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Enabling Delta Life

Dutch Approach to Levee Reliability and Flood Risk

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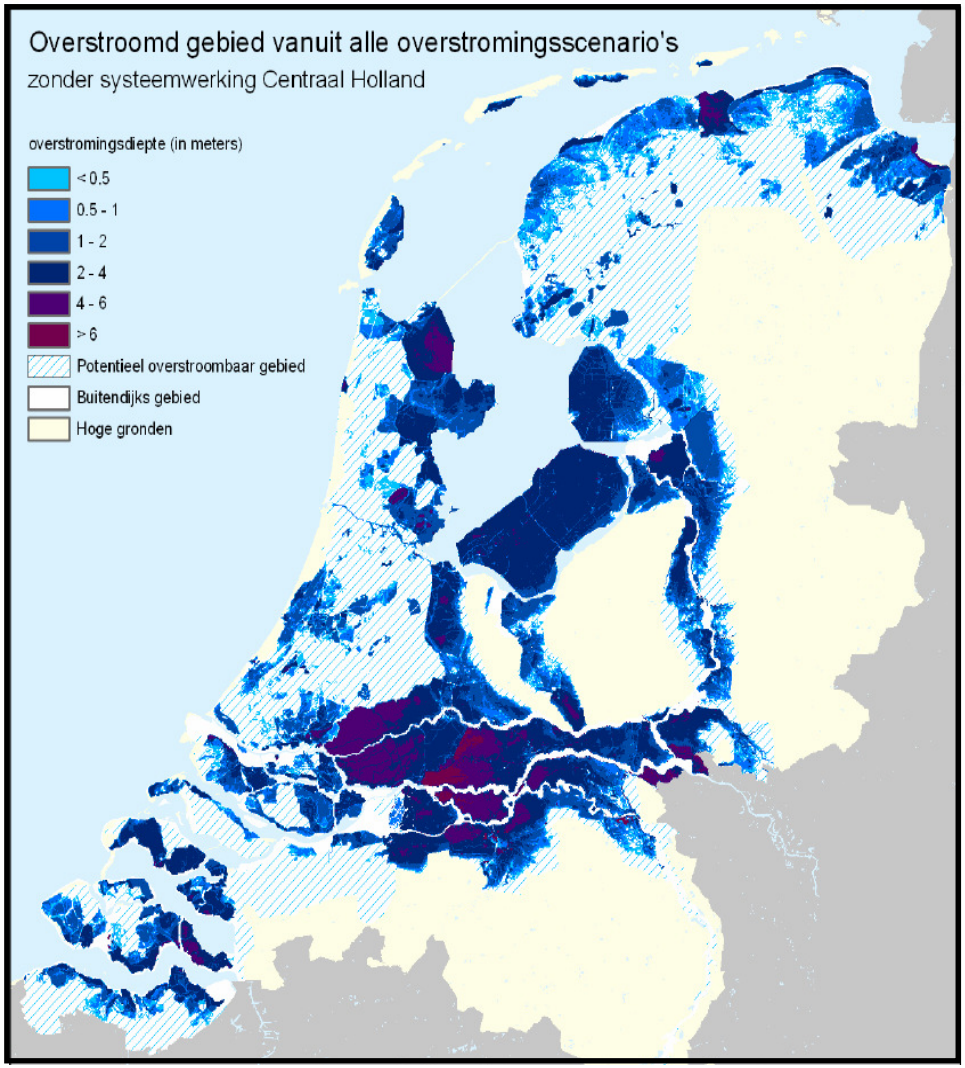
Deltares & Delft University of Technology

PFHA Workshop, Washington DC, January 29-31, 2013

Outline



1. Historical Background
2. Reliability and Risk Analysis
3. System Effects

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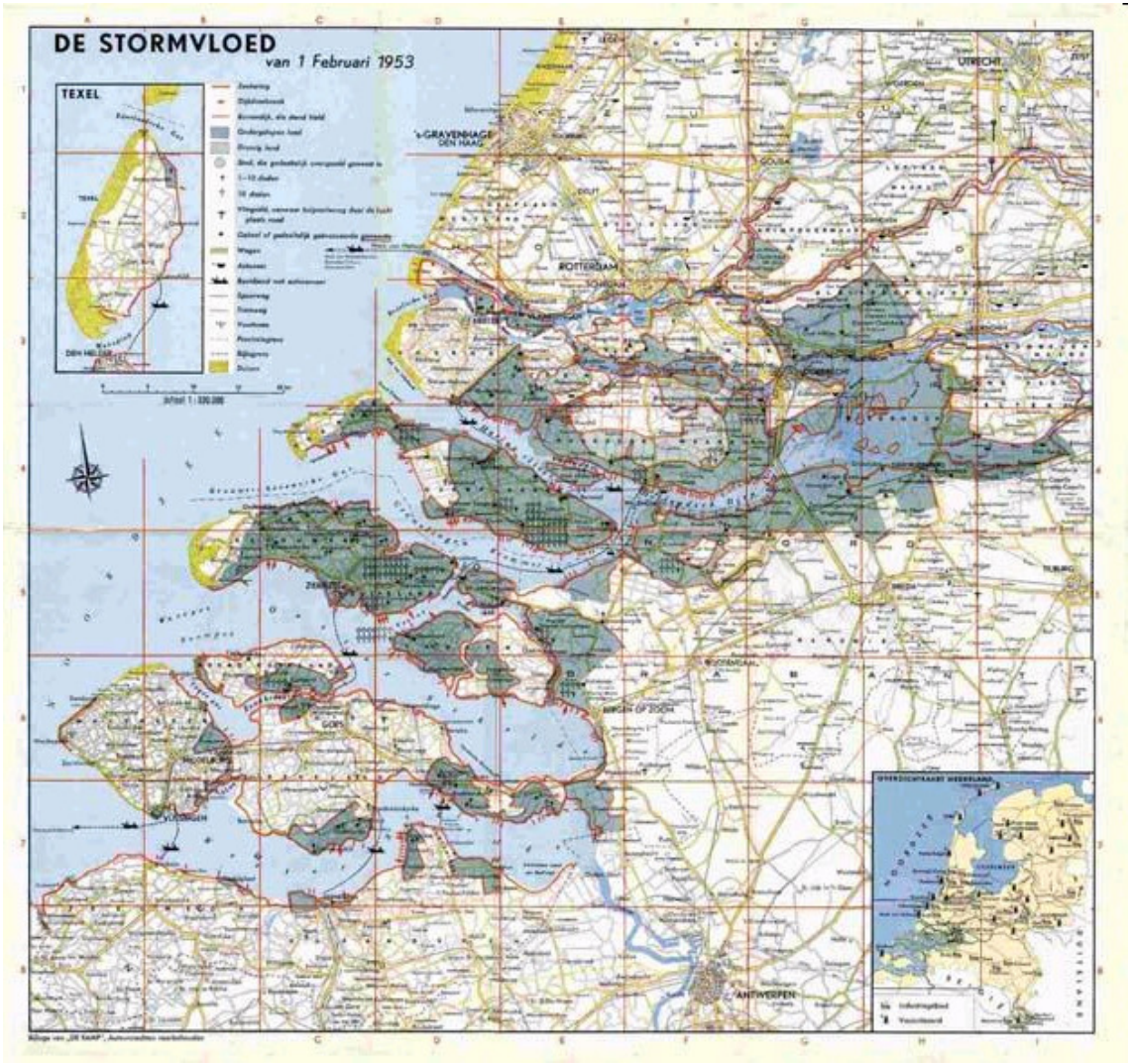
1953 Flood



