KATRINA: What Went Wrong? – And How to Fix it
'Lessons Learned'

ICHARM
Commemorative Symposium

United Nations University/PWRI
Tokyo, Japan
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Outline

- Summary/preview of current status of ***HPS*** (**Hurricane Protection System**) recovery
- Evolution of HPS in Louisiana
- Characteristics of Katrina – Design Criteria
- Summary Findings of Major Studies
- Lessons Learned for ICHARM & IHP

Corps Interagency Performance Evaluation Team (IPET) Report: Press Reviews

- "Levee Design, building system failed on many levels, report says" *N. Orleans Times Picayune 6/2/06*
- "Army Builders Accept Blame Over Flooding" *New York Times, 6/2/06*
- "Army Corps Admits Design Flaws in New Orleans" Flooding", *Los Angeles Times , 6/2/06*
- "Corps Faults Itself for Levee Breaks in New Orleans", *Associated Press, 6/2/06*
- "Katrina's Unlearned Lessons: A government agency admits error, and Congress wants to reward it" *Washington Post editorial, 6/7/06*

Four Main Points

- Hurricane Protection System was a ‘system’ in name only – highly fragmented & built incrementally over 40 years
- Safety and reliability traded off for economic efficiency
- Hierarchy of agency decision processes poorly coordinated; insufficient resources
- New integrated management framework needed + new decision rules & procedures
- A mission for ICHARM?

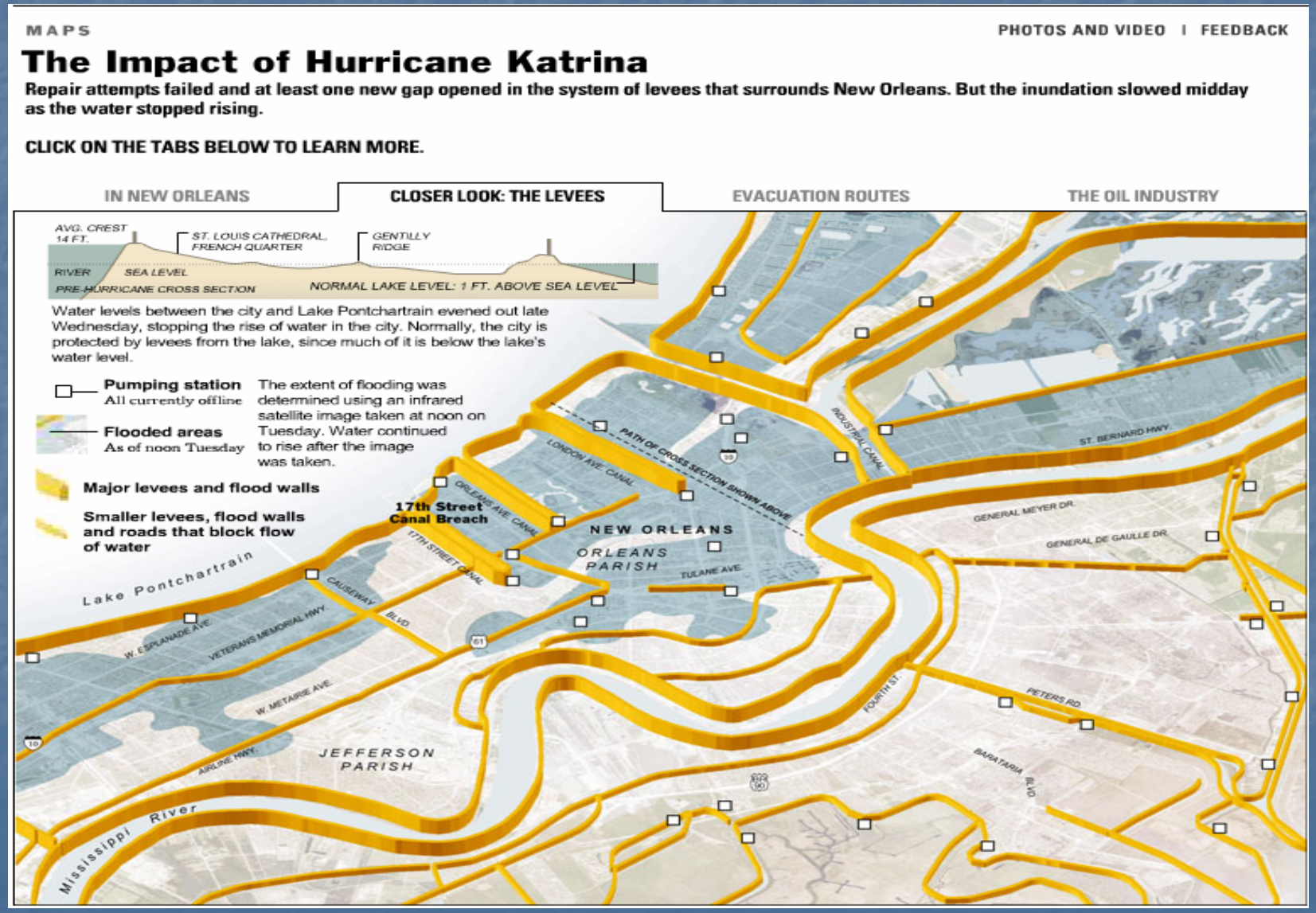
Some Facts

- $110B federal funds for recovery and reconstruction - $44B spent so far
- $10B for repair/replacement of levees, pumps, floodgates
- Insured damage ~ $55B
- 90,000 sq mi affected by Katrina – size of UK
- Orig pop. of New Orleans 455,000 – now ~210,000
- 19,000 businesses & 125,000 apartments/homes destroyed/damaged throughout Gulf Coast
- FEMA spent $900M on mobile homes that cannot be used in floodplains (FEMA regulations)

Federal Flood Insurance Programs not sustainable - need restructuring

- 45% of Katrina victims did not have flood insurance
- 65% of 58,000 flooded homes in NO had insurance
- Floodplain defined as > 1% chance flood
- $25B claims from Katrina, $2.2B fees collected in 2005
- FEMA began in 1969 - $15B paid out before Katrina
- Insurance mandatory in flood zones with federally regulated mortgages
- Typical insurance policy ~ $300-400/yr - subsidized
- 4.8M have policies, <50% in floodplains
- Congress plans to raise maximum insurance coverage on homes from $250K to $337K

New Orleans Levee System



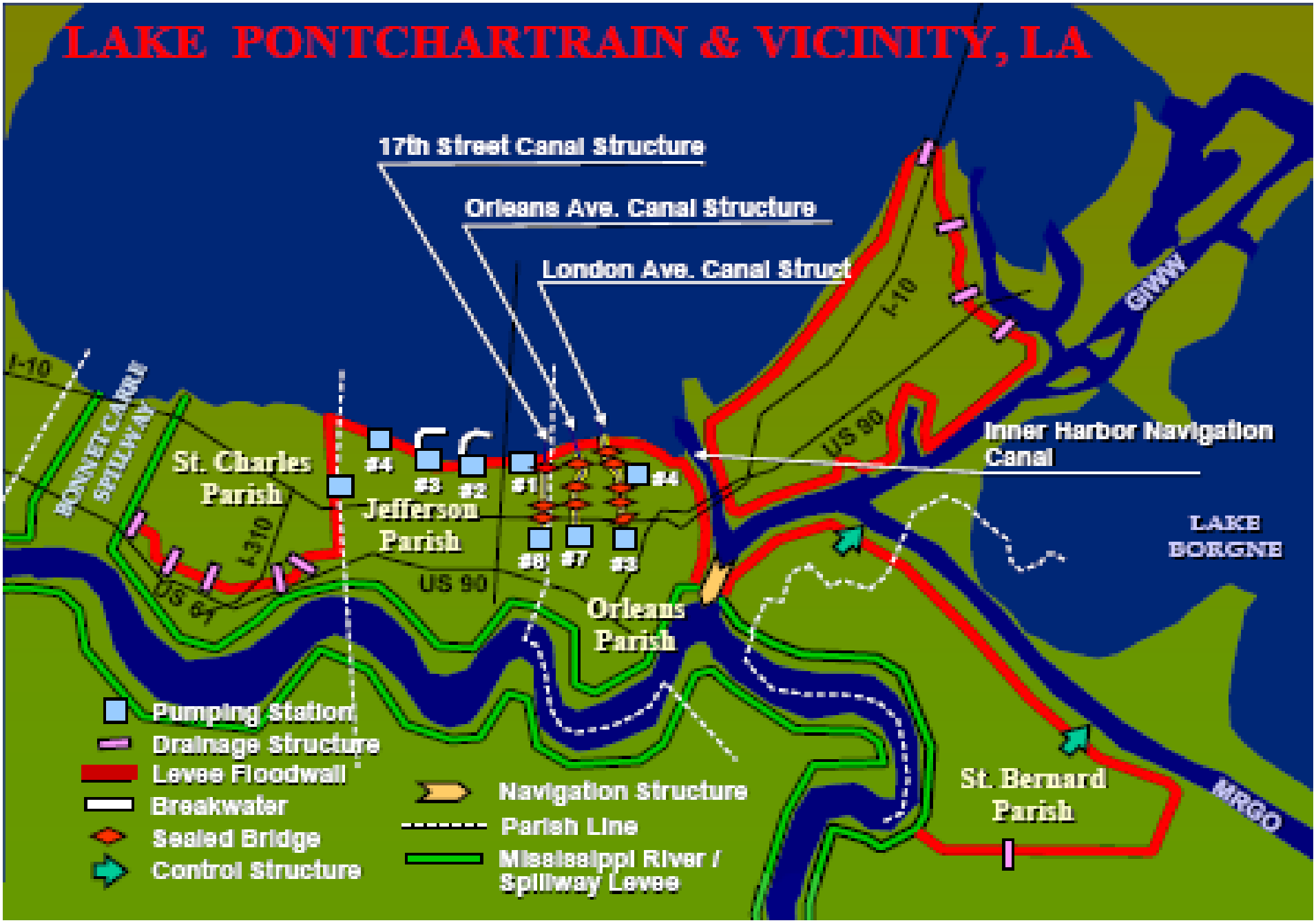
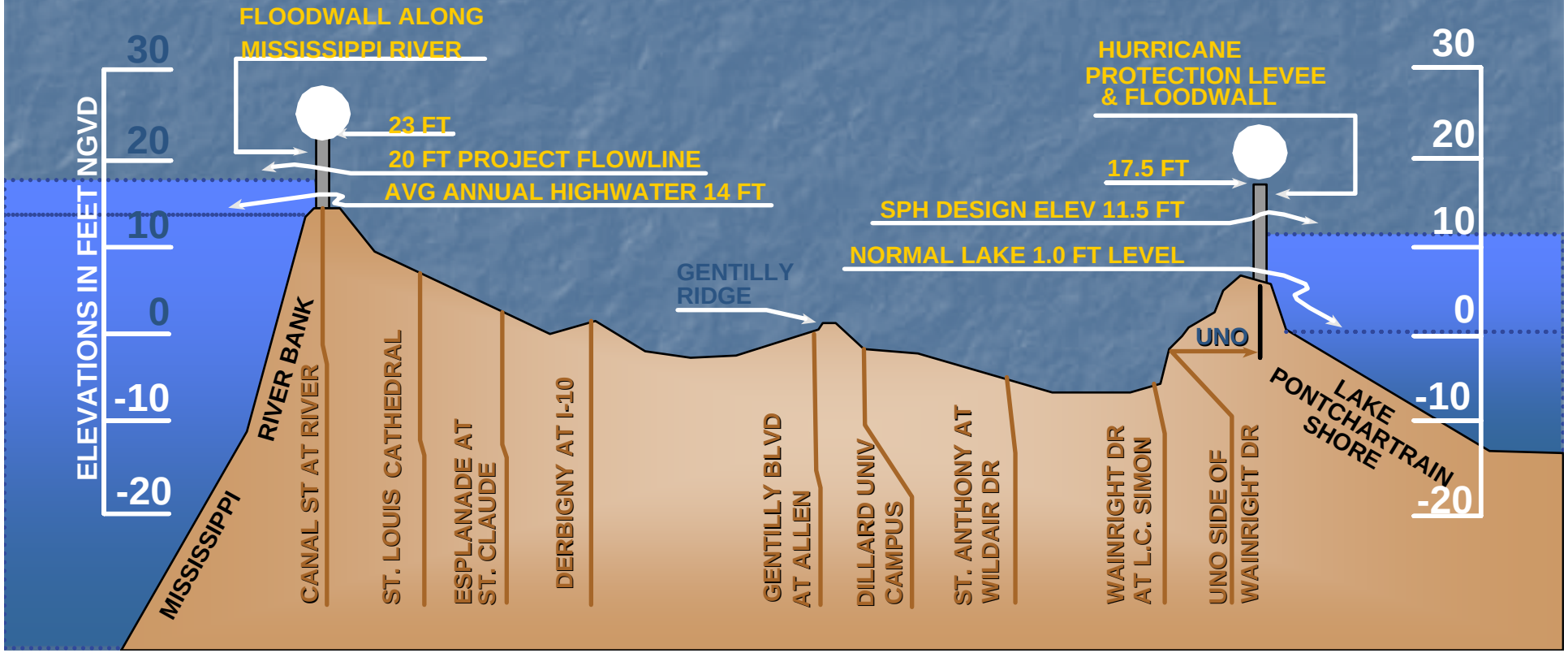


Figure 4. Map showing detailed geometry and features of the New Orleans metropolitan area

City of New Orleans Ground Elevations

From Canal St. at Mississippi River to the Lakefront at U.N.O.



Congressional Directives to Corps of Engineers for emergency response to and recovery from hurricanes of 2005....

- Secr Army "...is directed to restore the flood damage reduction and hurricane and storm damage reduction projects, and related works, *to provide the level of protection for which they were designed,* at full federal expense..."
- Also, levee system performance analysis
- Also, a study of options for future Category 5 protection for New Orleans and area

Southeast Louisiana Hurricane Protection

- Restore: ***Damaged*** Components to **Pre-Katrina Design Standards** – 1 June 2006
- Restore: ***Undamaged*** Levees/Floodwalls to **Authorized Design Levels** – Sep 2007
- Complete: ***Unconstructed Portions*** of Authorized Projects – Sep 2007
- Better and Stronger: Complete proposed ***additional improvements*** by Sep 2009

- ***Higher Levels of Protection (Category 5):***

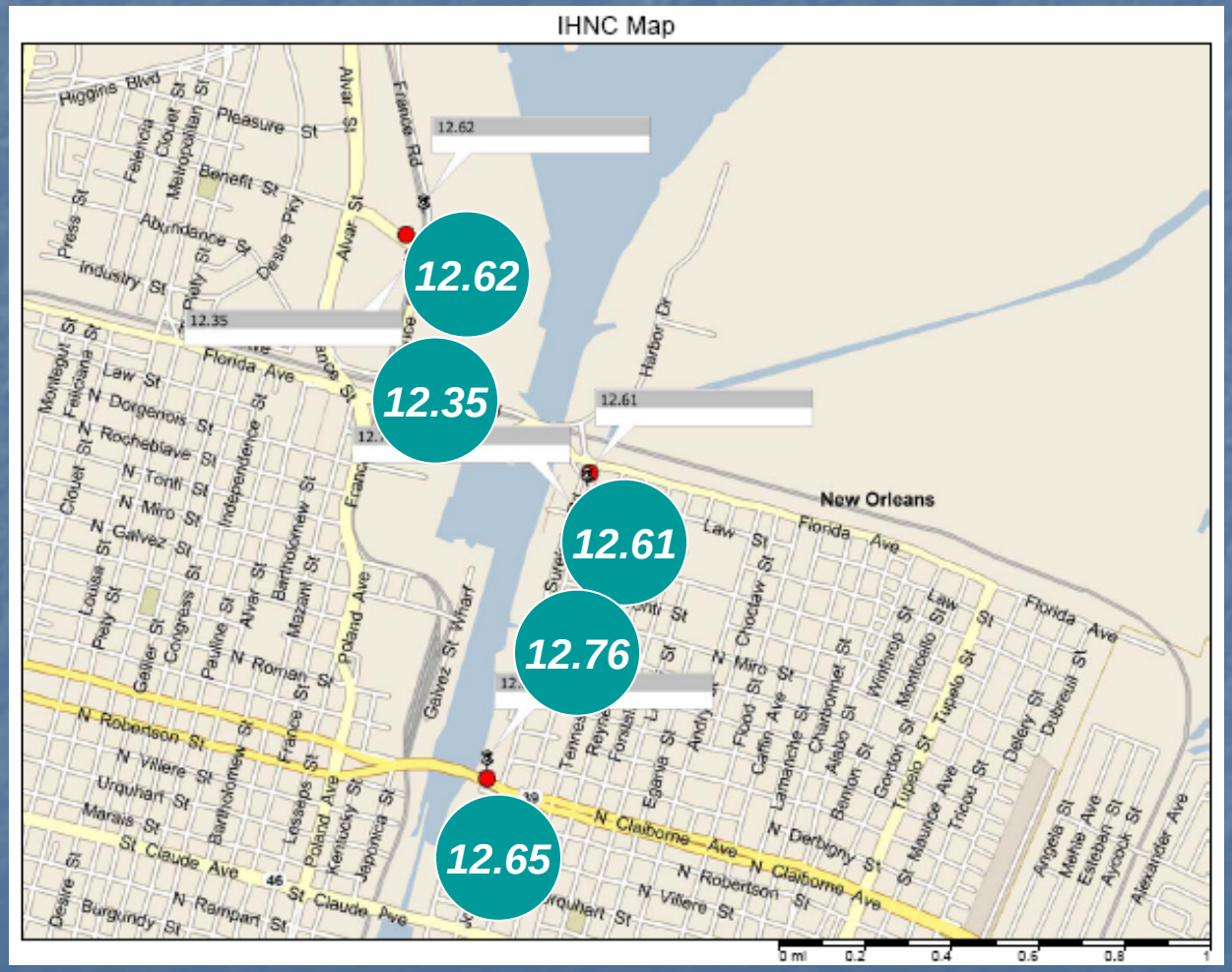
  South Louisiana Hurricane Protection and Restoration Report-June 2006; December 2007

Levees / Floodwalls
Not At Authorized Elevation
Due to Subsidence and Elevation Changes

Levee System	Total Length of System*	Levee Length Below Authorized	Floodwall Length Below Authorized
Orleans East Bank	19 miles	5.2 miles	14.4 miles
IHNC	12 miles	0.8 miles	7.6 miles
New Orleans East	39 miles	5.8 miles	6.0 miles
St. Bernard Parish	30 miles	5.2 miles	0.1 miles
Plaquemines Parish	109 miles	27.0 miles	0.0 miles
East Jefferson	16 miles	4.3 miles	0.5 miles
West Jefferson	66 miles	21.0 miles	6.0 miles
St. Charles	10 miles	6.0 miles	0.2 miles
Totals	301 miles	75.3 miles	34.8 miles

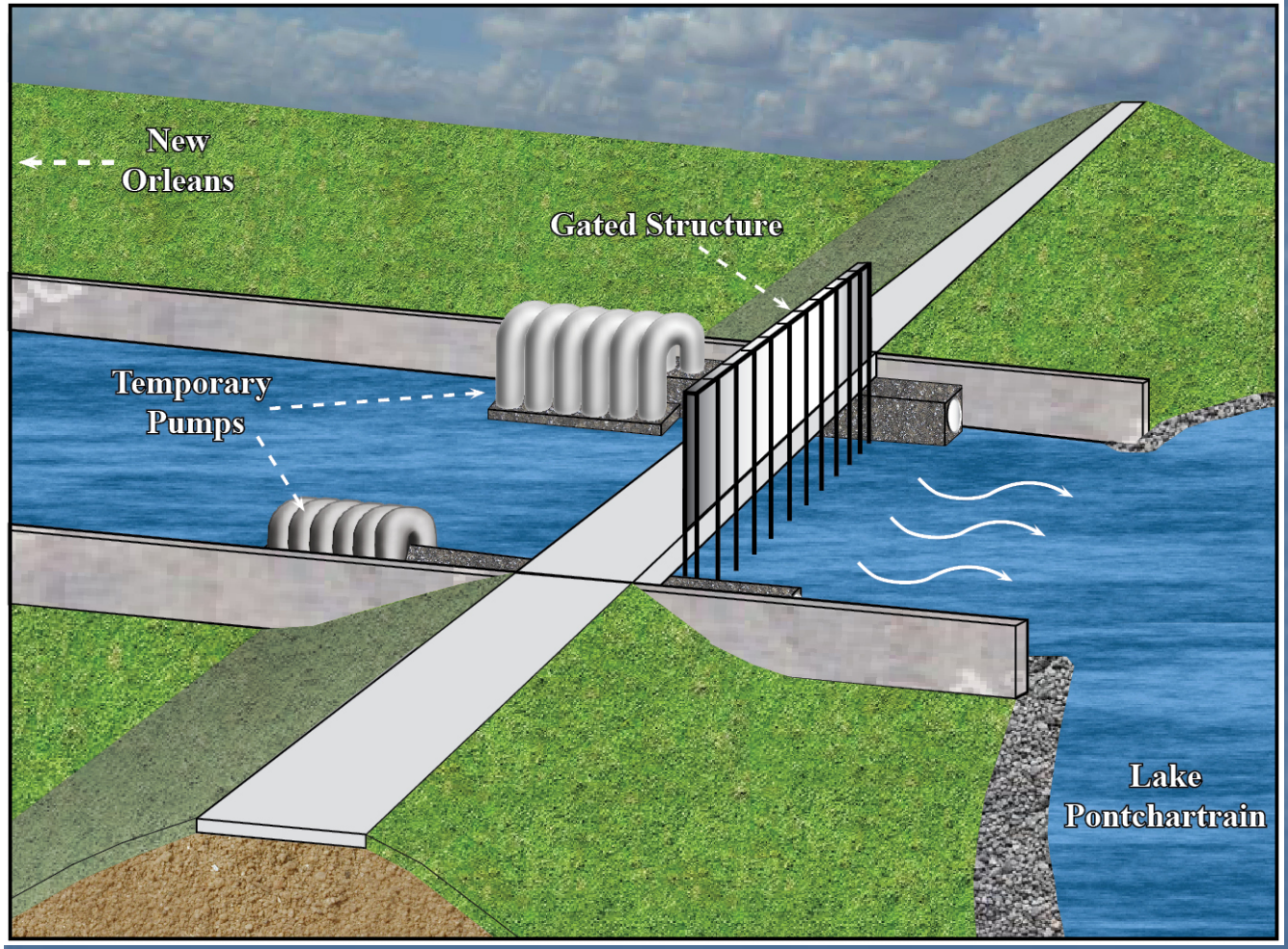
* **Includes Mississippi River Levees**

Subsidence and datum errors reduced protection levels



Authorized Protection = 15 ft.

