Flood risk management in the Netherlands

Ruben Jongejan

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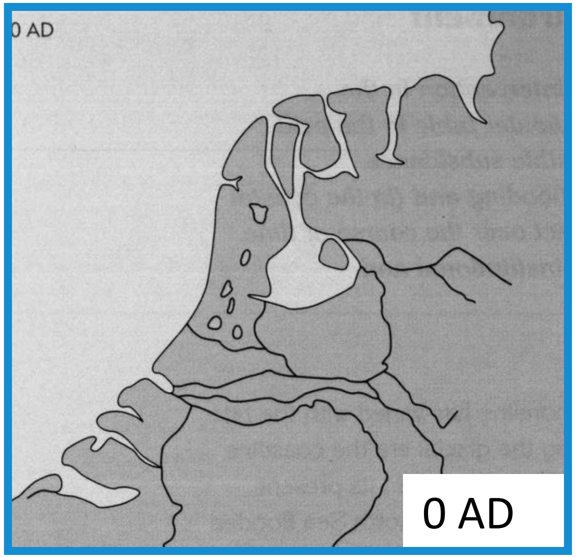
Risk Management Consulting

Outline

- Introduction
- Quantifying the risk of flooding
- Evaluating risk acceptability
- Conclusions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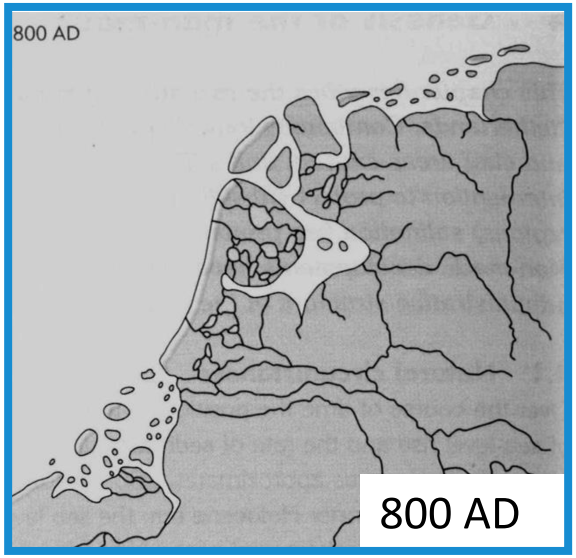
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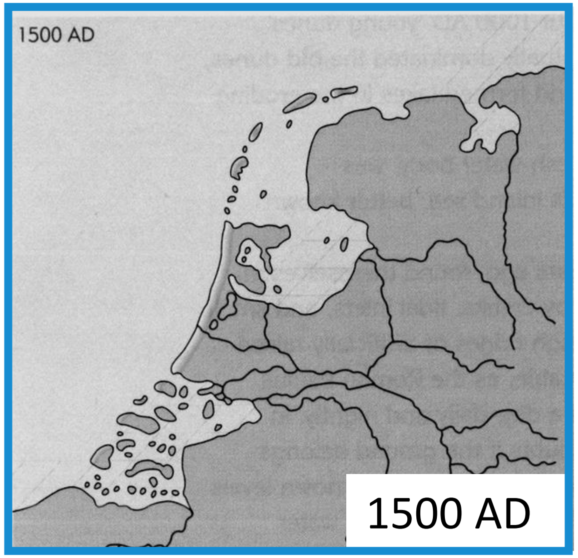
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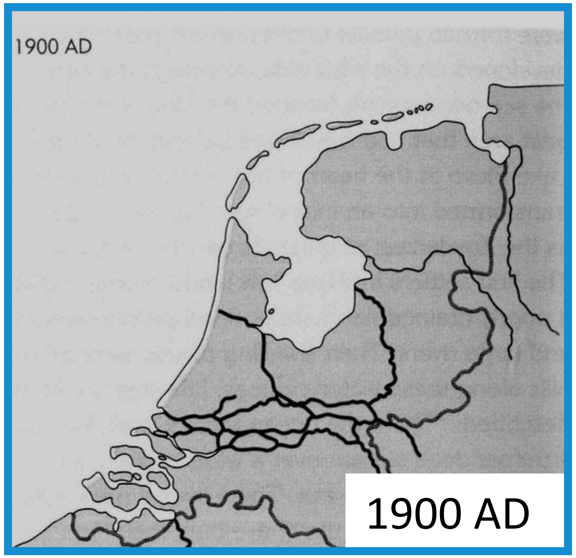
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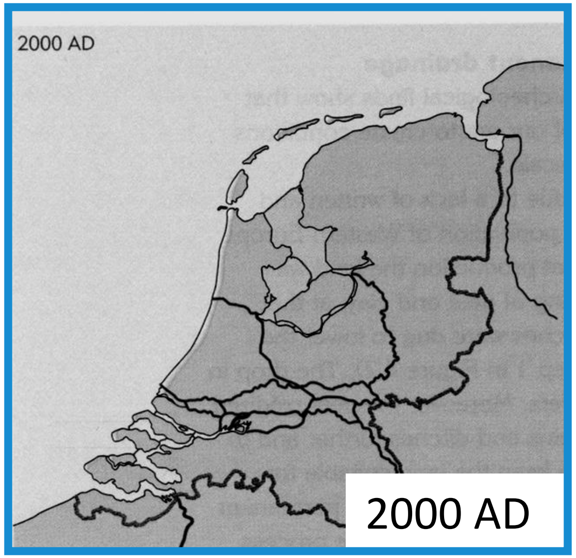
2000 AD
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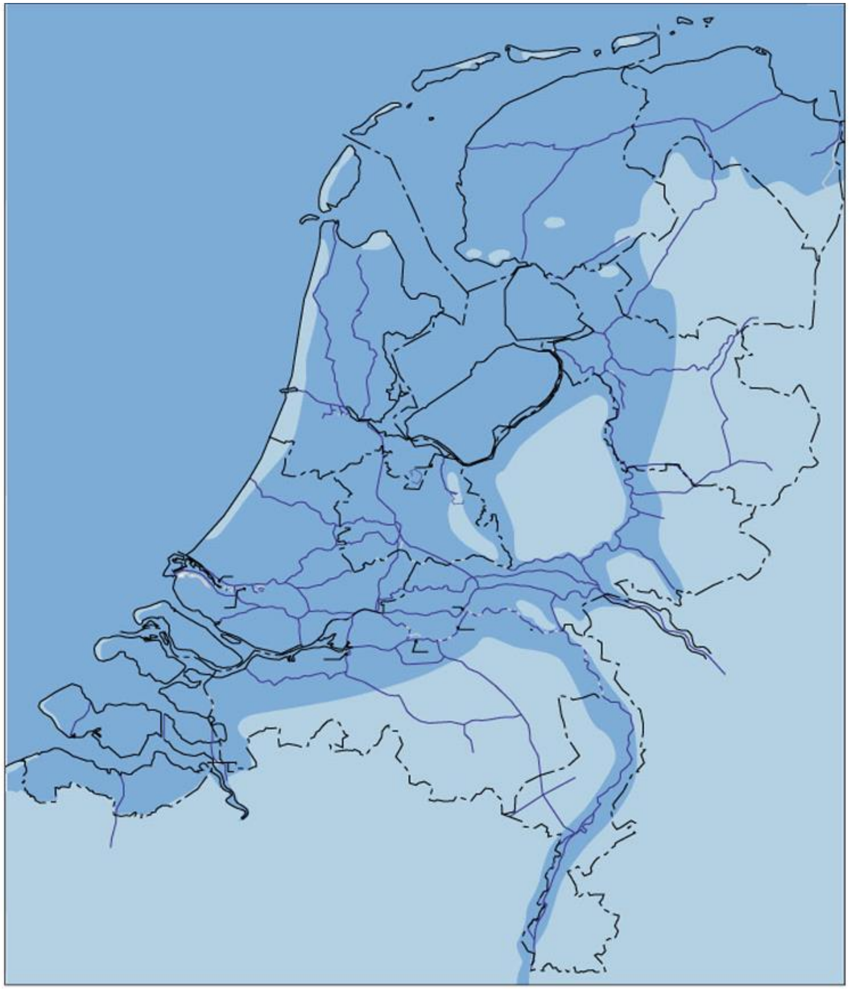
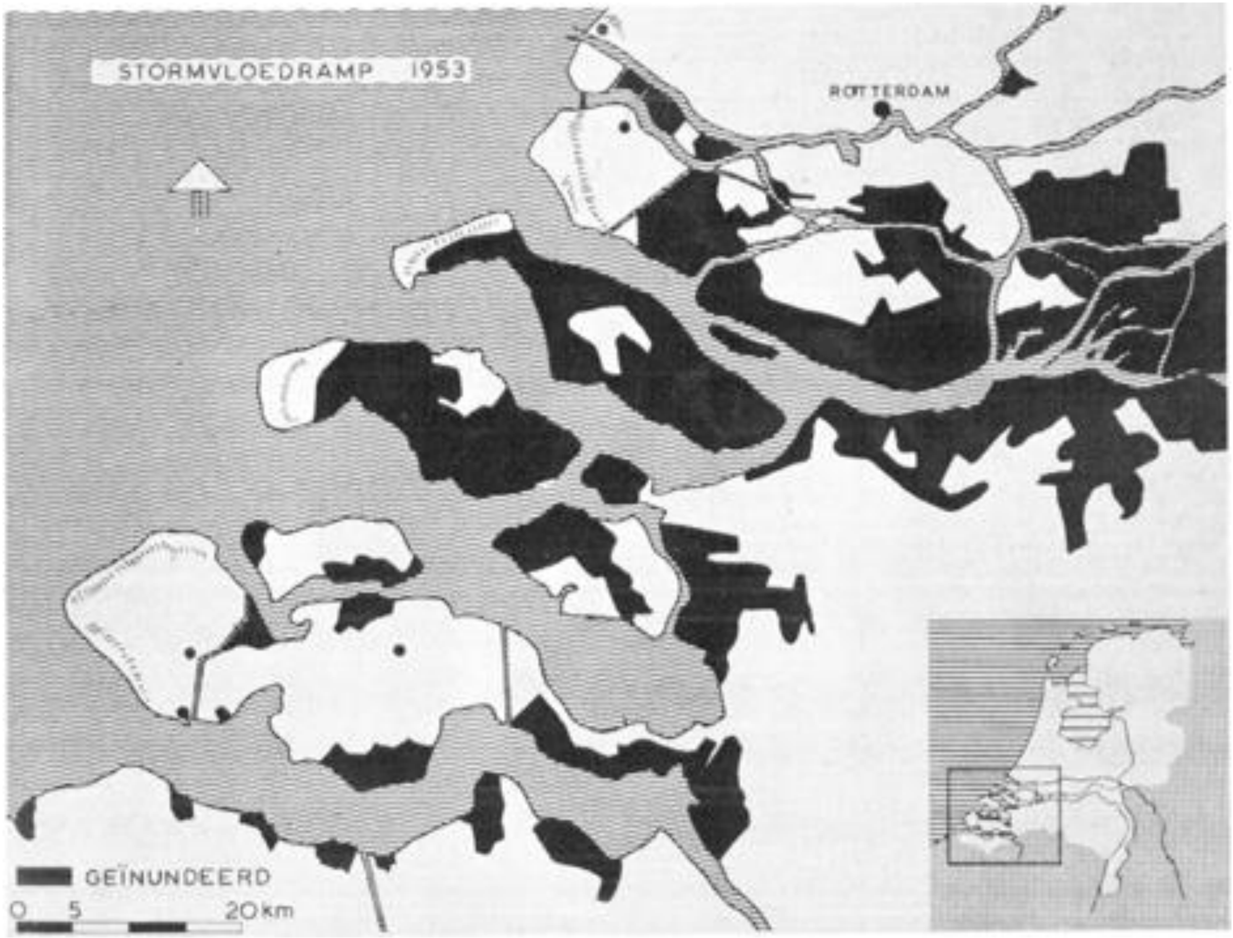