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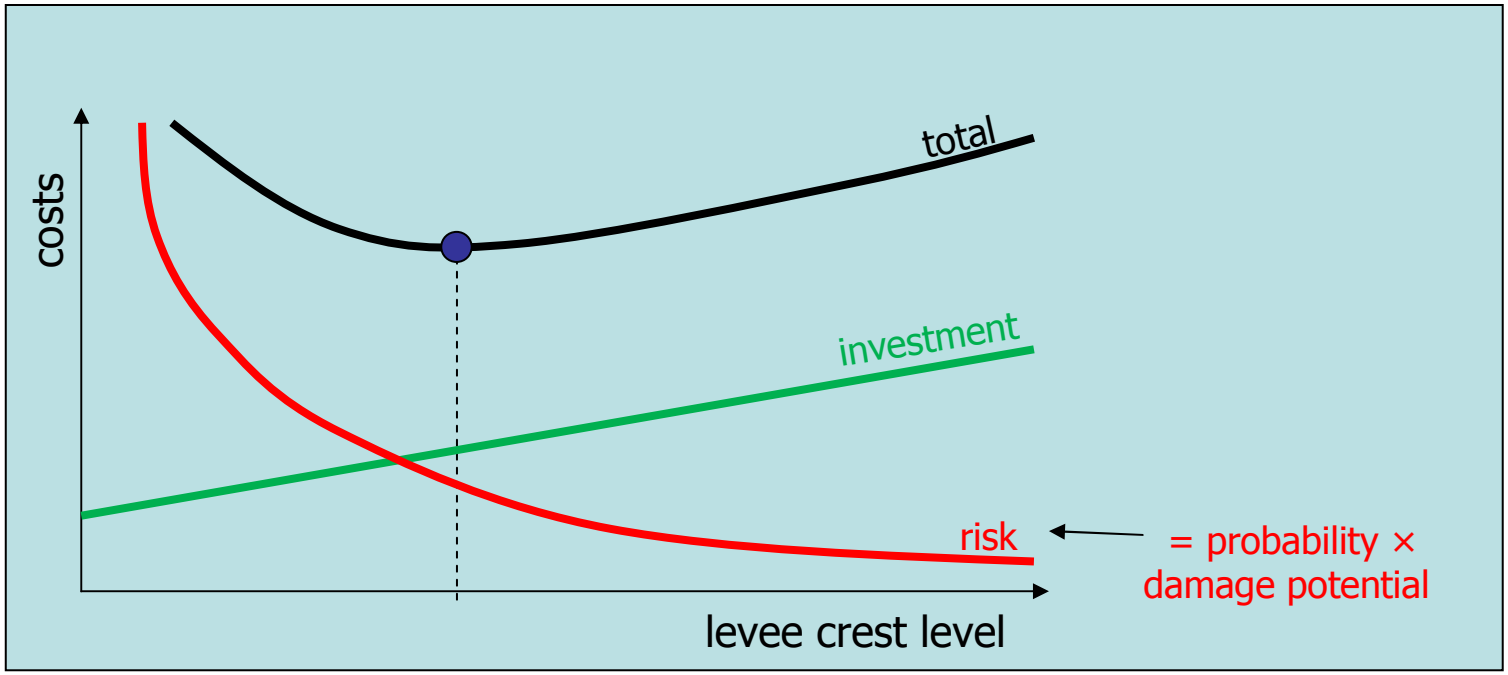
Risk-based optimization

Van Dantzig, D. (**1953**). "Economic Decision Problems for Flood Prevention." Econometrica 24(3): 276-287.



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Delta Committee 1953-1955

1. Delta works

2. **Reliability target**
   (for Central Holland):

   1/125,000 or 8 x 10-6
   (annual probability)

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Storm surge barriers (delta works)

Risk-based approaches in
Design an Construction Planning:

- hydraulic loads
- structural elements
- geotechnics
- operation and maintenance

Oosterschelde Dam, 1970

Maeslant Barrier, 1990

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Safety Standards (Water Act, 1990)

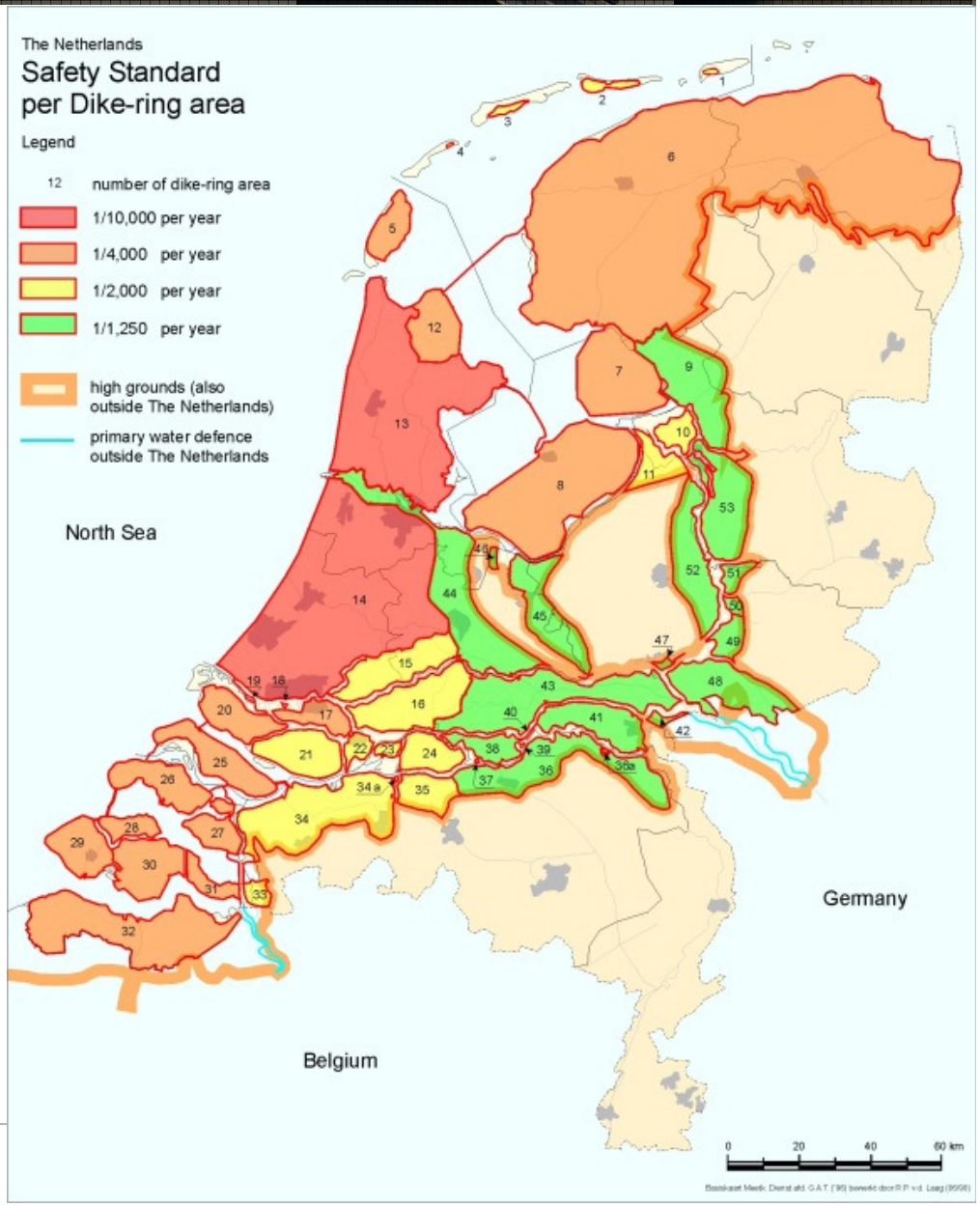
3600km of “primary” flood defenses

57 polders (“dike rings”)

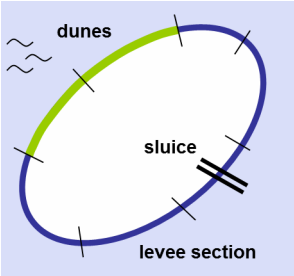
reliability targets per polder

safety assessments every 5 years

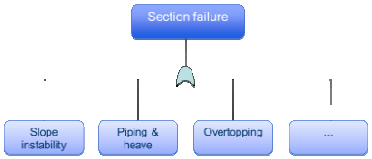
RISK ANALYSIS PER POLDER / DIKE-RING



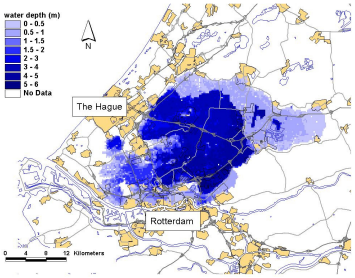
Risk Analysis – Basic Steps (VNK2)



