Probabilistic Flood Hazard Assessment
Panel 4 – Flood Induced Dam and Levee Failures

Risk Informed Decision Framework for Dam And Levee Safety

Rockville, MD

30 January 2013

US Army Corps of Engineers
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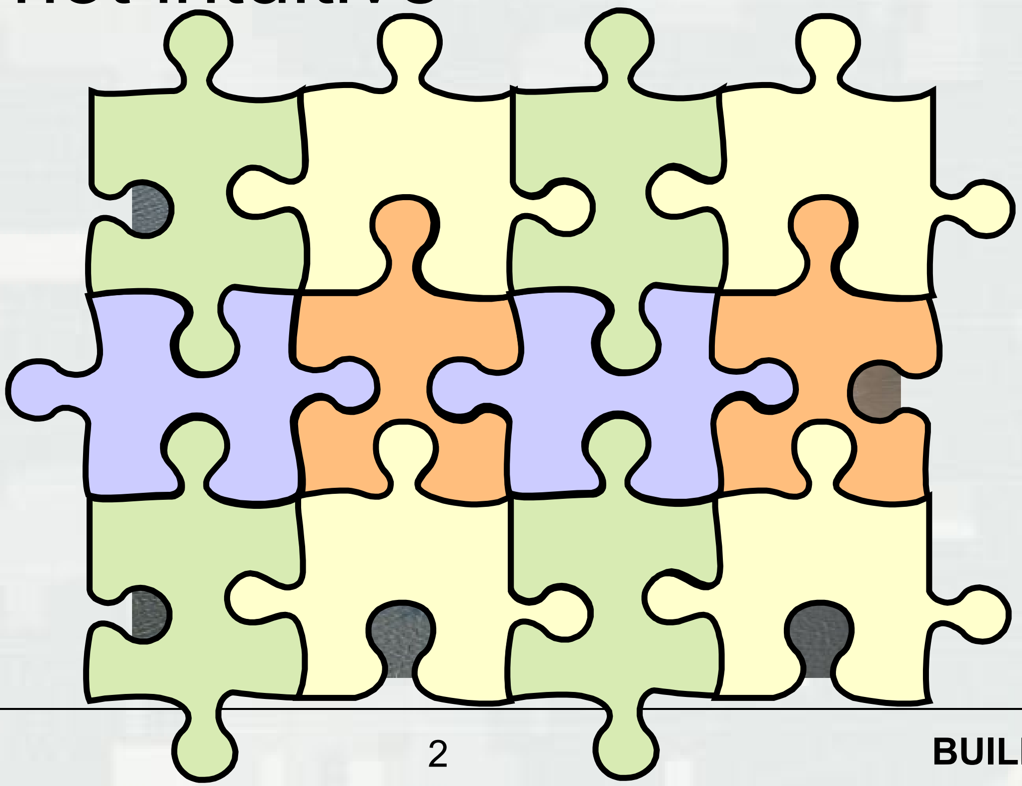
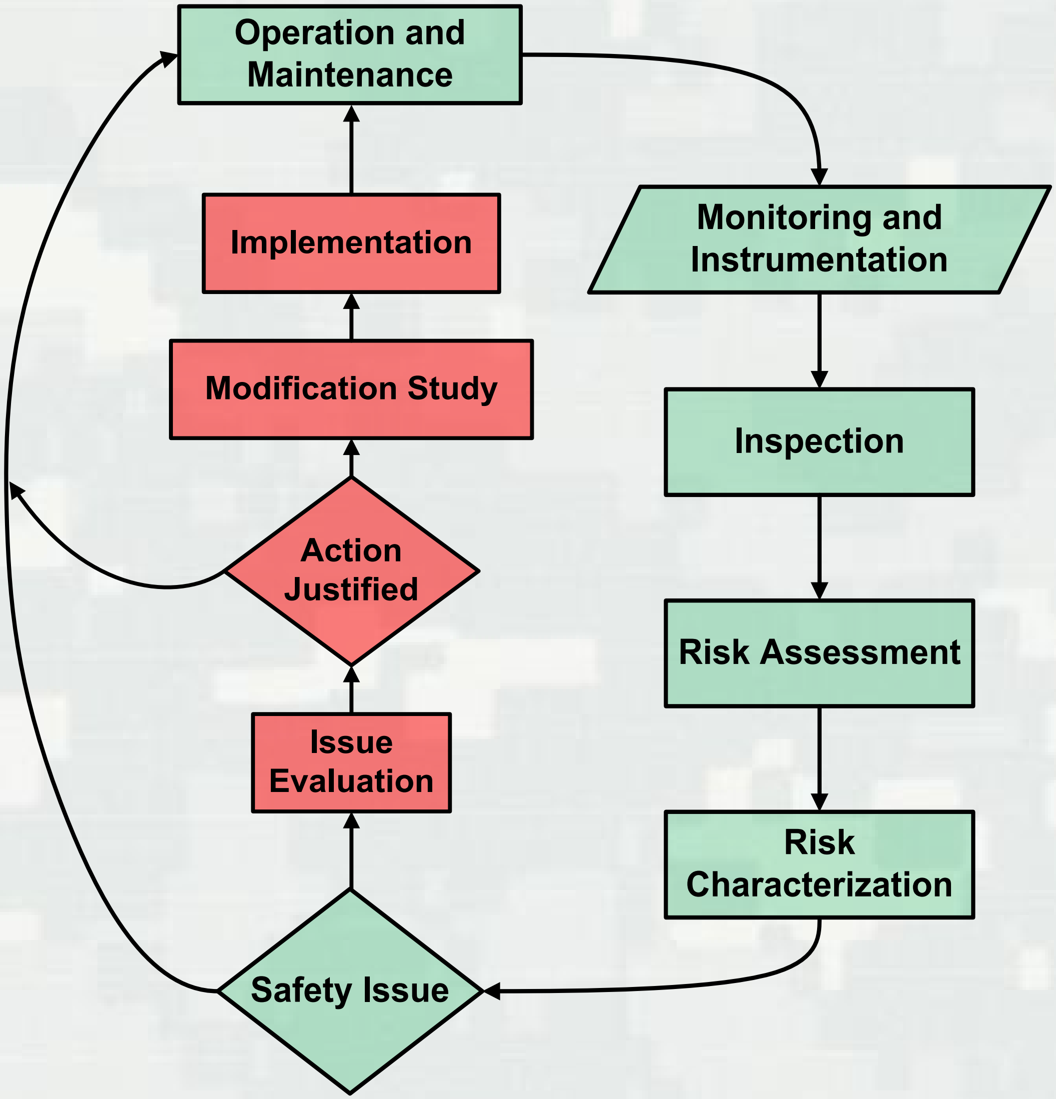
Why?

