

Development of the New Orleans Flood Protection System Prior to Hurricane Katrina

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for Technical Session #6 on

Coastal and Flood Plain Processes

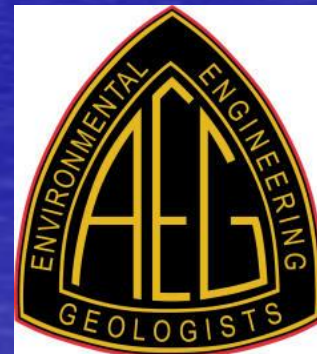
Annual Meeting

Association of Environmental &
Engineering Geologists

New Orleans

Sept. 18, 2008

Online at: www.mst.edu/~rogersda

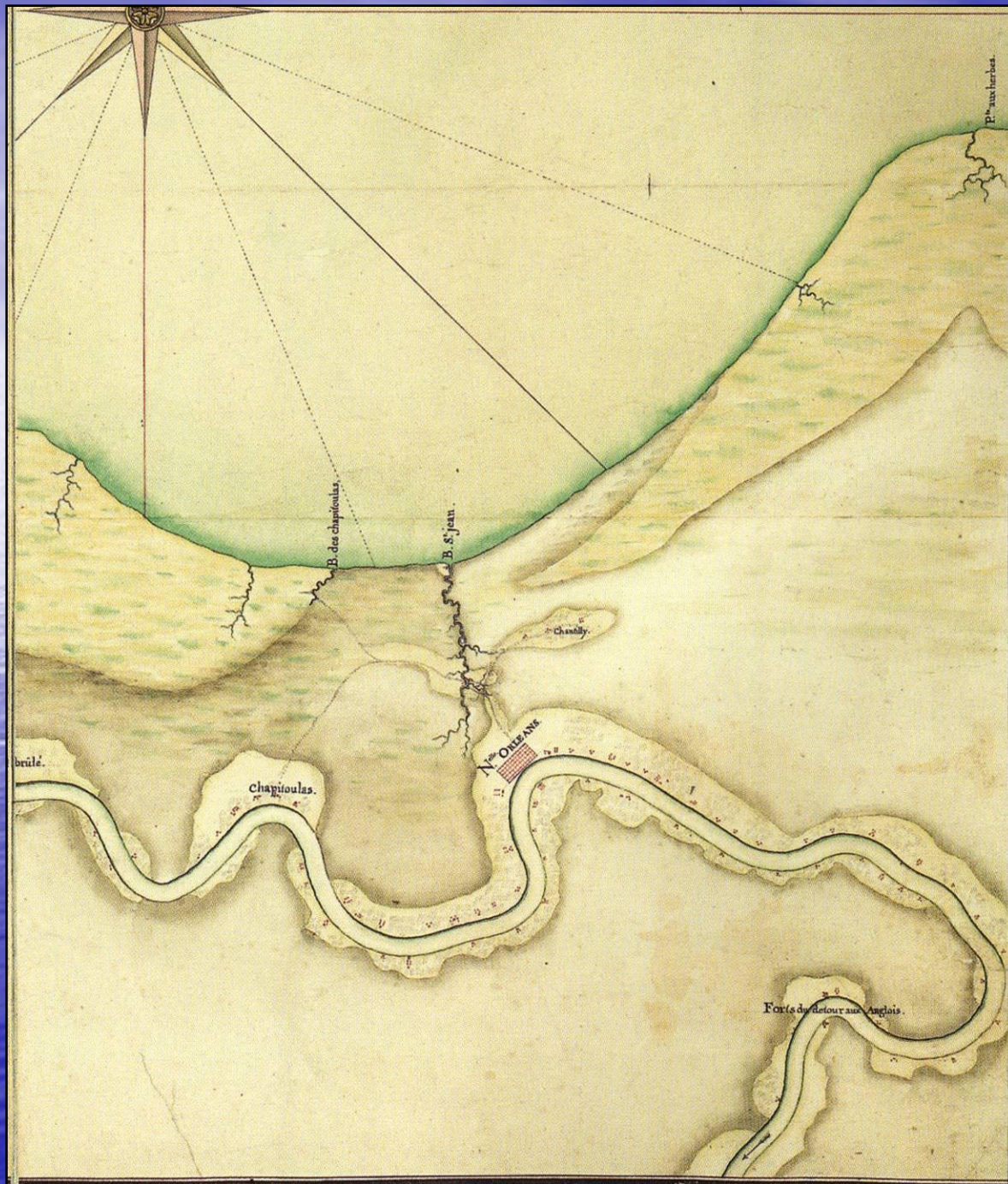


PART 1

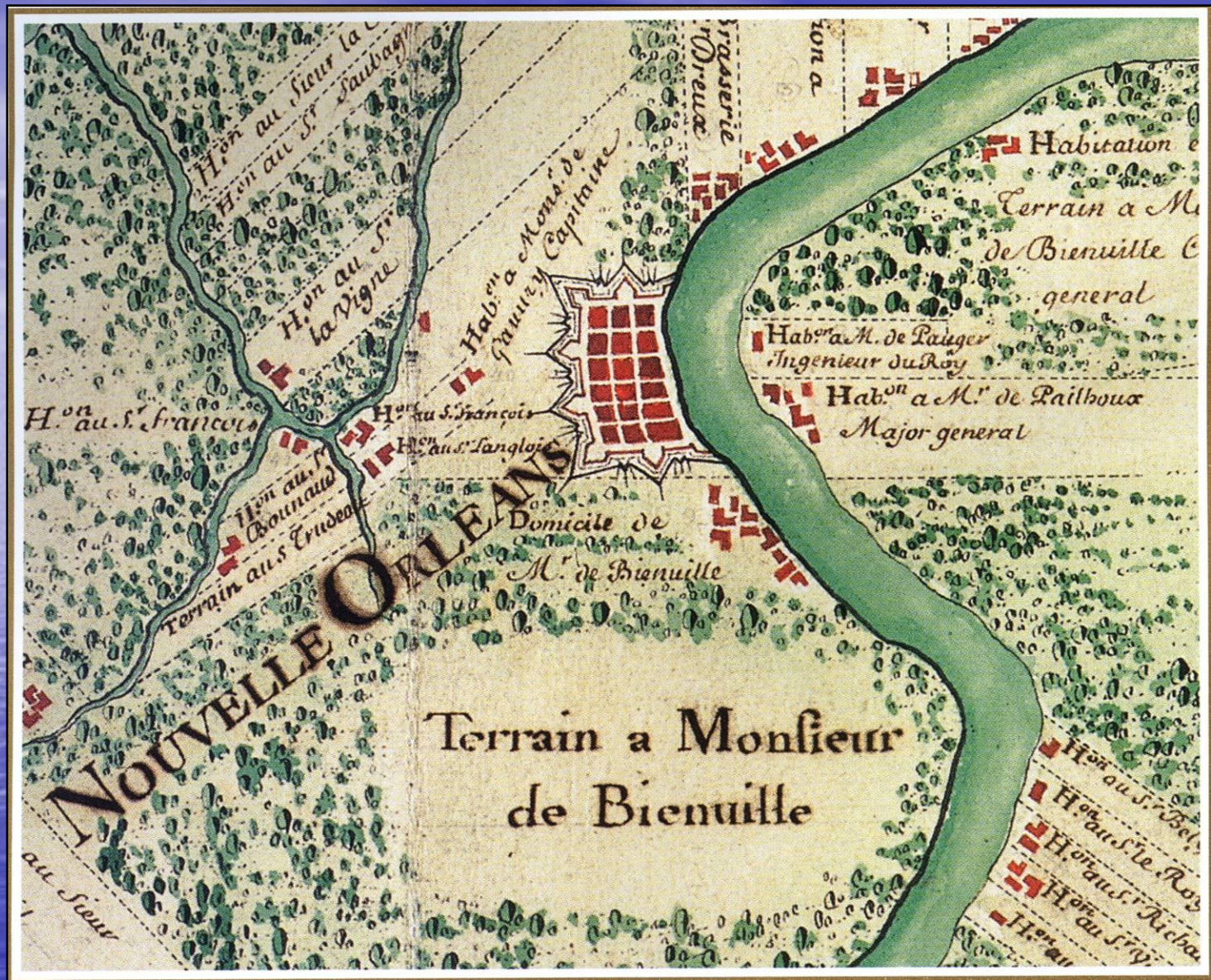
**ORIGINS OF
NEW ORLEANS**



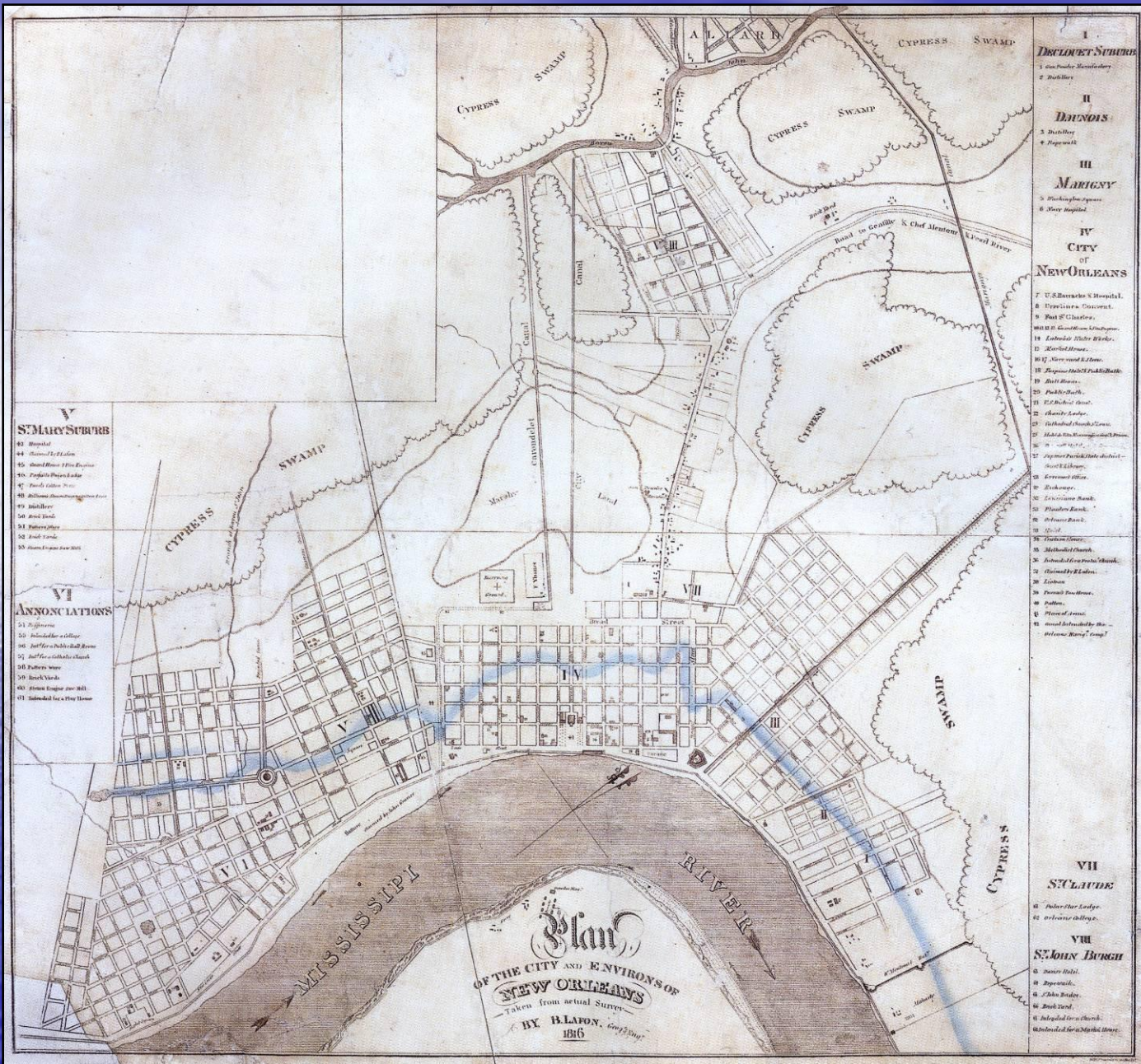
New Orleans is a deep water port established in 1718 about 100 miles up the main stem of the Mississippi River, on the eastern flank of the Mississippi River Delta.



