

Monitoring of regional dykes in their in-situ environmental conditions

Platform dijkmonitoring



Dyke monitoring at the Duifpolder

Project Sustainable dykes (NWO)

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Content

1. Problem statement
 2. Strategy
 3. Design of field monitoring
 4. Data impression
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Dutch dyke system & climate change

- Primary dyke system (+/-2.800 km)
- Secondary/Regional dyke system (+/- 14.000 km)

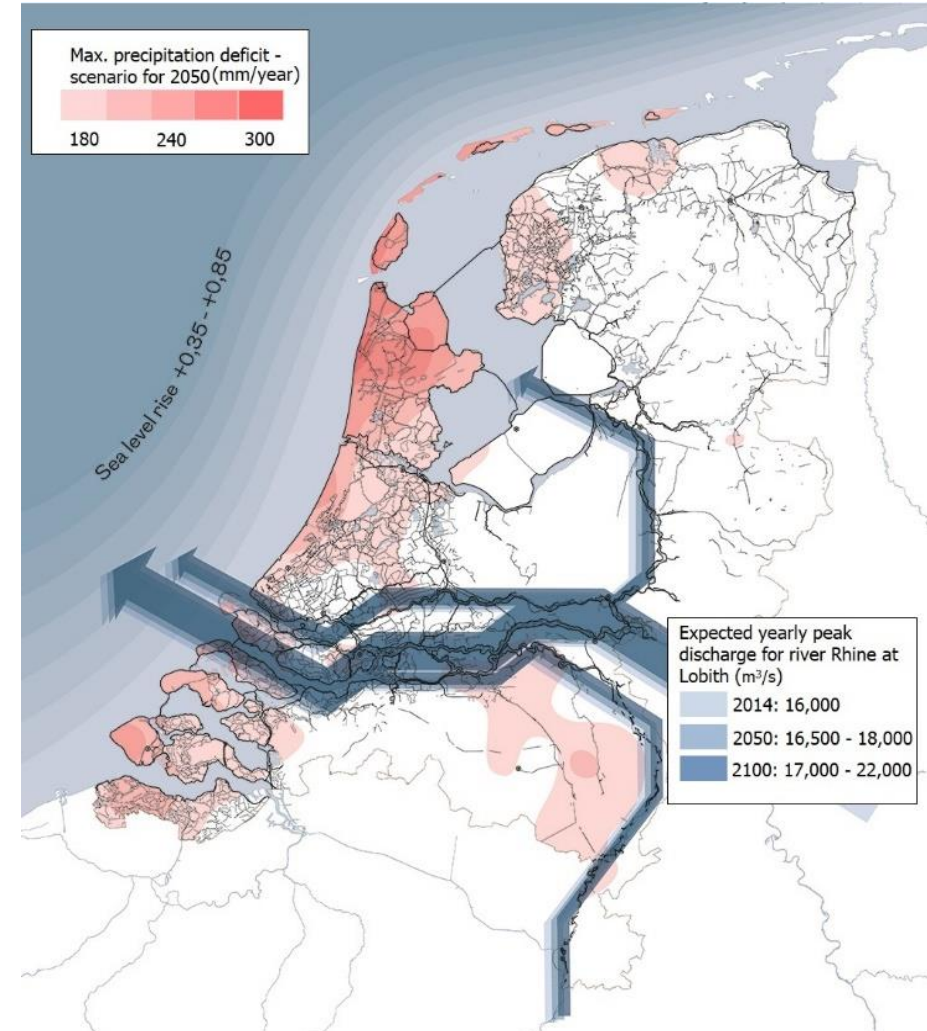
Changing environmental conditions:

Dyke load

- Hydraulic loads
- Environmental loads

Dyke resistance

- Degradation



Past incidents / failure events



Wilnis, 2003



High water event, 2021



Reeuwijk, 2021



Alblasserwaard, 2018



Hazepad, 2020

Dutch dyke system & climate change

Dyke load

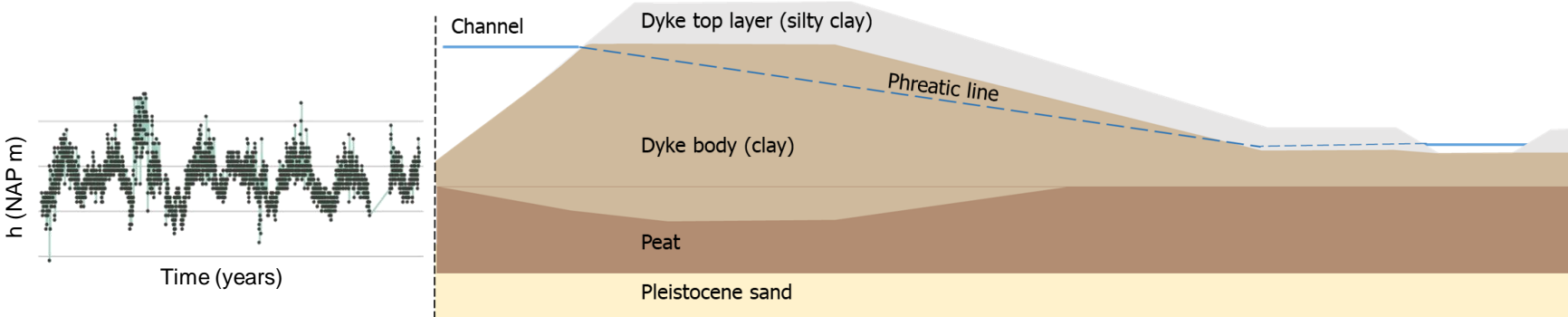
- Hydraulic loads
- Environmental loads

Dyke resistance

- Degradation

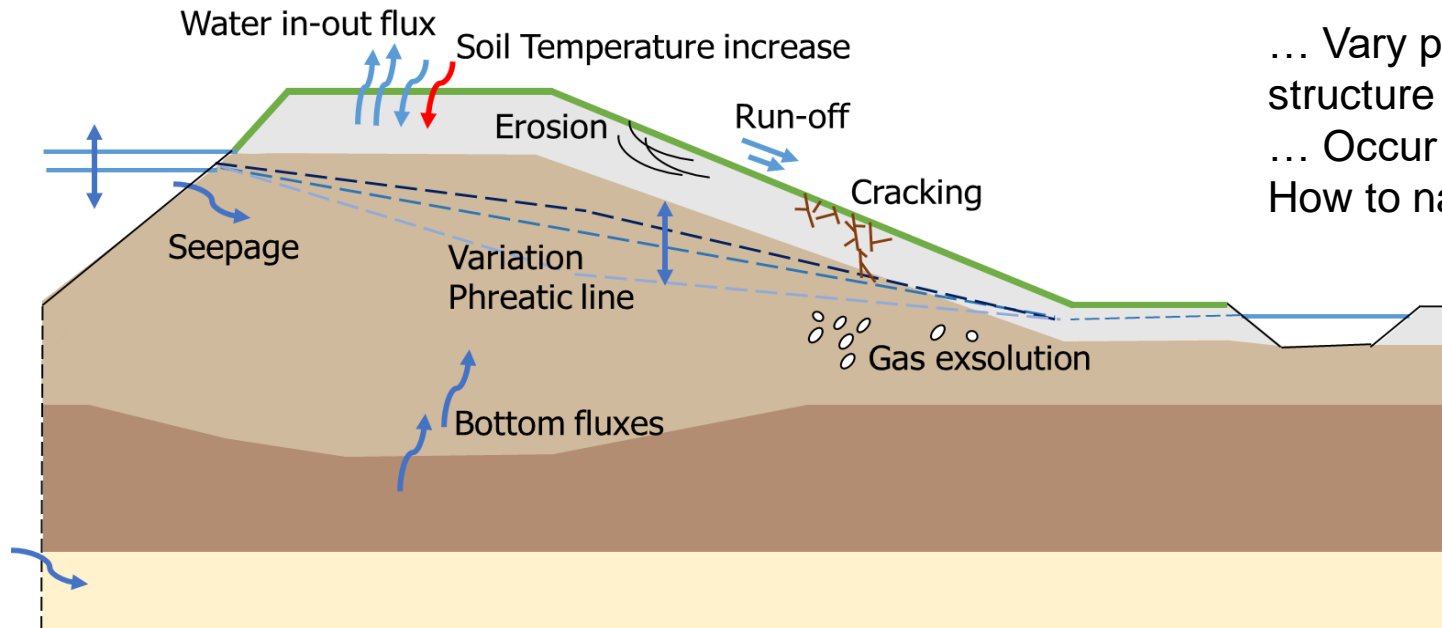
Enhanced understanding of climate – dyke interactions

- To identify soil physical processes relevant for geotechnical failure assessments
- To better predict impact of changing climatic conditions
- To support dyke asset management (inspections, modelling, maintenance)



Strategy

- Serious concern about long-term and short-term consequences of climatic stresses
- Lack of consensus on how to approach the problem
- Thermo-Hydro-Mechanical-Chemical-Biological processes...

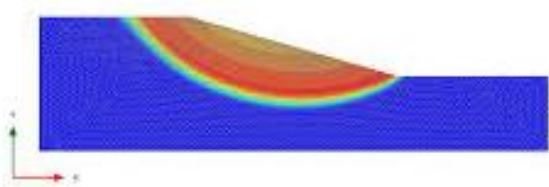


... Vary per soil type, per dyke structure
... Occur on different time scales
How to navigate through this?

Strategy

Modelling

- Prediction
- But only if...
- Insight into physical processes
 - Formulation of in-situ conditions
 - Choice for critical conditions



Assessment tools

Data: Field

- Full scale, under in-situ conditions
- Identify pre-failure behaviour
- Large degree of information

Though...

- Costly
- Specified per study



Leendert de Boerspolder, 2015

Laboratory

- Under controlled conditions of choice
- Monitoring soil response

Downsides...

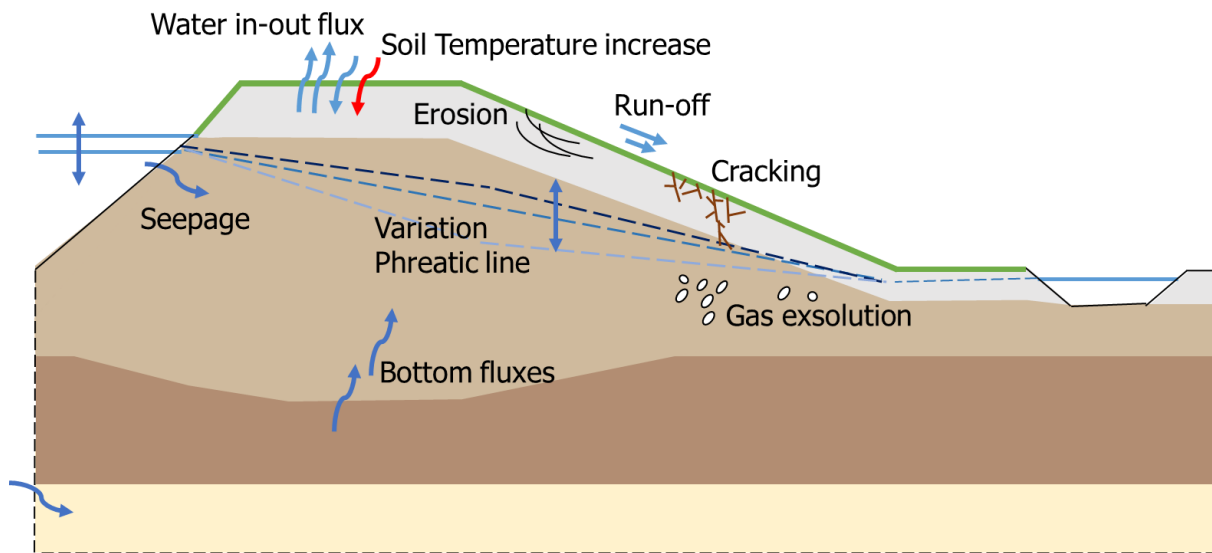
- Often isolating phenomena
- Scaling problems



Strategy

In-situ monitoring

- Under all triggering environmental conditions
- Further reduce the high degree of potential relevant geotechnical variables