- Decisions will be made
  - With incomplete information
  - In a constrained environment
- Risks are not intuitive



How?



- Portfolio Risk Management
  - Routine Activities
  - Non-Routine Activities

Who?

Where decisions are made

Leaders

- Understand basis for decisions
- Communicate risk

Managers

- Understand risk concepts
- Make important decisions

Analysts

- Conduct risk analysis
- Defend recommendations

Where organizational use of risk usually starts

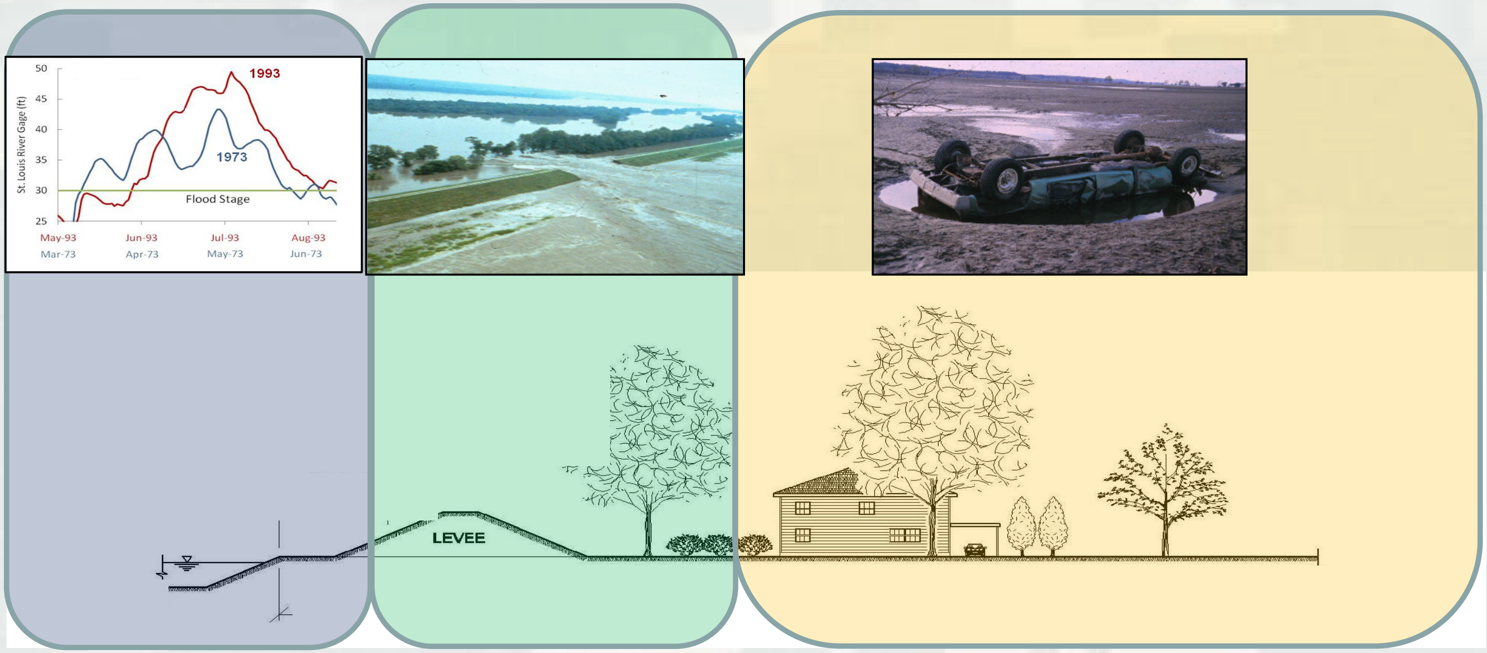
Decision Driven

- What decision are we making?
- Who is making the decision?
- How will the decision be made?
  - What criteria will be used?
  - What are the key factors?
- What information is available?
  - Will more information improve the decision?
- What are the consequences of a poor decision?

Risk Informed Decisions

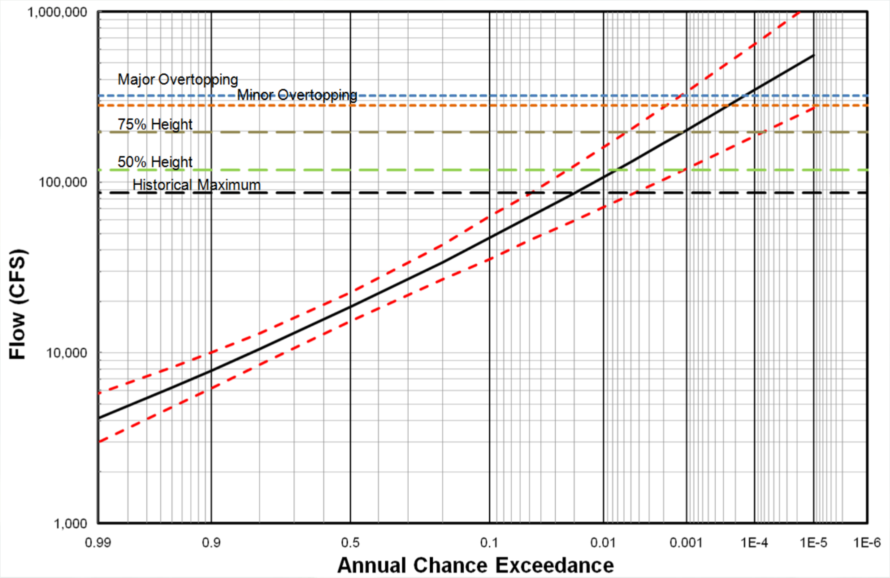
- Characterize risk
- Identify uncertainties
- Recommend actions