Higher lands
Flood prone areas

A history marked by floods

Major Flood of 1953



> 1800 fatalities

> 1800 km^2 flooded

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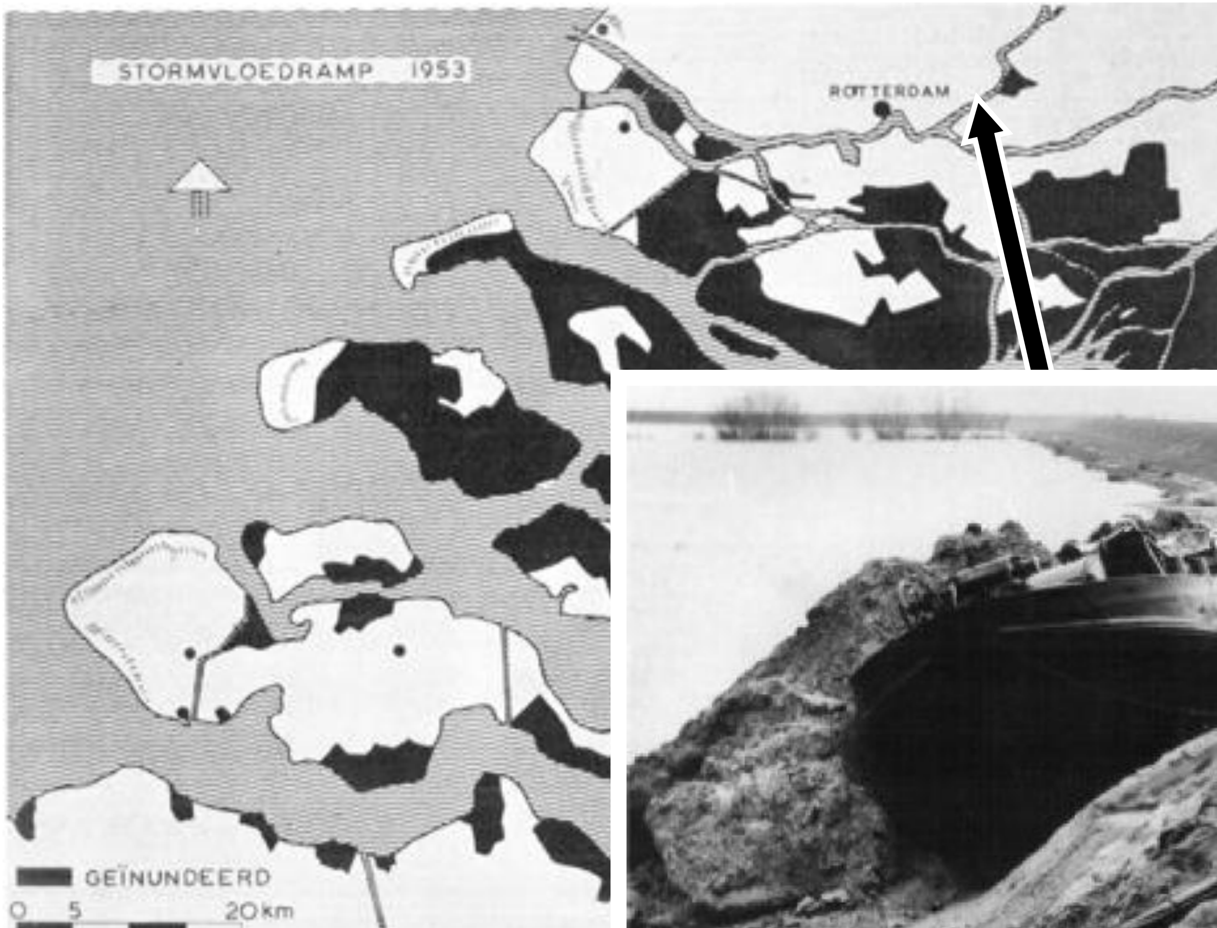
Major Flood of 1953



> 1800 fatalities

> 1800 km² flooded

>50 major levee systems

>3600 km of flood defenses

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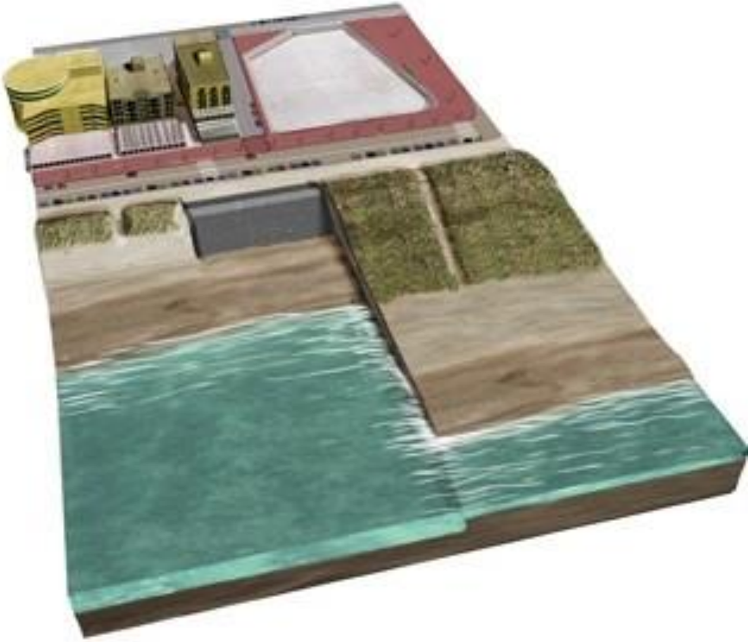
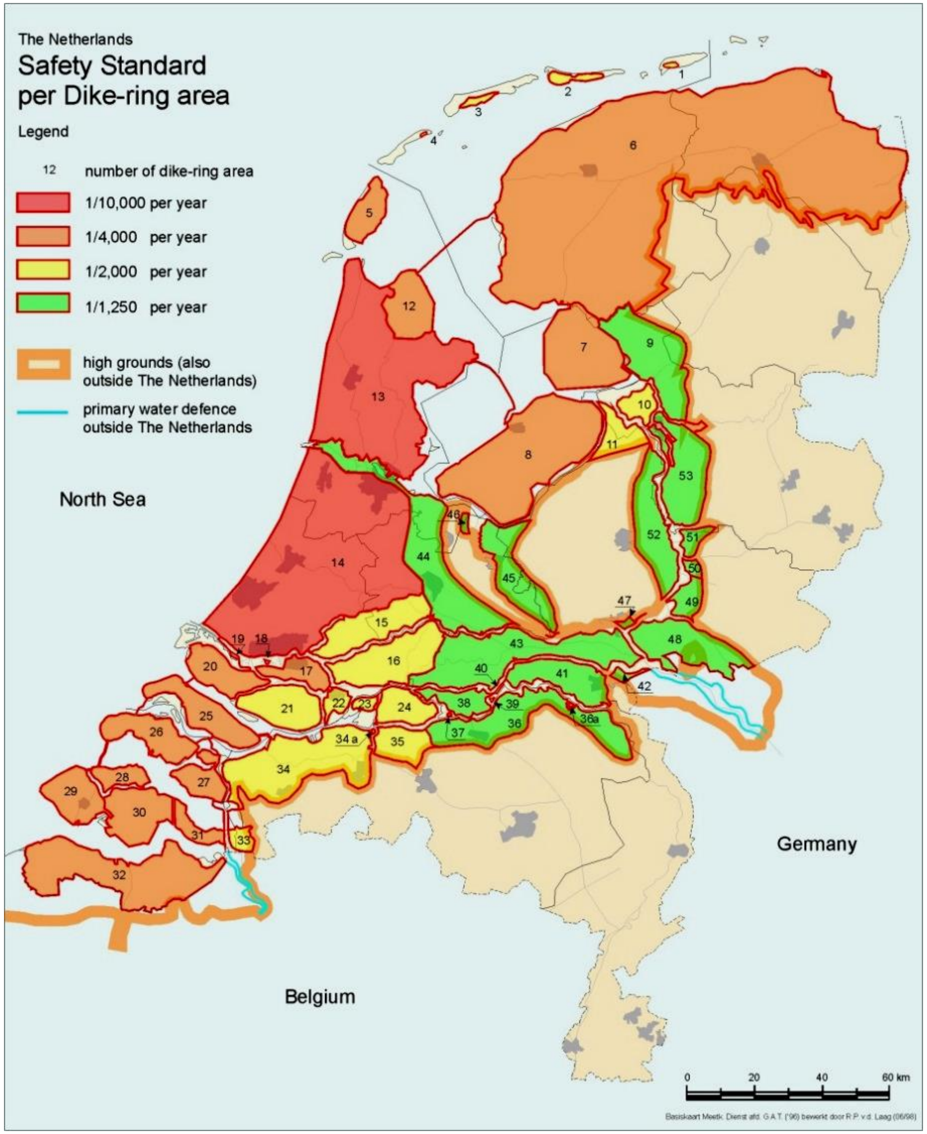
Recent innovations

