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DigiTwin and proven dike strength

DigiShape day | Dike Monitoring and AI

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in cooperation with Hoogheemraadschap Hollands Noorderkwartier

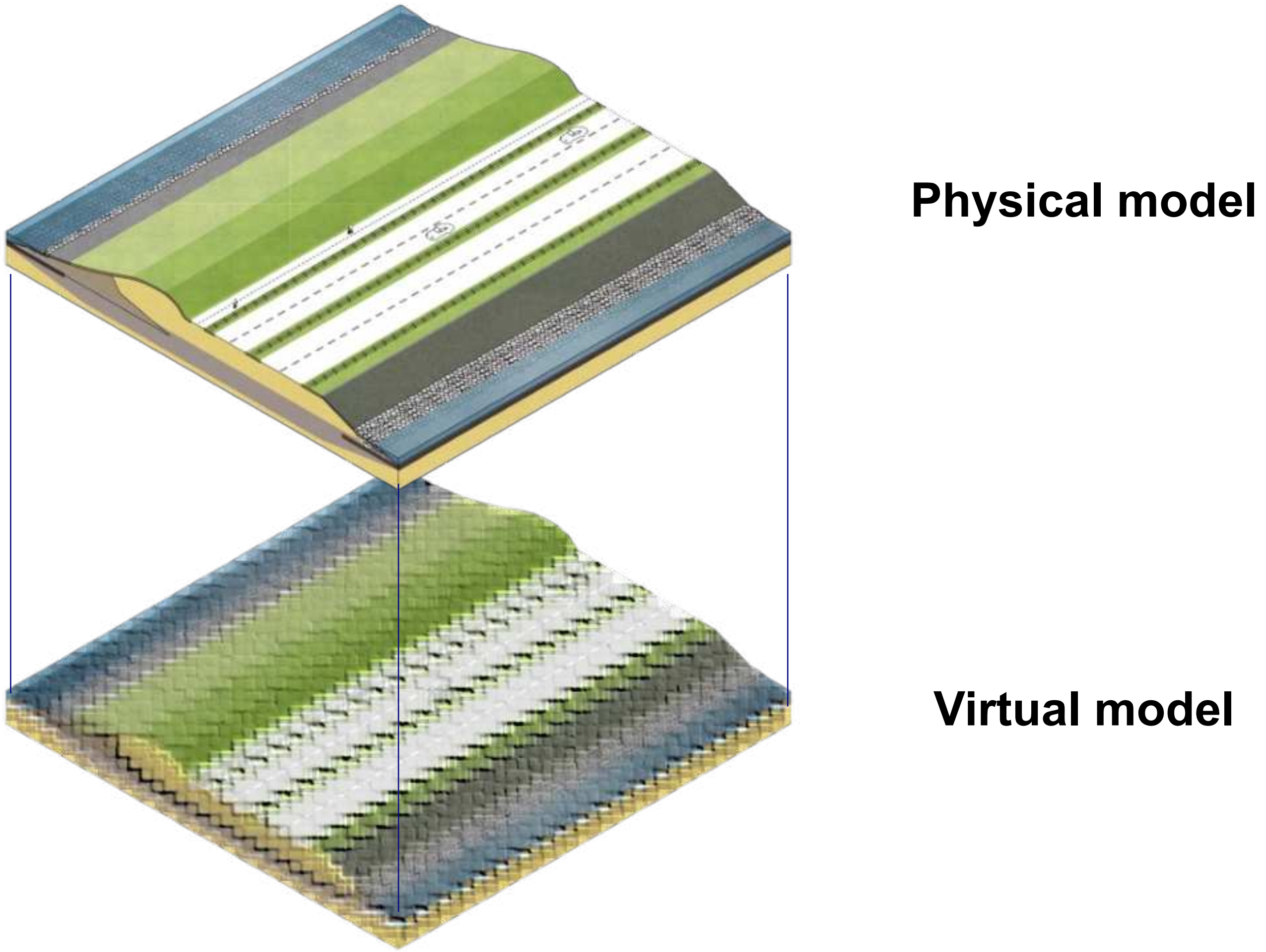
March 26th, 2024

Table of contents

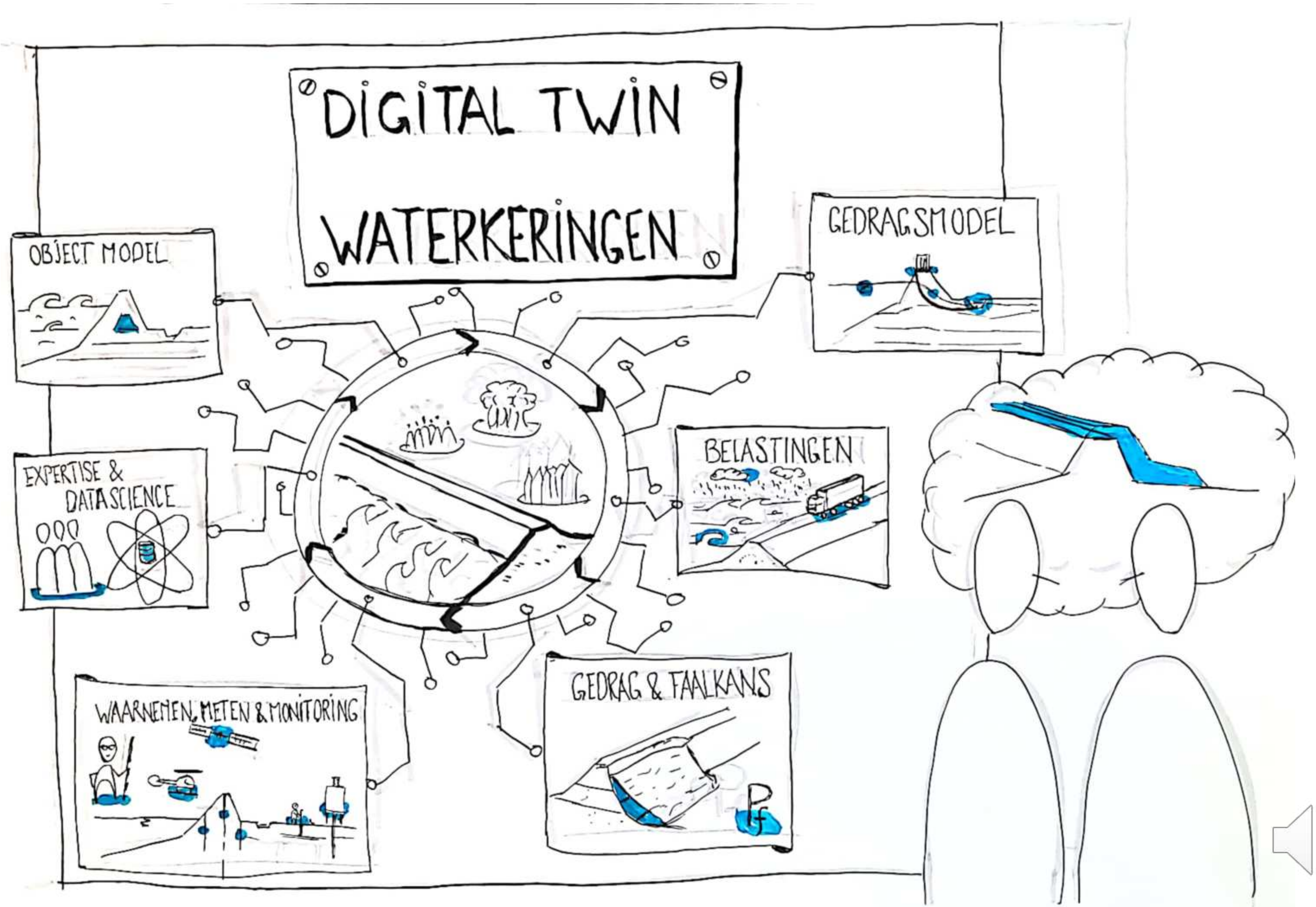
1. DigiTwin for flood defences and subsoil
2. The role of monitoring data science/AI in DigiTwin
3. Case Purmer – Proven dike strength with groundwater monitoring

What is a digital twin?