New Orleans Outfall Canal Interim Closure Plan

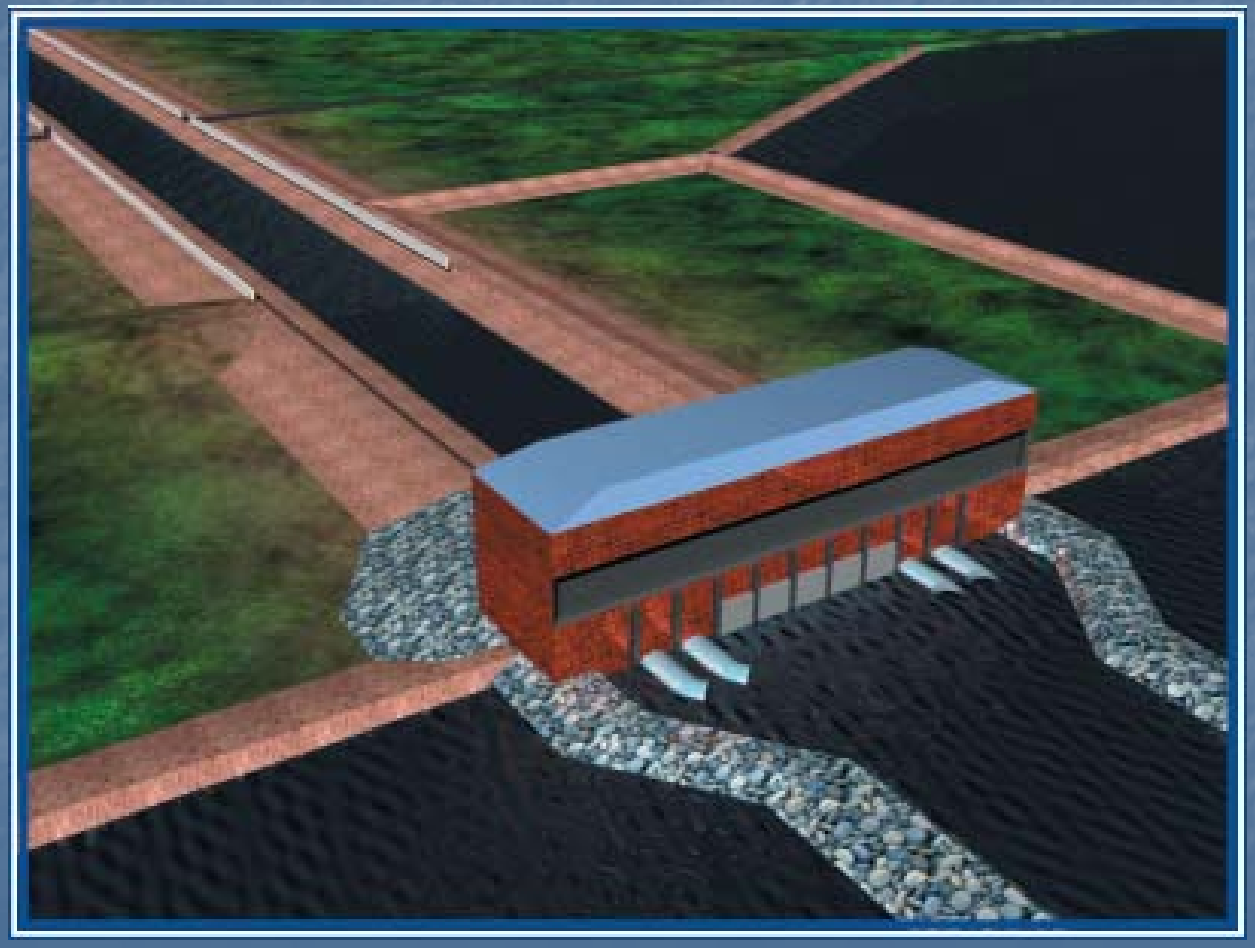


- Three locations on Lake Ponchartrain
- Protection by 1 June 2006
- Provide New Orleans with rainwater drainage
- Prevent storm surge
- Pumps permit drainage while closed

Southeast Louisiana HPS

Emergency Improvements

Outfall Canal Closures

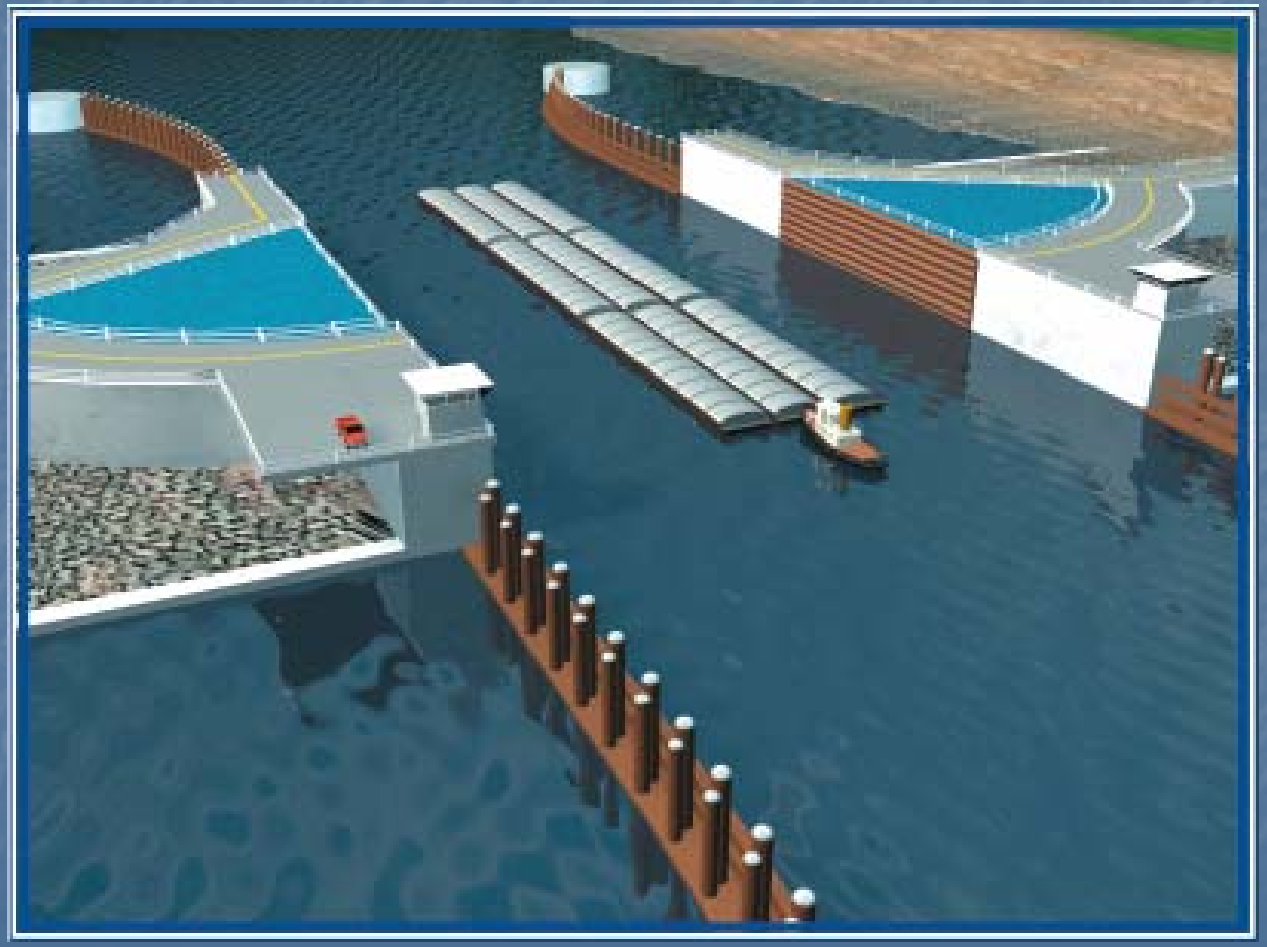


- Three locations on Lake Ponchartrain
- Provide New Orleans with rainwater and overtopping drainage
- Prevent storm surge into canals
- Removes 14 miles of floodwalls from primary HPS

Southeast Louisiana HPS

Emergency Improvements

Navigable Flood Gates

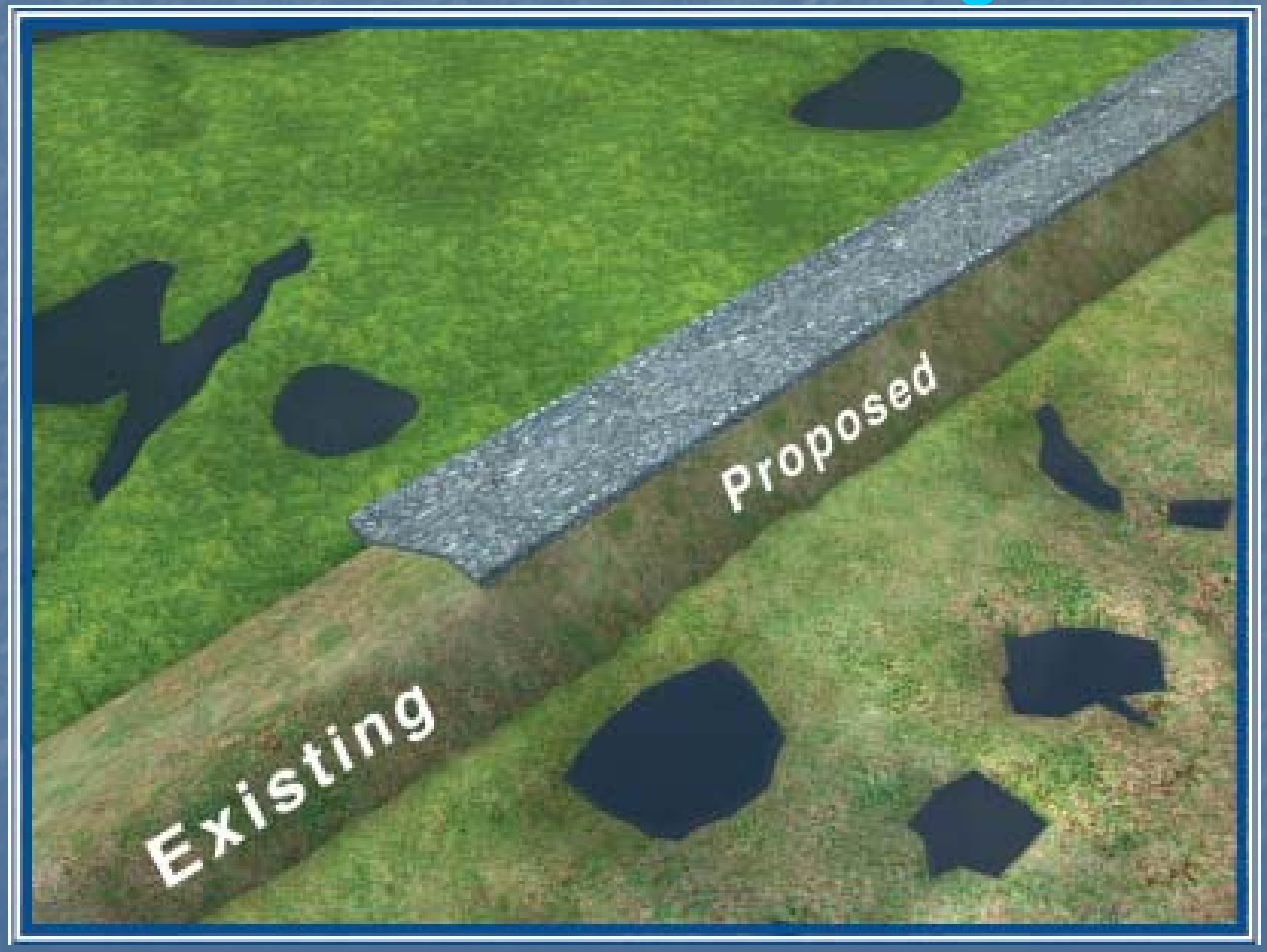


- Two Locations:
  - Seabrook
  - GIWW/MRGO
- Precise location GIWW/MRGO yet to be determined
- Prevents storm surge from Industrial Harbor area
- Removes 20 miles of levees and floodwalls from primary HPS

Southeast Louisiana HPS

Emergency Improvements

Selective Armoring



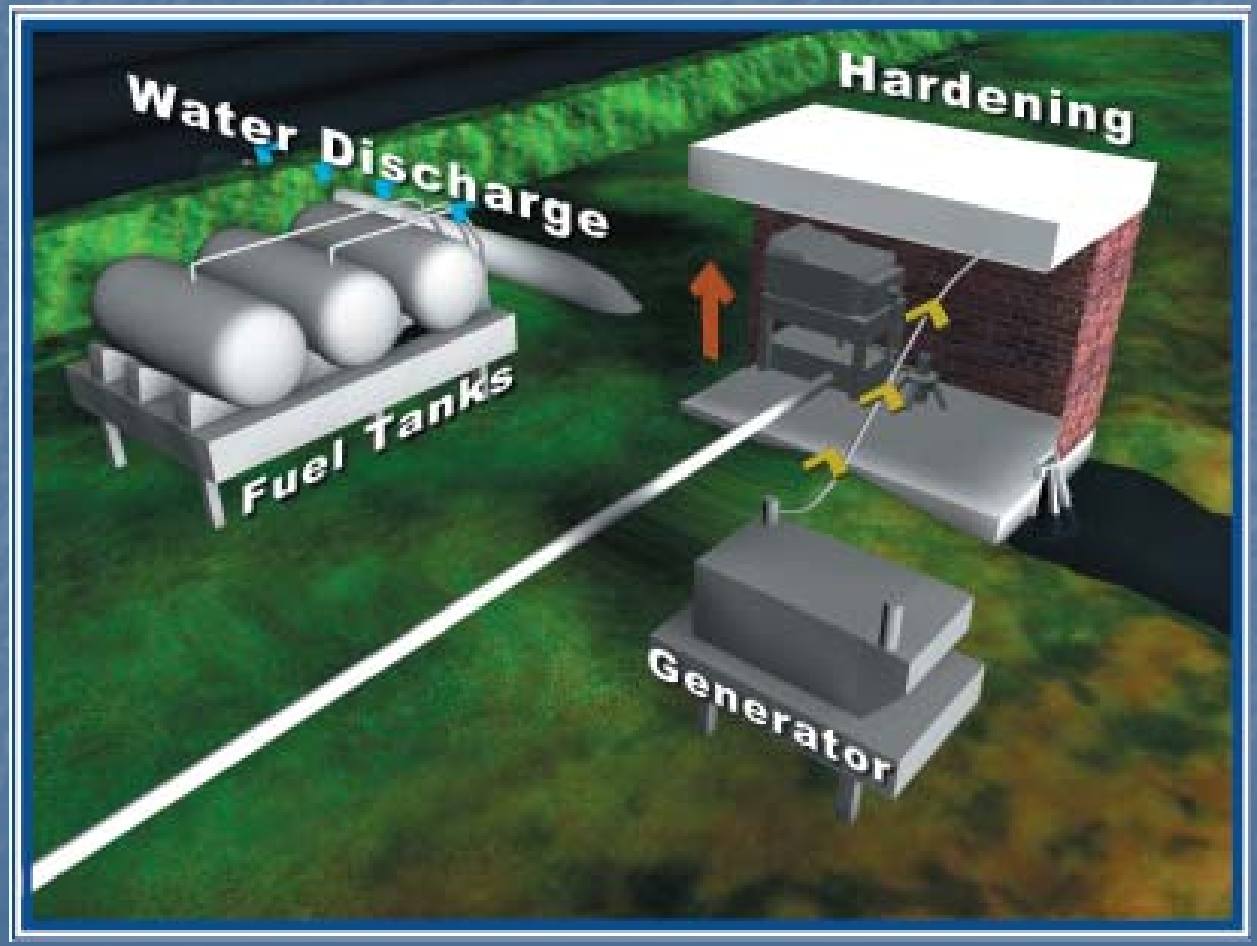
- Levees and floodwalls will be armored at critical points to resist damage from overtopping

- Transitions points between levees, floodwalls, and other structures will also be armored

Southeast Louisiana HPS

Emergency Improvements

Storm Proof Pump Stations



- Dozens of pump stations in Orleans, Jefferson, St. Bernard, & Plaquemines Parish

- Each station is unique. Study underway to determine specific needs

- Potential improvements include emergency power supplies, raising critical equipment, waterproofing, and hardening

London Canal: June, 2006

17 Street Canal: June, 2006

17 Str. Canal

Work continues on the 17th Street Canal floodgates. The new Army Corps of Engineers plan considers building levees of between 30 and 60 feet in height to hold back water from severe storms.

Pump/pipes – 17 Str Canal

Workers install pipes to pump out water at the 17th Street Canal.

Workers Assisting in Reconstruction of New Orleans

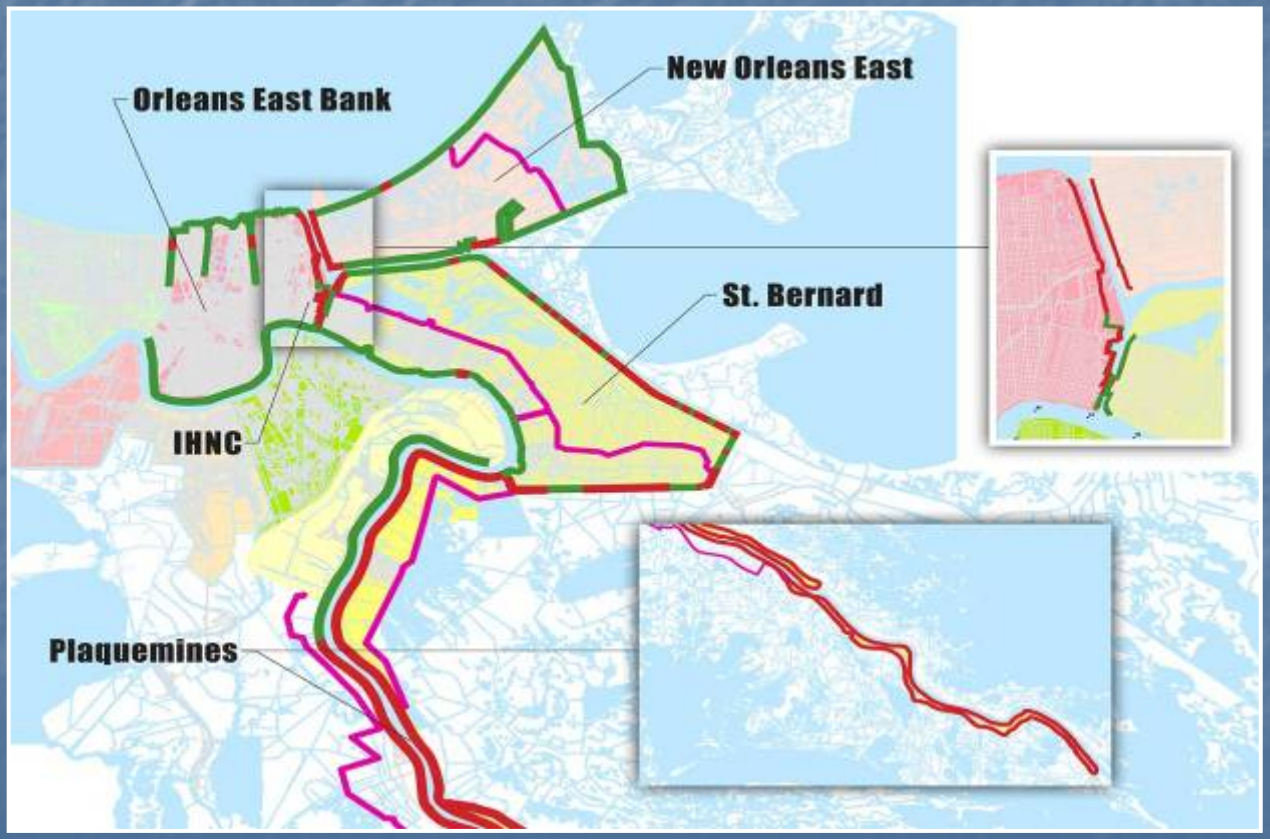
Levee Reconstruction-Lower Ninth Ward

Work is being done to shore up the area on the edge of the Lower Ninth Ward where the levee gave way during Hurricane Katrina. Many homes have still not been repaired

Levee Repair – T-Wall

Large earth-moving equipment and cranes are used to shore up and repair levees in New Orleans. The projected cost of the repairs may rise as high as $10 billion, according to some estimates.

