TIDE-1220 New Orleans & Hurricanes

Tulane University Prof. Stephen A. Nelson

Why New Orleans is Vulnerable to Hurricanes
Geologic and Historical Factors

Fall 2012

This document last updated on 10-Dec-2012

Myths Involving Hurricane Katrina

1. New Orleans survived Hurricane Katrina on August 29, 2005 - then the levees broke the next day to flood the city.

   False: All levees breached before 10:00 AM on the morning of August 29, 2005!

2. Mississippi River levees (or Lakefront levees) breached.

   False: No Mississippi River levees in New Orleans breached, some Lakefront levees did overtop, but none breached.

3. Levees that failed were built by "corrupt" local levee boards.

   False: All of the levees that failed in New Orleans were built under the supervision of the U.S. Army Corps of Engineers.

4. New Orleans is a city below sea level.

   Partially False: Roughly half the city and surrounding metropolis is above sea-level (Figure 1)

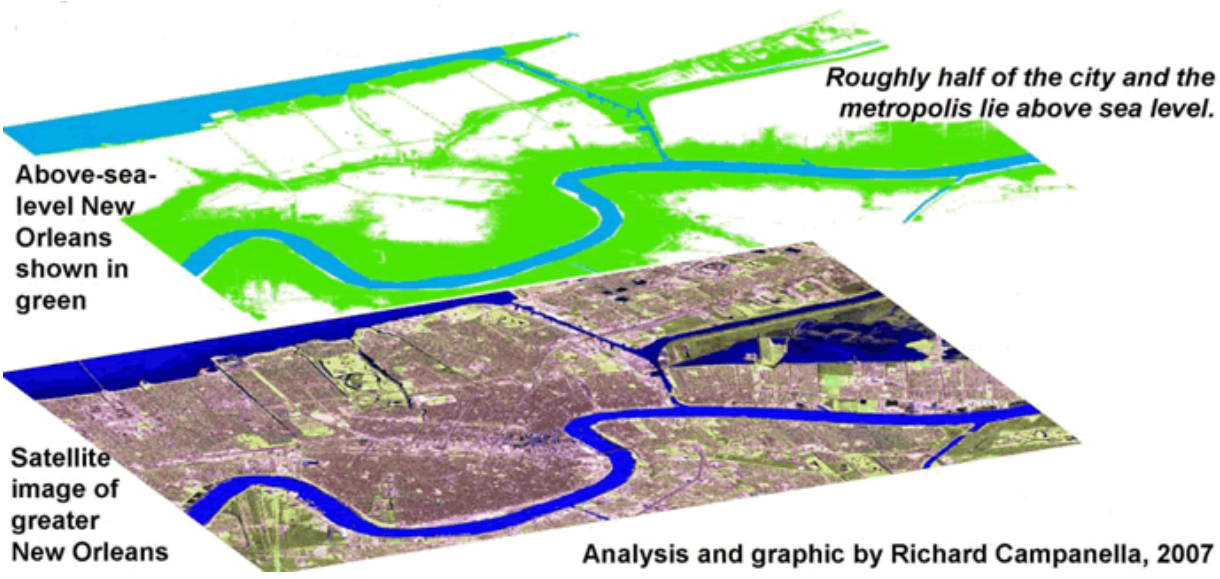


Figure 1

Geologic History of the New Orleans Region

The land on which New Orleans is built has origins that began about 5,000 years ago. As sea level was rising after the last glacial maximum, a series of barrier islands was built outward from the coast of Mississippi across what is now the southeastern edge of Lake Pontchartrain (Figure 2). These islands, called the Pine Islands were composed mainly of sand whose source was the Pearl River along the Mississippi – Louisiana border. At the time the Mississippi River was building its delta out toward the southeast of New Orleans building the Maringouin and Teche lobes of the delta complex (Figure 3). Beginning about 4,300 years ago the Mississippi River began to build the St. Bernard Delta lobe out toward the east. This lobe eventually intersected the Pine Island Barrier Island complex, eventually burying the sands, cutting off the drainage from the north to form Lake Pontchartrain, and building the land on which New Orleans would later be built.

