The Delta Project: Past and Future

ASCE Met Section Infrastructure Group Seminar 2009

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www.adaptation.nl
Content

1. Geographical location
2. History of Delta project
3. Climate Change: New Delta Project
Content

1. Geographical location
2. History of Delta project
3. Climate Change: New Delta Project
R’dam
Flood 1855
<table>
<thead>
<tr>
<th></th>
<th>NY 1938</th>
<th>Zeeland 1953</th>
</tr>
</thead>
<tbody>
<tr>
<td># casualties</td>
<td>600</td>
<td>1800</td>
</tr>
<tr>
<td>Max waterlevels</td>
<td>~4-6m</td>
<td>~4m</td>
</tr>
<tr>
<td># houses destroyed</td>
<td>14000</td>
<td>49000</td>
</tr>
<tr>
<td>damage</td>
<td>300 mill. U$</td>
<td>700 mill. U$</td>
</tr>
</tbody>
</table>
1. Geographical location

2. History of Delta project

3. Climate Change: New Delta Project
Delta-act → Delta Plan

The Netherlands
Safety Standard per Dike-ring area
Legend
- A: 1/10,000 per year
- B: 1/4,000 per year
- C: 1/2,000 per year
- D: 1/1,250 per year

- High grounds (also outside The Netherlands)
- Primary water defence outside The Netherlands

North Sea

Belgium

Germany
Series of dams and barriers
Arguments for Delta plan

- Full protection: Storm surge may not happen again
- Dams & barriers shorten the coastline: raising 1000 km of dikes is more expensive
- Create fresh water reservoirs & protection against salt intrusion
- Fresh water as potential for recreation
Brouwersdam
Haringvliet Sluices
Haringvliet sluices
Haringvliet sluices
Value of Estuary: Eastern Scheldt Barrier

- Rotterdam
- Antwerp
- Tide
- Tide free shipping route
- Mussel fishing
Eastern Scheldt barrier: 3 barriers over 3 km
Maeslantbarrier; Accessibility Rotterdam harbor
<table>
<thead>
<tr>
<th>Construction costs</th>
<th>Year in operation</th>
<th>Net present value 2007 million € [Disc rate 2%]</th>
<th>Net present value 2007 million € [Disc rate 4%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storm Surge barrier Hollandse IJssel</td>
<td>1954</td>
<td>98</td>
<td>126</td>
</tr>
<tr>
<td>Haringvliet barrier</td>
<td>1961</td>
<td>1,464</td>
<td>1,750</td>
</tr>
<tr>
<td>Brouwersdam</td>
<td>1961</td>
<td>353</td>
<td>421</td>
</tr>
<tr>
<td>Hellegatsplein and Volkerak sluices</td>
<td>1961</td>
<td>477</td>
<td>570</td>
</tr>
<tr>
<td>Grevelingen dam</td>
<td>1961</td>
<td>165</td>
<td>197</td>
</tr>
<tr>
<td>Storm Surge barrier Oosterschelde</td>
<td>1986</td>
<td>3,850</td>
<td>6,161</td>
</tr>
<tr>
<td>Compartmentworks</td>
<td>1984</td>
<td>837</td>
<td>1,295</td>
</tr>
<tr>
<td>Canal through Zuid-Beveland</td>
<td>1984</td>
<td>915</td>
<td>739</td>
</tr>
<tr>
<td>Maeslant storm surge barrier</td>
<td>1997</td>
<td>477</td>
<td>559</td>
</tr>
<tr>
<td>Europoort barrier and Hartel barrier</td>
<td>1997</td>
<td>253</td>
<td>259</td>
</tr>
<tr>
<td><strong>Total costs [Billions Euro]</strong></td>
<td></td>
<td><strong>8,9</strong></td>
<td><strong>12,1</strong></td>
</tr>
</tbody>
</table>
Content

1. Geographical location

2. History of Delta project

3. Climate Change: New Delta Project
Climate Change / Sea level rise

![Graph](image)