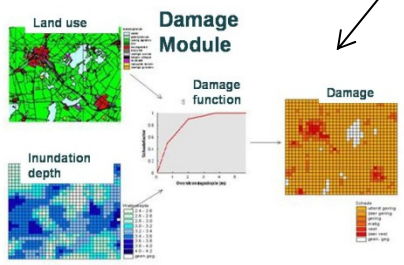
1. Define homogeneous reaches



2. Probability of failure per reach



3. Flood scenarios



4. Damage estimates

5. Combine probabilities and consequences

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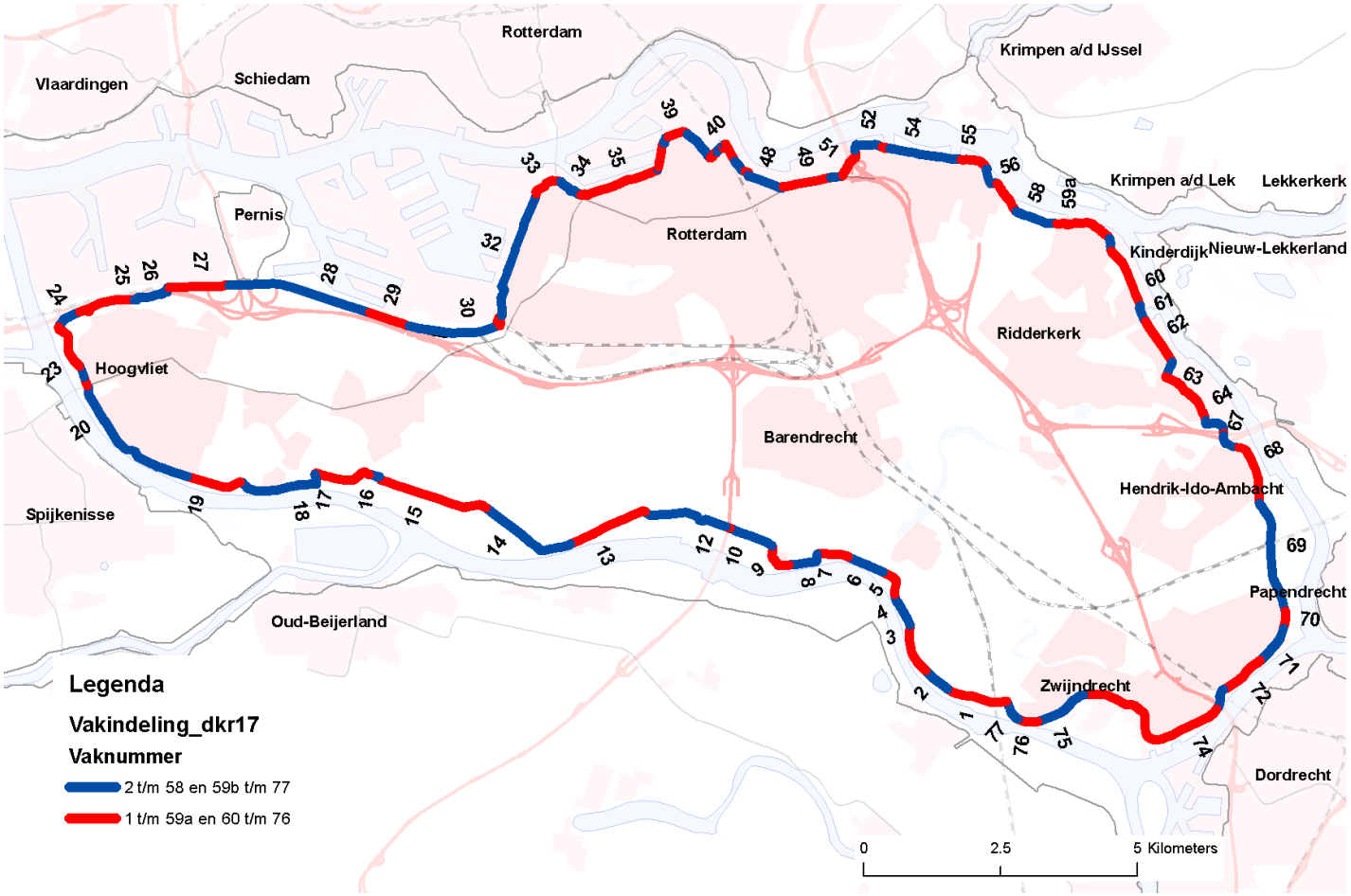
Define homogeneous reaches



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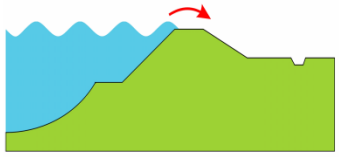
Failure Modes

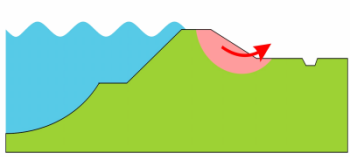
Most important:

Levees

Overtopping

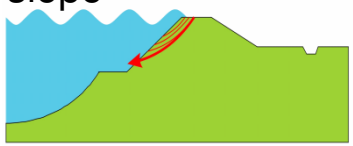


Slope instability



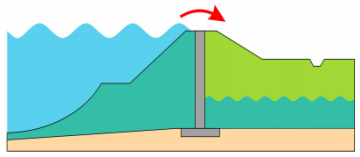
Piping

Erosion outer slope

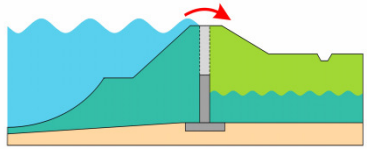


Hydraulic structures

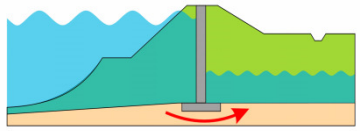
Overtopping



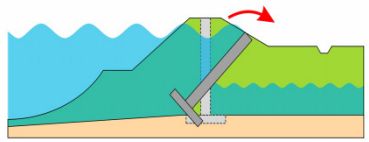
Non-closure



Piping



Structural failure



Dunes: Dune erosion

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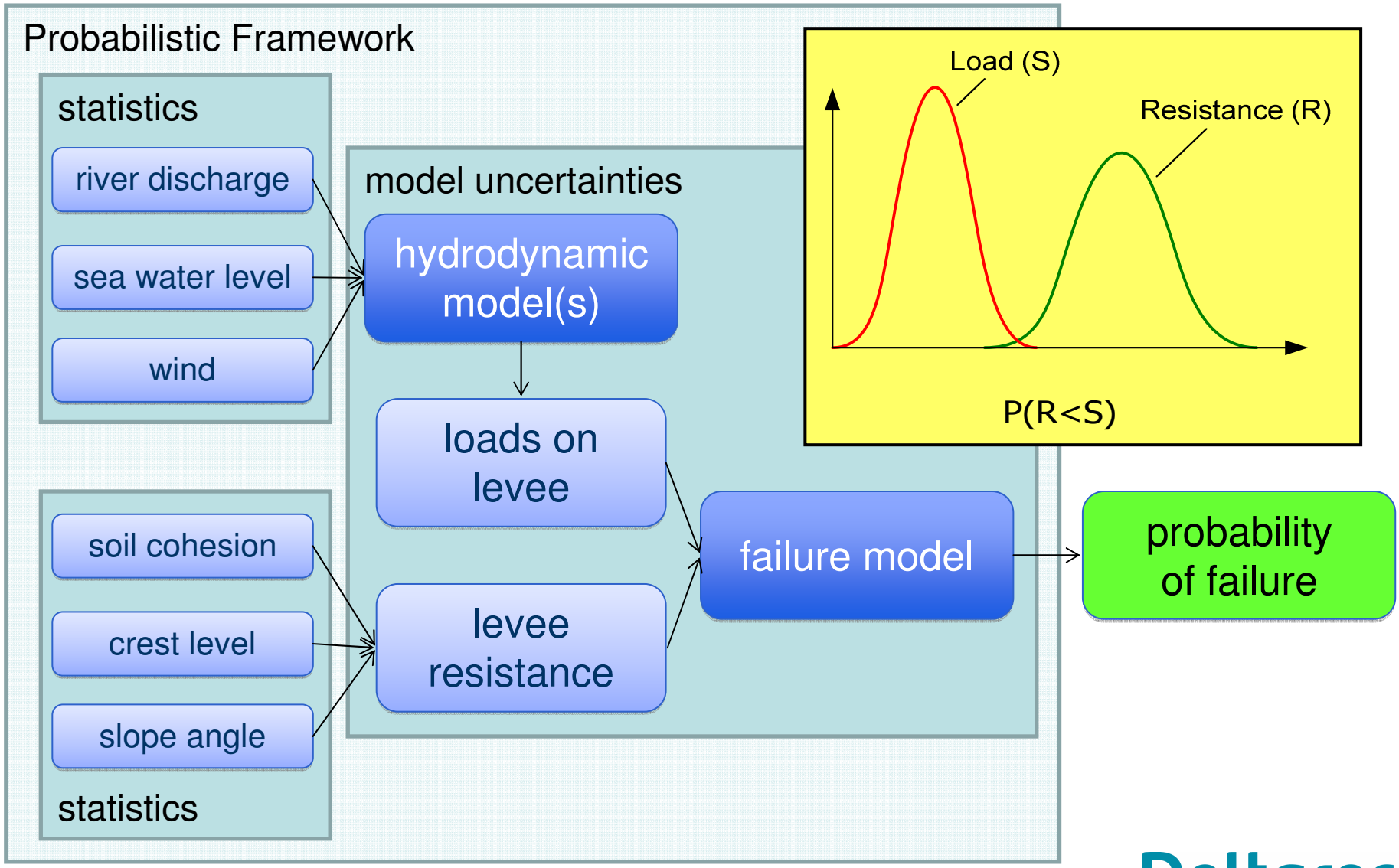
Reliability per Failure Mode (per Reach)



