Flood protection standards based on cost benefit analysis and casualty risk analysis

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Workshop Alberta Floods, Calgary, February 18-19, 2014
Flood prone areas in The Netherlands
Why are we working so hard on flood protection?

- international catchment
- 400 km river Rhine-Meuse
- 350 km coastline
- NL vulnerable to floods:
  - 60% of area
  - 9 million inhabitants
  - 1800 billion euro invested value
  - 65% GNP

our future depends on a good protection against floods
Time line for legal flood protection standards

1953
Dutch flood disaster

1958
1st Delta committee: standards for coastal areas in Delta Act

1993, 1995
Critical high water situations

1977
Standards for other areas added

2006
Vice Minister initiated update of standards
Cycles of setting and checking standards

Every 5 years (as of 1996):

- Safety assessments of dikes
- If dikes do not pass the test → raise or strengthen them
- 3 tests completed, shown some backlog, large improvement schemes

Every 25-50 years:

- Update the protection standards
- since 60’s: economy growth factor 6, population growth 50%
- Standards 10 times more severe have been suggested
System of legal protection standards

History of legal standards:

1953: Floods in Southwestern part of the NL
1958: (First) Delta Committee: protection standards for coastal areas
1977, 1993, 1995: protection standards for other areas proposed by other Committees
1996: Flood Defenses Act: protection standards enforced by law

Hence, existing legal protection standards:

1. have no common, scientific basis
2. are not up to date
Static optimization: how much?

Optimal protection when marginal benefits equal marginal costs

Costs (euro)

Levee height (cm)

Total costs

Investment costs

Expected damage cost
Characteristics of optimization problem

- Climate change $\rightarrow$ probabilities increase
- Economic growth $\rightarrow$ consequences increase
- Fixed investment costs $\rightarrow$ invest periodically
- Do not update standards too often (2050)

$\rightarrow$ Derive economically efficient protection standards from an optimal long term investment strategy:
• Minimize present value of sum of investment cost and expected damages over long term horizon
• Questions to answer:
  • when to invest?
  • where to invest?
  • how much to invest?

Optimization model:
• Advanced optimization algorithms (AIMMS)
• User friendly software package (OptimaliseRing)
Dynamic approach: when, how much and when again?

Probability

- **Probability of flooding**

- **When?**

- **How much?**

- **When again?**
Dutch flood expert team wins 2013 Edelman Award with method to calculate the economic optimal dike heights

April 9th, 2013 by nwp

A team of Dutch organisations specialized on flood control, headed by the Dutch Delta Program Commissioner, won the 2013 Franz Edelman Award for Achievement in Operations Research and the Management Sciences in San Antonio on April 8.

The Dutch organisations Delta Commissioner of Holland, Ministry of Infrastructure and the Environment, CPB Netherlands Bureau for Economic Policy Analysis, Delft University of technology, Tilburg University, research institute Deltares, consultancy Efficient and other partners used the method to calculate the economic optimal dike heights.
1. Costs of dike improvements

2. Flood probabilities
   • Existing flood probabilities
   • Effect of climate change (-scenarios)
   • Effect of dike improvements

3. Flood consequences
   • Material damages, business interruption, indirect effects, environmental damages, loss of life,..: all monetized
   • Effect of climate change and economic growth (-scenarios)
Flood patterns due to dike breaches

- 15 billion damage
- 580,000 affected
- About 280 killed
Assessment of “consequences”

vulnerability

Damage Module

exposure

Land use

Inundation depth

Damage function

Damage
Findings from Cost Benefit Analysis

Efficient standards

Existing standards
Conclusions on flood protection standards

Increase protection standards in:

- dike rings near Rotterdam
- dike ring Almere
- dike rings along Rhine and Meuse
## Comparison of policy alternatives

<table>
<thead>
<tr>
<th></th>
<th>Investment costs</th>
<th>Expected flood damage costs</th>
<th>Total costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>No change</td>
<td>0</td>
<td>15</td>
<td>15</td>
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<tr>
<td>2\textsuperscript{nd} Delta Committee</td>
<td>11.5</td>
<td>1.5</td>
<td>13</td>
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<tr>
<td>Cost benefit analysis</td>
<td>3.7</td>
<td>5</td>
<td>8.7</td>
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</table>
Acceptance of recommendations

- Accepted by 23 Water Boards
- Survived four governments
- Strong support by current government

Source: Rijkswaterstaat
1. **Individual:**
   - Local Individual Risk (LIR): The annual probability to die at a certain location due to flooding (taking into account possibilities for evacuation)
   - Aim: a base level of safety for everyone, everywhere