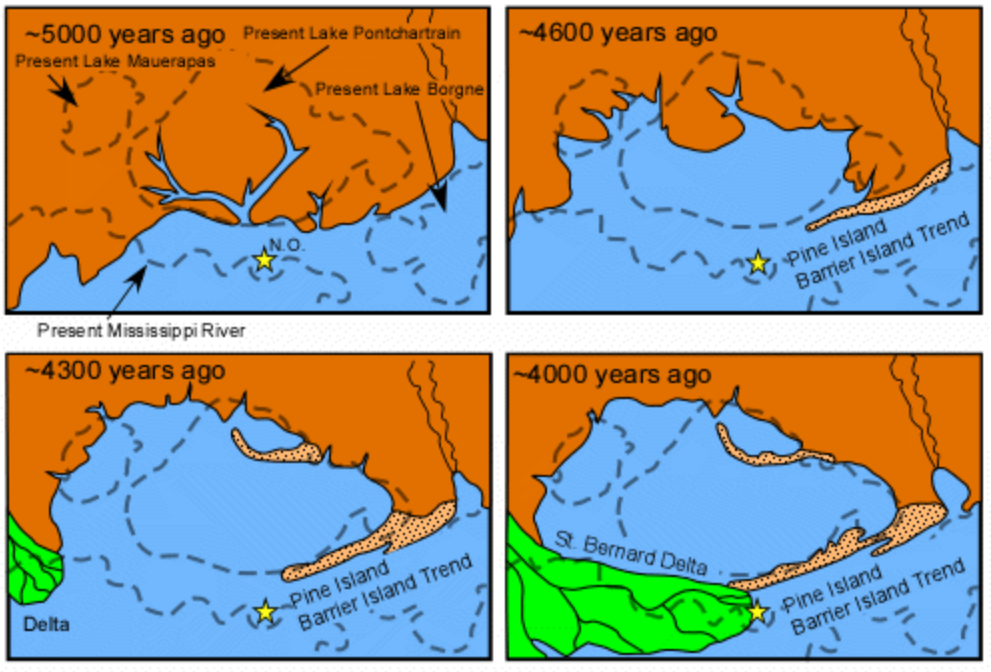


Figure 2

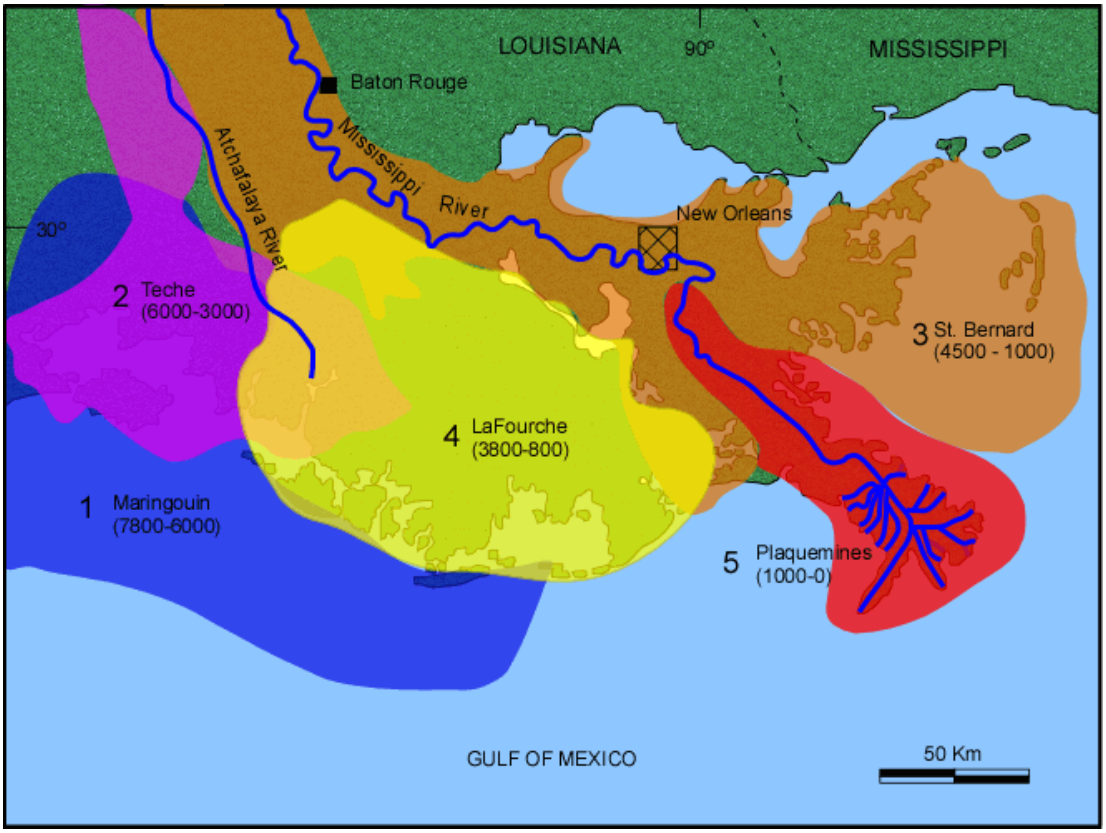


Figure 3

The streams forming the delta lobes normally break up into distributary streams due to the fact that they are continually depositing sediment which chokes of some channels requiring the formation of other channels. The distributary channels often flood, and during flood stage they deposit sediment on their banks which eventually build natural levees along the banks. The natural levees from areas of higher elevation on the delta plain, with the low lying areas in between forming marshes or swamps that accumulate fine-grained organic-rich sediment (organic clays) as illustrated in Figure 4.

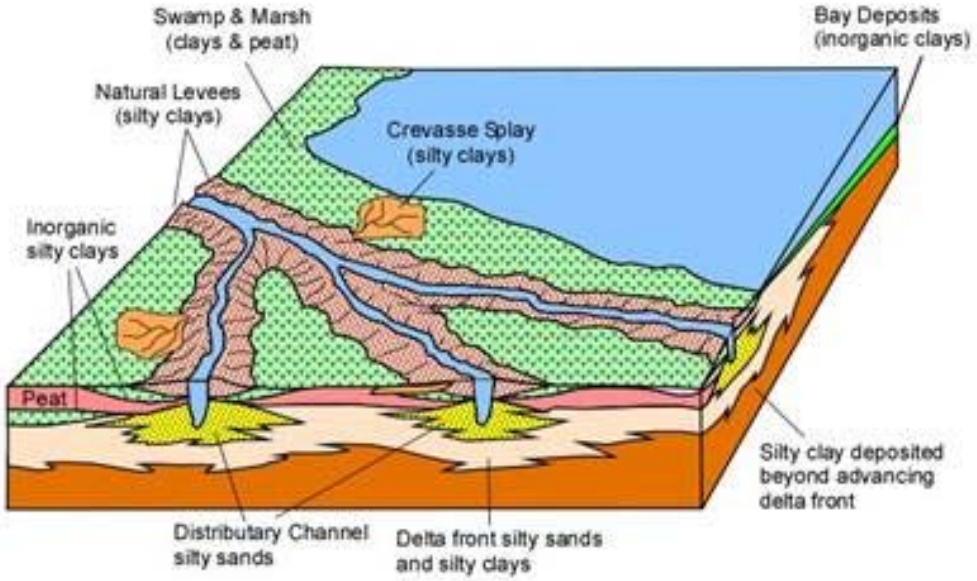
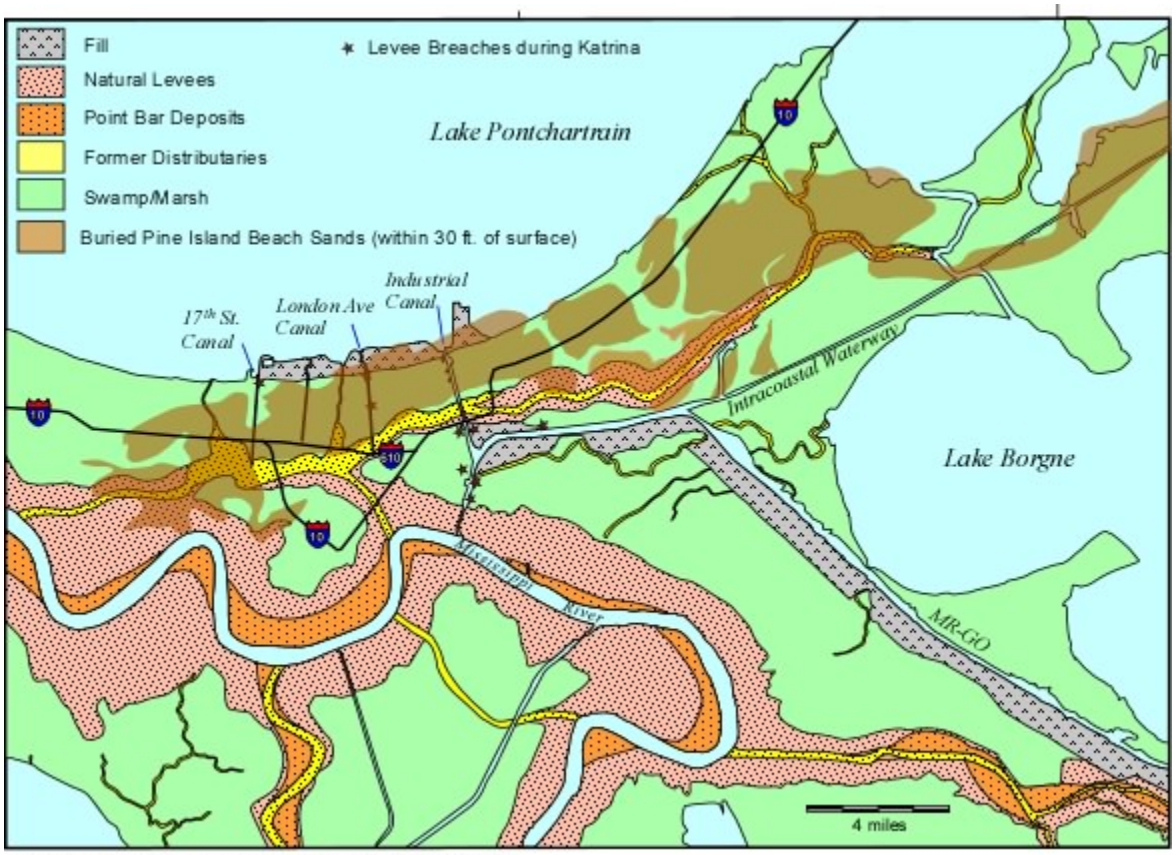


