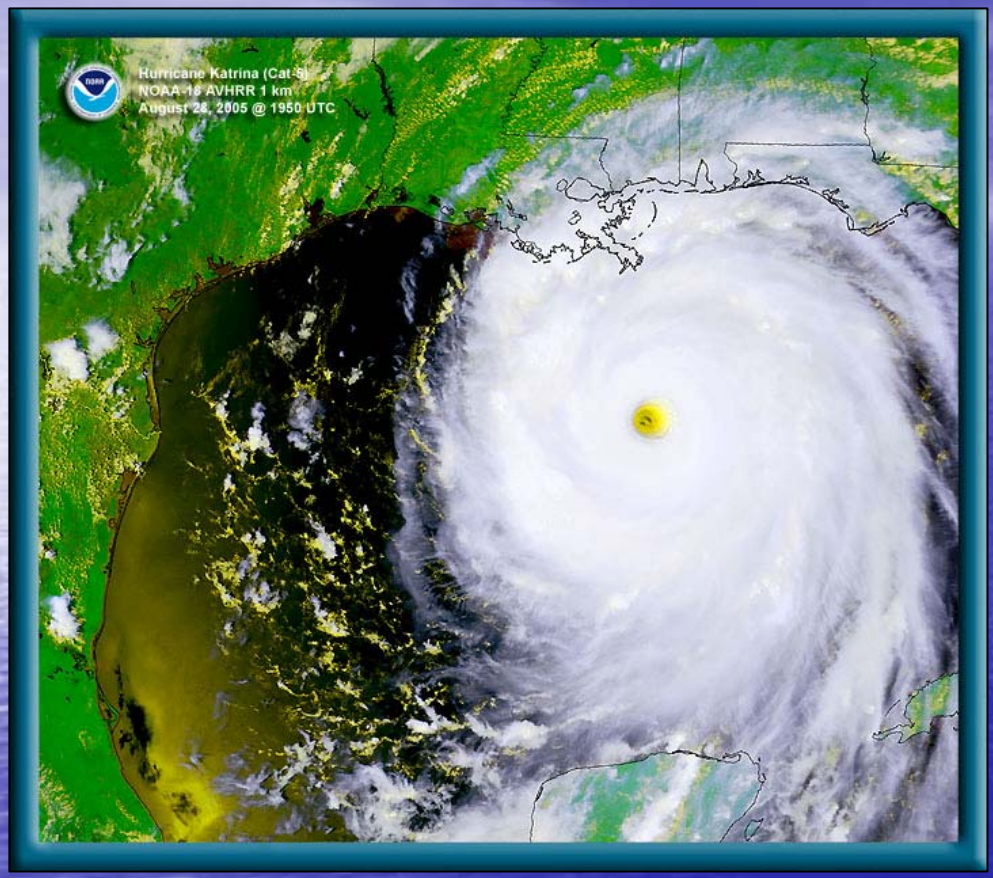
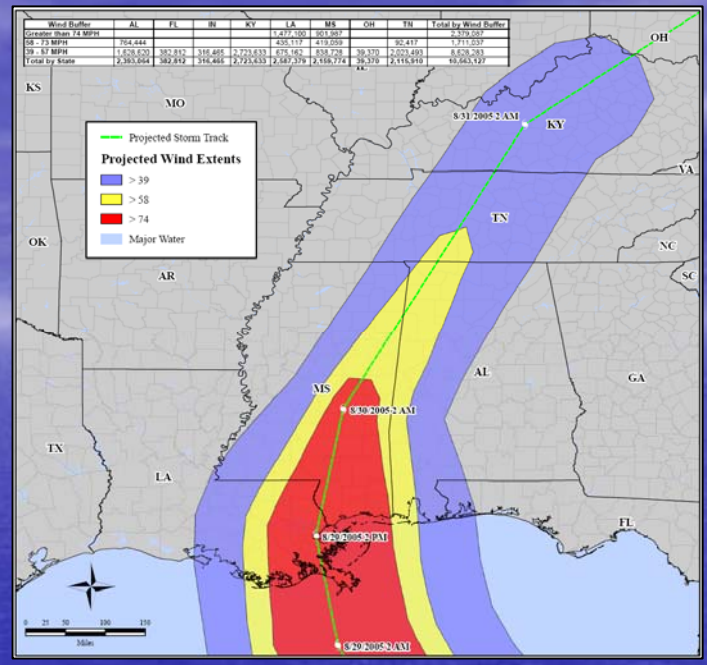
PART 4

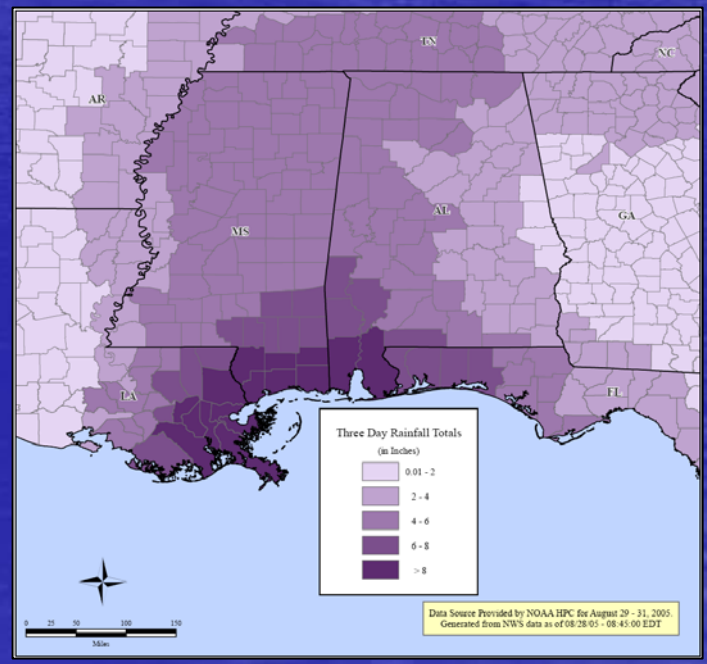
HURRICANE KATRINA STRIKES NEW ORLEANS

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.

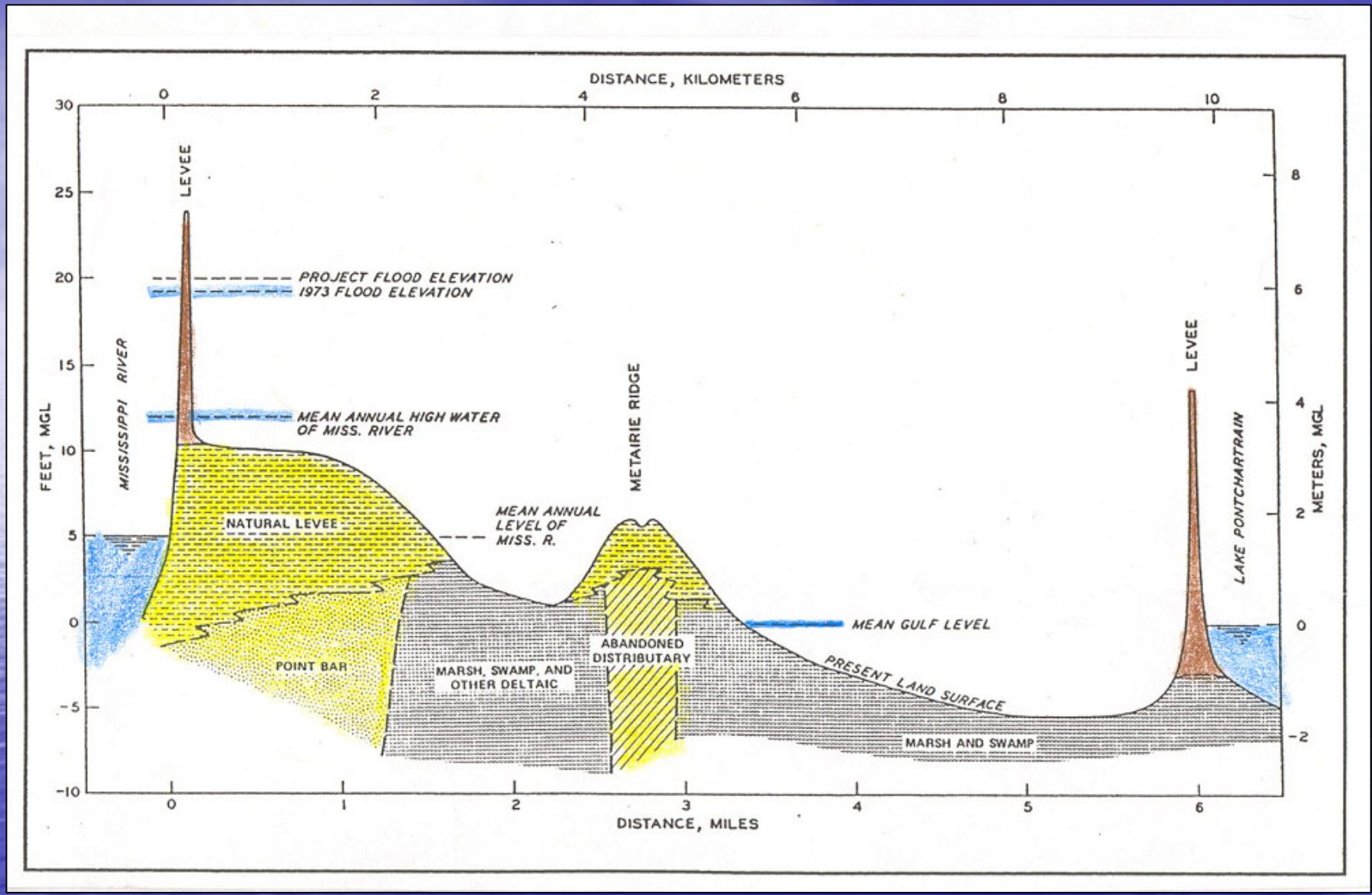
Katrina Landfall

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

New Orleans is a High Maintenance Place

- New Orleans has always been a high maintenance city
- The city did not stray much beyond the old Mississippi River levee mound until after the MR&T flood control project constructed Federal levees.