2. **Societal:**
   - Societal or group risk (GR): The probability of large numbers of casualties in a single event (eg. more than 10, 100 or 1000)
   - Aim: to prevent social disruption
Method: Mortality & fatality analysis

- Inhabitants
- People present at onset of flooding
- Casualties

Preventive evacuation

Mortality

- Flood characteristics
- Fleeding/sheltering during flooding
- People vulnerability & behaviour

Mortality functions
Local Individual Risk (LIR)

Probability per year of drowning in a flood at a certain location

Calculate from:
- Flood scenarios
- Flood probabilities
- Mortality = f(h, dh)
- Preventive evacuation
Setting a standard for the individual risk

Provide a base level of safety everywhere (within a dike ring).

Compare to the safety standard for industrial risk:
No urban development within $10^{-6}$ contour

However, flooding is not an industrial risk!
Difference between anthropogenic and natural cause?
Local Individual Risk

Current situation With new standards in 2050
‘Group risk’ expressed in a FN curve

- WV21 Riverrine area
- Transition area
- Tidal river area
- Riverrine area
- Upper river area

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Deltanet
Apply a risk averse safety standard?
Advisory Committee Water
Chair: Prince of Orange Willem-Alexander (King as of April 30, 2013)

“… the studies provide solid building blocks for the further discussion on an updated and robust flood risk management policy”

March 12, 2012
Policy Response

- No general tenfold increase in protection level
- Basic individual level of safety of $10^{-5}$ per year
- Regionally higher standards based on ‘group risk’ and cost-benefit analysis

- Mid 2014: proposal from Delta Commissioner to the Minister
- 2015: proposal to Parliament
<table>
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<th>The Dutch Delta Approach: 5 D’s</th>
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<tr>
<td><strong>Delta Programme</strong></td>
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<td><strong>Delta Decisions</strong></td>
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<td><strong>Delta Fund</strong></td>
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<td><strong>Delta Act</strong></td>
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<td>Yearly report to Parliament</td>
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<td>Strategic, (2015)</td>
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<td>Supervising adequate</td>
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<td>(regional) multi-governmental</td>
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<td>implementation (2010)</td>
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<td>1 billion euro/yr (&gt; 2020) (2011)</td>
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<td>“Anchoring” Delta Commissioner, programme</td>
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<td>and fund (2012)</td>
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<td>Country</td>
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| Netherlands | 1/10.000 – 1/250 (primary defenses), based on CBA  
1/1000 – 1/10 (regional defenses), based on impact analysis |                                                                         |
| UK          | 1/1000 – 1/200 Based on cost-benefit analysis and value for money  
1/1000 Special standard for city of London |                                                                         |
| Denmark     | 1/1000 – 1/200 Coastal: Thyborøron, Højer, Tønder and Ribe |                                                                         |
| Germany     | <1/100 Coastal: 1% plus a safety margin for wave run-up  
1/500 City of Hamburg |                                                                         |
| Ireland     | 1/100 Based on cost-benefit analysis  
1/200 (coastal) |                                                                         |
| USA         | 1/100 Based on insurability of real-estate |                                                                         |
| Australia   | 1/100 Based on cost-benefit analysis? |                                                                         |
| Hong Kong   | 1/200 (city) Drainage system, based on impact analysis  
1/50 (rural) |                                                                         |
Dynamic optimization: when and when again? (1)

Climate change and subsidence of soil
- Flood probability increases

Growth of population and wealth
- Damage by flooding increases

Expected damage increases
Mortality functions

Maximale waterdiepte [m] vs. mortaliteit

- stijgsnelheid >= 4 m/hr
- stijgsnelheid = 3 m/hr
- stijgsnelheid = 2 m/hr
- stijgsnelheid = 1 m/hr
- stijgsnelheid < 0.5 m/hr
Project characteristics

- Period: 2006-2011
- Budget: over 4 million euro
- Dozens of persons
- Many disciplines

Source: Rijkswaterstaat
... and a framework for decisions

- **We stay in the (flood prone) part of the Netherlands**
- Safety against flooding to be based on risk approach, incl. casualties, economic damage and disruption
- Solidarity among inhabitants and generations
- Work together with natural processes (“building with nature”), water system approach
- Flexible strategy (“no regret”, framework, no blueprint) to deal with uncertain future (**adaptive delta management**)
- Multifunctional design of measures → added value for society
issues to face; Delta under pressure

- More/extreme storms
- Sealevel rise
- Increased erosion
- Salt intrusion
- Subsidence
- More/intense rainfall
- spatial/economic developments
- Increased river discharge
- Decreased river discharge
Urbanisation in The Netherlands