New Orleans was established by the French in **1717-18** to guard the natural portage between the Mississippi River and Bayou St. John, leading to Lake Pochartrain. Note swamp contact, fresh vs brackish water

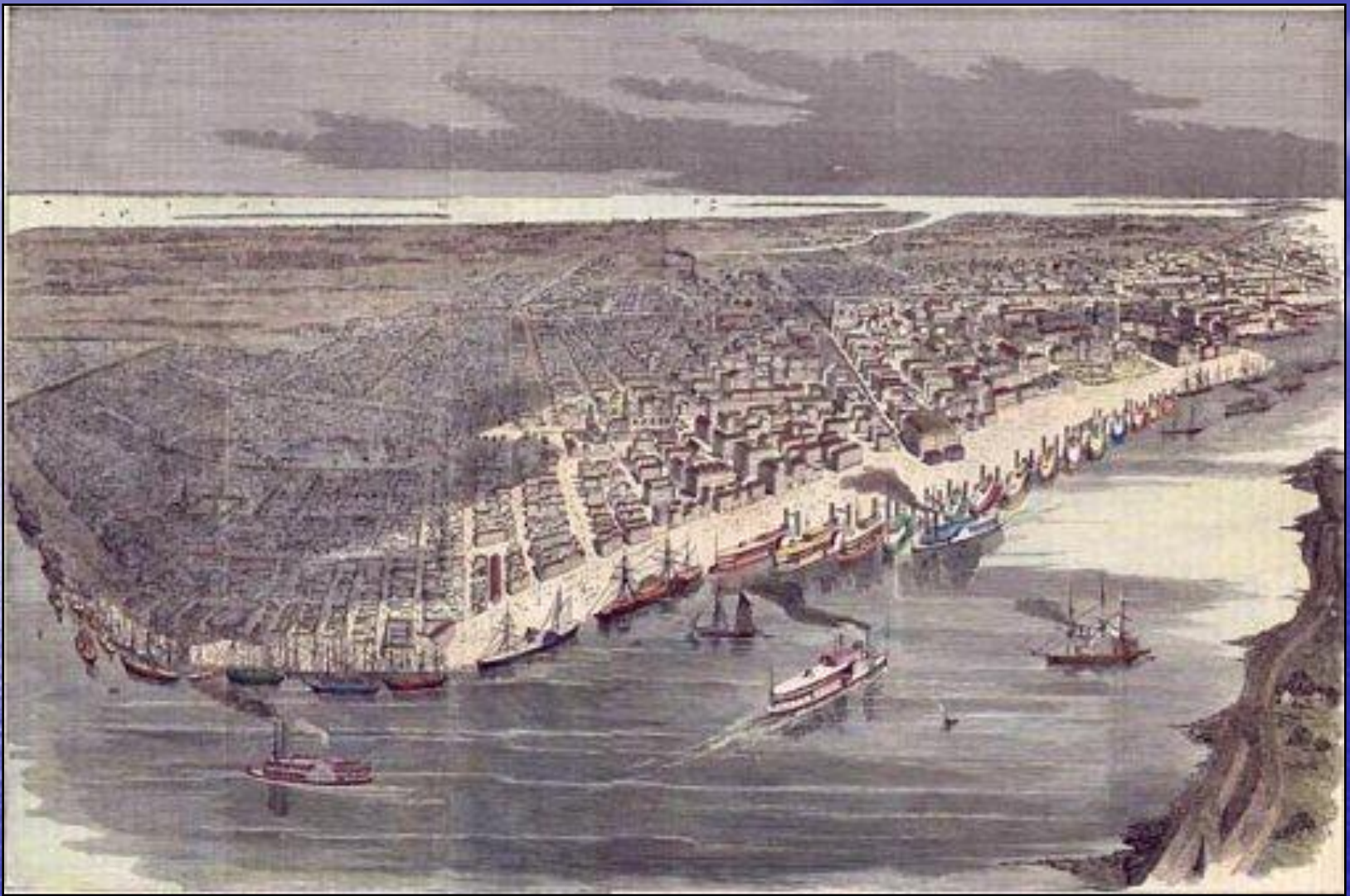


The formal settlement was laid out as 14 city blocks in 1721, with drainage ditches around each block. The original town was surrounded by a defensive bastion in the classic French style.



The first levee was erected in 1722; and the tendency to flooding during late spring and summer runoff came to characterize the settlement. Note "Cypress swamps" north of the city.

Areal limits of the flood of 1816 (blue)



- **During the steamboat era (post 1810), New Orleans emerged as the major trans-shipment center for river-borne to sea-borne commerce, and vice-versa, as well as a major port of immigration. It was the 9th largest American port by 1875.**

PART 2

THE CORPS 'LEVEES ONLY' POLICY

1.) River channel and floodplain prior to flooding

Water level at flood stage

2.) During flood stage

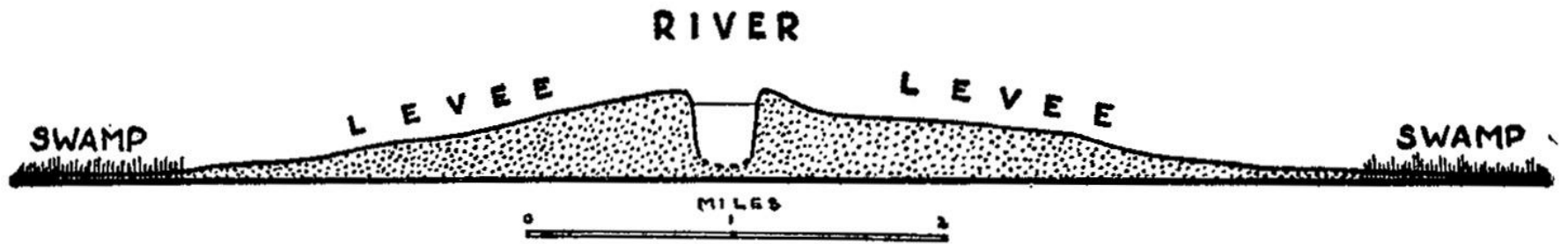
Granular sediment (sands and gravels) deposited adjacent to channel

Fine sediment (silts & clays) deposited farther from active channel

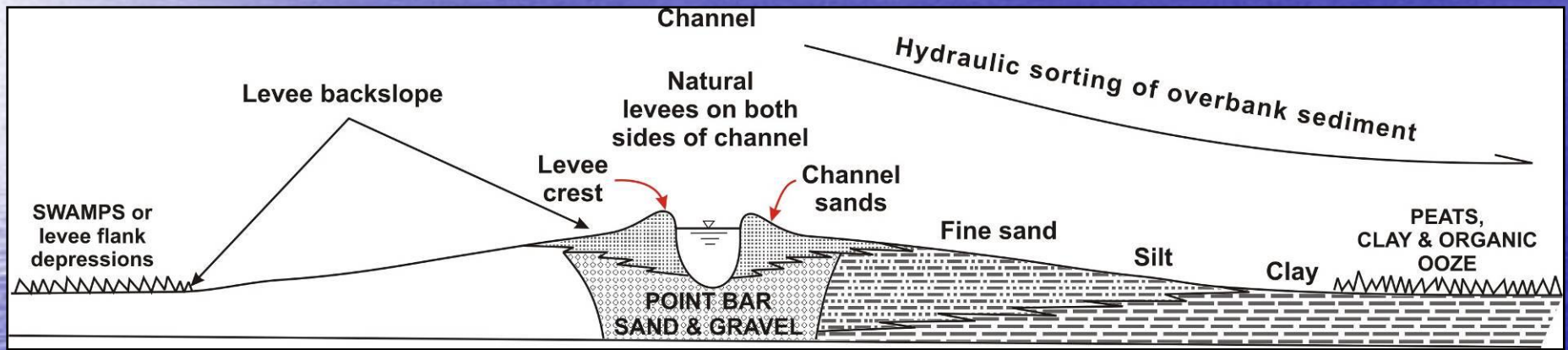
Natural levees deposited by repeated flooding

3.) After repeated flooding

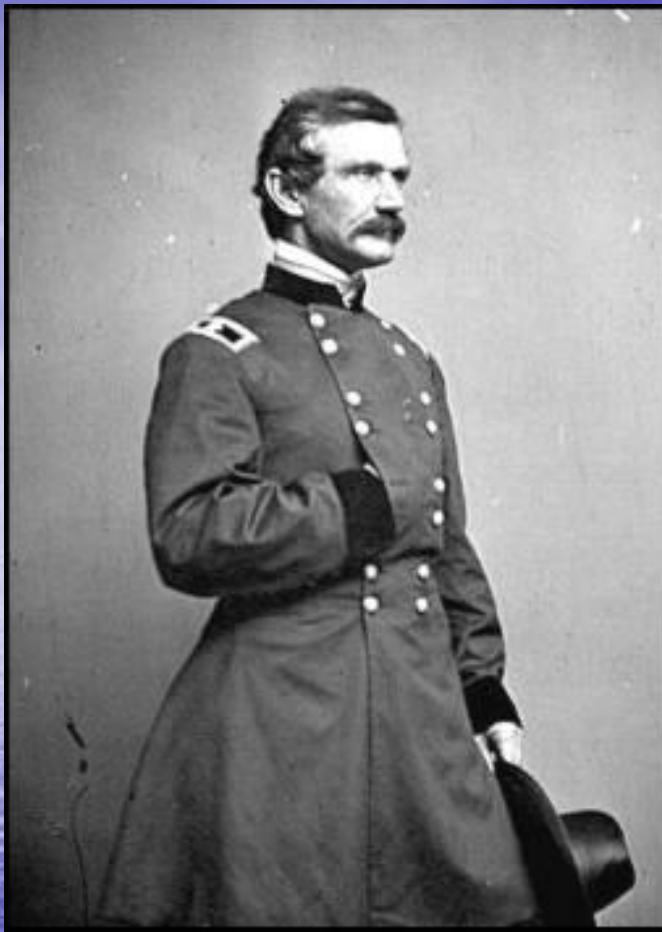
- The channel's natural levees form the high ground



PROFILE OF THE MISSISSIPPI RIVER AT BELLE POINT

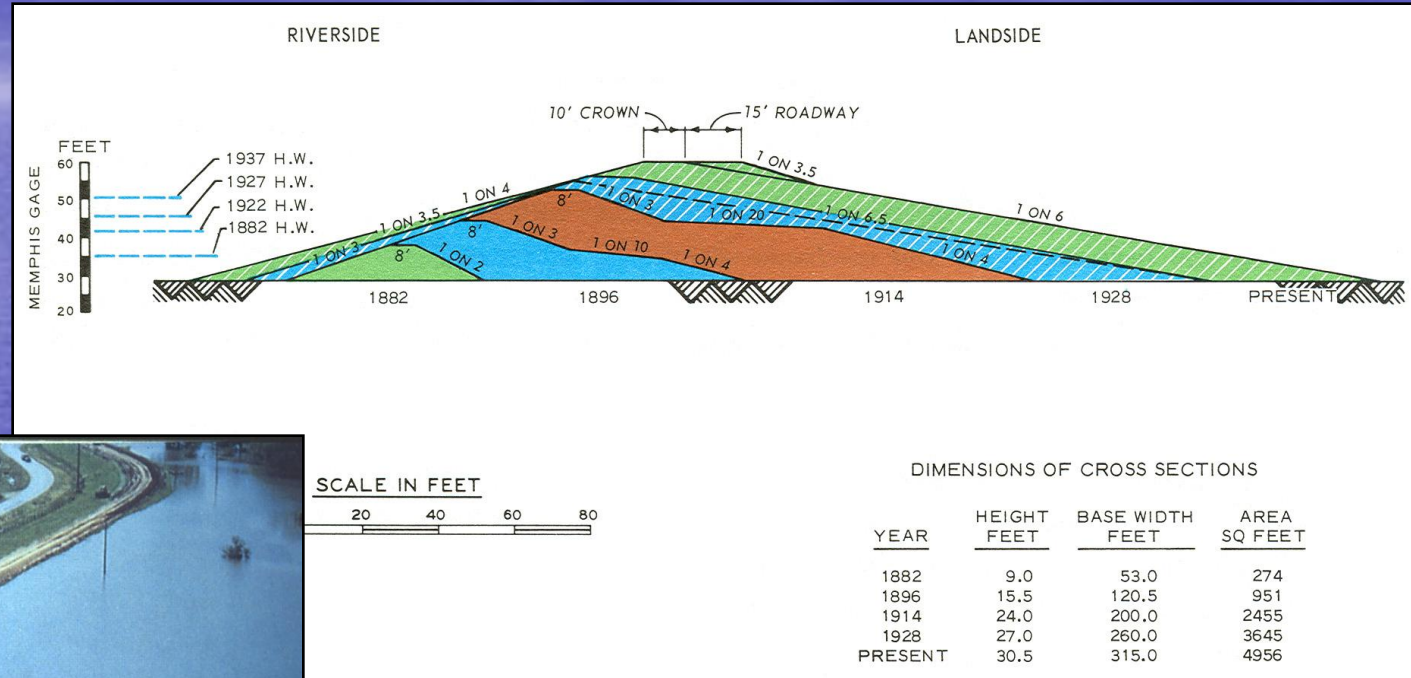


- Typical cross section through the sandy bank levees of the Mississippi River, illustrating how the river's **main channel lies above the surrounding flood plain**, which were poorly drained swamp lands prior to reclamation.
- There is significant **hydraulic sorting** of materials deposited on either side of these levees, as sketched below.



- **Army Engineer A.A. Humphreys** began studying the river in 1850, and virtually controlled it as Chief of Engineers between 1866-1879. He was the father of the Corps' flawed "levees only" policy of flood control.

