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Sensitivity analysis of river dike macro-stability: It's just hydro-logic!

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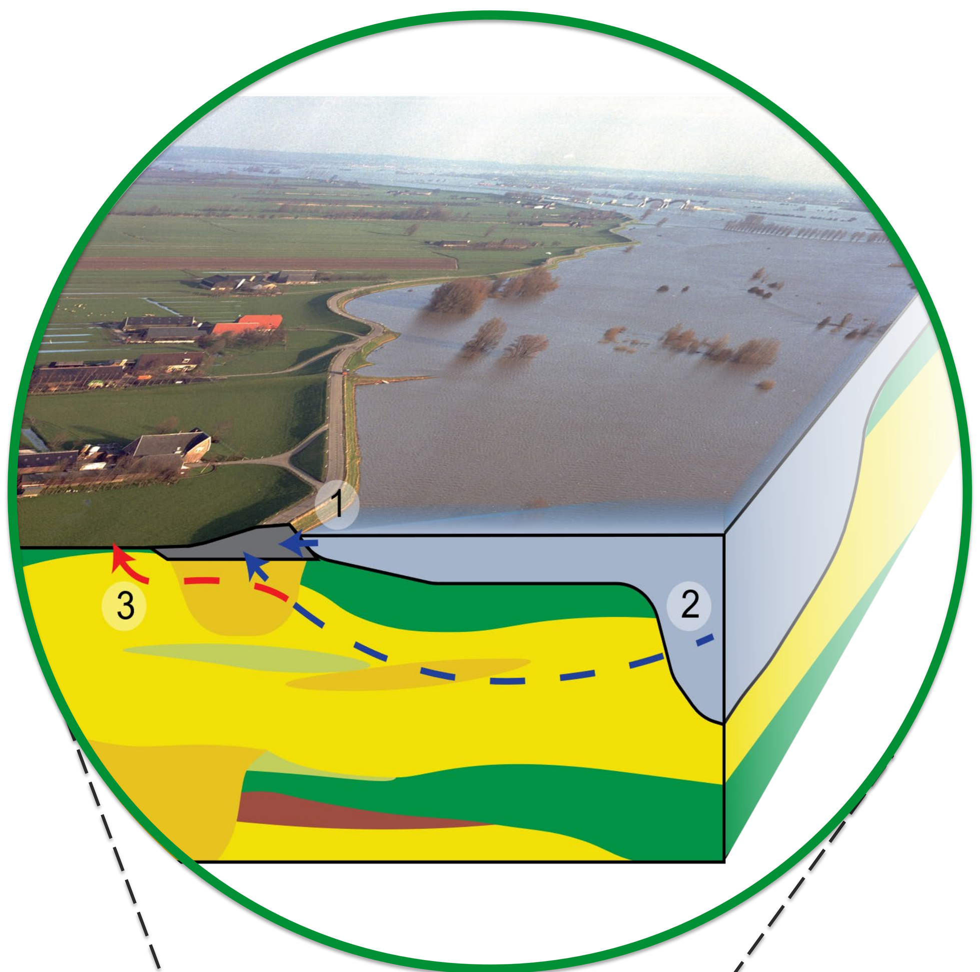
Undervaluation groundwater regarding dike stability

The groundwater hydrology of river dikes and their subsurface is often oversimplified in dike stability calculations, only roughly estimating the hydrological effect of natural and manmade variability in the dike and subsurface material. With up to 15% of the worlds population living in areas affected by river flooding, the upkeep and reinforcement of dikes will become increasingly important as new discharge extremes due to climate change will enlarge the risk of these flood-prone societies. We carried out an extensive sensitivity analysis of dike macro-stability including steady-state groundwater calculations, to indicate the relations between geometry, subsurface materials, groundwater hydrology and stability of a dike on worst-case scenarios.

