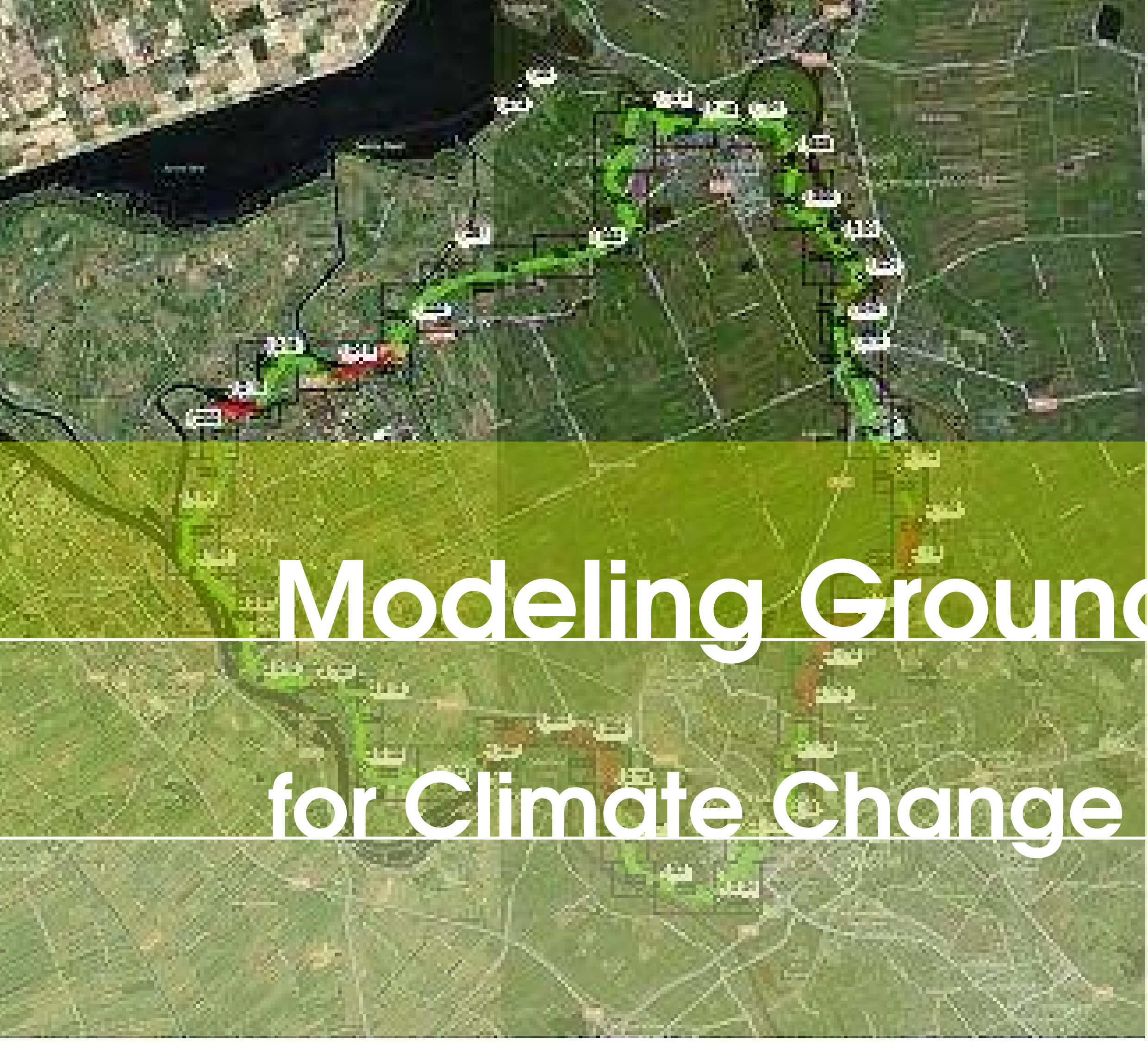

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John van Esch & Bert Sman

Modeling Groundwater Flow through Embankments

for Climate Change Impact Assessment

Introduction

Climate change may result in a reduction of the integrity and reliability of engineered slopes in general and can even lead to failure of the soil structure due to pore pressure changes. This poster proposes an assessment procedure that quantifies the impact of droughts and periods of heavy precipitation for embankments. The procedure couples an agro-meteorological model based on the Penmann-Monteith expression to a groundwater flow model based on Dupuit's approximation. The calculated water pressure fields support a Bishop stability analysis.