Levees were periodically raised between 1890-1960

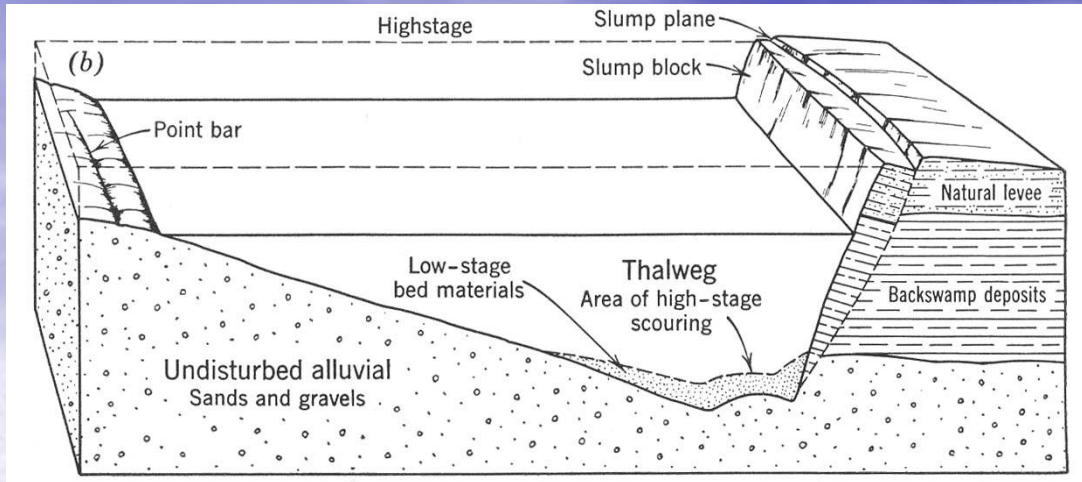


- Typical levee cross section in New Orleans area

Louisiana levee topped out during the record 1973 flood

Why the 'Levees Only' policy failed

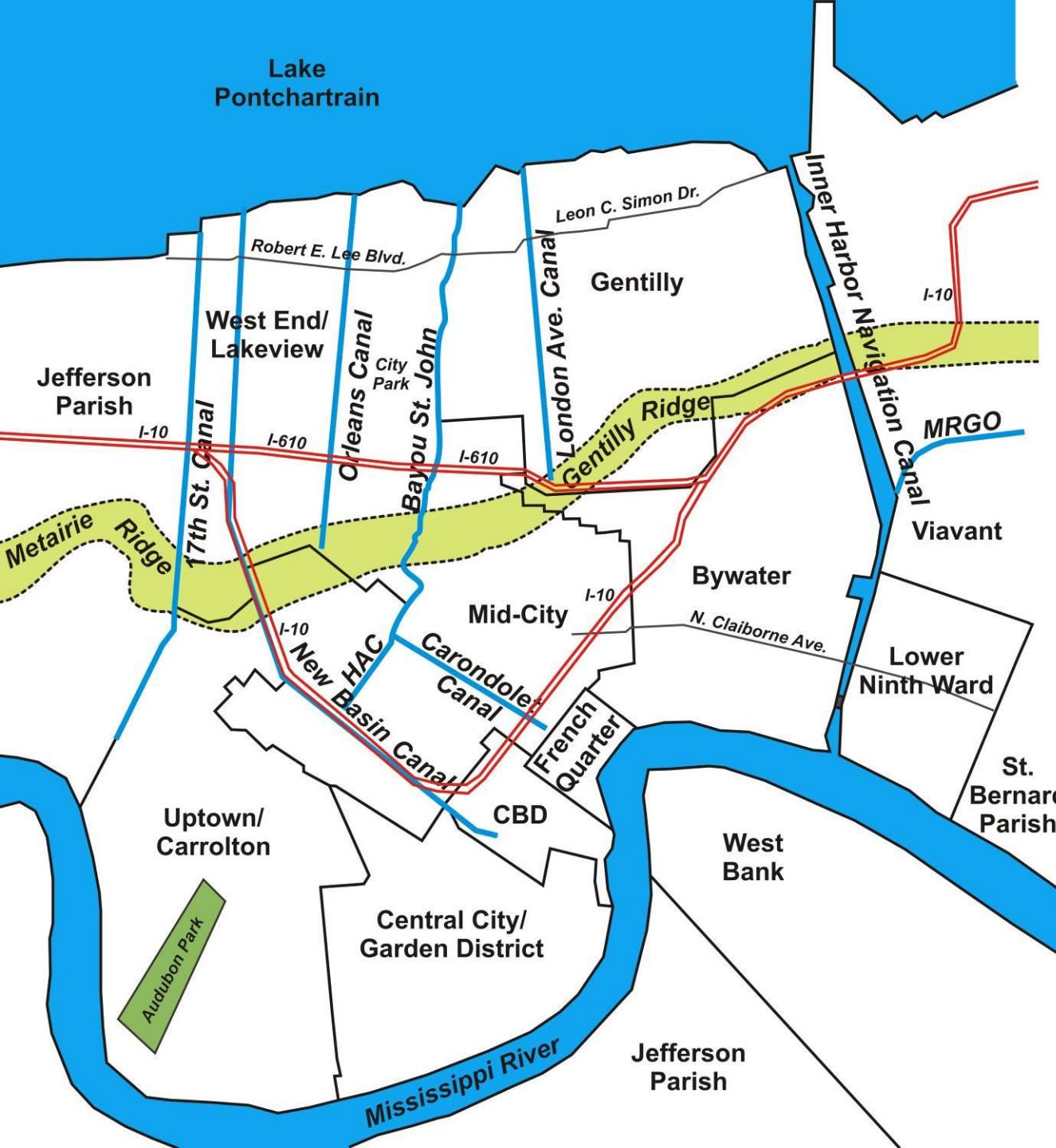
- The Mississippi channel is sinuous, and exhibits an asymmetric section
- It tends to migrate towards the outside of downstream bends through bank undercutting. Levees had to set back from these bends.



PART 3

NEW ORLEANS DRAINAGE CANALS

City Districts



- Prominent drainage features and neighborhoods of New Orleans
- Note Metairie - Gentilly Ridge distributary channel

Many Canals were filled or superseded by newer ones

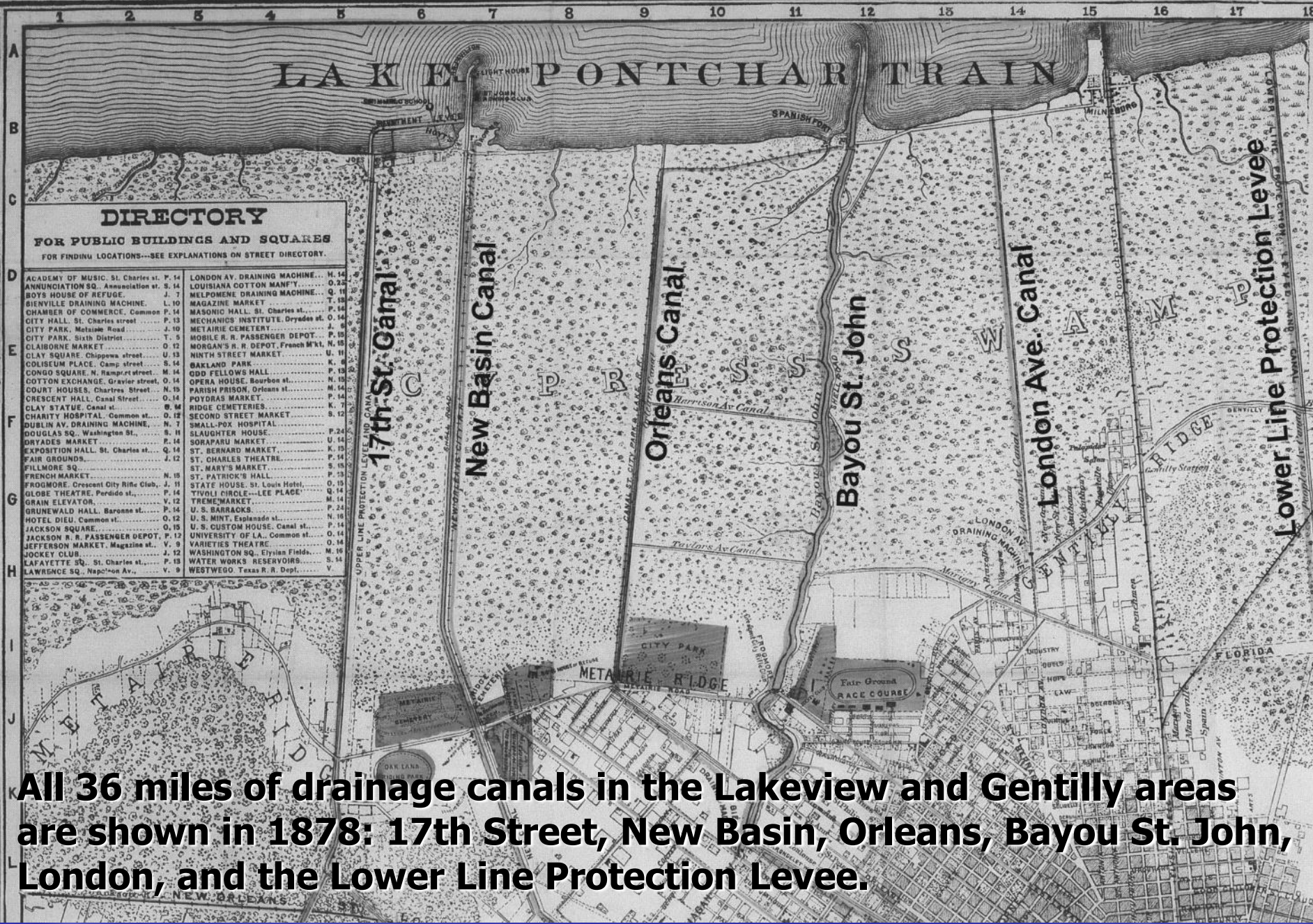
- The **Old Basin**, or **Old Carondelet Canal** was excavated for drainage and navigation (row boats), between the City and Lake Ponchartrain. It ended at Basin Street, and was infilled in the **1920s**, when it became railroad tracks and Lafitte Avenue.
- The **New Basin Canal** was excavated in the early **1830s** in the American Sector, yellow fever killing 10,000 Irish immigrants. The New Orleans City Railroad paralleled this canal in post Civil War era.
- The **New Basin Canal** cut through Metarie Ridge; causing flooding of the downtown area in **1871**.
- The portion south of Metarie Ridge was filled in the **1930s**; and the remainder in the **1950s**, with the **Ponchartrian Expressway** replacing the old canal.

Drainage Canal Chronology

- The **Orleans Canal** was excavated in **1833** to convey water from Bayou Metarie. The Turnpike Road ran along the west side of this canal.
- The **Upper Line/17TH St. Canal** along the Orleans-Jefferson Parish boundary was excavated prior to **1849** – along the upper end of today's **17th St Canal**. The lower portion was excavated in **1857-58**, all the way to Bucktown, along Lake Ponchartrain
- In **1853** the **Jefferson & Lake Ponchartrain Railroad** was built along the Upper Line Canal



The **1878 Hardee drainage map** was compiled after a yellow fever epidemic the previous year, which brought to City's accumulated death toll to in excess of **100,000** people.



All 36 miles of drainage canals in the Lakeview and Gentilly areas are shown in 1878: 17th Street, New Basin, Orleans, Bayou St. John, London, and the Lower Line Protection Levee.