Building with Nature:

Sand engine

Hidden structures





Current standards

Defined in terms of design loads

1 Standard for each major levee system

Based on cost-benefit analyses from the 1950s and 1990s

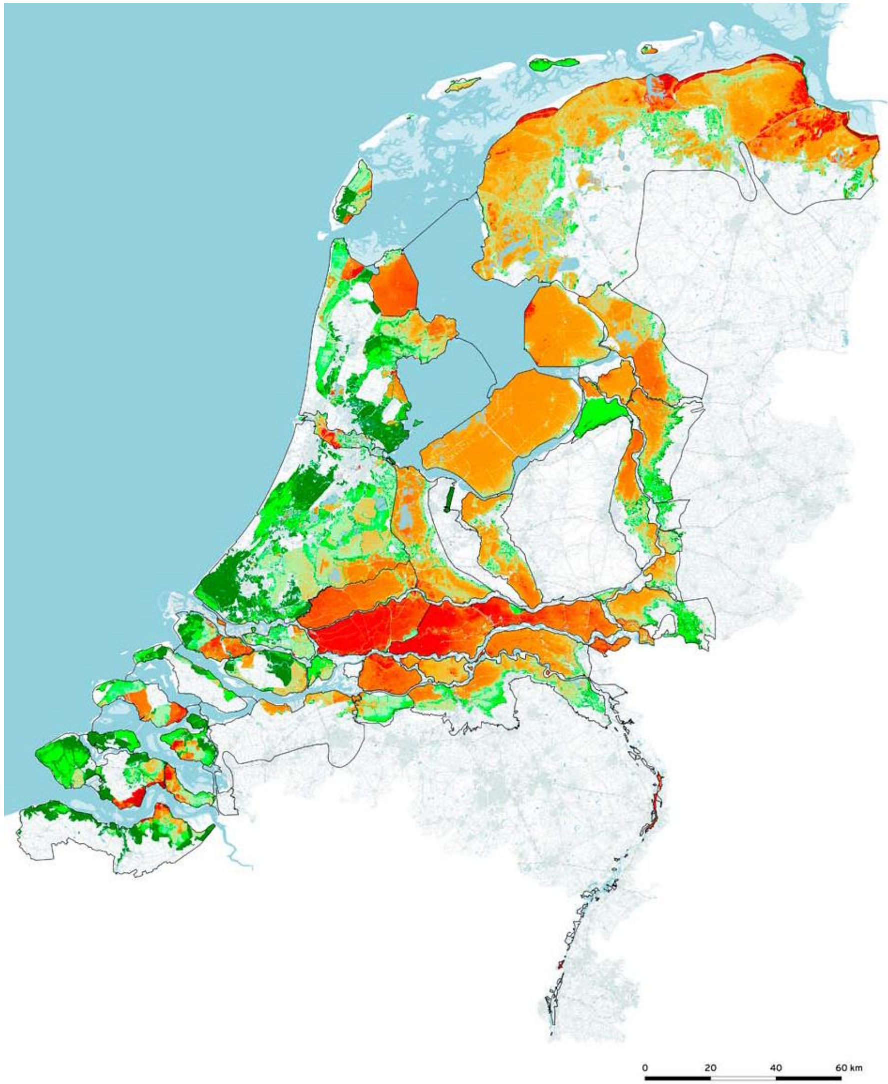
VNK2-project objectives

Provide detailed flood risk estimates…

- Economic risk
- Fatality risk

…for all 53 major levee systems

- 3600km of levees
- 60% of Dutch territory



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Participating organisations

Government bodies

- Rijkswaterstaat
- More than 20 water boards
- 12 Provinces

Research institutes/networks

- TNO
- Deltares
- Delft University of Technology
- Expertise Network for Flood Protection (ENW)

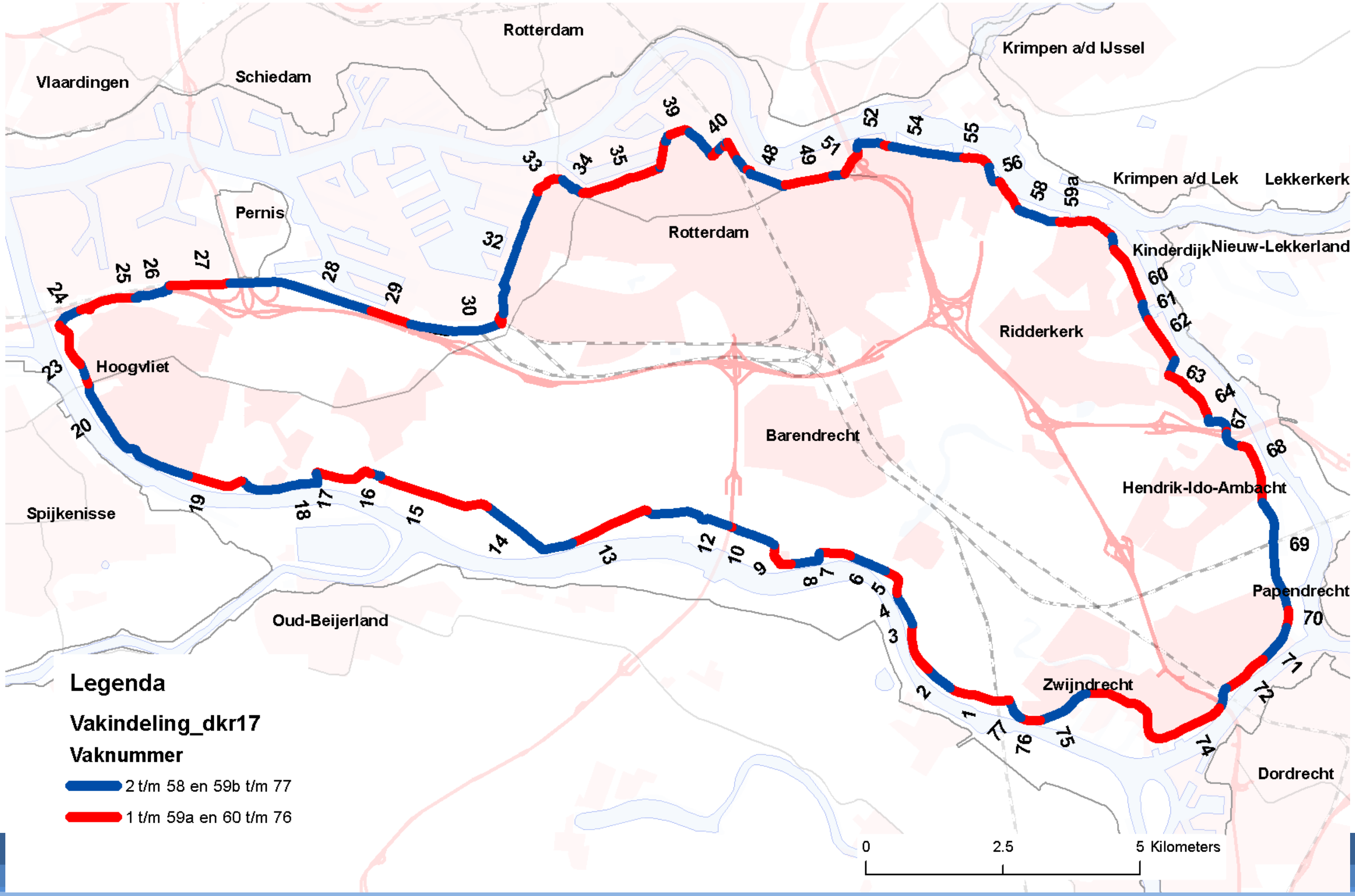
Engineering consultancies

- Arcadis
- DHV
- Fugro
- Greenrivers
- Grontmij
- HKV Consultants
- Hydraulogic
- Infram
- IV-Infra
- JongejanRMC
- Lievense
- Oranjewoud
- Royal Haskoning
- RPS
- Tauw
- Witteveen+Bos

Risk analysis procedure

1. Decompose levee system into smaller sections
2. Calculate failure probabilities per section
3. Define flood scenarios and compute their probabilities
4. Estimate consequences per flood scenario
5. Combine scenario probabilities and consequences

1. Decompose levee system



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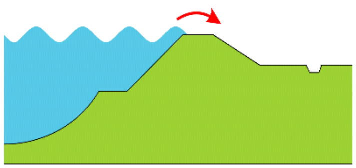
2. Calculate failure probabilities

