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Towards the incorporation of 3D subsurface heterogeneity in hydrological models for assessing dike stability

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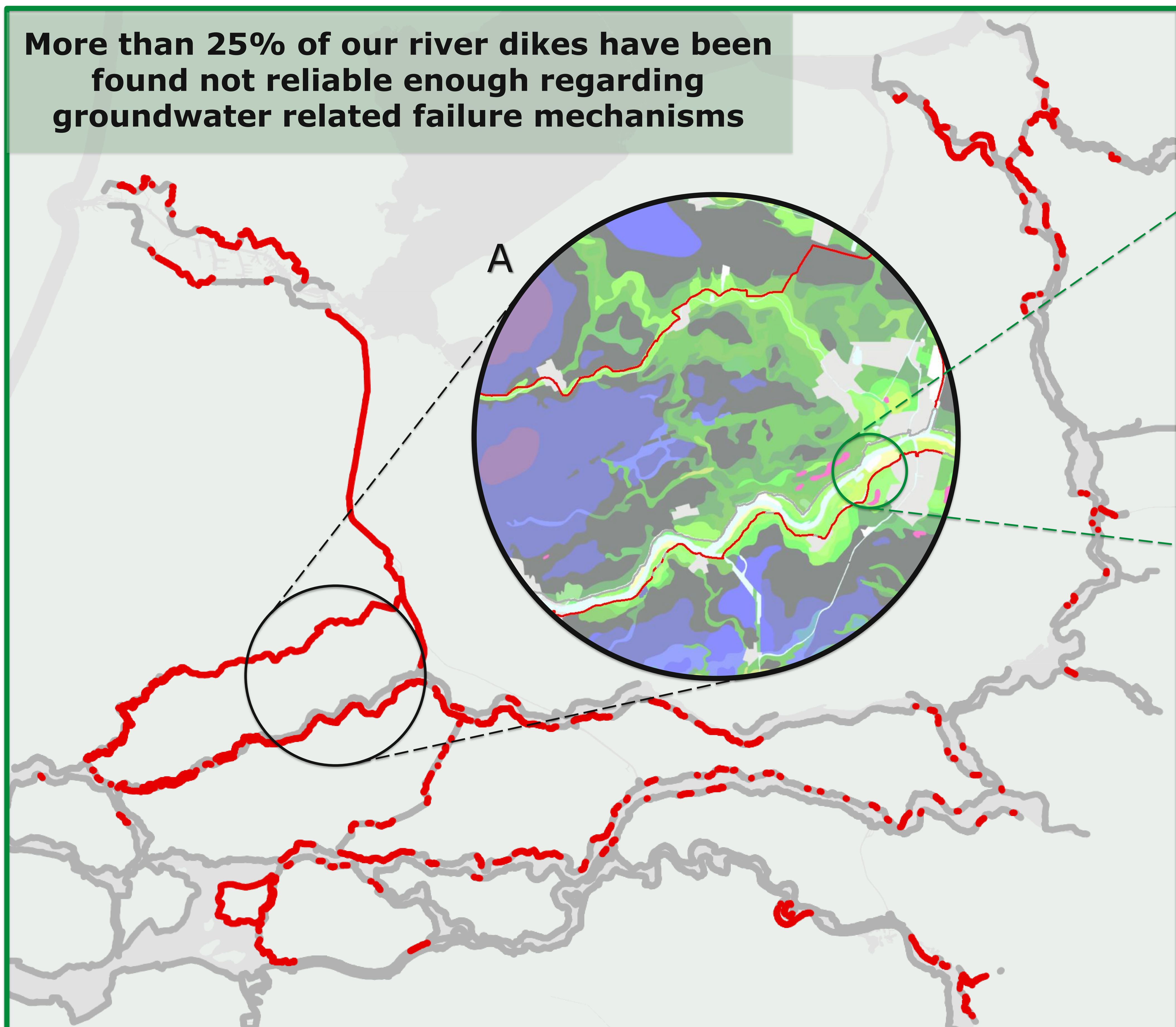
The importance of 3D subsurface heterogeneity for dike stability assessment

During high river water levels, groundwater flow and pore pressure increases underneath a dike vary, which depends on the subsurface characteristics. These are known to be highly heterogeneous and below dikes, due the spatial variability of fluvial architecture, such as connecting channel belts and units (Fig. 1A) of varying thickness (Fig. 1B). Current stability models use simple 2D approximations that are not able to capture the 3D variability present in both the subsoil and the dike core itself. The goal of this research is therefore to *enable rapid assessment of the groundwater-related failure risk of a given dike stretch with consideration of the subsurface heterogeneity*.