Drainage Canal Chronology

- The **1853** Ponchartrain Harbor Map shows brackish water tidal influx zone around the mouth of Bayou St. John, extending westward, to the New Basin Canal.
- The **Upper Protection Canal** was excavated around **1857-58** out to Lake Ponchartrain. This became the **17th Street Canal** (the street was renamed Palmetto Avenue in 1894)
- By **1863** there were a series of east-west **feeder canals** serving Bayou St. John from the west side
- By **1863** there were a series of NNE trending drainage canals in St. Bernard Parish



- **Photo looking north along the eastern side of the New Basin Canal in 1890, when the levee was about 4 feet high, supporting a shell surfaced road. These embankments were raised in 1915 and again in 1947.**

Drainage Canal Chronology

- The **upper London Avenue Canal** was constructed in the **1860s**, north of Bayou Gentilly. A steam-powered draining machine near the intersection of London and Pleasure Street dumped this water into the cypress swamp near what is now Dillard University, north of Gentilly Ridge.
- The **lower London Avenue Canal** was extended out to Lake Ponchartrain sometime between **1873-78**

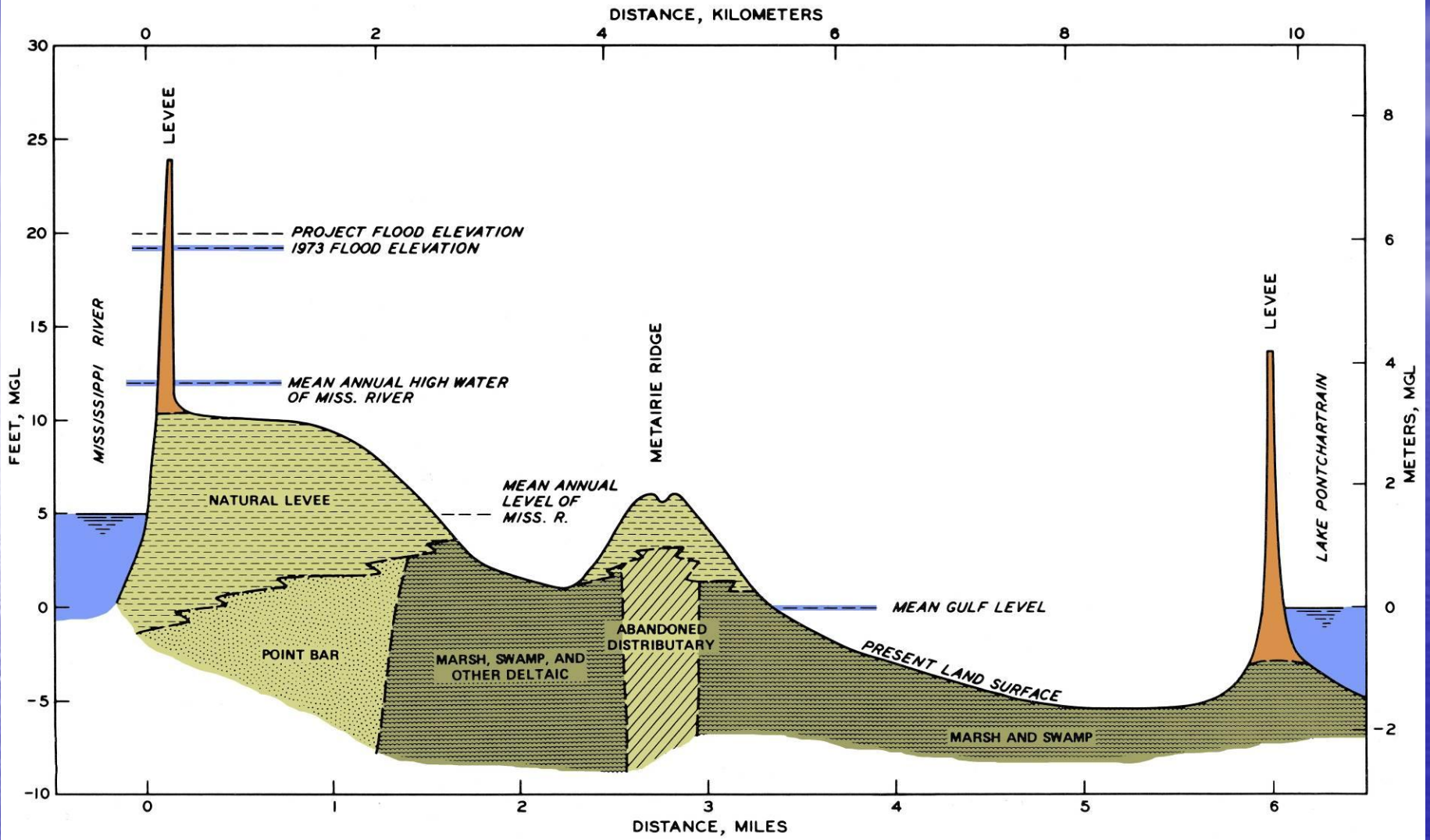
PART 4

KEEPING THE CITY DRY

ORIGINS OF THE SEWERAGE & WATER BOARD

EARLY WARNINGS

- In **1871**, the New Orleans City Surveyor **W.H. Bell** warned of the potential dangers posed by the big outfall drainage canals
- He told city officials to place pumping stations on the lakeshore, otherwise *"heavy storms would result in water backup within the canals, culminating in overflow into the city."*



Much of New Orleans lies below sea level, Lake Pontchartrain, and the Mississippi River, making it particularly vulnerable to flooding. Mississippi levee 24.5 feet; Pontchartrain levee 13.5 feet.

Drainage Commission - 1896

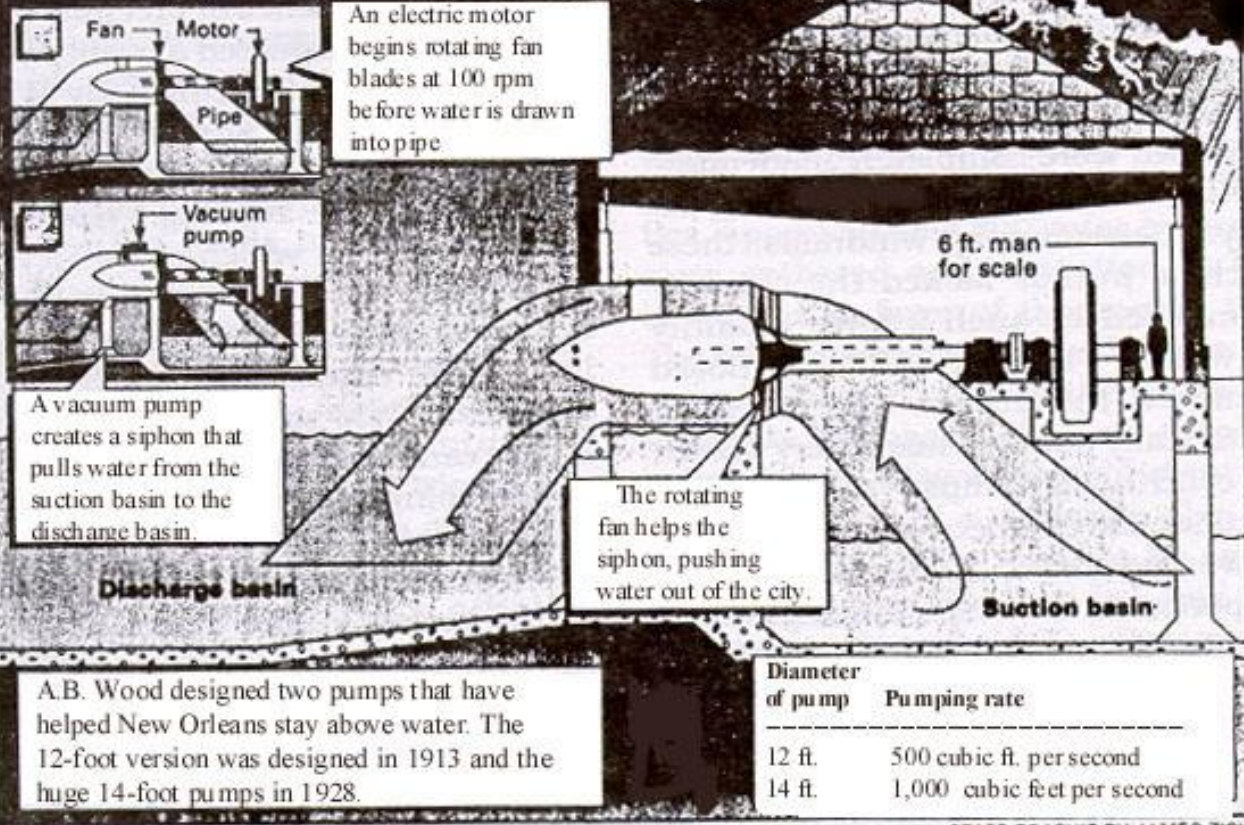
- The Louisiana legislature created a drainage commission in **1896** to deal with drainage of New Orleans
- This subsequently became the **New Orleans Sewerage and Water Board** in **1899**.
- By **1915** there were **70 miles** of canals and **three new pump stations** in place. By **1926** the system cost **\$27.5 million**
- Eventually, this system has expanded to **172 miles** of drainage canals, **90 miles** of which are covered.



A. Baldwin Wood was a young S&WB engineer who designed the enormous screw pumps, 12 to 14 feet in diameter, which run on 25 Hz electric power using 20 ft diameter dynamos. The City began by installing 11 Wood pumps in **1915** for a cost of \$159K. These replaced the old steam powered paddle wheel pumps.

Keeping New Orleans dry

The A.B. Wood Screw Pump revolutionized the draining of the city



This 1920s drawing shows the arrangement of a Wood screw pump, which uses a powerful siphon action to lift water into the drainage canals, where it flows by gravity to Lake Ponchartrain. The City's 21 pump stations can lift 47,000 csf of water. Prior to Katrina it had only been overwhelmed on a few occasions, in 1978 and again, in 1995.

Pumping the floodwater out ...

Once New Orleans' breached levees are repaired, the city's complex system of levees, floodwalls, canals, pumps and locks can be used again to make the below-sea-level city dry.

THE SYSTEM

Pumps at drainage pumping stations throughout the system move runoff water from storm sewers to Lake Pontchartrain; can manage 29 billion gallons daily.

2 Pumps
Draw water

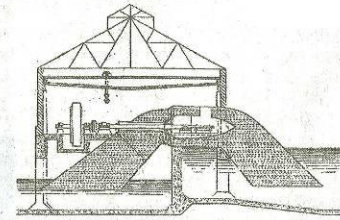


1 Collection
Stormwater collects in box culvert, flows into pumping station.

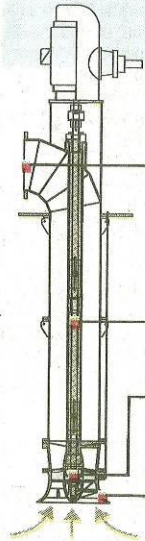
FIRST PUMPS

Original pumps, known as Wood screw pumps, were designed in 1913 by Albert Baldwin Wood; about 50 still in use.

Canal-spanning pumping stations (right) Similar to locks; raise level of water in canal so it can flow easily into lake.



4 Locks
Allow water from canal to flow into lake; may be opened if water level in lake is lower than that in canal or to let small vessels into canal; keep lake water from backing up.



TYPICAL MODERN PUMP
Vertical pumps have replaced some original pumps; lower part is submerged in water in canal or storm sewer system.

Water discharge
Capacity: Most used in New Orleans can pump up to 250,000 gallons per minute.

Height: 30-40 feet

Drive shaft: Connected to diesel or electric engine; powers impeller.

Impeller: Propeller-like device moves water up pump.

Suction bell: Water enters pump here.

CRACKS IN THE WALL

First built in 1897, the aging system was breached in at least three places.

17th St. Canal

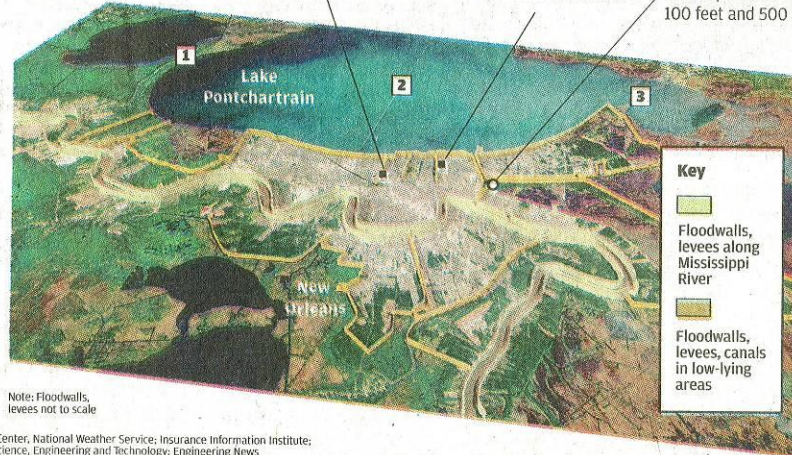
About 300-foot breach created when storm surge from lake topped floodwall and moved levee wall horizontally about 20 feet.

London St. Canal

About 300-foot breach in floodwall.

Industrial Canal

Possibly two breaches, 100 feet and 500 feet.



