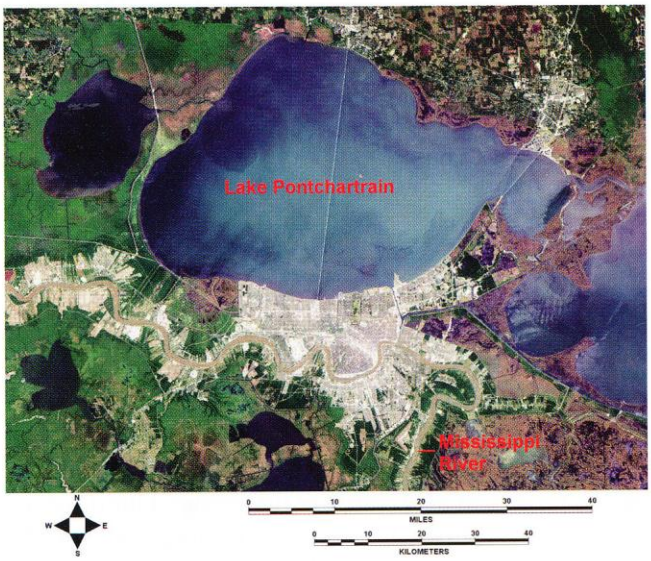

Figure 1 Landsat 7 true-color composite of New Orleans and environs taken on November 18, 1999.

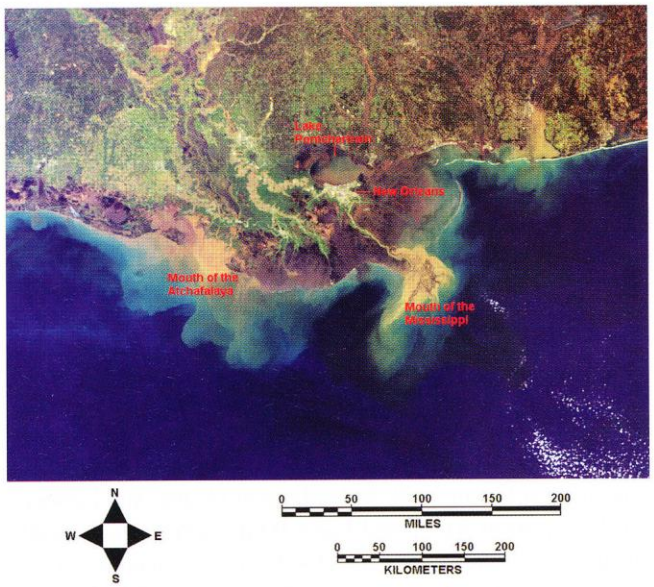

Figure 2 A true-color MODIS image taken on March 5, 2001. Image produced by Liam Gumley, Space Science and Engineering Center, University of Wisconsin-Madison and the MODIS science team.

As this silt builds up, it forms a natural levee, which gradually decreases away from the banks. These natural levees provided some of the best dry land for settlement along the river. Figure 3-A is a map of the river in 1749. The natural levees can be seen along the river, and New Orleans, which was platted in 1718, is shown on the north side of one of the large bends in the river. This section of New Orleans is today called the French Quarter. Figure 3-B identifies elevation conditions within the present city. The green colored areas are sections of city where the land is above sea level. Note how these areas correspond to the natural levees indicated on the 1749 map. The blue colored areas are sections at sea level and the red areas represent sections below sea level. Due to the great semicircular "Crescent Curve" in the river, the natural levees merged together from three different directions providing a large area of land above sea level. Figure 3-C is a Landsat 7 image of the city, which can be spatially related to Figure 3-A and 3-B.* The older and main parts of New Orleans rest on the natural levees where the land is the most solid and the driest. The newer sections of the city lie at or below sea level (Figure 4).

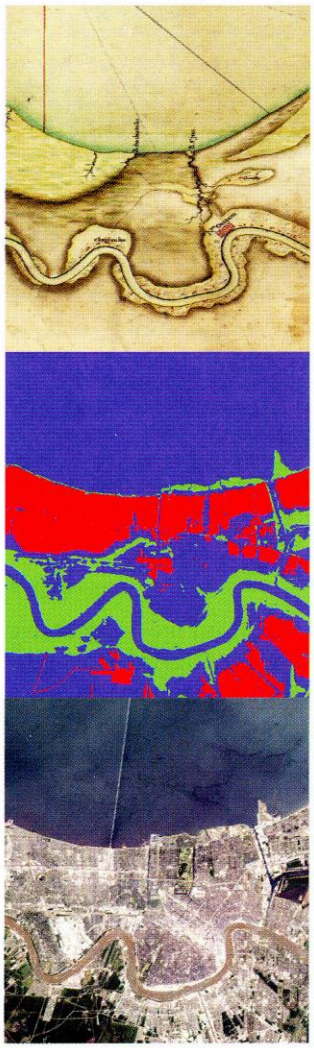

Figure 3 A-B-C: Figure 3-A (top) is a 1749 map of New Orleans; Figure 3-B (middle) shows current elevation conditions within the city; and Figure 3-C (bottom) is a Landsat 7 image.

