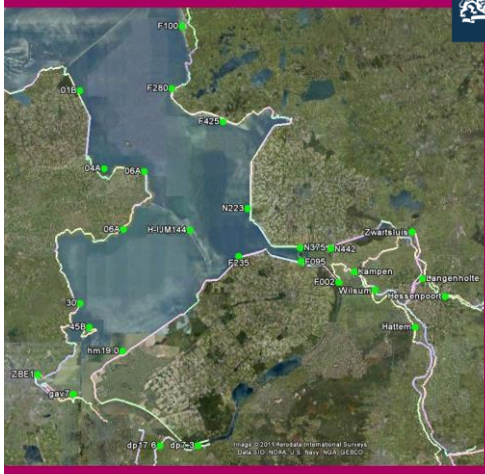

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Economical optimal water safety in a multi-level system

a new method applied to the Lake IJssel region

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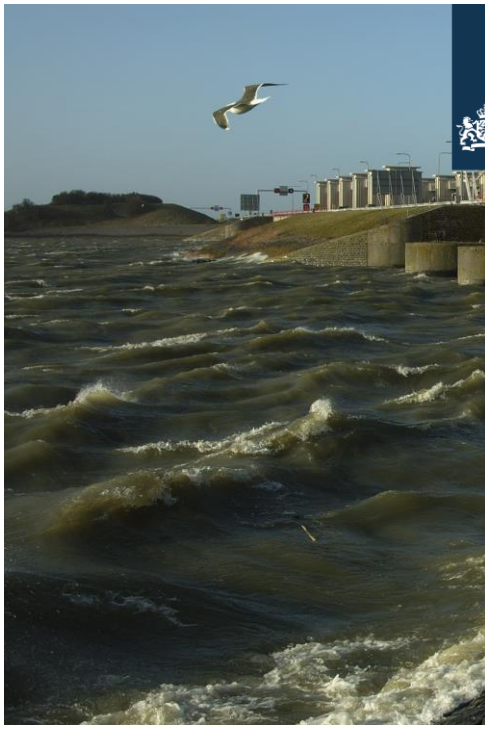
CPB Netherlands Bureau for Economic Policy Analysis

Centraal Planbureau



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Content

- Policy questions and other aims
- Economical optimal water safety?
- New approach: Diqe-Opt model
  - Flood probabilities
  - Investment costs
  - Costs in case of flooding
- Results

Policy questions and other aims

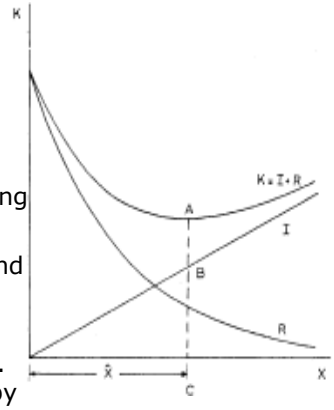
- Main policy questions from Ministry:
  - What are the economic optimal flood probabilities of type B barrier dams: Afsluitdijk and Houtribdijk?
  - What are the costs and benefits of different methods for controlling water levels in Lake IJssel and Lake Marken?

- Other project aims:
  - Assess cost and benefit of recent Cabinet decision to renovate the Afsluitdijk.
  - Develop a general applicable model to assess economical optimal water safety in a multi-level system
  - What are the costs (and benefits) of additional water storage in Lake IJssel?

Economic optimal water safety

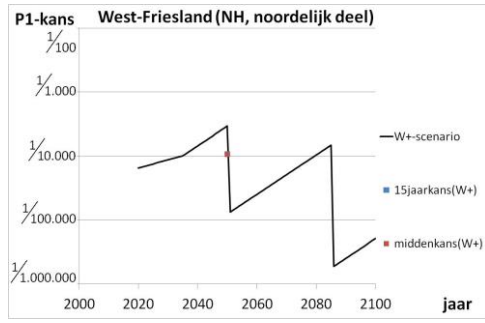
- **Objective: minimize**
  - Investment costs +
  - Expected flood risk costs

- Current approaches:
  - Van Dantzig (1956):optimal heightening
  - Eijgenraam (2005) : optimal timing and heightening
  - Deltares, CPB, Tilburg University et al. (2011): extension of 2005 approach by allowing multi-dike segments



Typical result of economic optimal water safety

- Saw tooth pattern.
- Heightening of dikes every 30 years or so
- Gradually decreasing optimal flood probability due to economic and population growth