Observations
on field scale

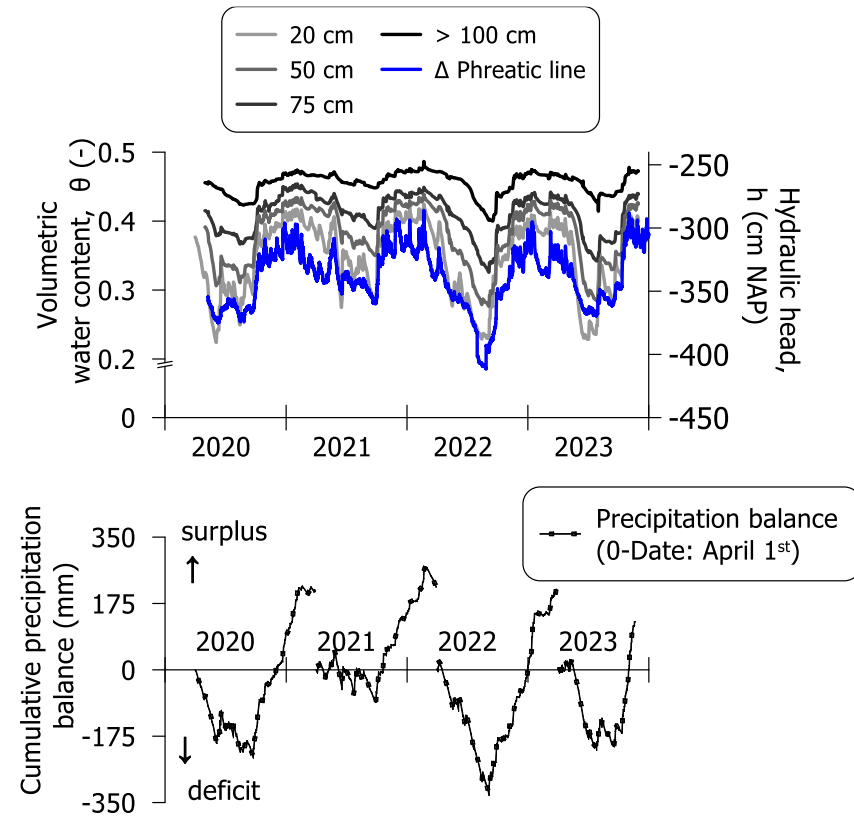
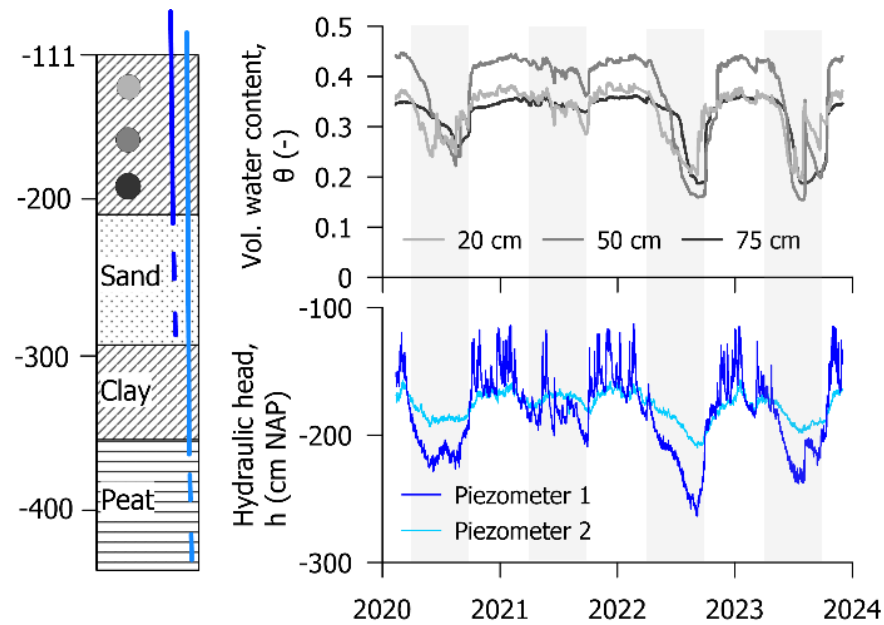
Soil physical
processes
(Laboratory)

