How the tides changed in the Schelde-estuary under influence of natural changes and human interference

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Lisboa, 6-9 November 2013
How the tides ...

Gravitational attraction earth - moon

Centripetal acceleration around barycenter

- Tide generating forces
  - Moon
  - Sun (46% of M-E)

- Variations due to:
  - Elliptical orbits
  - Inclinations
  - Continents

- Predictable (harmonic analysis)
Temporal variations

• Semi-diurnal (12h25)
• Diurnal inequality (24h50)
• Spring-neap cycle (14 days)
• Nodal cycle (18.6 years)
... in the Schelde-estuary ...
Tidal propagation: processes

Amplification ~ convergence
Damping ~ friction

Source: Vandenbruwaene et al., 2013
Tidal propagation: processes

Amplification ~ convergence

Damping ~ friction

Amplification ~ convergence

Damping ~ friction
... tides changed ... (LT)

Distance to Vlissingen [KM]

Tidal range (Coen et al., 1988)
... but also outside the Schelde!

Source: Tide toolbox
Tides: up-estuary

Spring
Mean
Neap

High water

Low water

Antwerpen

Tielrode
Tides: up-estuary

Rising (LW => HW)

Falling (HW => LW)

Delay of HW to HW Vlissingen
... natural changes and human interference.

Sea level rise
18,6 year nodal cycle

Atlantic Multidecadal Oscillation
... natural changes and human interference.

![Map of the area in 1807](image1.png)

- Sea level rise
- Poldering
- Sediment extractions
- Channel enlargement
- Canalisation
- Hard bordering

![Map of the area in 2011](image2.png)
Human interference

• Numerical models (1D, 2D)
• Initial effect of individual measures
  • Sea level rise
  • Inverse poldering
  • Channel enlargement (with/without extraction)
  • Sand mining
  • Changes in fresh water discharge
  • Canalisation
• Analysis of water level and tidal volumes
Human interference

Sea level rise

Inverse poldering

Sand mining

Channel enlargement

Sum of individual initial effect of measures • real evolution
Tides ↔ sediments?

• Tides (asymmetry) ~ residual sediment transport
• Sediment ~ hydraulic resistance

Not for the Schelde!

Winterwerp, 2013
Conclusions

• Gradual increase HW ~ sea level rise + human activities
• Stepwise decrease of LW ~ human activities
• Importance of morphological evolutions (indirect effect)
  => important increase of tidal range + maximum up-estuary
• Similar evolution in other estuaries (Elbe, Weser, Loire,...)

• Future challenges (~ “morpho-system” services):
  • Reduction high water level ~ inundations
  • Reduction tidal dynamics ~ safety + ecology
  • Measures creating “win-win”-situations
  • “Global” measures with effects in whole estuary
Measures: present and future

Crucial to strive for win-win-situations!

... or doing more with less!
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