Source American Automobile Association



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

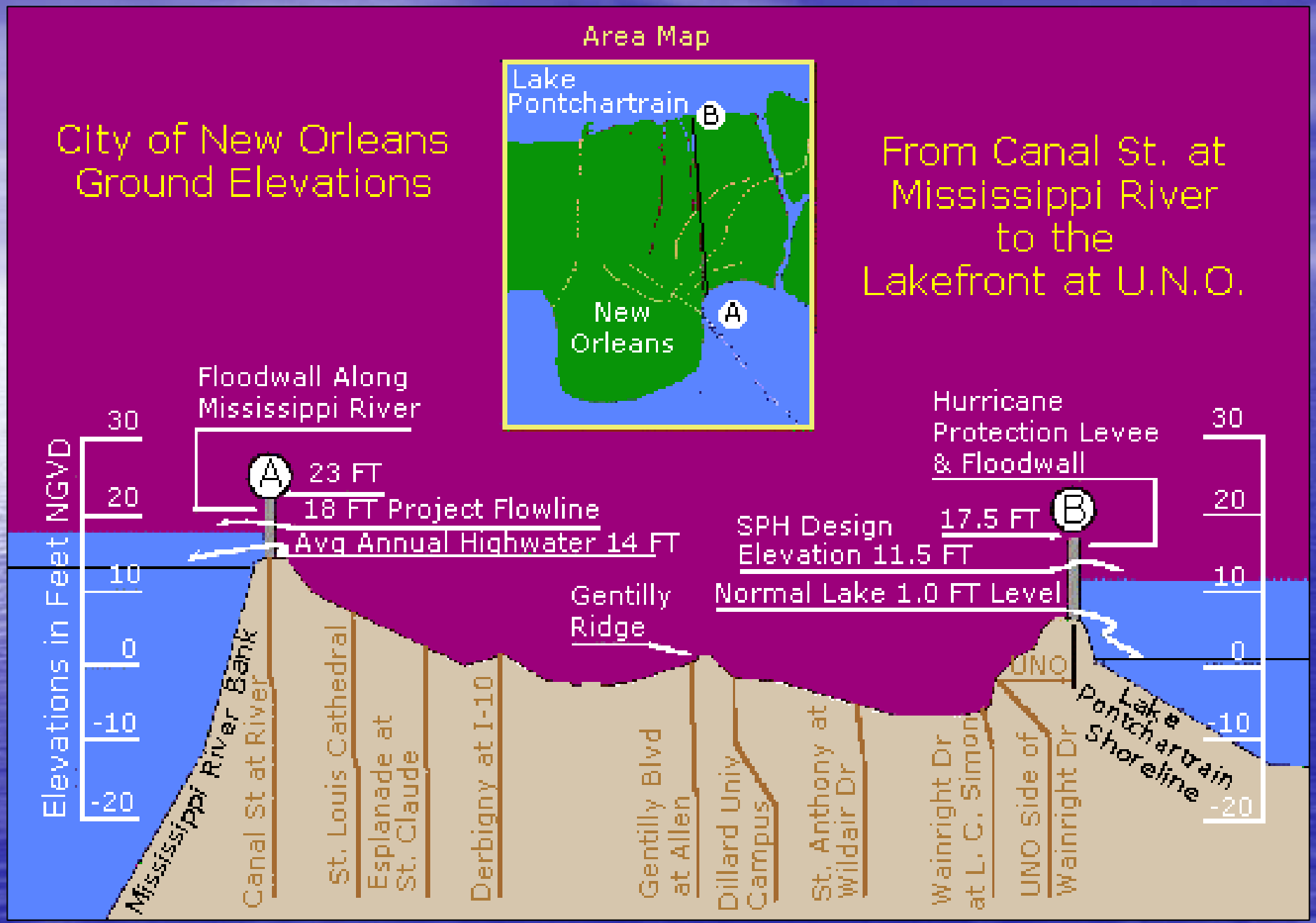


Image from US Corps of Engineers

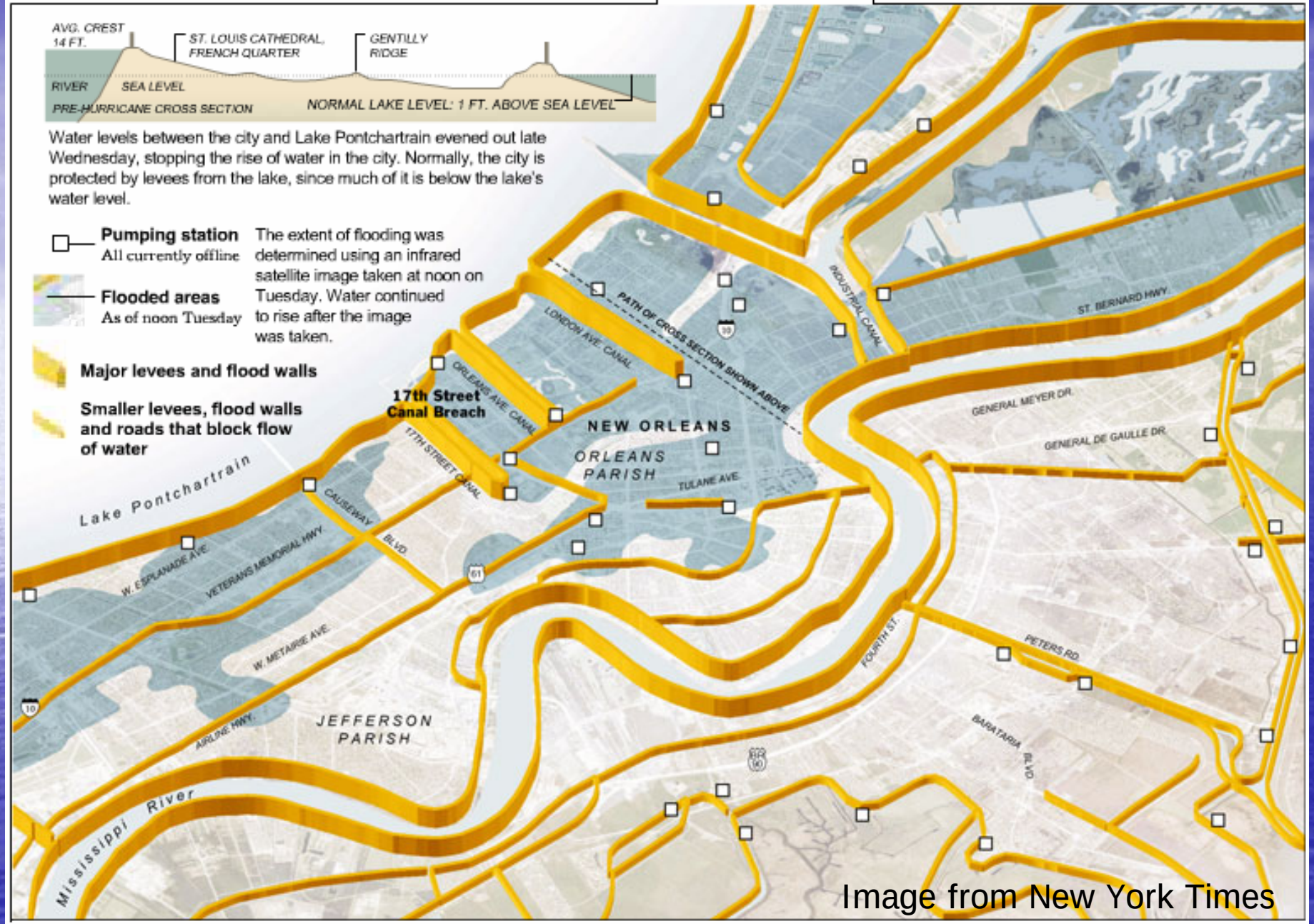
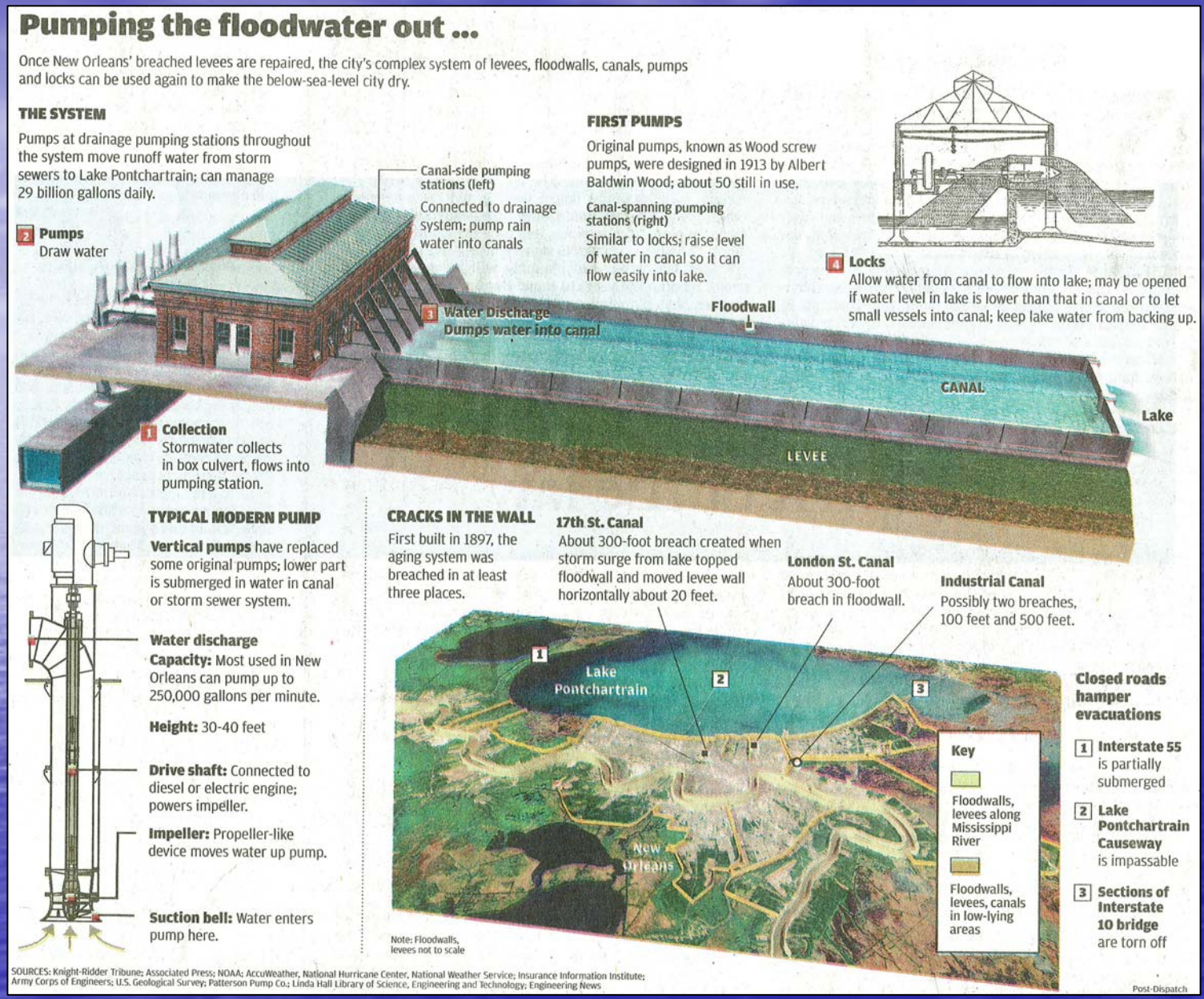