Modelling

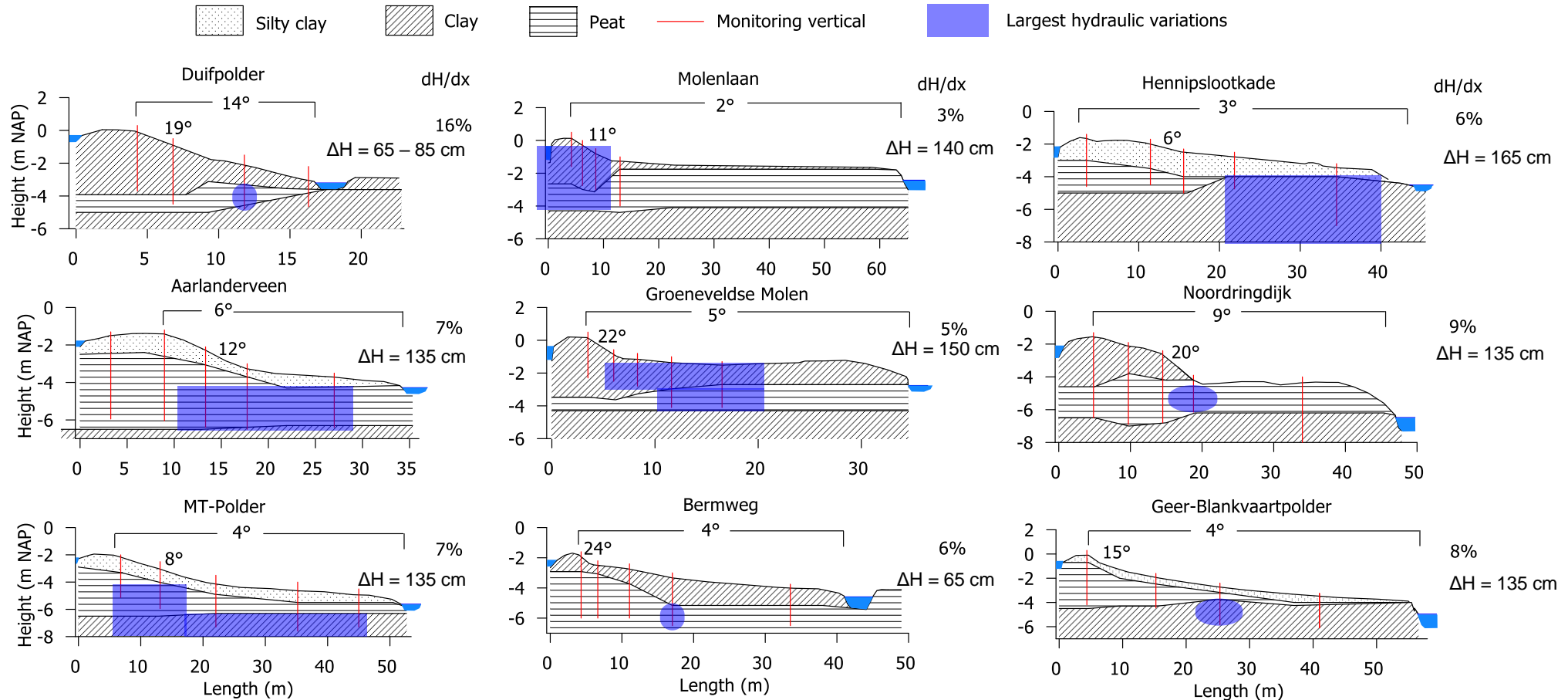
Drought Monitoring

Bart Strijker, waterboards Delfland, HHSK, Rijnland

- Importance of top boundary condition



Hydraulic variations

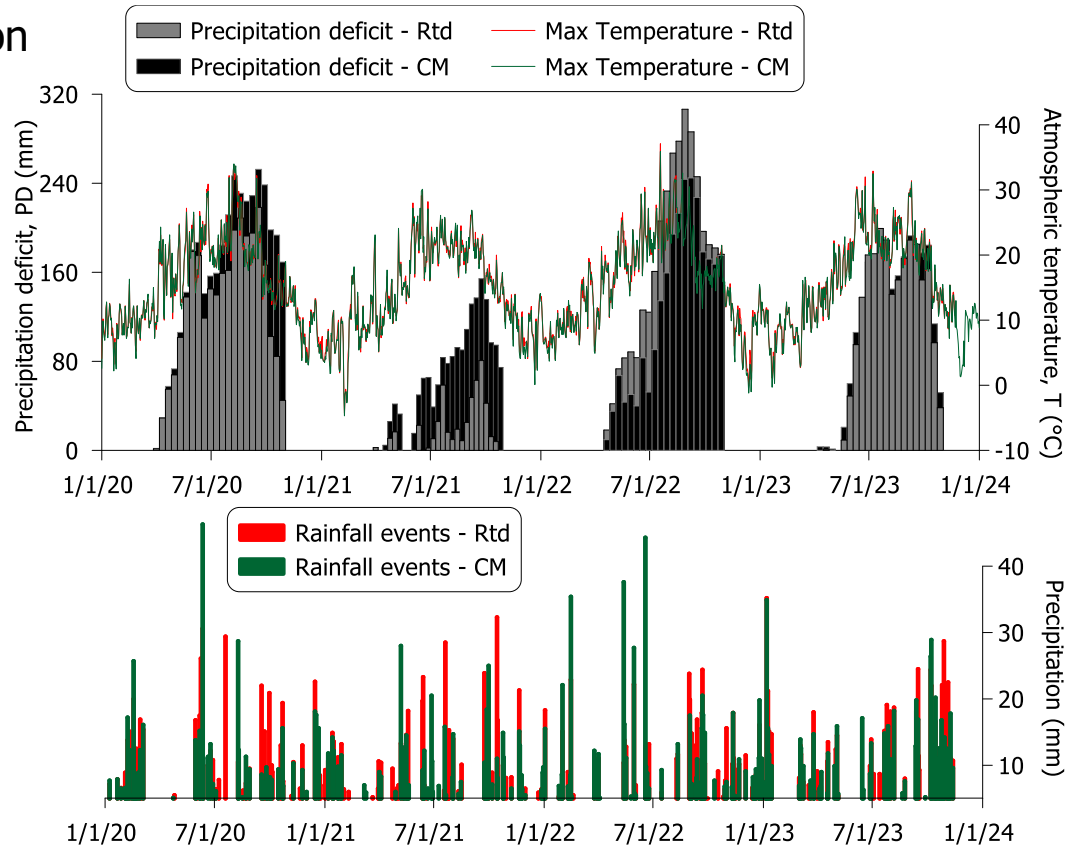


Spatial factors

- Varying boundary conditions
- Dyke geometry
- Soil composition

Weather conditions

Subsurface hydrology

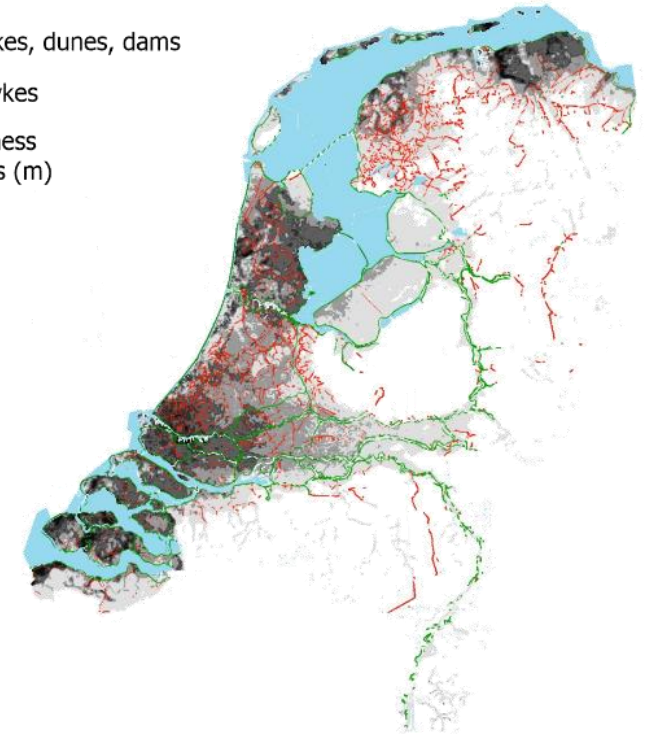


Primary dykes, dunes, dams

Regional dykes

Cumulative thickness
Holocene deposits (m)