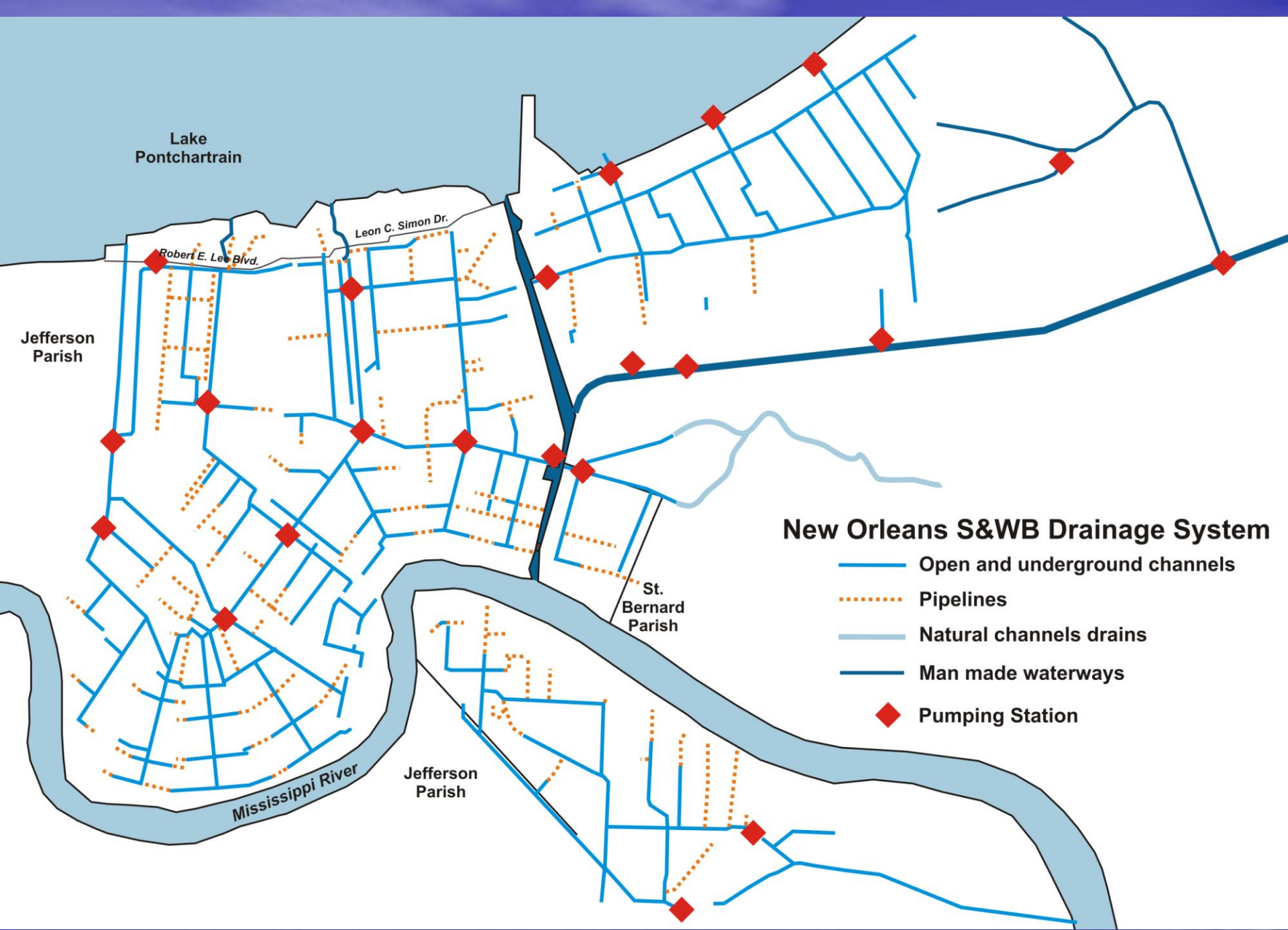
Closed roads hamper evacuations

- 1 Interstate 55** is partially submerged
- 2 Lake Pontchartrain Causeway** is impassable
- 3 Sections of Interstate 10 bridge** are not off

SOURCES: Knight-Ridder Tribunes; Associated Press; NOAA; AccuWeather; National Hurricane Center; National Weather Service; Insurance Information Institute; Army Corps of Engineers; U.S. Geological Survey; Patterson Pump Co.; Linda Hall Library of Science, Engineering and Technology; Engineering News.

Post Dispatch

New Orleans also employs vertical pumps with impellers to lift water from subterranean storm drains to the drainage canals.



PART 5

**HURRICANE-
INDUCED
FLOODING IN
1915, 1947, 1965,
1969, and 1998**

1915 FLOOD ENTERED CITY VIA THE DRAINAGE CANALS

- In **1915** a powerful hurricane lifted the water level in Lake Ponchartrain to 6 feet above mean gulf level.
- The drainage canals were overtopped and much of the city flooded
- The City's new pump system was overwhelmed when the power stations were flooded
- **275 people** were killed in the flooding

1927 Flood

The political leadership of New Orleans dynamited the Mississippi levee downstream of New Orleans to save the city from being flooded. It was not necessary, but prompted by fear.



RESPONSE TO 1915 and 1947 OVERTOPPINGS

- After the **1915 flood**, Sewerage and Water Board General Superintendent George Earl ordered the levees along the drainage canals to be raised.
- After several of these heightened drainage canal levees were overtopped in **1947**, the state's congressional delegation asked the federal government to assist in protecting the city



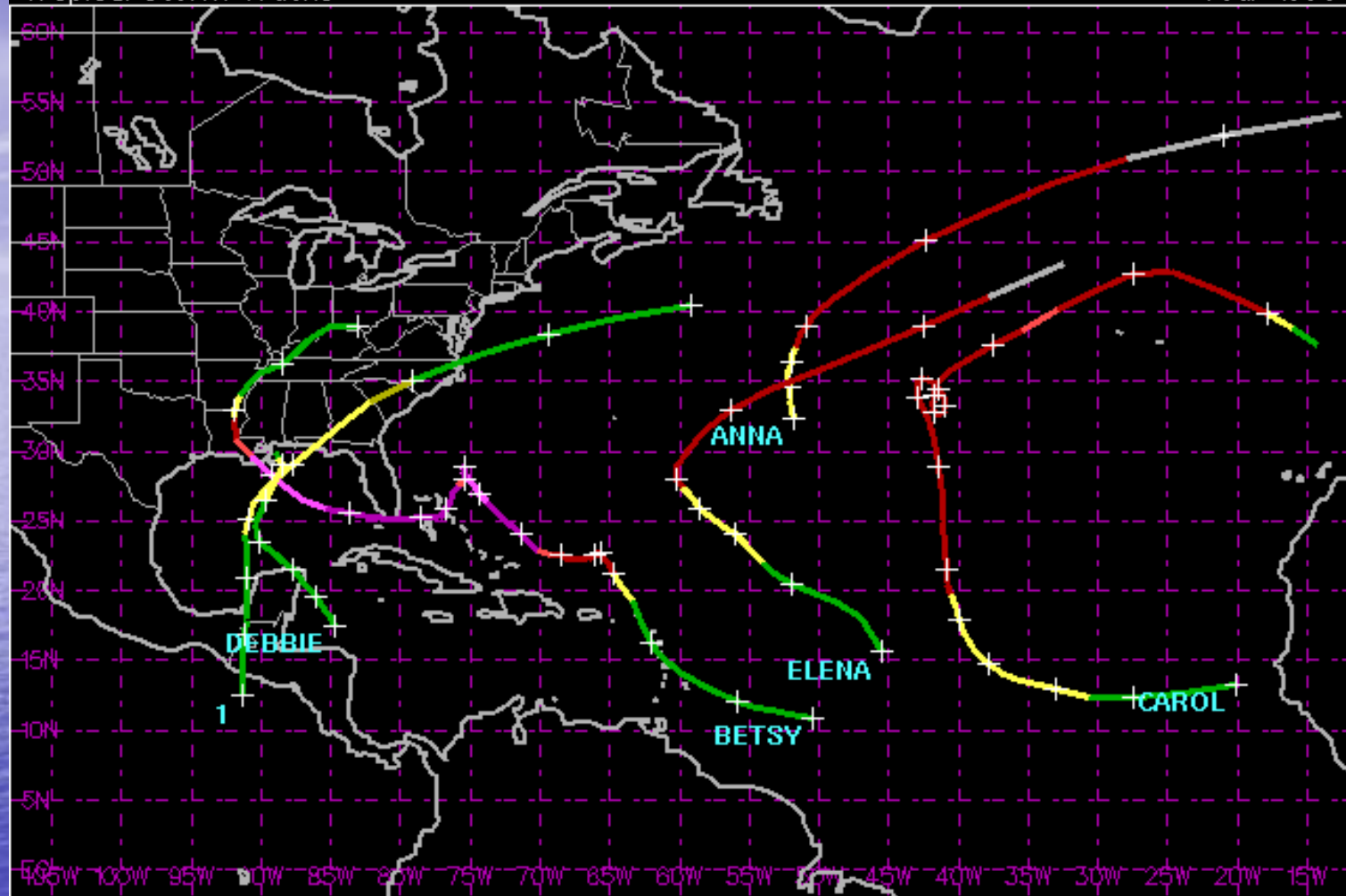
- **Flooding of Jefferson Parish and Metairie was caused by a breach along the western side of the 17th Street Canal, across from site of the 2005 breach.**

1947 Flooding Emanating from Inner Harbor Navigation Canal

- In the **1947 flood**, a back protection levee broke at Tennessee Street, spilling 10 feet of water into the East Side
- This was quickly cleaned up
- Also, lots of flooding in Metairie and Jefferson Parish, through a breach in west side of the 17th St Canal
- Flood inundation map published in the *New Orleans Times-Picayune*

Tropical Storm Tracks

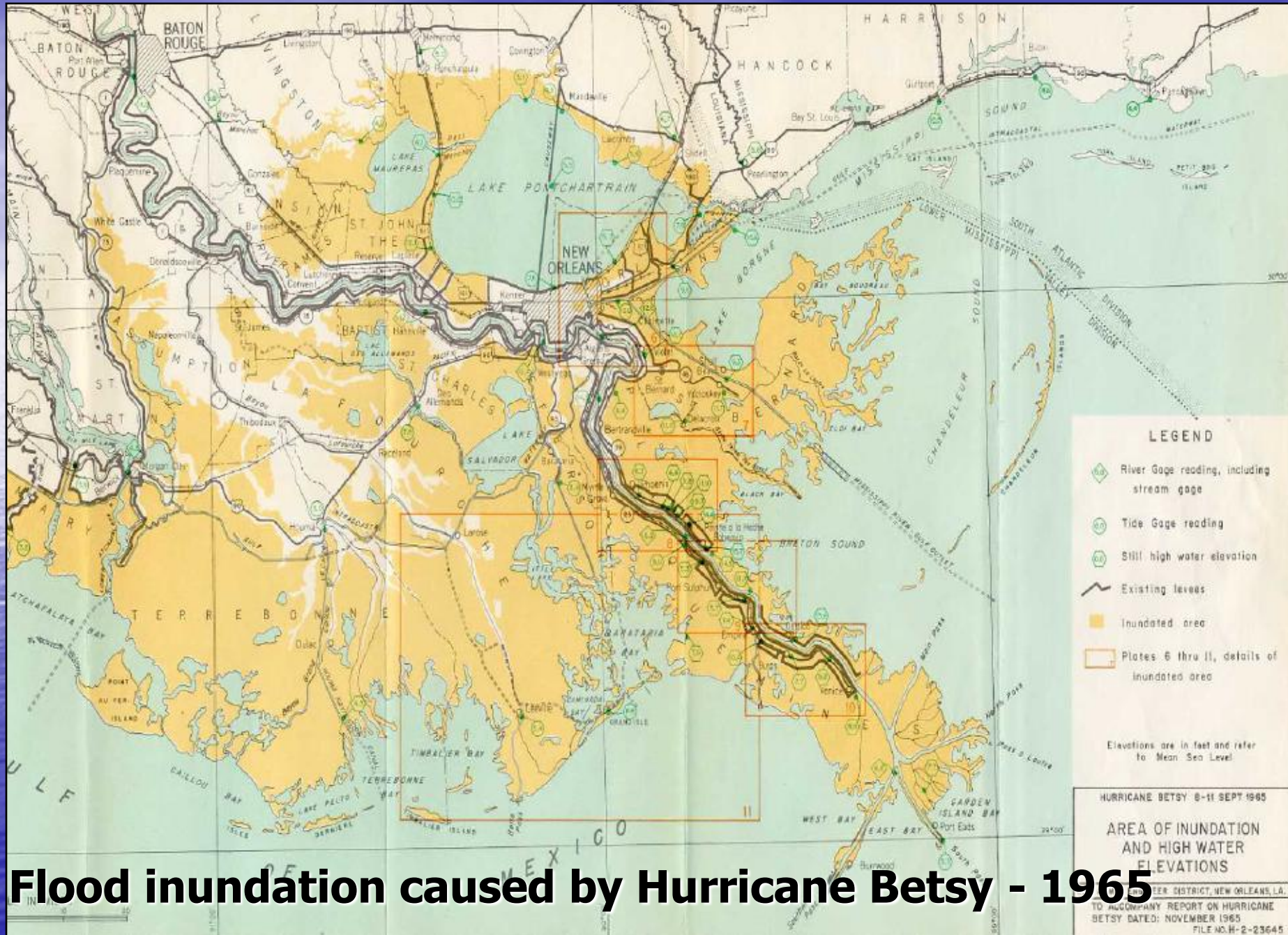
Year 1965



Hurricane Betsy clobbered New Orleans in 1965, with winds of up to 125 mph and a storm surge of 8 to 10 feet. It was the first hurricane to cause more than \$1 billion in damages.