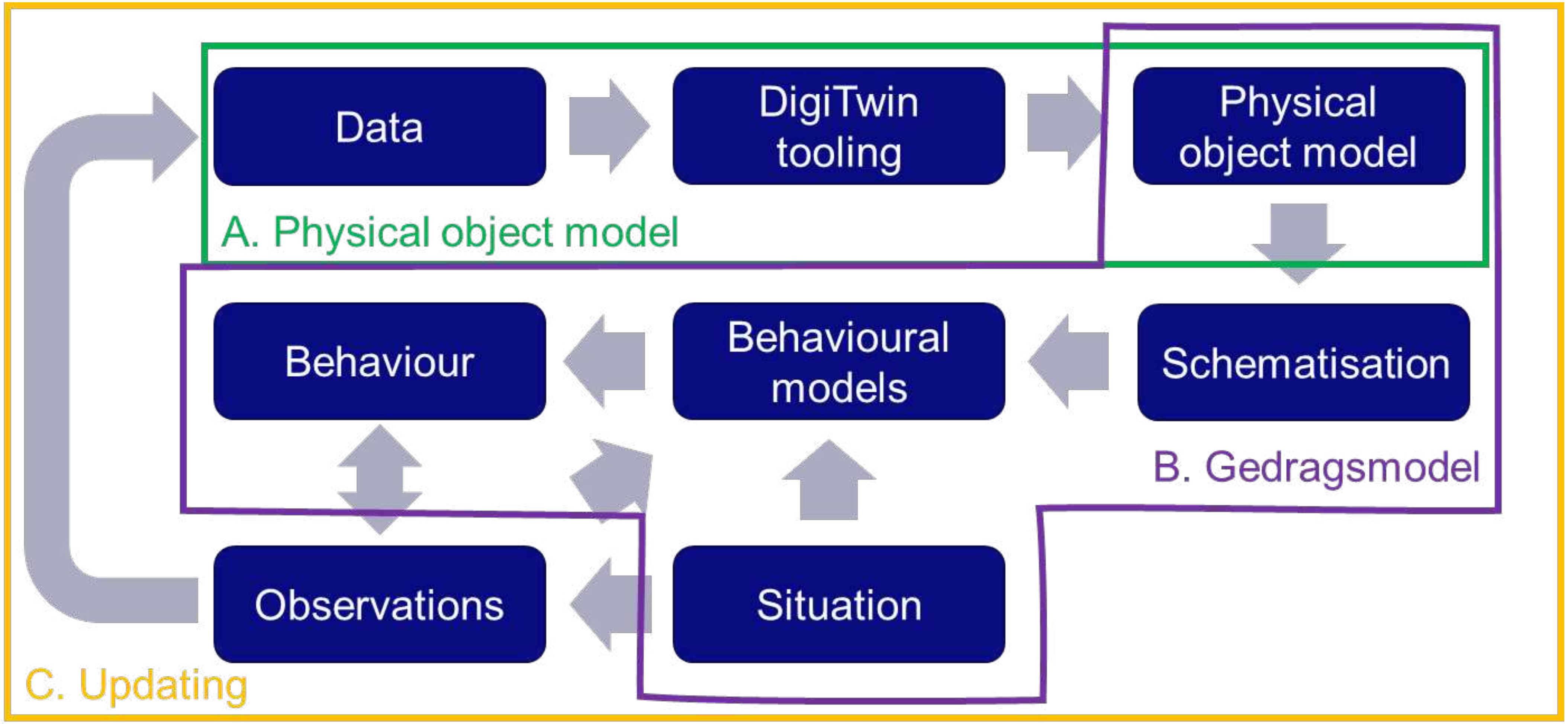
A digital twin is a **dynamic, virtual representation** of a **physical asset, product, process, or system.**



Dutch Dikes | Eric-Jan Pleijster, Cees van der Veeken (LOLA Landscape Architects) | 9789462081512. (n.d.). Retrieved February 23, 2023

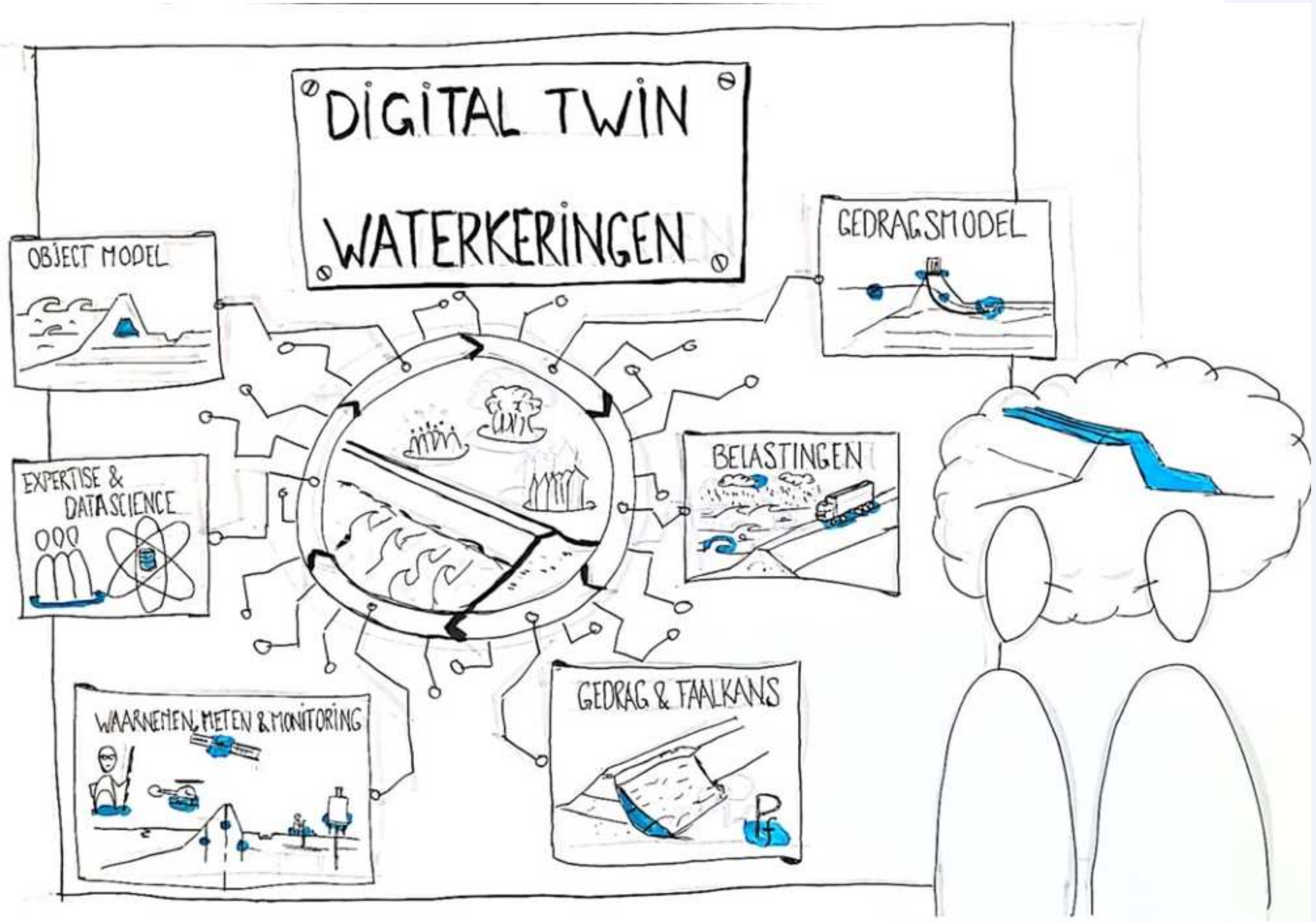

DIGITAL TWIN
WATERKERINGEN
OBJECT MODEL
GEDRAGSMODEL
EXPERTISE &
DATA SCIENCE
BELASTINGEN
GEDRAG & FAALKANS
WAARNEMEN, METEN & MONITORING
Pf

DigiTwin framework



The role of monitoring data and science/AI in DigiTwin

- Monitoring, observations and sensing technology are input for the existing models
  - Also indirect data, like remote sensing
- Data science/AI supports experts to link monitoring, observations and sensing technology with the existing models
  - Expertise still needed for creativity, domain expertise and critical thinking
- Updating the models with monitoring, observations and sensing technology
- AI in decision support