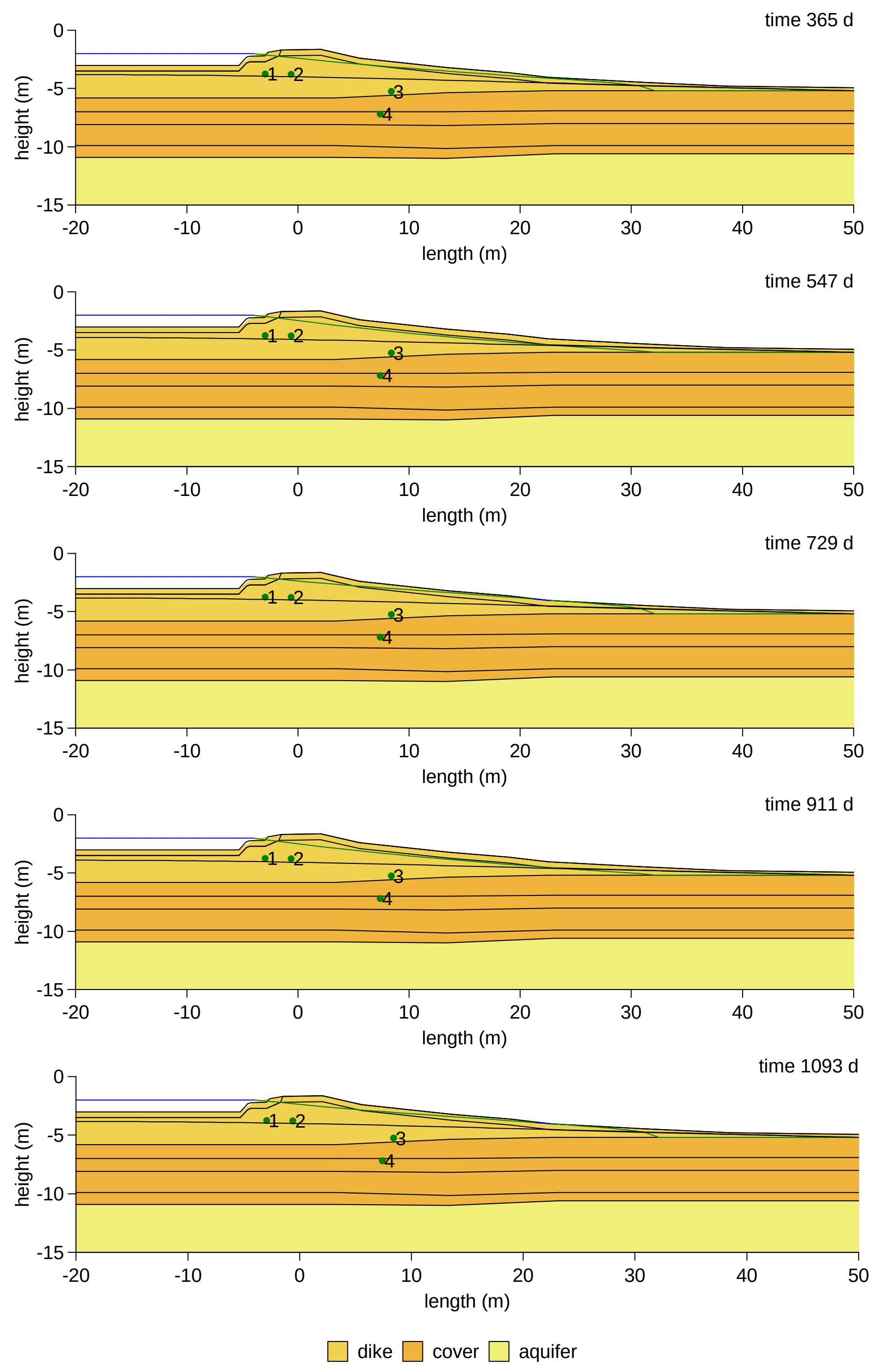

Figure 1: Dike cross section.