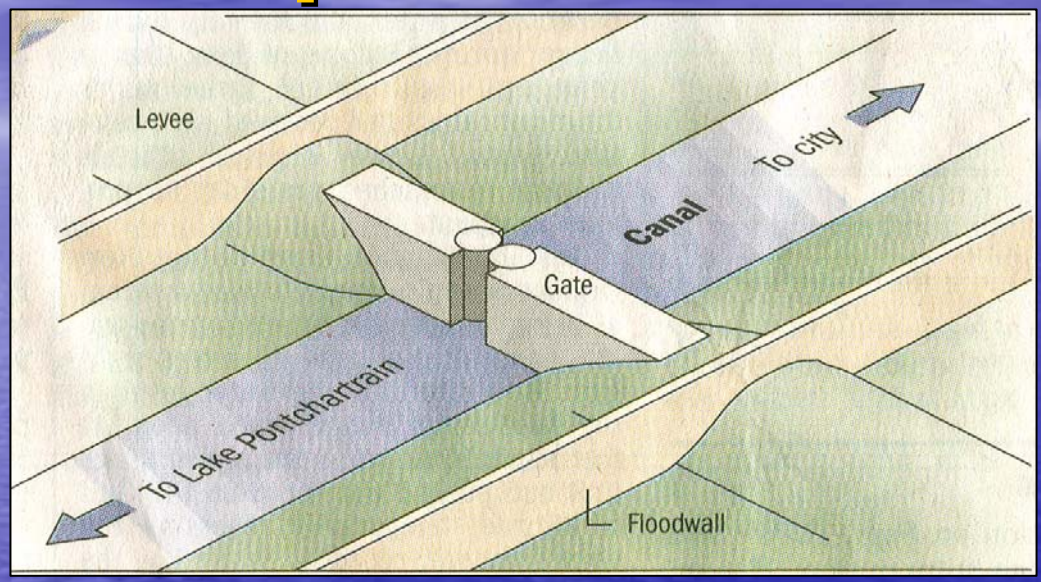
Image from New York Times

A complex network of levees protected the city from flooding, but it was two drainage canals that were overtopped on August 29, 2005.



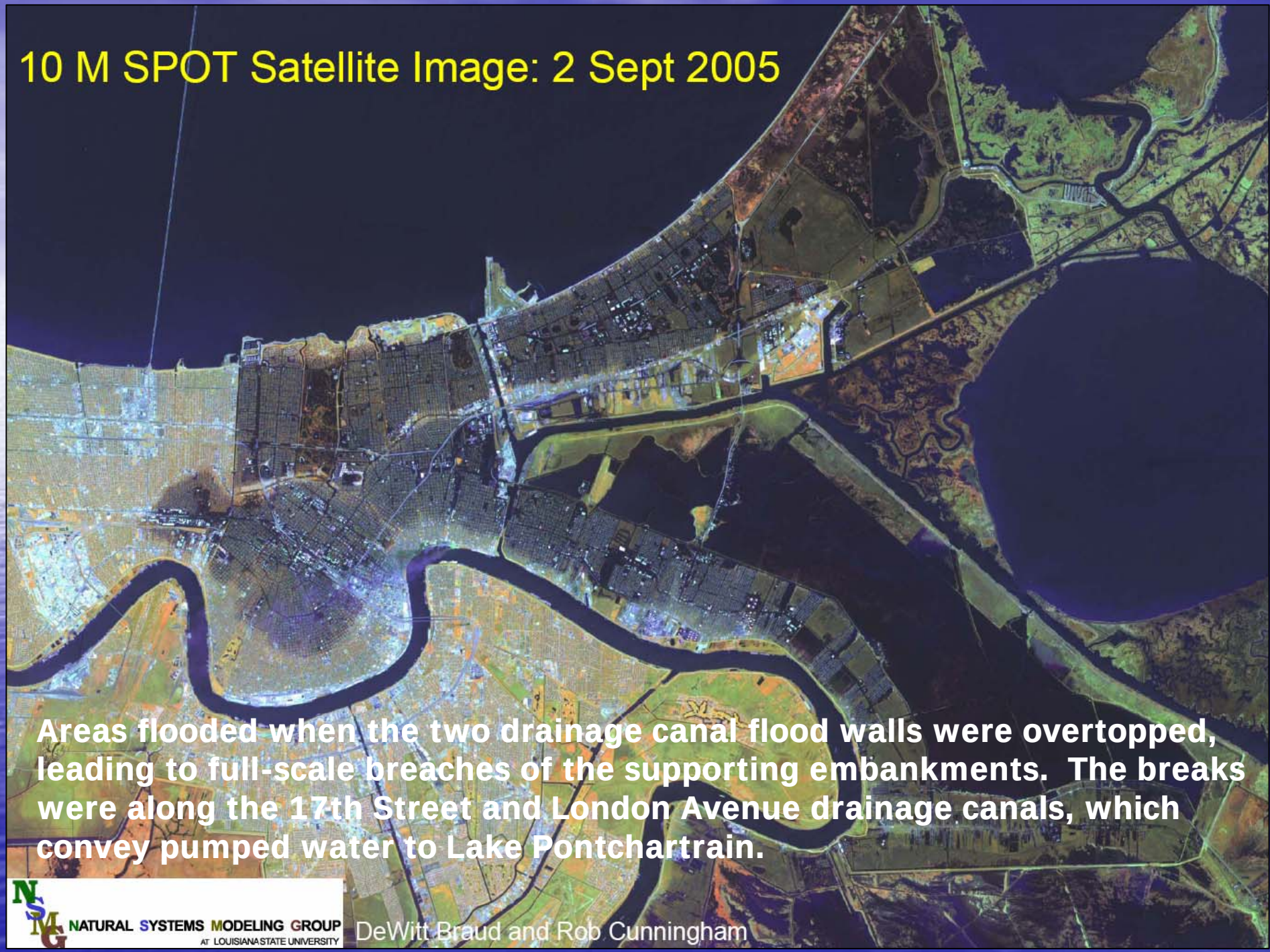
All water entering the city must be pumped out, otherwise it would pond in the low-lying areas. Image from St. Louis Post-Dispatch