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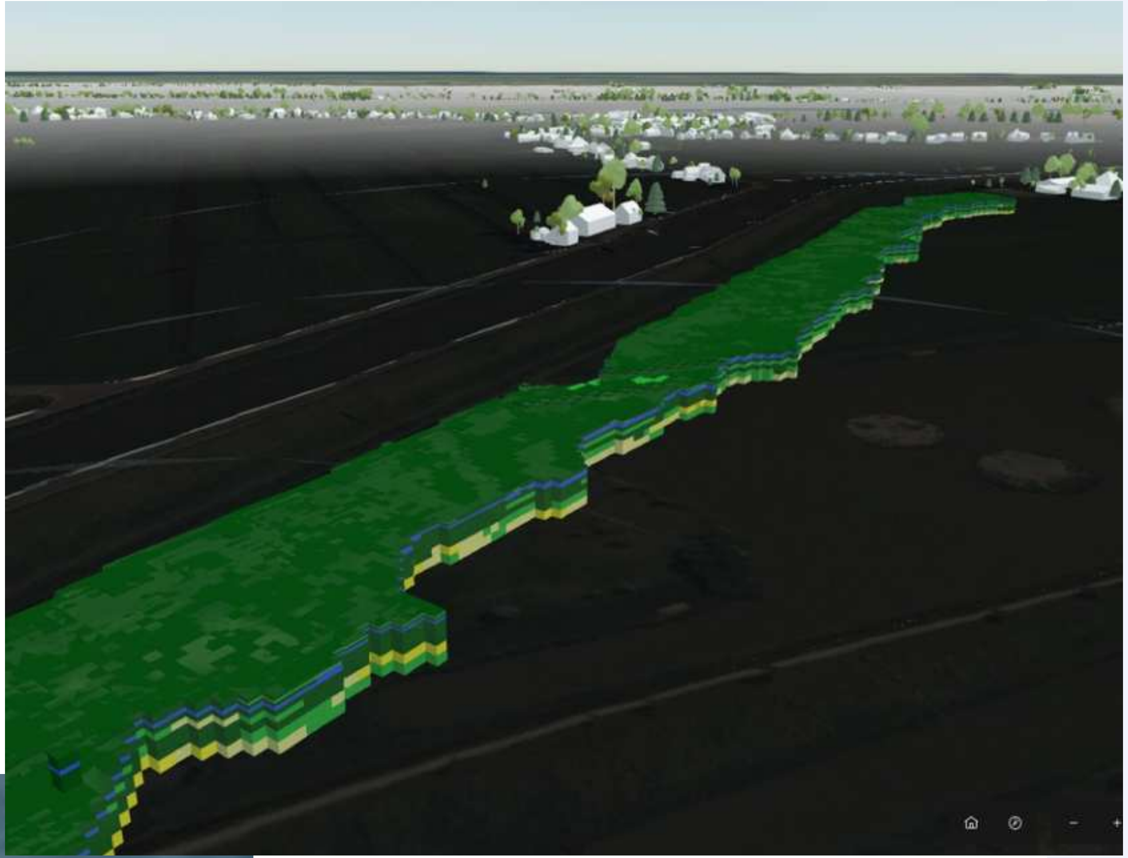
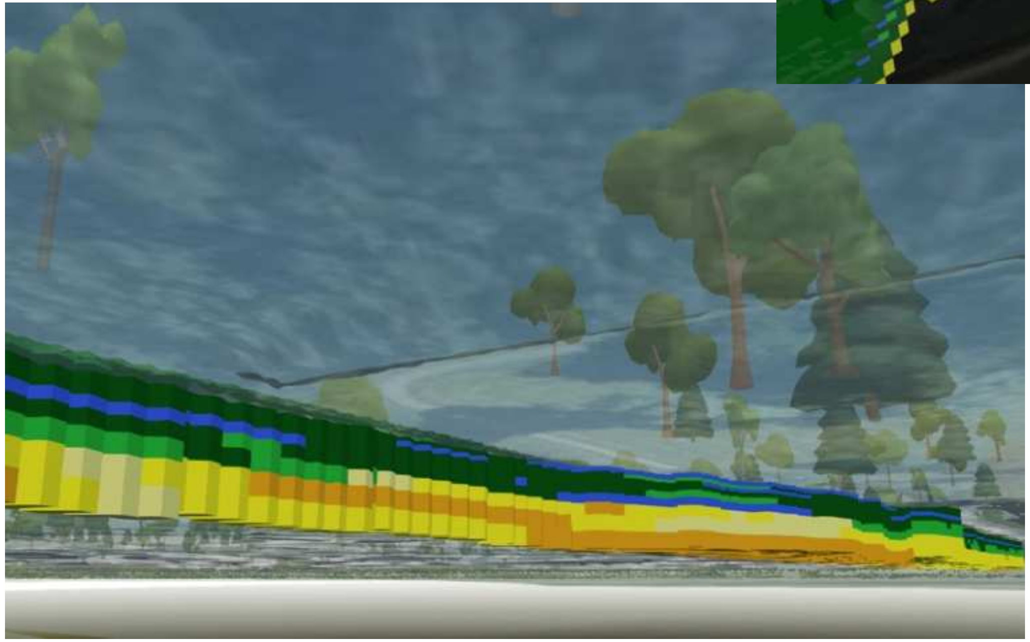
Example: subsoil modelling



- Data:
  - Boreholes
  - CPTs
  - EM measurements
  - (InSAR)
- Data Fusion:
  - ML algorithms
- Subsoil Model

