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Avulsion in action: sedimentation pace and upstream flood water levels following a Medieval tidal-river diversion and storm surge catastrophe

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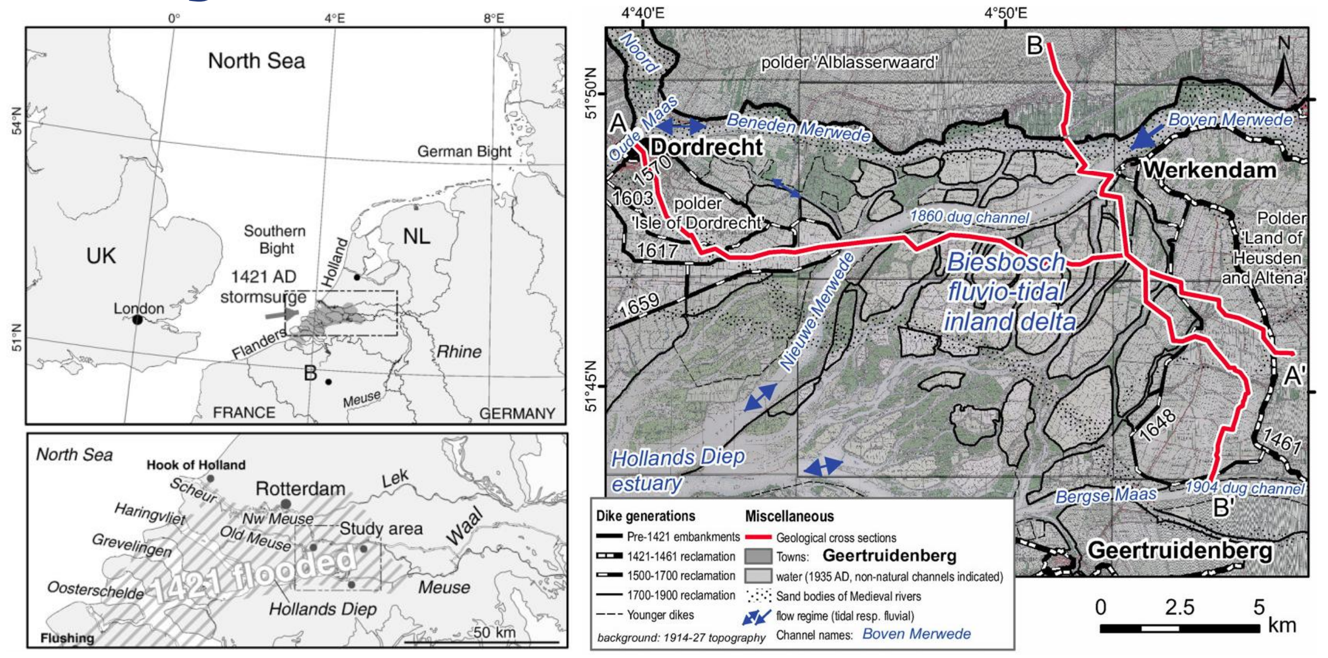
Research group
River and delta morphodynamics