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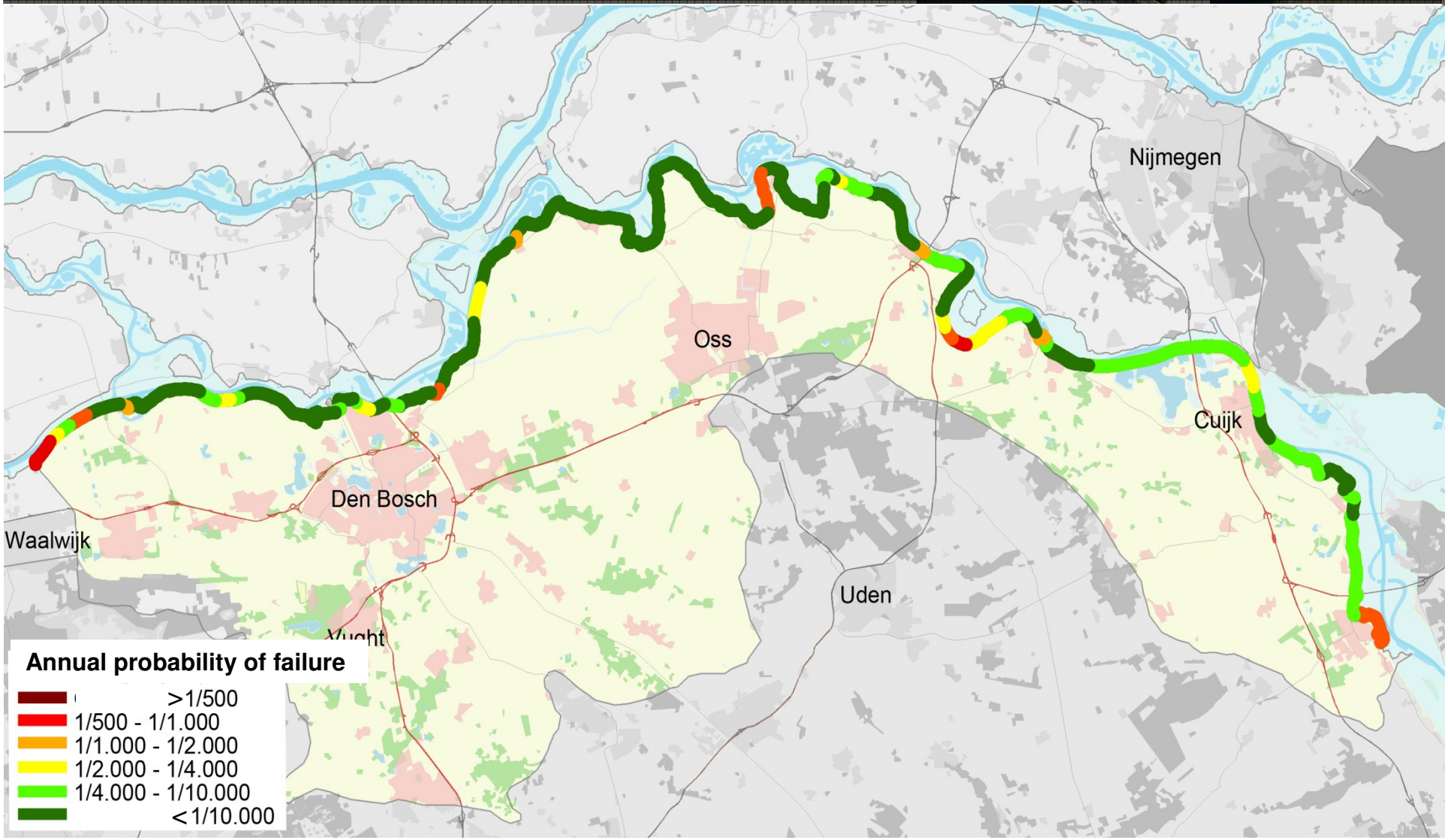
What do the results look like?



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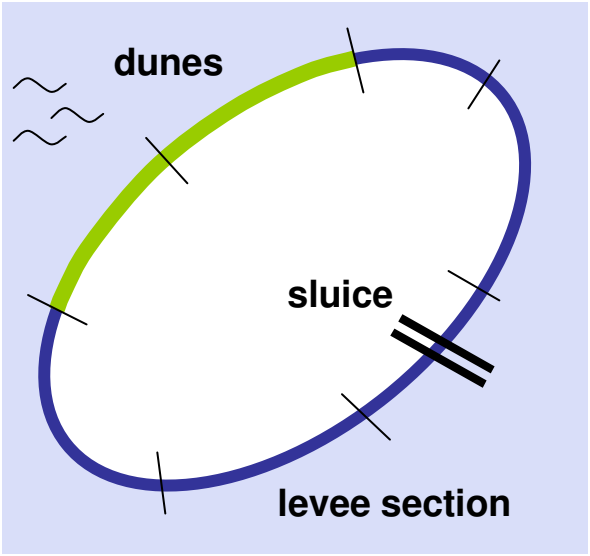
System Modeling & Fault Tree



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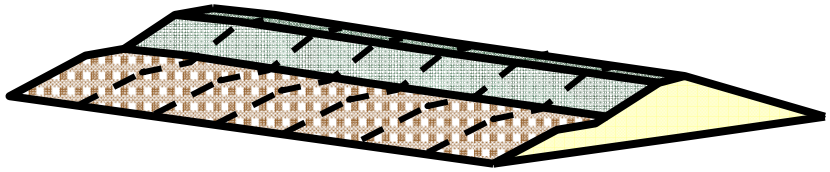
Correlations / Length-Effect