- **Return Period [years]**
  - Delfzijl 1884-1999
  - Hoek van Holland 1888-1999

- **Surge [m]**

- **Gumbel variate** = \(-\log(-\log(i/(n+1)))\)

- **1953**
Climate Change / Sea level rise

![Graph showing climate change and sea level rise over time. The graph plots surge against return period in years. The data points for Delfzijl 1884-1999 and Hoek van Holland 1888-1999 are shown with blue and red lines, respectively. The Gumbel variate is defined as $-\log(-\log(i/(n+1)))$. The year 1953 is marked on the graph.]
Socio Economic trends

- Pop growth: 22 milj (+2.5%)
- Economic growth: 10 milj (+1%)
- Pop decrease: 16 milj

2015 - 2100
Rotterdam 2000

http://takeoff.to/rotterdam
landgebruik

"Gezicht op Nieuw Amsterdam" by Johannes Vingboons (1664)
landgebruik
landgebruik
Land use 2015

16 Mil. inhabitants

Source: project Aandacht voor Veiligheid 2007
www.adaptation.nl
Land use 2100

W-scenario 2100

22 Mil. inhabitants

Source: project Aandacht voor Veiligheid 2007

www.adaptation.nl
Risk based approach

- Socio – economic impacts:
  - Casualties
  - Direct damage
  - Indirect damage
- Probability of an extreme flood
- Risk = probability * damage

Resilience
- Adaptive capacity (o.a. finance, recovery, governance ....)
<table>
<thead>
<tr>
<th>City</th>
<th>Current Exposure</th>
<th>Annual Average Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Population (000)</td>
<td>Assets (US$ bil)</td>
</tr>
<tr>
<td></td>
<td>Approximate Protection Standard (Return period in years)</td>
<td>Population (000/yr)</td>
</tr>
<tr>
<td>London</td>
<td>397</td>
<td>60</td>
</tr>
<tr>
<td>Shanghai</td>
<td>2,353</td>
<td>73</td>
</tr>
<tr>
<td>Osaka</td>
<td>1,373</td>
<td>216</td>
</tr>
<tr>
<td>New York</td>
<td>1,540</td>
<td>320</td>
</tr>
<tr>
<td>Tokyo</td>
<td>1,110</td>
<td>174</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>839</td>
<td>128</td>
</tr>
<tr>
<td>Rotterdam</td>
<td>752</td>
<td>115</td>
</tr>
<tr>
<td>New Orleans</td>
<td>1124</td>
<td>234</td>
</tr>
</tbody>
</table>

Nichols et al, 2008
Risk: probability * Damage

Development of flood risk for the Netherlands

- Only 150cm SLR
- Only 85cm SLR
- Only 60cm SLR
- Only 60cm SLR
- Only high economic growth
- Only low economic growth

Current risk:
~100 milj. Euro/year
Uncertainty

Source: http://info.insure.com, 2002

<table>
<thead>
<tr>
<th>Rank</th>
<th>Location</th>
<th>Possible insured losses*</th>
<th>Potential total economic losses**</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miami/Ft. Lauderdale, Fla.</td>
<td>$61.3 billion</td>
<td>$122.6 billion</td>
</tr>
<tr>
<td>2</td>
<td>New York City, N.Y.</td>
<td>$26.5 billion</td>
<td>$53 billion</td>
</tr>
<tr>
<td>3</td>
<td>Tampa/St. Petersburg, Fla.</td>
<td>$25.1 billion</td>
<td>$50 billion</td>
</tr>
<tr>
<td>4</td>
<td>Houston/Galveston, Texas</td>
<td>$16.8 billion</td>
<td>$33.6 billion</td>
</tr>
<tr>
<td>5</td>
<td>New Orleans, La.</td>
<td>$8.4 billion</td>
<td>$16.8 billion</td>
</tr>
<tr>
<td>6</td>
<td>Mobile, Ala.</td>
<td>$6.0 billion</td>
<td>$12 billion</td>
</tr>
<tr>
<td>7</td>
<td>Boston, Mass.</td>
<td>$5.1 billion</td>
<td>$10.2 billion</td>
</tr>
<tr>
<td>8</td>
<td>Biloxi/Gulfport, Miss.</td>
<td>$5.1 billion</td>
<td>$10.2 billion</td>
</tr>
<tr>
<td>9</td>
<td>Myrtle Beach, S.C.</td>
<td>$4.3 billion</td>
<td>$8.6 billion</td>
</tr>
</tbody>
</table>