Figure 4

During the building of the St. Bernard Delta lobe, several such distributary channels crossed

through what would later become New Orleans, and the natural levees for these distributaries are now seen as ridges of slightly higher elevation, now known as the Metairie, Gentilly, and Esplanade Ridges (Figs. 5 & 6).



Based on Army Corps of Engineers Geologic Maps

Figure 5

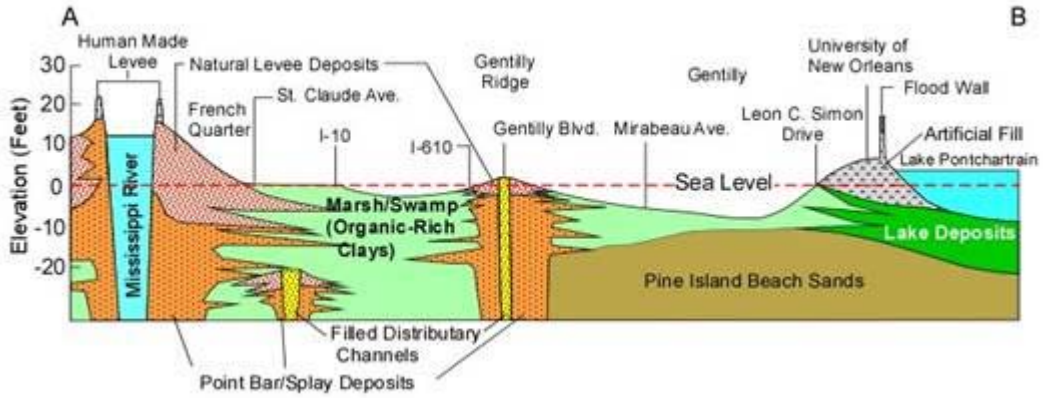


Figure 6

Human History of New Orleans

New Orleans was founded in the year 1718 by Jean Baptiste La Moyne, Sieur de Bienville where the first settlement was at the location of the French Quarter (about 17 feet above sea-level). The city grew along the high ground, which included the natural levee of the Mississippi River and the Metairie and Gentilly ridges (about 3-4 feet above sea-level). Because of its crescent shape along the meander bend of the River, it gained its nickname, The Crescent City. Drainage was a continual problem because of the topography of the region and although Bayou St. John offered a natural

drainage from the central part of the crescent to Lake Pontchartrain, it was not enough to drain the often heavy rainfall that occurred. Thus, a drainage system consisting of canals that drained into three outfall canals running from South to North into the Lake was designed and built. Because of the intervening high ground of the Metairie/Gentilly ridges, it was necessary to raise the water at the ridges to get it into the outfall canals.