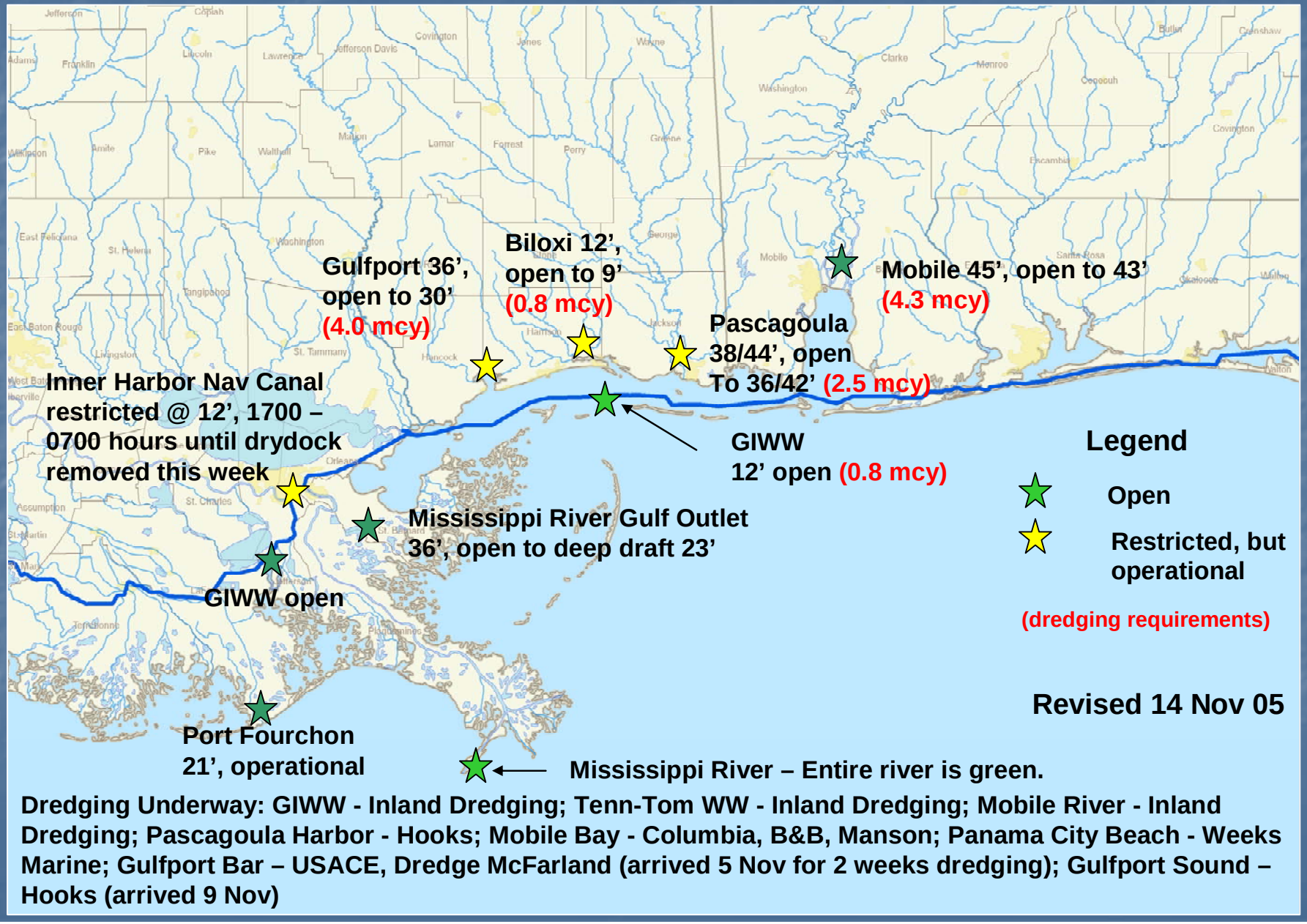
Hurricane Protection System (HPS) Restoration Program Summary - Repairs to Damages (to Cat 2+ level)



- Restore pre-Katrina protection by 1 Jun 06 (now July 1, 2006)
- 269 miles (430km) exposed
- 164 miles (262 km) damaged (60%)
- 71 Pump Stations – 34 damaged
- Estimated Program Costs - $2.9 Billion

~ 95% Complete

Restore Navigation Mission



Dredging Underway: GIWW - Inland Dredging; Tenn-Tom WW - Inland Dredging; Mobile River - Inland Dredging; Pascagoula Harbor - Hooks; Mobile Bay - Columbia, B&B, Manson; Panama City Beach - Weeks Marine; Gulfport Bar – USACE, Dredge McFarland (arrived 5 Nov for 2 weeks dredging); Gulfport Sound – Hooks (arrived 9 Nov)

Arthur Maass – "Muddy Waters" (1951)

"Public policy is being formed as it is being executed, and it is executed as it is being formed"

Current Status

- Mar 3, 2006 : Levee repair costs have tripled to almost $10B – $3.2B (billion) original cost
- Flood Insurance Program (FIP) requires higher level of protection – FEMA would not certify rebuilt levees – less than 100-year protection.
- Of the extra $6B, half would go to protect 2.4% of the population, while the remaining half would protect 50% of the population
- Are less than fully-certified levees acceptable in low density population areas?
- Full cost of Category 5 protection ~ $30-50 B
- Show map

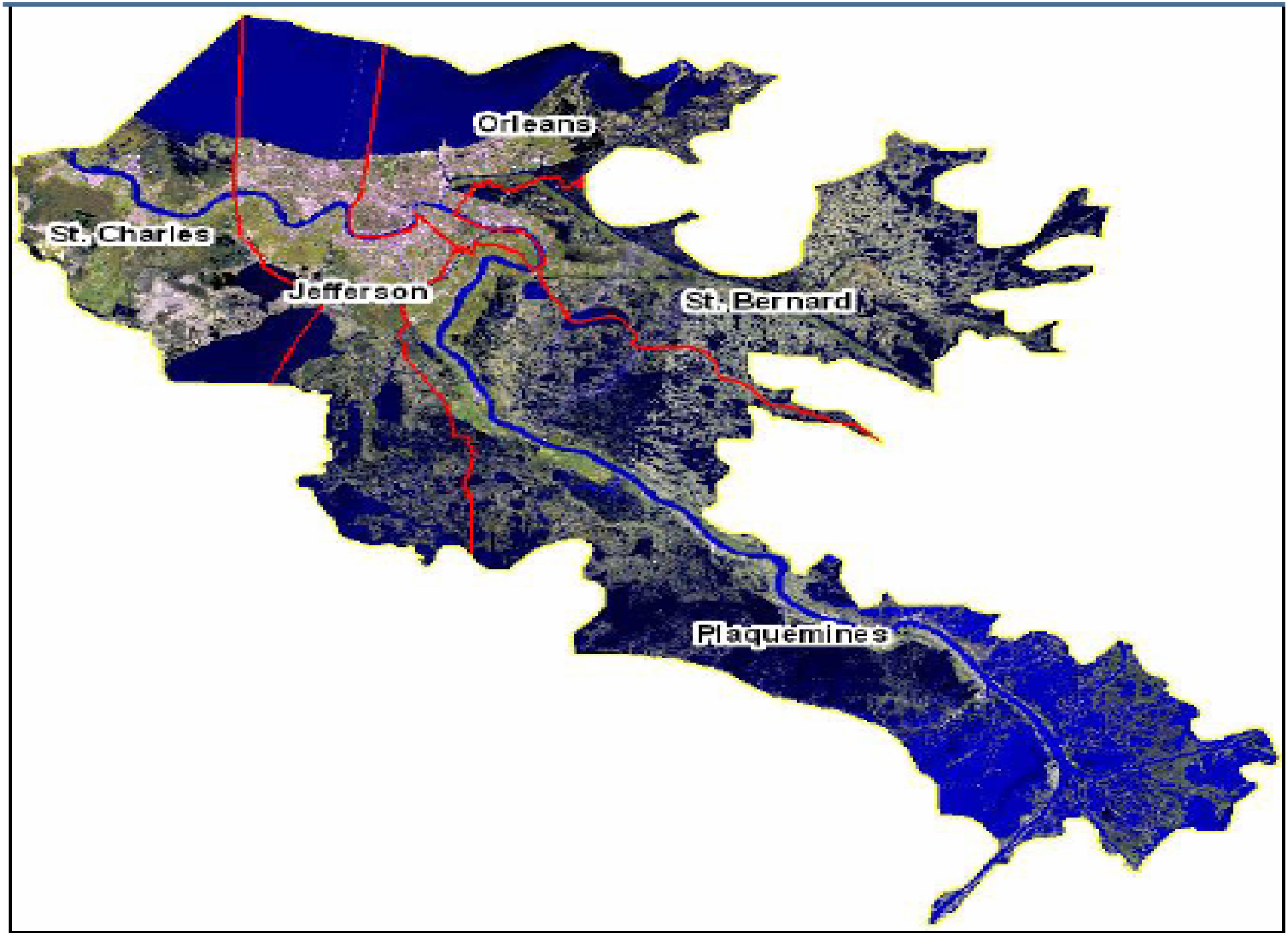
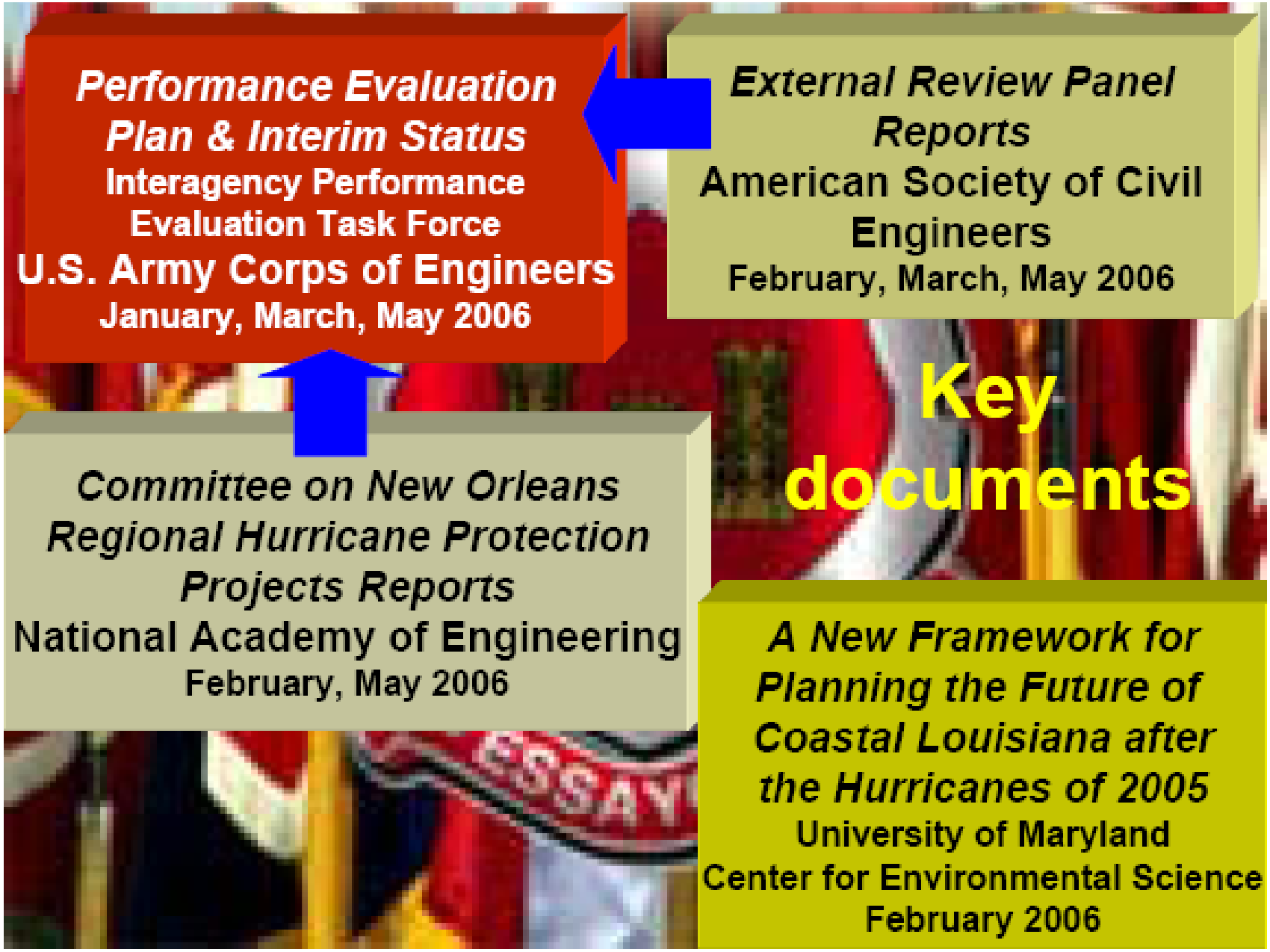
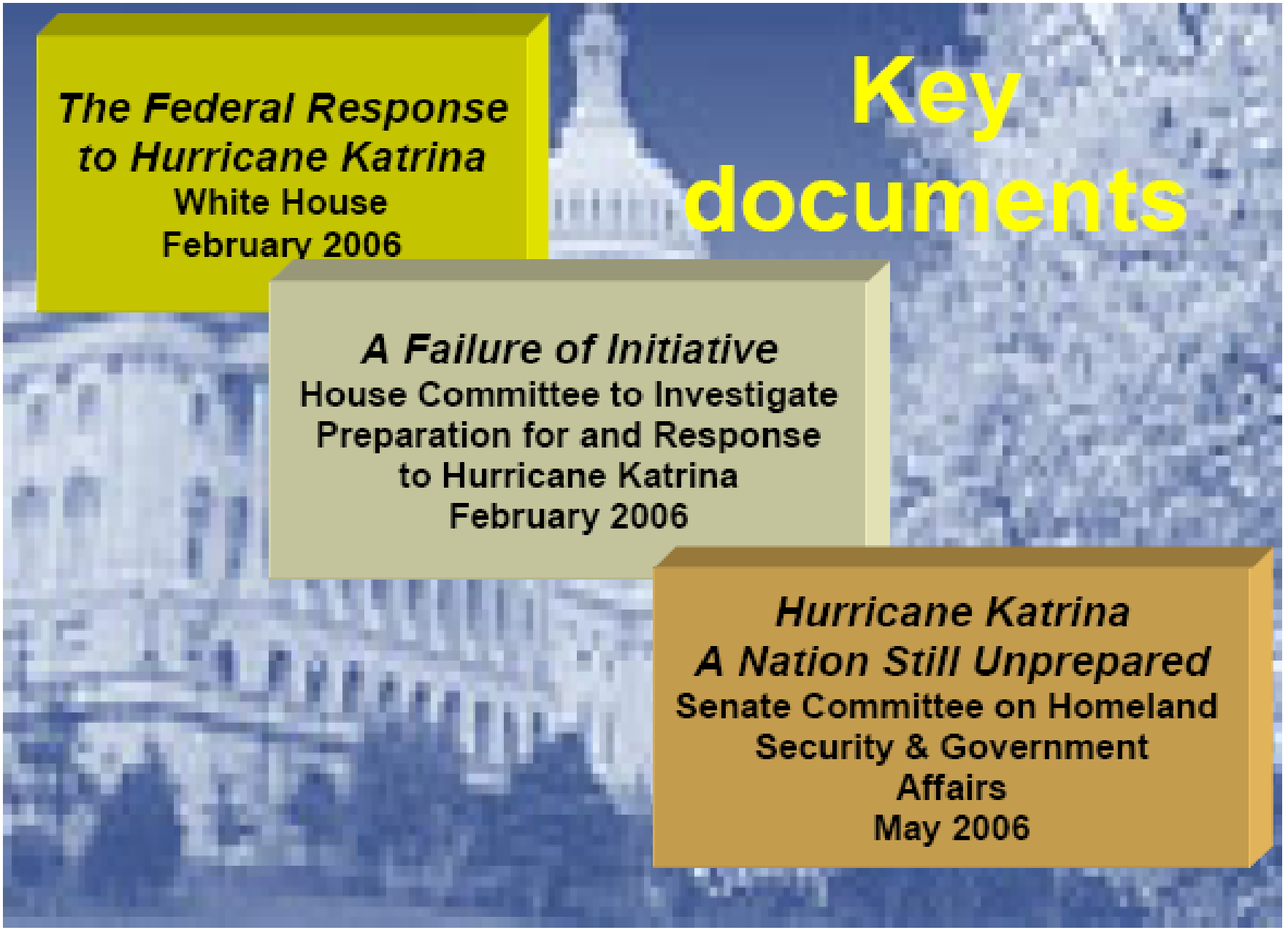


Figure 1. Principal area of analysis

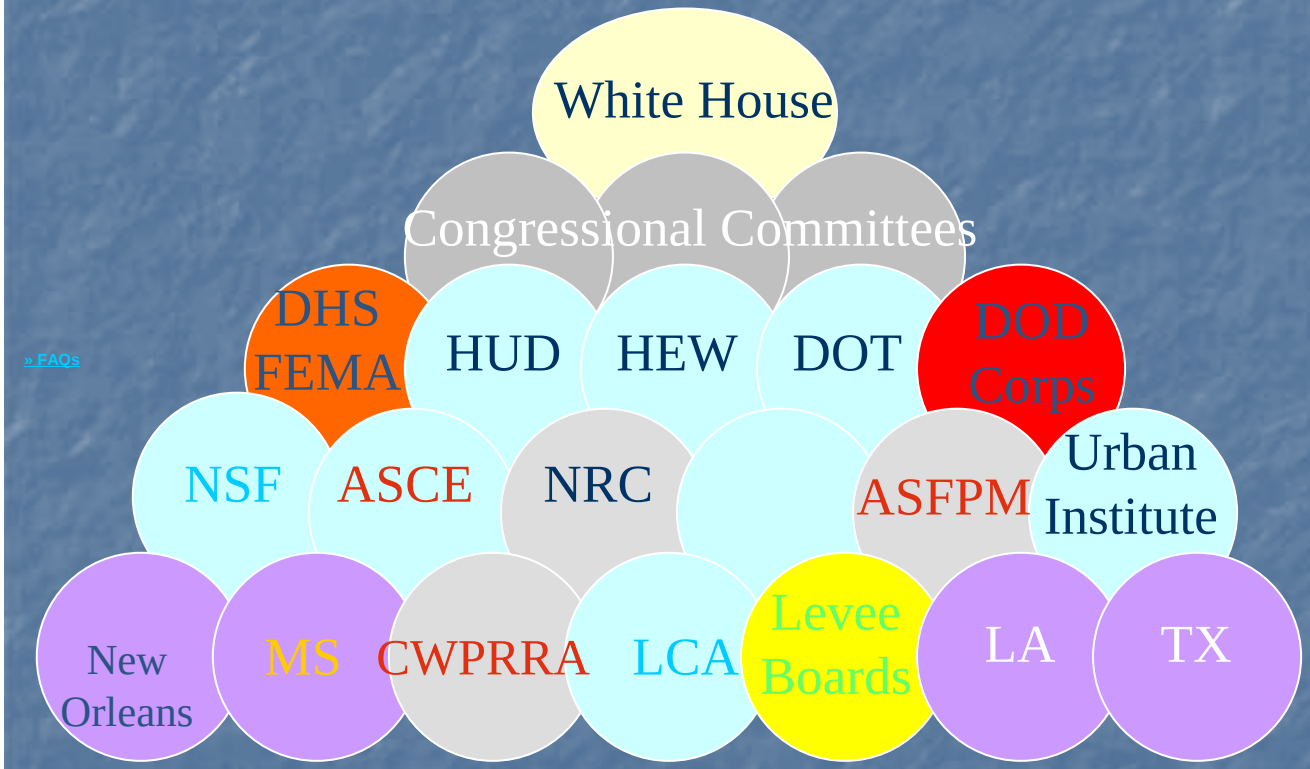
Some recent events

- May 21, 2006 – Mayor Ray Nagin gets reelected : “We’re going to bring back all the citizens who want to come back to New Orleans” Mayor Nagin has no plan for rebuilding New Orleans (What does ‘subsidiarity’ mean in this case?)
- Senate Report
- White House Report
- House Report
- May 22 - National Science Foundation Report on Levees,
- May 25 – ‘practice’ Hurricane “Alicia” exercise in Loiusiana cancelled in middle of drill - disagreements over responsibilities for evacuation between NO, LA, FEMA
- ASCE Report released May, 2006
- NSF Report released May, 2006
- Corps IPET Report Released June 1, 2006