- 1 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- > 20

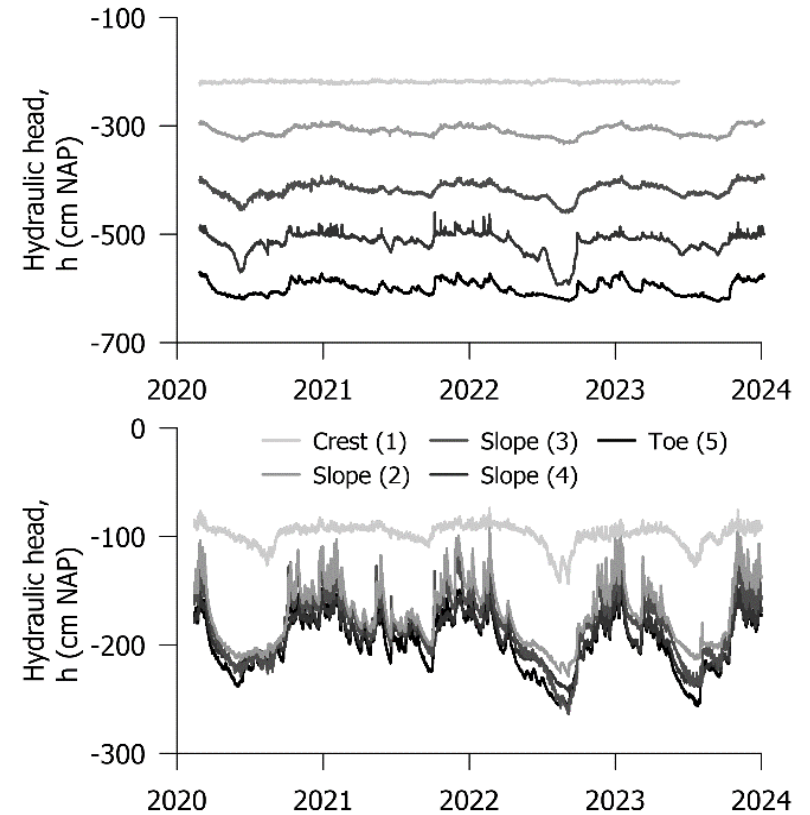
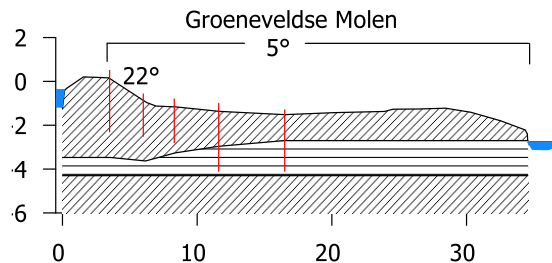
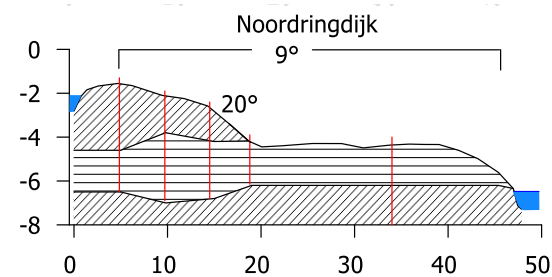