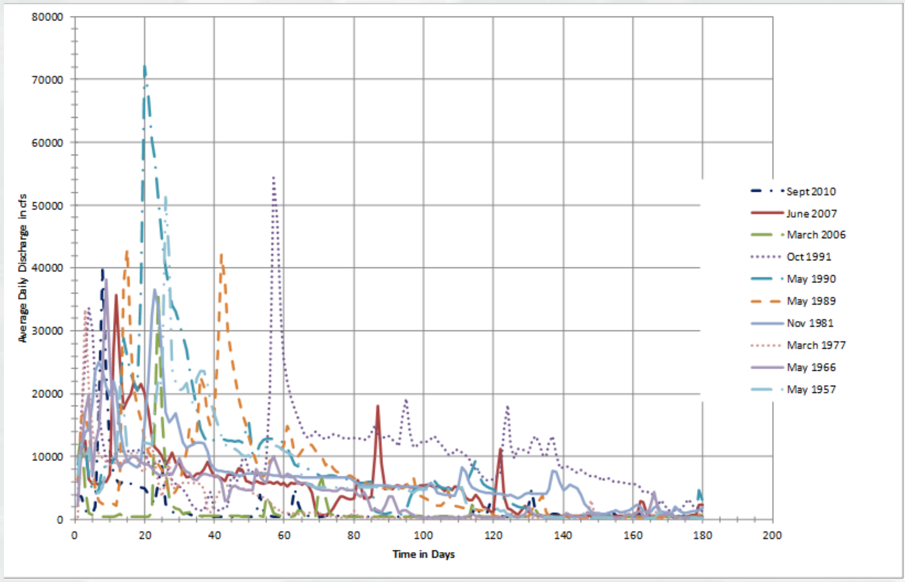
Components of Risk

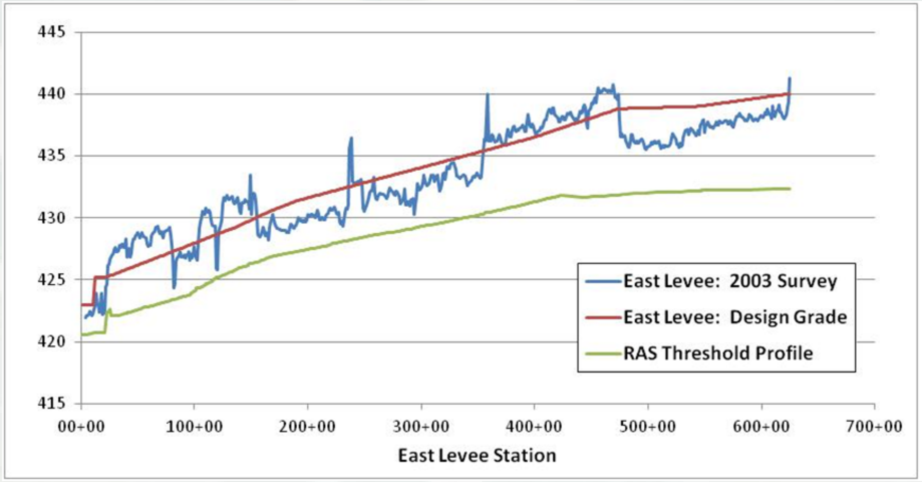


Risk = f(<u>Hazard</u>, <u>Performance</u>, <u>Consequences</u>)

Hazard –
Magnitude, Frequency, Duration, etc

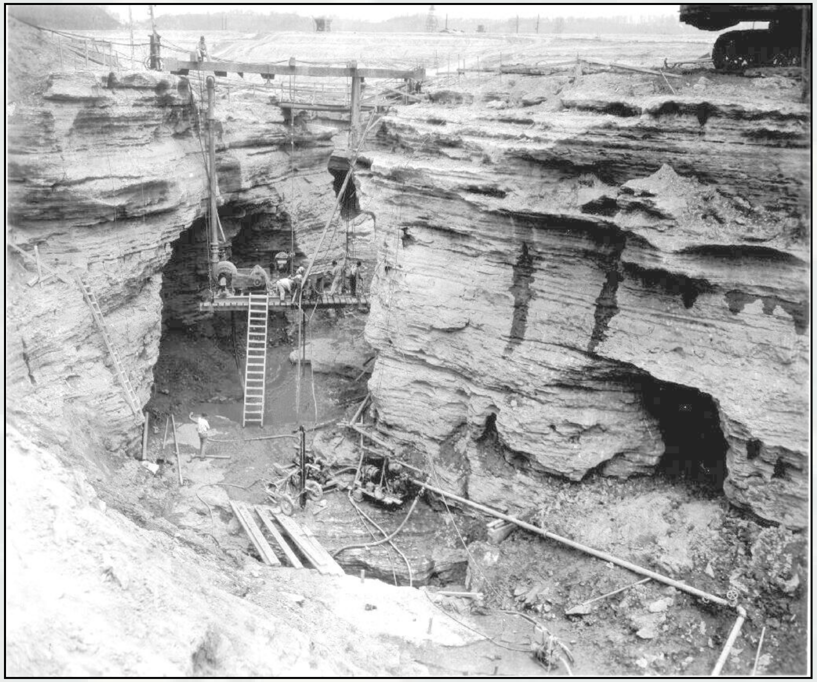






Performance – Potential Failure Modes Analysis

- How does the system perform
- What can lead to failure
- How credible and likely is it

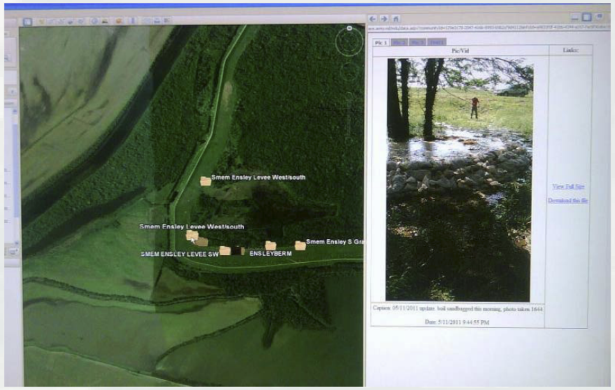


Failure Mode - Description

- A large flood raises the river to unprecedented levels which imparts high water pressures in an exposed basal sand/gravel layer through an outcrop in the river channel or bridge pier penetrating to the sand layer. The sand layer is continuous beneath the alluvial clays in the foundation of the levee and outcrops on the land side in a low sump or ditch. A path for unrestricted water flow through the foundation develops. Internal erosion begins by movement of soil into the sump or ditch on the land side of the embankment and progresses towards the river by backward erosion beneath a foundation clay layer capable of forming a roof. Erosion progresses to the river and water entering the piping channel erodes and expands the pipe until eventually the embankment sloughs into the void and breaches causing uncontrolled flooding. This is most likely to occur at a pumping station where there are exposed channels on both the river side and land side.