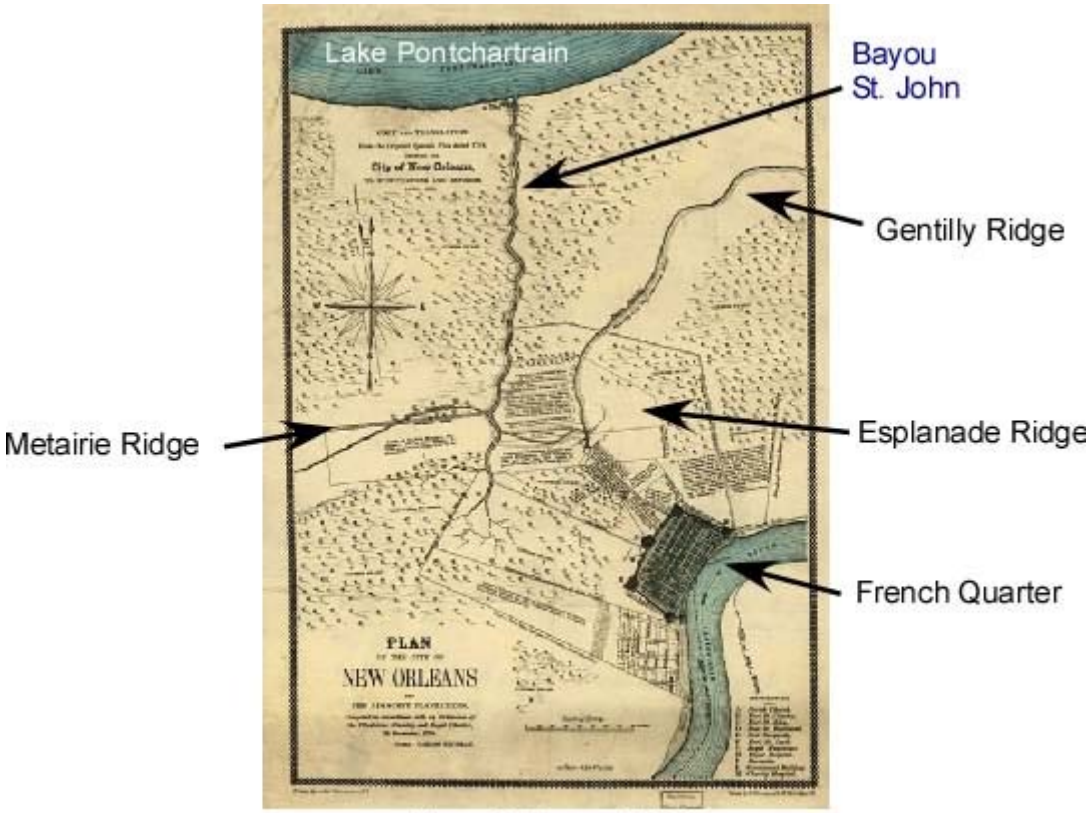


Figure 6

By the mid 1800's this had been accomplished with the main outfall canals from west to east being the Metairie Outfall Canal (now called the 17th St. Canal), the Orleans Canal, and the London Ave. Canal. These canals can be seen on the 1878 map of New Orleans shown in Figure 7. Initially water-wheel like machines (called drainage machines) lifted the water about 8 feet at the ridges after which it would flow by gravity through the outfall canals and into the Lake. Still, by the late 1800s the area in the central part of the city and nearly all of the area north of the Metairie and Gentilly ridges was swamp or marsh.

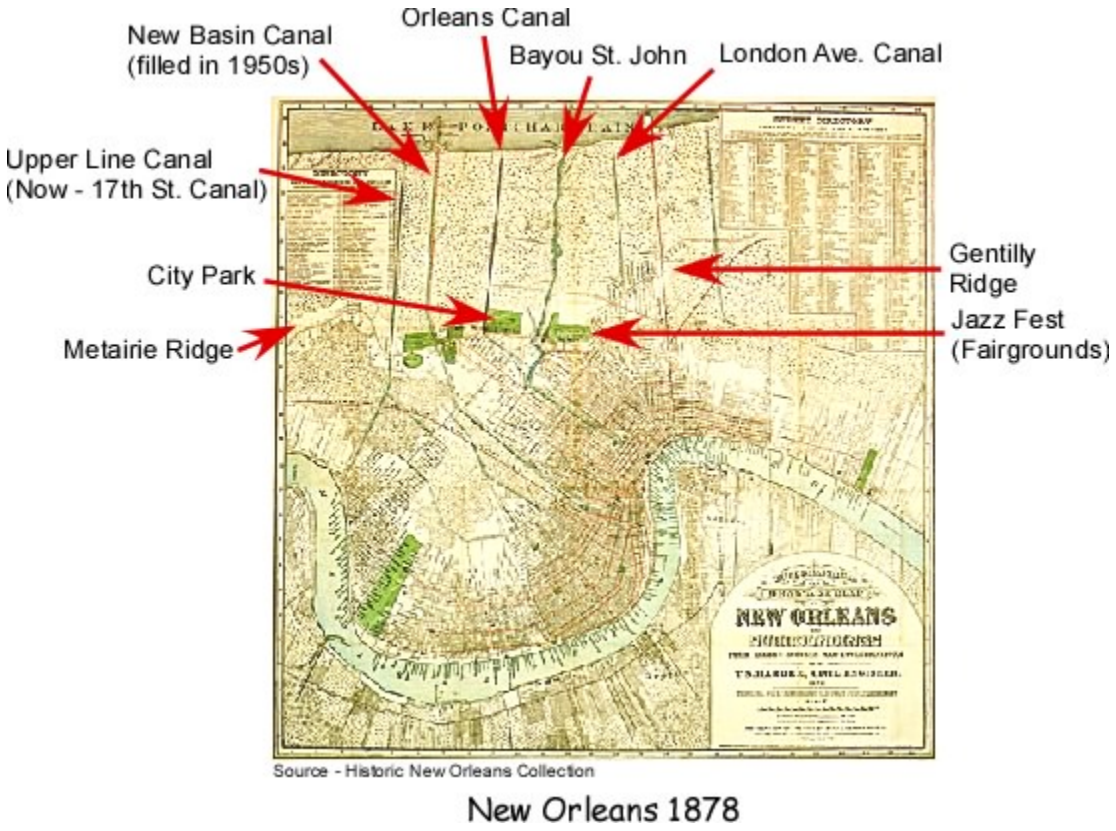


Figure 7

Then, in 1913, Albert Baldwin Wood, a New Orleans Sewerage and Water Board engineer, invented giant screw pumps. These pumps were employed at the ends of the outfall canals to lift the water from the low lying areas to the south of the ridges into the canals. With this improvement in drainage capacity, the swamps north and south of the ridges were drained to provide further habitable land for the growing city. But, it also left the city much more vulnerable to storm surge entering from Lake Pontchartrain, as the outfall canals bounded by low levees, contained water at levels higher than the surrounding land. It was a mistake that would prove critical on the arrival of Hurricane Katrina when levees on the 17th St. and London Ave. canals failed and allowed Lake Pontchartrain to essentially drain into the city.

Critical Events in New Orleans' Hurricane History

- Since the year 1759, 176 hurricanes have struck the Louisiana Coast
- Frequency is about two hurricanes every three years
- 38 hurricanes have caused significant flooding in New Orleans
- Hurricane Flooding frequency is about once every 6.5 years.

Significant Hurricane Flooding Events

First hurricane in 1722 - nearly wiped out New Orleans

Other Hurricanes in 1778, 1779, 1790, & 1794 destroyed buildings and sunk ships in the

Mississippi River

Aug. 9, 1812 “Great Louisiana Hurricane” flooded areas north of city along Lake Pontchartrain. Populated part of New Orleans was protected by the Metairie/Gentilly Ridges

Aug. 16,1831 “Great Barbados Hurricane - Mississippi River levee broke and flooded French Quarter

Although not related to a Hurricane, a Levee Breach in 1849 on the Mississippi River upstream at the Suave Plantation caused water to flow into New Orleans south of the Metairie Ridge causing serious flooding.