All current approaches

Important prerequisites:

- Consider a single dike ring area
- No independency of dike ring areas
- All locations at a dike ring area fail under identical circumstances

These prerequisites do not apply to the IJsselmeer region

Hence: a new model is needed! Called the Diqe-Opt model

Characteristics of the Diqe-Opt model (1)

For Lake IJssel: 3 flood probabilities

P1 = flood probability when barrier dam intact

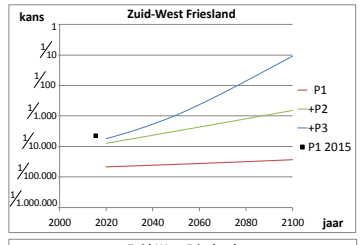
P2= flood probability while barrier dam is failing

P3 = flood probability in period while barrier dam is broken and not yet repaired

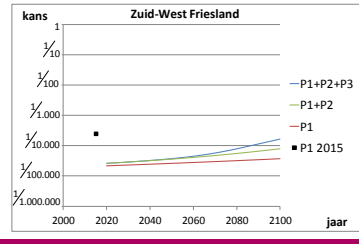
All flood probabilities were determined by using standard hydrologic model

P2 and P3 represent interdependencies

At present (barrier dam 1/250): P2 and P3 are relatively large.



After strengthening (barrier dam to 1/100.000): P2 en P3 significantly smaller.



barrier dam = 'Afsluitdijk' in 2020

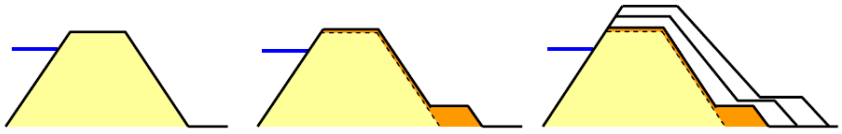
Characteristics of the Diqe-Opt model (2)

Maximum flexibility towards modeling of:

- flood probabilities
- investment costs for strengthening a dike

Previous models: height is all important

At present: other failure probabilities than overtopping: piping and slope instability need to modeled as well.



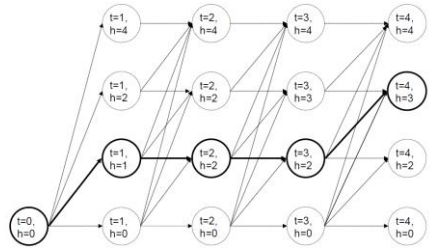
Required input data

- **Flood probabilities**: 'Hydra-VIJ'-model from Rijkswaterstaat, operated by Deltares with additional calculations from CPB
- **Investment costs** of dike heightenings and strenghtening: data from Deltares, Rijkswaterstaat and previous CPB-studies.
- **Damage costs** in case of flooding: extensive simulations of economic damage, casualties and evacuates ('HIS-SSM' model)
  - Deltares from previous study "Water safety in de 21st century"

Mathematics of the Diqe-Opt model

- Flood Probability, dependent on:
  - year
  - height/strength type B barrier
  - height/strength type A barrier
  - Scenario: 'climate' and 'water control method'
- Mixed Integer Programming model
  - Operations Research
  - model : GAMS
  - solver: CPLEX
- Optimization and 'what if'-analyses

Modeling idea: shortest path or minimal costs flow



Results ! (1)

Two - Dutch - reports :

- **2012:** What are the costs and (safety) benefits of 'pumping' and 'discharging and raising the water level'?
  - including additional fresh water in summer period.
- Pumping is much cheaper!
- Raising water not needed for fresh water usage
  - Small water level increase in summer time:
    - Small investment costs
    - No additional safety risks
    - Sufficient for the near future

Results ! (2)

- **2014**: Economical optimal water safety in Lake IJssel region?

Economical optimal flood probability:

- **Afsluitdijk**:
  - pumping 1/9.000
  - discharging 1/2.500
- **Houtribdijk**:
  - pumping: 1/60
  - discharging: 1/200

(current: both 1/10.000)

Pumping reduces flood risk.... and may avoid costly dike strengthening

17 dike ring areas (type A barriers):

- minority needs tighter flood probabilities

Dutch reports, no English publication (yet)

2012:

http://www.cpb.nl/publicatie/een-snelle-kosten-effectiviteitanalyse-voor-het-deltaprogramma-ijsselmeergebied

2014:

http://www.cpb.nl/publicatie/economisch-optimale-waterveiligheid-het-ijsselmeergebied

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