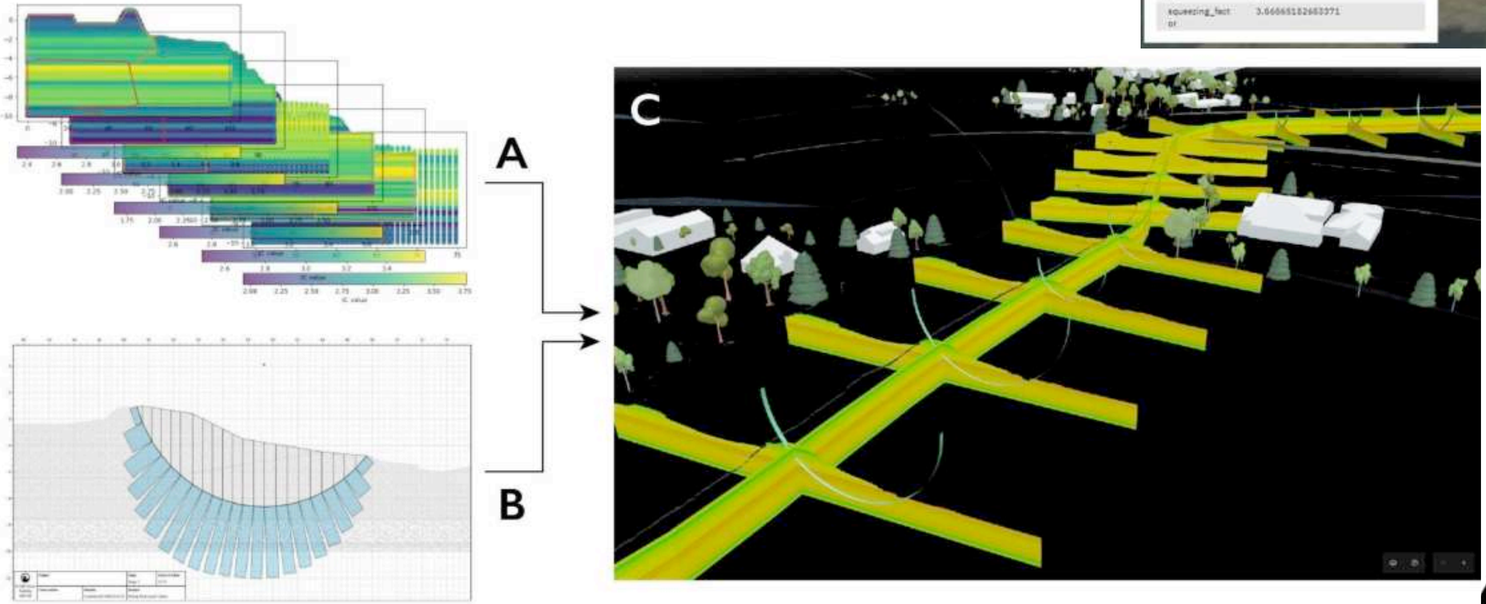


- Updating with new CPT’s and borholes

Pilot case Purme
Data/results just for demonstration purpose

Example: subsoil modelling

- Subsoil Model
- Behaviour
  - Squeezing
  - Stability



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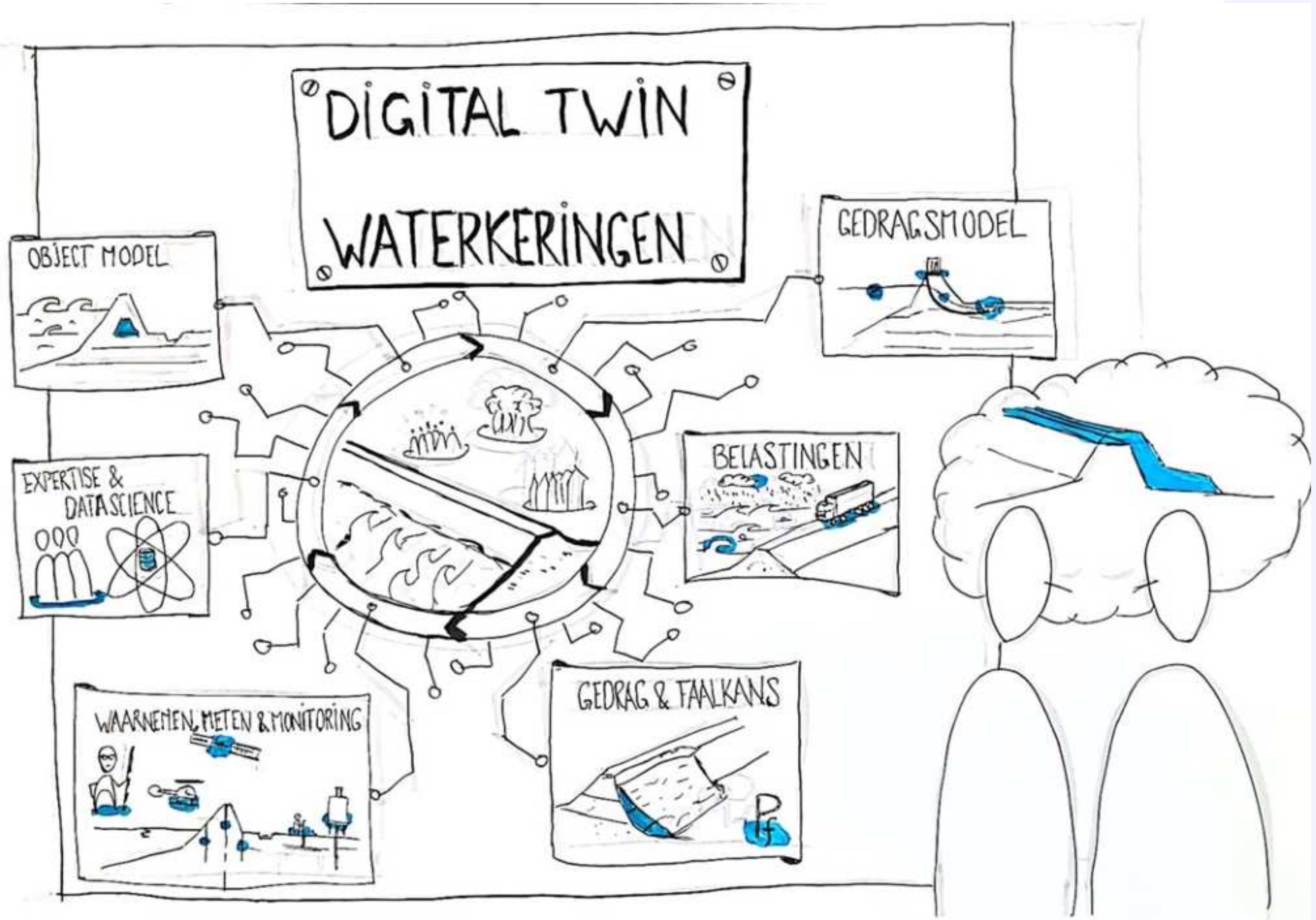
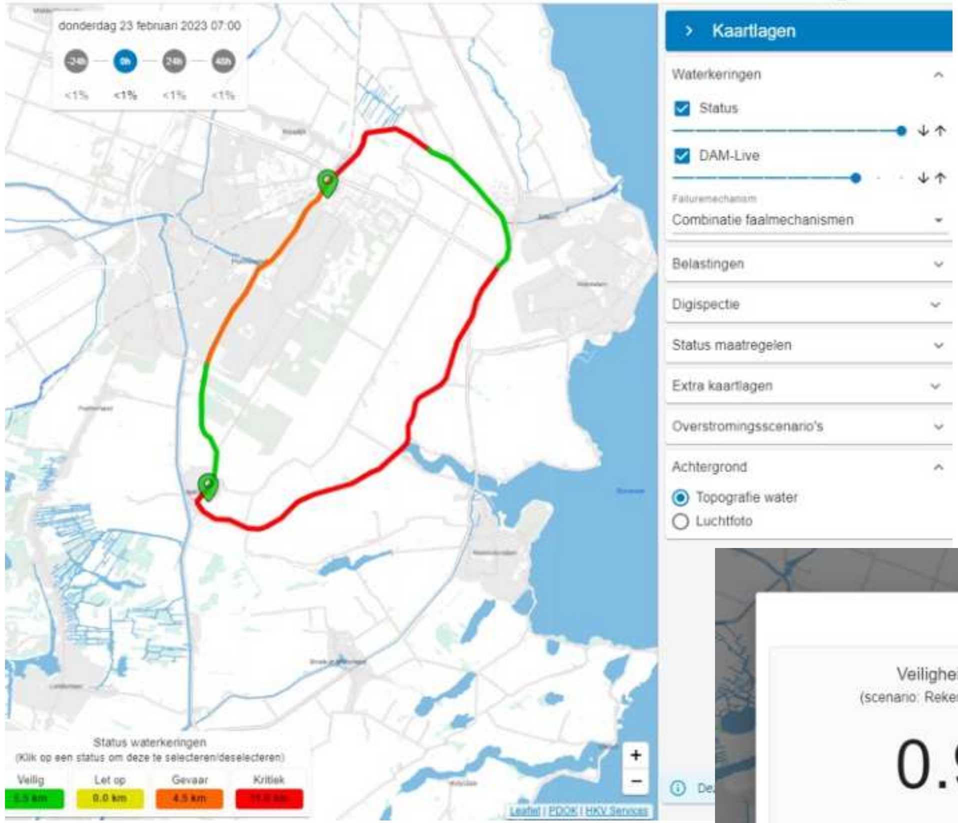
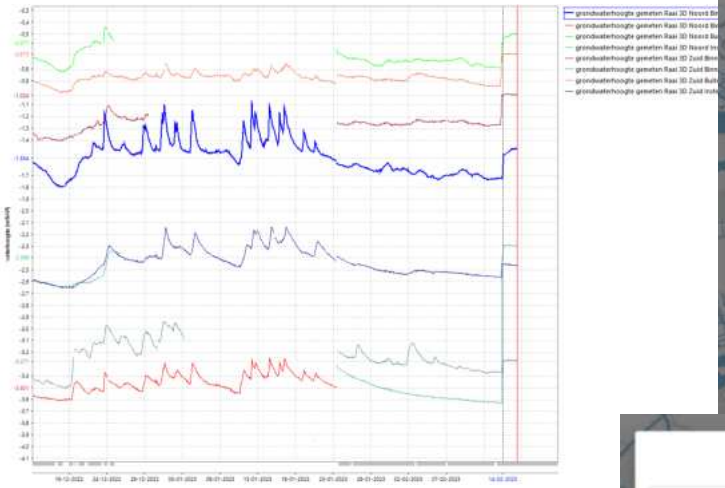
Case Purmer – Proven dike strength with groundwater monitoring

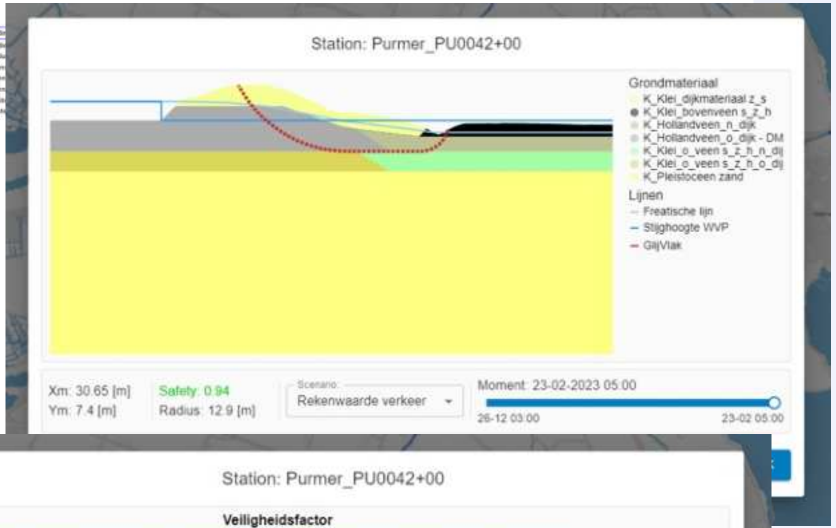
- Earlier pilot: real time stability with groundwater monitoring in a operational system
- Goal: Updating the probability of failure with groundwater monitoring
- Forecast/hindcast of the groundwater levels
- D-Stability/Probabilistic Toolkit