Performance Evaluation Plan & Interim Status
Interagency Performance Evaluation Task Force
U.S. Army Corps of Engineers
January, March, May 2006
External Review Panel Reports
American Society of Civil Engineers
February, March, May 2006
Key documents
Committee on New Orleans Regional Hurricane Protection Projects Reports
National Academy of Engineering
February, May 2006
A New Framework for Planning the Future of Coastal Louisiana after the Hurricanes of 2005
University of Maryland
Center for Environmental Science
February 2006


Key documents
The Federal Response to Hurricane Katrina
White House
February 2006
A Failure of Initiative
House Committee to Investigate Preparation for and Response to Hurricane Katrina
February 2006
Hurricane Katrina
A Nation Still Unprepared
Senate Committee on Homeland Security & Government Affairs
May 2006

‘Integrated (?)’ Institutional Response



» FAQs

DHS FEMA: Department of Homeland Security / Federal Emergency Management Agency

HUD: Department of Housing and Urban Development

HEW: House Education and the Workforce (HEW) Committee

DOT: Department of Transportation

DOD Corps: Department of Defense, U.S. Army Corps of Engineers

NSF: National Science Foundation

ASCE: American Society of Civil Engineers

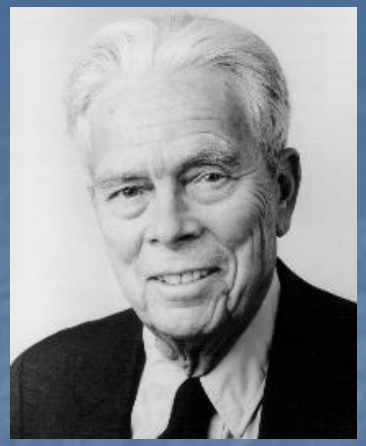
NRC: National Research Council

ASFPM: Association of State Floodplain Managers

CWPRRA: Coastal Wetland Planning, Protection and Restoration Act (task force)

LCA: Louisiana Coastal Area (restoration study)

States of MS, LA, TX



Gilbert White – "Human Adjustments to Floods" (1945)

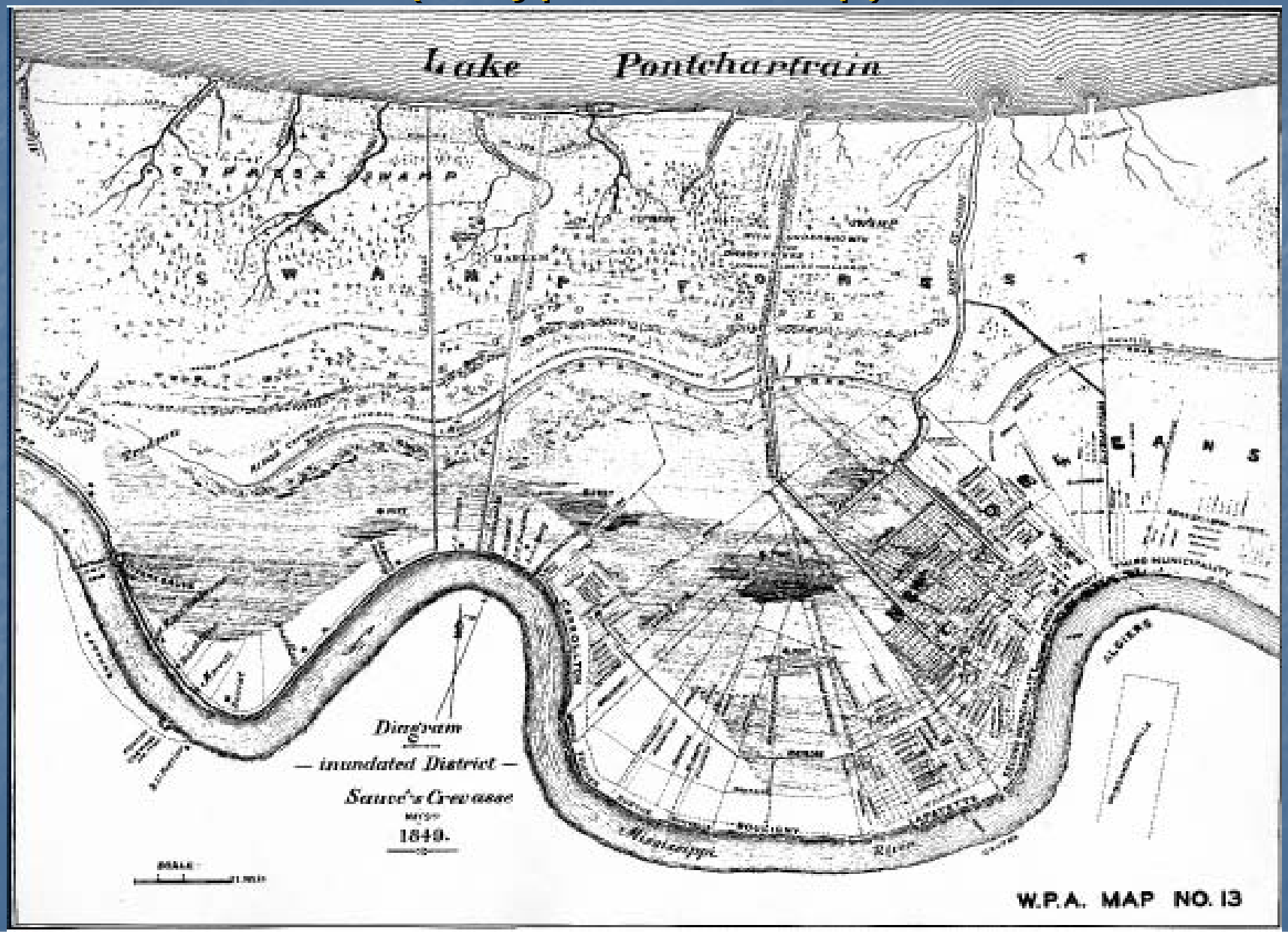
"Floods are Acts of God, but flood losses are largely acts of man"

(who's in charge of land use planning?)

Do we aim for perfection? (Integrated Water Resources Management) or... do we adjust incrementally? (or Adaptive Management?)

- Institutional (legislation, legal, regulatory)
- Economic incentives, cost-sharing
- *Engineering design standards, criteria*
- Water Management/Administration
  - Enhanced effective response and coordination
  - Providing cost-effective services
  - Efficient resource use
  - Access and availability to services
  - Compliance with rules & regulations

1849 Inundation Map of New Orleans (& Cypress Swamp)



New Orleans Losses

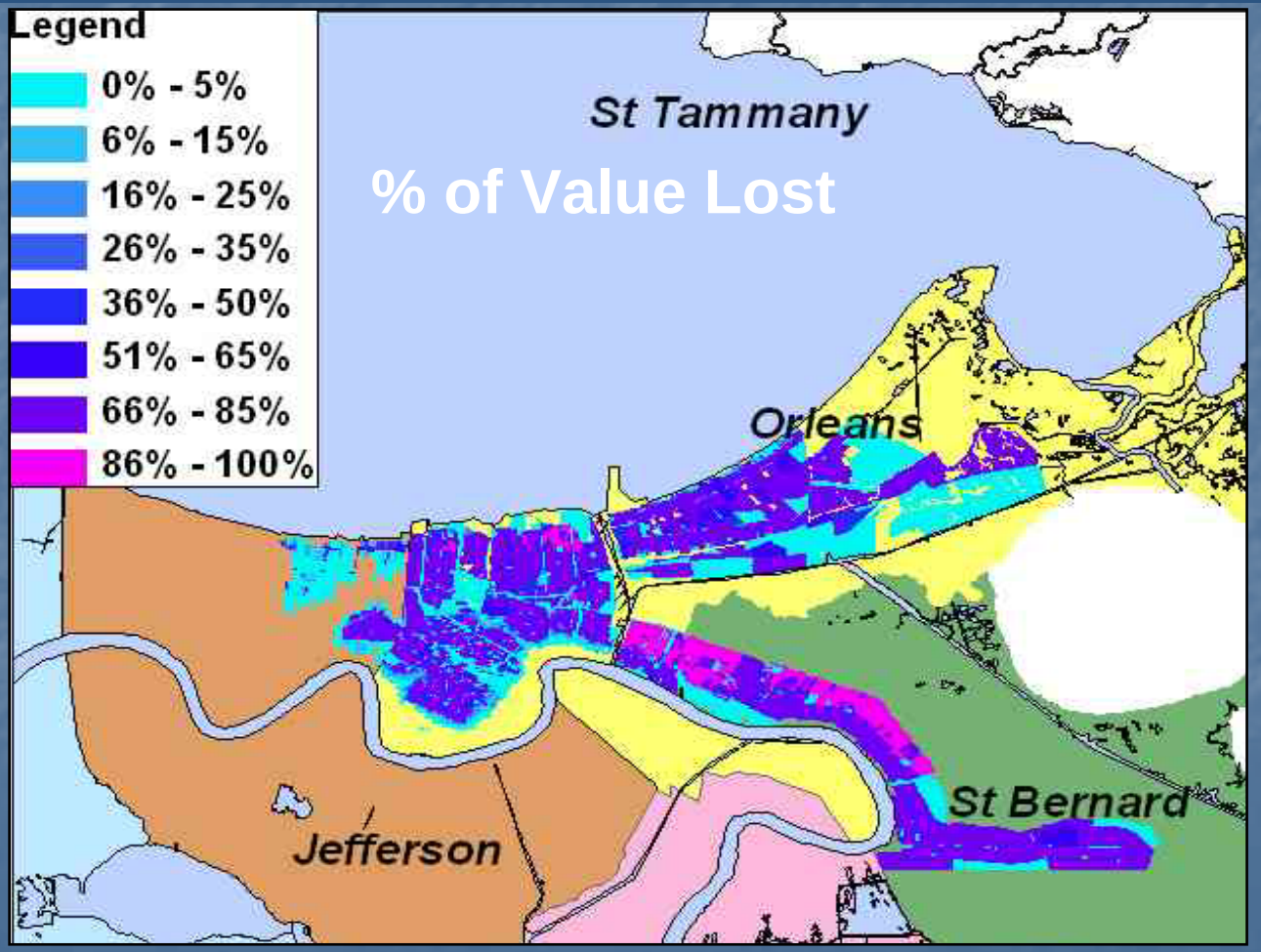
Losses were concentrated in low residential areas, and with those unable to self evacuate

Loss of Life = 1300+
(75 % > 60 yrs)

Direct Property = $20B

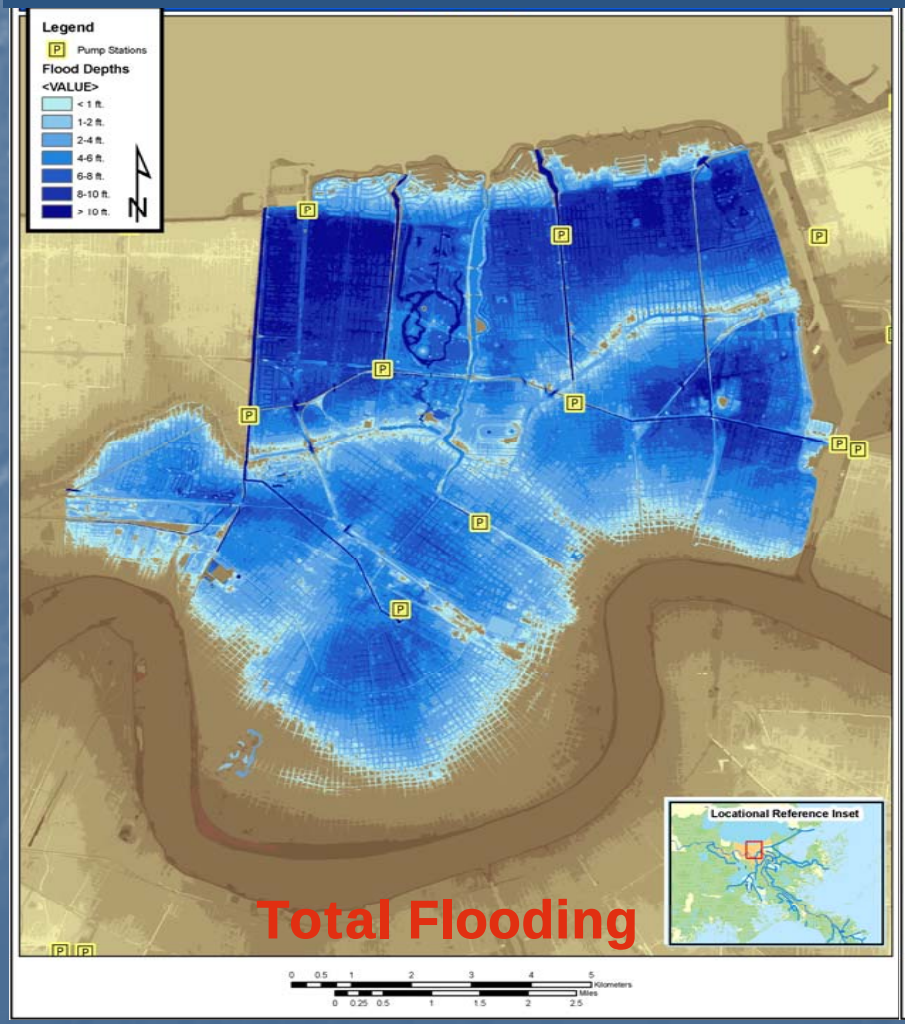
Social and Cultural Losses = Staggering Migration, Slow Recovery

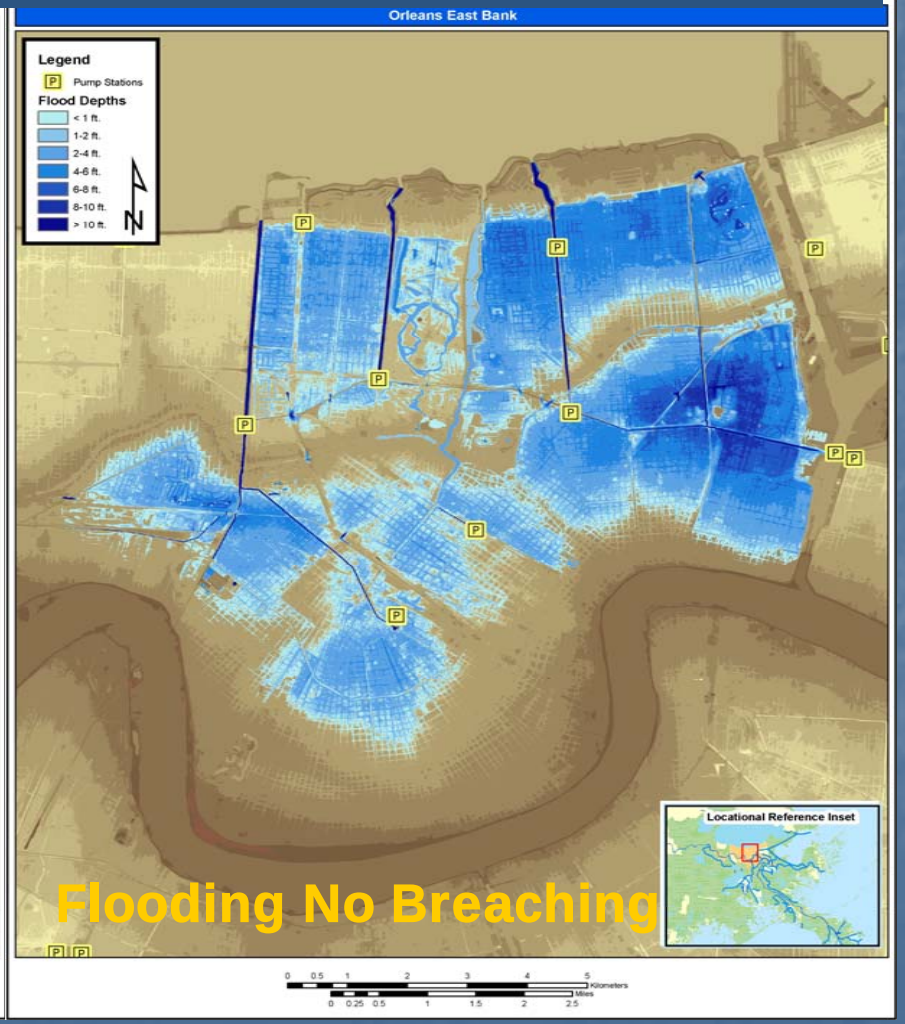
Total Loss ~ $200B



The Consequences

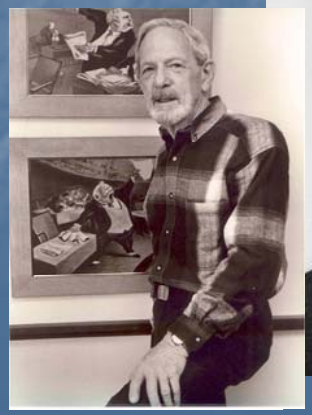
Design deficiencies resulted in 2/3 of flooding, and ½ of losses in some areas





Thoughts on Comprehensive Planning & IWRM

- **1958-61 Harvard Water Program**
- **1962 Design of Water Resources Systems (Maass, et.al.)**
- **1965 Water Resources Planning Act**
  - Basin Planning Commissions
  - Principles and Standards
  - Water Resources Council



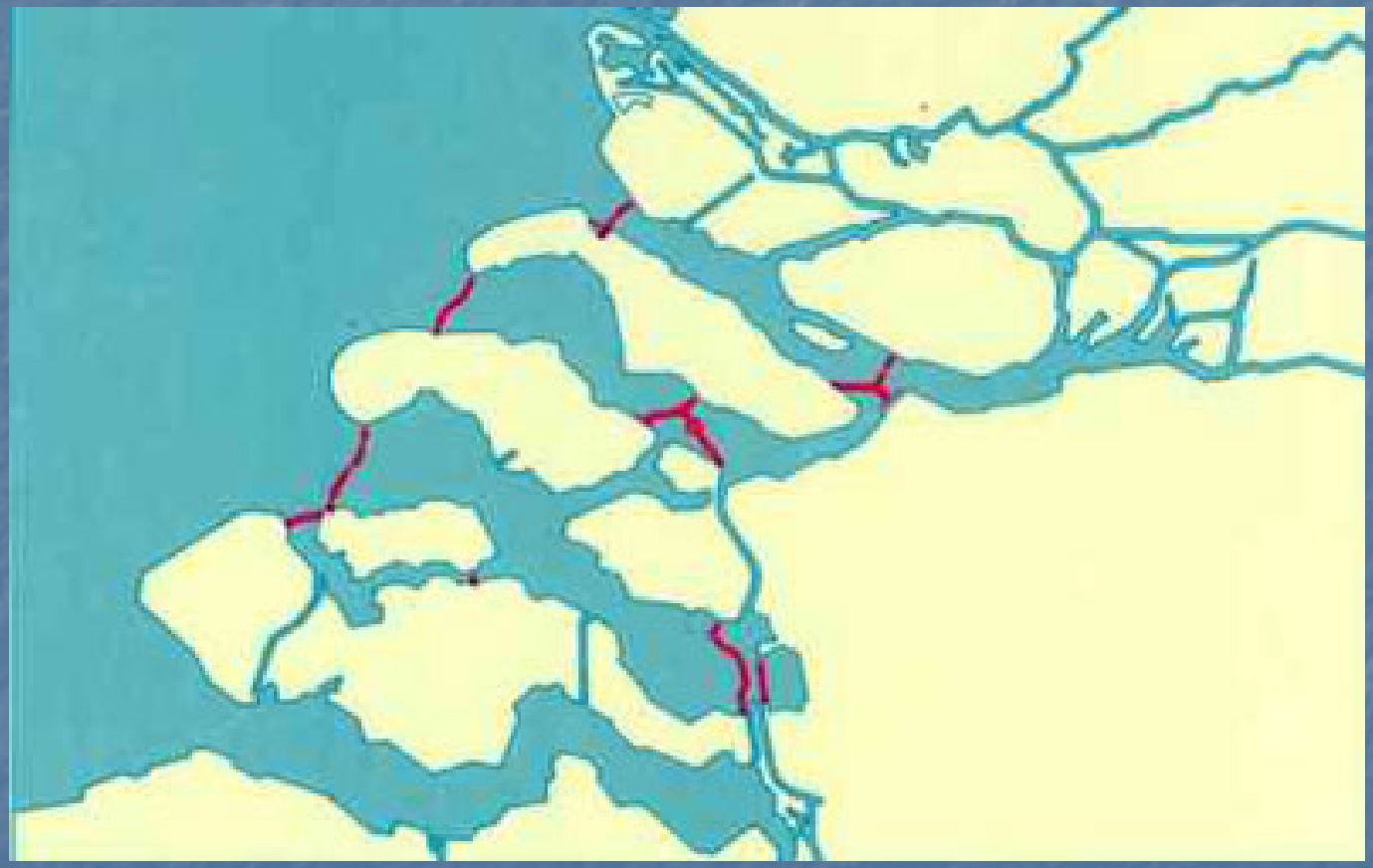
US Flood Policy Development & Non-Structural Floodplain Management

- Gilbert White, 1942 Dissertation
- Executive Order 11988, *Floodplain Mgmt* (1977)
- P&S requirement for nonstructural plan (1980)
- Water Resources Development Act (WRDA1986)
- Unified Nat'l Prog for Floodplain Mgmt (1992)
- Upper Miss R. Flood (1993)
- "Galloway Committee" Report (1994)
- "Challenge 21" Legislation (WRDA 99)
- Response to Katrina (2005- ?) – not good so far

PRINCIPLES: Unified National Flood Plain Management Program

- Modify Human Susceptibility to Flood Damage *(relocation, flood warning forecasting, disaster preparedness, assistance, land acquisition, etc.)*
- Modify Impact of Flooding on People and Communities *(emergency response, flood recovery)*
- Preserve and Restore Natural Floodplain Resources *(land acquisition, restore habitats)*
- Modify Flooding *(dams, dikes, detention basins)*

Netherlands Storm Surge Barrier Protection System ~ $16B;
Built to 10,000yr return period, 1965-2005



Netherlands Storm Surge Barrier Protection System

Proposed Venetian Storm Barrier Protection System

Thames River Storm Surge Barrier

New Orleans Levee System
(so how did this happen?)