The groundwater model simulates flow through aquifers, aquitards and the embankment itself. Special boundary conditions capture inflow and outflow of water into this geo-hydrological system by precipitation, evapotranspiration and seepage.

Meteorological modeling

The Penmann-Monteith model translates daily meteorological measurements of maximum and minimum temperature, average wind speed, incoming short wave radiation and actual vapor pressure into a potential evapotranspiration flux. The model also requires agricultural information on the grass covering the embankment and its location.

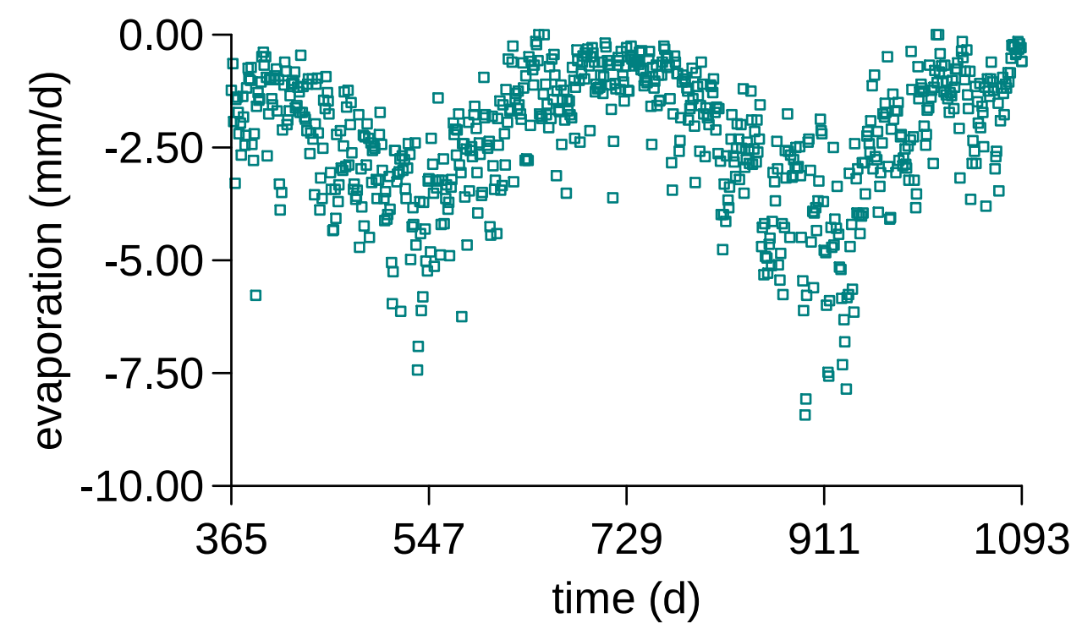

Figure 3: Evapotranspiration forecast.

Groundwater modeling

The groundwater model computes the actual evapotranspiration and precipitation out of the potential values. Observation wells monitor the geo-hydrological system behavior and provide data for model calibration. The Levenberg-Marquardt algorithm solves the inverse flow problem.