1. BETWEEN FAILURE MODES
   (correlated through common variables)

2. BETWEEN REACHES (LENGTH-EFFECT)



3. IN TIME

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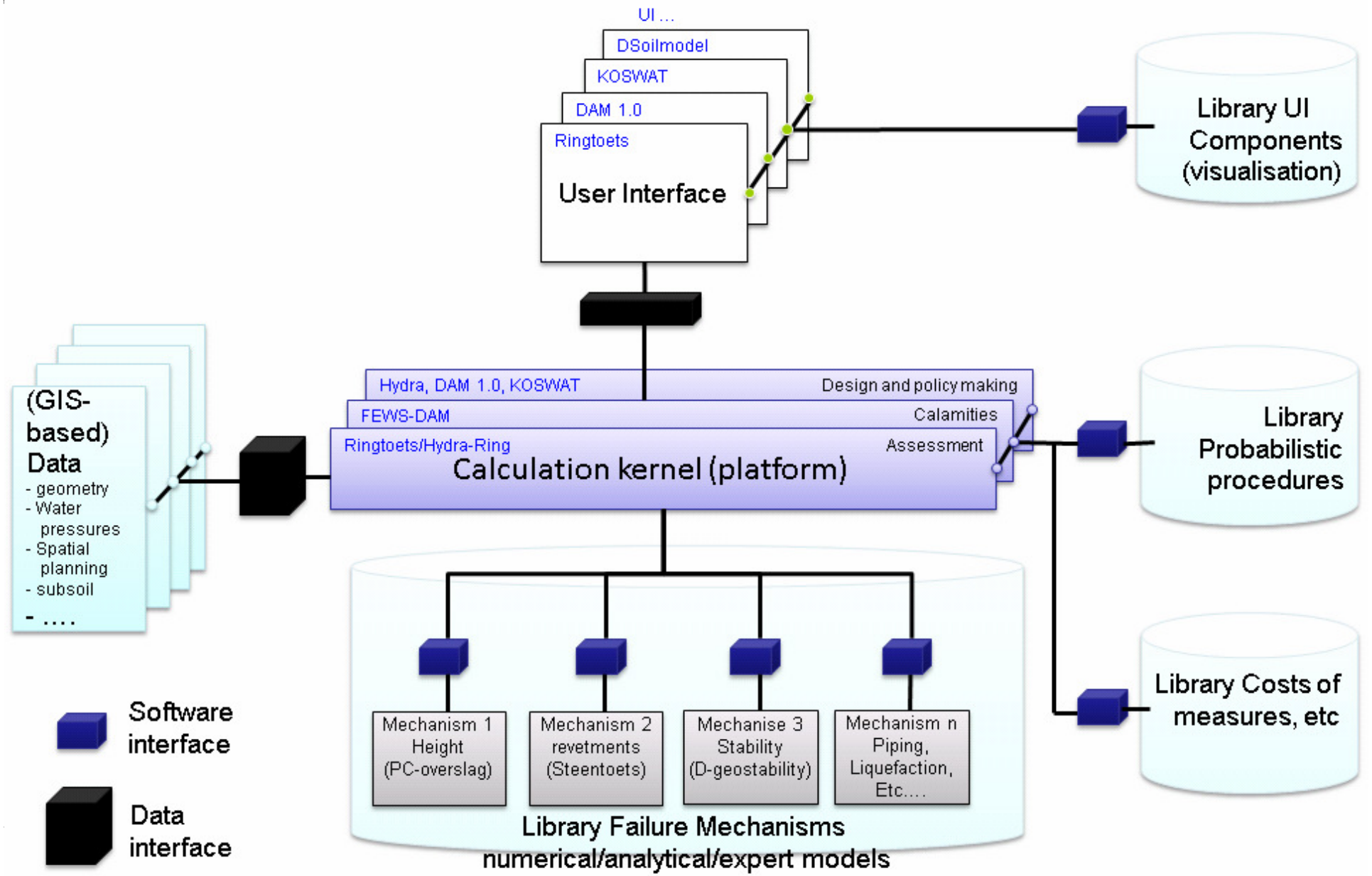
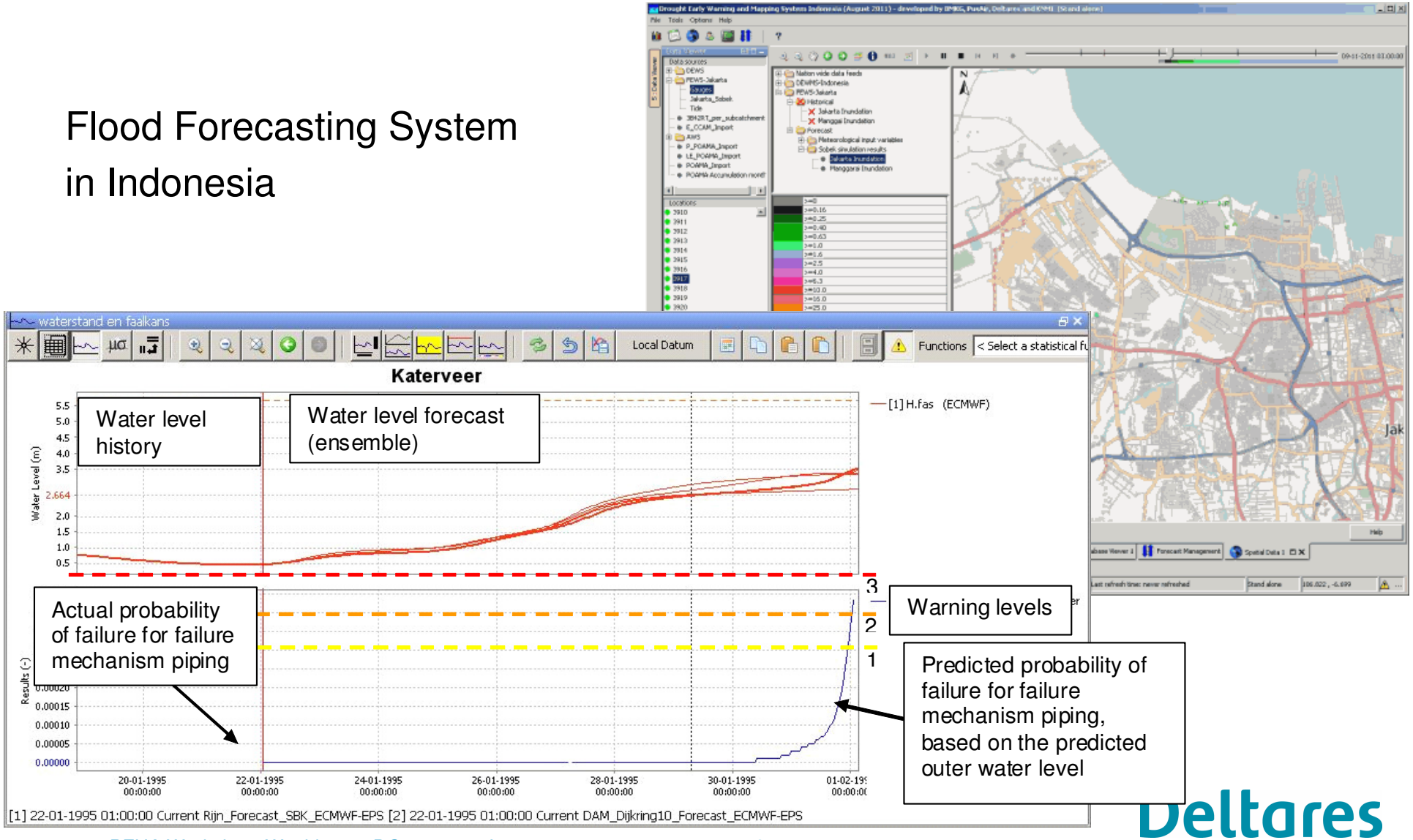
Hydra-Ring / DAM / FEWS / …



FEWS-DAM: Real-time Levee Safety

Flood Forecasting System
in Indonesia



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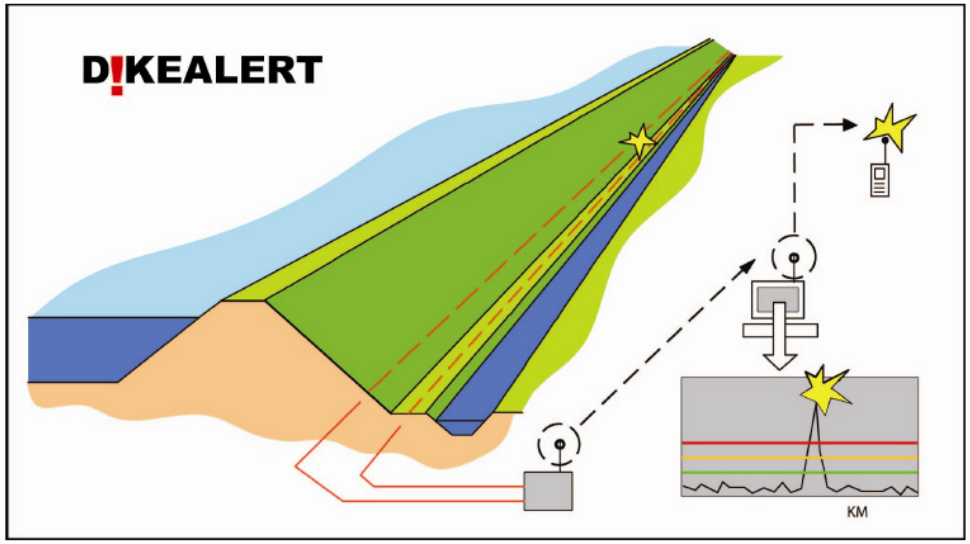
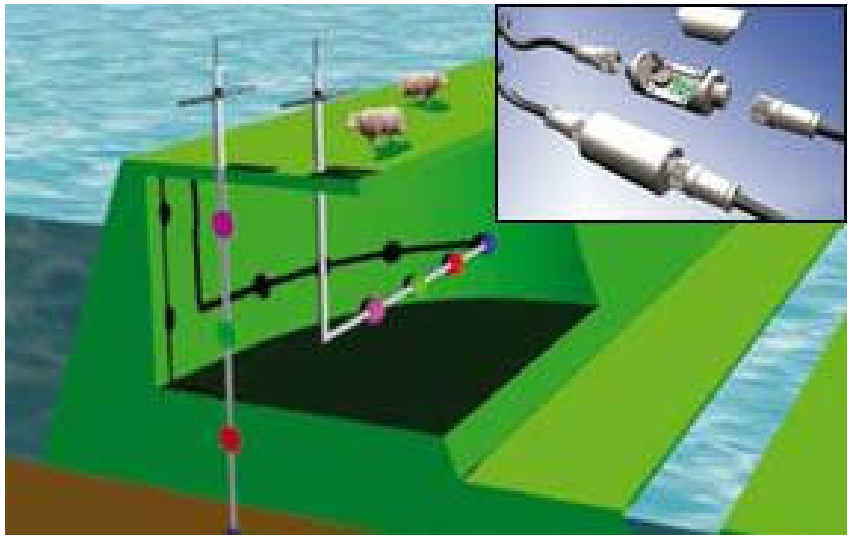
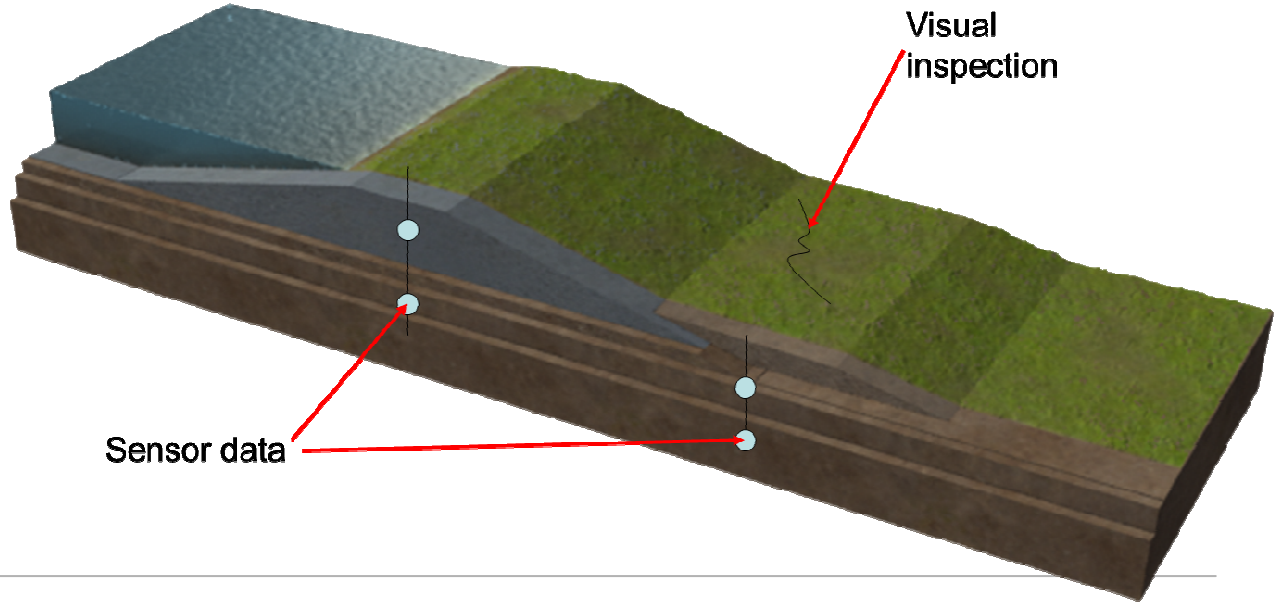
Real-time Levee Monitoring