The importance of hydrology for dike stability assessment

Internal triggering mechanisms (e.g. slumping) are related to reduced resistance and within- and sub-dike pore pressure conditions. Increasing pore pressures can occur due to **(1)** direct seepage or **(2)** subsurface flow and base pressure. Other failure mechanisms, as piping, are strongly related to flow along the dike base **(3)** (Fig. 1B).



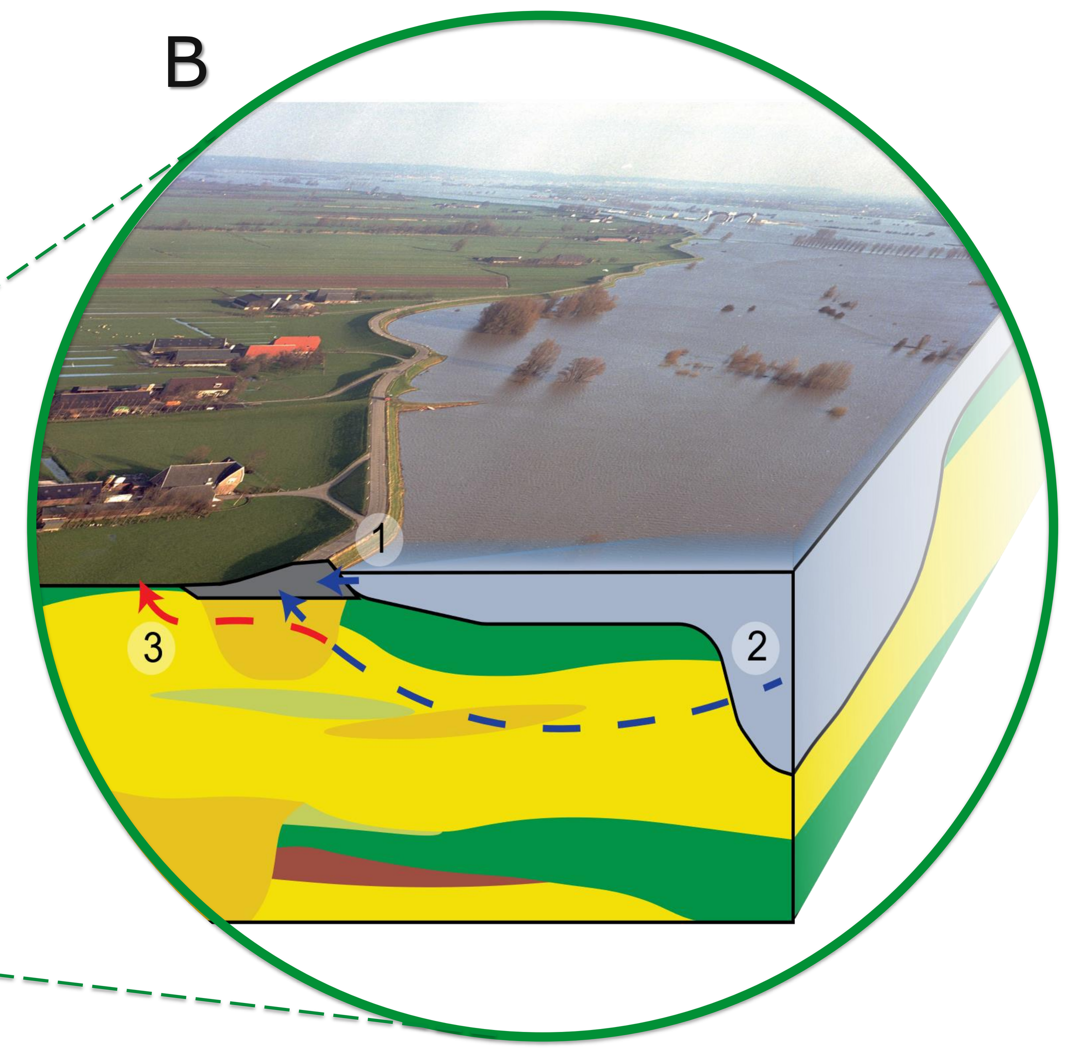


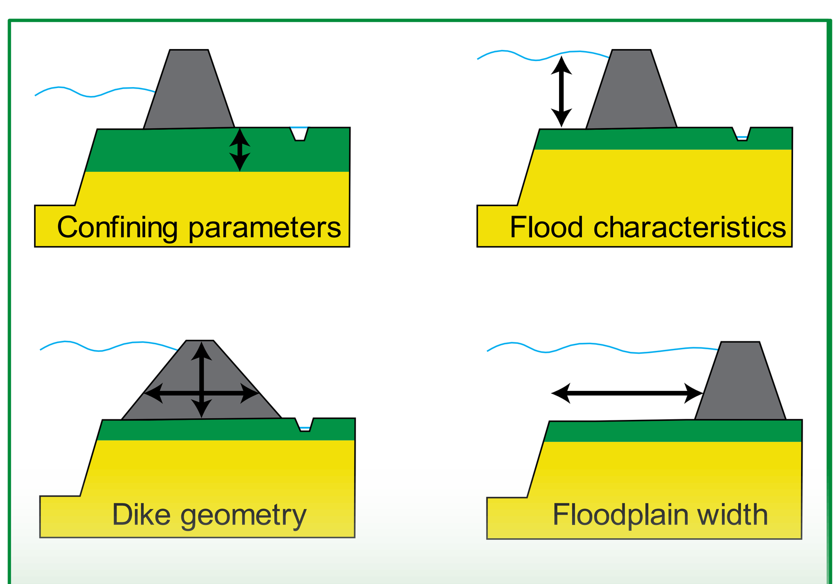
Figure 1; River dikes in the Netherlands and those found not reliable enough regarding failure mechanisms strongly related to hydrological conditions (red). These are located on strongly heterogeneous soils (A), which influence the hydrological conditions (B). A 3D approach is needed to capture the full variability and correctly predict its effect.

Sensitivity of stability to (sub)surface characteristics