1860 - Three Hurricanes struck New Orleans area. One on October 2, caused storm surge in Lake to destroy lake front villages and flood areas north of French Quarter. Again the populated part of the region was somewhat protected from storm surge from Lake Pontchartrain by the Metairie/Gentilly Ridges

1871 - 3 hurricanes create storm surge in Lake that causes localized flooding in New Orleans. City Surveyor W. H. Bell warns of storms moving up drainage canals - suggests moving pumps to lakefront.

1915 Hurricane floods city through drainage canals. 275 deaths

Sept. 19, 1947 Hurricane floods part of city along Industrial Canal and drainage canals. 51 deaths

Sept. 9, 1965 Hurricane Betsy floods on both sides of Industrial Canal. Storm surge entered from Lake Borgne through the recently completed Mississippi River-Gulf Outlet (MR-GO). Hurricane Protection System authorized by Congress shortly thereafter.

Aug. 17, 1969 Hurricane Camille (Cat. 5) hits Mississippi Coast, New Orleans spared from flooding

Sept. 26-28, 1998 Hurricane Georges approaches New Orleans - first time evacuation of city is called for.

Sept. 14-15, 2004 Hurricane Ivan approaches New Orleans, - second evacuation - first time for Contraflow

August 29, 2005 - Hurricane Katrina passes to the east of New Orleans (See Figure 8).

- Creates 28 foot high storm surge on Mississippi Gulf Coast
- 18 foot high storm surge in Lake Borgne flooding nearly all of the populated portion of St. Bernard Parish.
- 15 foot storm entering the Industrial Canal through the MR-GO, Intracoastal waterway, and Lake Pontchartrain overtops floodwalls, and breaches levees on floodwalls on both sides of the Industrial Canal.
- 11 foot storm surge in Lake Pontchartrain enters 17th St. and London Avenue drainage canals. Canal floodwalls are not overtopped, but floodwalls/levees fail at two locations on the

London Ave. Canal and one location on the 17th St. Canal.

- All levee breaches were on human made navigation or drainage canals and all were levees and floodwalls that had been built by the U.S. Army Corps of Engineers, some as recently as the mid- 1990s

- Floods over 80% of the city and results in over 1500 deaths.

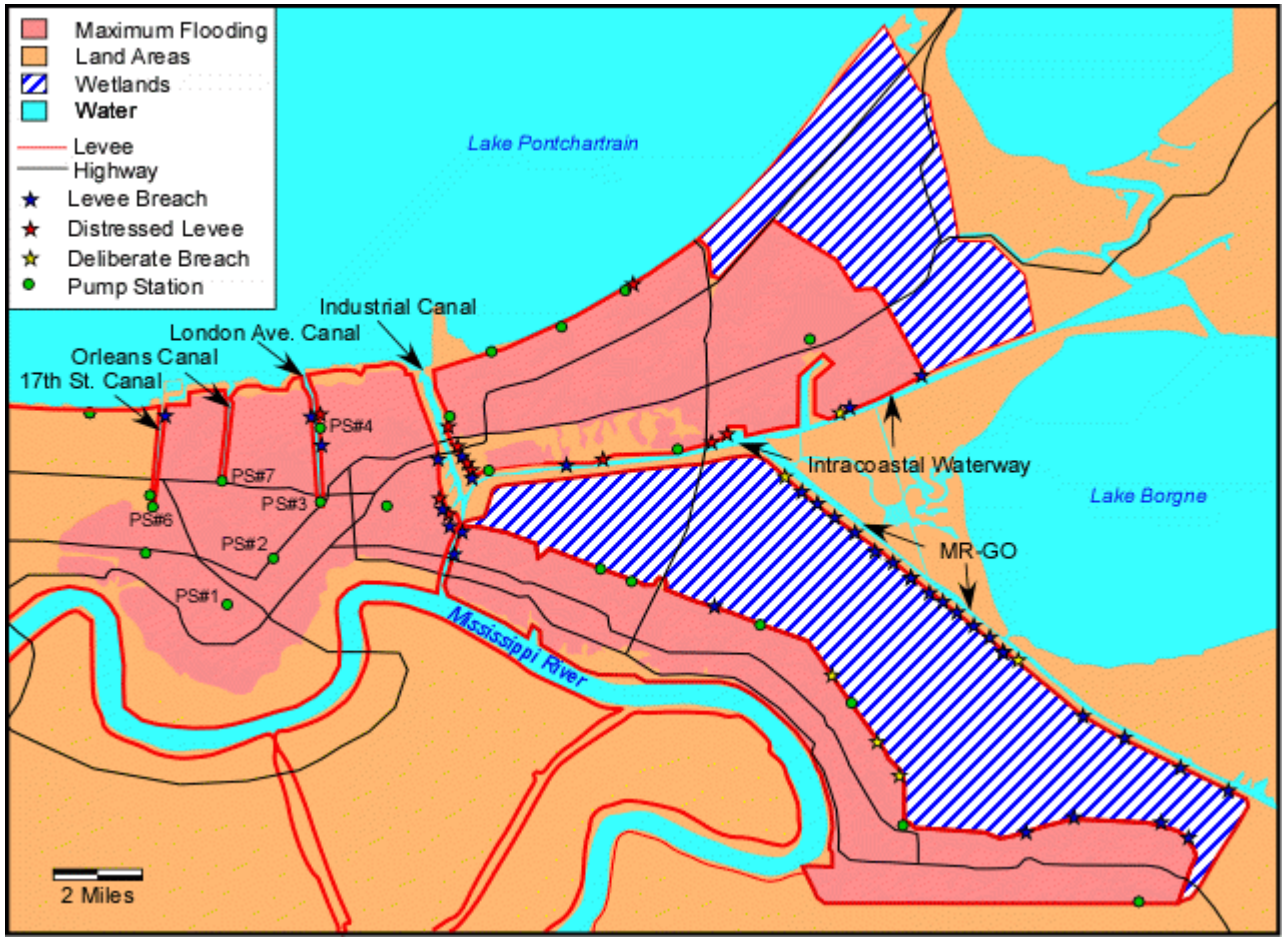


Figure 8

Sept. 1, 2008 Hurricane Gustav - New Orleans Evacuated. Did not flood New Orleans, but did fill the Industrial Canal dangerously close to the top of the floodwalls.