Evolution of New Orleans HPS
(GAO Report, Congressional Testimony 28/9/05)

- Congress authorized projects in 1965; $85M; estimated ***completion 1979***
- Designed for **NWS-SPH, ~ Cat 2+ today**, return period of about **200-300 yrs.** Basically two alternatives:

PLAN 1 -Two rings of protection: inner ring of 9-13' levees; ***+ outer storm surge barrier with flood gates*** (similar to "Dutch Plan")

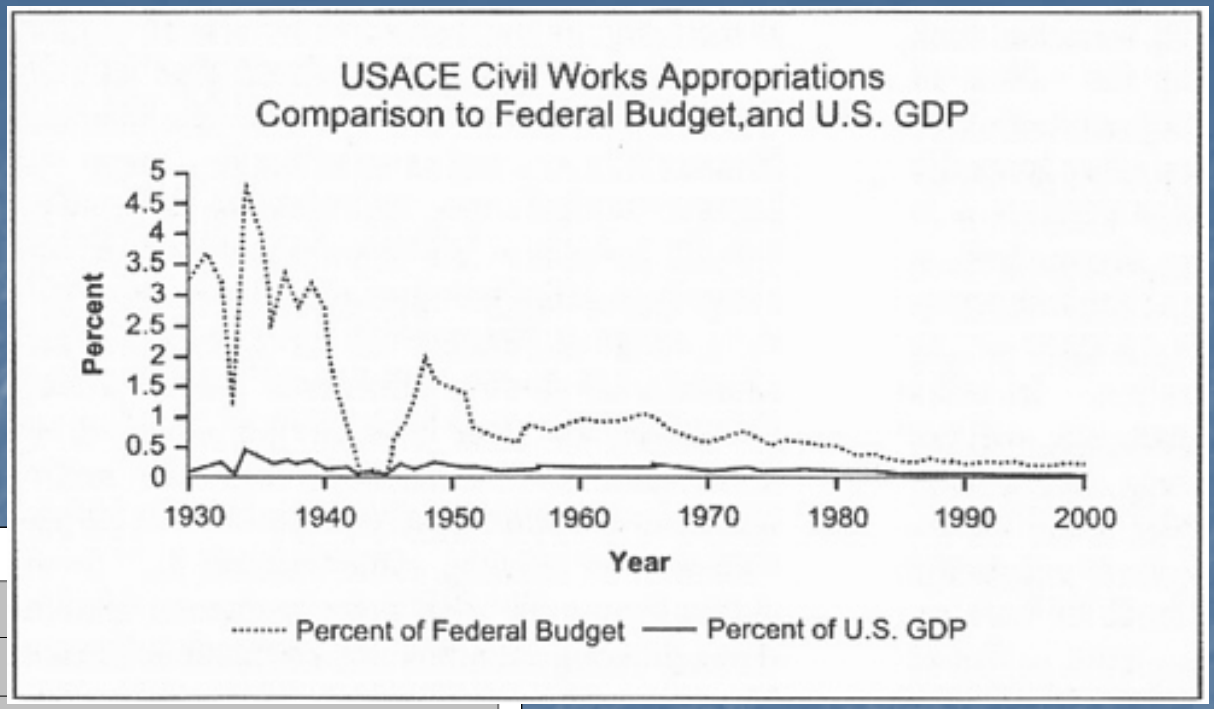
PLAN 2 - Inner ring of high levees, 16-18.5'

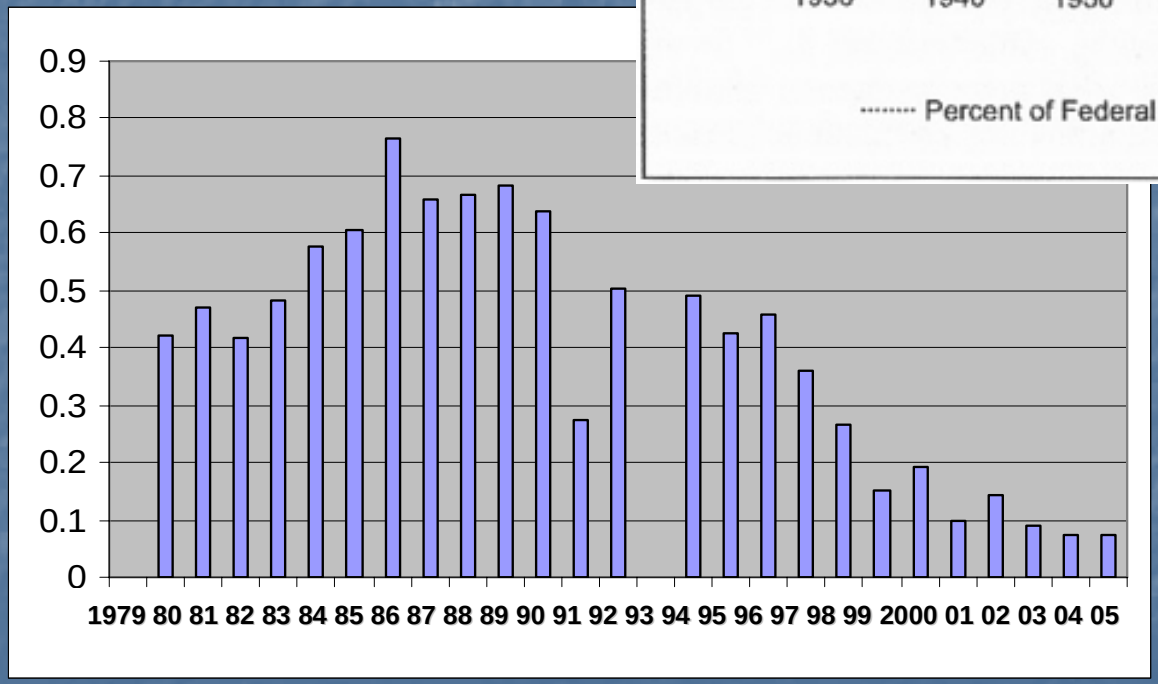
- Public opposition (1975), and environmental lawsuits (1977) over two-ring plan; ***Plan 1 abandoned***

Evolution of New Orleans HPS (Cont'd)

- By 1982, the costs rose to~$800M; est. ***2015 completion***
- ***PL 101-640 (WRDA 1990) House Conf Rpt No 101-966***
- By 2005, 60-90% of 125 mi levees complete in project areas
- From 1995-2005, Congressional appropriations declined from $15-20M/yr to $5-7M/yr
- 2002 Corps requested funds for a study to strengthen HPS
- 2006 appropriation of $2.8B, est ***completion 2006/2007***

Corps of Engineers Budget Allocations





House Conf Report 101-66 (Oct 27, 1990)

- As originally authorized by Section 204, PL 89-298:

"...high level levees plan was substituted for the barrier plan."

"Local authorities have raised concerns about floodgates that will impede drainage of canals during hurricanes"

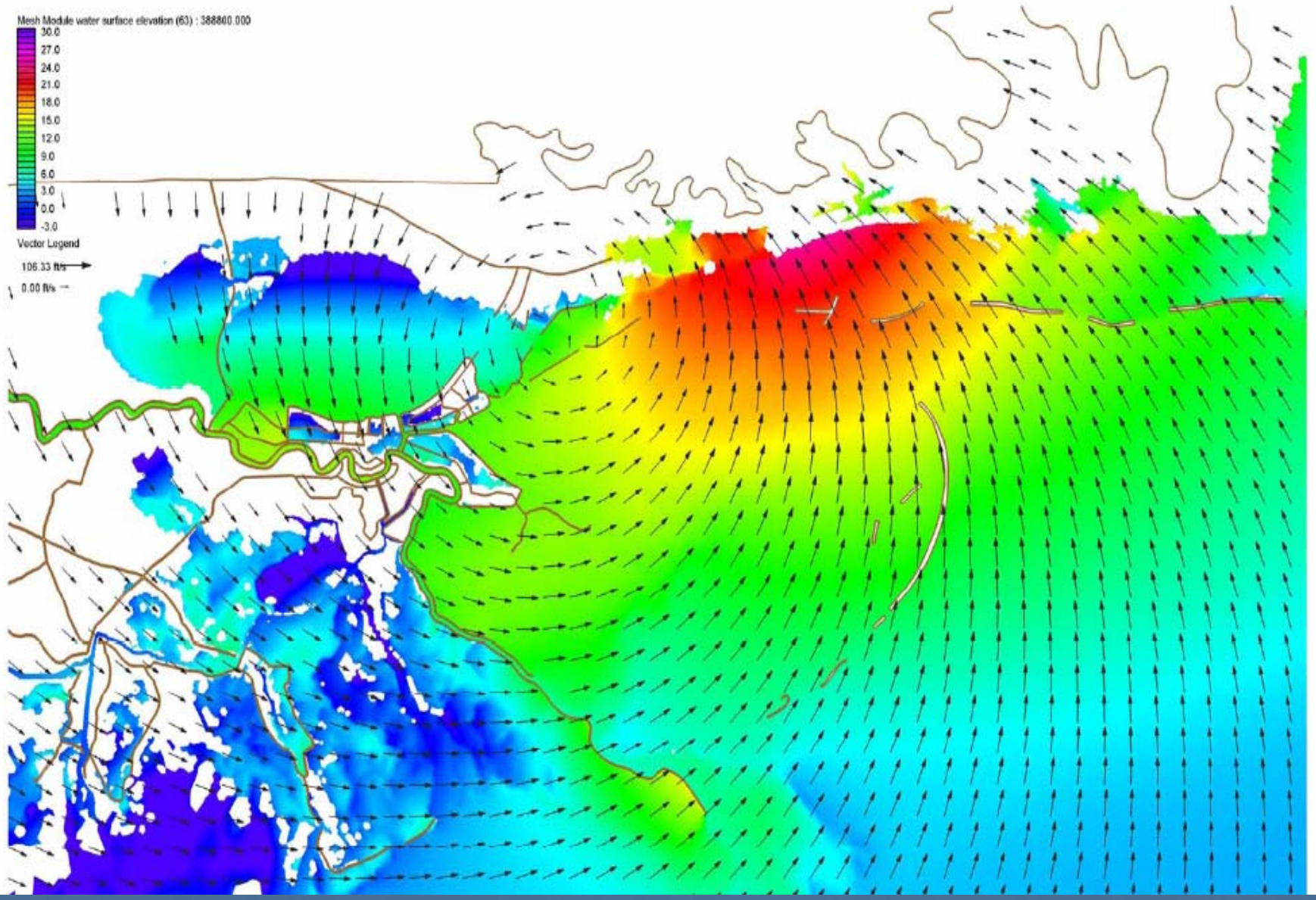
"The conferees do not believe it was the intent of Congress in authorizing this project to compound flooding or drainage problems in New Orleans."

"It was not necessary for the original barrier plan to provide drainage of storm waters into L. Ponchatrain"

"...***the conferees direct the Corps*** to treat the outfall canals as part of the overall hurricane protection project... and to favorably consider a plan that raises the levees along the entire length of the London Ave and N.O. Ave. Canals... sufficient for a SPH..."

Katrina Path from August 23 - 31, 2005

8/29/15Z


Mesh Module water surface elevation (63) : 388860.000
30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
-3.0
Vector Legend
106.33 ft/s
0.00 ft/s

Hurricane ***Saffir-Simpson*** Scale

- Category 1: Wind Speed 74-95 mph
  Storm Surge 4-5 ft above normal
- Category 2: Wind Speed 96-110 mph
  Storm Surge 6-8 ft above normal
- Category 3: Wind Speed 111-130 mph
  Storm Surge 9-12 ft above normal
- Category 4: Wind Speed 131-155 mph
  Storm Surge 13-16 ft above normal
- **Category 5**: Wind Speed >155 mph
  Storm Surge > 18 ft above normal

Hurricane vs. River Flooding

- Storm surge (+waves) is the relevant physical force for levees; wind is for roofs and structures
- **Katrina** (Cat 3+ wind speed) had equivalent **Category 5 storm surge**
- Frequency of hurricanes (magnitude, duration, fetch, pressure) cannot be calculated in same manner as floods – need a comparable method
- Standards-based design vs risk-based design (PMH, SPH, Cat 3, Cat 5, 200-yr, 500-yr, 10K-yr, select design that minimizes risk-cost ?)
- What else goes into the risk calculation? (Health, trauma damages, dislocation/disruption, job loss, education, etc.)

Authorized Protection Levels Vary -No clear attempt to integrate

Design Hurricanes

Project Location	Date Authorized	Central Pressure Index	Wind		Forward Speed
			Speed	*At Radius of*	
Lake Pontchartrain & Vicinity	**October 1965**	**27.6 inches**	**100 mph**	**34.5 miles**	**5.75 – 12.66 mph**
Grand Isle & Vicinity	**1965 – 1976**	**28.15 inches**	**87 mph**	**35 miles**	**13 mph**
New Orleans to Venice	**October 1962**	**28.1 inches**	**90 mph**	**34.5 miles**	**11 mph**
West Bank & Vicinity	**1986**	**27.4 inches**	**115 mph**	**34.5 miles**	**12.6 mph**

Congress currently authorizes protection from flood waters resulting from winds of 90-115 MPH.

Saffir-Simpson Scale (1970)

Scale #	Winds (mph)
1	74 – 95
2	96 -110
3	111 – 130
4	131 – 155
5	155 +

Katrina at LA Landfall

Category 3
127 mph wind
27.17 inches central pressure
15 mph forward speed
90 miles – extent of hurricane force winds
230 miles – extent of tropical force winds

Why Difference in Standards?

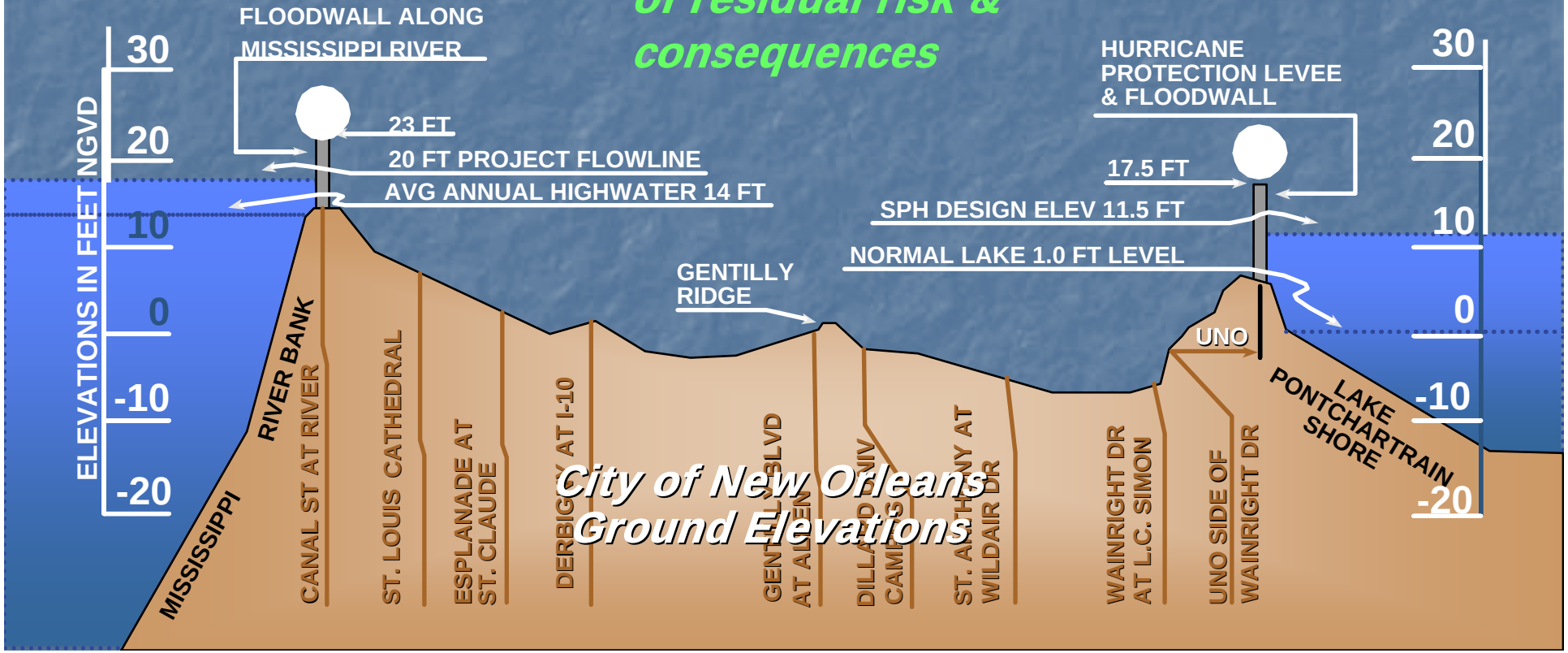
MR&T Project

~ 700 – 1000 Year Design Level

- Influence of cost considerations
- Loss of system perspective
- Lack of consideration of residual risk & consequences

LP&VHP Project

~ 100 – 200 Year Design Level



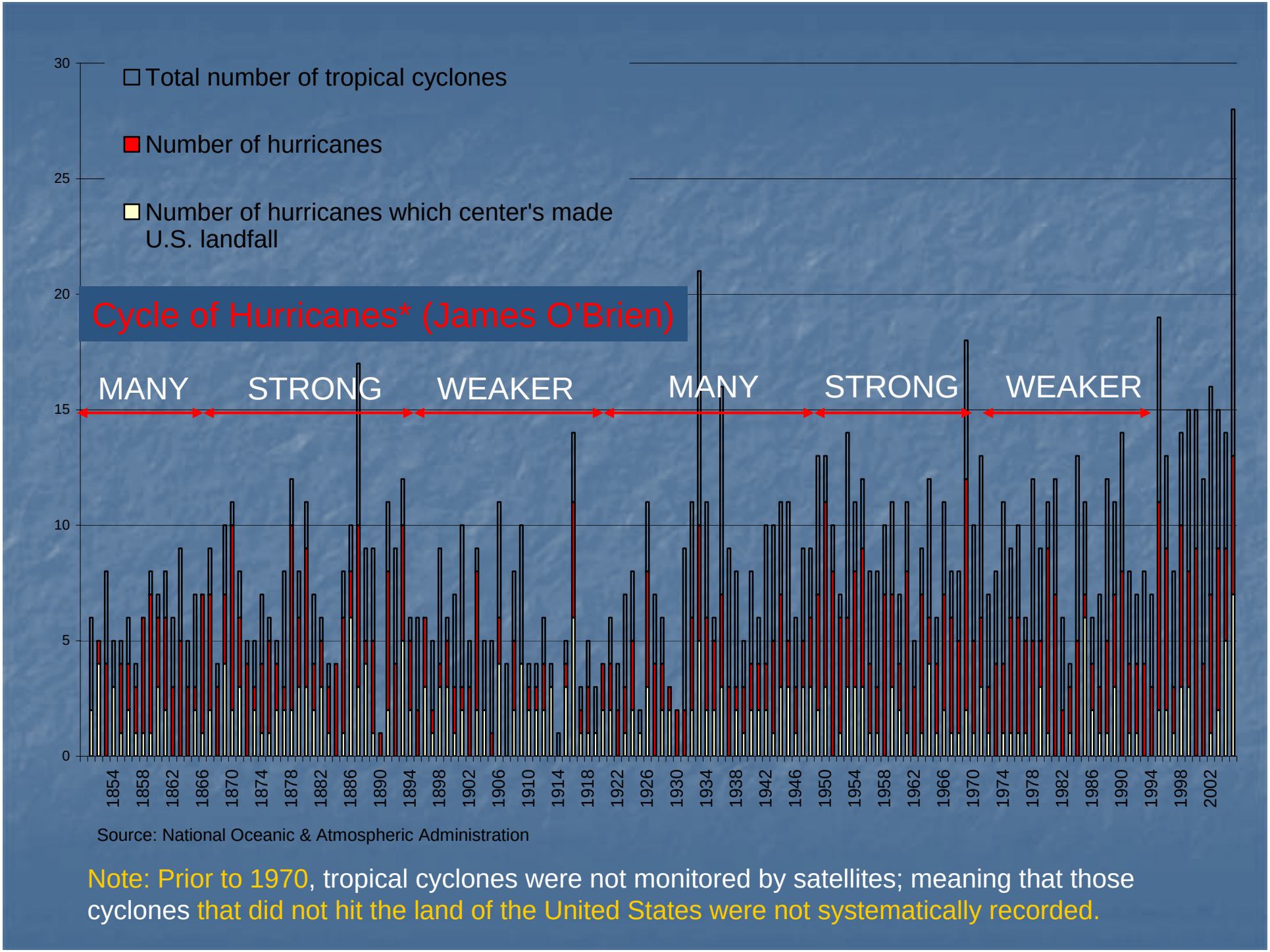
Hurricanes & Global Warming?