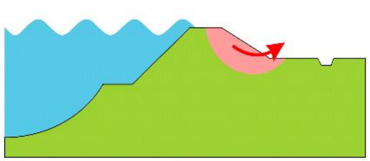
Failure mechanisms

levees

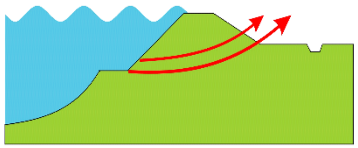
Overtopping



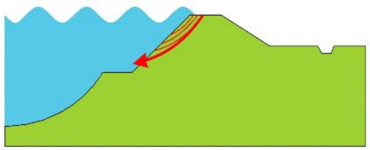
Slope instability



Piping

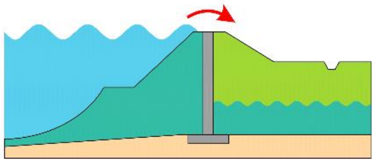


Revetment failure

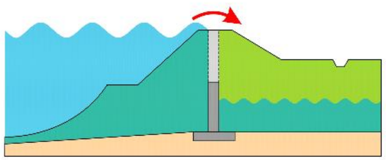


Hydraulic structures

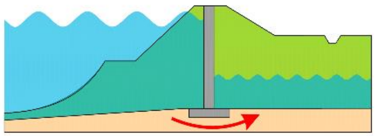
Overtopping



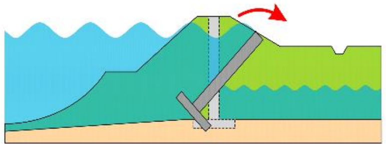
Non-closure



Piping



Structural failure



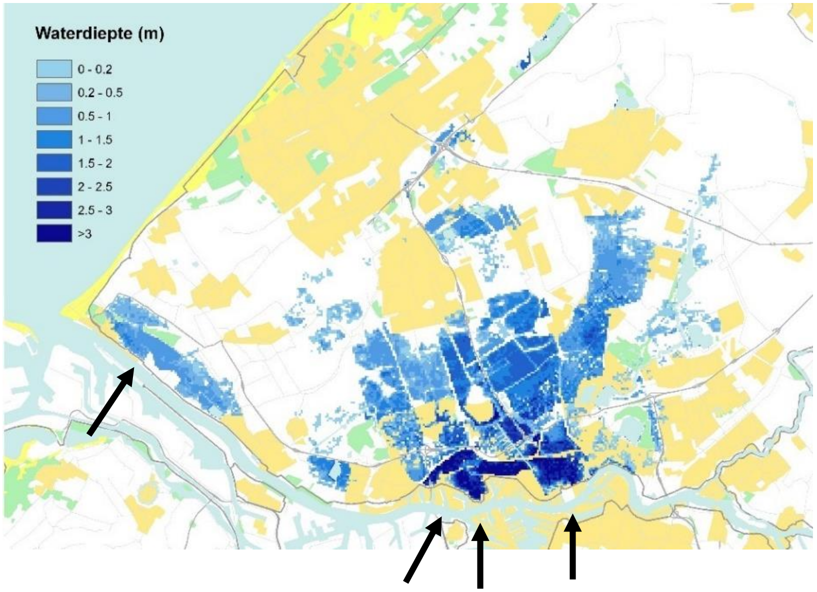
2. Calculate failure probabilities

	Section 1	Section 2	Section j	Combined
Mechanism 1	P_{11}	P_{12}	P_{1j}	$P_{1,ring}$
Mechanism 2	P_{21}	P_{22}	P_{2j}	$P_{2,ring}$
Mechanism i	P_{i1}	P_{i2}	P_{ij}	$P_{i,ring}$
Combined	$P_{mech,1}$	$P_{mech,2}$	$P_{mech,j}$	P_{flood}

Correlations are taken into account

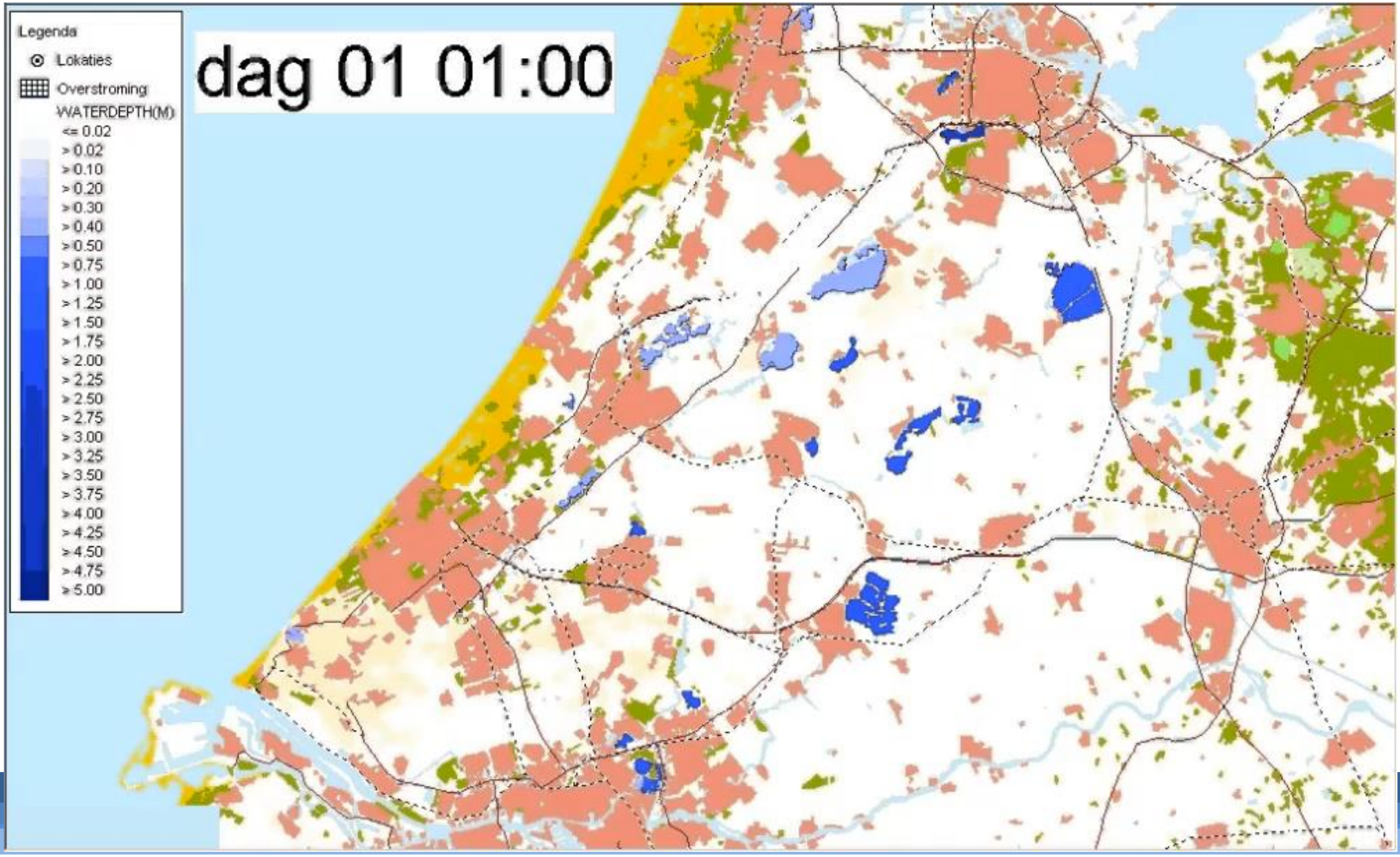
3. Define flood scenarios and calculate probabilities

Flood scenario = Sequence of events, initiated by one or more section failures



These 4 sections fail and no other section fails

4. Estimate consequences per scenario



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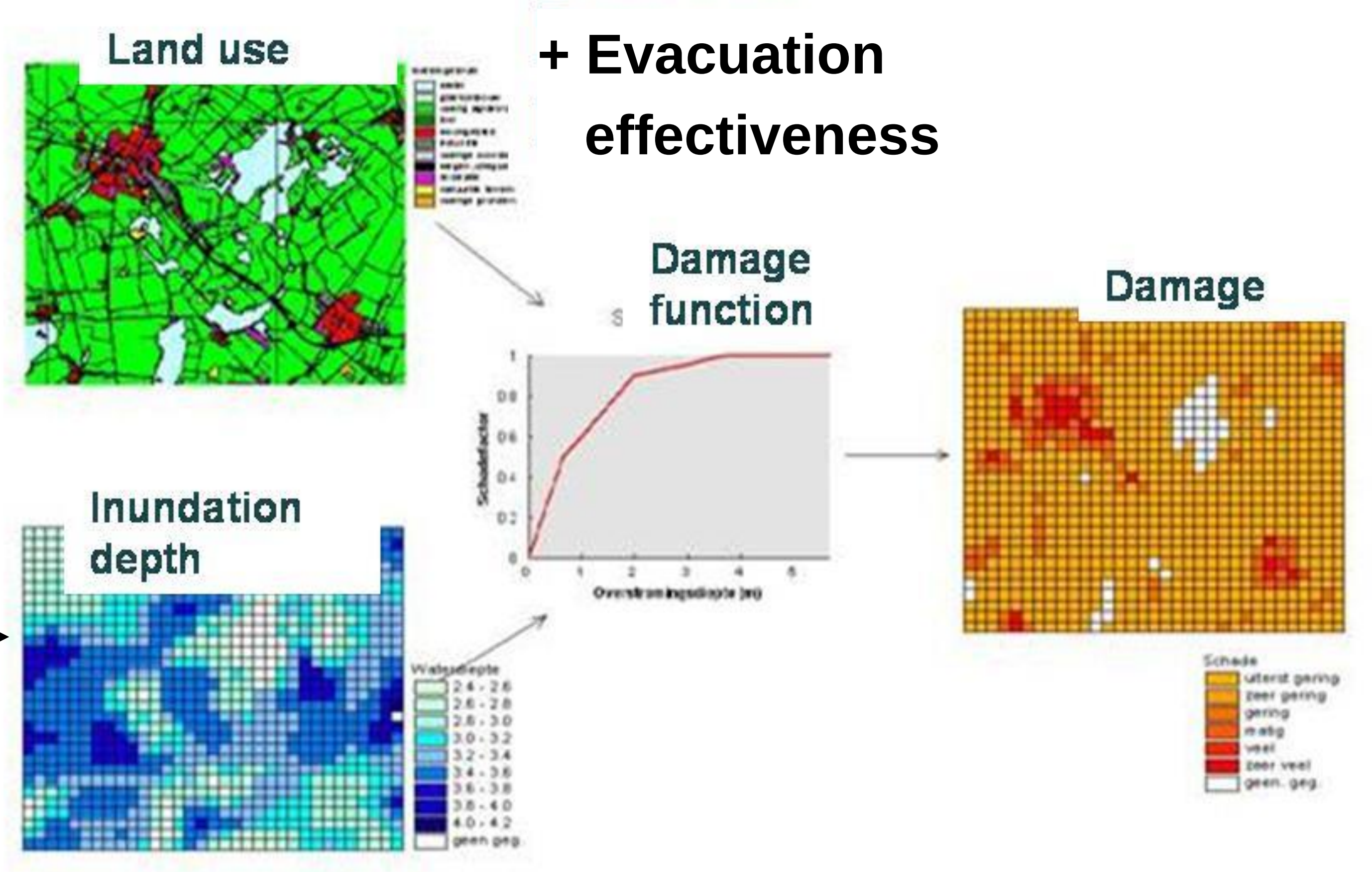
4. Estimate consequences per scenario