New Orleans files $77 billion claim against Corps

POSTED: 2:47 a.m. EST, March 2, 2007

STORY HIGHLIGHTS
- Thursday was last day for residents to file claims under Federal Tort Act
- Bush visits Gulf Coast region, vowing to “stay committed” to recovery
- Corps has 6 months to either accept, settle or reject claims
- Corps’ designed levee system that was supposed to protect the levee-hung city

NEW ORLEANS, Louisiana (CNN) -- The city of New Orleans filed a $77 billion damage claim against the Army Corps of Engineers Thursday for flooding that inundated the city when levees failed after Hurricane Katrina in August 2005.
Erosion: work with nature
NY area: +/- 4 million m³ sand/ year
Netherlands: +/- 20 million m³ sand/ year
New Delta Plan

- Extra pumping capacity
- River widening
- Beach Nourishment
Building codes, Innovation in Architecture
## Costs of adaptation

<table>
<thead>
<tr>
<th>Scenario's</th>
<th>2040</th>
<th>2100</th>
<th>2100</th>
<th>2100</th>
<th>Far Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLR [cm]</td>
<td>24</td>
<td>60</td>
<td>85</td>
<td>150</td>
<td>500</td>
</tr>
<tr>
<td>Max Discharge Rhine [m3/s]</td>
<td>16.800</td>
<td>18.000</td>
<td>18.000</td>
<td>18.000</td>
<td>18.000</td>
</tr>
<tr>
<td>Max Discharge Meuse [m3/s]</td>
<td>4200</td>
<td>4.600</td>
<td>4.600</td>
<td>4.600</td>
<td>4.600</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Re enforcement Leves [Billions Euros]</th>
<th>2.7</th>
<th>5.5</th>
<th>5.5</th>
<th>5.5</th>
<th>5.5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.3</td>
<td>4.2</td>
<td>4.2</td>
<td>4.2</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>1.8</td>
<td>2.6</td>
<td>6.1</td>
<td>36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Beach nourishment [Billions Euros]</th>
<th>1.9</th>
<th>6.4</th>
<th>9.1</th>
<th>16.0</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.1</td>
<td>3.8</td>
<td>5.4</td>
<td>9.6</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>0.4</td>
<td>0.6</td>
<td>1.1</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>1.9</td>
<td>2.3</td>
<td>2.6</td>
<td>3.4</td>
<td>8</td>
</tr>
</tbody>
</table>

| Total [Billions Euros] | 9   | 24  | 30  | 46   | >80  |
When to invest?

Risk

Acceptable level of risk

Time

2006 2050 2100
Original costs in 1970: 1.5 Billion Euro’s (2007)

Option 1. Replacement of doors for 60cm = 100 Million Euro
Option 2: replace whole barrier = 1 Billion Euro’s
Lifetime barrier = 100 years

Design criteria in 1970 = 20cm sea level rise in 100 years

→ Barrier is 50 years old: “only 10cm sea level rise to go”
→ With a SLR of 60cm/100 years, the barrier would not fit design criteria in ~2025
→ In 2025 invest 100 Million Euro to replace doors (replacement whole barrier in 2070-2120)
However: If SLR is 150cm

then replacement of whole barrier would be much earlier, and hence, replacing only doors in short term is not an option
Conclusions

• Barrier concept works, but adjustments needed:
  – Environmental aspects
  – Shipping

• Working with nature
  – Beach nourishment
  – River widening

• Architecture / building codes

• Climate change poses new challenge
  – How to design measures such they are flexible to accommodate different future scenario’s
Thanks!

www.adaptation.nl
www.deltacities.com