Maarten Kleinhans

Objectives

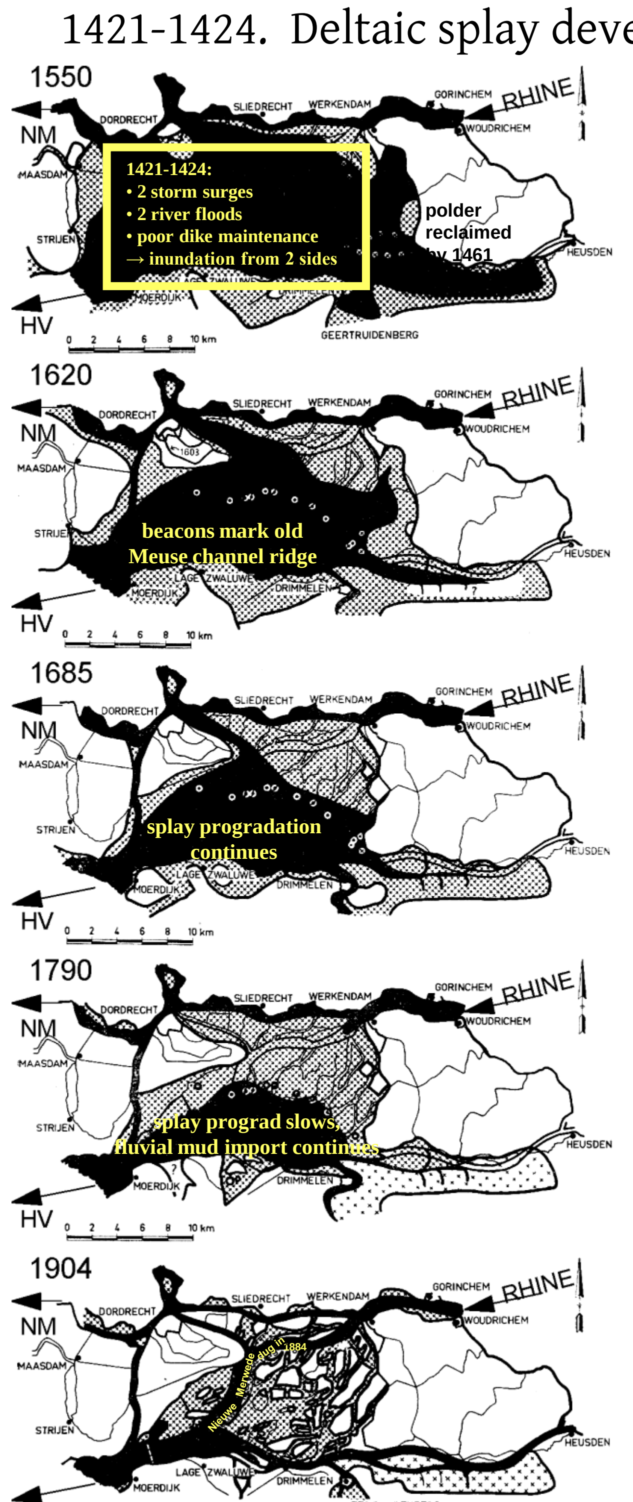
- understand which factors determine initiation of a river diversion;
- quantify pacing and morphology of sedimentation generically
- assess quantitatively the effect of sedimentation on upstream flood water levels

Study location



Historical reconstruction

1. dewatering at low tide → peat compaction (10th-15th century)
2. civil war going on → poor dike maintenance (14th-15th century)
3. two floods from the Rhine, two inundations from the North Sea 1421-1424. Deltaic splay developed since 1450:

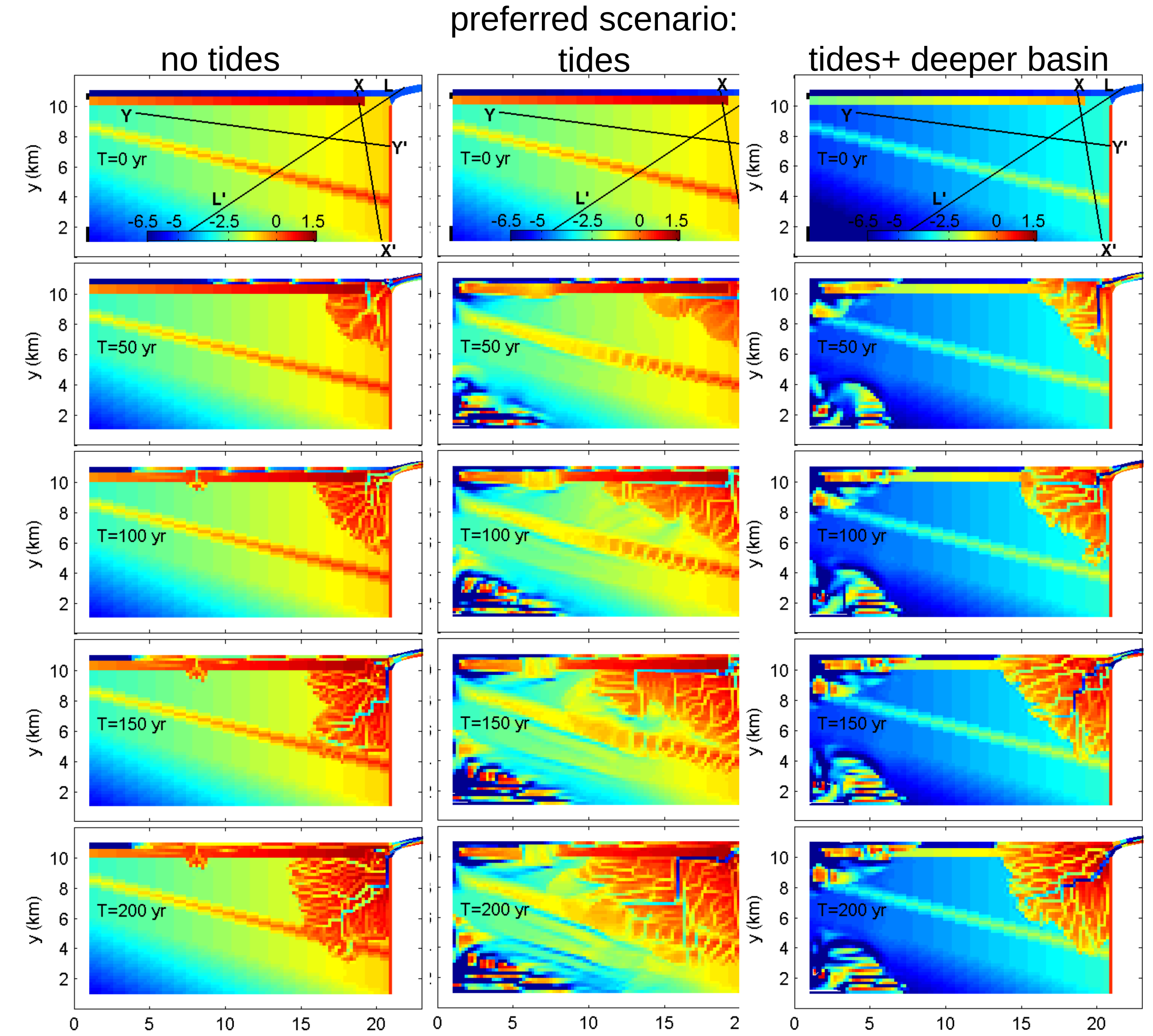


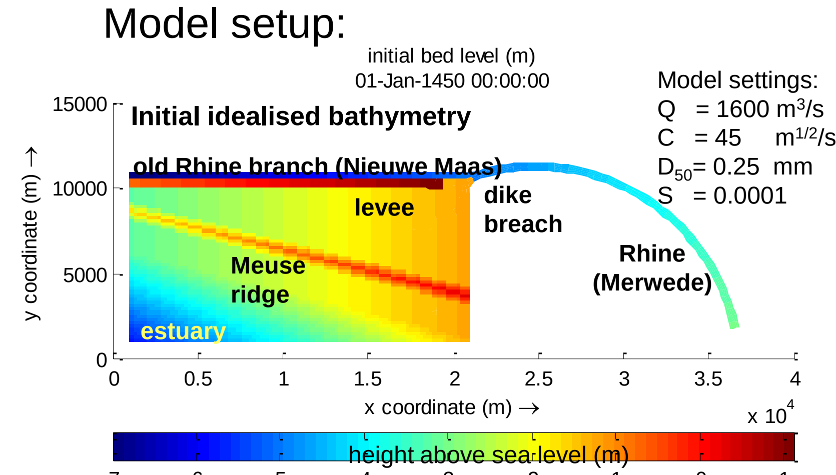
Zonneveld 1960

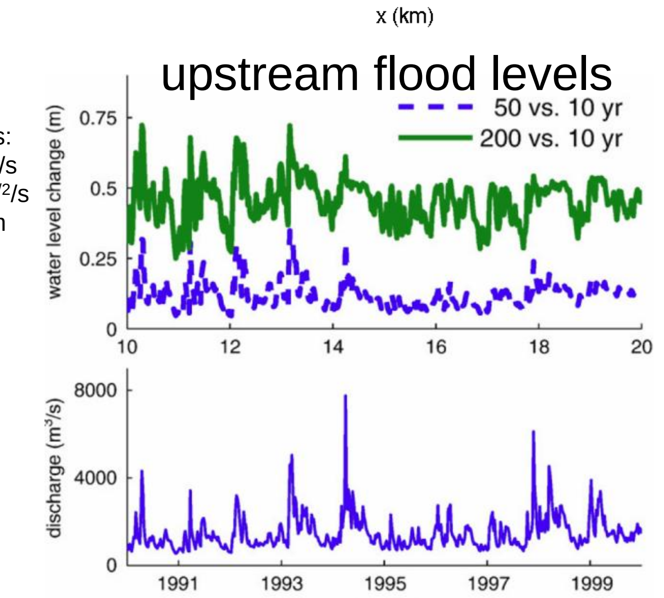
Description: Kleinhans et al. 2010

Simulated morphodynamics

- Delft3D numerical modelling:
  - 2D depth-averaged flow, spiral flow approximation
  - Engelund-Hansen sediment transport prediction
- Idealised scenarios:
  - shallow vs deep basin (initial compaction uncertain)
  - tides / no tides (effect of tides on the avulsion)
  - 1 decade of floods over 10, 50 and 200 year old delta
- Results:
  - delta builds out in avulsion cycles: mouth bar formation, back-sedimentation, avulsion
  - tides make delta much larger; deeper basin reduces tide effect
  - bifurcation unstable → old channel fills up (see poster de Haas & Kleinhans EP51C-0559 Friday 8:00 am)
  - new delta increase friction → backwater increases upstream flood levels