- “An Inconvenient Truth” – Al Gore
- 2004, 2005 Atlantic hurricane seasons broke many records
- 2006 predicted to have 15 named storms; 10 hurricane strength; 4-5 making landfall in US
- Debate among US meteorologists:

  A. 25-40 year cycle? (e.g. Landsea & Gray) or

  B. part of global warming cycle? (e.g. Emmanuel)
- 80% increase in Cat 4-5 cyclones worldwide since 1970. Doubling in N. Atlantic.

  or POOR DATA ?



Source: National Oceanic & Atmospheric Administration

Note: Prior to 1970, tropical cyclones were not monitored by satellites; meaning that those cyclones that did not hit the land of the United States were not systematically recorded.

Most Damaging Hurricanes

	Year	Cat	Cost
Katrina (FL, LA, MS)	2005	3+	$ 120.0 B +
Andrew (FL, LA)	1992	5	43.6 B
Charley (FL)	2004	4	15.0 B
Ivan (AL, FL)	2004	3	14.2 B
Hugo (SC)	1989	4	12.2 B
Agnes (FL, GA, SC, PA)	1972	2	11.3 B
Betsy (FL, LA)	1965	3	10.8 B
Frances (FL)	2004	2	8.9 B
Camille (MS, LA, VA)	1969	5	8.9 B
Diane (East Coast)	1955	1	6.9 B
Jeanne (FL)	2004	3	6.9 B

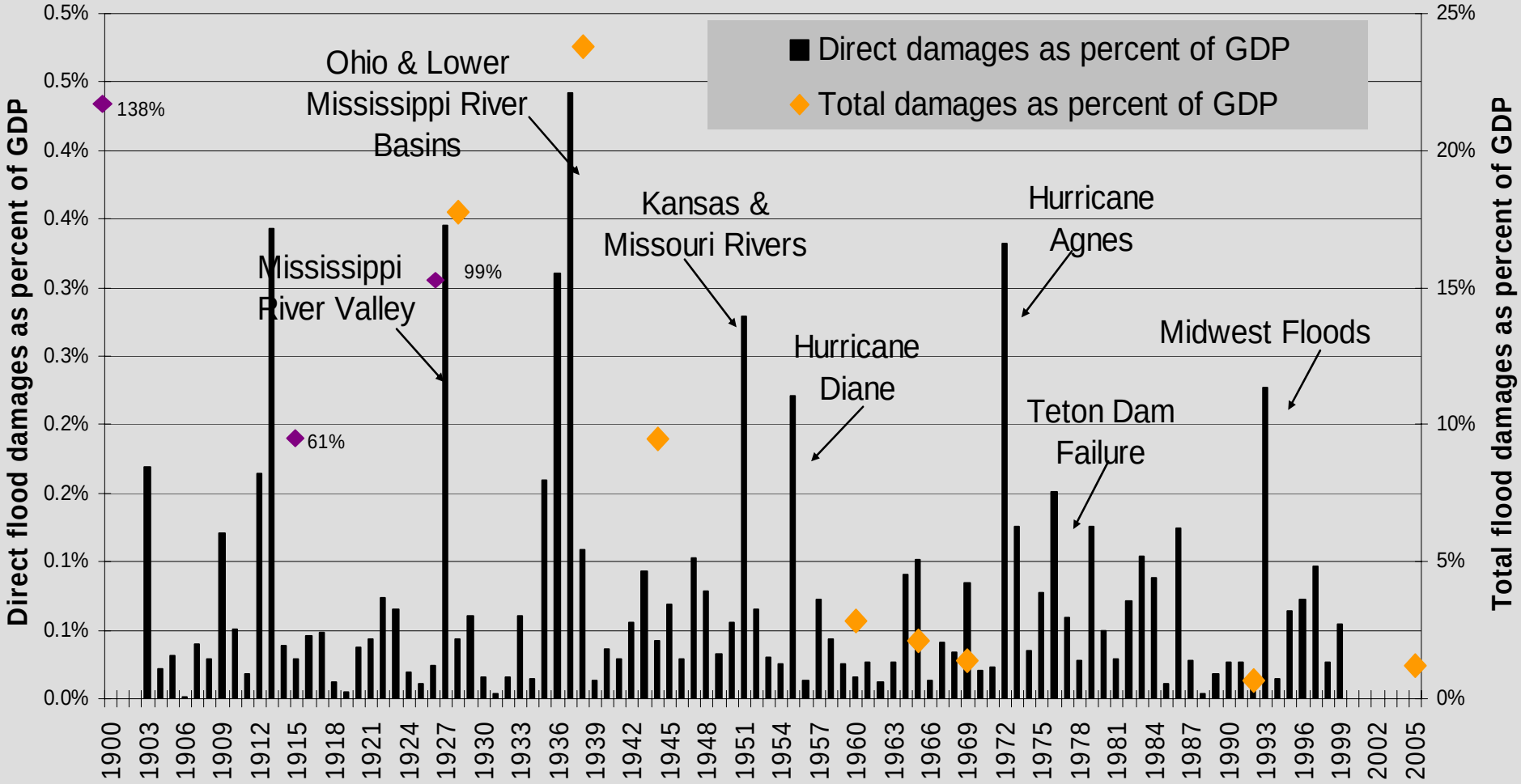
Calculating Damages/Impacts: (What should be used for BCA?)

- Direct damages to infrastructure, homes
- Indirect economic damages (jobs, economy, production, agriculture, fisheries, oil/gas production, transport, etc.)
- Loss of life, health, psychological trauma
- Cultural, social, community cohesion, etc.
- Other vulnerability measures ?

(Economists, planners, engineers have been debating these issues for the past 100 years)

Flood Damages as Percent of GDP

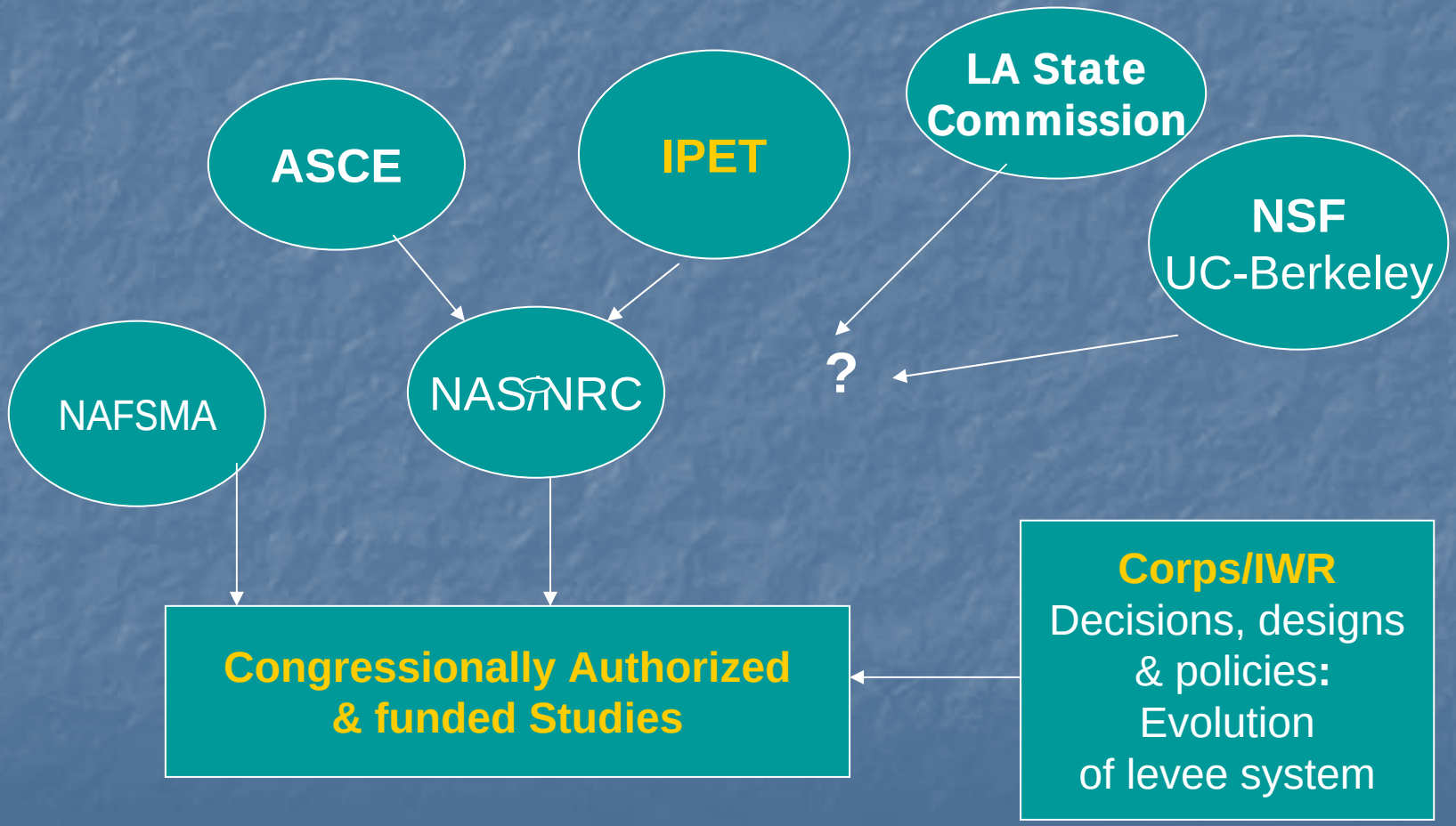
(Based on damages and GDP data in 2000 dollars)



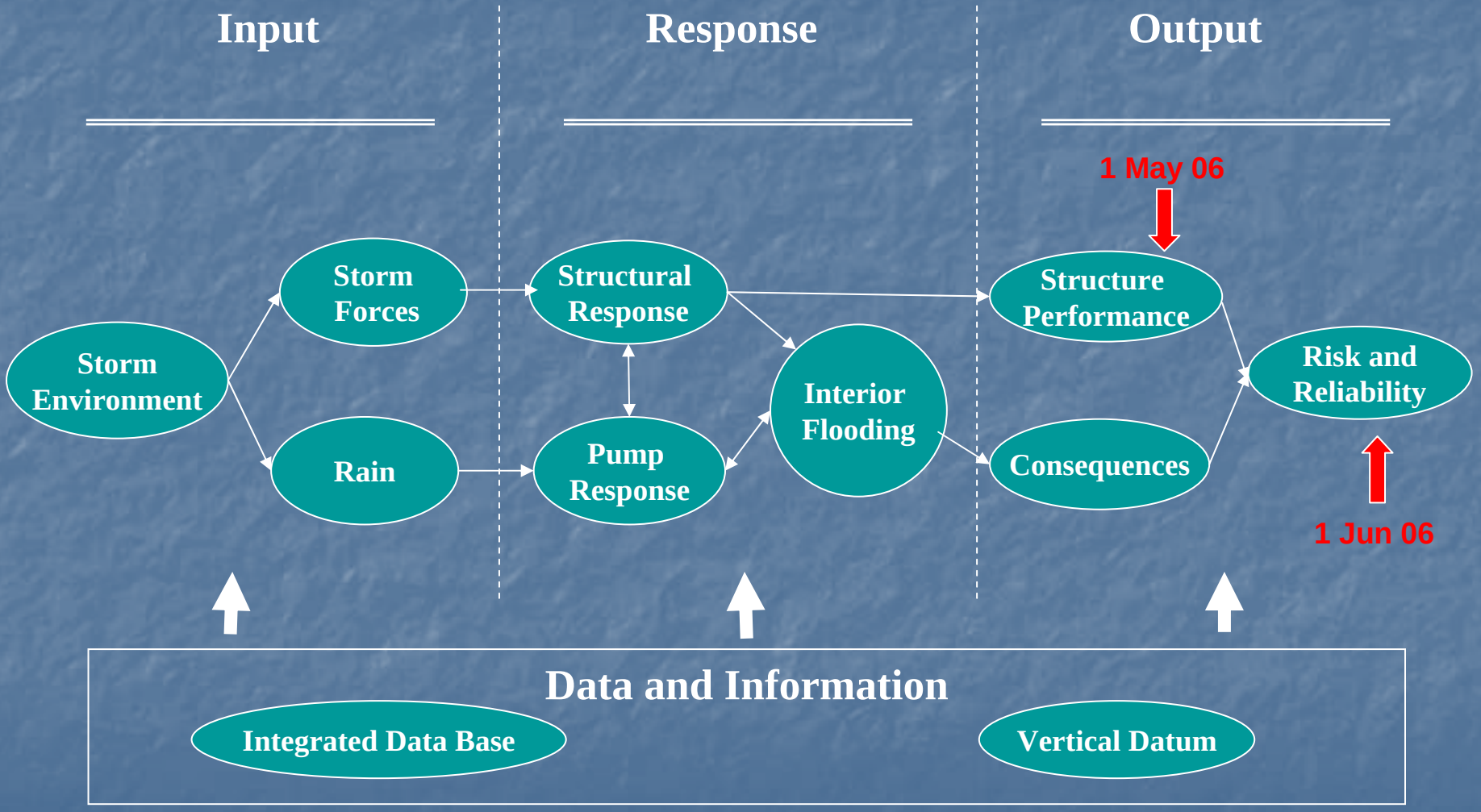
Recent REPORTS/REVIEWS

- Gov't Accounting Office Reports (numerous)
- Congress. Research Service Reports (numerous)
- Urban Land Institute (Nov 12-16, 2005)
- Gulf of Mexico Alliance Governor's Action Plan (2006)
- House Report – "A Failure of Initiative"
- White House Report – Feb 2006 'The Federal Response to Hurricane Katrina – Lessons Learned'
- ASCE, IPET, NRC, NSF "Forensic Analysis" (what went wrong, why, how to improve the designs)
- Corps Cat 5 SE Louisiana protection study
- Independent Working Group (IWR): "A New Framework for Planning the Future of Coastal LA"

Forensic Analysis of Hurricane Protection System (causes & modes of failure, damages)



Interagency Performance Evaluation Task Force (IPET)

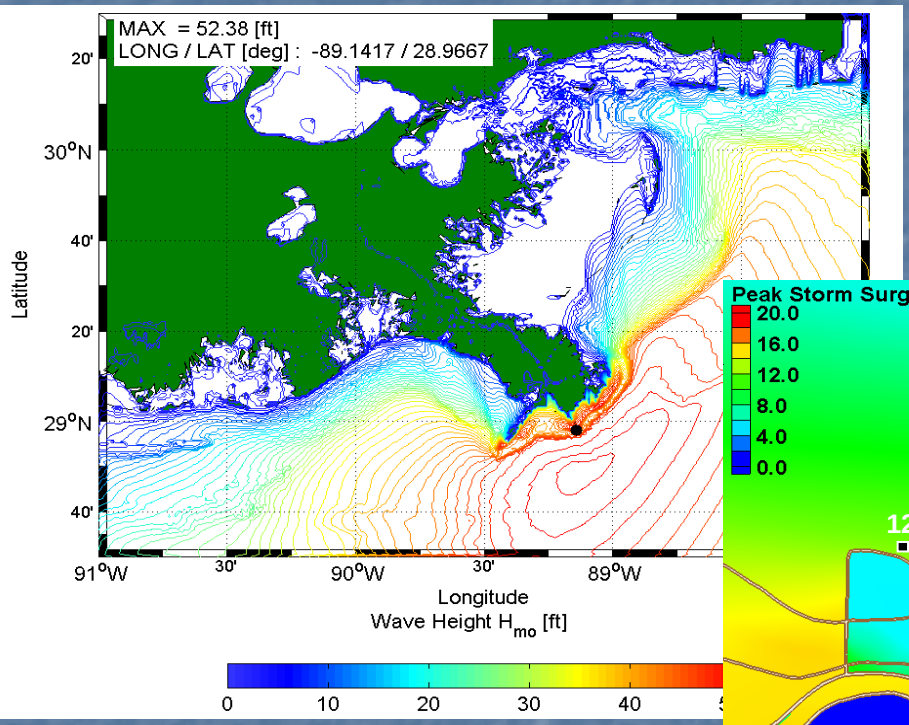


IPET Team: >150 experts; >50 organizations

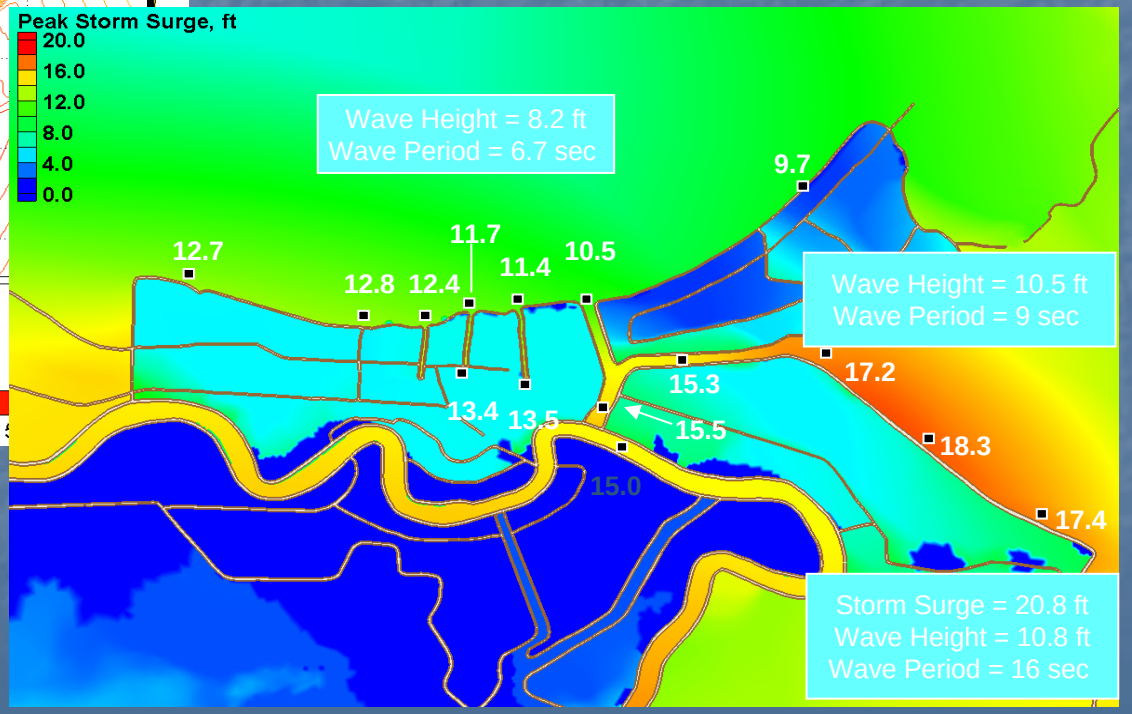
- **Federal Agencies**
  - Corps of Engineers (Lead agency)
    - MVD/MVN/MVK/MVS
    - Task Force Guardian
    - Engineer Research and Development Center
    - Huntington District (Task Force Co-Lead)
    - Louisville District
    - Tulsa District
    - Jacksonville District
    - Portland District, Hydropower Design Center
    - Institute for Water Resources / HEC
  - FEMA (Team member)
  - NOAA
    - NGS (Team Co-lead)
    - CO-OP (Team Co-lead)
    - NWS
    - HRD
  - USBR (Team co-lead)
  - USDA Economic Research Service (Team Co-lead)
  - USGS (Team member)
  - NIST
- **State and Local Agencies**
  - Louisiana DOT
  - New Orleans Levee and Drainage Districts
  - South Florida Water Management District (Team Co-lead)
  - Harris County Flood Control District, TX (Team Co-lead)
- **International**
  - River Bureau, Ministry of Land, Infrastructure and Transportation, Japan
  - Geo-Delft, Netherlands
- **Academia**
  - University of Maryland (Task Force Lead)
  - Louisiana State University
  - Jackson State University
  - Utah State University
  - Penn State University
  - University of Florida (Team Co-lead)
  - University of Delaware
  - University of North Carolina
  - University of South Carolina
  - University of Norte Dame (Team Co-lead)
  - University of Texas
  - Stanford University
  - Texas A&M U
  - University of Wyoming
  - Georgia Institute of Technology
  - Massachusetts Institute of Technology
  - Oklahoma State University
  - Virginia Polytechnical Institute and State University (Team Co-lead)
  - Villanova University
  - Rensselaer Polytechnic Institute
  - University of Missouri
  - University of Illinois
- **Industry**
  - Steedman, Ltd., UK (Team Co-lead)
  - Ocean Weather, Inc
  - ARA, INC
  - CH2M Hill
  - RAC Engineering

Storm Surge and Wave Modeling

What surge and waves did the levees and floodwalls experience from Katrina?