Tidal Gates on Drainage Canals could have prevented flooding



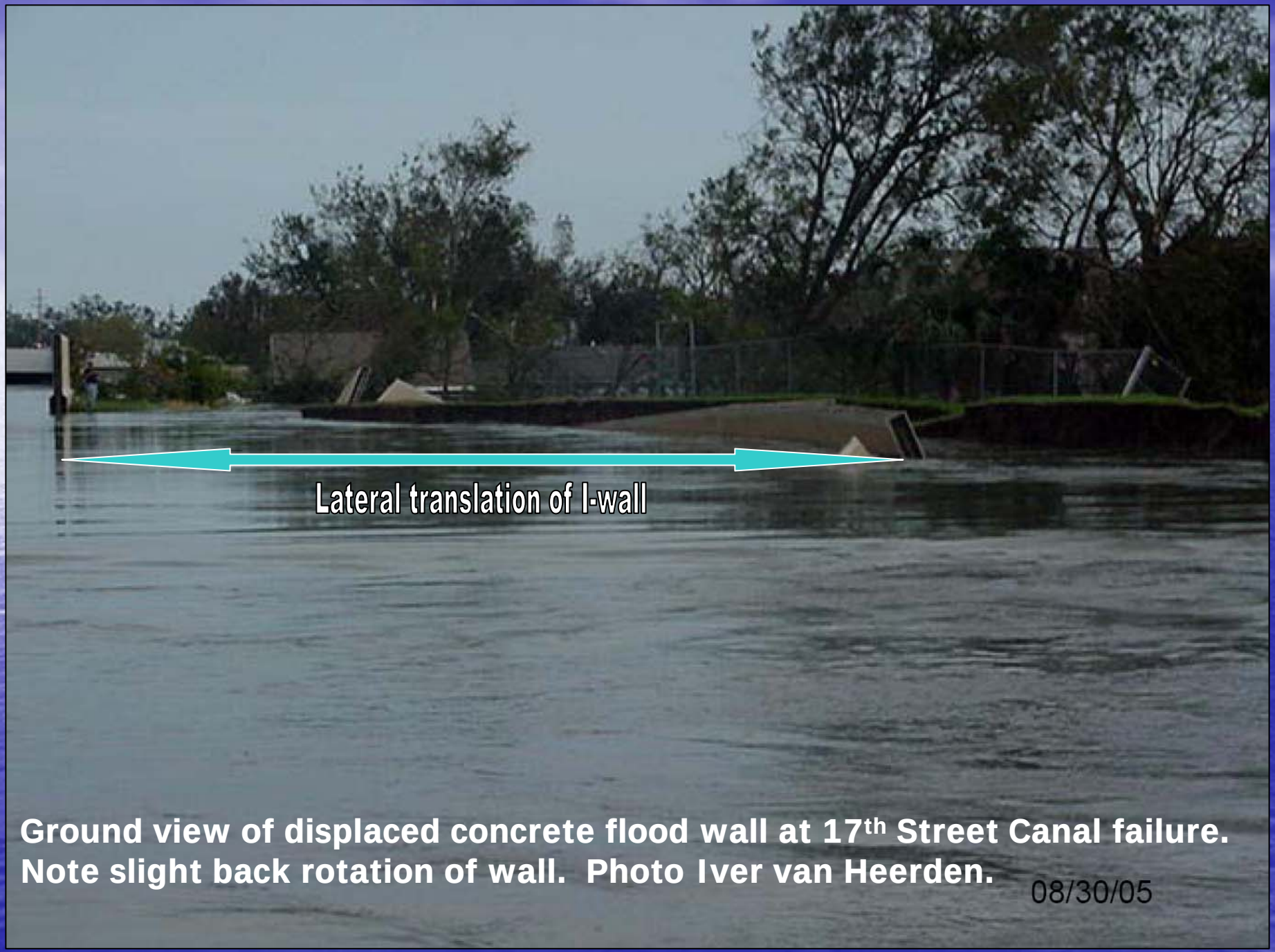
- In 1955 Congress directed the Army Corps of Engineers to survey coastlines to study how to build hurricane protection systems as apart of the Lake Pontchartrain and Vicinity Hurricane Protection Plan.
- In 1961 the Corps proposed a hurricane flood plan for New Orleans area whose main feature is barriers at the passes into Lake Pontchartrain that will prevent storm surge water from entering the lake. These were opposed by local agencies, so never built.

Image taken from Wall Street Journal.

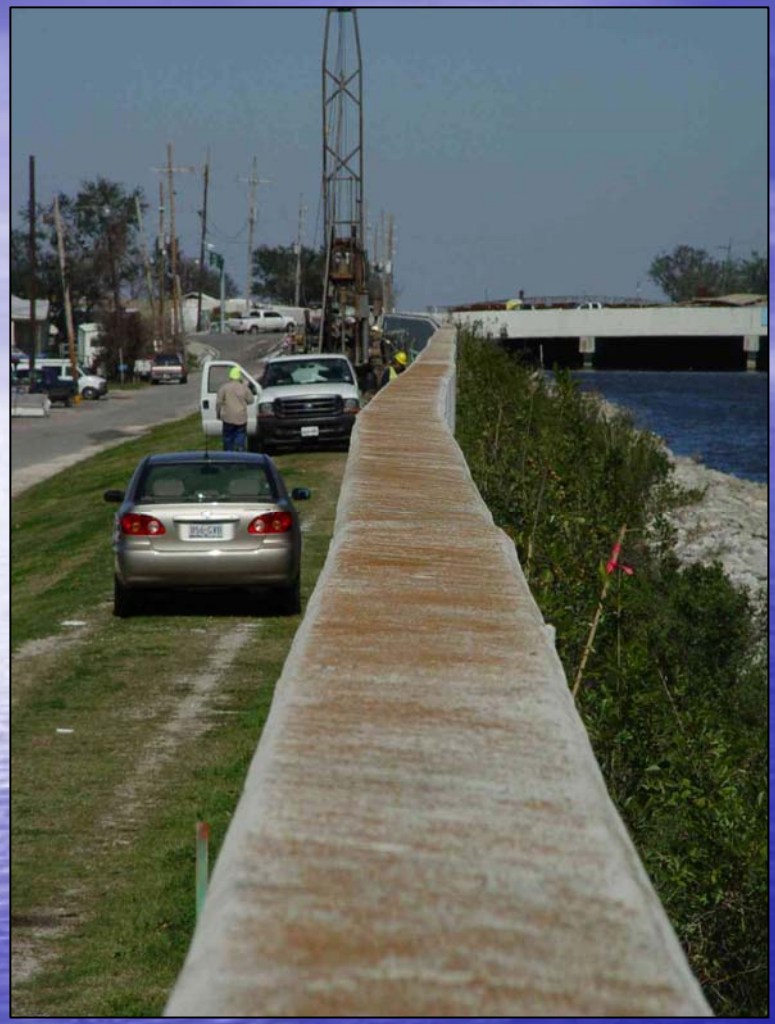

10 M SPOT Satellite Image: 2 Sept 2005
Areas flooded when the two drainage canal flood walls were overtopped, leading to full-scale breaches of the supporting embankments. The breaks were along the 17th Street and London Avenue drainage canals, which convey pumped water to Lake Pontchartrain.
NSMG
NATURAL SYSTEMS MODELING GROUP
AT LOUISIANA STATE UNIVERSITY
DeWitt Braud and Rob Cunningham

The break on the 17th Street Canal is circled. Note debris piled up against Hammond Highway Bridge in foreground.

- Aerial oblique view of the 17th Street Canal break, looking east. Note lateral translation of concrete flood wall, between 35 and 50 ft. Photo by Ivor van Heerden.



Ground view of displaced concrete flood wall at 17th Street Canal failure. Note slight back rotation of wall. Photo Iver van Heerden.

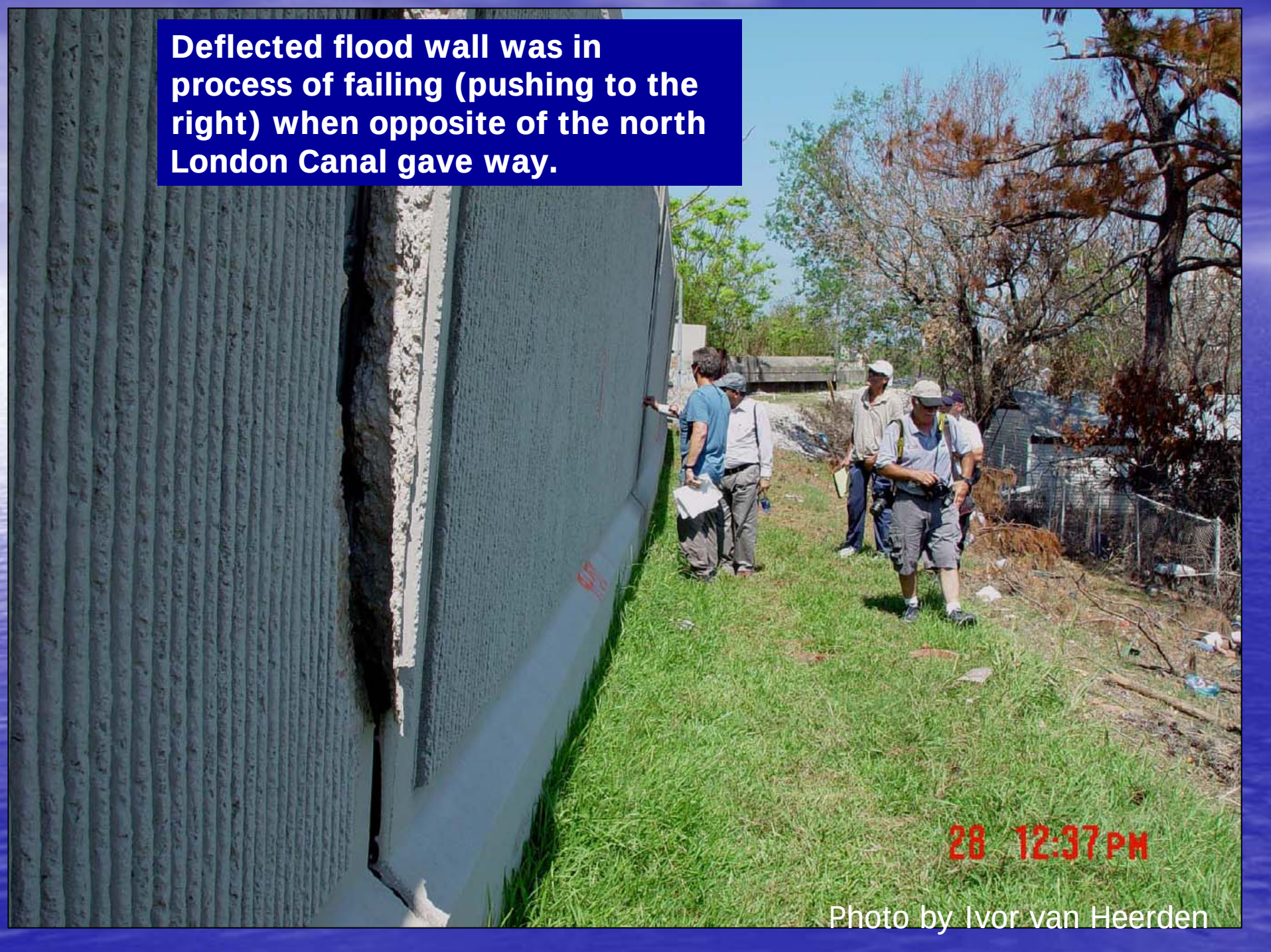


- Apparent displacement of the 17th Street Canal flood wall on the west (Jeffereson Parish) side, opposite the 17th Street failure.