Spatial factors

- Varying boundary conditions
- Dyke geometry
- Soil composition

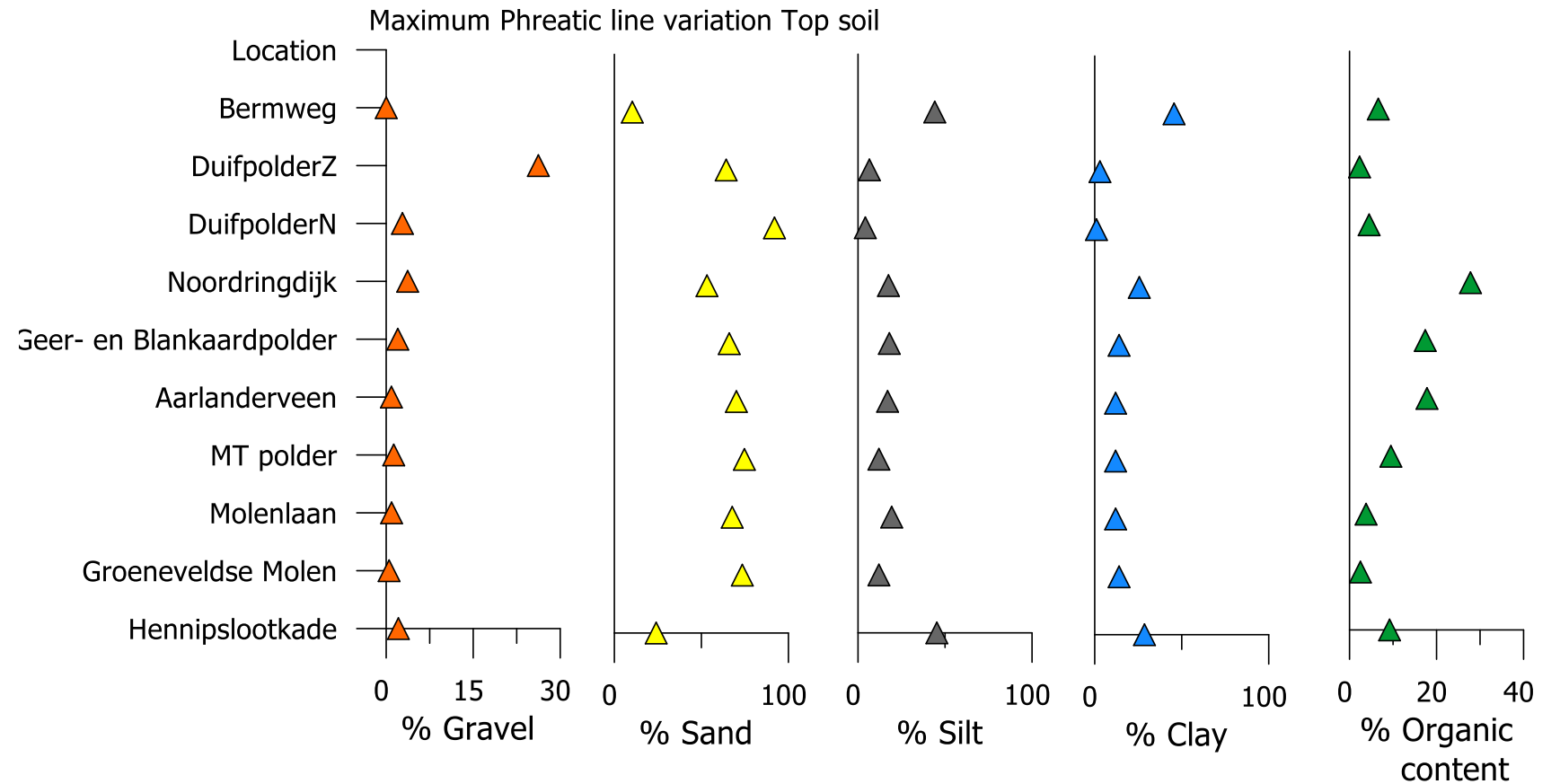
Weather conditions

Subsurface hydrology



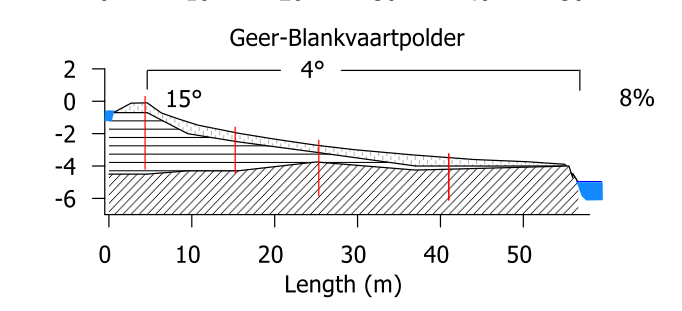
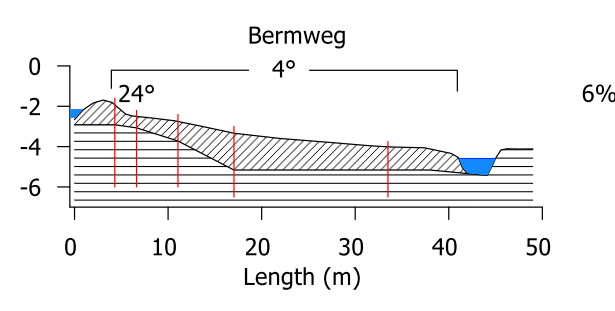
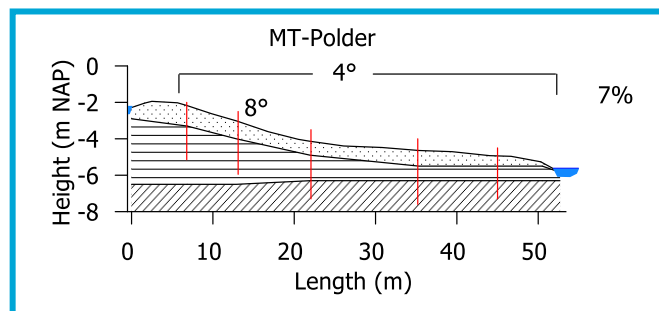
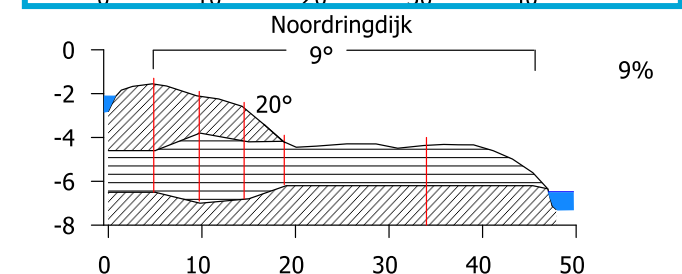
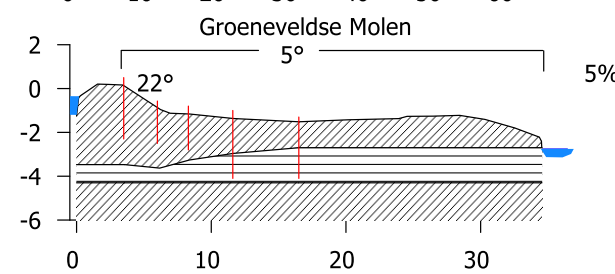
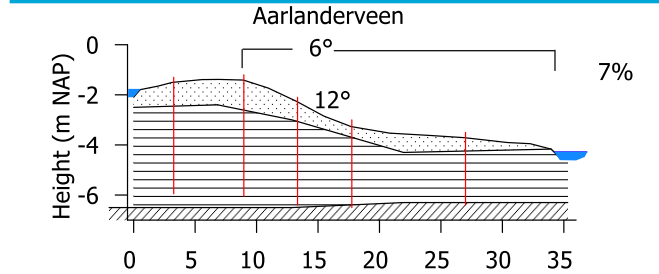
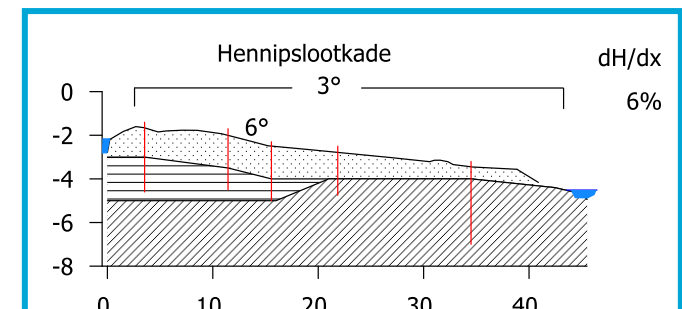
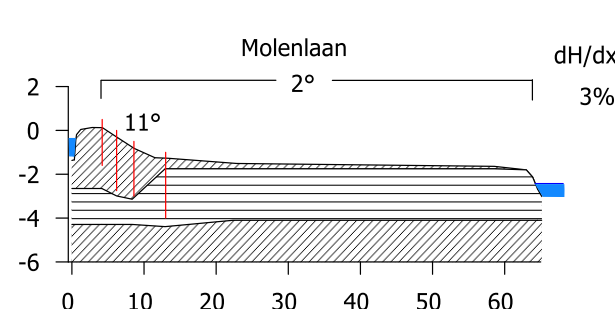
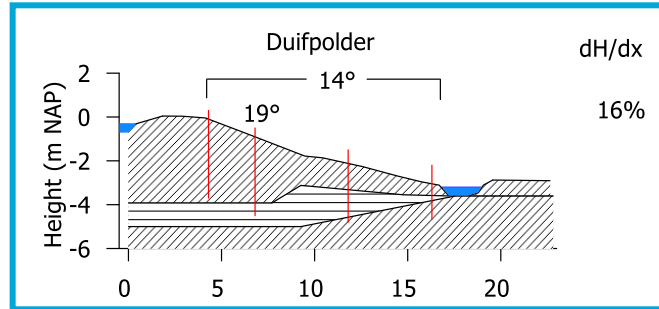
Spatial factors