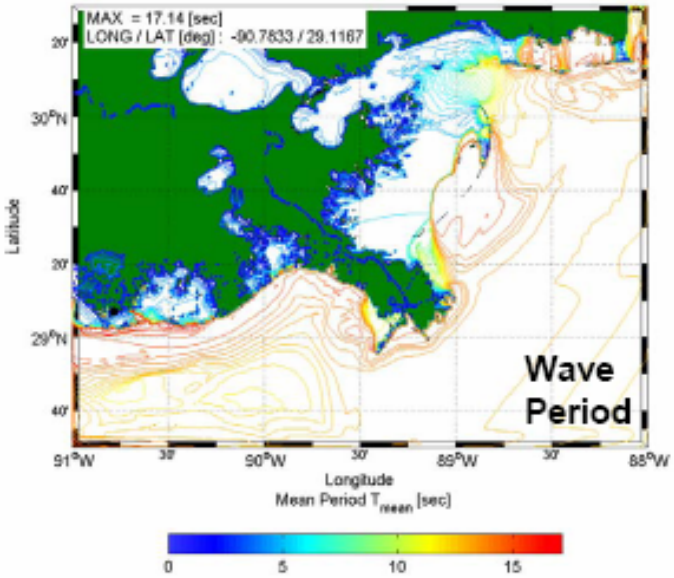
High resolution coupled storm surge and wave models

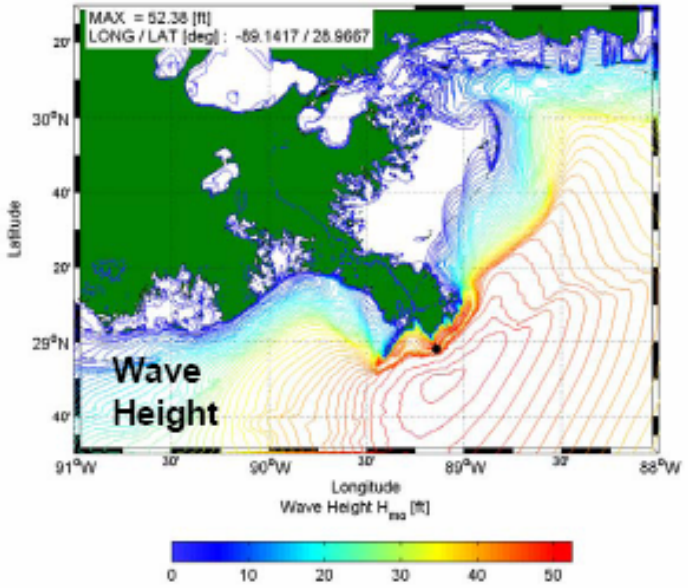


Nested Offshore Wave Modeling Approach

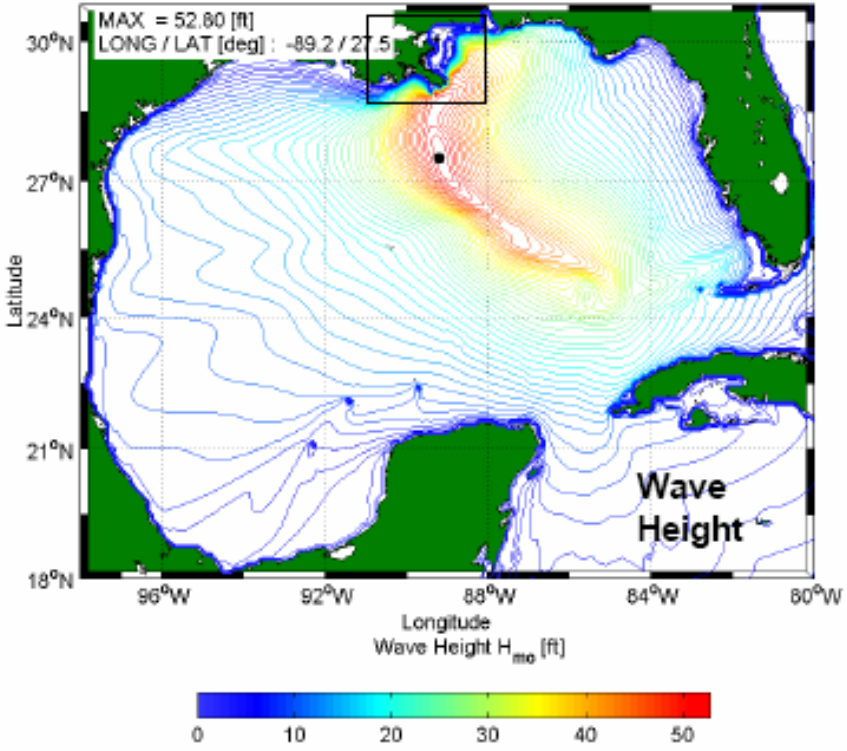
- Lateral boundary conditions for regional-scale model from the basin-scale model
- Winds from higher-resolution regional wind fields

Regional-Scale WAM Model





Basin-Scale WAM Model



Physical Performance Analysis

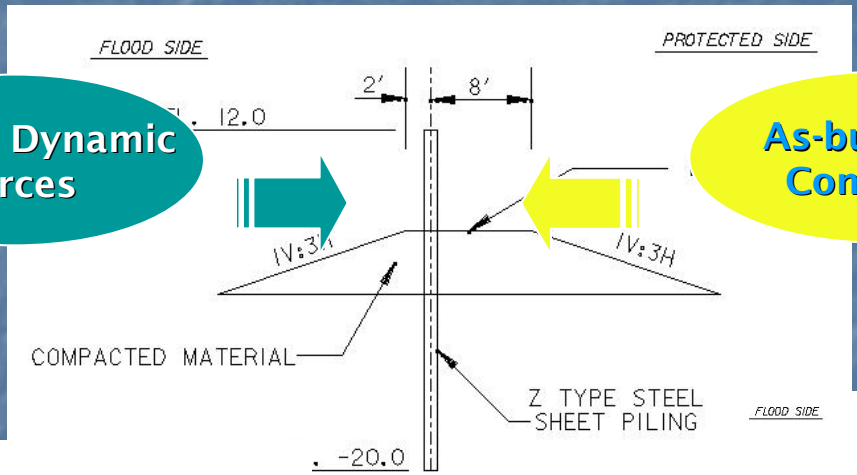
What forces were the structures designed and built to withstand?

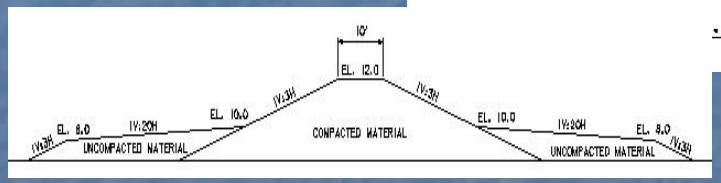
Surge and Waves

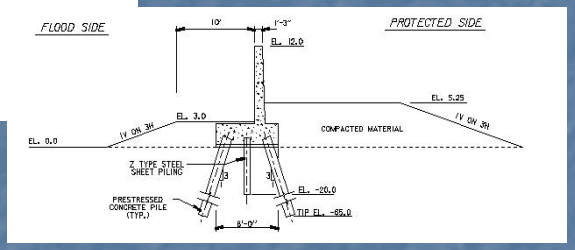
Static & Dynamic Forces

Design & Intent

As-built and Condition







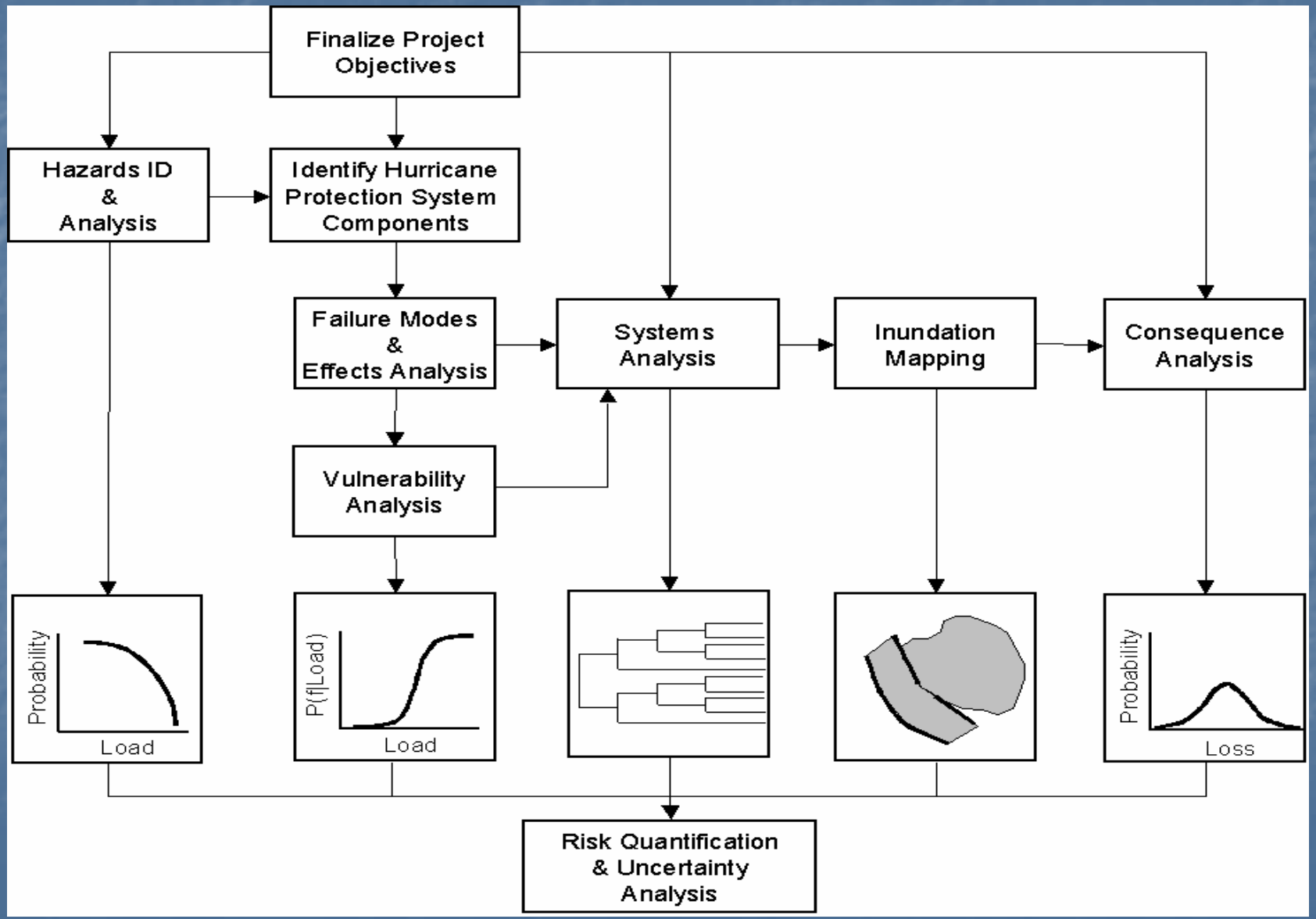
Observed Performance

Expected Performance

Behavior Insights

Flooding

Risk and Reliability Methodology



HPS Definition in Risk Model

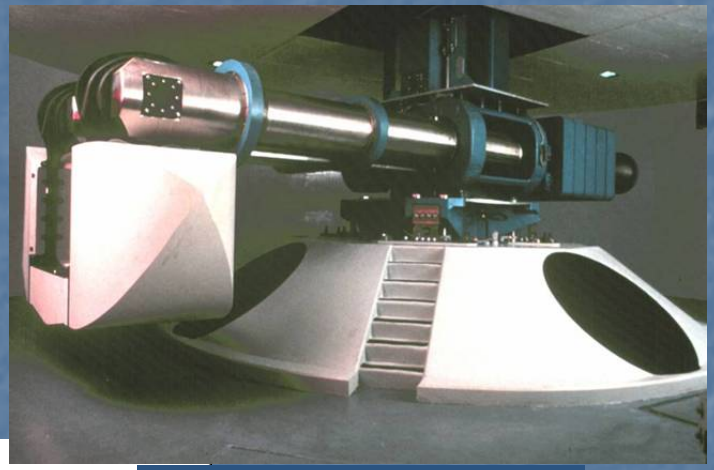
Note: Plaquemines not shown but is in the risk model

Geotechnical Factors and Behavior

How did the structures perform and why?

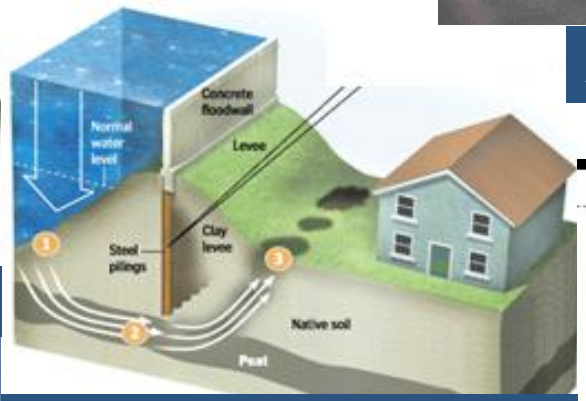
Combination of numerical and physical modeling

Sophisticated soil-structure analysis will use the Army and RPI centrifuges with support from Geo-Delft

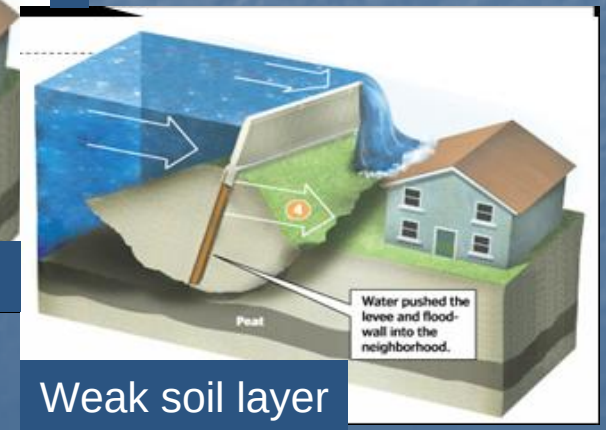


Army Centrifuge

Overtopping & Scour



Piping and Uplift



Weak soil layer

Key Response analyses

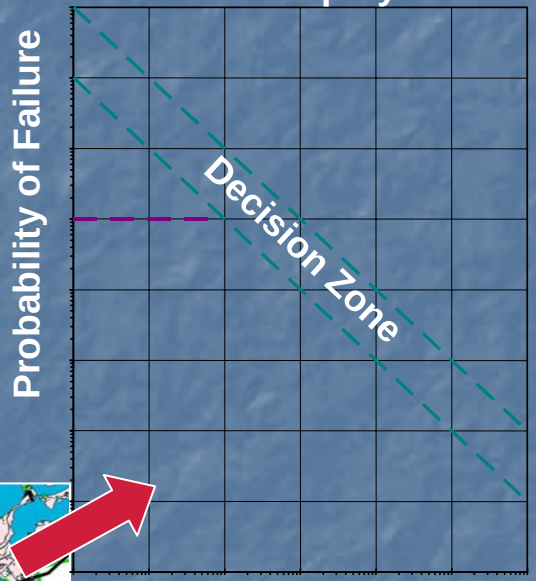
Consequence and Risk Analysis

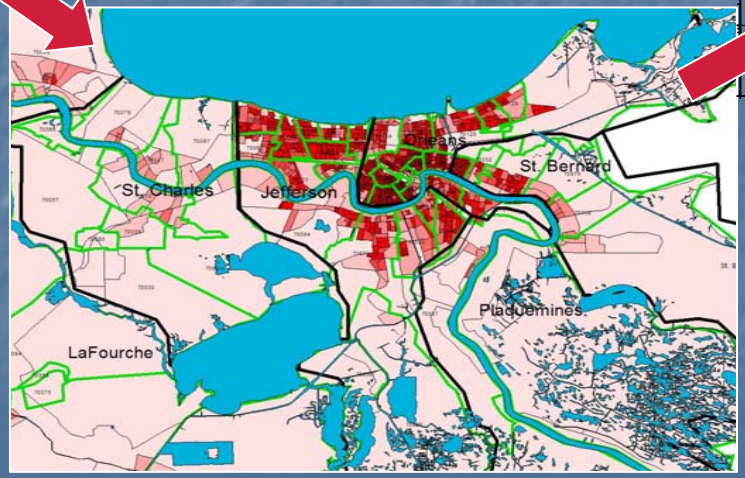
What were the consequences of Katrina?

What is the risk for the future?