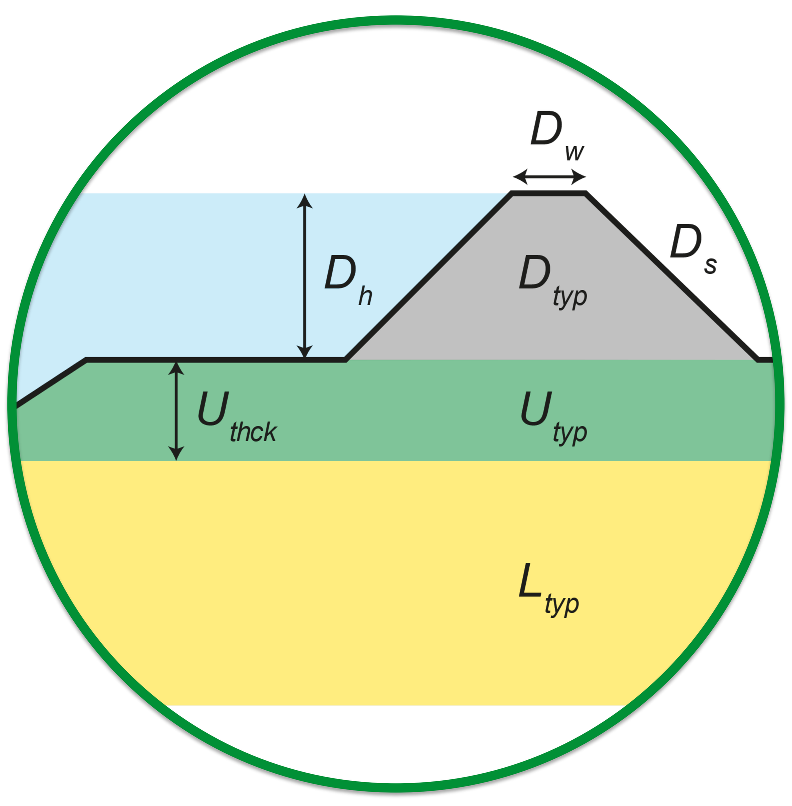


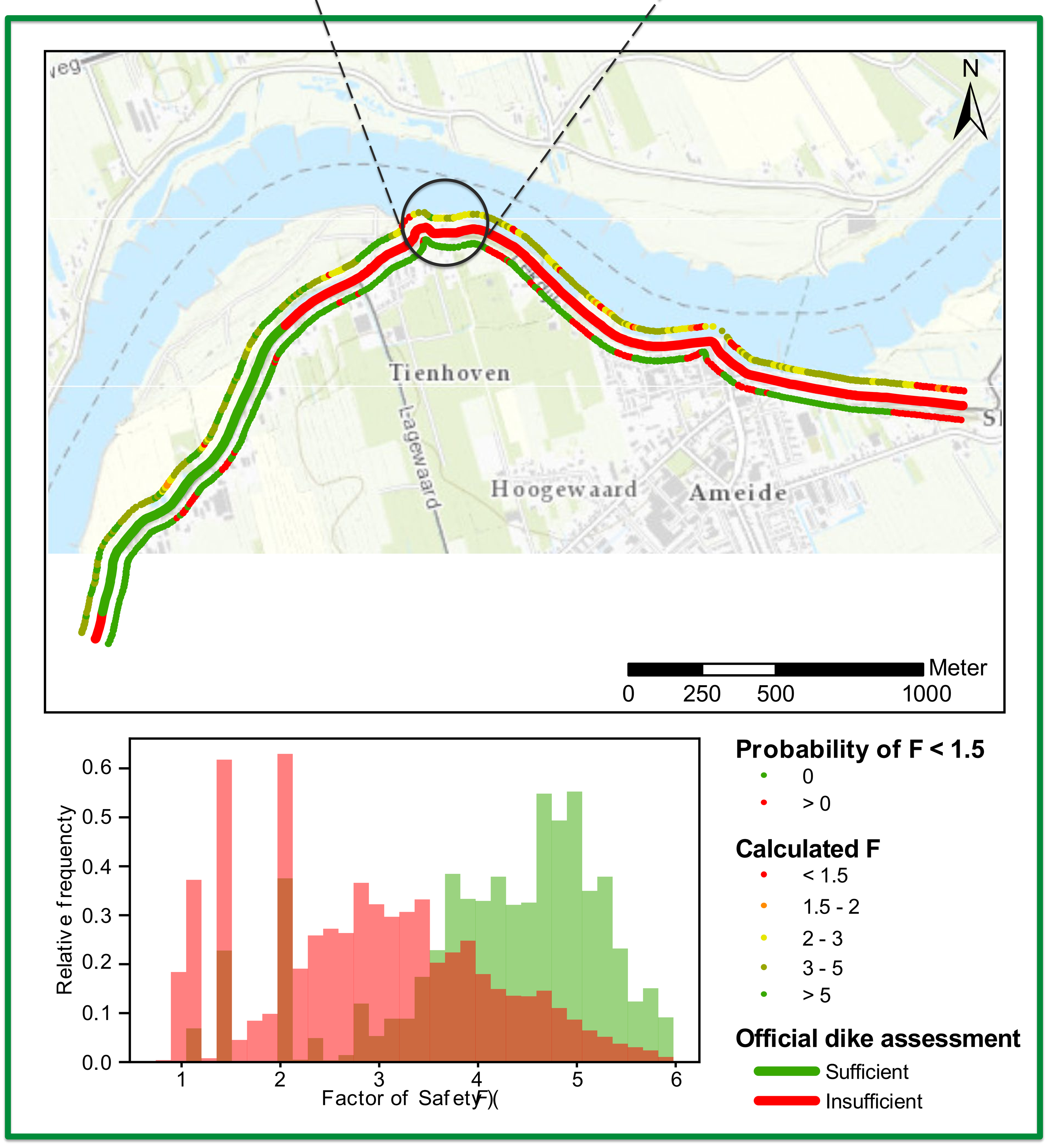
Linking groundwater flow to subsurface variability