- Varying boundary conditions
- Dyke geometry
- Soil composition



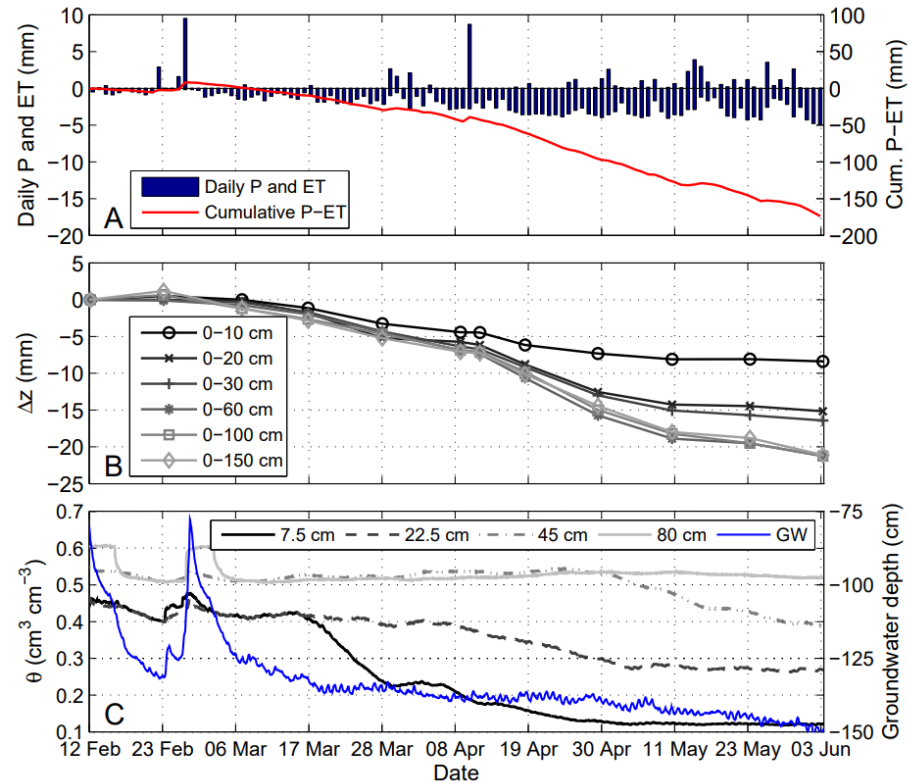
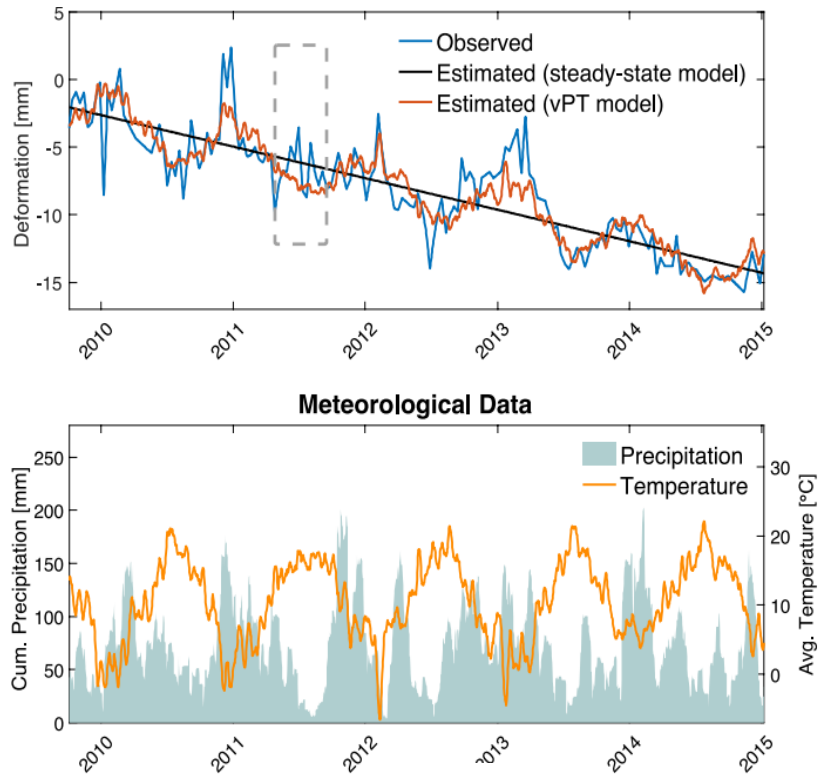
Selection of case studies

- Slope geometry
- Pleistocene Sand position
- Vegetation
- Hydraulic variation
- Stratigraphy



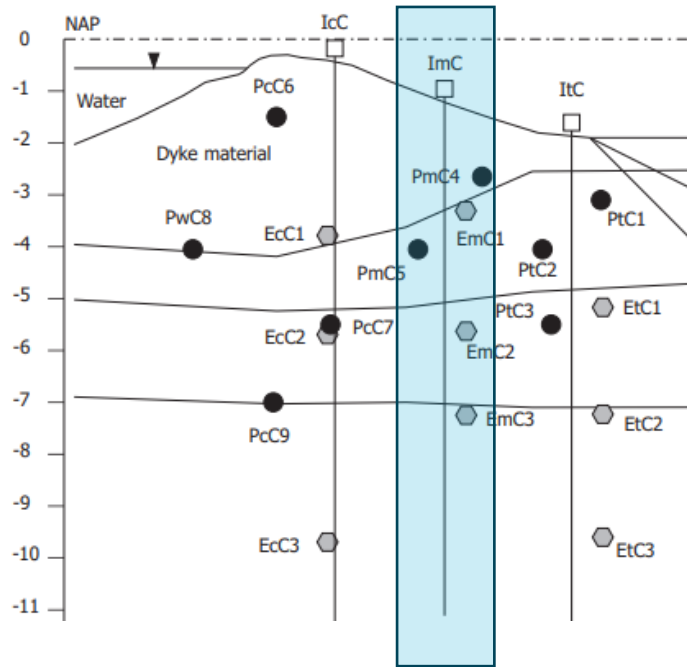
Monitoring of deformation

- Hydromechanical behaviour of individual soil layers
- Understanding how hydraulic changes are brought about (soil storage capacity)
- Understanding impact over depth

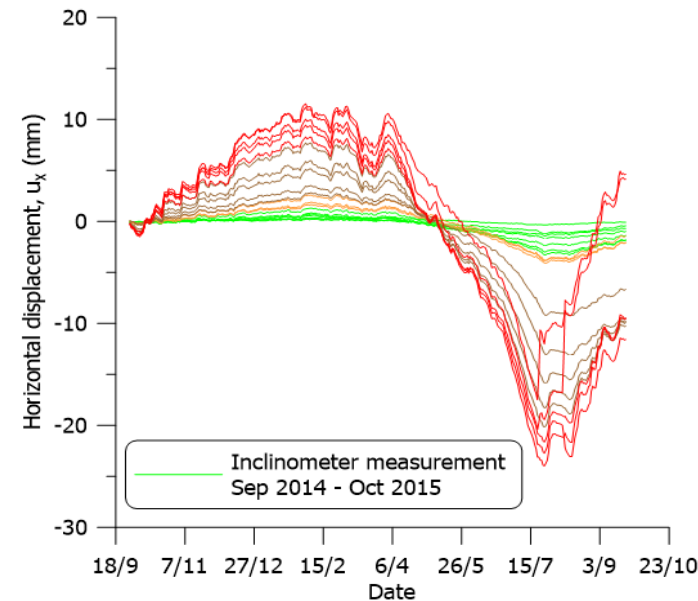


Monitoring of deformation

- Understanding how hydraulic changes are brought about (soil storage capacity)
- Understanding impact in depth
- Behaviour of individual soil layers



Muraro, 2019



Leendert de Boerspolder

Monitoring plan

What variables to gather?