London Avenue Canal – North Breach

From NSF report November 2005


London Ave Canal – Filmore Breach
SEP 7 2005
Photo by Ivor van Heerden

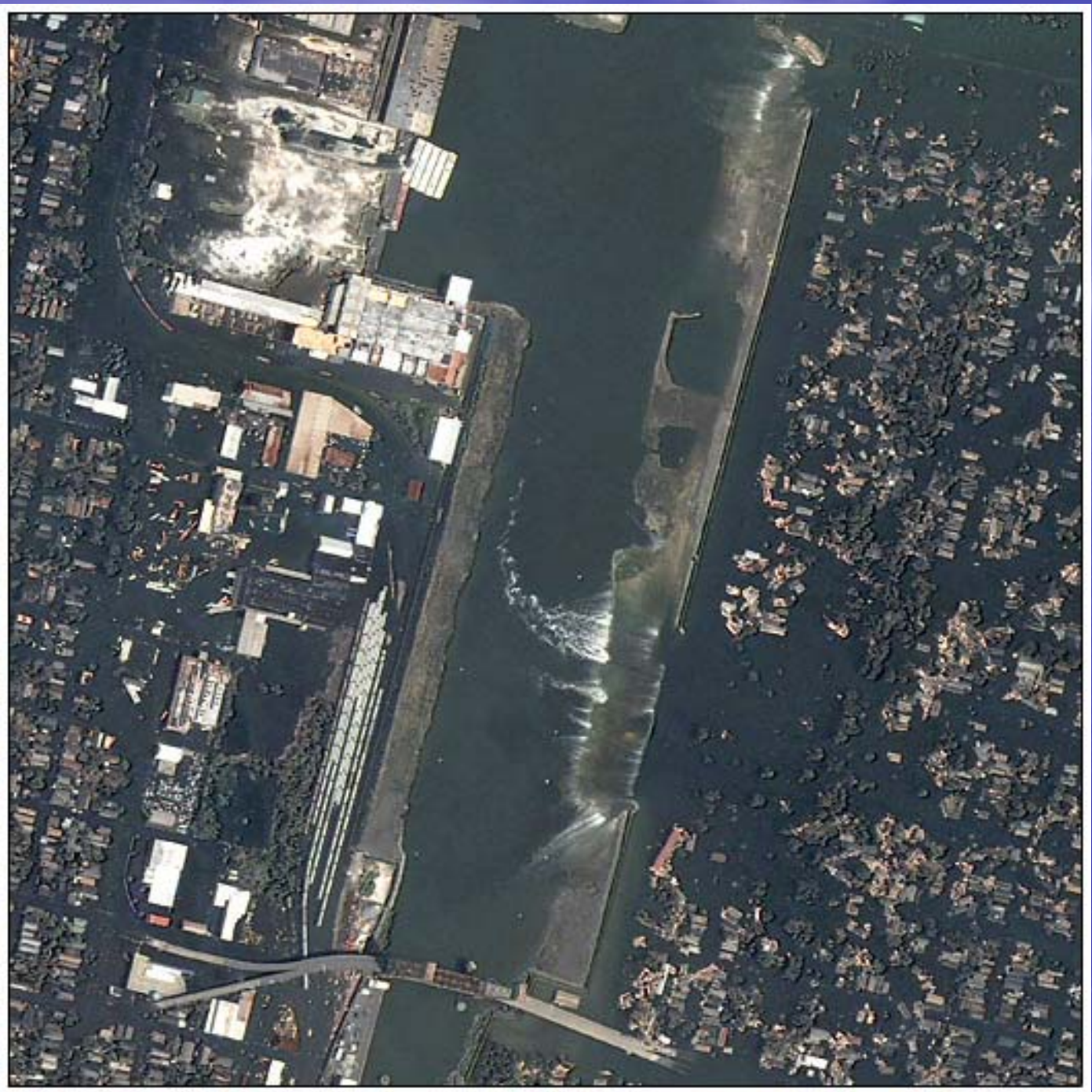

Deflected flood wall was in process of failing (pushing to the right) when opposite of the north London Canal gave way.
28 12:37 PM
Photo by Ivor van Heerden


South London Avenue Canal breach, just north of Mirabeau Drive
SEP 15 2005
Photo by Ivor van Heerden

Deflection of concrete I-walls along eastern side of Inner Harbor Navigation Channel. Photo Ivor van Heerden.


10.04.2005 12:08

An **empty barge** moored at the Lafarge North America construction materials facility on Lake Pontchartrain tore loose of its moorings and crashed through the levee along the Industrial Canal, coming to rest next to a house, shown here. The barge appears to have bumped the flood wall, but only after it had overtopped and failed.



This aerial view shows an example of reverse flow, back into the Inner Harbor navigation Channel.

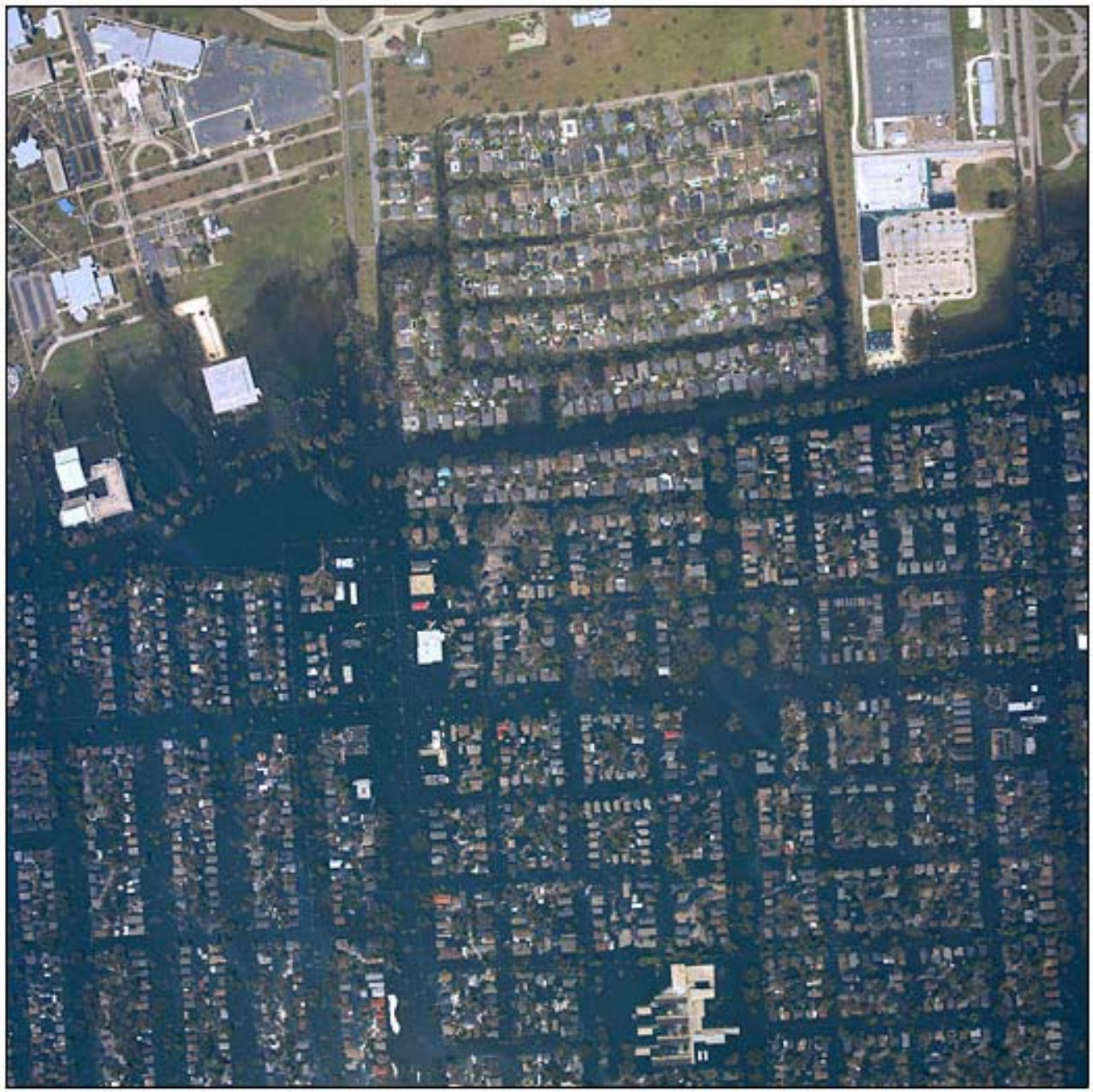
Note the absence of the concrete flood wall capping the earthen levee, removed by toe scour of the supporting levee embankment when it was initially overtopped

Levees are erodible

Earthen embankment levees usually fail by underseepage along preferential flow paths, engendered by permeability contrasts.

Levees are also susceptible to erosion by overtopping, by edified flow, and by undercutting.