August 29, 2012 Hurricane Isaac - A slow moving Category 1 hurricane caused power outages and wind damage in New Orleans. The new hurricane protection system did will, but the conditions were not severe enough to give it a substantial test. Areas outside the hurricane protection system suffered severe flooding. In Particular the community of Braithwaite, on the east bank of Plaquemine Parish flooded when storm surge overtopped the non-federal levee and was trapped between that levee and the Mississippi River levee. LaPlace at the southwestern end of Lake Pontchartrain, and Madisonville, Mandeville, and Slidell on the northern shore of Lake Pontchartrain flooded from storm surge from the Lake.

The Hurricane Protection System
(Pre-Katrina)

- Hurricane Betsy in 1965 flooded portions of eastern New Orleans, the Upper Ninth Ward, Lower Ninth Ward, and Gentilly.
- In response, Congress authorized the Lake Pontchartrain and Vicinity, Louisiana Hurricane Protection Project - authorized by Congress in the Flood Control Act of 1965.
- Expected to take 13 years to complete and cost $85 million.
- Designed to protect the New Orleans region from a fast moving Category 3 Storm that would be expected to strike once every 200 to 300 years. Such a storm was designated as the "Standard Project Hurricane".
- Costs were shared - 70% Federal, 30% Local (taxes collected by Levee Districts)
- By 1982, the estimated cost had grown to $924 million
- In 2005 (before Katrina) the expected completion date was projected to be 2017.

Two plans were proposed by the Army Corps of Engineers:

The Barrier Plan

- In the 1970s the Corps proposed building barriers and closeable navigation gates across the 2 inlets into Lake Pontchartrain to prevent hurricane storm surge from Lake Borgne and the Gulf of Mexico from entering the Lake.
- An organization called Save Our Wetlands, filed a lawsuit objecting to the 4 page Environmental Impact Statement (EIS) presented by the Corps, and Judge Charles Schwartz in 1977 ruled that the EIS was inadequate, ruling that the Corps must return with a better EIS (Schwartz, 1977).
- In 1980, the Corps, rather than issue an acceptable EIS, decided against the construction of the barriers and gates.

High Level Plan

- In the 1980s the Corps proposed building levees and floodwalls to a height necessary to keep storm surge from the Lake Pontchartrain and Lake Borgne from entering the city.
- For the three drainage canals, the Corps propsed two plans. One involved putting moveable gates at the Lake ends of the drainage canals (London Avenue, Orleans, and 17th St.). Alternatively they proposed to raise the height of the levees on the canals. The latter was called the Parallel Plan. The Corps stated that it believed either plan would be equally effective.
    - The Sewerage & Water Board and Orleans Levee Board objected to putting gates at the end of the canals because the Corps refused to consider inclusion of pumping stations at the gates that would pump rainwater out of the city into the Lake when the gates were

closed during a hurricane.

- For the 17th Street Canal, the Corps had no stated prefence because the cost of the gates was roughly the same as the Parallel Plan. The Corps approved raising the height of the levees along the canal because local officials preferred this option.

- For the London Avenue and Orleans Canals, the Corps preferred the gates plan because it was significantly cheaper than the Parallel Plan (three times less for London Avenue and five times less for Orleans).

- The Sewerage and Water Board and Levee Board successfully lobbied Congress for more money for the Parallel Plan. The Corps was ordered to raise the levees and floodwalls on the canals and not build the gates, through passage of the Water Resources Development Act of 1990 (passed in 1992).

- A levee is a mound of dirt piled up to prevent the inflow of water. Raising the height of a levee also requires widening the levee because dirt can't hold up to steep slopes. In an urban environment like New Orleans, widening a levee would require buyouts of property along the levee. This would have been quite expensive.

- Instead, concrete floodwalls were proposed and built since a floodwall can be quite steep and still provide a higher level of protection.

- Two types of floodwalls were used in the New Orleans hurricane protection system (Figure 9)

  - I-walls were the most commonly used type of floodwall in the New Orleans flood protection system.

  - T-walls offer more resistance to failure, but are more expensive.

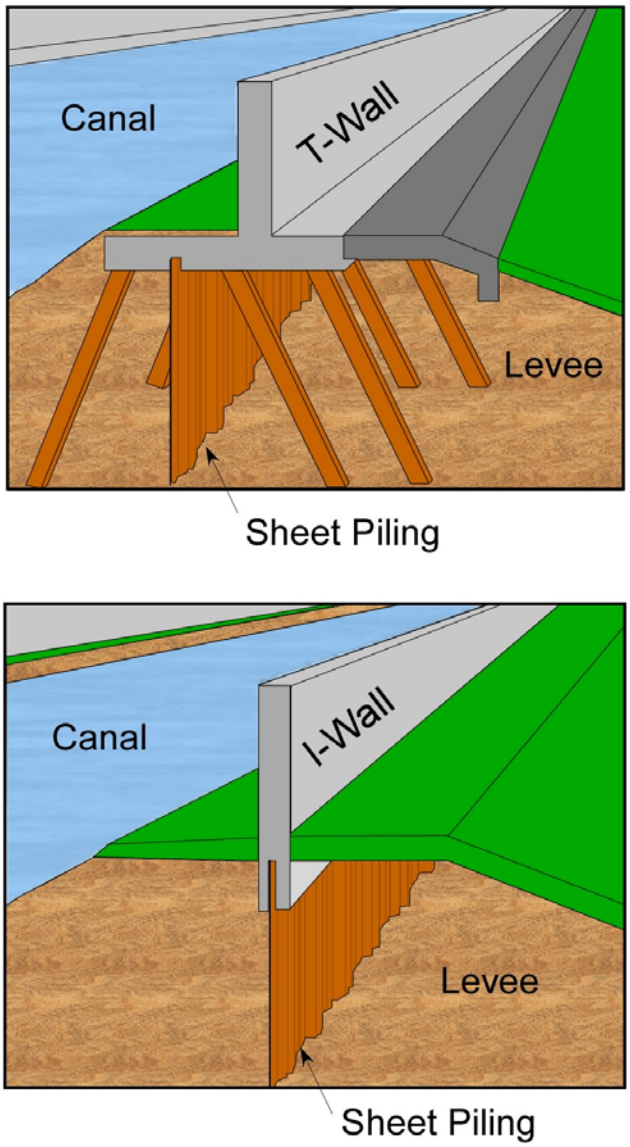


Figure 9

- Failure of I-wall type floodwalls was the most common problem during Hurricane Katrina, and these failures resulted in severe flooding in the main basin of the city.

