Katrina Through Your Rearview Mirror

W. F. Marcuson, III
Director Emeritus, Geotechnical Laboratory
U.S. Army Engineer Waterways Experiment Station
Vicksburg, Mississippi
Path Forward

• The Setting
• What Went Wrong
• Risk
• Lessons Learned
• Conclusions
The Setting
New Orleans – 1849
New Orleans
The HPS

- Begun in **1965**
- Scheduled for completion in **2015**
- 350 miles in length
- 12-15 feet above MSL

- 284 miles of federal levees
- 66 miles of non-federal levees
- 56 miles of I-wall
- 2 miles of T-wall
Raising the height of an earth levee
Hurricane Katrina
Wind vectors
Storm surge
What Went Wrong
We saw it coming

• “...If a lingering category 3 storm – or a stronger storm, say category 4 or 5 – were to hit the city, much of New Orleans could find itself under more than 20 ft (6 m) of water...”
The catastrophe was borne out of a failure to recognize:

• How fragile the levees were
• How devastating the consequences would be
Katrina simply overwhelmed the HPS

- The storm exceeded the design, but the constructed project did not meet the design intent
- 169 miles of damaged levees
- 50 breaches, which increased flooding by at least **300 percent**
Breaching

FRENCH QUARTER

No breaching
Two direct causes of breaching

1. Uncontrolled overtopping and ensuing erosion led to catastrophic failure of levees and floodwalls

2. Four I-walls collapsed before water reached design levels
1. Uncontrolled overtopping and ensuing erosion led to catastrophic failure of levees and floodwalls
Katrina’s Surge in East Orleans
(Location: Near Power Plant)
Location: Near Power Plant
2. Four I-walls collapsed before water reached design levels – designs failed to account for:

- Variability in soil strength
- Wall deformation, which opened a water-filled gap on the flood side
- Critical water pressures beneath the levees
Borings made at levee centerline
Designer assumed A and B to have equal strength
But, strength = \( fn \) (depth of overburden) for a normally consolidated clay
So, the strength at A << strength at B
Shear strength
Un-Conservative Estimate of Soil Strength

- ELEVATION IN FEET
- CLAY
- SHEAR STRENGTH – TONS PER SQ FT
- DESIGN SHEAR STRENGTH ENVELOPE
- IPET SHEAR STRENGTH AT CENTERLINE
- IPET SHEAR STRENGTH AT TOE
THE WATER-FILLED GAP
The Corps ignored its own research on I-walls.

From the E-99 report: “Although the test wall was not loaded to ‘failure,’...failure may have been imminent.”
LONDON AVENUE

THE WATER-FILLED GAP

MARSH

SAND

Lacustrine Clay

Lacustrine Clay
South Breach

* Courtesy of Professor James M. Duncan, VA Tech
17th Street Canal
Strengths over-estimated
 Loads under-estimated
 $F < 1$
Failure plane


Eric Holdeman’s Four Stages of Denial

• It won’t happen
• If it happens, it won’t happen to me
• If it happens, and it happens to me, it won’t be so bad
• If it happens, and it happens to me, and it’s bad, there is nothing I can do to stop it anyway
The Risk to People was Misunderstood*

* Courtesy of Robert B. Gilbert, Univ. of Texas, Austin
"Historical performance of Hurricane Protection System"

USBR Threshold: "Justification to take expedited action to reduce risk."

"Justification to take action to reduce risk."

USBR Threshold: "Diminishing justification to take action to reduce risk."

* Courtesy of Robert B. Gilbert, Univ. of Texas, Austin
Guidance for offshore structures in the Gulf*

* Courtesy of Robert B. Gilbert, Univ. of Texas, Austin
Offshore structures

- $30 billion in damages
- 100 percent evacuation
- 0 fatalities

NOLA HPS

- $30 billion in damages
- 80 percent evacuation
- >1100 fatalities
Lessons Learned
Failure to think globally, act locally

- Subsidence and vertical datum adjustments were not considered
- The Standard Project Hurricane was never updated

Typically varies 1.5 to 2.5 feet
Failure to understand, manage, and communicate risk

- Risks were seriously underestimated
- Designs pushed the envelope at each stage
- I-wall designs were not sufficiently conservative to deal with unknowns. A flood-side water-filled gap should always be assumed.
Failure to build in quality

• Rigorous internal review processes (QA-QC) would have assured that designs met project goals
• External peer review could have been effective
  – At embedding an appropriate margin of safety into the culture of the design process
  – Ensuring that designs meet the appropriate standards of practice
Understand risk and embrace safety

• Keep safety at the forefront of public priorities
• Quantify the risks
• Communicate the risks and decide how much is acceptable
Demand engineering quality

- Upgrade engineering design procedures
- Bring in independent experts
- Engineers *must* place safety first
Acknowledgements

► Lawrence H. Roth, P.E., G.E., F.ASCE
► U.S. Army Engineer Research and Development Center
► Corps’ Interagency Performance Evaluation Taskforce
  ■ Levee and Wall Performance Group: Reed L. Mosher and James Michael Duncan
► Professor Robert B. Gilbert
► Tracey Waddell, ERDC
Questions?