Flooding from Hurricane Betsy in 1965

- **Both sides of the IHNC experienced breaks and overtopping during Hurricane Betsy in Sept. 1965.**
- **6,560 homes and 40 businesses** were flooded in water up to 7 ft deep on the west side of the IHNC
- **The east side of the IHNC also failed, flooding the west end of St. Bernard's Parish**



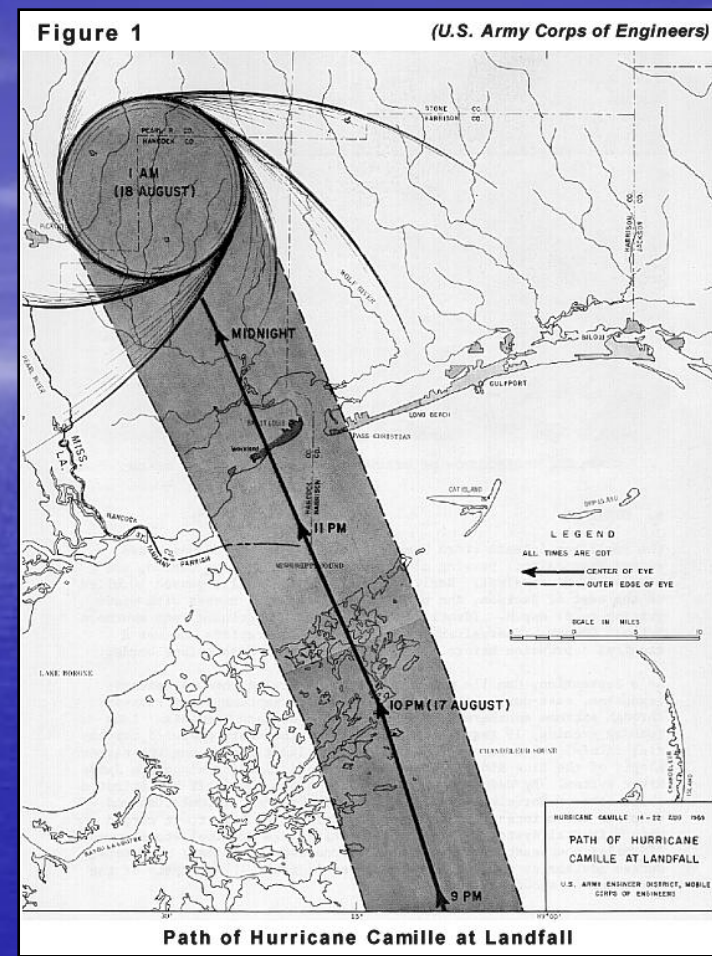
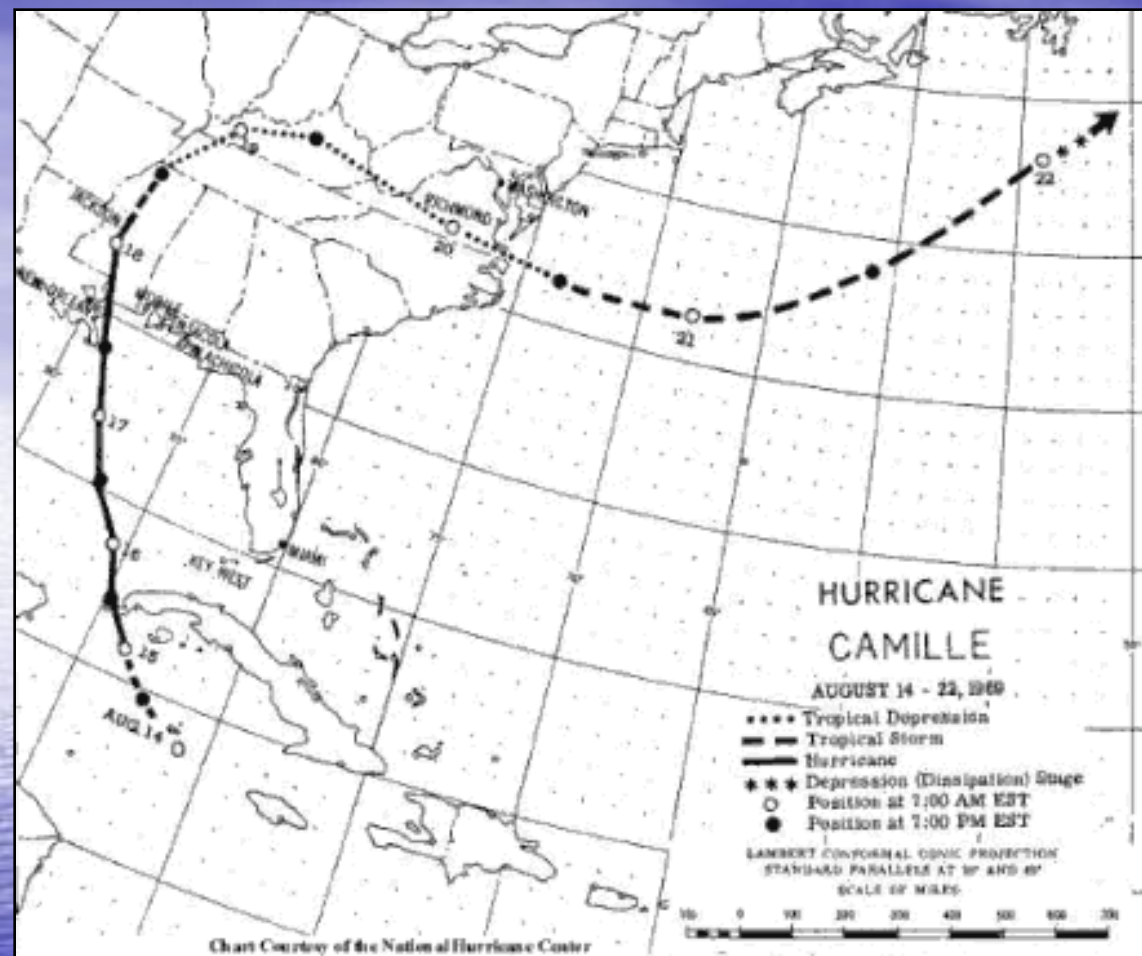
Flood inundation caused by Hurricane Betsy - 1965

Flood inundation of New Orleans caused by Hurricane Betsy in September 1965.

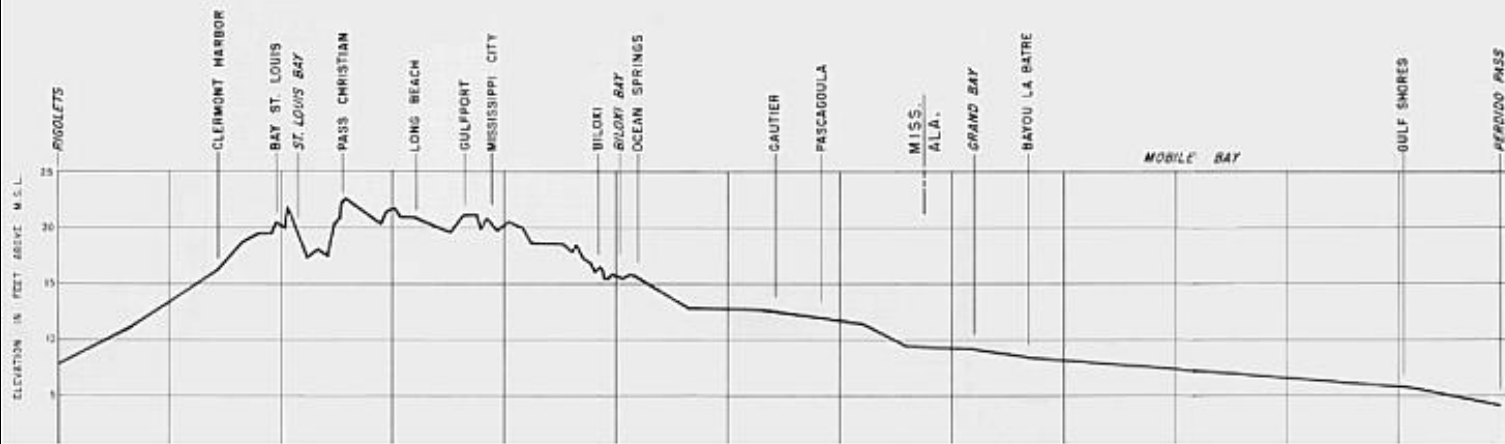
Both internal levee failures and overtopping occurred along the Inner Harbor Navigation Canal, along both sides.

The triangles note depth of water above ground surface.





Betsy's record damage was eclipsed by Hurricane Camille, which struck the Gulf Coast in August 1969. It's eye made landfall about 60 miles east of New Orleans and went up the Mississippi Embayment, causing unprecedented levels of storm-related damage in Virginia, killing more than 300.

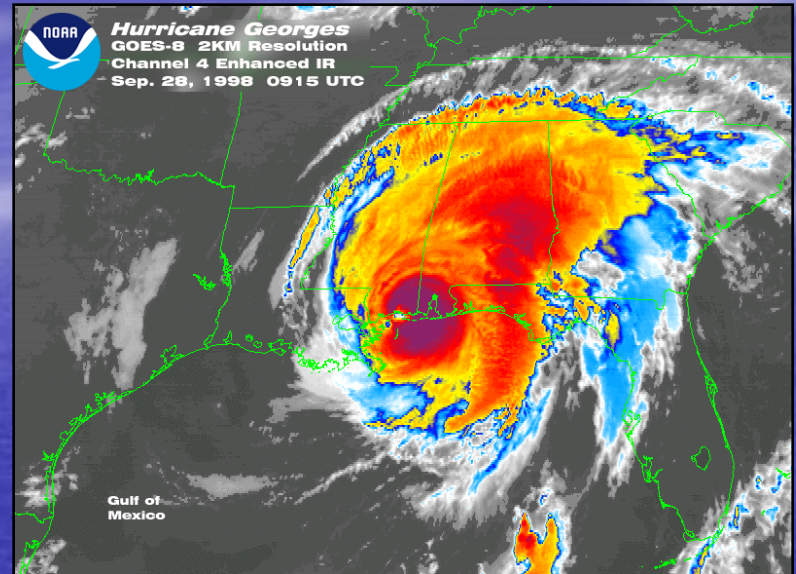


High Water Profile for the U.S. Gulf Coast

(U.S. Army Corps of Engineers)

Recorded storm surge on Gulf of Mexico landfall of Hurricane Camille in 1969. Pass Christian recorded a storm surge of 22.5 feet, Bay St. Louis 20.2 feet, and Biloxi 16 feet.

Hurricane Georges Sept 1998



The **9 foot tidal surge** caused by Hurricane Georges came within inches of overtopping the Lake Pontchartrain levees and drainage canal gates on September 27, 1998.

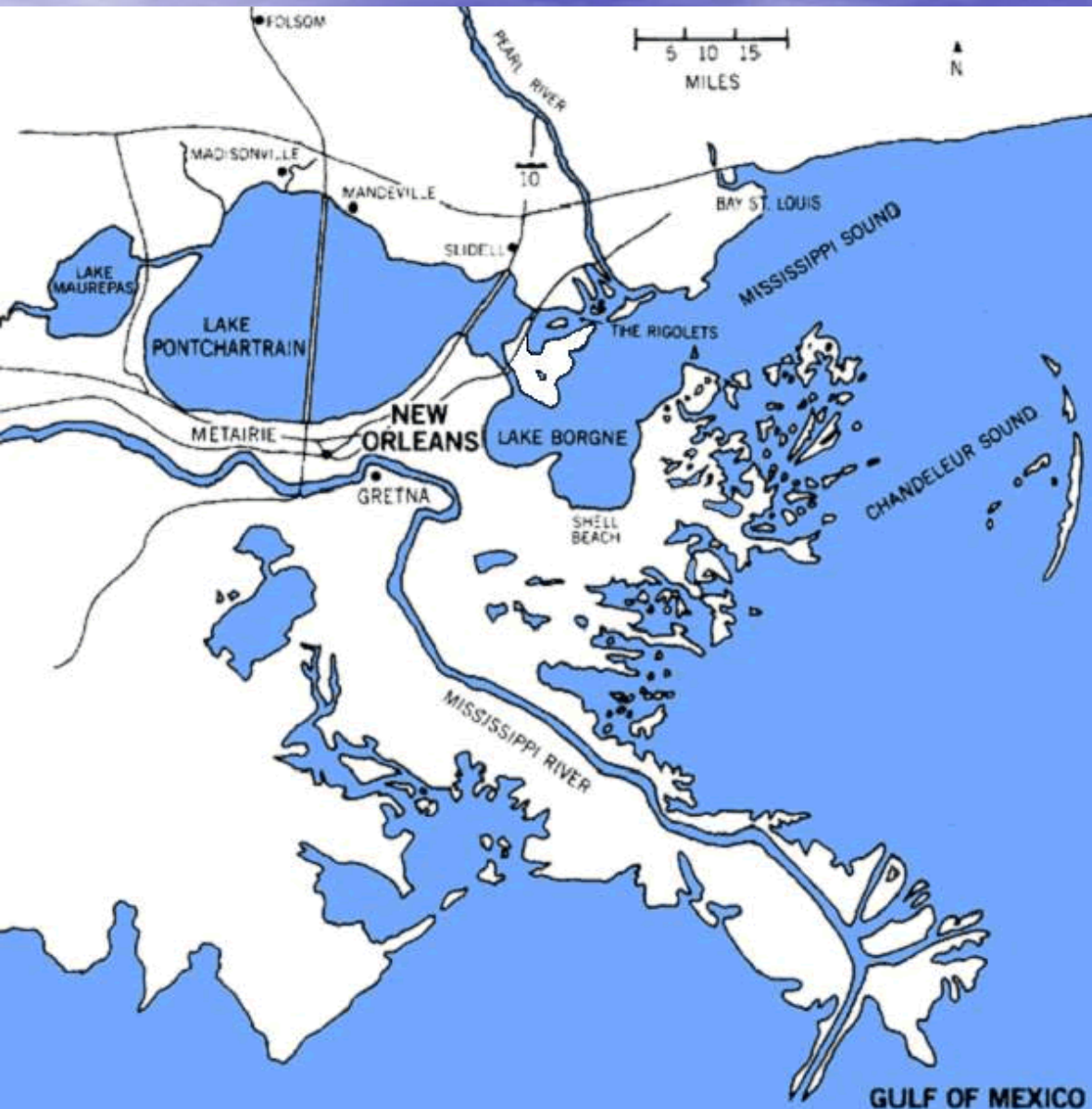
PART 6

Lake Ponchartrain and Vicinity Hurricane Protection Project 1956-2005

FEDERAL INVOLVEMENT

- Federal involvement in the drainage canals began in **1955** with approval of the **Lake Ponchartrain and Vicinity Hurricane Protection Project**
- Clash of cultures and goals between local levee districts, the S&WB, and the Corps of Engineers ensued.
- The Corps preferred gates at the mouths of the canals, but S&WB and many residents opposed, fearing they would malfunction, inhibiting outflow of storm water.