Flooding Exposure by Polder

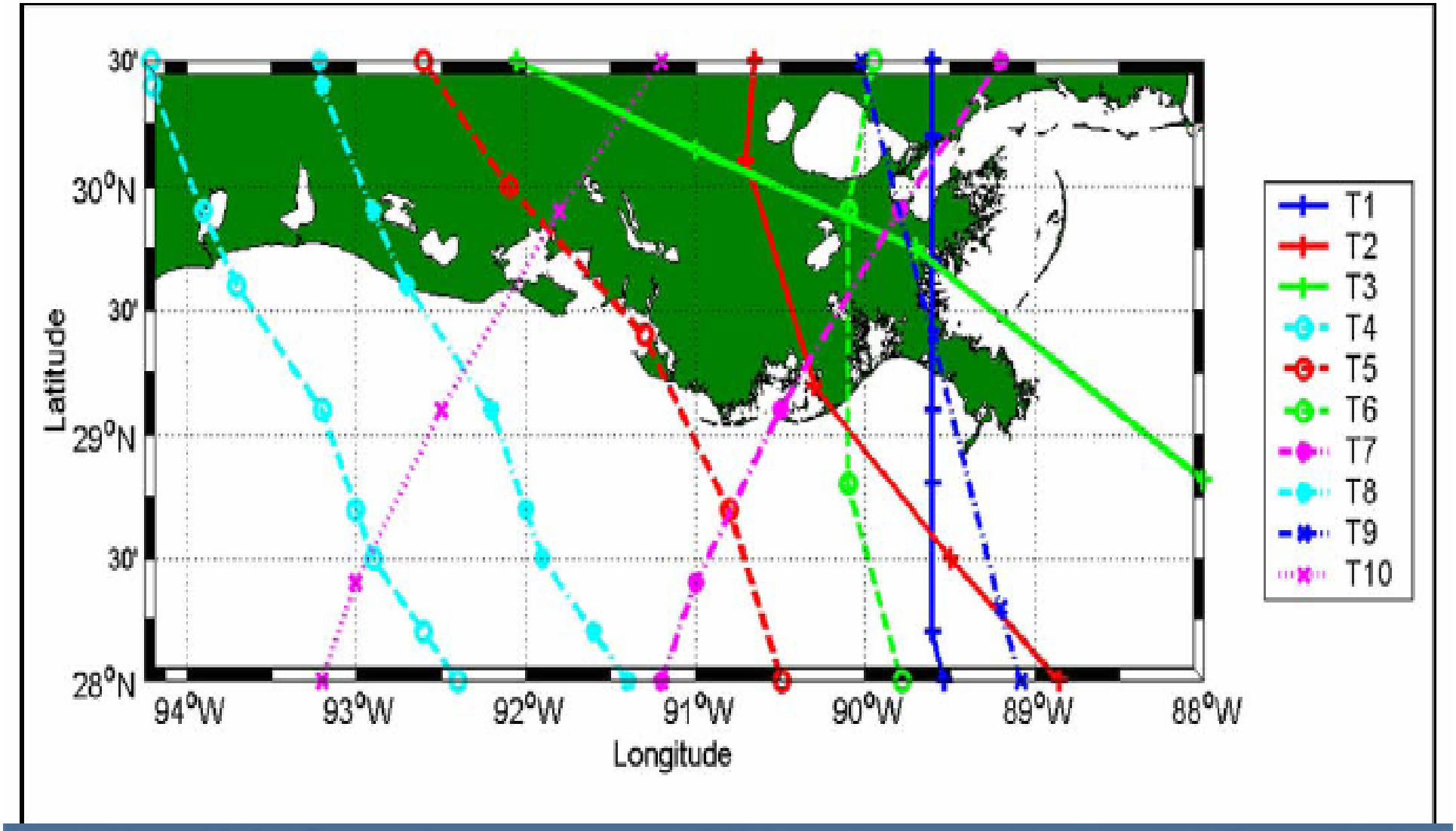
Risk Relationship by Polder

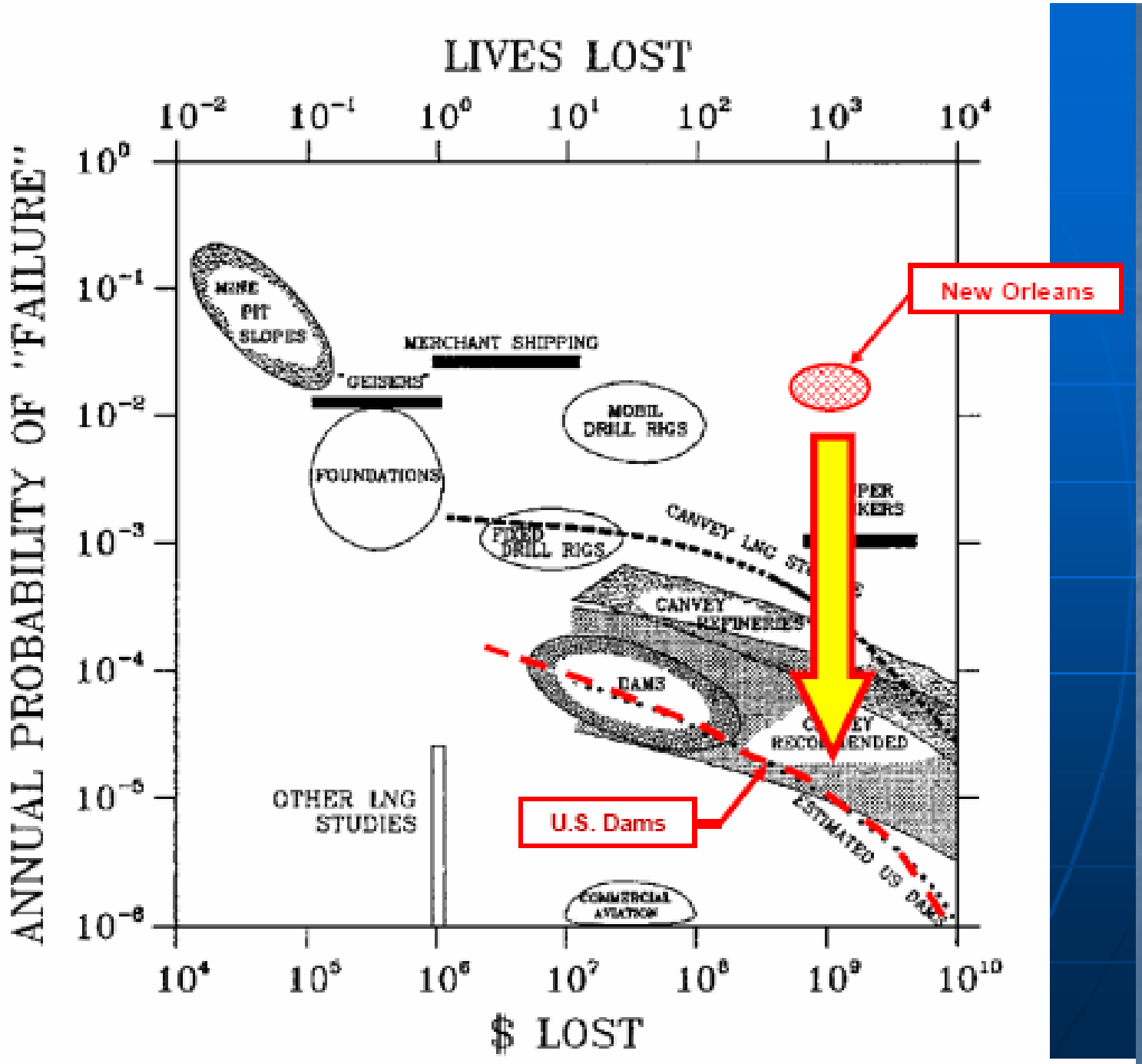




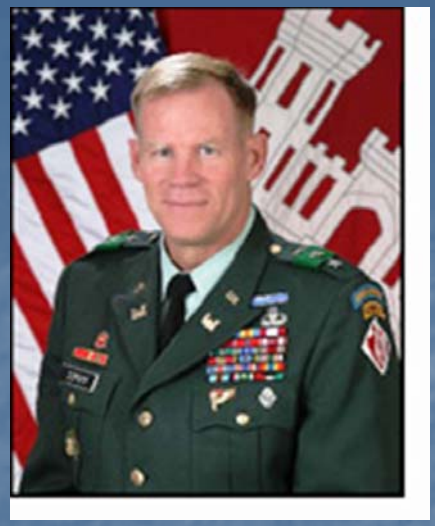
Losses by Zip Code and census block

Selected Hurricane Tracks




LIVES LOST
10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4}
ANNUAL PROBABILITY OF "FAILURE"
10^{0} 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6}
10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9} 10^{10}
$ LOST
MINE PIT SLOPES
GEISERS
MERCHANT SHIPPING
MOBIL DRILL RIGS
FOUNDATIONS
FIXED DRILL RIGS
CANVEY LNG
CANVEY REFINERIES
DAMS
OTHER LNG STUDIES
COMMERCIAL AVIATION
ESTIMATED US DAMS
New Orleans
U.S. Dams

Remarks of LTG Strock
Chief of Engineers
US Army Corps of Engineers



- ‘building resilient systems is difficult because of complicated rules of Congress...”
- “...we have to look beyond economic criteria.”
- “...top of the list reforms is requiring independent peer review of our projects...”
- “We can’t simply look at engineering independent of political and social issues...”

6/2006 Louisiana Coastal Protection and Restoration Interim Report to Congress – Options for Category 5 Hurricane Protection

- Hurricane risk reduction Decision Framework
- Restoring the first line of defense – coastal & marsh restoration – an integral part of plan
- Characterizing hurricane threat
- Develop new risk-based assessment methodology
- Formulate initial set of plans/strategies that provide alternative risk reduction strategies and measures
- Upgrade/update technical analysis (storm surge, wetlands, ecosystem, social impacts, economic impacts, etc.
- The “Dutch Approach” considered, rejected
- FINAL REPORT to Congress – December, 2007

South Louisiana Hurricane Protection and Restoration TEAM (Category 5 Study)

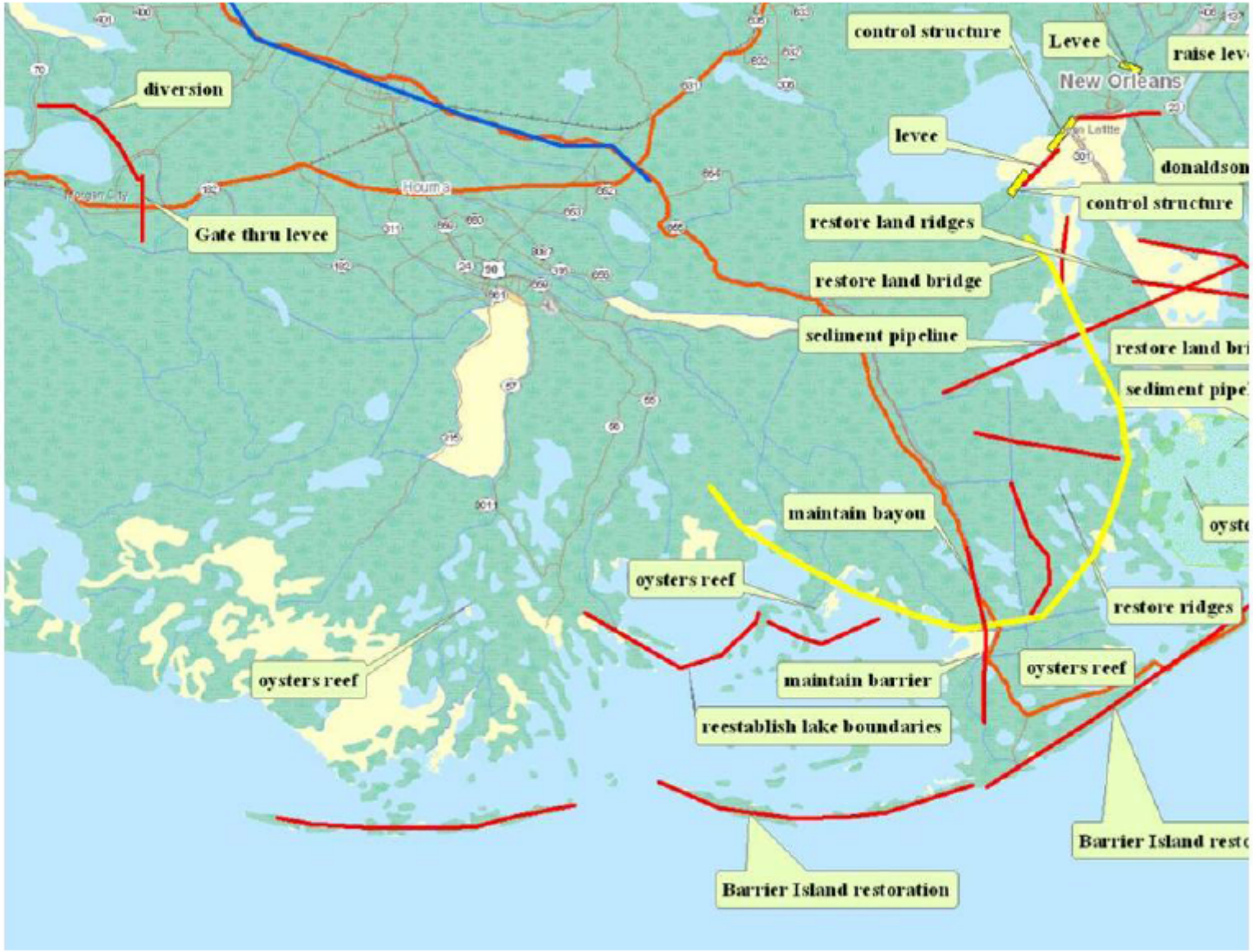
National – International Expert Team

- **Federal - State**
  - Corps, USGS, FWS, EPA, NOAA, NRCS, NMFS, MMS
  - LA CPR Authority, DNR, DOTD
- **Private sector**
  - Numerous private firms and expert consultants
- **Academia**
  - LSU, U Colorado, Notre Dame, Ohio State, UNO, MIT, many others
- **International experts**
  - Netherlands, Japan
- **NGOs**
  - DU, Lake Pont. Foundation, CRCLA, many others

Possible Lake Pontchartrain Basin Barrier System

A system of restored wetlands, stronger levees, and surge barriers east of New Orleans may offer the best approach for protecting communities around the Pontchartrain basin.

Coast Options & Ideas 3



Coast Options & Ideas 2

Coast Options & Ideas 1

Analytical, Technical & Engrg Failures

- Datum and subsidence issues
- Dynamic information on hurricane intensity and frequency
- Technology advances for modeling storm surge
- Contemporary consideration of structural reliability
- Emerging information on implications of Gulf wetlands loss

- ***Risk & Reliability.*** Neither a system-wide consideration of residual risk, or a deliberate treatment of system reliability issues are evidenced in record. Little focus on:
  - Considering and evaluating implications of risk and reliability during iterative design changes
  - Communicating residual risk and potential consequences to stakeholders/public

Implications for IHP-VII/ICHARM ?

- What are the scientific/technical issues that jump out of the Katrina event? For ICHARM ?
- Flood warning/evacuation/recovery planning
- Risk-cost based standards vs. deterministic standards (PMF, PMH, SPF or .01, .001, .0001)?
- Risk and reliability analysis & communication
- Role of public participatory processes in decision making and setting of safety standards
- Role of governance/institutions/consensus
- Ethical standards and obligations of engineers
- Basic Geotechnical engineering technology


Thank You

Questions?

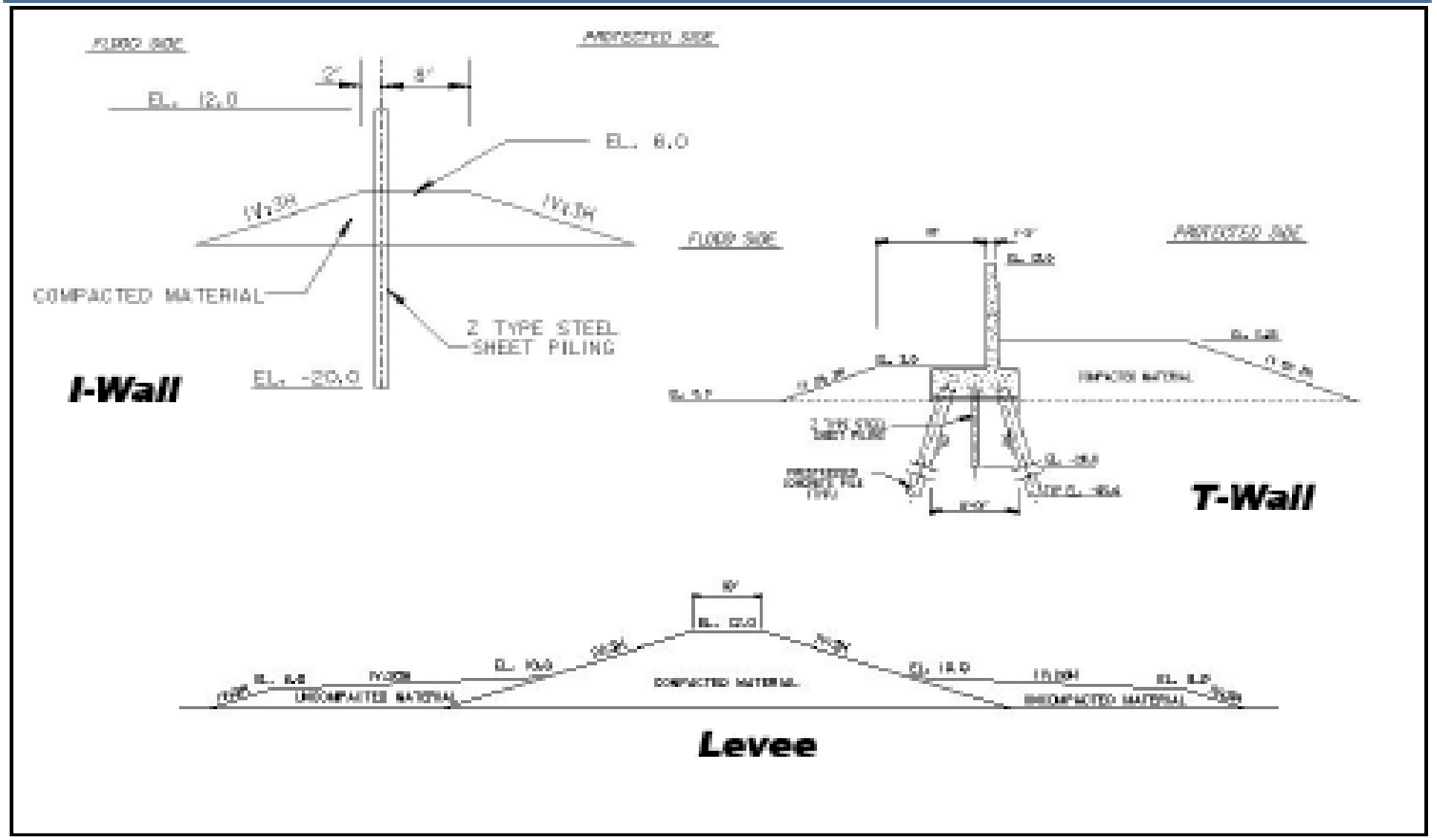


Figure 3. General schematic of major hurricane protection structures used in New Orleans and vicinity

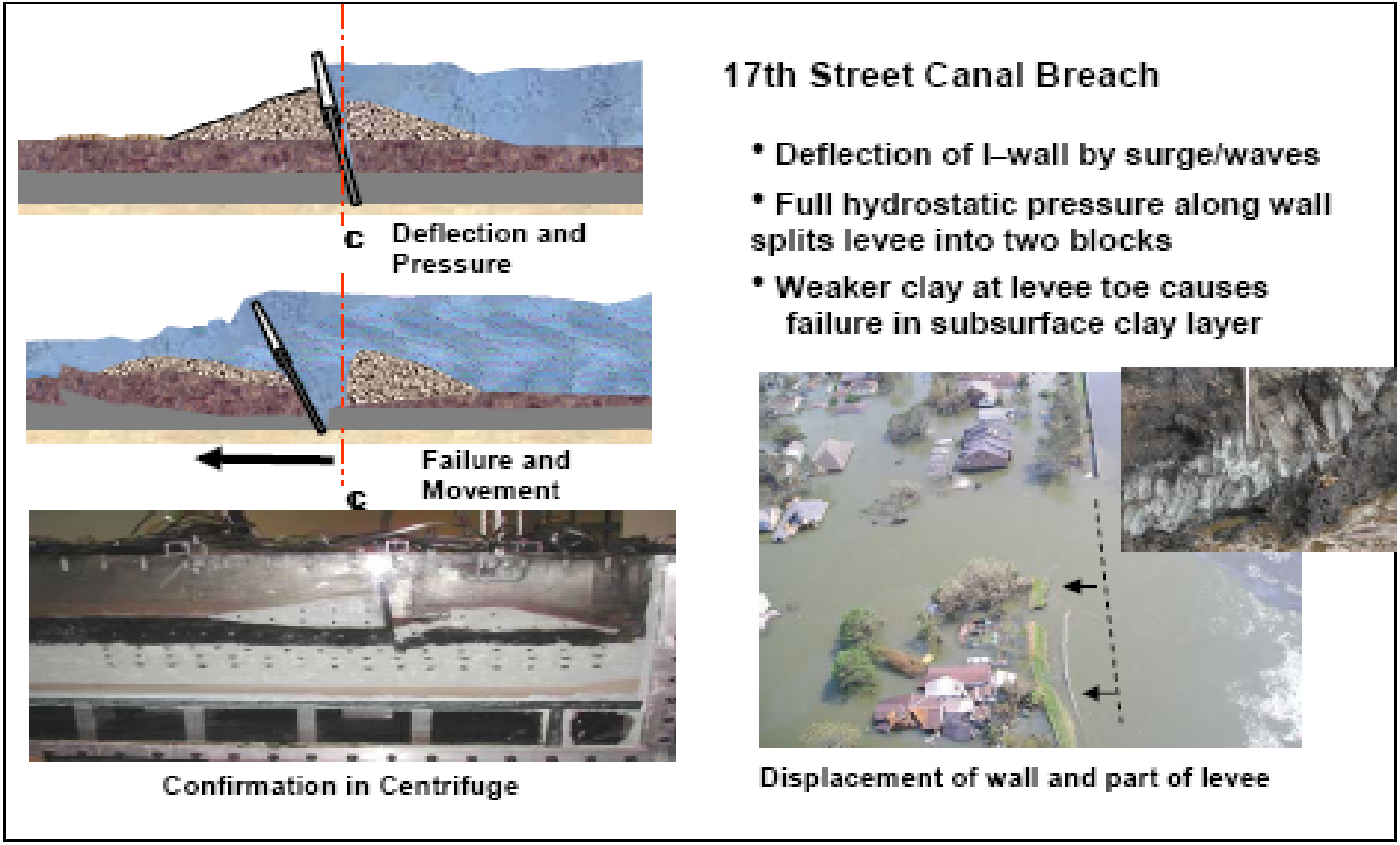


Figure 17. Depiction of failure mechanism for 17th Street and IHNC foundation failures. A crack forming along the front of the I-wall introduced high forces down the face of the sheetpile, resulting in lateral movement of the floodwall along a shear plane in the weak clay foundation

Emergency Repairs to Damaged Inner Harbor Navigation Canal Floodwall

Although construction of the Inner Harbor Navigation Canal T-wall proceeded at a rapid pace to restore protection for Orleans and St. Bernard Parishes after Hurricane Katrina, parts of the city and region remain vulnerable to large storms.

Independent Working Group for Post-Hurricane Planning for Coastal LA (IWR)

"A New Framework for Planning the Future of Coastal Louisiana after the Hurricanes of 2005" Jan 26, 2006

- Protection for NO can only be secured from combo of levees and sustainable coastal landscape
- Most coastal landscape can be maintained thru end of 2100 with efficient mgmt of sediment resources
- Must integrate planning, investment and mgmt decisions under a new multiobjective framework
- Priority ecorestoration choices of LA should be revised to support storm damage reduction
- Develop a spatially explicit vision of a future coastal LA that includes long-term goals and opportunities

Cont'd

- "Dutch' protection model may not be applicable in LA – focus on strong inner defenses, marsh restoration and barrier island maintenance
- Integrated planning should account for disruption of coastal dynamics from navigation projects
- *Independent*, joint federal-state body should have responsibility and fiscal support for guiding planning and implementation
- Authorization and financing should *be separate from* Water Resources Development Act process
- Employ innovative planning and decision analysis, engage stakeholders and agencies, resolve conflicts

Charles Perrow (1999)
"Normal Accidents: Living With High Risk Technologies"

- Most high-risk systems have characteristics that make failures inevitable – almost "normal"
- Systems with many components ('*interactive complexity*') are likely to fail from unanticipated combinations of failures
- '*Tightly coupled*" systems are those that have high interactive complexity and operate/move very fast – time-dependent - reducing reaction time to detected failures
- *'System accidents'* are rare, but usually catastrophic
- Organizational and technological fixes usually exacerbate complexity
- '**Katrina'** is an example of a **system failure**: both the HPS and the evacuation plan are tightly coupled and have a high degree of complexity

Fiering & Kindler: a taxonomy of surprises

- **Structural surprise** - collapse of a component
- **Embedded surprise** -system errors
- **Hydrologic surprise-** change in catchment
- **Institutional surprise** – shift in system operation
- **Informational surprise** - disruption of crucial info
- **Mechanistic surprise** - not understanding response to stresses
- **Demand surprise** - outside the range of expectation

Minimize likelihood of surprise and/or optimize system design characteristics ?