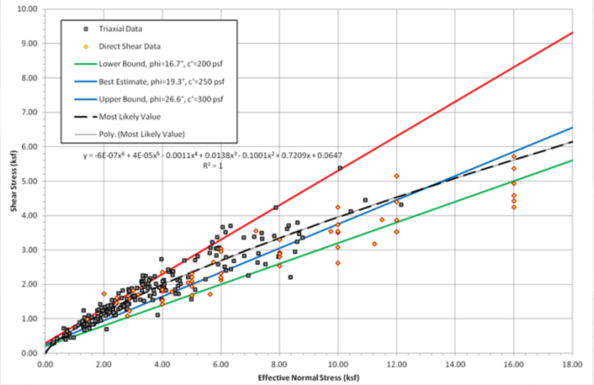
Failure Mode - Evidence

Flood Fighting

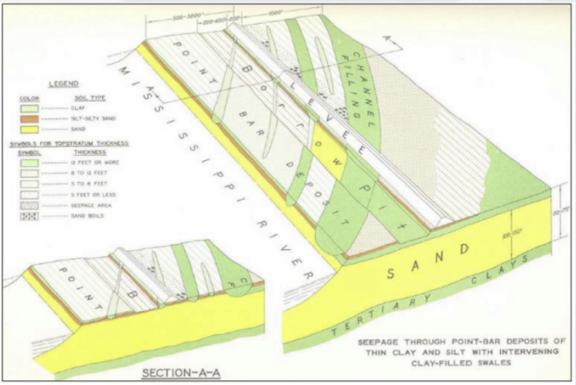


Full Scale Tests

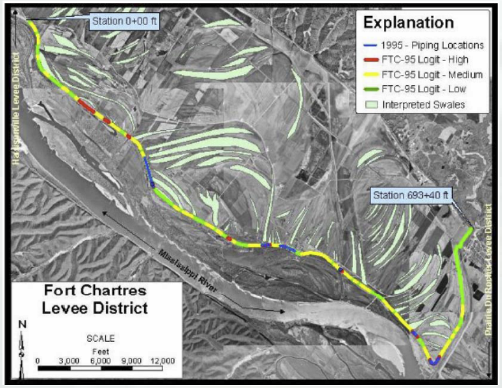
Investigations



Geomorphology



Incidents

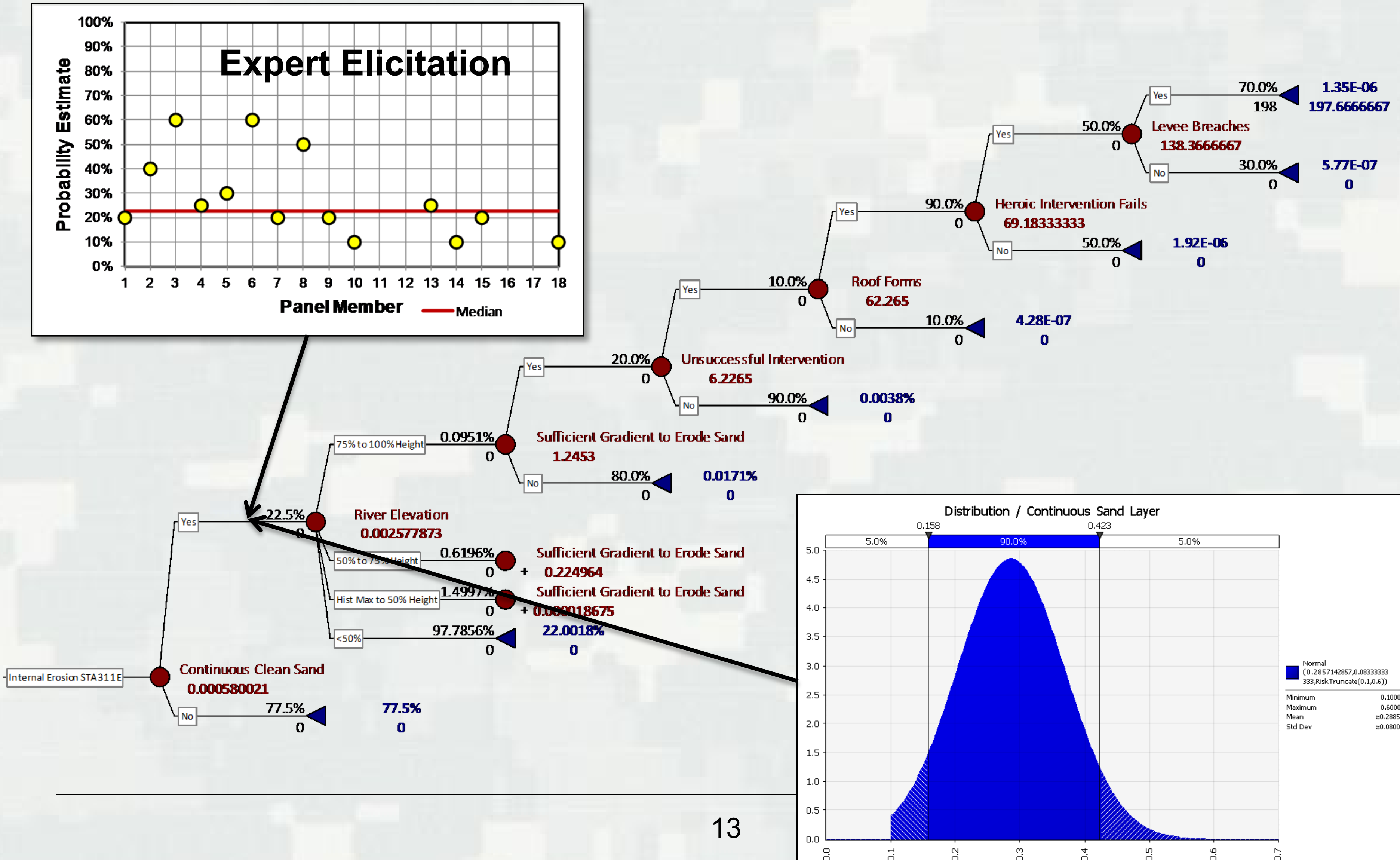


Indicators

Failure Mode – Key Factors

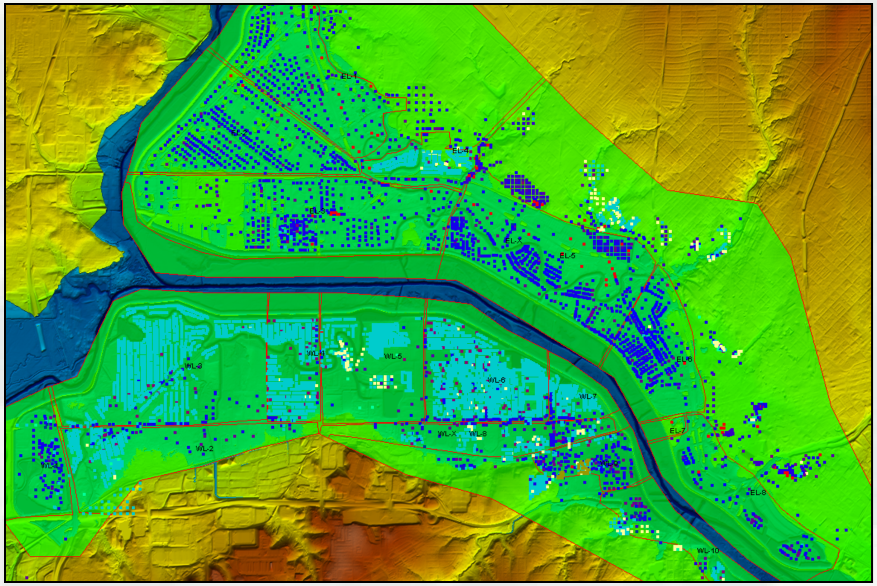
- More Likely (Adverse)
  - Geomorphology indicates three point bars extending through the foundation
  - Sand and gravel layers exist in the foundation
  - Critical gradient may be low for fine sand
  - Numerous sand pockets are possible in the foundation due to meanders of the river and depositional environment
- Less Likely (Favorable)
  - No seepage has been observed through the known sand layer
  - Average gradient is low due to long distance between source and exit
  - Lower sand layers in foundation soils are unlikely to daylight on protected side