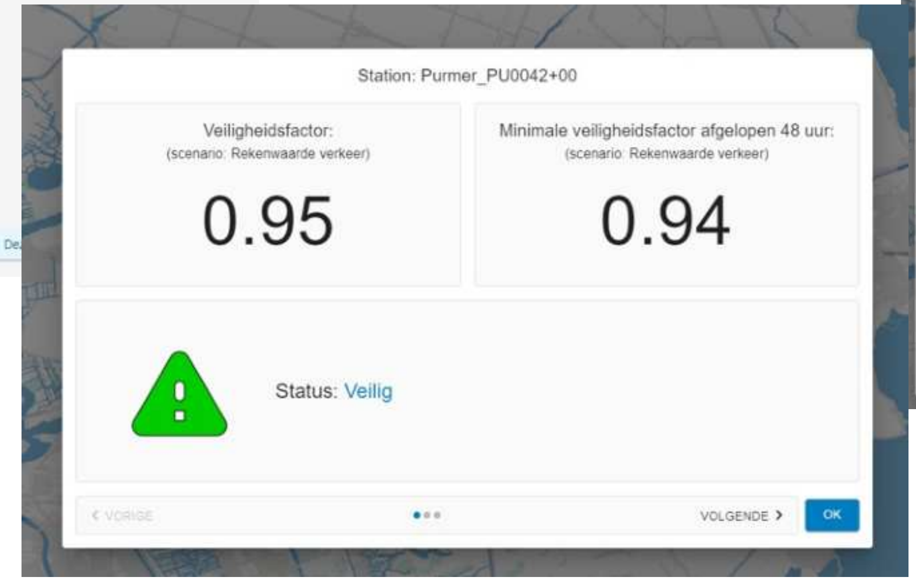


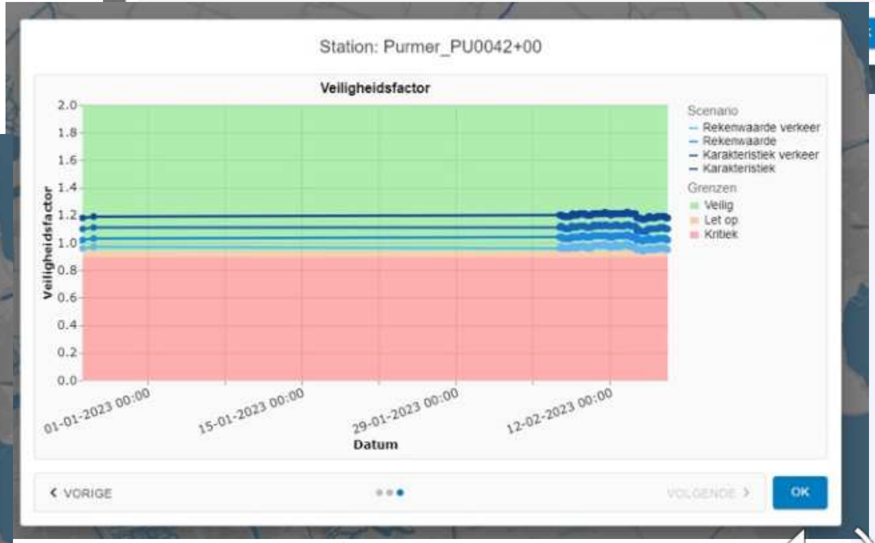
Earlier pilot: real time stability with groundwater monitoring in a operational system











Visualisation in HKV Continu Inzicht Dashboard

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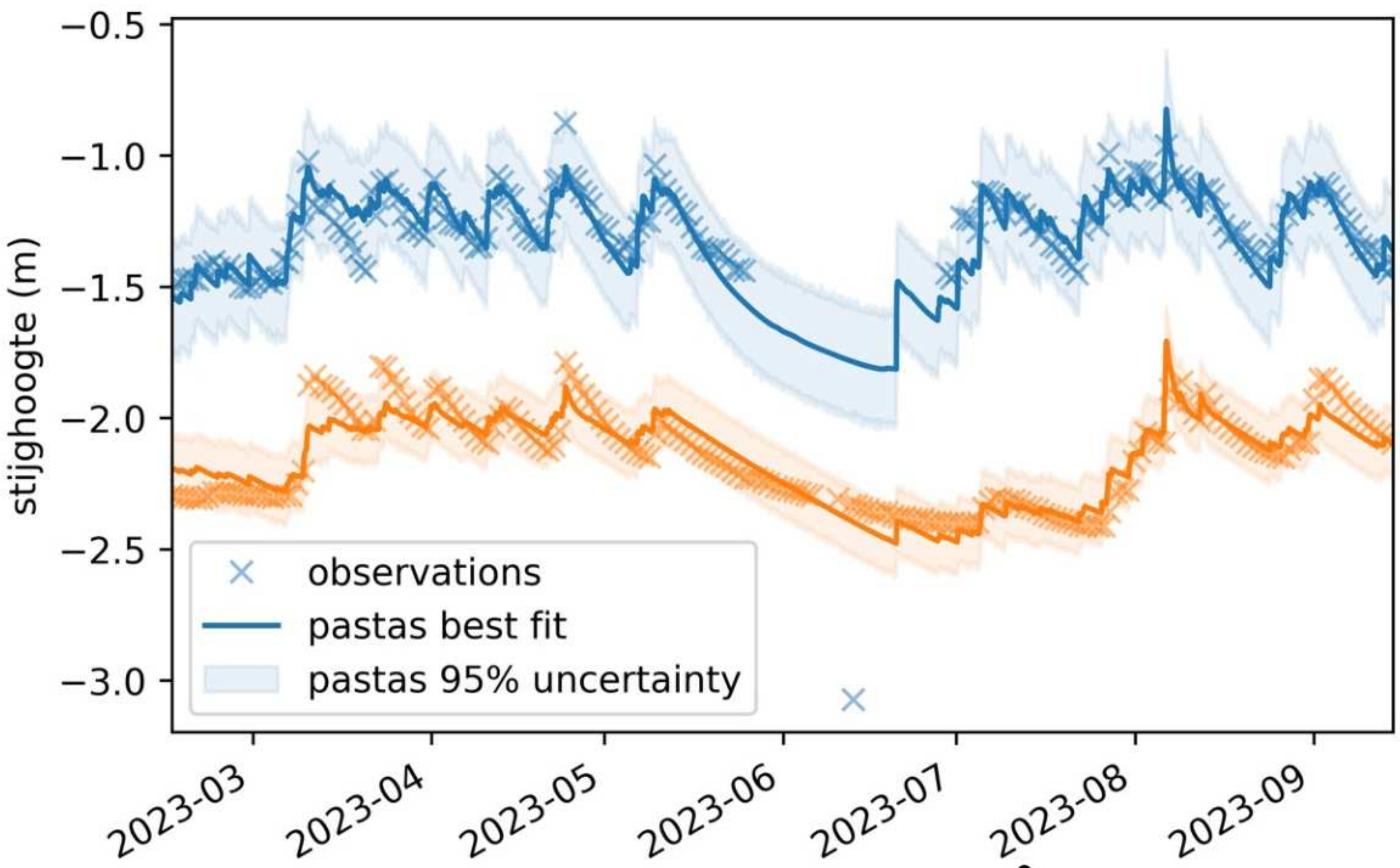
Forecast/hindcast of the groundwater levels

- Input time series:
  - precipitation
  - Evaporation
  - Grondwater level in gauges