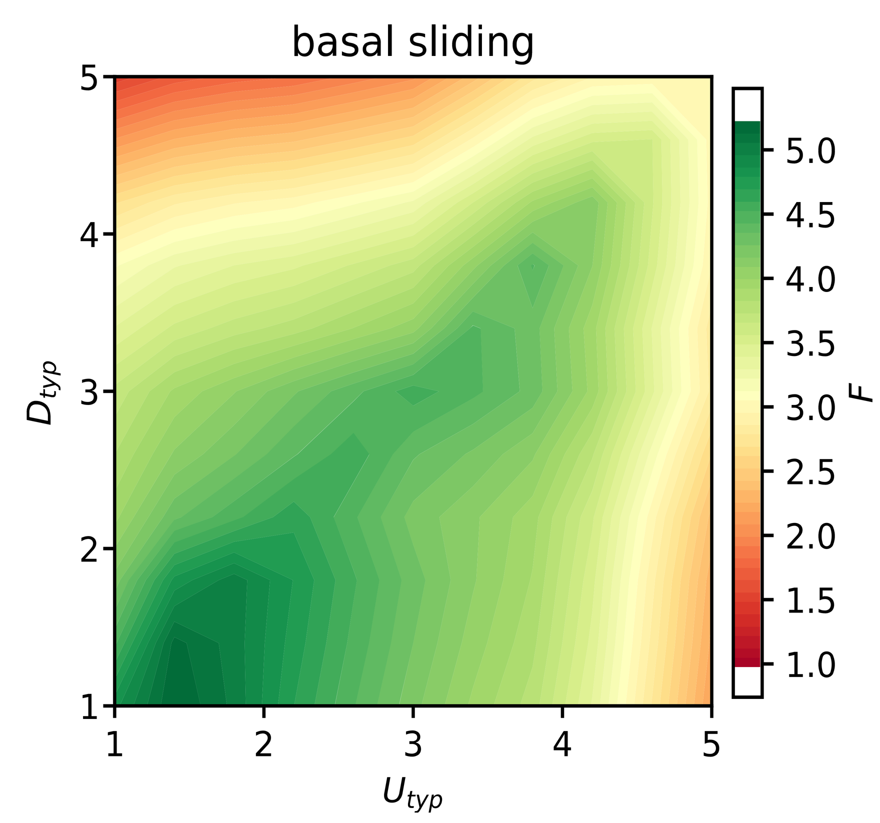
During high river water levels, groundwater flow and pore pressure increases underneath a dike vary, which depends on the subsurface characteristics. These are known to be highly heterogeneous and below dikes, due the spatial variability of fluvial architecture, such as connecting channel belts and units of varying thickness Internal triggering mechanisms (e.g. slumping) are related to reduced resistance and within- and sub-dike pore pressure conditions. This research focuses on (see left):