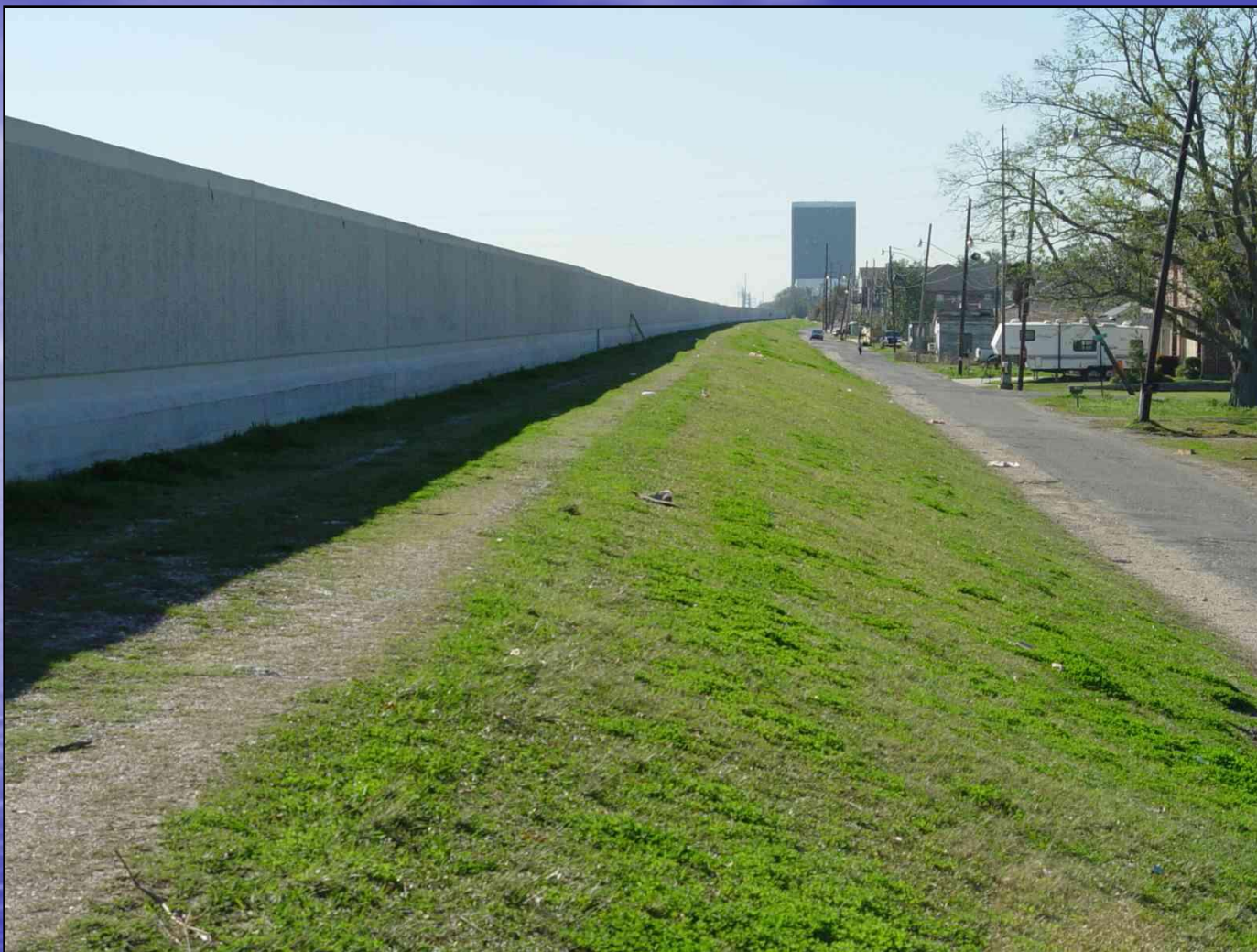
New Orleans is situated between Lake Pontchartrain and the Mississippi River.



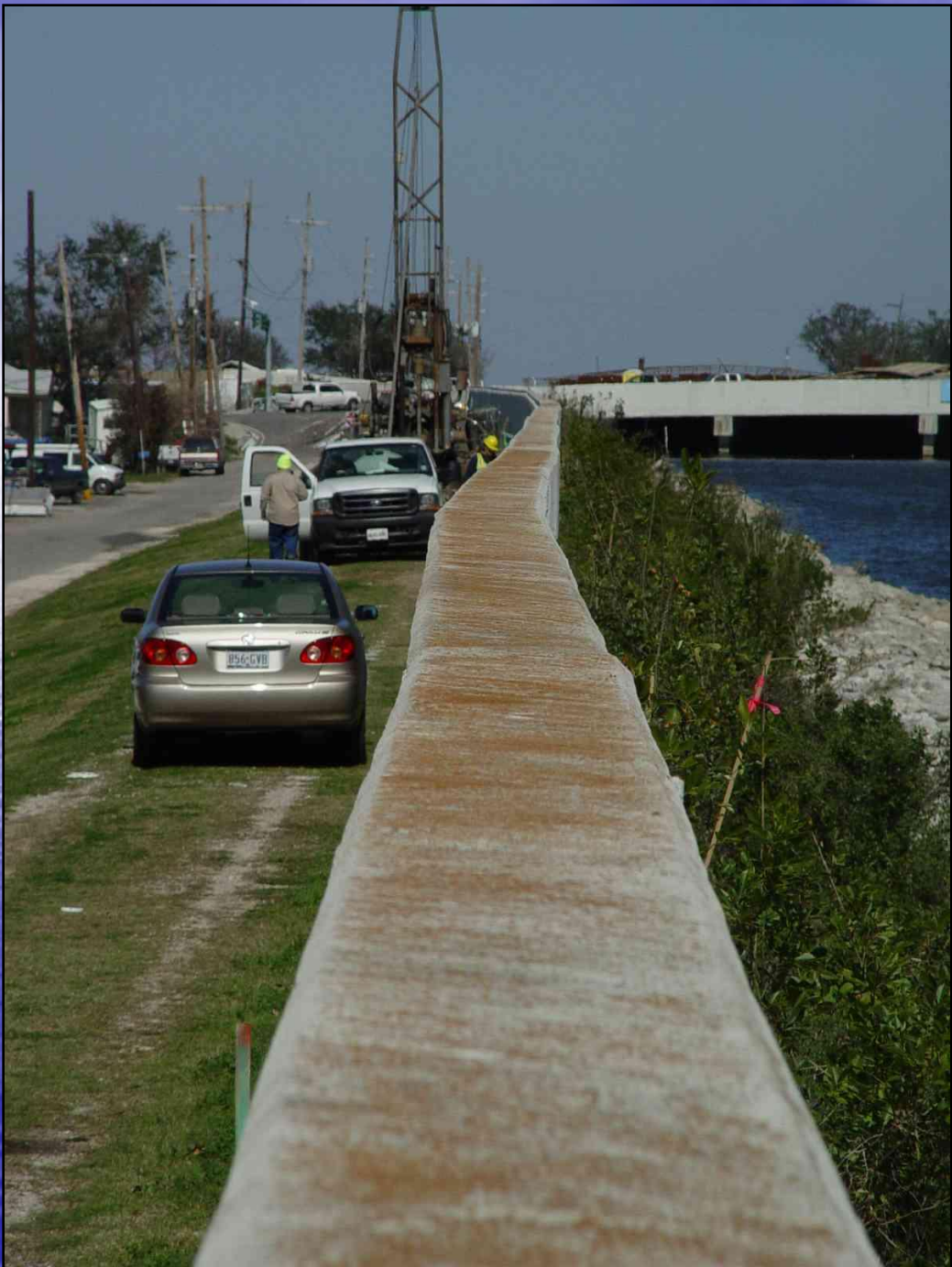
After Hurricanes Betsy (1965) and Camille (1969) it was proposed that the Corps of Engineers construct a tidal gate across the outlet of Lake Pontchartrain to prevent potentially destructive tidal surges from entering the lake and impacting the back side of New Orleans. This would have the added benefit of protecting the causeways and viaducts leading to the city.

24 YEAR BATTLE

- The issue of how to address improvement of the drainage canals dragged on for almost 40 years.
- In the meantime, intense residential development encroached upon the drainage canals, beginning in **1955**.
- The federal Court of Appeals decided the issue in **1979**, ordering the Corps to go with heightened levees able to withstand a **Category 3 storm** with 12 ft tides and 130-mph winds.



Flood Walls were constructed on the crowns of drainage canals and the Inner Harbor Navigation Canal to accommodate functionality during high storm surges. The walls in the Lakeview and Gentilly Districts were supposed to be +14 ft above MGL (actually 12.1 ft).

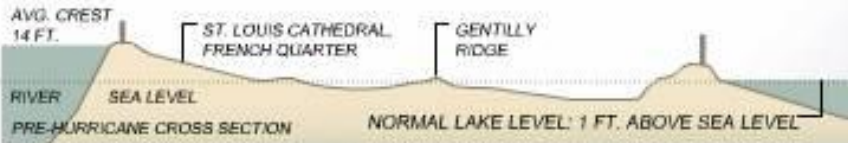


Flood Walls

Prior to Hurricane Katrina, the drainage canals feeding into Lake Ponchartrain never exceeded a flow height of **7 feet above MGL**

This shows deflection of the western 17th Street Canal flood wall, opposite the August 29, 2005 break of the eastern wall, near the Hammond Highway Bridge.

The canal levee had previously breached at this position in 1947



Water levels between the city and Lake Pontchartrain evened out late Wednesday, stopping the rise of water in the city. Normally, the city is protected by levees from the lake, since much of it is below the lake's water level.

- Pumping station**
 All currently offline
- Flooded areas**
 As of noon Tuesday

The extent of flooding was determined using an infrared satellite image taken at noon on Tuesday. Water continued to rise after the image was taken.