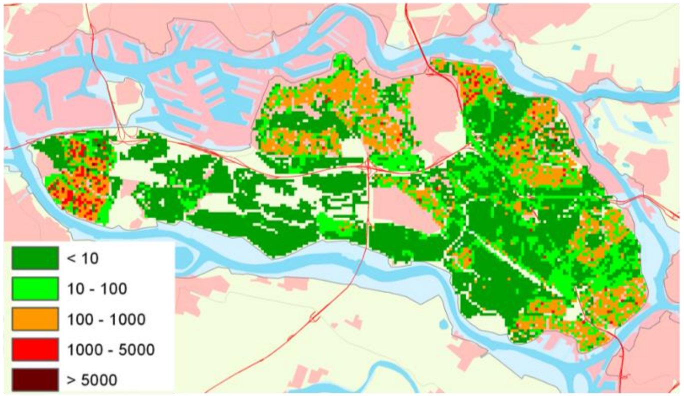
+ Evacuation effectiveness

Flood simulation →

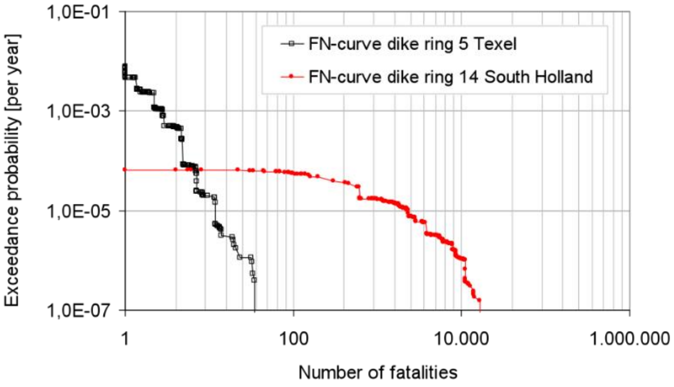


5. Combine probabilities and consequences

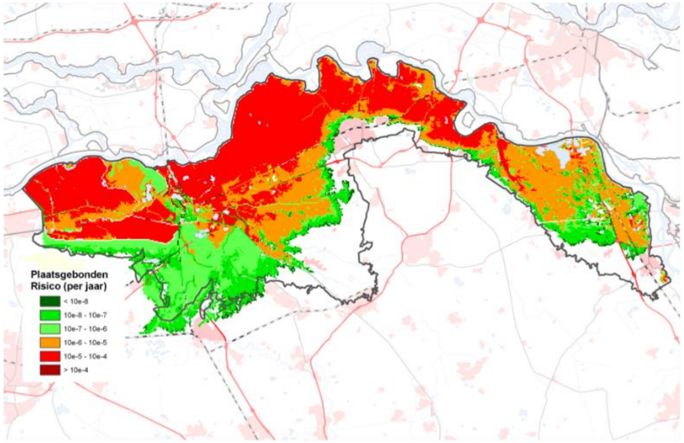
Expected value of economic damage [euro yr^{-1}ha^{-1}]



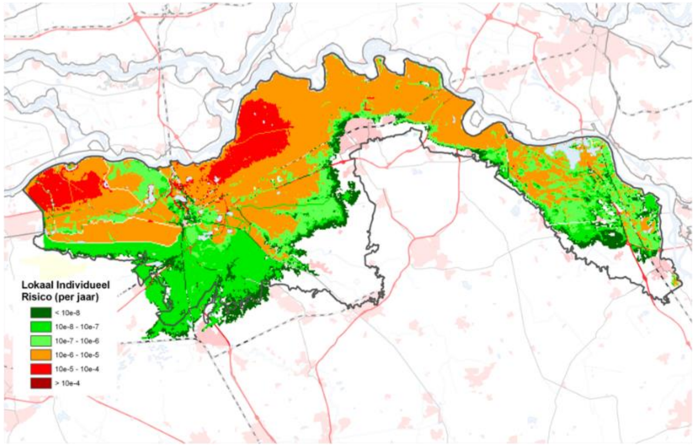
FN-curve



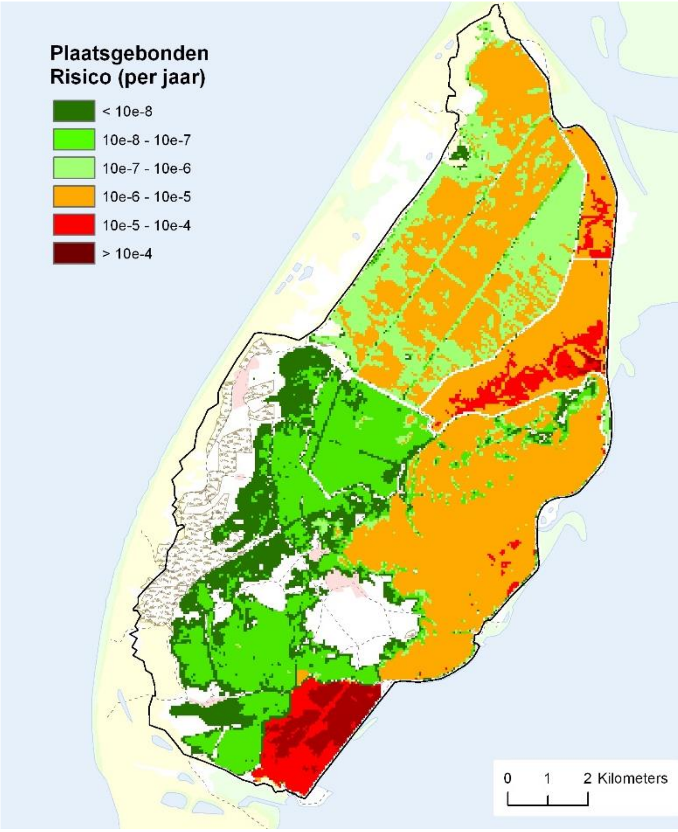
Individual risk excl. the effect of evacuation [yr^{-1}]



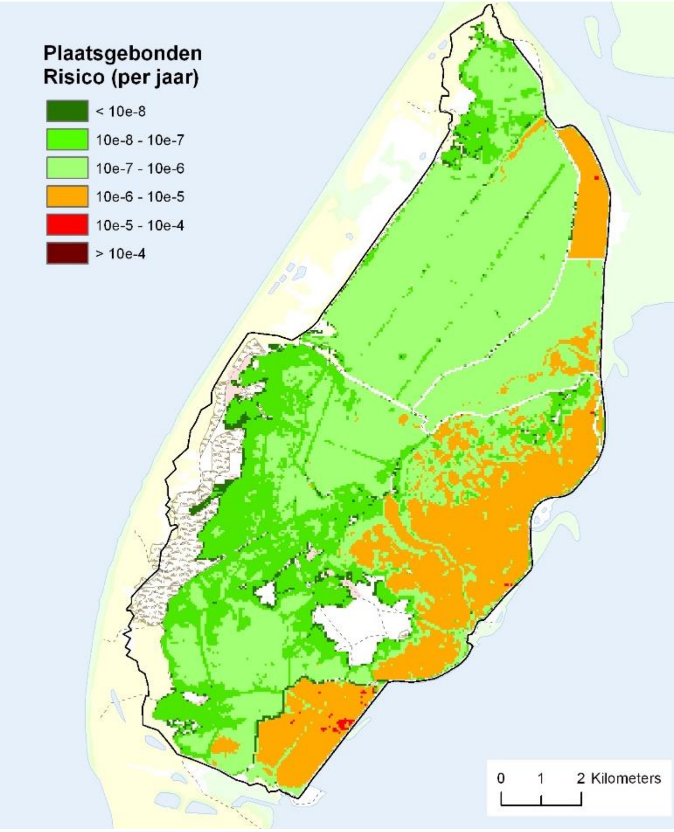
Individual risk incl. the effect of evacuation [yr^{-1}]



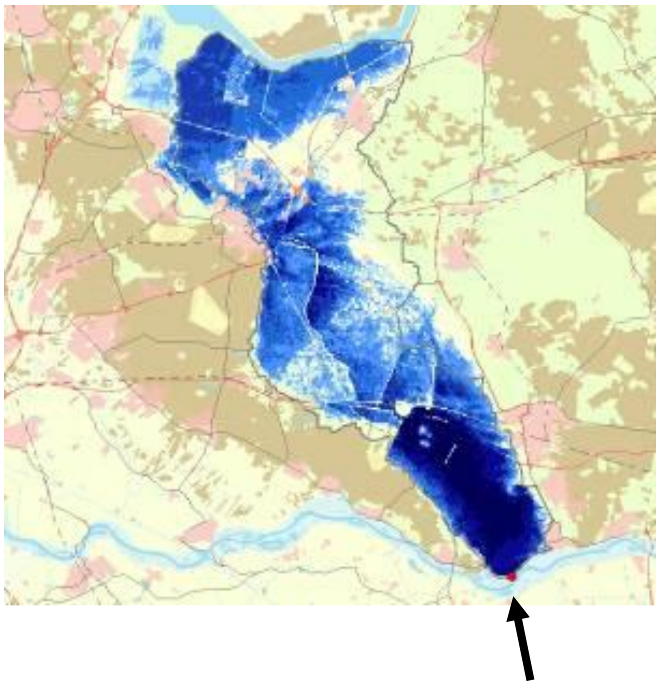
Analyzing the effect of flood risk management actions

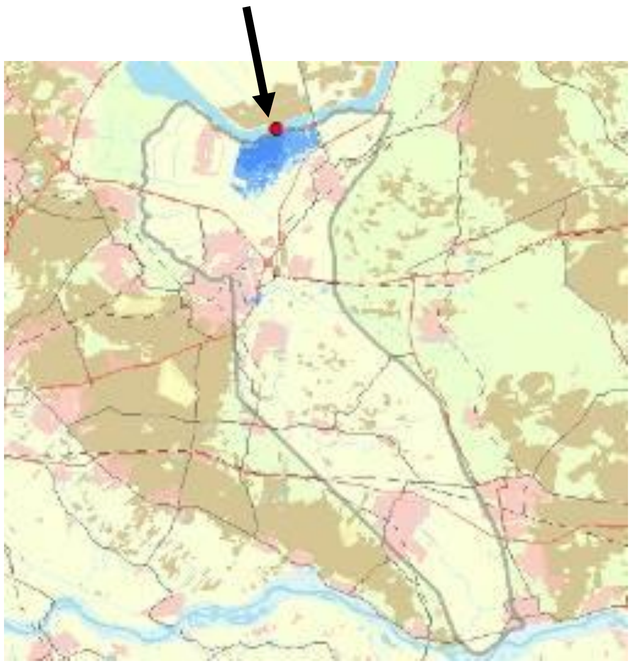


10 measures



Evaluating current practice





The same standards for the north and the south?