Even with these natural levees, it has been necessary to construct artificial levees around the city. Today, 20 foot (6.1 meters) high levees guard the city against the river and 15 foot (4.5 meters) levees hold back Lake Pontchartrain. In addition to protecting the city against floods, the levees elevate the river so that it is normally 10 to 15 feet (3.0 to 4.5 meters) above sea level. Standing in the French Quarter's Jackson Square one must look up to observe river traffic. Artificial levees extend down the river toward the Gulf and in many sections the river is higher than its adjacent floodplain. No natural levees developed along the banks of Lake Pontchartrain. Thus, artificial levees had to be constructed. Most of the land behind these levees is below sea level (Figure 3-B).

The artificial levees, designed to hold back flood waters, enhance the "bowl effect" within the city. To keep water from accumulating in the bowl after heavy rains, floods, and storm surges, the city has twenty-two large pumping stations (Figure 5). Collectively, these stations are capable of pumping 35 billion gallons of water per day, most of which is drained into Lake Pontchartrain. This amount of water relates to a lake that covers 8 square miles (12.8 square kilometers) and 10 feet (3.0 meters) deep. A network of 185 miles (298 kilometers) of covered and open canals throughout the city channel water to the stations. A canal under Napoleon Street is wide enough to handle three side by side buses.

In addition to levees and pumps to keep the city dry and protect it from floods, the Bonnet Carre Spillway, located about 30 miles (48 kilometers) up-river, can be used to divert flood water into Lake Pontchartrain. The spillway is approximately a mile and a half wide and covers 8,000 acres (3238 hectare) of floodway land. It is designed to send 250,000 cubic feet (7080 cubic meters)

Figure 4 A motel complex behind a levee. The rooms on the first floor are below sea level.

* Note that the river has changed course slightly since 1749.

of water per second into the lake. Due to the spillway, levees, and pumps New Orleans has not experienced a flood from the Mississippi or Lake Pontchartrain since 1927.

However, as the levees keep the city dry, they also prevent the land within the city from being replenished through flooding. As a result, the land continues to sink and the "bowl" becomes deeper, making it more vulnerable to flooding from hurricane storm surges. Also, as the artificial levees channel sediment down the river into the Gulf of Mexico, they keep the sediment from depositing on the coastal wetlands to the south of the city and become one of the major contributors to the loss of coastal land in southern Louisiana. Within the last 50 years, more than 1,000 square miles (1,609 square kilometers) of Louisiana have been consumed by the Gulf of Mexico, the equivalent of a football field every half-hour. The loss of this land reduces the effectiveness of the coastal wetlands as a barrier for the city against a hurricane. According to the Louisiana Department of Resources Office of Coastal Restoration and Management, the current land loss rate of coastal wetlands will by 2050 place the Gulf of Mexico 30 miles (48 kilometers) more inland (Hallowell). To rebuild these wetlands will take time and an estimated $14 billion. In effect, the levees that are protecting the city against the river are exposing it more to hurricanes.

Hurricanes

A tremendous amount of effort and cost has gone into making the site of New Orleans a livable and workable place. Much of this effort and cost has been directed toward making the city safe against floods. However, little has been done to protect the city from hurricanes. In the case of a flood, water can be diverted. No method exists to divert a hurricane. When a flood is coming down the Mississippi, its path and timing are known and the appropriate action can be taken to move to higher land. Hurricanes are erratic. They can change paths within a few hours, providing little or no time to react.