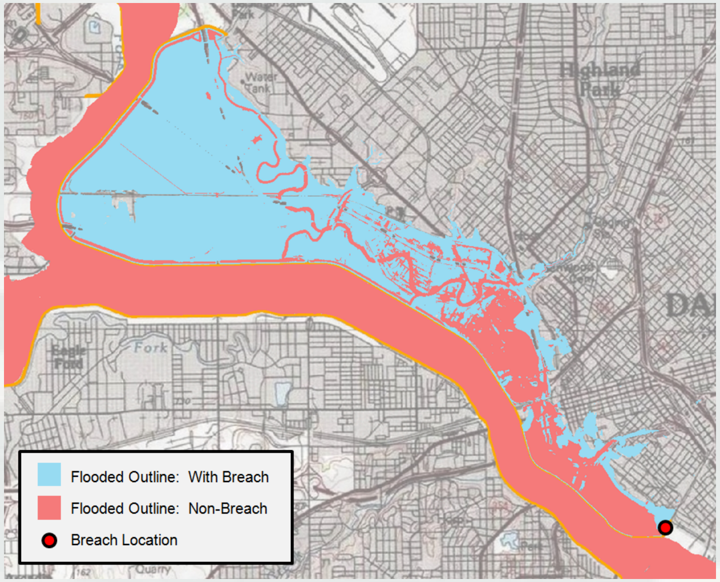
Failure Mode - Event Tree



Consequences

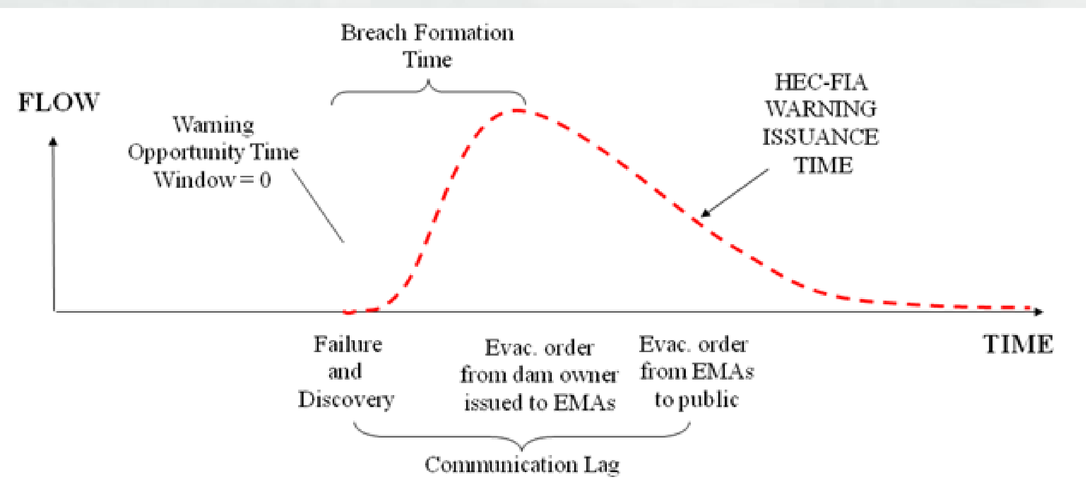
- People and property at risk

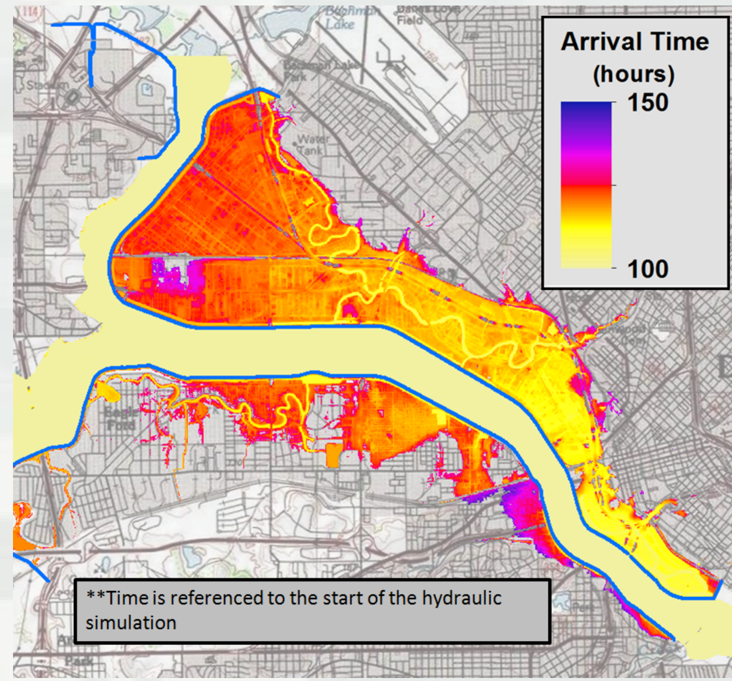




Consequences

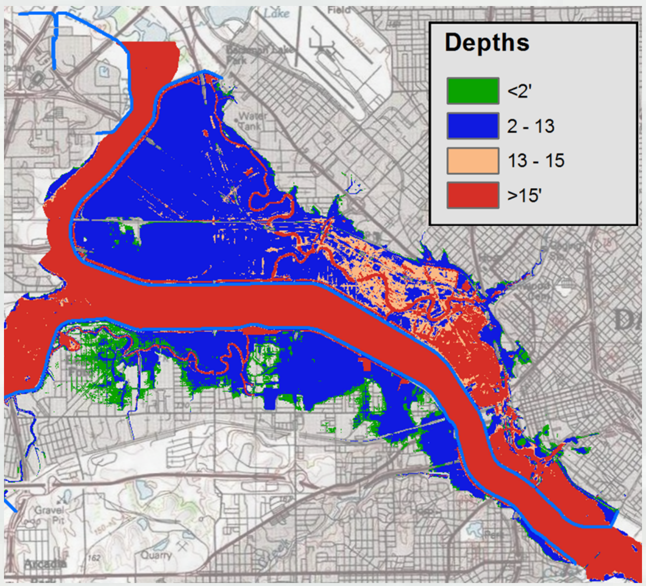
- Warning and evacuation

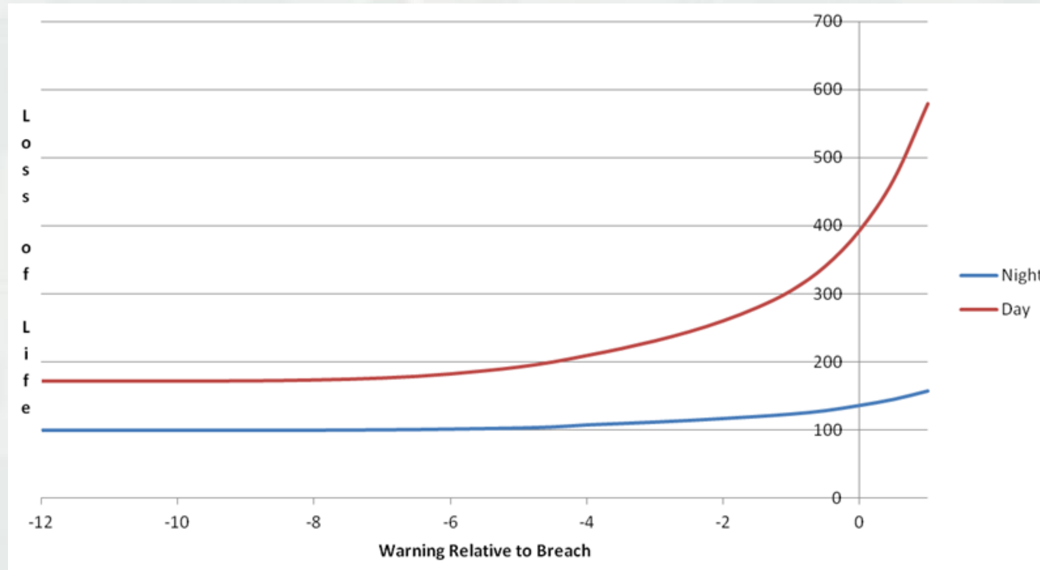




Consequences

- Life loss

