Probabilistic design of levee and floodwall heights for the Hurricane Protection System in the New Orleans area

US Army Corps of Engineers

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Motivation

- Current FEMA certification guideline:

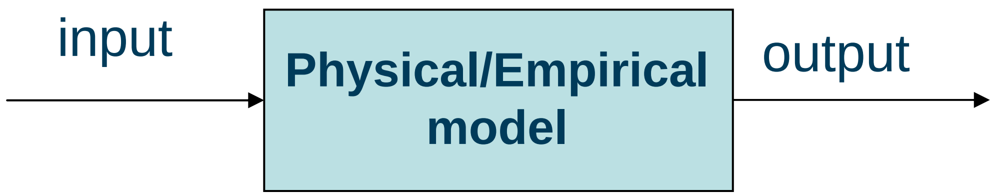
*“the levee height at the coast should be equal to the 1% water level plus the 1% wave height or the maximum **<u>runup</u>** whichever is greater plus **<u>1ft of freeboard</u>**”*

- US Army Corps guidance includes a minimum 90% assurance for providing 1% level of protection

- IPET stresses the importance of risk and uncertainties in design of flood defences

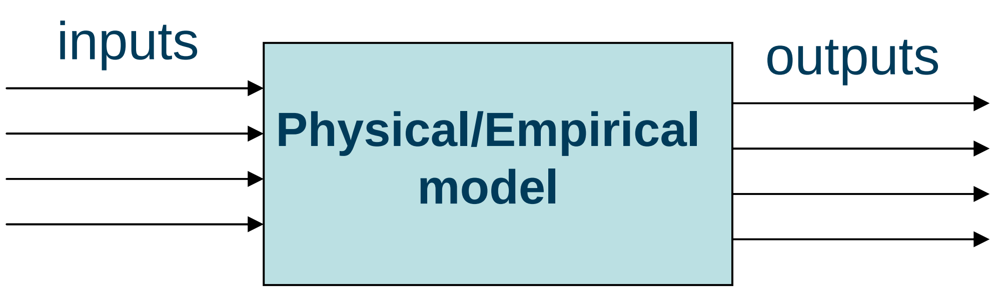
Methods

Traditionally: deterministic approach



Now: probabilistic approach

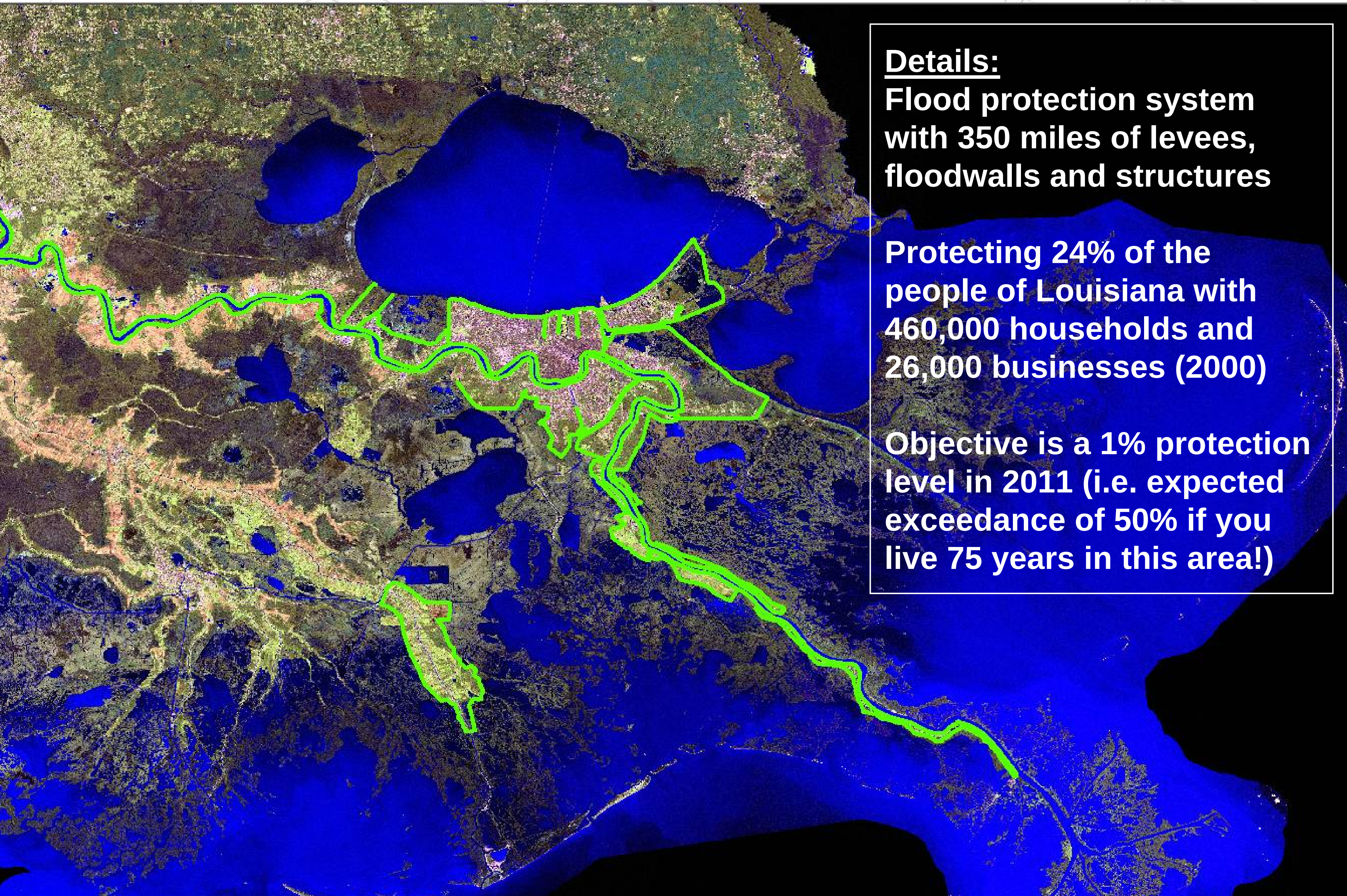
- Defining probability functions for inputs
- Processing multiple combinations of inputs
- Assessing uncertainty in outputs



Summary of conclusions

- Design approach including uncertainties explicitly
- More robust system design (“the higher the local uncertainty, the more freeboard is included”)
- More insight in magnitude of nearshore waves and its uncertainties

Hurricane Protection System



Details:
Flood protection system with 350 miles of levees, floodwalls and structures

Protecting 24% of the people of Louisiana with 460,000 households and 26,000 businesses (2000)

Objective is a 1% protection level in 2011 (i.e. expected exceedance of 50% if you live 75 years in this area!)

Current guideline

- Current FEMA certification guideline:

*"the levee height at the coast should be equal to the 1% water level plus the 1% wave height or the maximum **runup** whichever is greater plus **1ft of freeboard**"*

- Definition maximum runup? 2% wave runup?
- Application for flood walls?
- Freeboard concept? +1ft enough?

New design criterion

- Overtopping rate (or better: inner slope velocity) governs inner slope erosion

- Literature review of Hughes (2007) suggests that 0.1 cfs per ft can be allowed on well-mainated grass-covered levees