In recent decades such major hurricanes as Andrew (1992), Betsy (1965), and Camille (1969) have come extremely close to New Orleans, only to change courses slightly at the last moment. Andrew, a Category 5 hurricane, slammed into Louisiana about 100 miles southwest of New Orleans at 165 mph (265 kph); Betsy, a Category 4 hurricane, came ashore about 50 miles (80 kilometers) southeast of the city at 155 mph (249 kph); and Camille, a Category 5 hurricane, battered southern Mississippi about 60 miles (97 kilometers) east of the city at 200 mph (322 kph). Of these three huge storms, Betsy came the closest to hitting New Orleans directly. It crossed the city as a downgraded Category 2 hurricane with winds at 105 mph (169 kph) and created a storm surge in Lake Pontchartrain that pushed water over the levees and flooded large sections of the city (Todd). The 8 to 10 foot (2. 4 to 3.0 meters) surge submerged parts of the city in 7 feet (2. 1 meters) of water. Based on current U.S. dollars, it did $8.4 billion in damages, tying it for the third most expensive hurricane in U.S. history. Betsy prompted the U.S. Congress to authorize the U.S. Army Corps of Engineers to increase the levees along Lake Pontchartrain to 16 feet (4.9 meters) (Shallat). At this level, these levees might withstand a Category 2 hurricane but studies indicate that a Category 4 or 5 - and even a slow moving Category 3 storm - will send water over these levees (Hallowell).

Figure 5 One of the city's twenty-two large pumping stations.

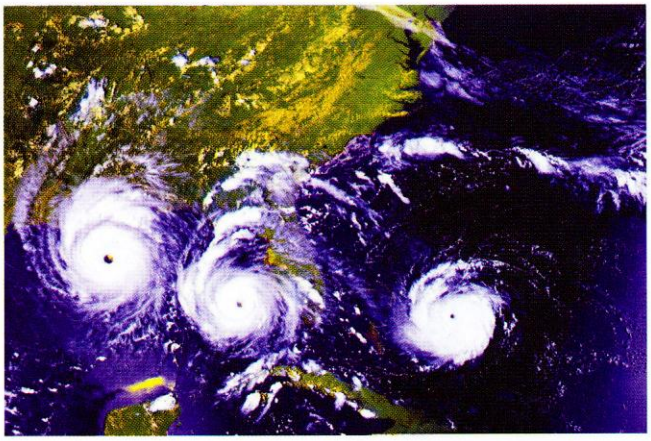

Figure 6 This image shows three views of Andrew corresponding to August 23, 24 and 25, 1992 as the hurricane first bears down on southern Florida, then crosses the Gulf of Mexico, and heads for southern Louisiana and New Orleans. This images was constructed using cloud data from GOES-7 (Geostationary Operational Environmental Satellite) and vegetation coverage from AVHRR (Advanced Very High Resolution Radiometers). Image produced by F. Hasler, M. Jentoft-Nilsen, H. Pierce, K. Palaniappan, and M. Manyin

Computer models developed by the Louisiana Water Resources Research Institute at Louisiana State University project that a slow-moving Category 3 or any Category 4 or 5 hurricane passing within 20 to 30 miles (32 to 48 kilometers) west of New Orleans would with its counterclockwise winds create storm surges over shallow Lake Pontchartrain that would overwhelm the 15-foot (4.5-meters) levee along the lake. Water would pour into the city as high as 20 to 30 feet

(6.1 to 9.1 meters), inundating most homes and reaching the first three or four stories of buildings. The pumping station would be under water and not able to function. The city and its surrounding environs could be submerged for more than 10 weeks and it would take years to rebuild (West). The human and economic consequences of such a disaster would reach far beyond New Orleans and impact all Americans.

On September 27, 1998, Hurricane George swirled out of the Gulf and was heading directly for New Orleans with winds at 110 mph (177 kph). The threat of this storm resulted in the largest evacuation of any American city when over 300,000 people fled the city heading for higher ground. This number does not include the thousands living in the immediate environs who also fled for protection. An estimated 100,000 people were forced to remain in the city. These were people from poor neighborhoods, elderly or disabled people, and tourists. These people had no access to cars, and if they did have transportation, they would have found themselves trapped on Interstate 10 with all of the other people trying to leave. Fortunately, at the last moment, the storm downgraded to a Category 2 hurricane and shifted slightly eastward toward Gulfport, Mississippi (Lewis). If George had followed the worst case scenario identified by the computer models, 100,000 people could have perished.

A similar situation occurred in September 2004 when Ivan came across the Gulf and appeared to be bearing down on New Orleans with winds of 140 mph (225 kph). Again, traffic on Interstate 10 was near a standstill and west of the city the highway was converted into a one-way route out. The Louis Armstrong Airport was closed. The national convention for the National Safety Council ended a day early in order for its delegates to leave before the hurricane arrived but most of the 10,000 delegates had no transportation to get out of the city (Grunwald and Roig-Franzia). Ivan eventually shifted eastward toward the coast of Alabama and the panhandle coast of Florida. New Orleans again avoided the "Big One" but someday it will arrive.

Addendum

As this paper was being sent to press, Hurricane Katrina hit the New Orleans area. Preliminary reports indicate that the Big One may have arrived.

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