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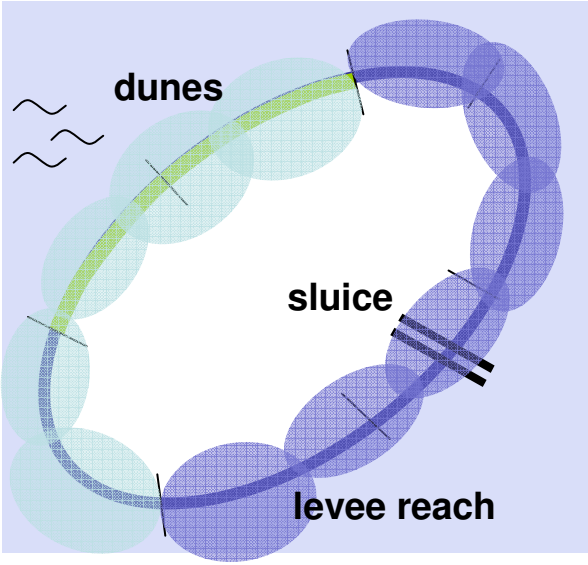
Inundation Scenarios



scenario	Reach		probability
	1	2	
scenario 1	X		P_1
scenario 2		X	P_2
scenario 3	X	X	P_3
			P_{tot}

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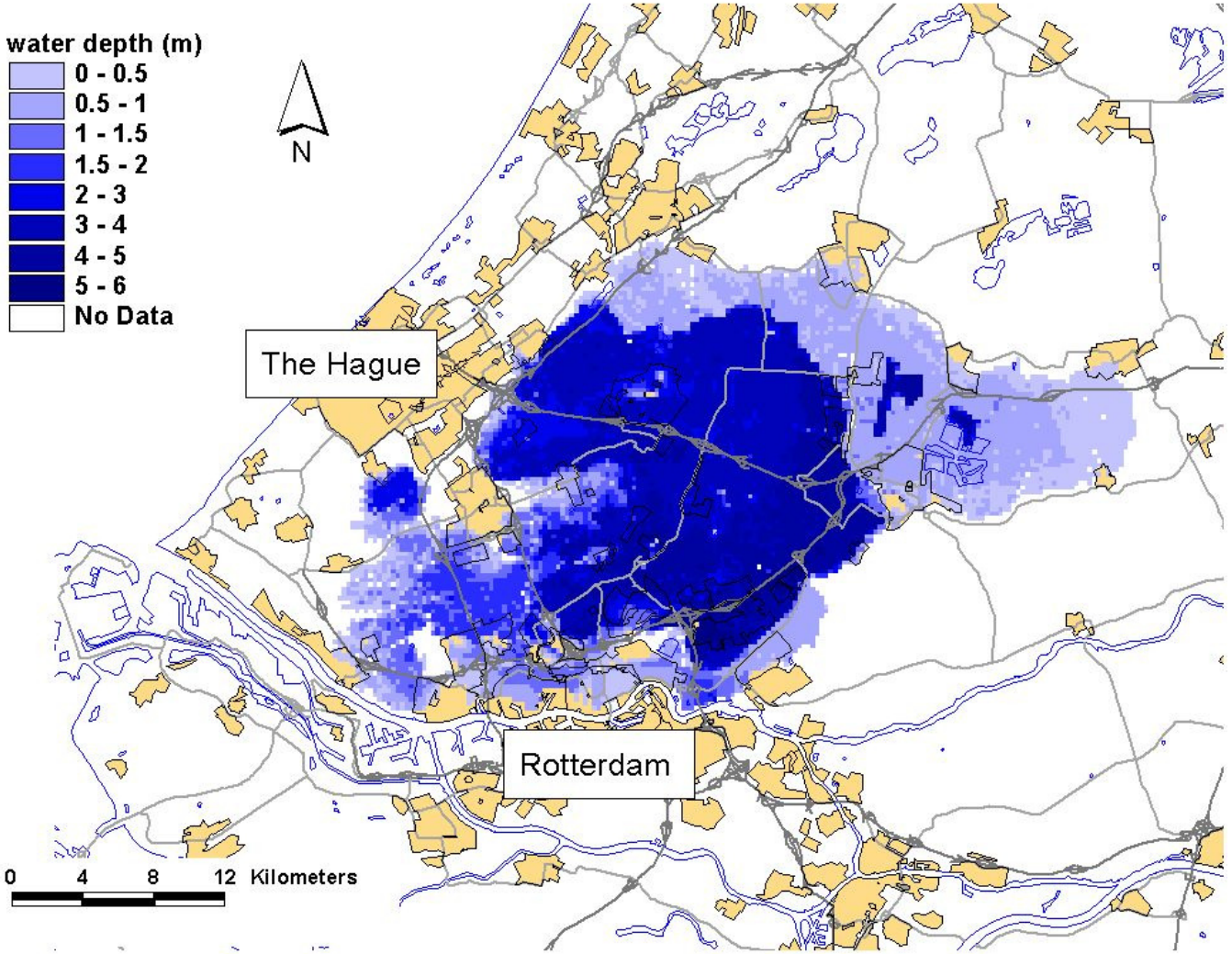
Inundation Simulation



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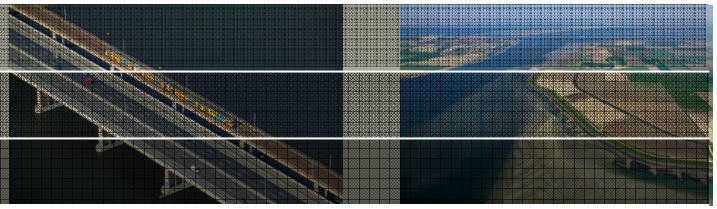
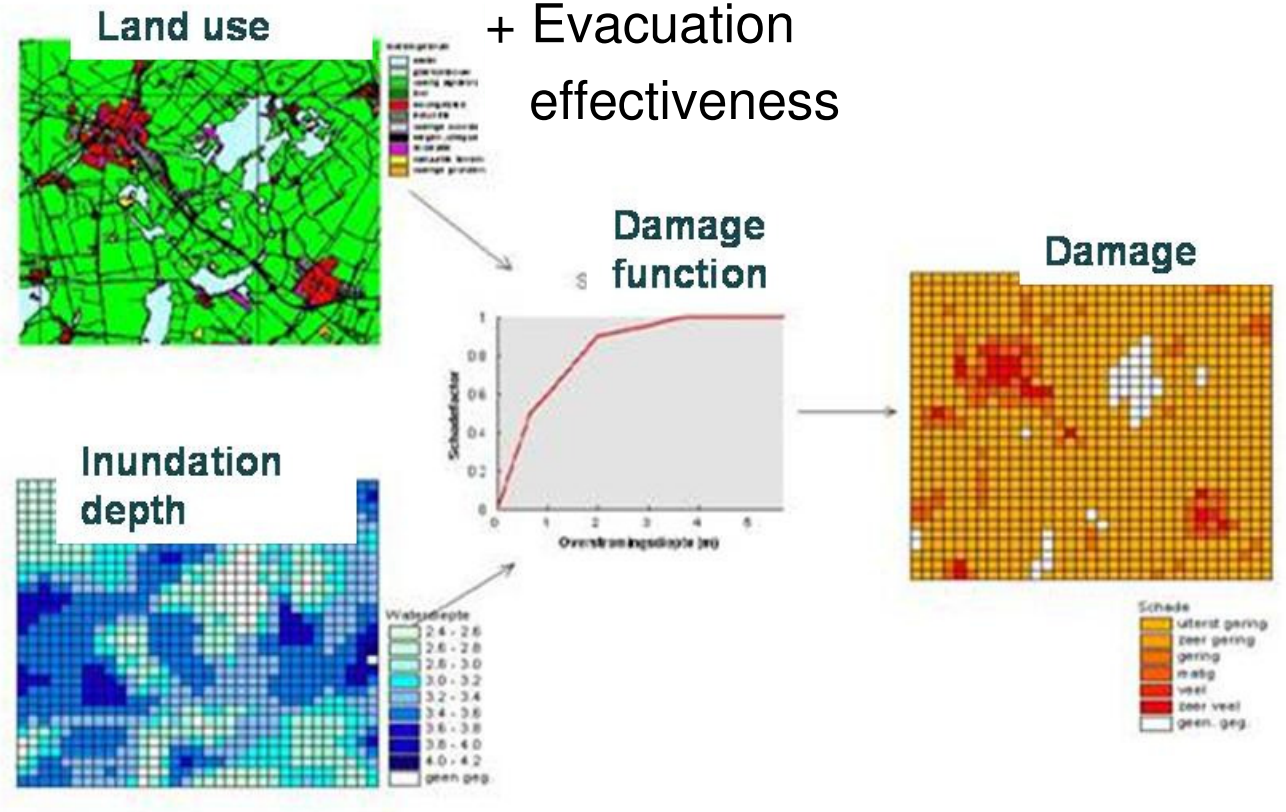
Consequences per scenario