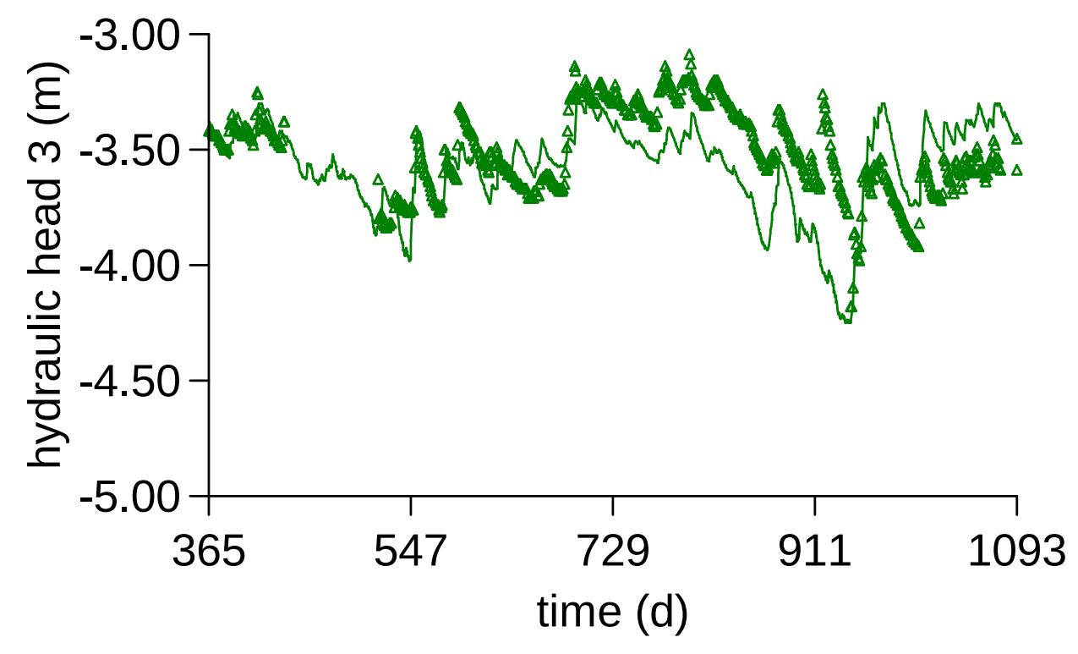

Figure 4: Hydraulic head propagation.

Geotechnical modeling

A modified Bishop model assesses the geo-mechanical stability. For cases where the slip circle intersects a low permeable layer boundary, the slip surface is allowed to partly follow this boundary.