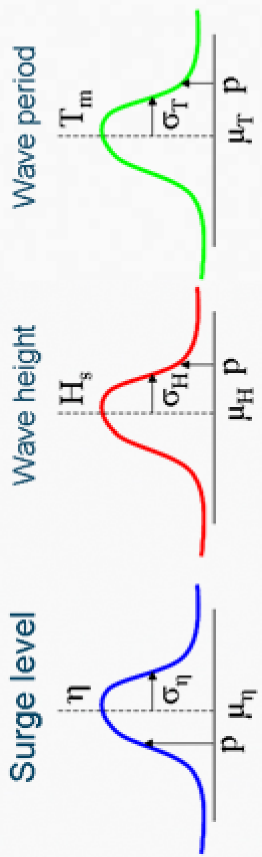
- Current design criteria:
  - 0.01 cfs per ft with 50% confidence
  - 0.1 cfs per ft with 90% confidence

- Need for more experimental validation

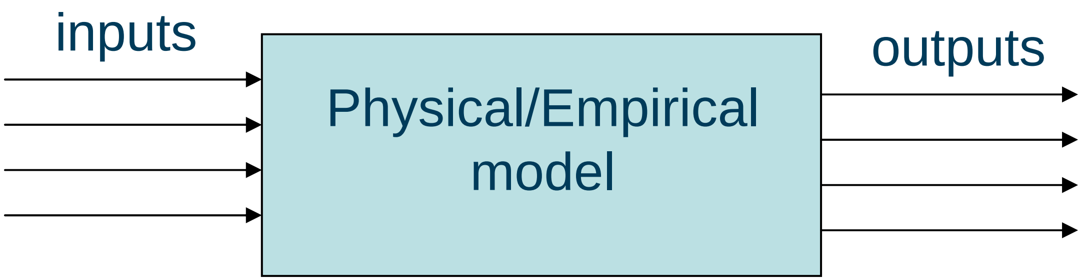
Intermezzo

- EU COMCOAST experiments

Probabilistic method (1)