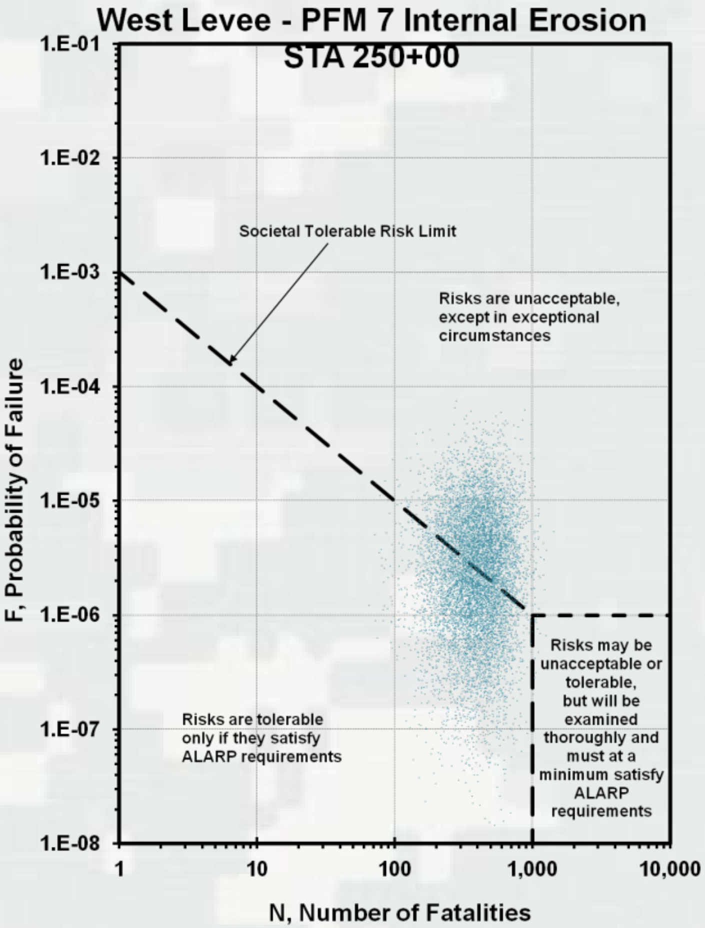




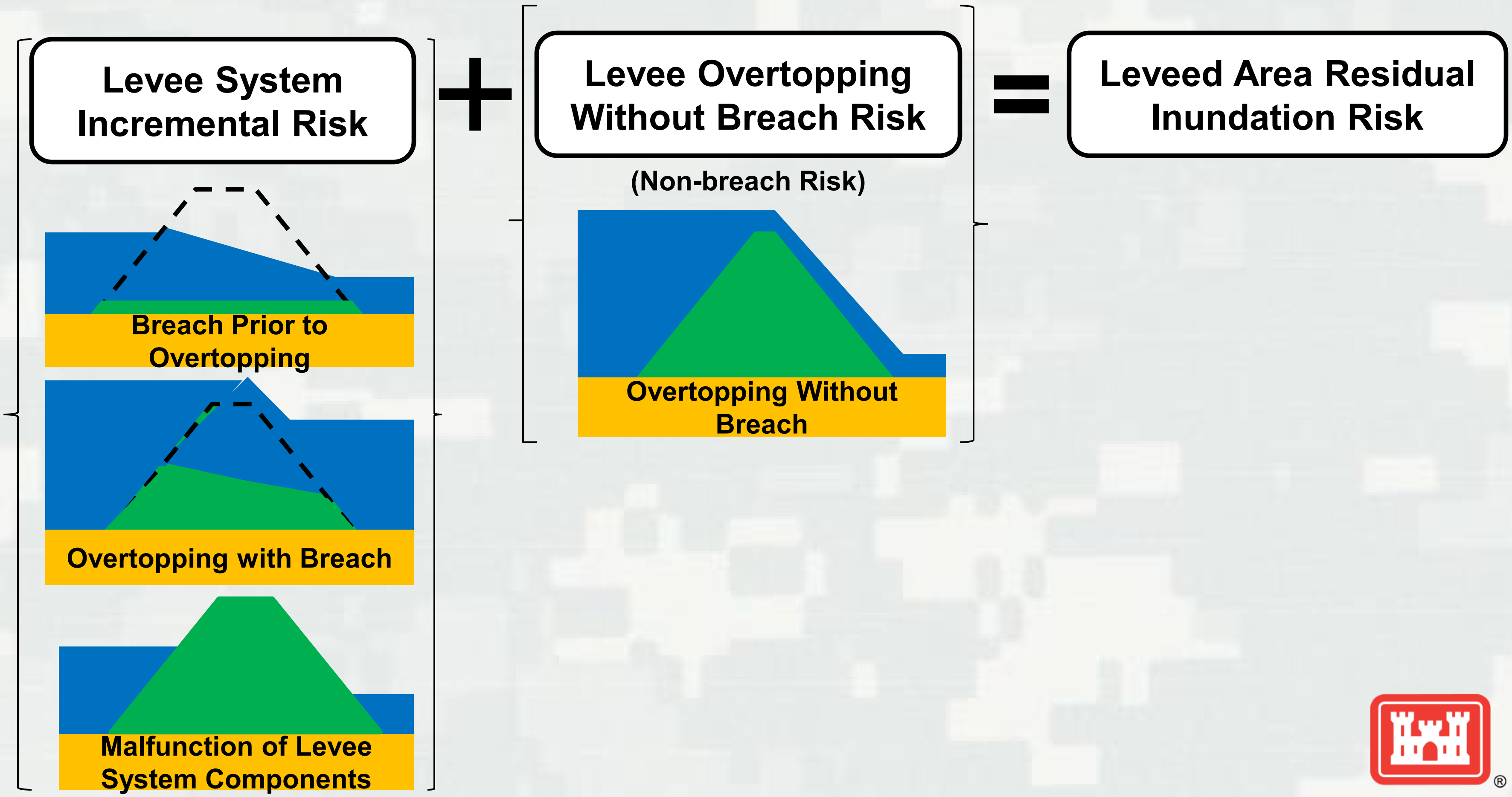
Risk Characterization – Tolerable Risk Guidelines

Evidence:

- No observed seepage or erosion at lower flood events
- Continuity is questionable (river-side to land-side)
- Moderately long seepage path
- Relatively short duration of loading
- Opportunity to intervene