For some processes, the critical pore pressure to destabilize the dike can be modelled using static equilibrium as a first approximation. Using many realizations of possible scenarios, the most unstable possibility can be determined. The variables include:

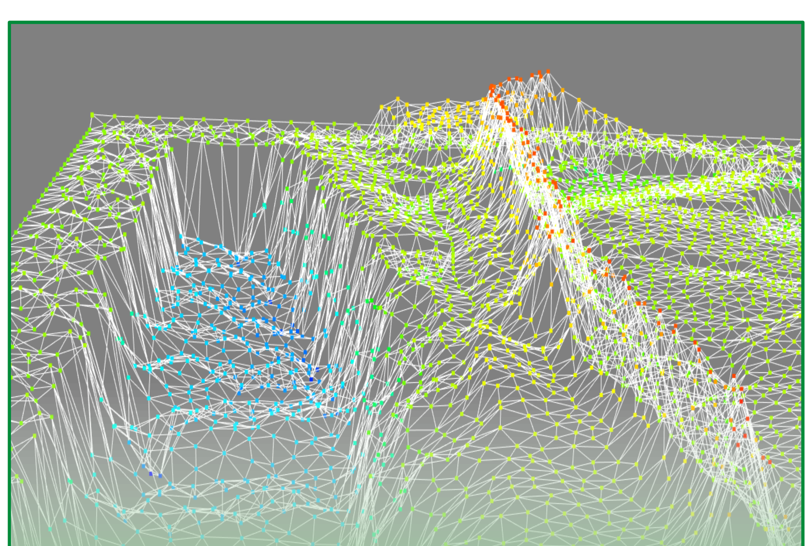
- **Subsurface geometry**
  (confining layer thickness, conductivity)
- **Flood characteristics**
  (height, duration, flood wave shape)
- **Dike geometry**
  (width, slope, height)
- **Supporting parameters**
  (floodplain width, drainage)

Current and future research



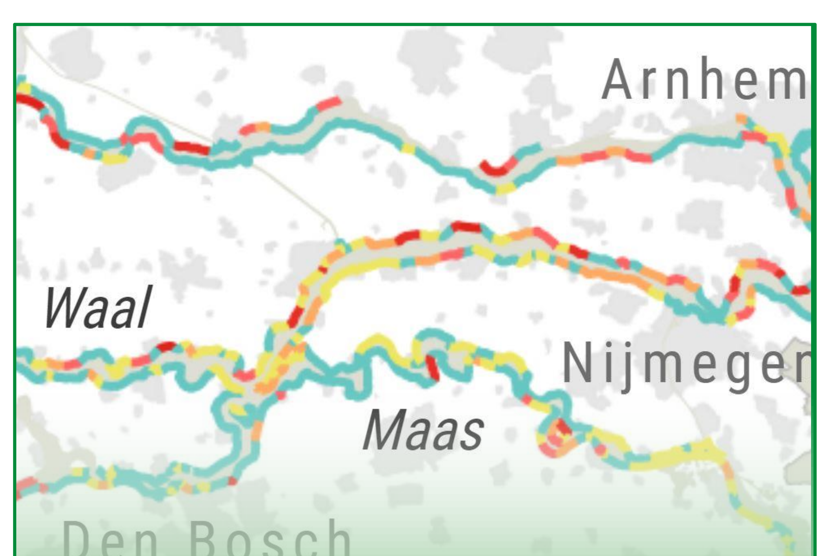
2D sensitivity

- Which combination of dike and subsurface characteristics are unstable?



3D hydrological modelling

- Analyzing the effect of 3D subsurface variability on pore pressures



Combine susceptibilities into tool

- Indicate high-risk dike stretches and most relevant failure mechanisms