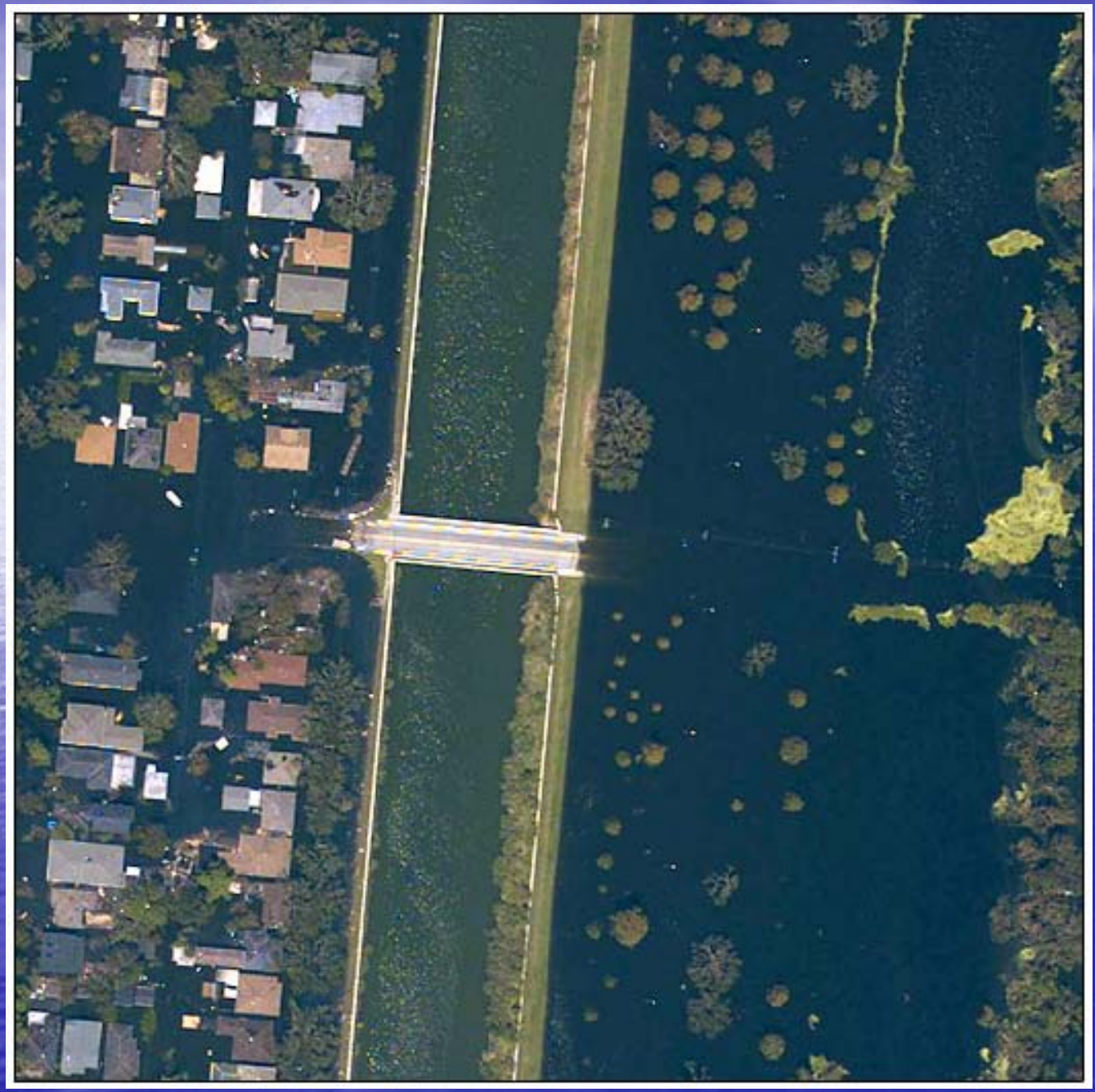
Once flood waters overtop an embankment they quickly scour the land-side toe of the embankment, and deep scour holes develop on either side of the “hydraulic jump” that forms at the point of overflowage, enlarging the breach, as shown here.



Aerial view of flood inundated urban neighborhood in New Orleans.

The pool level extends to the upper fifth of the image, which is higher ground, lying above the inundated zone.

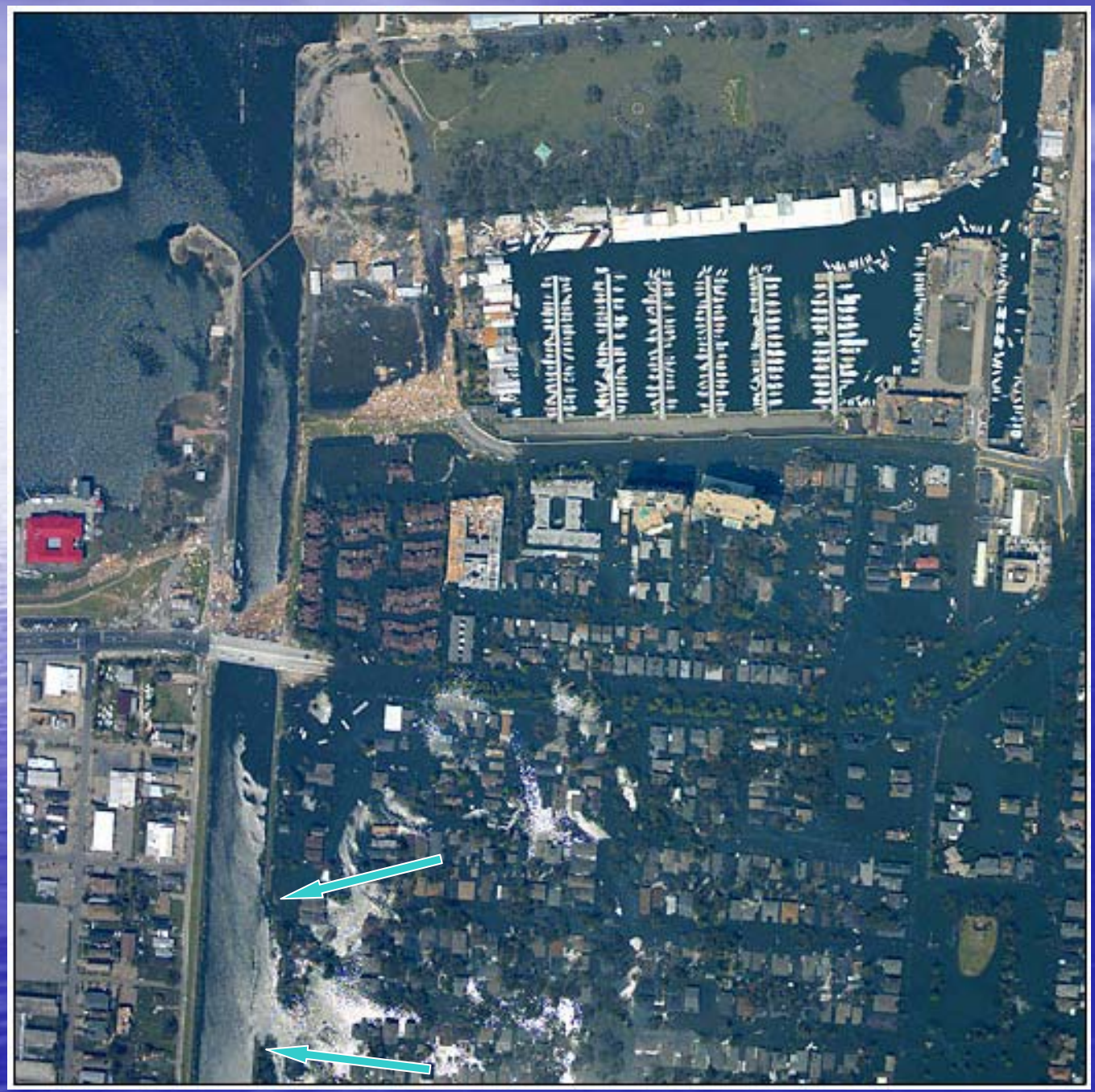
Old river channels form the high ground across old New Orleans because these channels deposited silty sand levees, which now form low ridges.



Post flood aerial image showing inundated zones on either side of a drainage canal.

Note how the street crossing the canal is higher than on either side of the canal

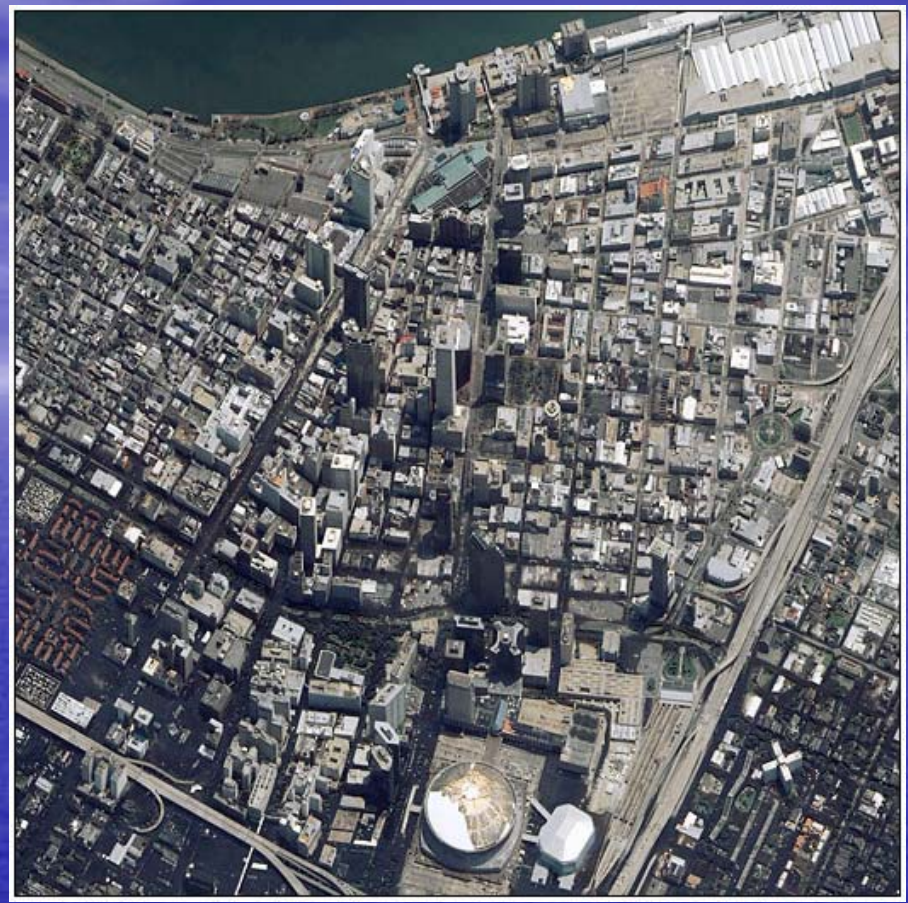
Variances in reflectance of the ponded water is ascribable to dissolved and entrained solids, depth, temperature, oxygen content, temperature, turbidity, and current.