- Output time series:
  - Best fit
  - Reliability interval



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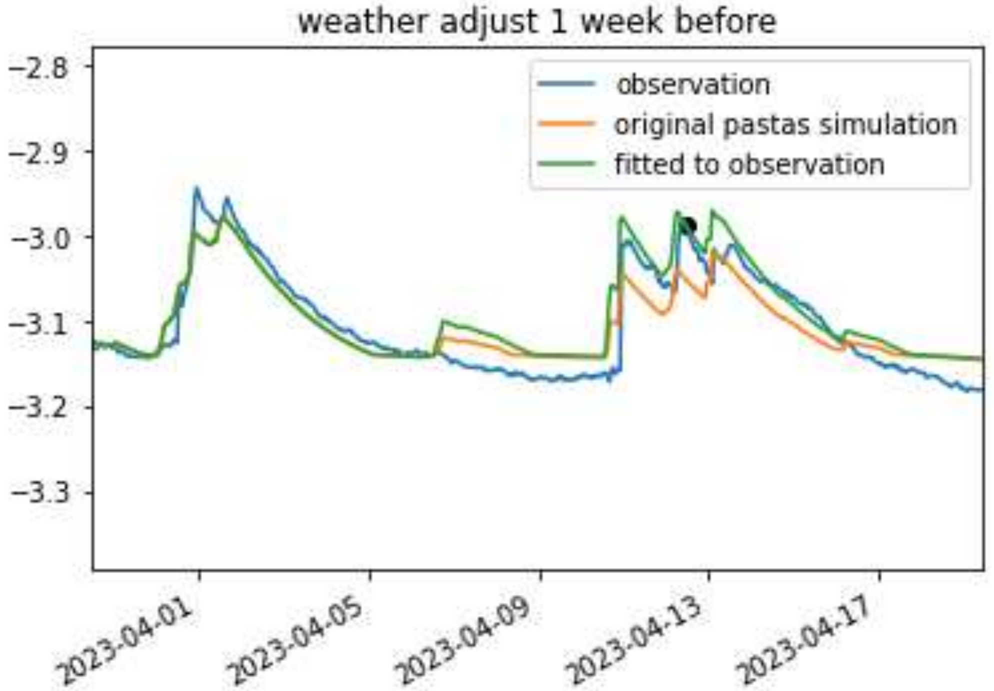
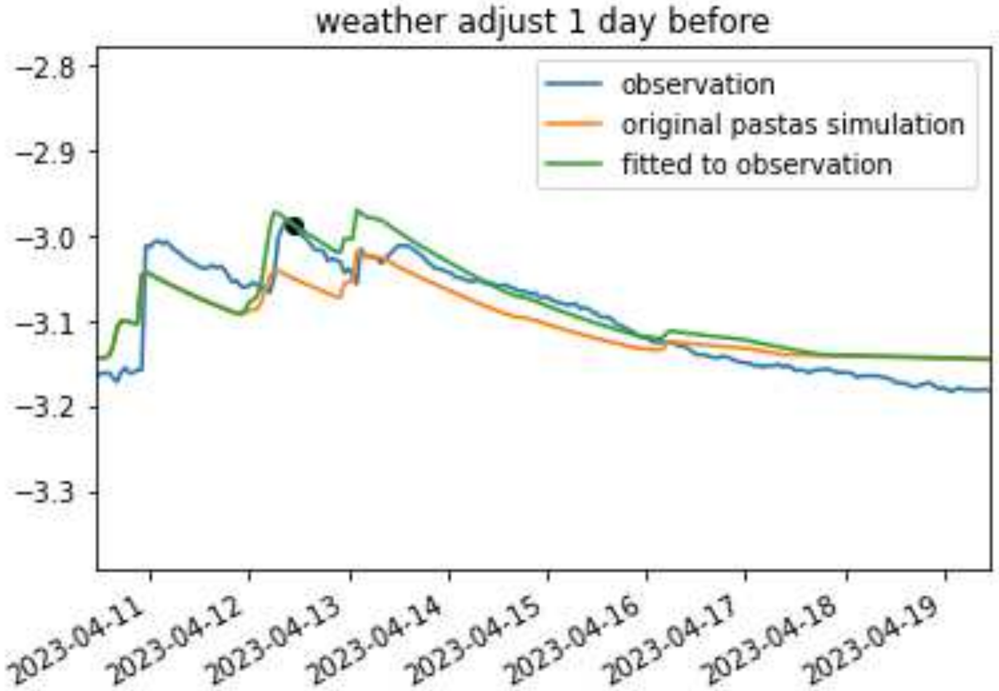
Forecast/hindcast of the groundwater levels





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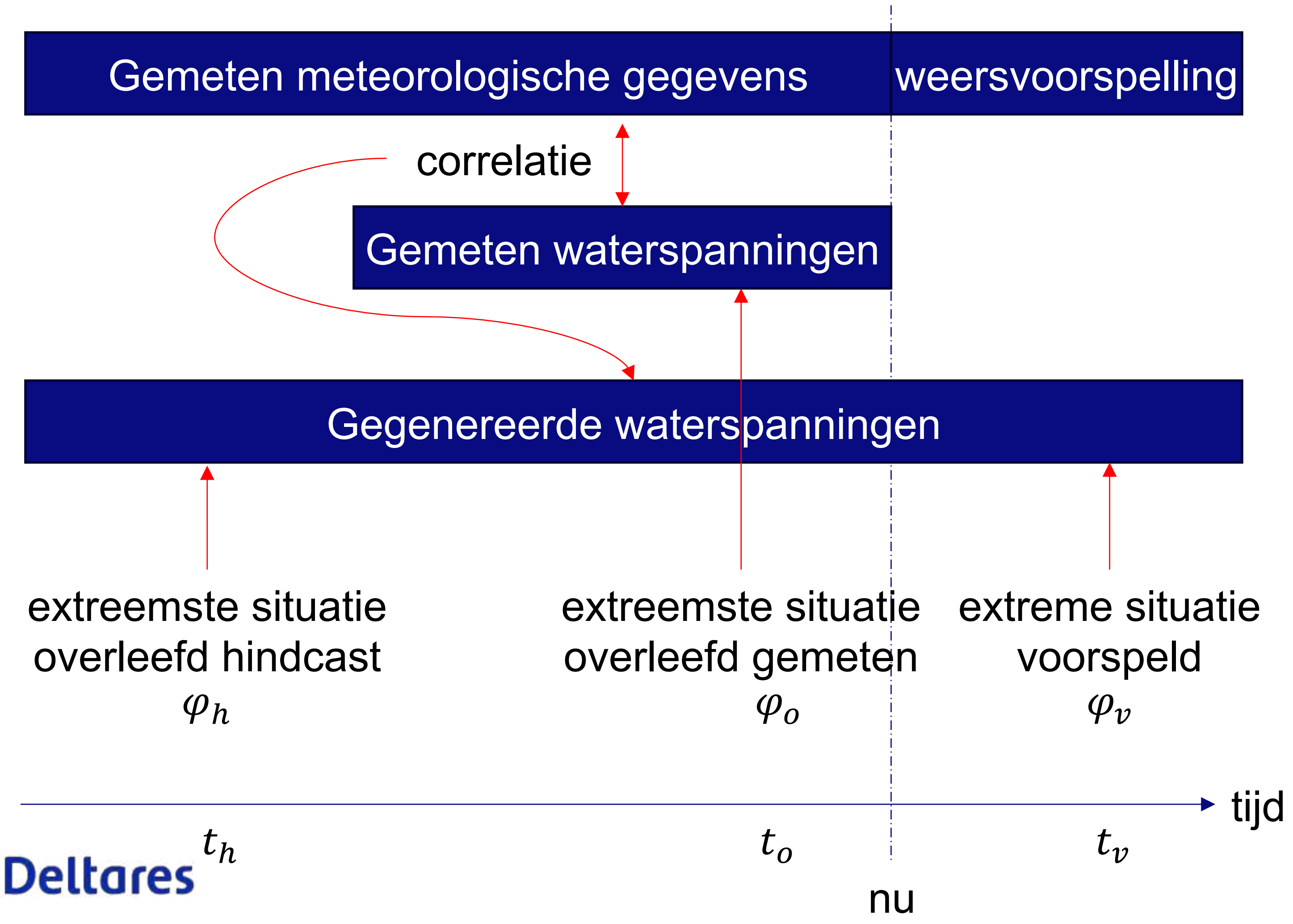
Updating failure probability



$$Z = Sterkte - Belasting$$

$$Z < 0 \rightarrow falen$$

$$P(Z(\varphi_v) < 0)$$

Updating:

$$P(Z(\varphi_v) < 0 | Z(\varphi_o) \geq 0)$$

$$P(Z(\varphi_v) < 0 | Z(\varphi_h) \geq 0)$$

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Stability and probability of failure

Dike Monitoring Purmer

Large Map | Time Series | Cross Section

This dashboard presents the stability of a cross-section of the Purmer levee. The location of the cross-section is given on the map above. The stability is dependent on the pore water pressures in the levee and subsoil. Those are described by the hydrauylic head. We distinguish between the phreatic line (PL) and a headline (HL) in the aquifer. The PL and HL are measured from 2022 with 5 different stand pipes, shown on the map. The PL and HL vary with varying surface water level (canal and polder) and effective precipitation (rain and evatranspiration). Since the polder level and the canal level are controlled and fixed the HL and PL can be correlated with the effective precipitation.