- In 1985, the Army Corps of Engineers research branch conducted tests on sheet pile flood walls with the same design that they were using for New Orleans' hurricane protection system, called the E-99 study. Later analyses of this test found that they would likely fail as a result of deflection of the sheet pile (Figure 10).

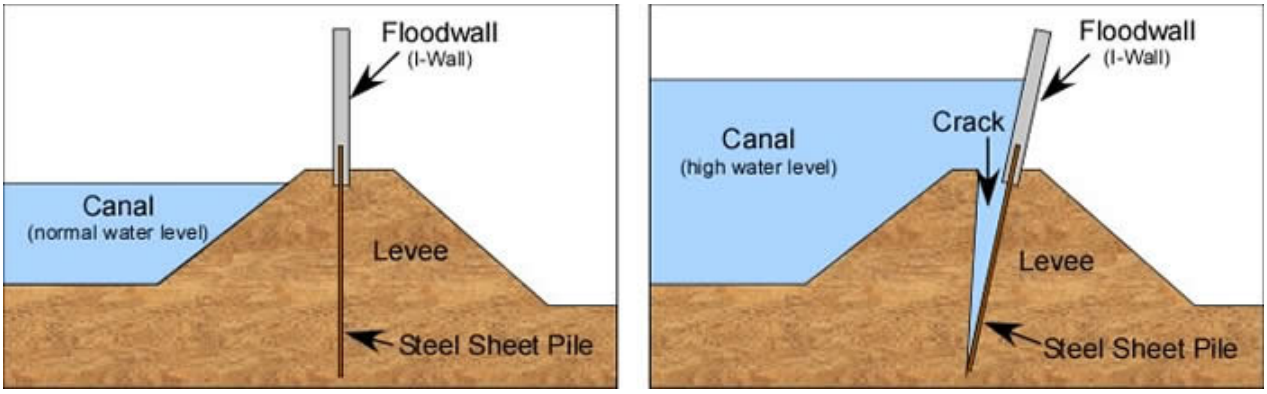


Figure 10

- The results of the E-99 study were misinterpreted and the Corps determined that shorter sheet pile penetration depths could be used, resulting in a cost savings for constructing the canal floodwalls of approximately $100 million.

- After Katrina it was determined that sheet piles on the 17th St. and London Avenue canals were too short, a major factor responsible for the floodwall failures on these canals.

- Poorly constructed levees in St. Bernard Parish resulted in erosion of the overtopped levees.

- Levee overtopping and levee breaching are two different things. Levee breaching is a more serious matter (see figure 11)

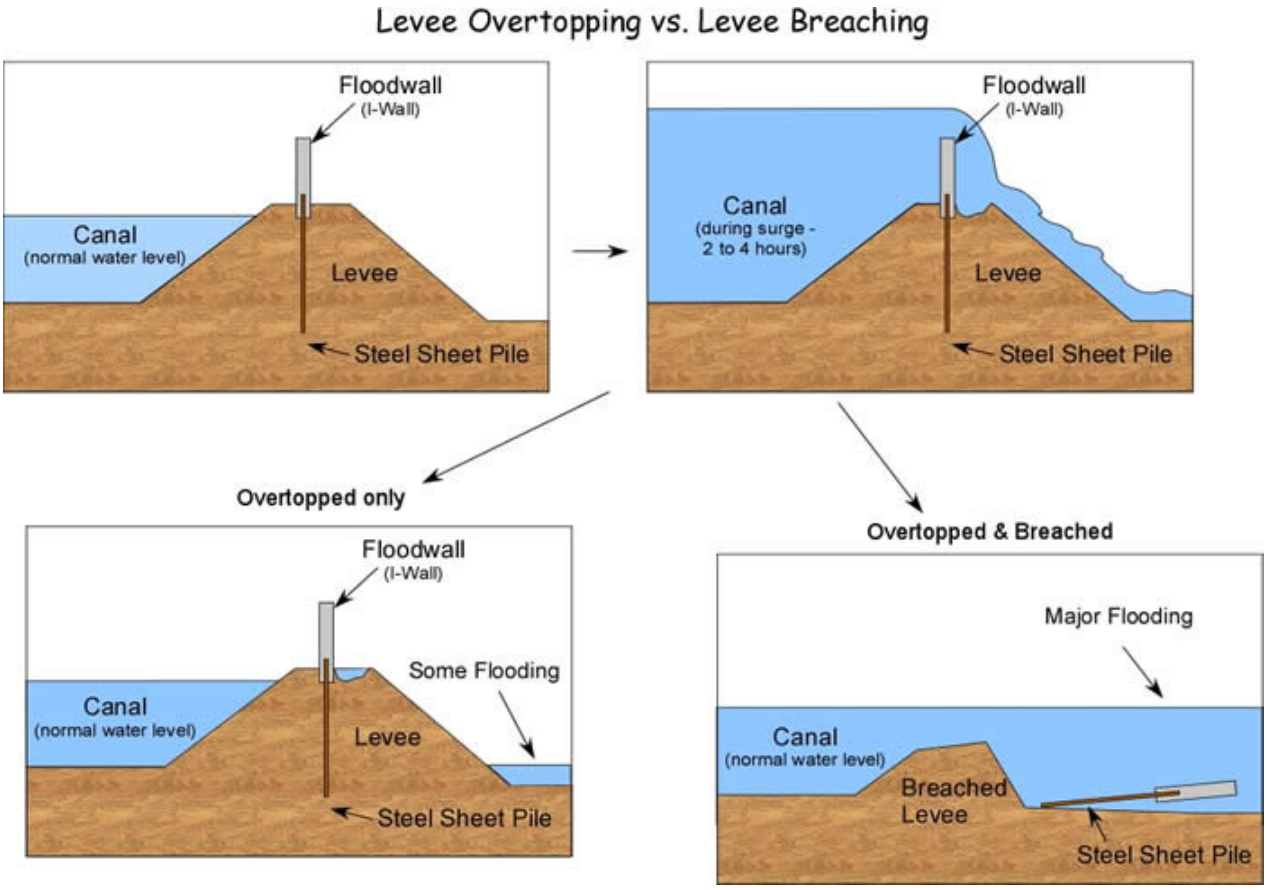


Figure 11

The commission appointed to investigate what when wrong during Katrina - The Interagency