Results of VNK2

- Insight
  - into the risk of flooding
  - into the inefficiencies of the “old” standards/practices
  - into key risk factors
- Confidence in the feasibility of a probabilistic approach
- Greater familiarity with basic concepts in risk analysis

Strategic choices - the Delta Program

1. Crisis management
   e.g. www.overstroomik.nl

2. Spatial planning

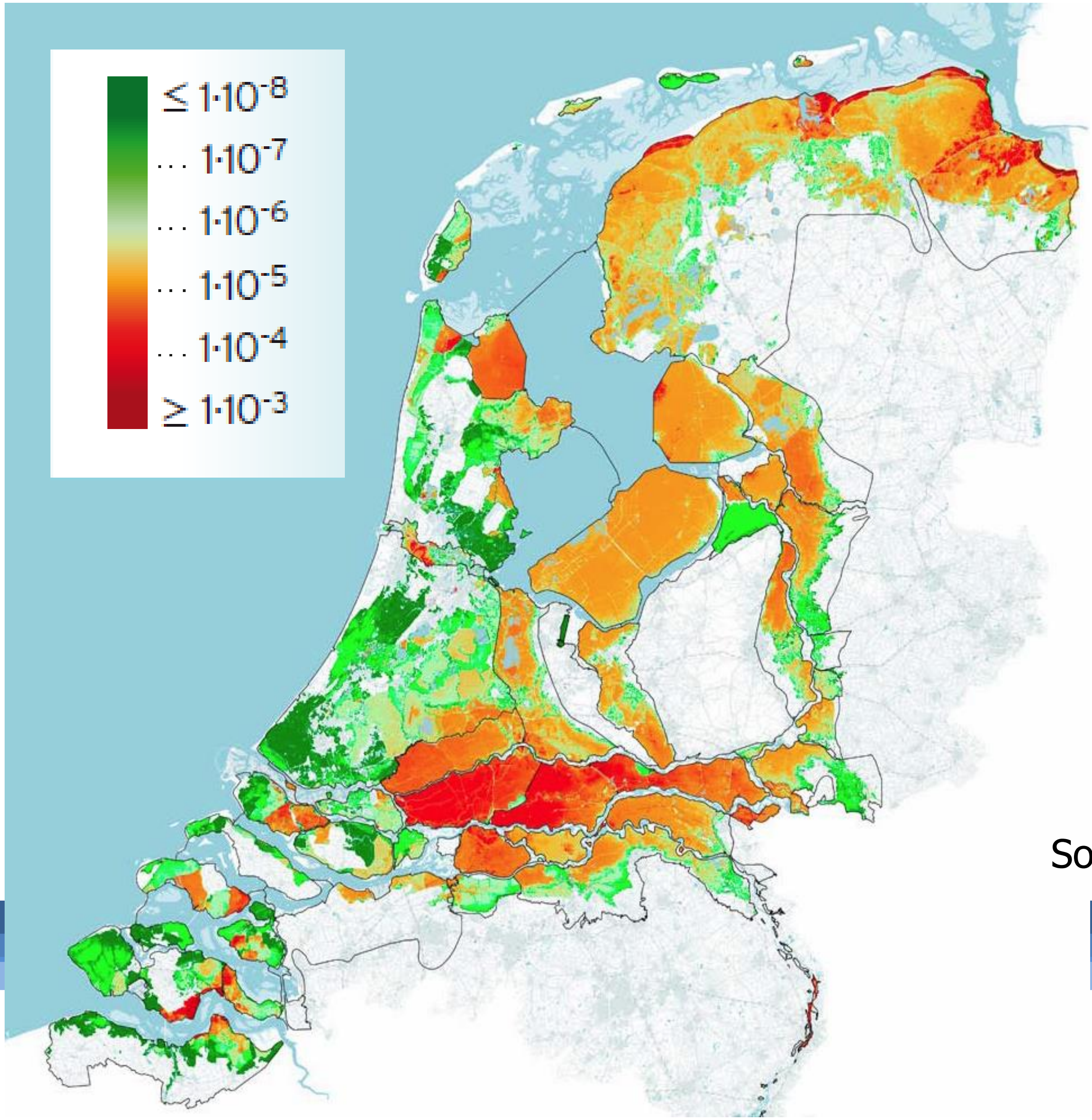
3. Prevention

New standards of protection (2017)

Based on:

- Individual risk < 10^{-5} per year
- Societal risk
- Cost-benefit analysis

Individual risk < 10^{-5} per year



Source: VNK2, 2014

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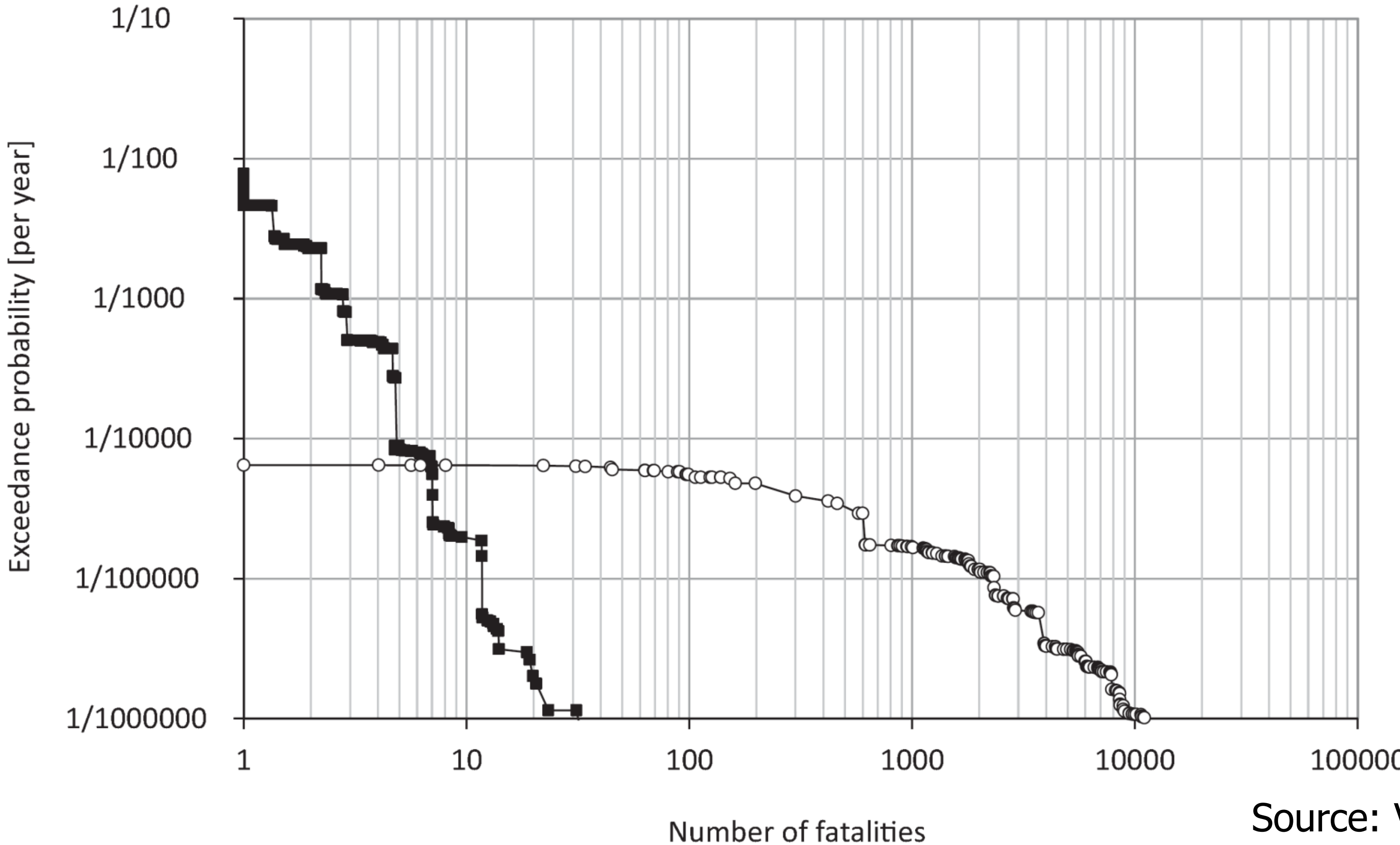
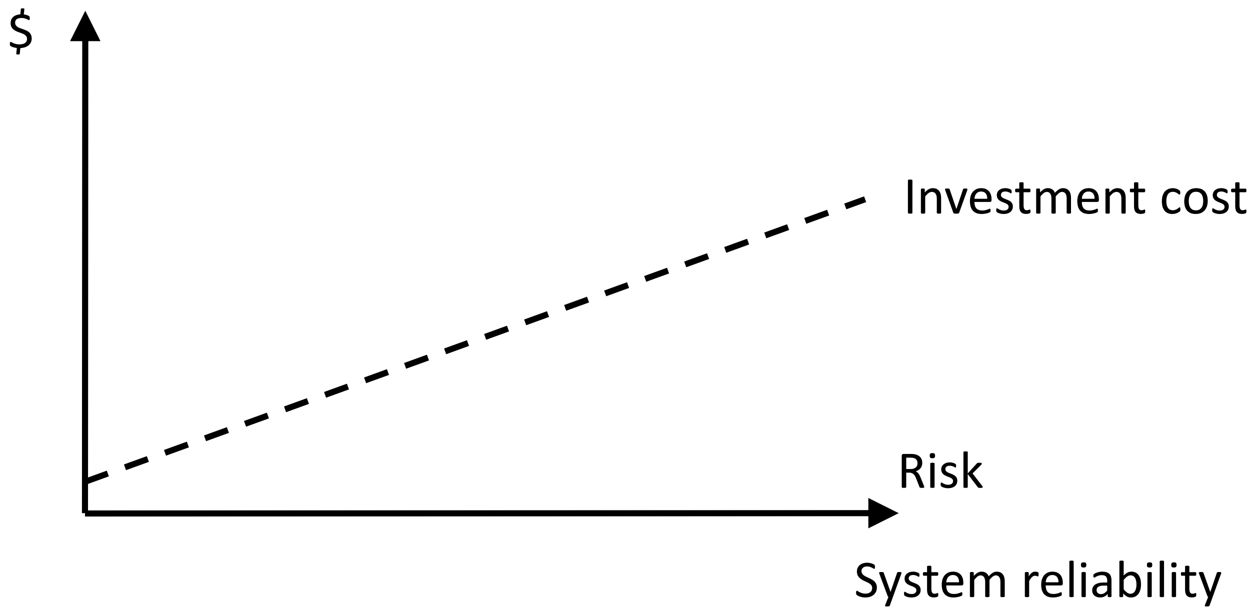
Societal risk