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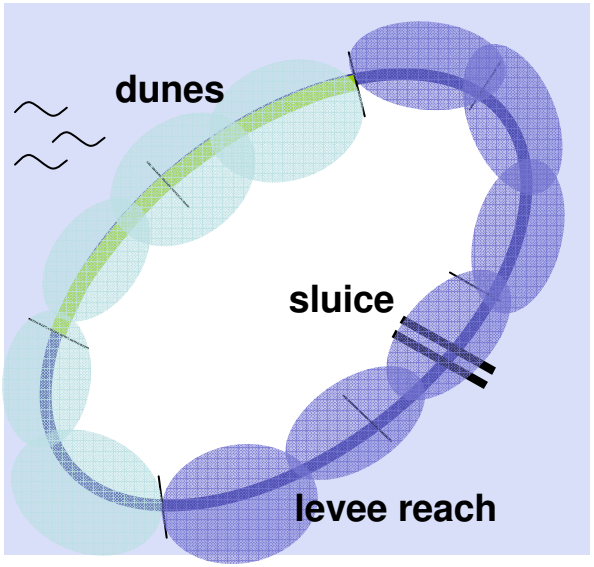
Risk Integration (e.g. economic damage)



scenario	Reach		probability	damage
	1	2		
scenario 1	X		P_1	C_1
scenario 2		X	P_2	C_2
scenario 3	X	X	P_3	C_3
			P_{tot}	

$$E[C] \approx \sum_i C_i P_i$$

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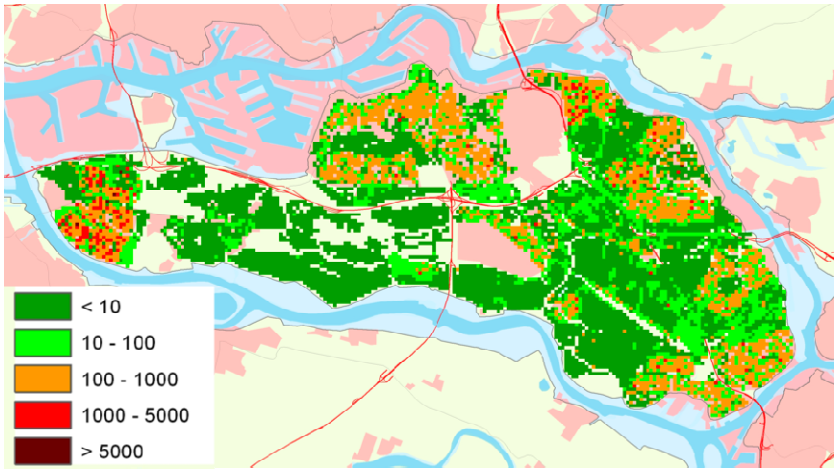
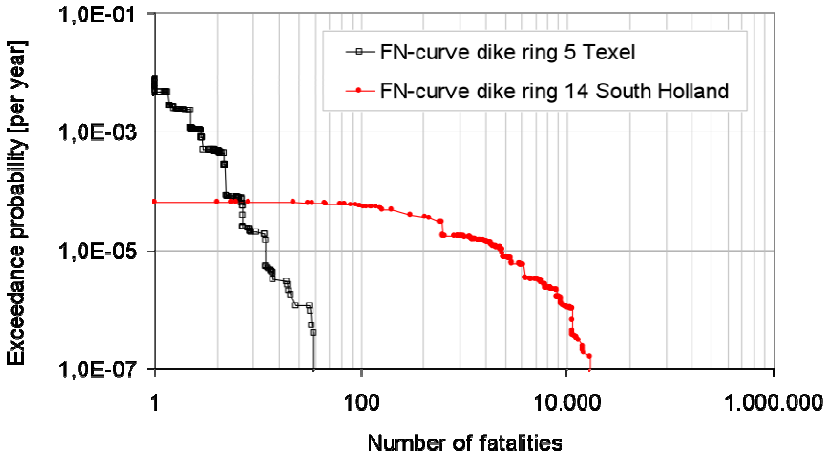
Dimensions of Risk

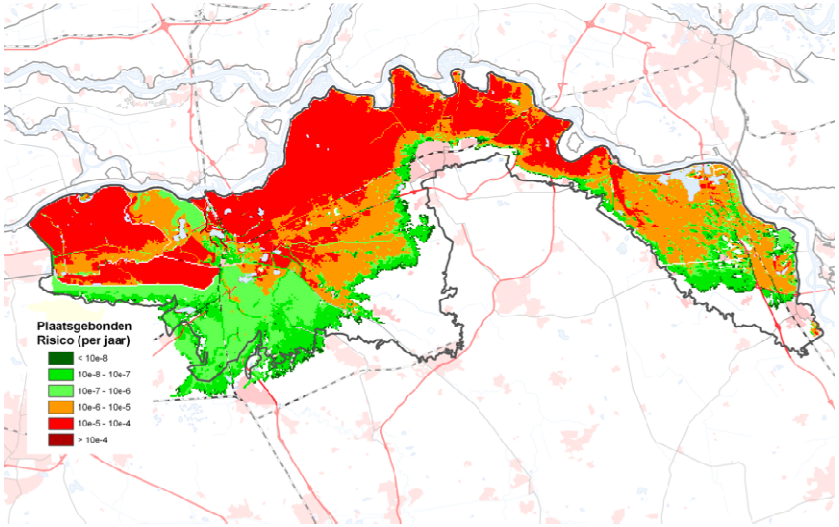
Expected value of economic damage [euro $yr^{-1}ha^{-1}$]