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Stability and probability of failure

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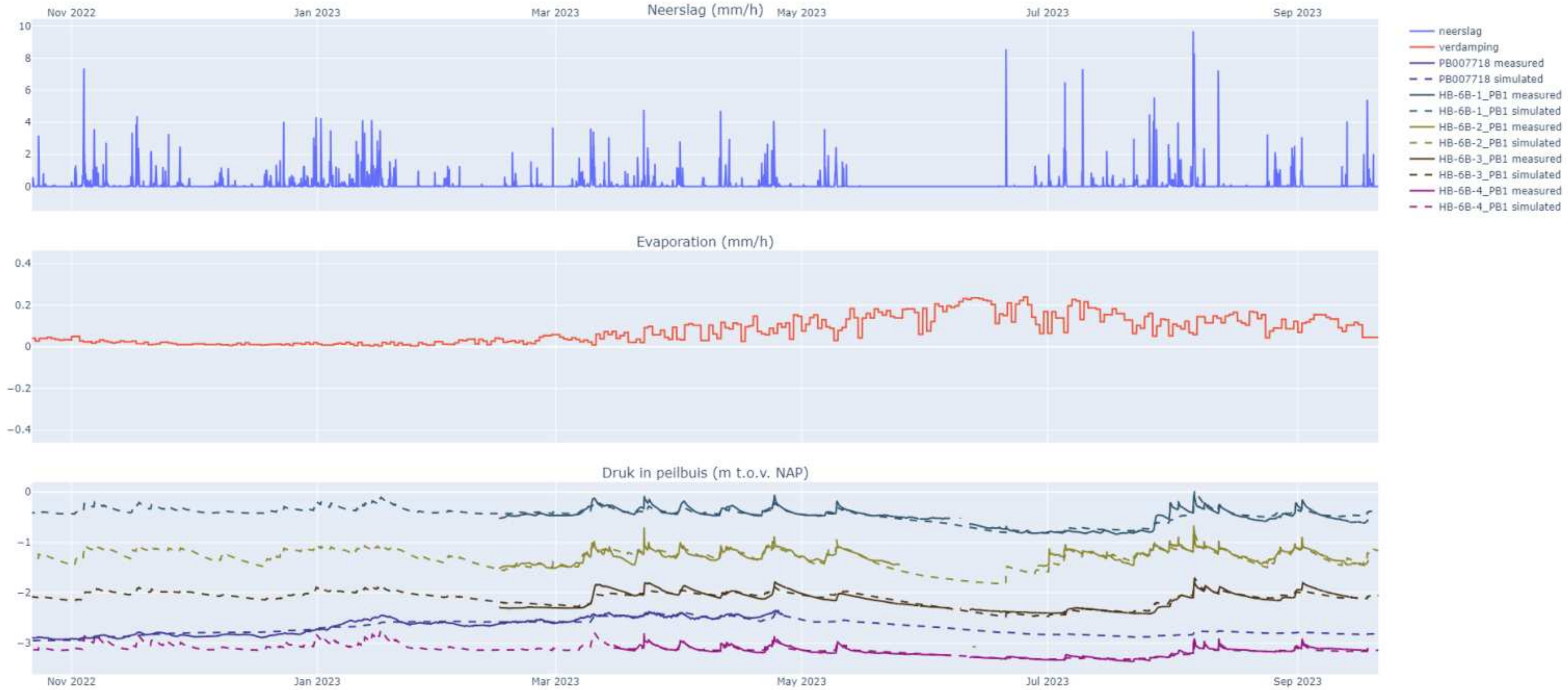
Stability and probability of failure



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Stability and probability of failure

Stability

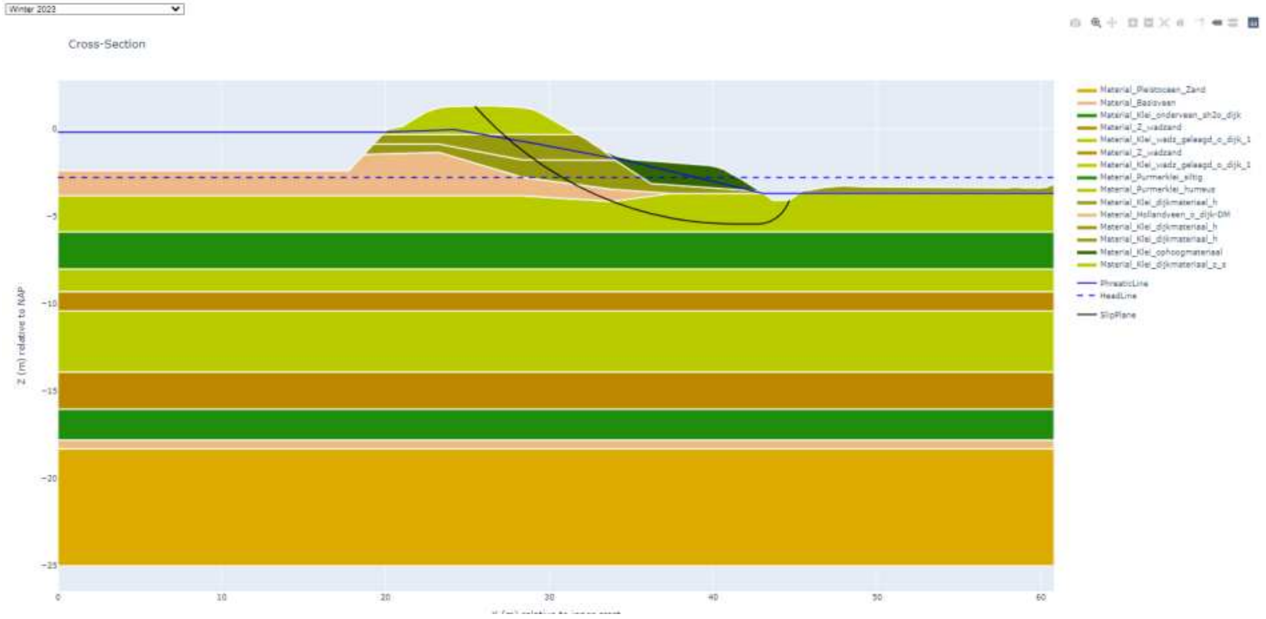
The stability is time dependent and the main time dependent drivers controlling the variation in stability are the pore water pressures and external loads (such as traffic loads). Here the stability is calculated based on three scenarios of PL and HL. The first is the highest measured PL (based on the inner crest stand pipe) with the corresponding HL. The second the highest hindcasted PL with the corresponding HL. And the last the PL and HL with a 1000 years return period. The corresponding dates are shown in the table below. The stability factors are calculated with D-Stability using D-GEOLib. The probability of failure for the scenario "1000 years return period" is calculated with the Probabilistic Toolkit.

Scenario	Date	Stability Factor	Probability of Failure	Convergence (prob)
maximum measured (until 18 Sept 2023)	2023-08-06 06:00:00	1.670710968666013	nan	nan
maximum hindcasted (until 20 sept 2023)	2019-10-01 22:00:00	1.4246732912121818	nan	nan
1000 year return period (extrapolated)	None	1.300366398512559	0.385365139255325	0.997170647182928
10 year return period (idf)	None	1.3048554703417017	nan	nan
100 year return period (idf)	None	1.2813114291905716	nan	nan
1000 year return period (idf)	None	1.2485670600595935	nan	nan
Winter 2023	None	1.4005026534881904	nan	nan

Details per Scenario

Choose below the pore water pressure scenario to be shown in the graph.