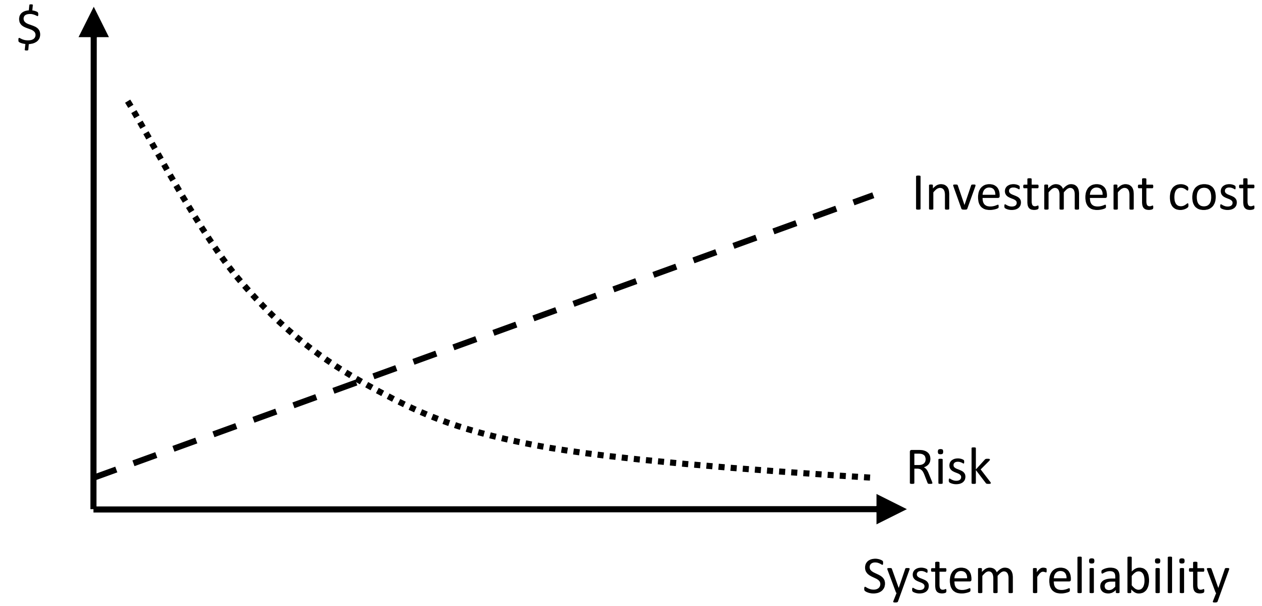


Source: VNK2, 2014

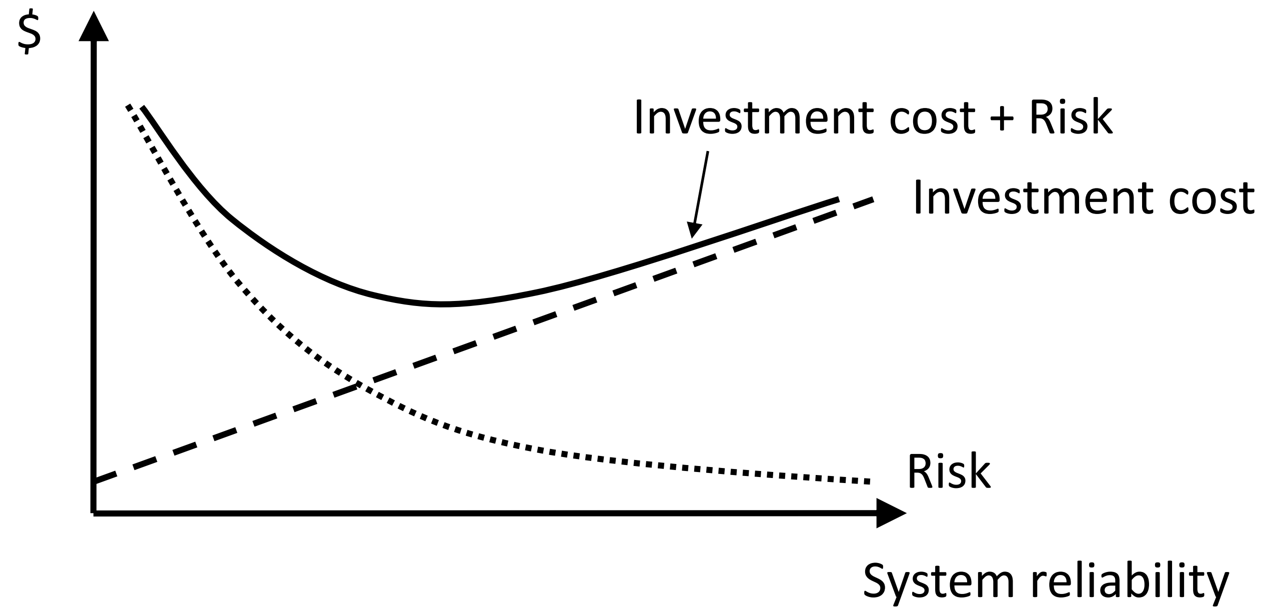
Cost-benefit analysis



Cost-benefit analysis



Cost-benefit analysis



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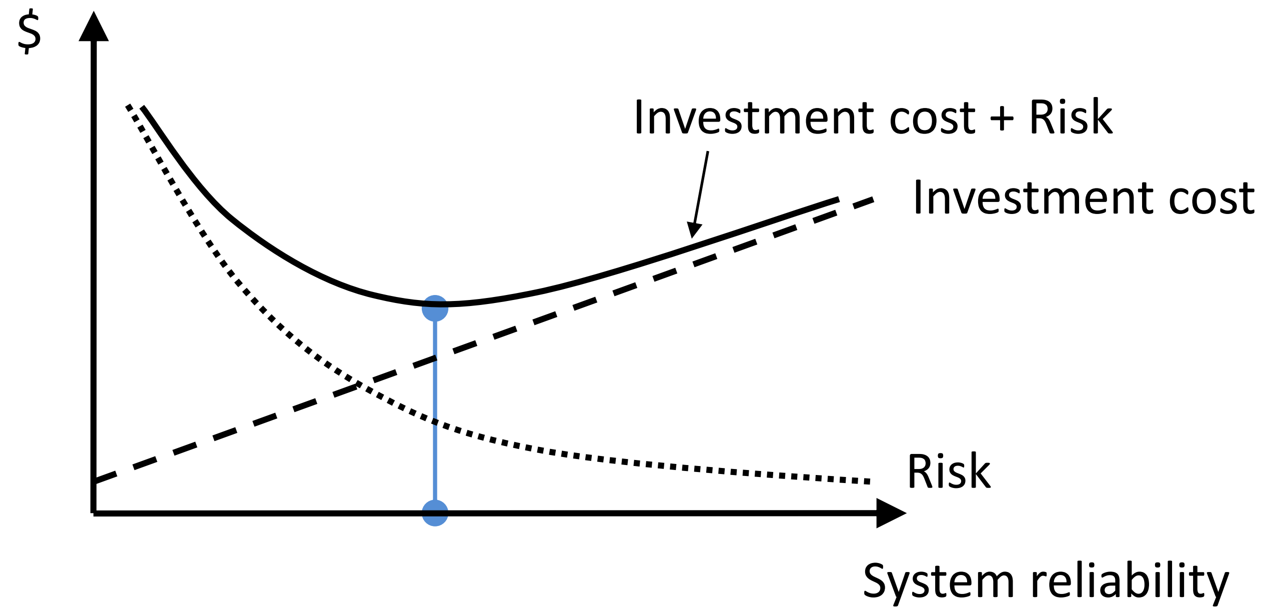
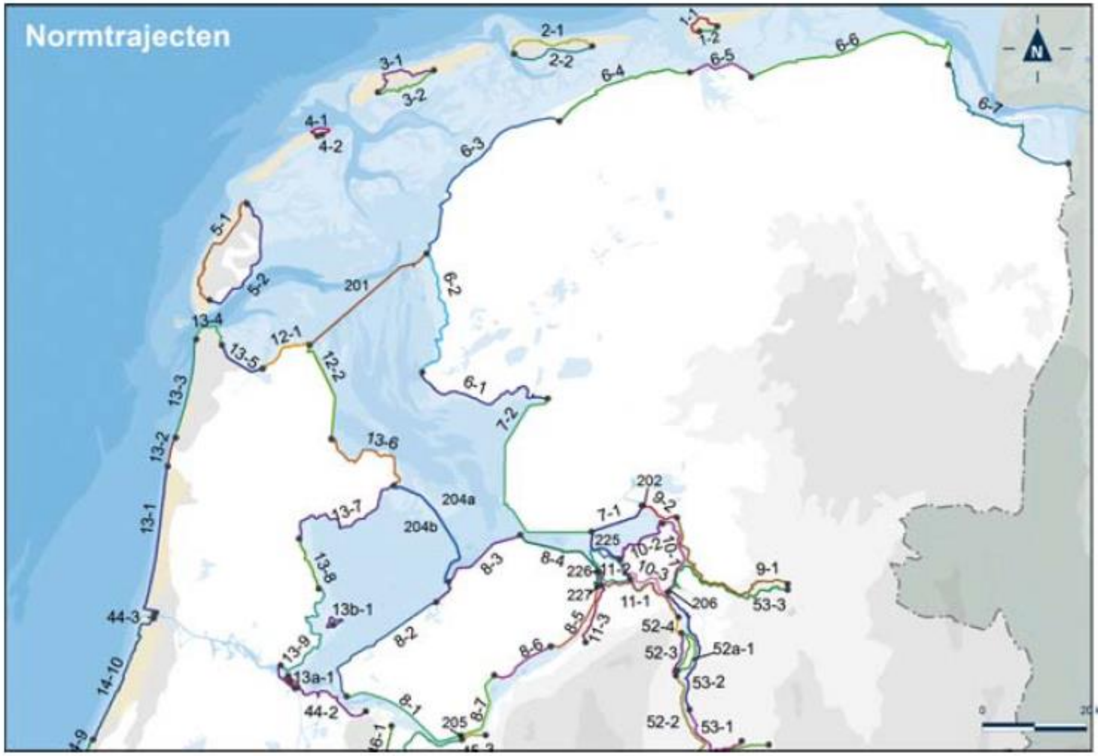
Cost-benefit analysis



New flood protection standards (2017)



- 1/100 – 1/100,000 per year
- Variations within major levee systems

Closing remarks

- Dutch flood risk management practices are strongly risk-informed
- The focus lies heavily on prevention, with an eye for crisis management and spatial planning
- New flood protection standards (2017) based on:
  - individual risk < 10^{-5} per year
  - societal risk evaluation
  - cost-benefit analysis

Questions?