Risk Characterization – Inundation Scenarios



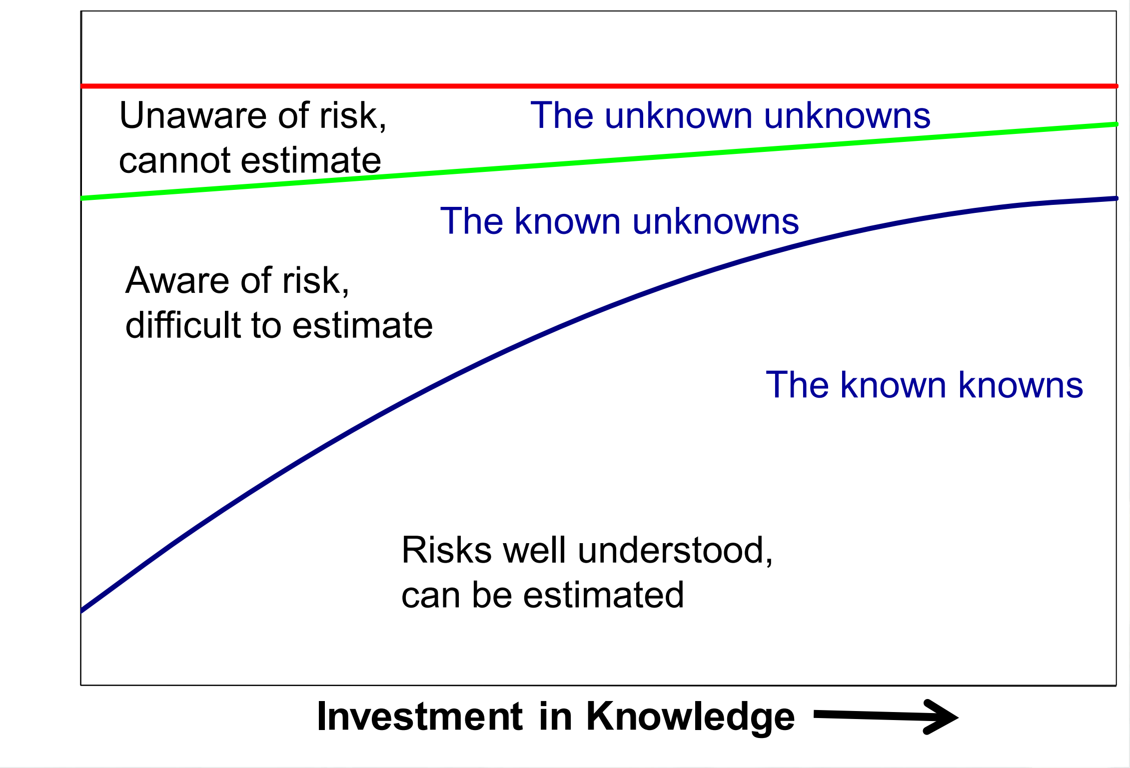
Risk Characterization - Classification

Levee Safety Action Classification		
Urgency of Action	**Actions**	**Characteristics**
Very High	**Actions recommended for each class.**	**Likelihood of inundation with associated consequences characterizes each class.**
High		
Moderate		
Low		
Normal		