Performance Evaluation Task Force (IPET) concluded the following in their final report:

> ***"The System did not perform as a system: the hurricane protection in New Orleans and Southeast Louisiana was a system in name only ... The system's performance was compromised by the incompleteness of the system, the inconsistency in levels of protection, and the lack of redundancy. Incomplete sections of the system resulted in sections with lower protective elevations or transitions between types and levels of protection that were weak spots."***

Why New Orleans is Vulnerable To Hurricanes

Natural Causes

- Location near Gulf of Mexico
- Low elevation (near sea-level)
- Subsidence - caused by compaction of river deposited sediments
- Erosion of inactive delta lobe
- Sea-level rise due to global warming

Human-Related Causes

- Levees on River prevent flooding, but deprive floodplain of sediment which would normally compensate for natural compaction Levees on River prevent flooding, but deprive floodplain of sediment which would normally compensate for natural compaction.
- Coastal Erosion accelerated by human changes to system. The coastline of Louisiana is eroding at an incredible rate, estimated at 25 square miles per year. (**1 football field of area every 45 minutes**). Causes of Coastal Erosion, include the natural processes listed above, as well as the following:
    - Navigation and Exploration Canals. During Katrina, all levee/ floodwall breaches occurred on human made navigation and drainage canals that bring water into the heart of the city (See Figure 8).
    - Over the last 100 years, hundreds of miles of exploration and navigation canals have been cut through south Louisiana wetlands. This allows salt water to get into the fresh water swamps and marshes, killing the fresh-water vegetation which holds soil in place. Storms and boat traffic can then easily erode the soil.
    - Petroleum Extraction - When oil and natural gas are extracted from the subsurface, sediment that once held the oil in the pore spaces, compacts, resulting in subsidence.
    - Invasive Species - Nutria are beaver-like animals that were imported from South America in the early 1900s to expand the fur trade. Nutria eat marsh grass and their roots. Without these grasses, storms erode the soil and turn land into water.

- Increased Population - Puts more people and infrastructure at risk

- Population expanding into lower lying areas - When swamps are pumped out to make dry land, the groundwater table is also lowered. Without the groundwater in the pore spaces between sediment grains, the grains compact and cause subsidence. When New Orleans was founded in 1718, none of the current city was below sea-level. Expansion into the swampy areas north of the original city has resulted in as much as 8 feet of subsidence since 1895.

- Inadequate, poorly designed, & incomplete hurricane protection system - as discussed above.

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What's Next?

Over the next few weeks we will further explore the problems that occurred during Katrina and explore what is being done to reduce the risk and vulnerability.

Appendix
Time Line of Important Events Leading up to Hurricane Katrina*

5000–4500 BP	Deposition of Pine Island Barrier Island/Beach Sands
4500–1000 BP	Deposition of St. Bernard Delta Lobe & formation of Metairie/Gentilly/Esplanade Distributary channels
~1000 BP	Current Mississippi River course established
1718	Founding of New Orleans
1722	Hurricane destroys New Orleans
Aug. 9, 1812	Great Louisiana Hurricane, struck - flooded areas north of city along Lake Pontchartrain
1821	Easterly winds forced water from Lake Pontchartrain up Bayou St. John to flood northern edge of city.
Aug. 16,1831	"Great Barbados Hurricane" Mississippi River levee broke and flooded French Quarter.
1833-34	Orleans Canal mostly excavated
1854-58	Upperline Canal (17th St. Canal) excavated
1860	3 Hurricanes struck New Orleans area. One on October 2, caused storm surge in Lake to destroy lake front villages and flood areas north of French Quarter.
1860s	Lower London Avenue Canal excavated
1871	3 hurricanes create storm surge in Lake that causes localized flooding in New Orleans
1871	City Surveyor W. H. Bell warns of storms moving up drainage canals – suggests moving pumps to lakefront.
1873-1878	Upper London Avenue Canal excavated
1895?	Lake Pontchartrain hurricane protection levee (6 ft. above lake level)
1915	Hurricane floods city through drainage canals. 275 deaths
1915	Baldwin Wood invents high capacity screw pump - allows swamps to be drained for habitation.
1923	Industrial Canal completed
1940s	Inner Coastal Waterway completed
Sept. 19, 1947	Hurricane floods part of city along Industrial Canal and drainage canals. 51 deaths
1960	Corps proposes plan for movable gates at the Lake end of drainage canals
1961	Corps proposal for gates at Rigolets and Chef Menteur Pass the "Barrier Plan"
1964	MR-GO completed
Sept. 9, 1965	Hurricane Betsy causes flooding on both sides of Industrial Canal
1965	Lake Pontchartrain and Vicinity Hurricane Protection Plan authorized by Congress
Aug. 17, 1969	Hurricane Camille (Cat. 5) hits Mississippi Coast, New Orleans spared from flooding
1970s	Floodwall built on Industrial Canal
1977	Courts rule against "Barrier Plan", Corps adopts "High Level Plan"

1984	Corps modifies Lake Pontchartrain & Vicinity plan to include floodgates at mouths of canals
1992	Water Resources Development Act gives Corps responsibility for hurricane protection on Canals (previously the responsibility of the Orleans Levee district) after Levee District lobbyists successfully have language inserted into the bill.
1993-1999	Floodwalls built on drainage canals, but bridges still in progress in 2005.
Sept. 27-28. 1998	hurricane Georges approaches New Orleans – first time evacuation of city is called for.
Sept. 10-11, 2004	Hurricane Ivan approaches New Orleans, - second evacuation – first time for Contraflow
Aug. 29 2005	Hurricane Katrina
Dec., 2005	Funding for gates at mouths of canals
August 2006	Completion of gates,
Sept. 1, 2008	Hurricane Gustav strikes, city evacuated, floodwalls on Industrial Canal overtopped.

*Based on ILIT (2006), Braun & Varabedian (2005), and Schleifstein (Nov. 1, 2005)

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