Major levees and flood walls

Smaller levees, flood walls and roads that block flow of water

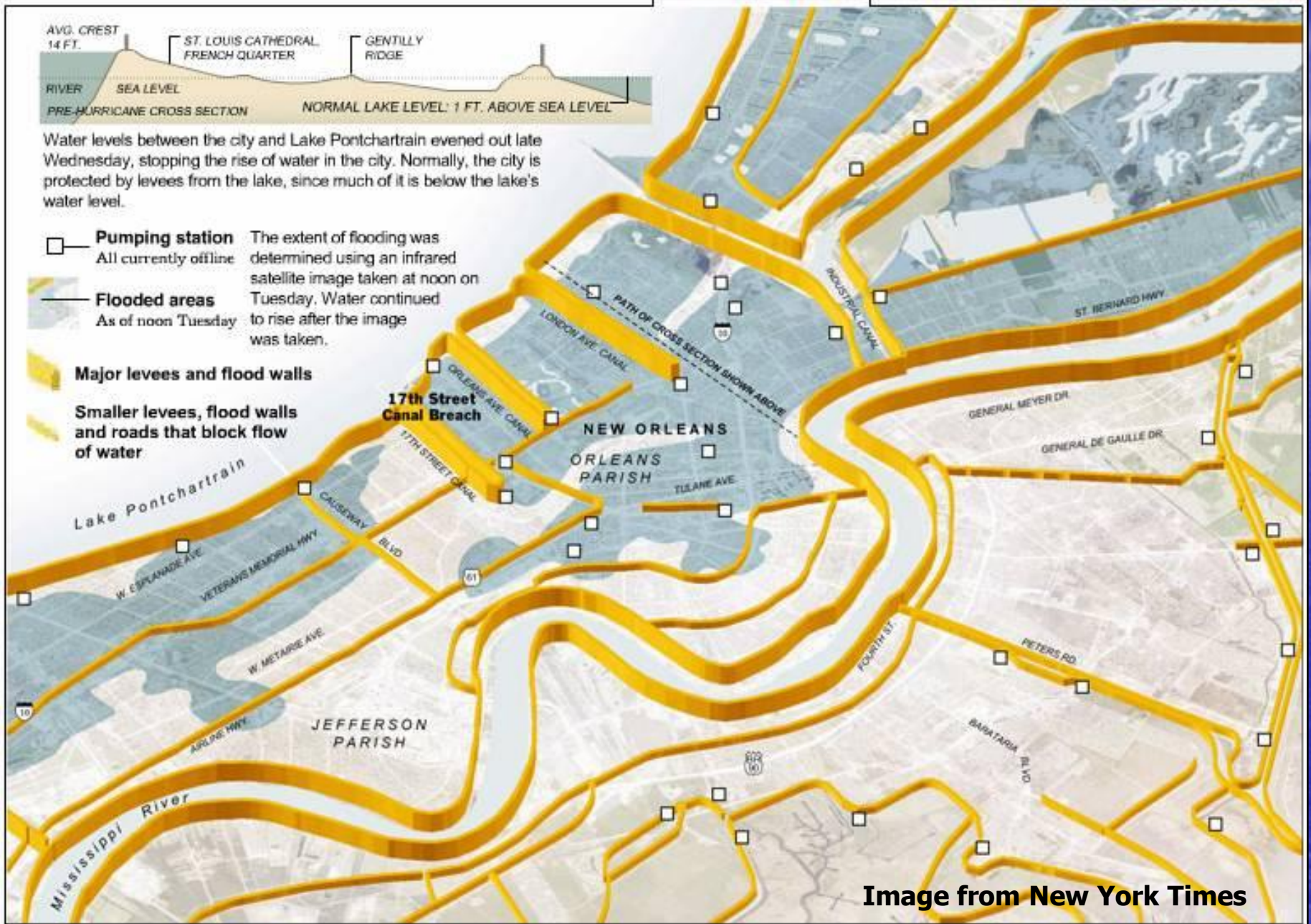


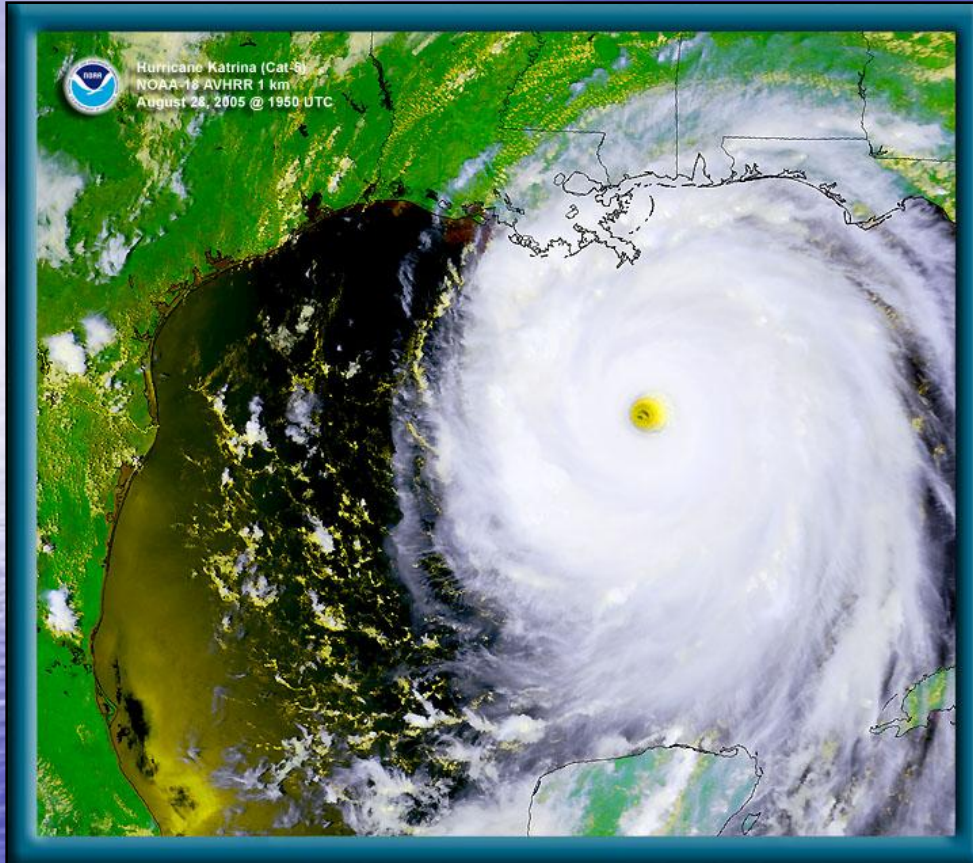
Image from New York Times

A complex network of levees protected the city from flooding, but it quickly failed on August 29, 2005, when water levels rose.

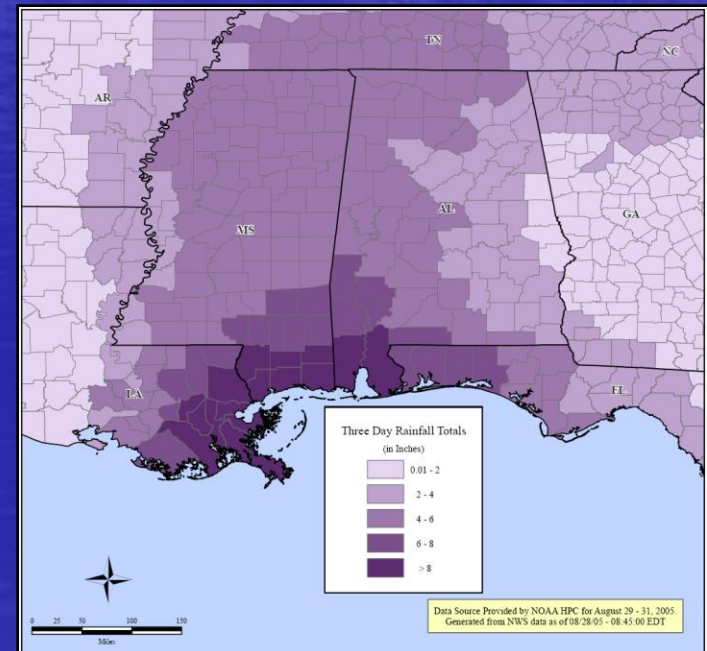
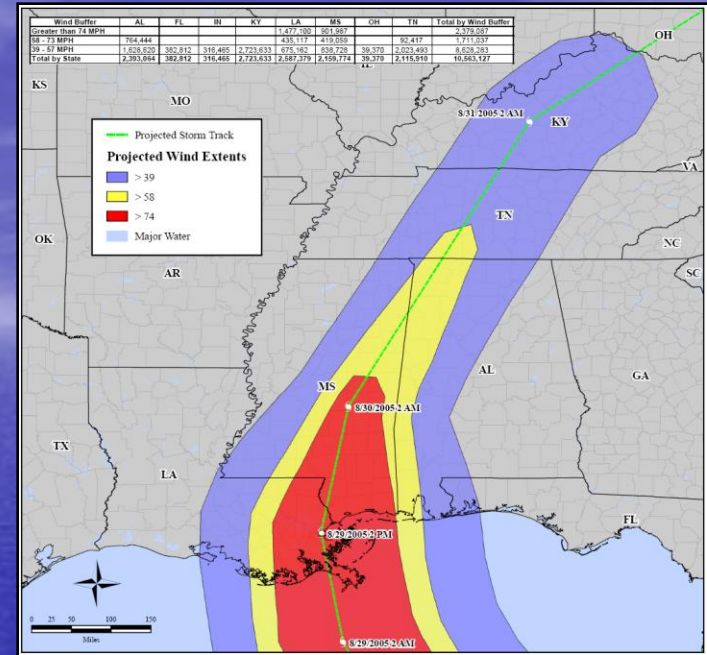
PART 7

**HURRICANE
KATRINA STRIKES
NEW ORLEANS
AUGUST 2005**

Hurricane Katrina



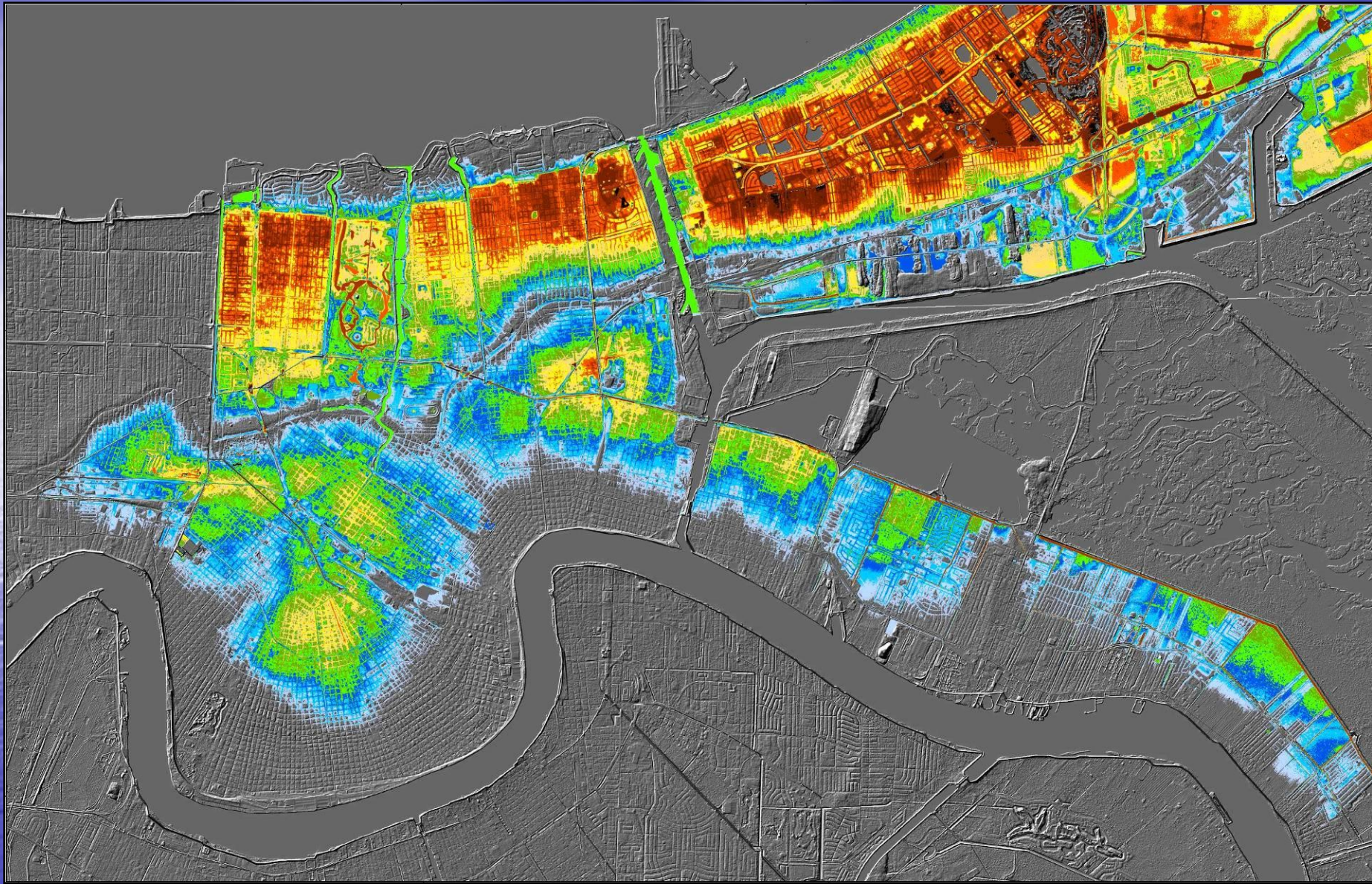
Hurricane Katrina swept across southern Florida and lost momentum, then gained speed and water, showing the second lowest barometric pressure ever recorded. The predicted storm surge was 18 to 28 feet; a record for New Orleans.



Katrina Landfall

- Historically, there haven't been but a handfull of Category 4 or 5 hurricanes that have ever been photographed making landfall.





Predicted water depth in New Orleans flood inundation area based on water level of 2.37 ft in Lake Ponchartrain on Sept 2, 2005. Overlay on 2002 5 m LiDAR DEM by USGS-MCGSC in Rolla. The dark red tones >9 ft.

This lecture will be posted at

www.mst.edu/~rogersda/levees

in .pdf format for easy downloading and use by others.

This lecture summarizes an article of the same name published in the May 2008 issue of ASCE's *Journal of Geotechnical and Geoenvironmental Engineering*. It can be downloaded in pdf format with color graphics towards the bottom of the same folder