1) Direct seepage from the river to the dike

2) Subsurface flow and base pressure increase, increasing pore pressures below and in the dike.







Sensitivity modelling parameters

The conducted sensitivity analysis is carried out using a combined hydro-stability model. Pore pressures and phreatic water levels are derived from the MODFLOW software. The most important model parameters are:

- **Flood characteristics** (most extreme: water at dike crest)
- **Dike geometry** (width, slope, height)
- **Subsurface geometry** (2-layer thickness)
- **Subsurface geology** (related to conductivity, cohesion, unit weight etc.)

Stability-subsurface interrelations

The basal sliding stability of a dike (see above) is a clear example of the influence of subsurface material and hydrology on the dike stability. The most stable dikes are those with a similar material in the dike and subsurface layer.

- **Every change** away from this equality causes a **decrease** in dike stability.
- Inter-depency of **cohesion, effective friction angle & saturated conductivity** linked to a material *typ* value.

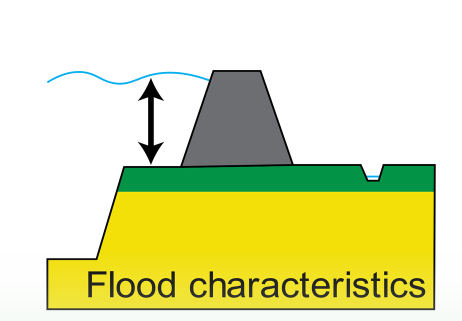
Use of a-priori knowledge for dike reinforcement projects

By calculating dike stability factors for many parameter combinations, a database is constructed with groundwater induced safety values. This database, as a-priori knowledge, can be compared against the case data. This is done for a case study on the Southern Lekdijk near Ameide (see center). With this information locations on the edge of sufficiently safe and unsafe can easily be detected, and used to in an early stage in dike reinforcement projects as a guideline for where to conduct additional field surveys. This might reduce the costs and needed time for these projects to finish substantially.

The most important results are:

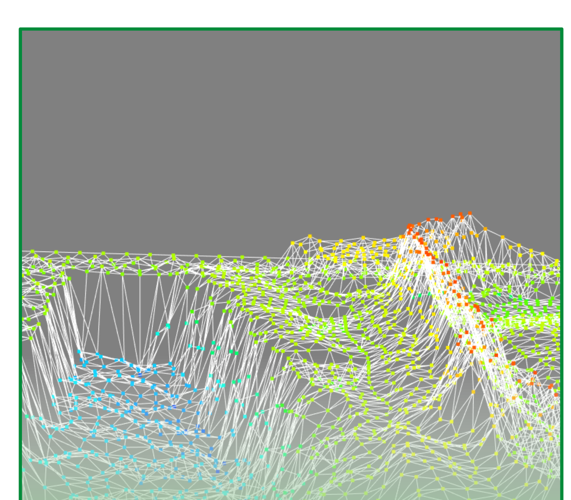
- The **higher resolution** comparison can result in a **quick analysis** of the most critical sections
- The histogram shows **insufficient** stretches have a **lower safety value** (4.60±0.96 vs 3.24±1.15).
- The database comparison could help **focusing further research** in the next stage of dike reinforcement design.

Future research direction



Dynamic rivers

- Focusing on dynamic river levels and pore pressure timing



2D-3D comparison

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