Winter 2023



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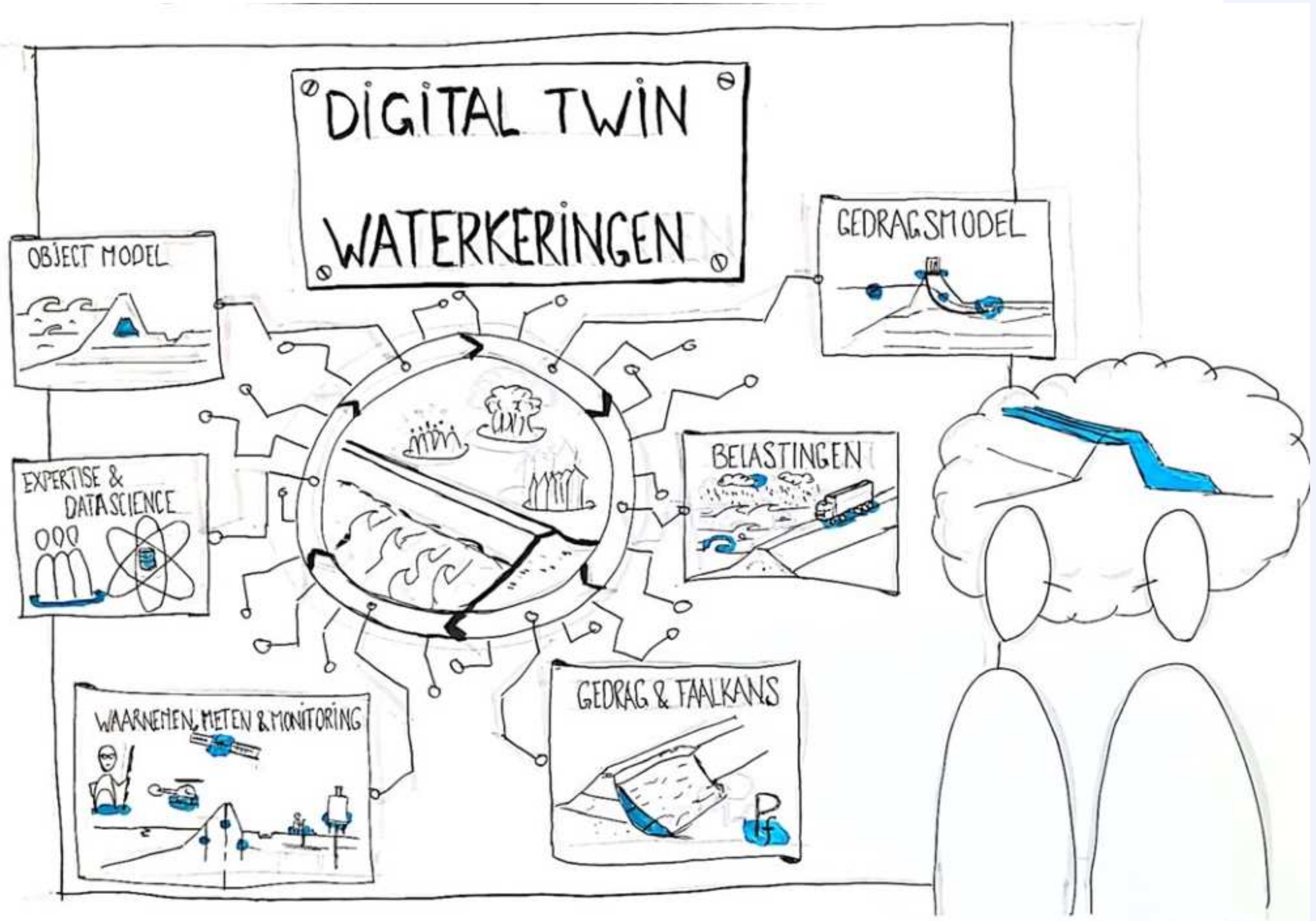
Conclusions

- Real time stability with groundwater monitoring
- Forecast/hindcast of stability with forecast/hindcast groundwater time series
- Updating the probability of failure with groundwater monitoring
- Possibilities to improve the models and predictions with more and better data (monitoring), other AI and data science techniques.



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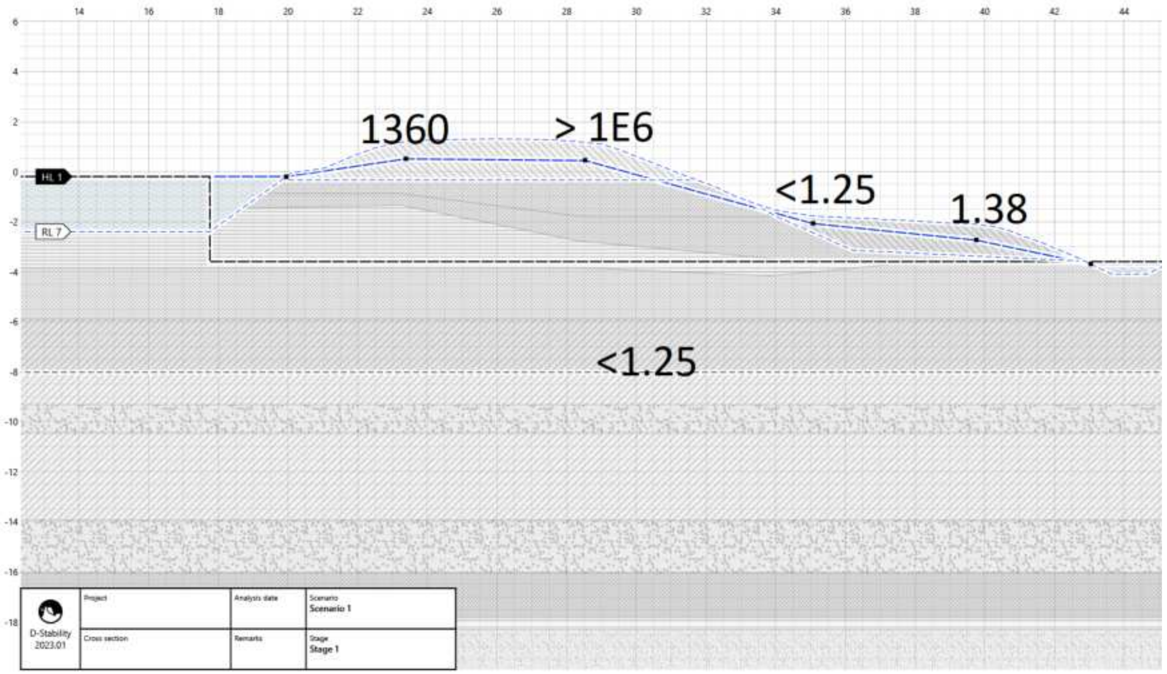
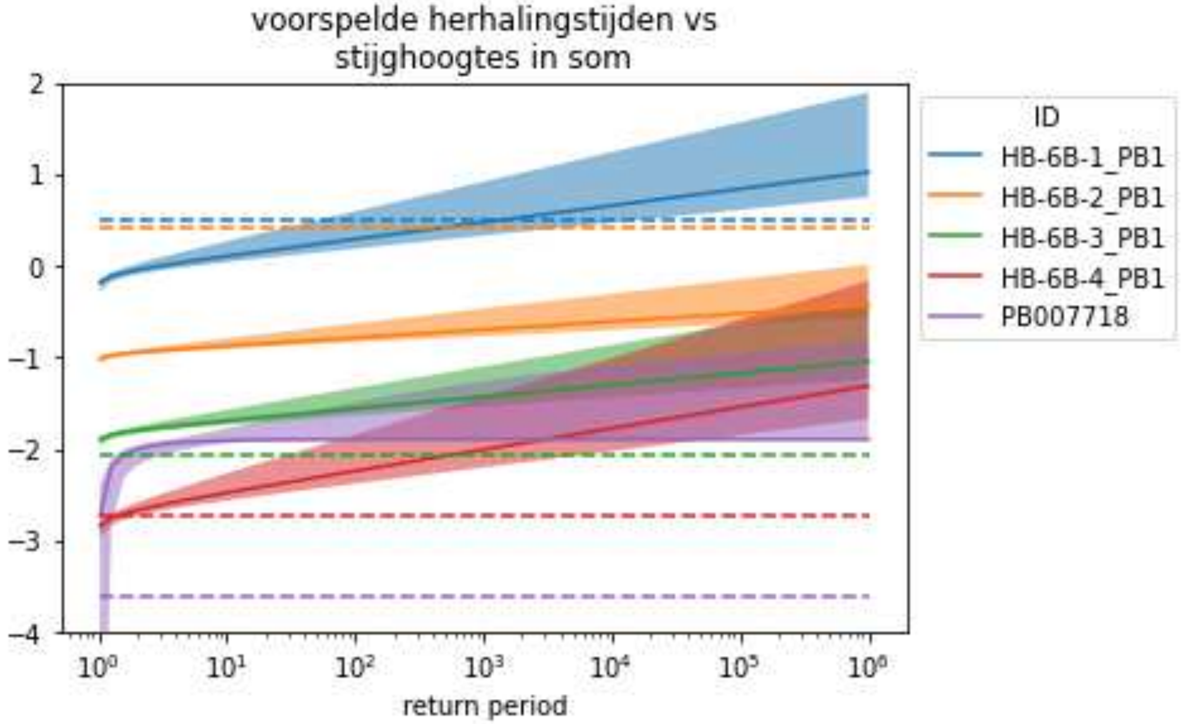
Comparison with assessment





Return periods

The hindcasted heads are extrapolated into heads with a 2, 10, 20, 100, 200, 1000 year return period. The result including the uncertainty band are shown in the graph below.