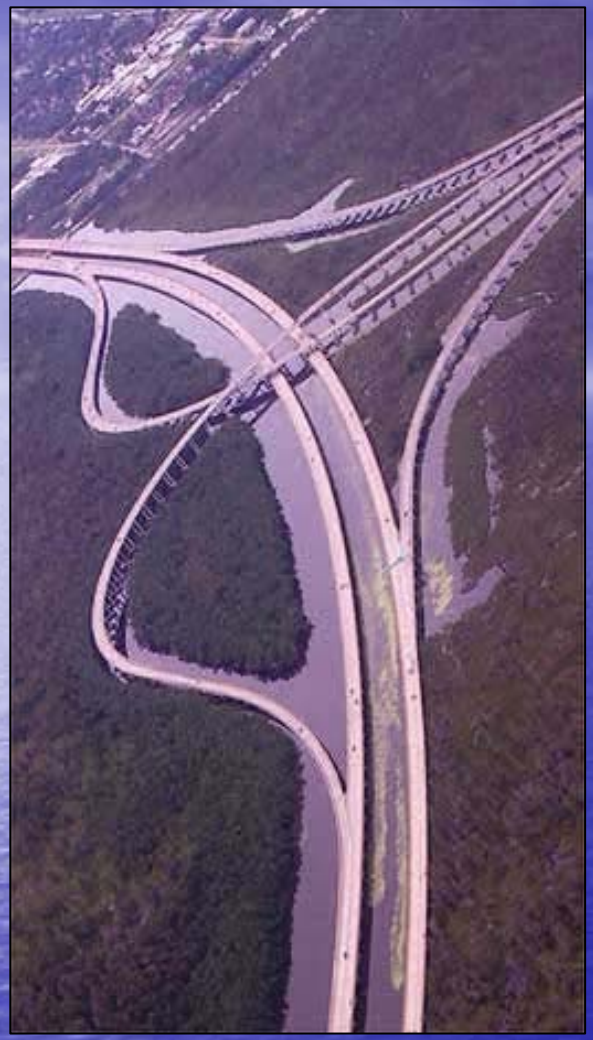
Lower 17th Street Canal

The eastern side of 17th Street Canal I-wall and embankment shifted 50 feet laterally, between arrows, spilling water into the Lakeside neighborhood at right. The Eastern Jefferson Parish (left of the canal) was spared inundation.

Louisiana Superdome



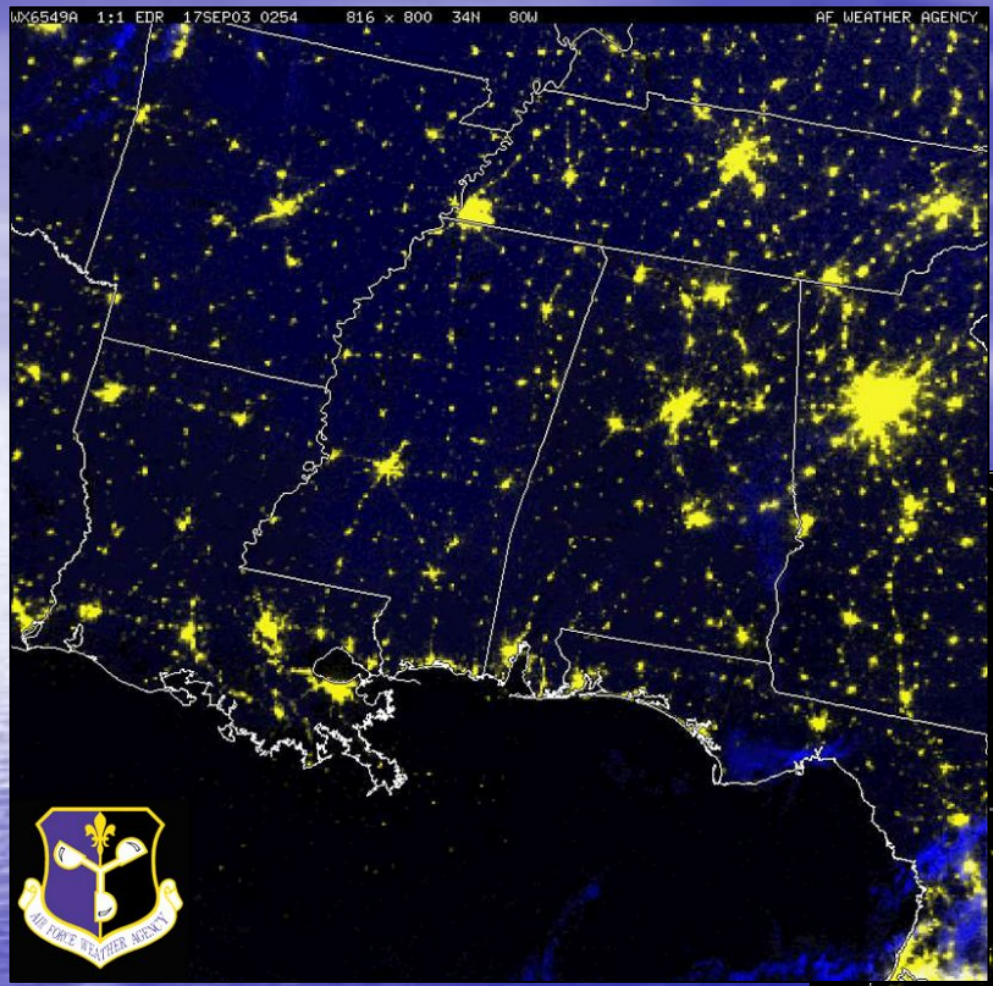
When the Cold War ended in 1991, everyone searched for “peace dividends.” Civil Defense operations were curtailed or discarded and a new paradigm in emergency services preparedness emerged. A popular concept was replacing Civil Defense shelters with sports stadiums and arenas, using whatever stores they had onsite. This alternative failed to encompass the need for water and power at such facilities, and assumed that they would come through any natural disaster relatively “unscathed”; being designed for extreme events.



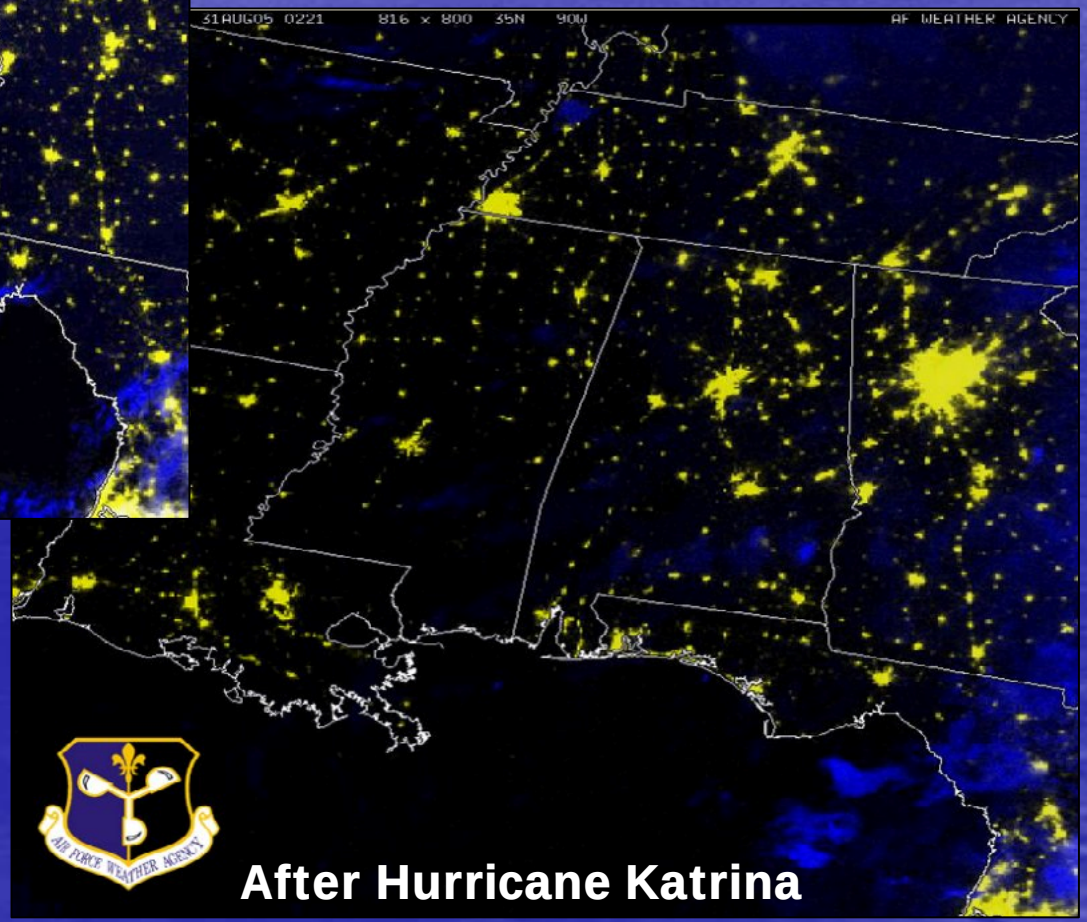
Highways in low-lying swampland are difficult structures to construct because they are usually founded on poorly-drained compressible soils. These foundation conditions are problematic for either elevated embankments (which cause additional settlement) or for pile supported viaducts (subject to downdrag forces). If the highway lies below flood levels, it can't be used to effect vehicular access.