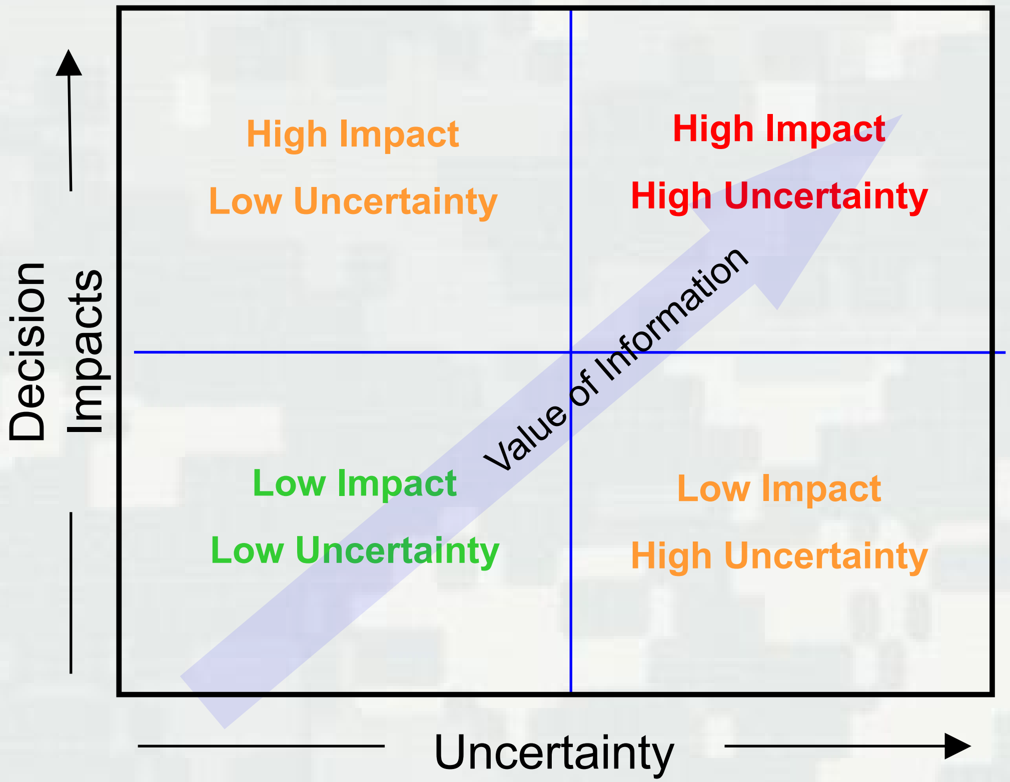
Likelihood	Moderate Risk	High Risk	High Risk	Very High Risk	Very High Risk
	Moderate Risk	Moderate Risk	High Risk	High Risk	Very High Risk
	Low Risk	Moderate Risk	Moderate Risk	High Risk	High Risk
	Very Low Risk	Low Risk	Moderate Risk	Moderate Risk	High Risk
	Very Low Risk	Very Low Risk	Low Risk	Moderate Risk	High Risk
	Consequences				

Uncertainty

- This is what we are reasonably certain of
- This is what we think is likely but is by no means proven
- This is what we think is unlikely but still possible

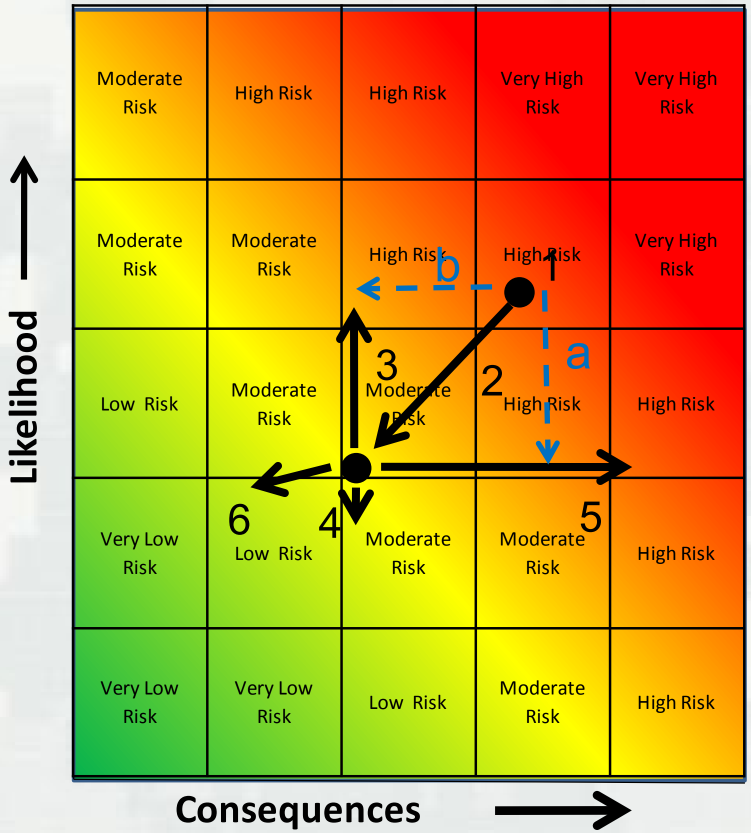


Value in Reducing Uncertainty



Recommended Actions

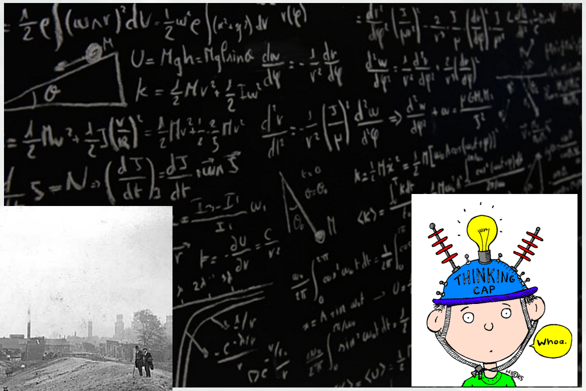
- This is what we are doing (or not doing) to reduce the risks and/or uncertainty that remains

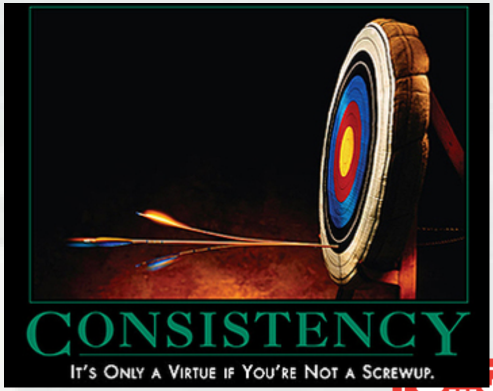


1. Estimate of current risk.
2. Risk reduction and management measures implemented.
   a. *Actions that reduce likelihood*
   b. *Actions that reduce consequences*
3. Trend due to aging and wear and tear.
4. Trend due to proper maintenance, repairs, and operations
5. Trend resulting from development
6. Trend resulting from continued risk management activities

Making the Case

- Interpretation by the experts
  - No simple numerical solutions
- Supports a credible decision
  - Consistency between risk estimate, evidence, and recommendations
- Answers the ‘So What’ question





Closing Thoughts

1. Do your homework with literature, experts, and users
2. Let the problem drive the analysis
3. Make the analysis as simple as possible, but no simpler
4. Identify all significant assumptions
5. Be explicit about decision criteria and policy strategies
6. Be explicit about uncertainties
7. Perform systematic sensitivity and uncertainty analysis
8. Iteratively refine the problem statement and the analysis
9. Document clearly and completely
10. Expose to peer review

Morgan, M. G. and Henrion, M., (1990). Uncertainty: a guide to dealing with uncertainty in quantitative risk and policy analysis, Cambridge University Press, New York

Closing Thoughts

- Theory and calculations are not substitutes for judgment, but are the bases for sounder judgment. (Peck)