- **Empirical model:** Van der Meer formulations

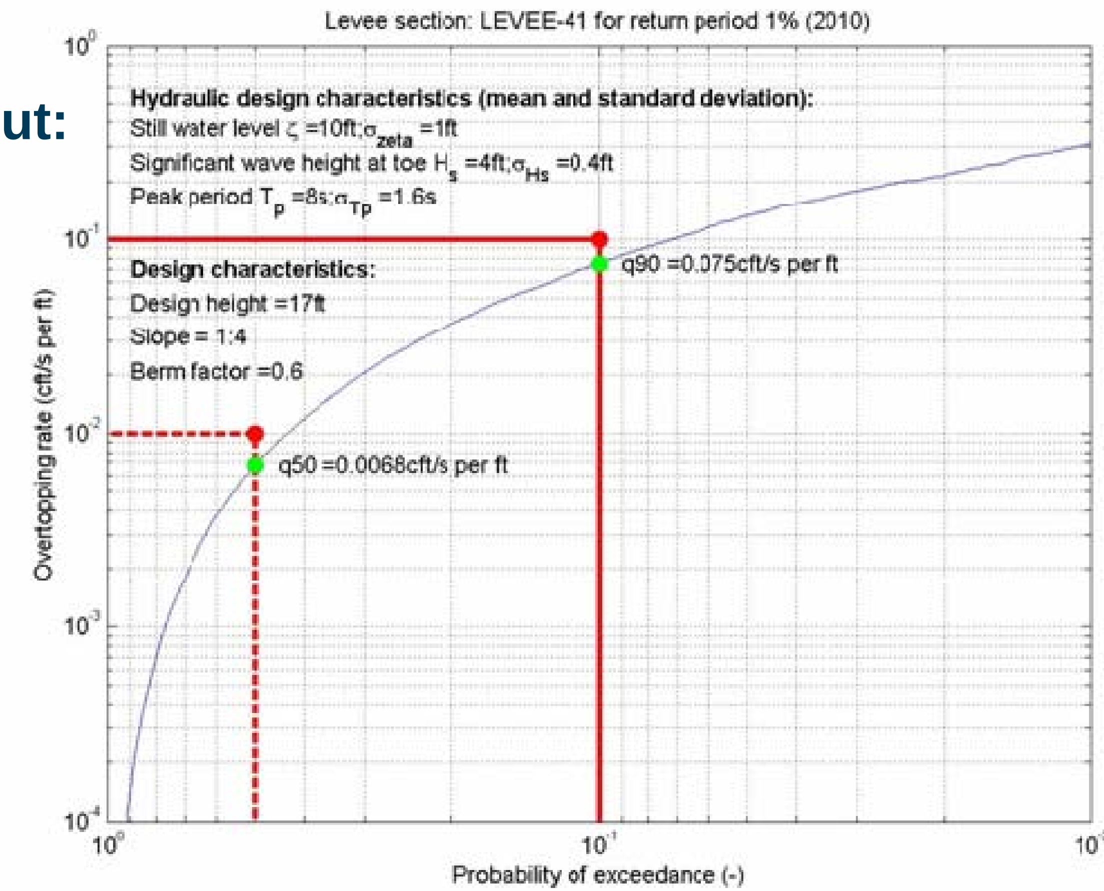


- **Input:**
  - Mean values hydraulic parameters (water level, wave characteristics) and empirical coefficients
  - Standard deviations (based on models/experts)
  - Distribution types (normal distributions)

Probabilistic method (2)

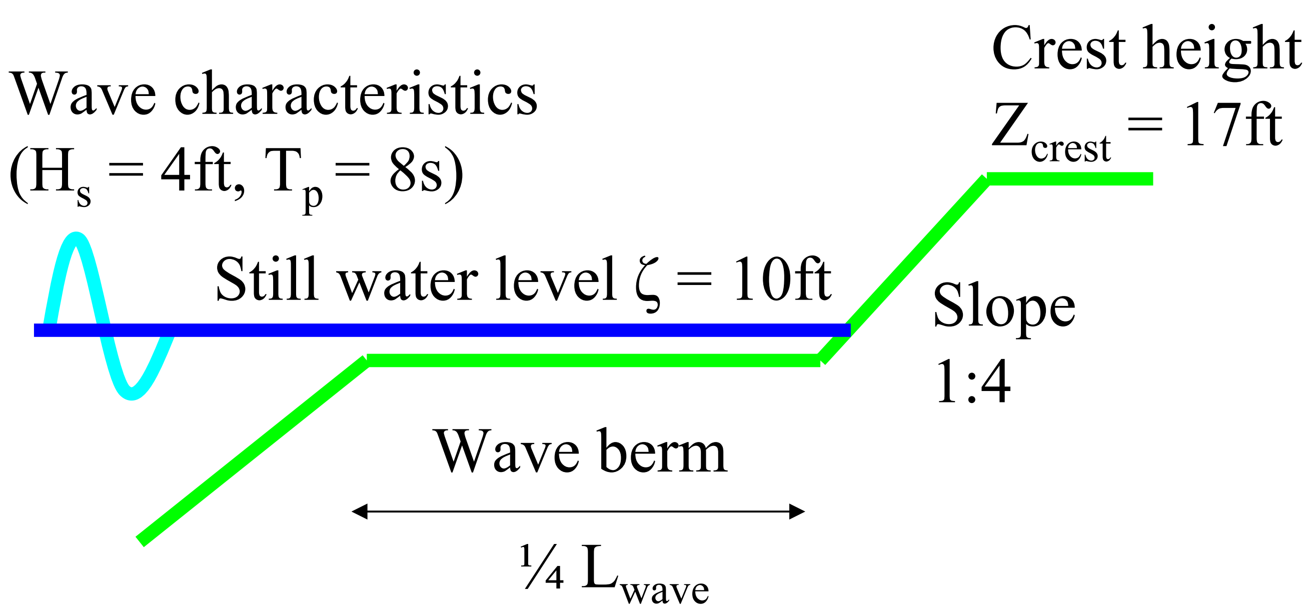
- **Proces:** N evaluations with different input combinations