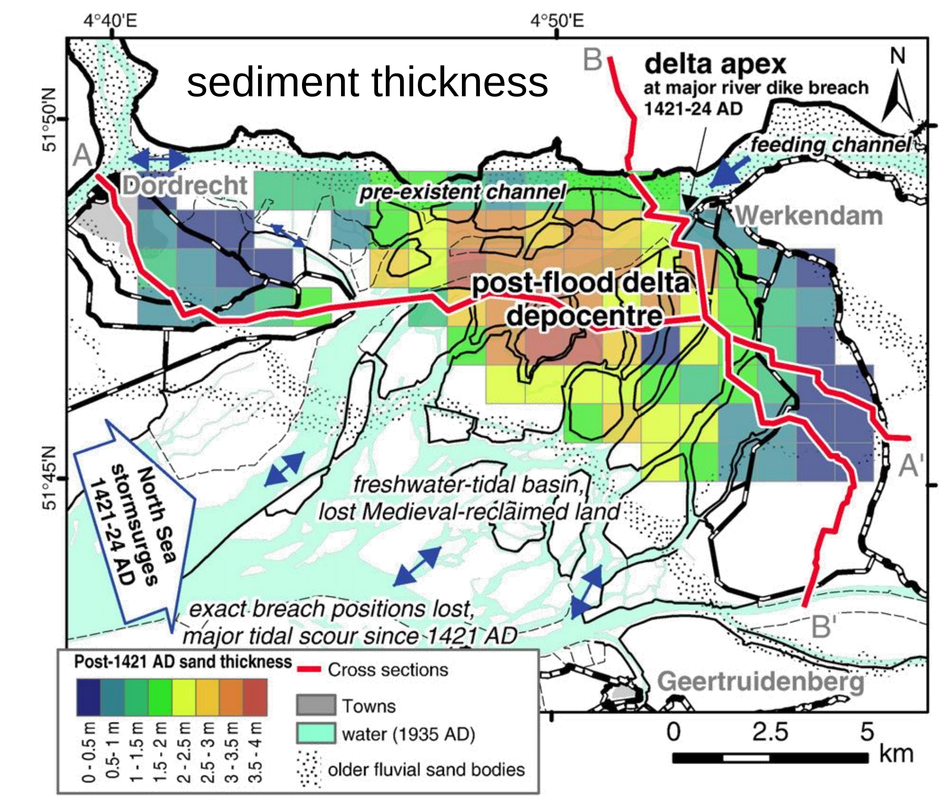




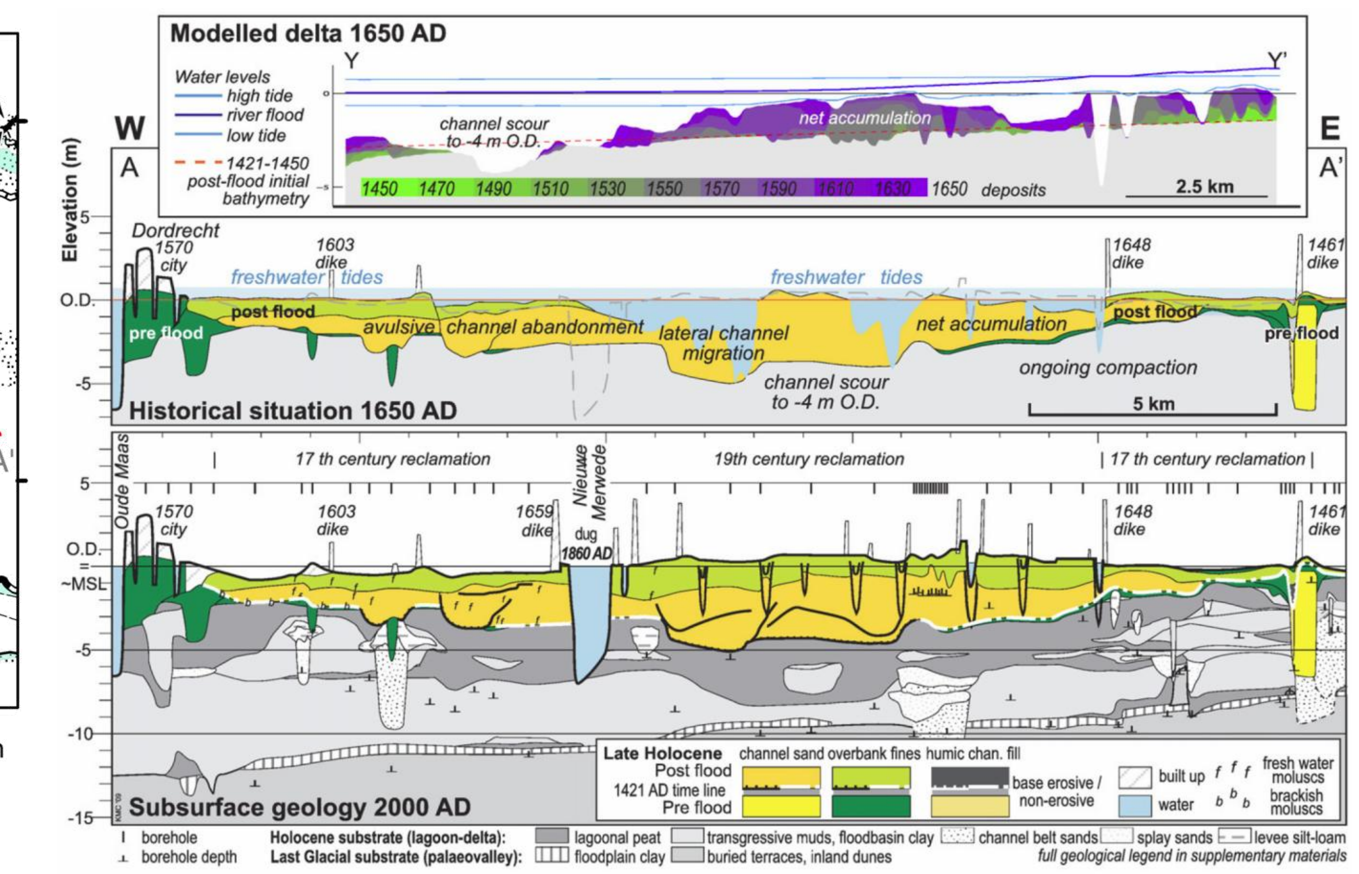


Geological reconstruction

- delta splay prograded into an inland basin (see poster Lavooi et al. EP51C-056 Friday 8:00 am)
- sediment influx = total bed sediment load of the Rhine branch



→ 151×10^6 m^3 ≈ 580000 m^3/yr ≈ 8 mm/yr



Synthesis

- Comparisons of "reconstruction" and "simulation" approach:
  - model and historical maps in good agreement on progradation rate and overall shape
  - sediment budgets from model, geology and present-day measurements in good agreement (factor 2)
- Avulsion pacing:
  - a new connection between river and estuary was forged
- Application to building new land, e.g. Mississippi delta:
  - river diversions can be used to build new land, ***but***
  - delta building is slow (centuries)
  - bifurcations (at the diversion) are unstable and rapidly change discharge and sediment division
  - upstream flood water levels increase significantly

This work is pubished as Kleinhans et al. 2010 in Earth Surface Processes and Landforms. Funding MGK: NWO-ALW

Conclusions

Ultimate causes of flooding disaster were human action (→ peat compaction) and negligence (→dike breaches)

New bifurcation was unstable and unbalanced →

- Former channel silted up (and is being dredged annually to date)
- Inland deltaic splay captured entire sediment load of the Rhine; sedimentation proceeded through cycles of mouth bar formation, channel gradient reduction, backward sedimentation, local upstream avulsion and renewed mouth bar build up;
- Increased flow resistance caused higher upstream flood water levels and no backward channel degradation

Building new land to mitigate flooding risk in subsiding deltas must account for bifurcation instability, slow delta building and increased upstream flooding risk.