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Organization of flood protection

National government
- legislation (protection standards)
- financial assistance
- management of coastline, rivers and several large dams/barriers

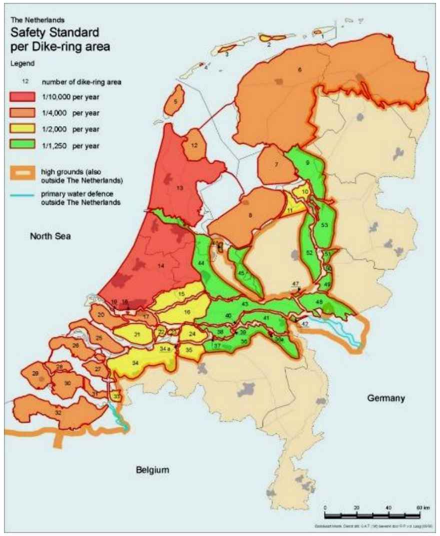
12 Provinces
- supervision
- spatial planning

25 Water boards (levee owners)
- periodic safety assessments
- maintenance, restoration projects

A short history of the Dutch protection standards

1953 Major Flood

1953-1960 Delta Committee
Design standards based on cost-benefit analysis



1995 Flood Protection Law (later: Water Law)
Standards codified, also for river areas

A short history of the Dutch protection standards

2007-2008 2nd Delta Committee
Policy review

2010 Delta Programme starts

Regional studies, discussions

2014 Proposal

2015 Draft update of Water Law

Strategic

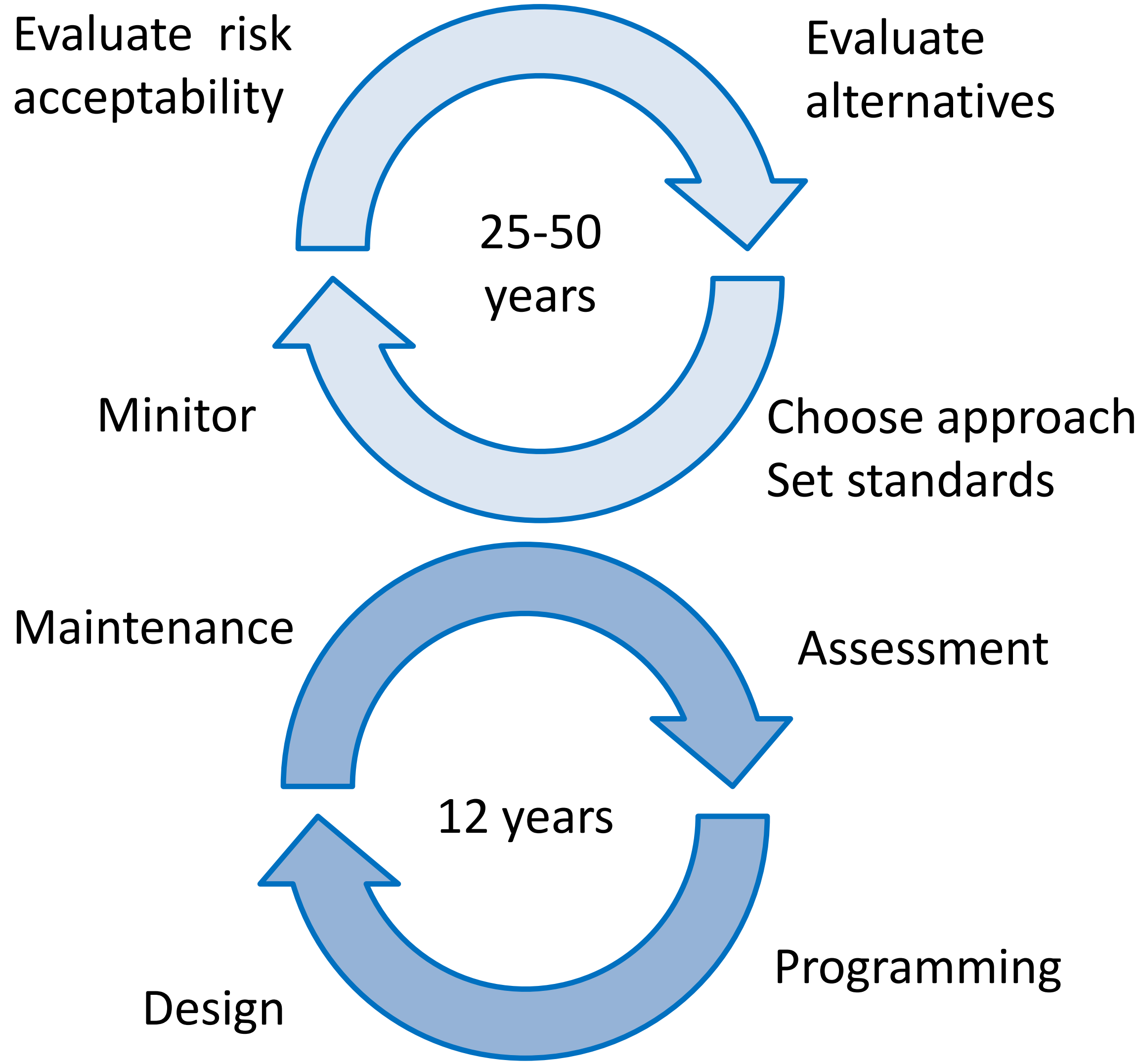
Important aspects:

- Climate change
- Economic growth
- Population growth
- Changing preferences

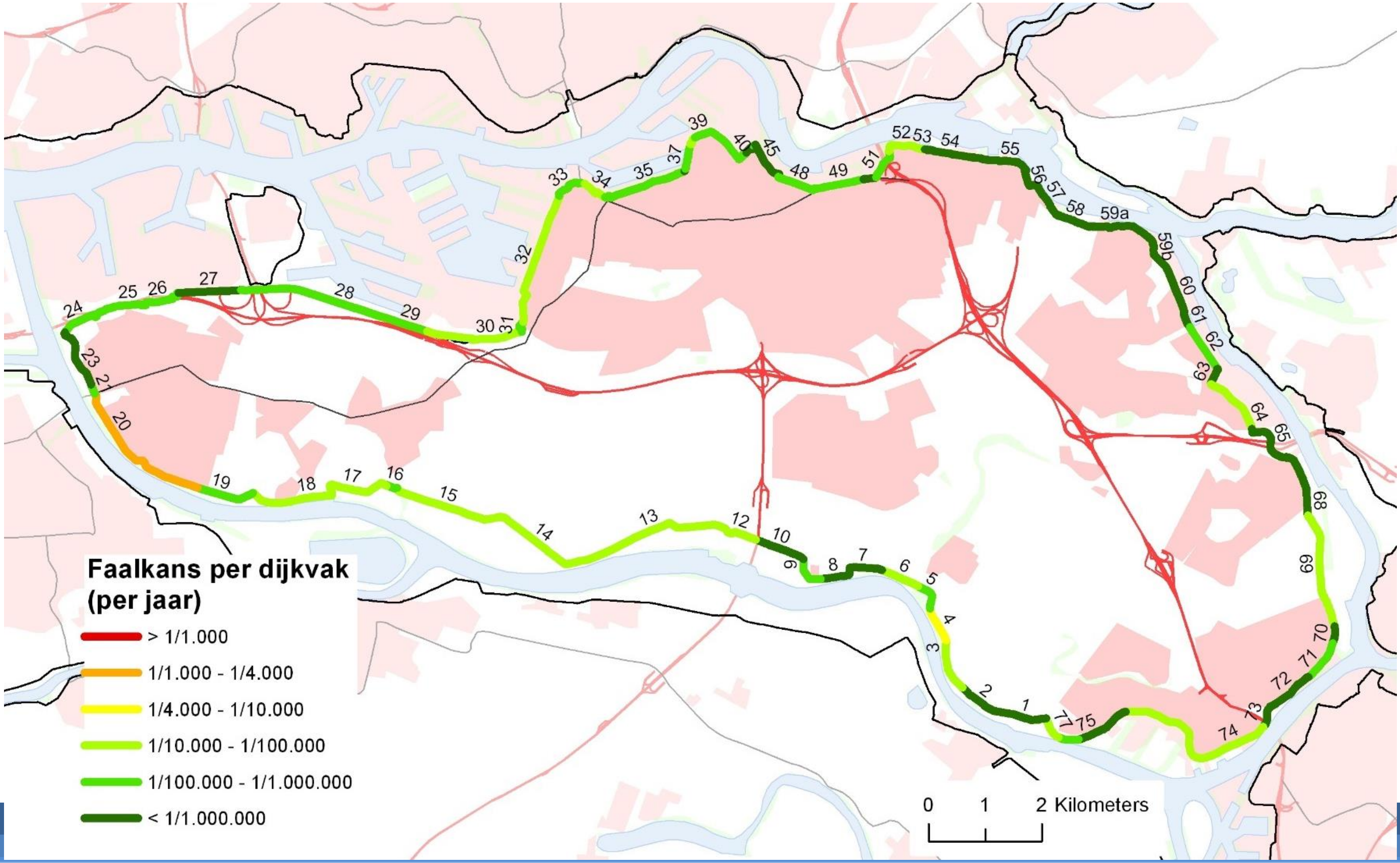
Operational

Important aspects:

- Budget constraints
- Scientific progress



2. Calculate failure probabilities



Individual risk

Probability of dying at a particular location:

$$IR(x,y) = \sum_i (1 - P_{evacuation}) P_{f,i} P_{d|f,i}(x,y)$$

Probability of succesful evacuation

Probability of flood scenario i

Probability of dying at location (x, y) given scenario i