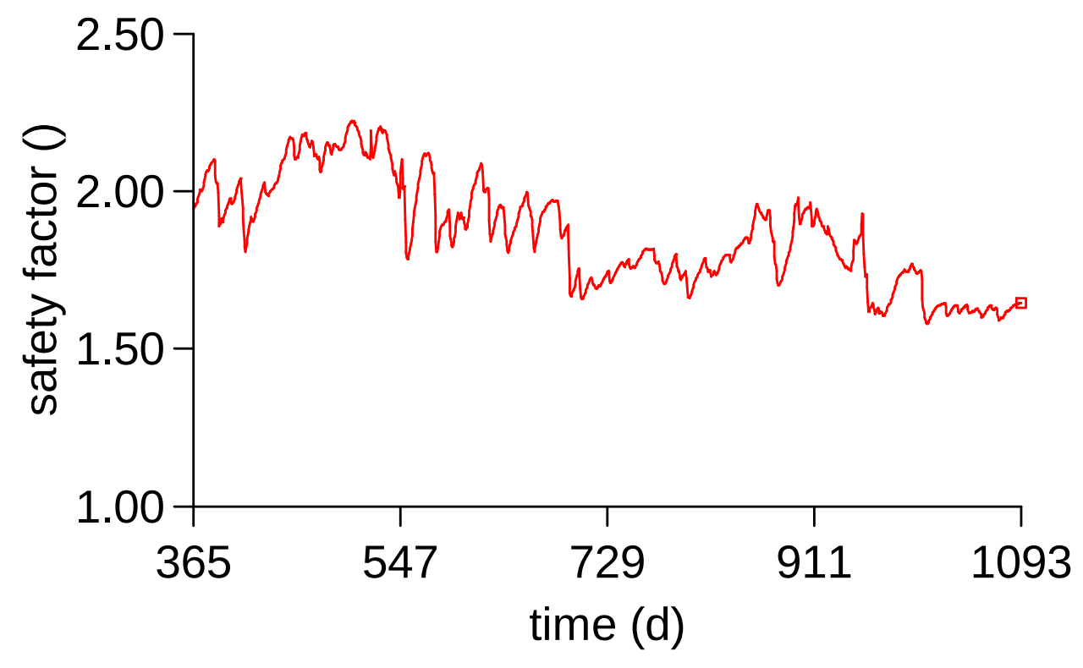

Figure 5: Stability response for current loading.

A tipping point analysis reveals the increase of evapotranspiration which leads to failure of the embankment.

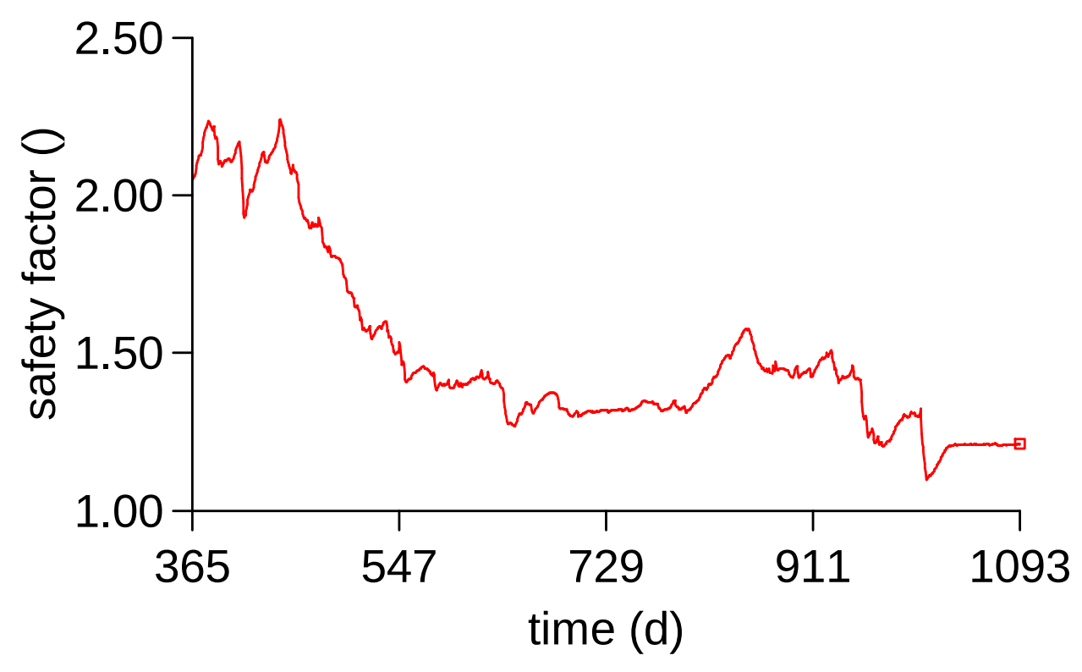

Figure 6: Stability response at tipping point.

Conclusions

The quasi two-dimensional Dupuit model gives more robust results and is computationally more efficient than the fully two-dimensional Richard model. Effective porosity and permeability parameters capture the unsaturated flow behavior and can be found by homogenization of functional relations for permeability, saturation and suction. At the present their values follow from inverse modeling. The groundwater flow model was used for simulating the geo-hydrological behavior of a peat dike. In the saturated zone the layering of peat dominates the flow in horizontal direction and in the unsaturated zone preferential flow through cracks dominates the flow in vertical direction. These observations justify the use of the Dupuit approximation supplemented by the proposed boundary conditions for precipitation and evapotranspiration. The module will be linked into the dike analysis module FEWS-DAM, which provides a tool for scenario studies.

Figure 6: Dike failure.

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