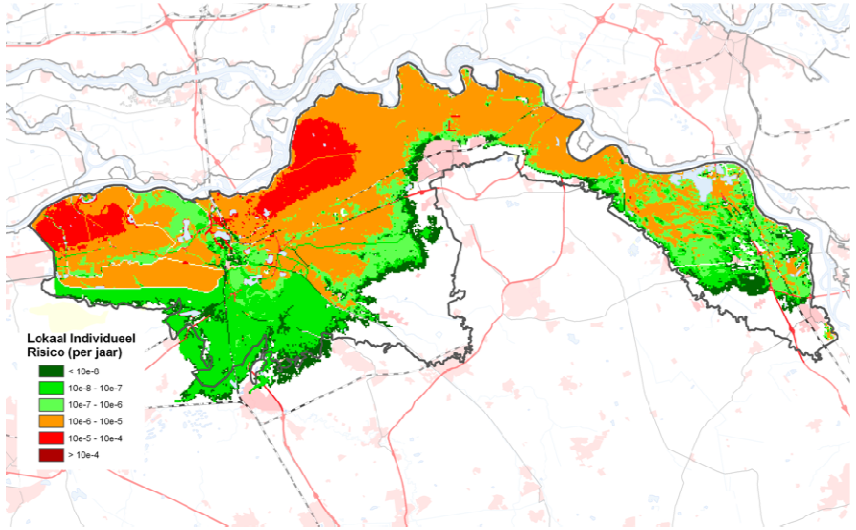
FN-curve



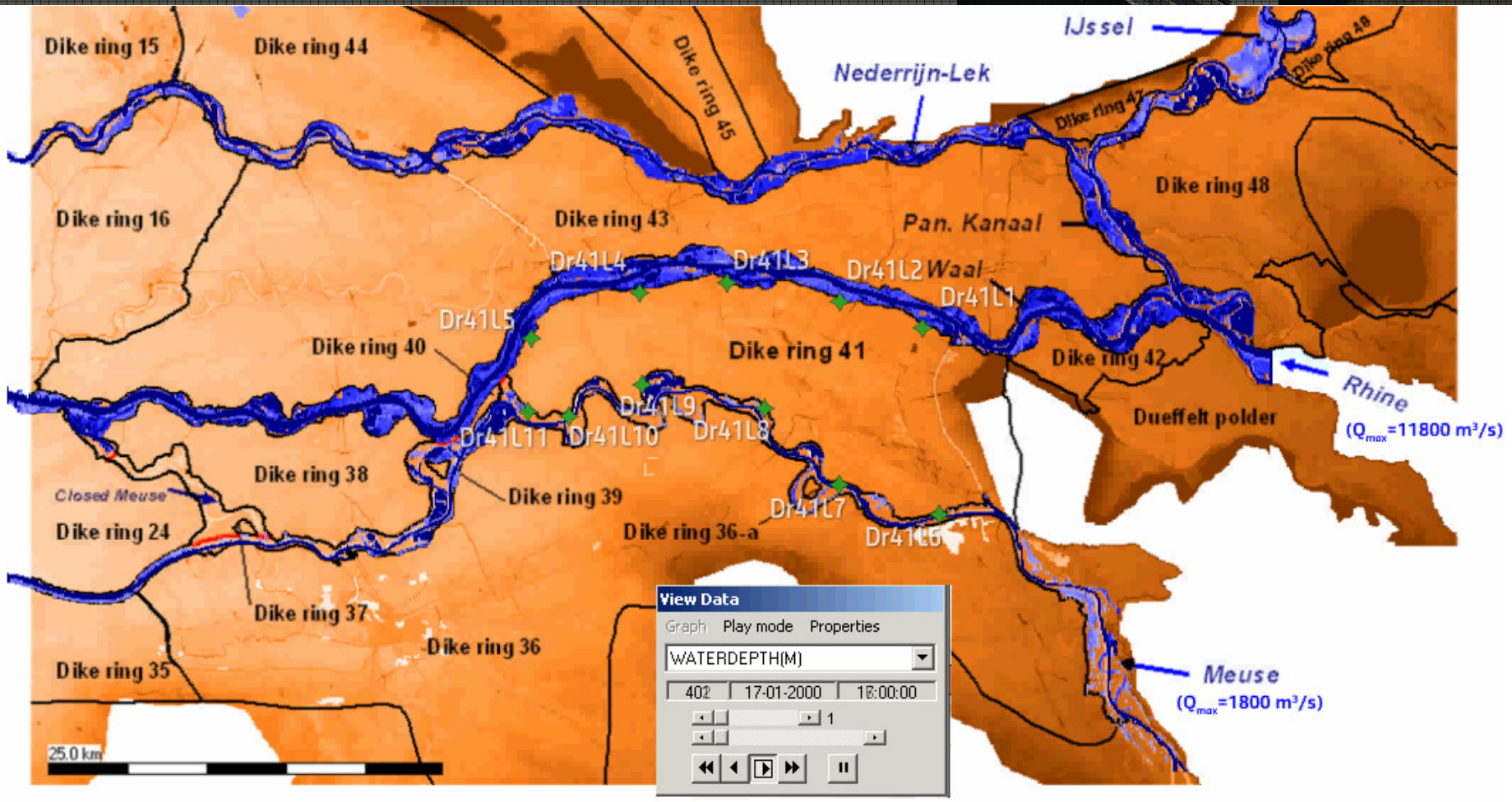
Individual risk excl. the effect of evacuation [yr^{-1}]



Individual risk incl. the effect of evacuation [yr^{-1}]



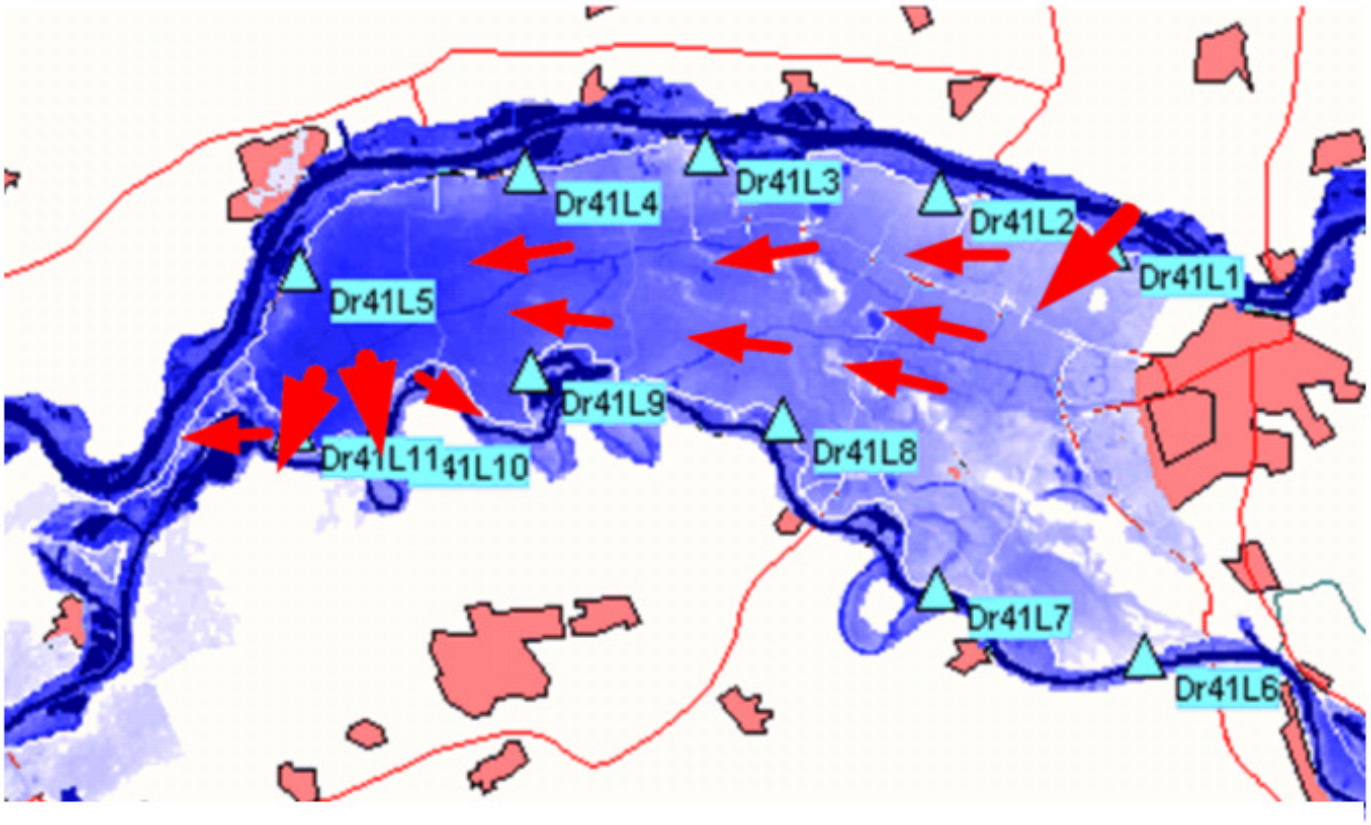
System Effects



- DR41L1: Failure induced by river; Heave & Piping failure mechanism
- DR41L11: Failure induced from Dikering, Overflow failure mechanism

- Primary flood protection work, category a (protects so-called dikering ares against flooding)
- Primary flood protection work, category b (connects dikering areas)
- Considered dike breach location

System Effects



Van Mierlo, M.C.L.M. et al, 2007, Assessment of floods risk accounting for River System Behaviour, Intl J. River Basin Management Vol 5, No 2 (2007), pp 93-104.

Courage, W., Vrouwenvelder, A.C.W.M., van Mierlo, T. & Schweckendiek, T. (2013): System Effects in Flood Risk Calculations. Georisk, special issue on "Levee Reliability and Flood Risk". (in press)

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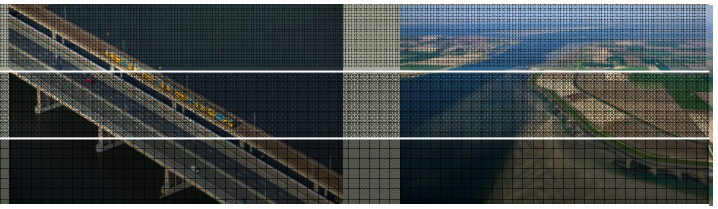
In a nutshell



1. Approach historically grown since the 1950s.
2. Risk analyses for all major flood defenses.
3. Reliability part based on physics-based computational models.
4. Expert judgment mostly at the level of basic random variables.
5. Account for dependencies / correlations.
6. Failure probabilities in the order of 10^{-6}.
7. Current efforts:
   - upgrade / revision (methods and software)
   - improve shortcomings (e.g. system effects).
8. International experience: Singapore, Germany, Indonesia, US, …

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Dutch Approach to Levee Reliability and Flood Risk

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