Impacts on Electrical Power

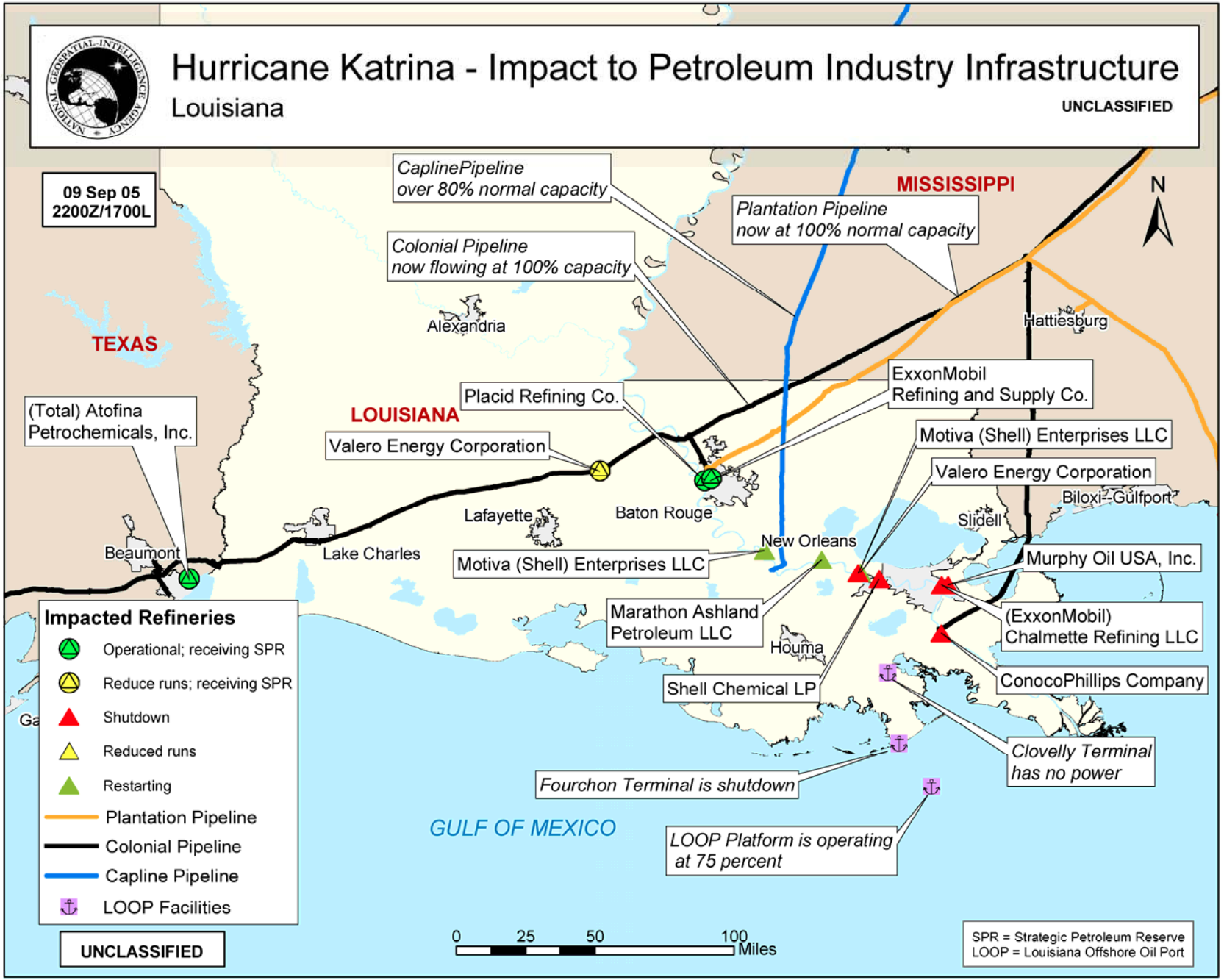
These ELINT images show how much electrical power was knocked out throughout much of the region.



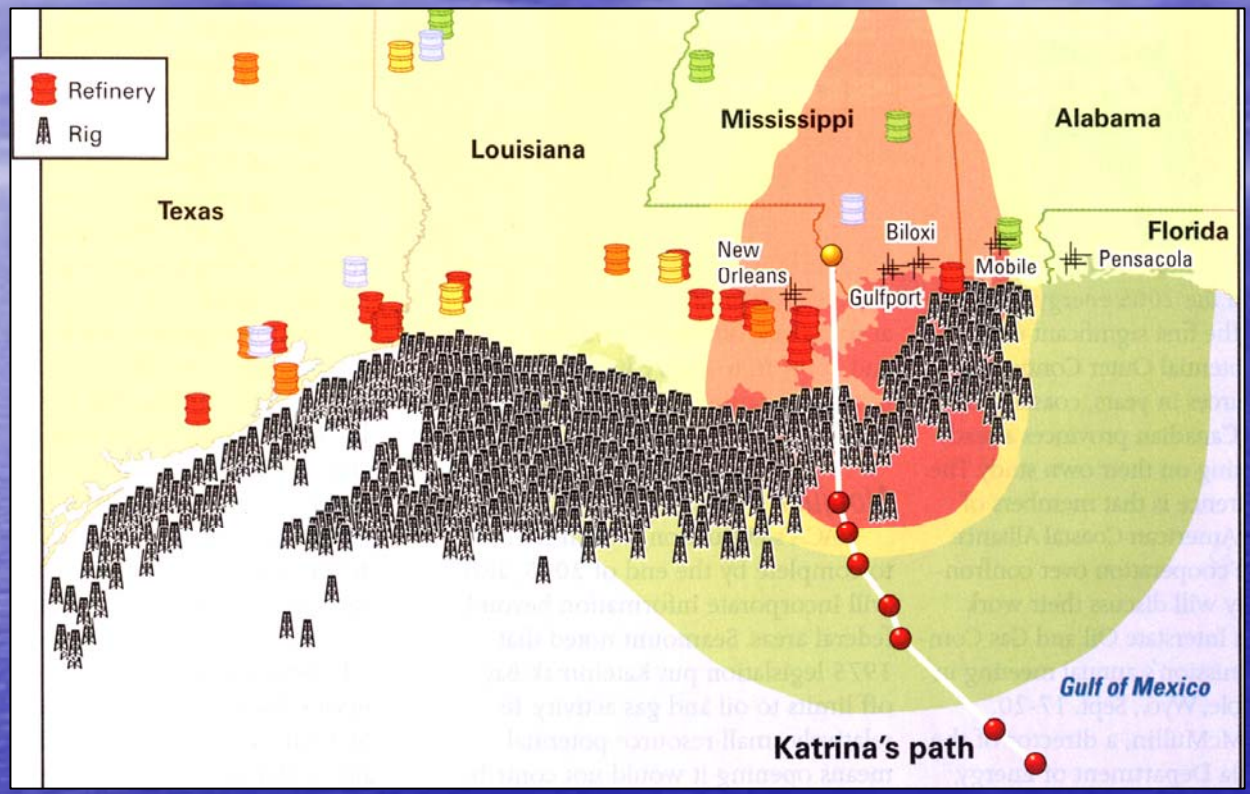
Before Hurricane Katrina



After Hurricane Katrina


Hurricane Katrina - Impact to Petroleum Industry Infrastructure
Louisiana
UNCLASSIFIED
09 Sep 05
2200Z/1700L
CaplinePipeline
over 80% normal capacity
Colonial Pipeline
now flowing at 100% capacity
Plantation Pipeline
now at 100% normal capacity
MISSISSIPPI
N
TEXAS
LOUISIANA
Alexandria
Hattiesburg
(Total) Atofina
Petrochemicals, Inc.
Placid Refining Co.
ExxonMobil
Refining and Supply Co.
Valero Energy Corporation
Motiva (Shell) Enterprises LLC
Valero Energy Corporation
Biloxi-Gulfport
Lafayette
Baton Rouge
Slidell
New Orleans
Beaumont
Lake Charles
Motiva (Shell) Enterprises LLC
Murphy Oil USA, Inc.
Marathon Ashland
Petroleum LLC
(ExxonMobil)
Chalmette Refining LLC
Houma
ConocoPhillips Company
Shell Chemical LP
Clovelly Terminal
has no power
Fourchon Terminal is shutdown
GULF OF MEXICO
LOOP Platform is operating
at 75 percent
Impacted Refineries
Operational; receiving SPR
Reduce runs; receiving SPR
Shutdown
Reduced runs
Restarting
Plantation Pipeline
Colonial Pipeline
Capline Pipeline
LOOP Facilities
UNCLASSIFIED
0 25 50 100
Miles
SPR = Strategic Petroleum Reserve
LOOP = Louisiana Offshore Oil Port

Impacts on Petroleum Industry



- 79 drilling rigs and 482 production platforms were evacuated during Katrina; stopping 1.4 million b/d of oil and 8.3 bcfd of natural gas production