- **Output:**

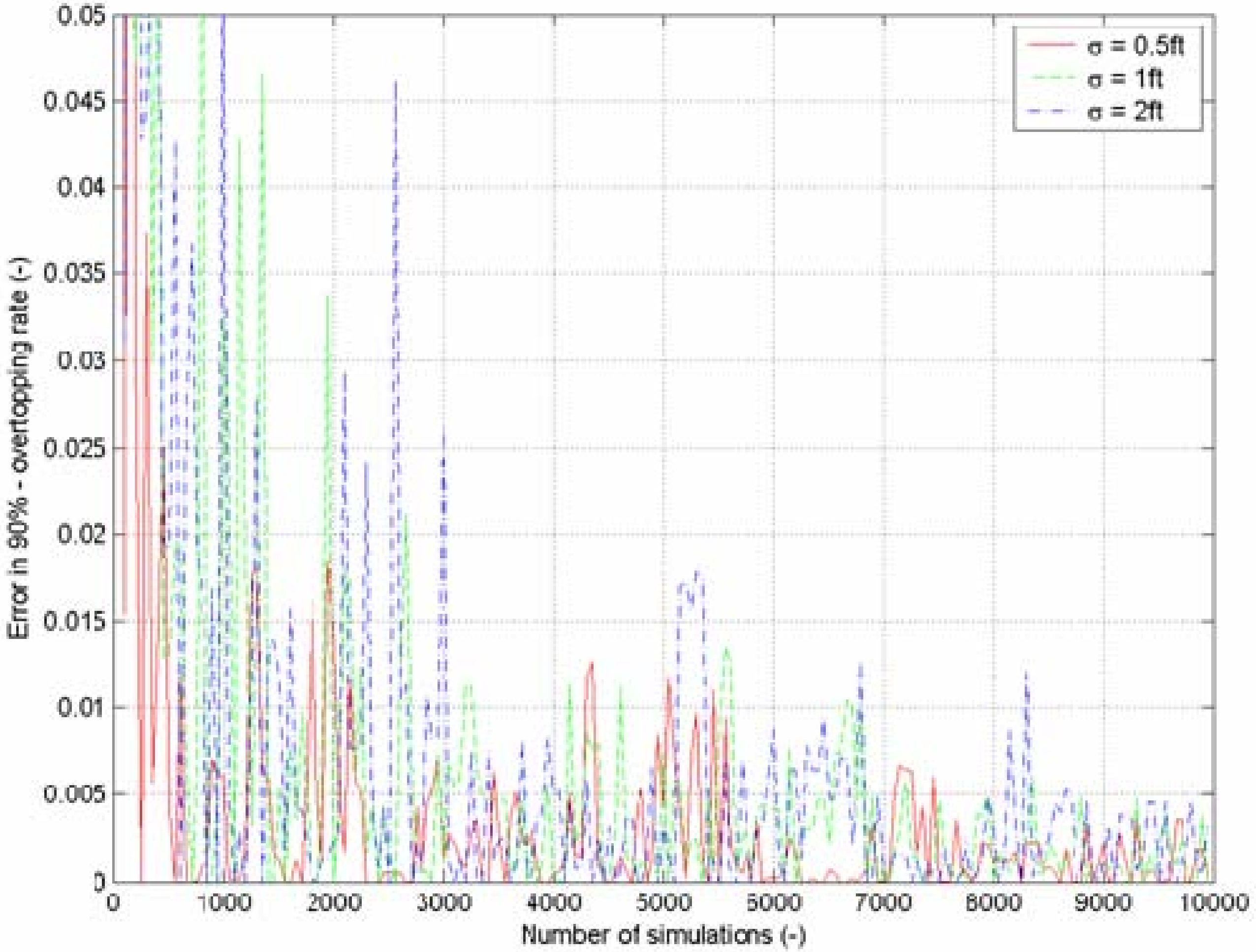


Test case

<u>Idealized levee section:</u>



Test 1: Required simulations



Test 2: Correlation

Situation	Overtopping rate (cfs per ft)		Design height (ft)	Correlation		
	50% value	90% value		Water level ζ	Wave height H_s	Peak period T_p
1. Base case (partial correlation)	0.007	0.078	17.0	No	Yes (T_p only)	Yes (H_s only)
2. Full correlation	0.004	0.090	18.0	Yes (H_s and T_p)	Yes (ζ and T_p)	Yes (ζ and H_s)
3. Partial correlation	0.008	0.090	17.0	Yes (H_s only)	Yes (ζ only)	No
4. Partial correlation	0.005	0.084	17.5	Yes (T_p only)	No	Yes (ζ only)
5. No correlation	0.007	0.063	17.0	No	No	No

- Different combinations of “error correlation”
- Full correlation between errors of all variables is unlikely
- Effect of correlation is small on final design height

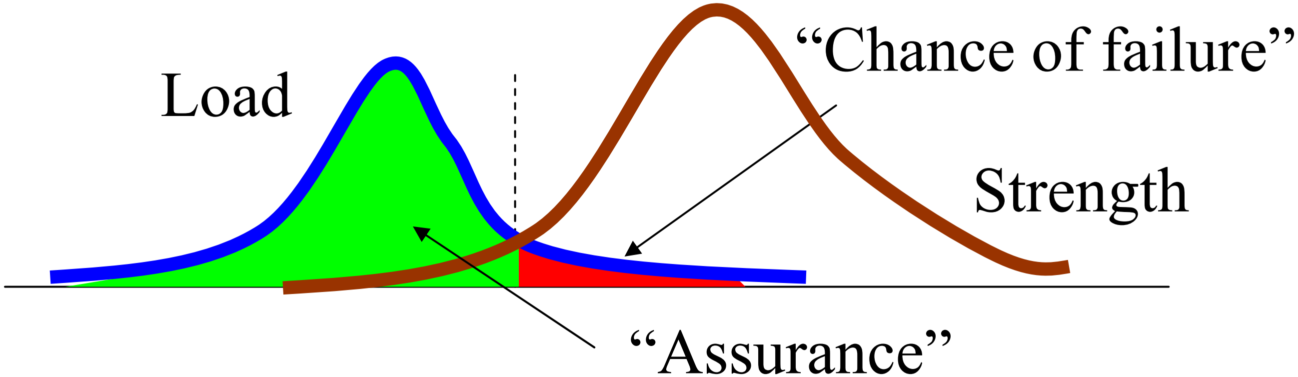
Test 3: Comparison with FEMA guideline

Slope	Situation with wave berm ($\gamma_b = 0.6$)			Situation without wave berm ($\gamma_b = 1.0$)		
	FEMA guideline	Probabilistic method (Set 1)	Probabilistic method (Set 2)	FEMA guideline	Probabilistic method (Set 1)	Probabilistic method (Set 2)
1/3	22.0	18.5	22.5	23.5	20.0	24.0
1/4	19.5	17.0	20.0	23.0	19.5	23.5
1/5	17.5	16.0	18.0	22.0	19.0	22.5
1/6	16.5	15.0	17.0	20.5	18.0	21.0
1/7	16.0	14.5	16.5	19.0	17.0	19.5

- Set 1 overtopping criteria are current values; set 2 is 10 times lower for both 50% and 90%;
- FEMA guideline results in design heights comparable with probabilistic method (set 2)

Suggestions for further work

- Nearshore wave modeling and overtopping experiments
- Choices of error magnitudes/distributions have to be further validated
- Inclusion of other load variables but also the strength for a full risk-based approach



Summary of conclusions

- Probabilistic method for hydraulic levee design
- More robust system design (“the higher the local uncertainty, the more freeboard is included”)
- More insight in magnitude of nearshore waves and its uncertainties
- Rest of levee/floodwall design world has to be educated how to use this information

Thank you for your attention

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