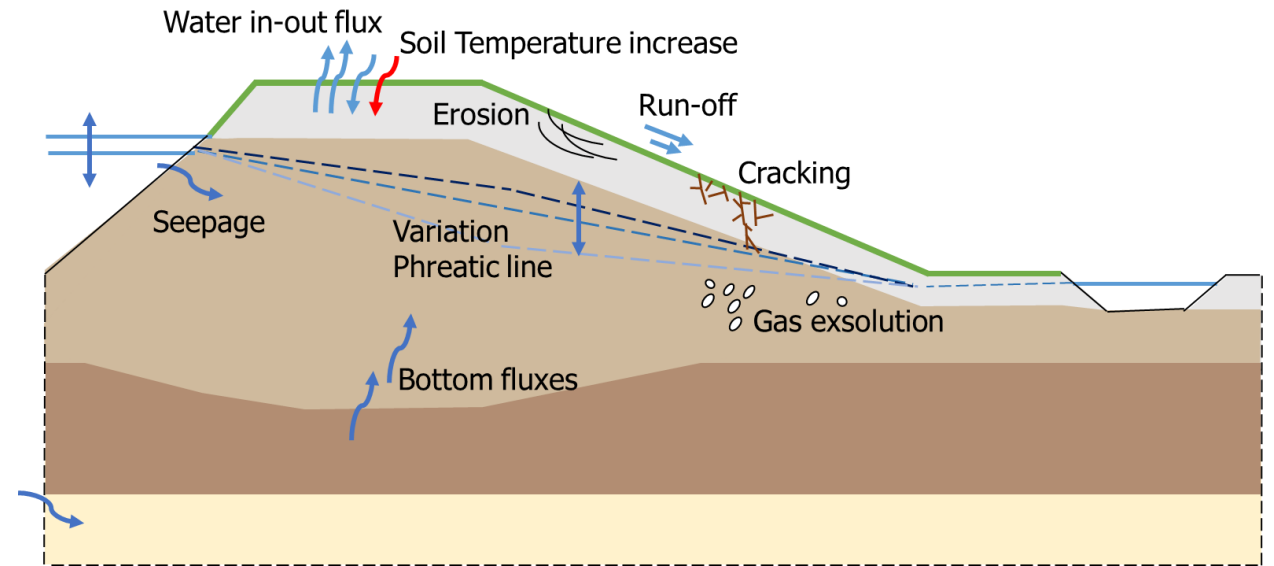
To verify our hypothesis (on possible soil degradation processes)

To verify modelling attempts (state variables)

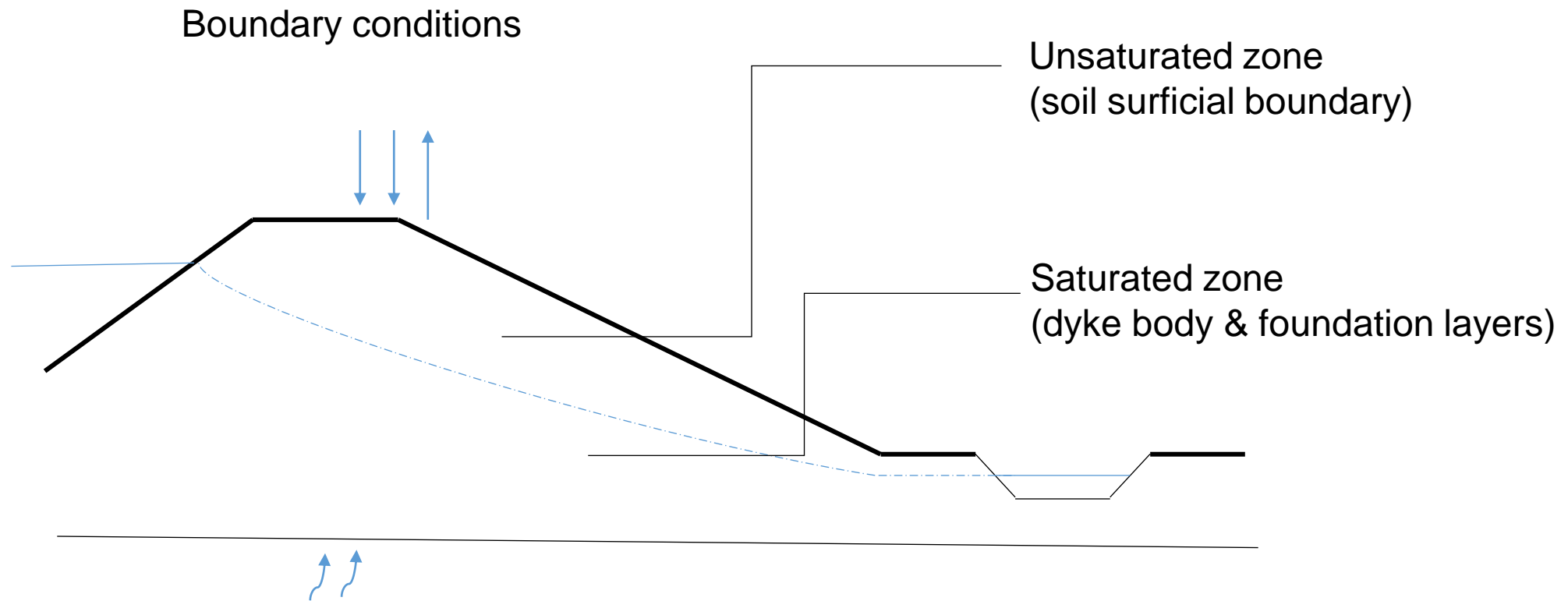
How to ensure reliability?

The reliability and accuracy of [sensor itself](#)

The reliability of the monitoring configuration to allow a representative [2D schematization](#) of the dyke bodies.



Monitoring variables



Monitoring variables



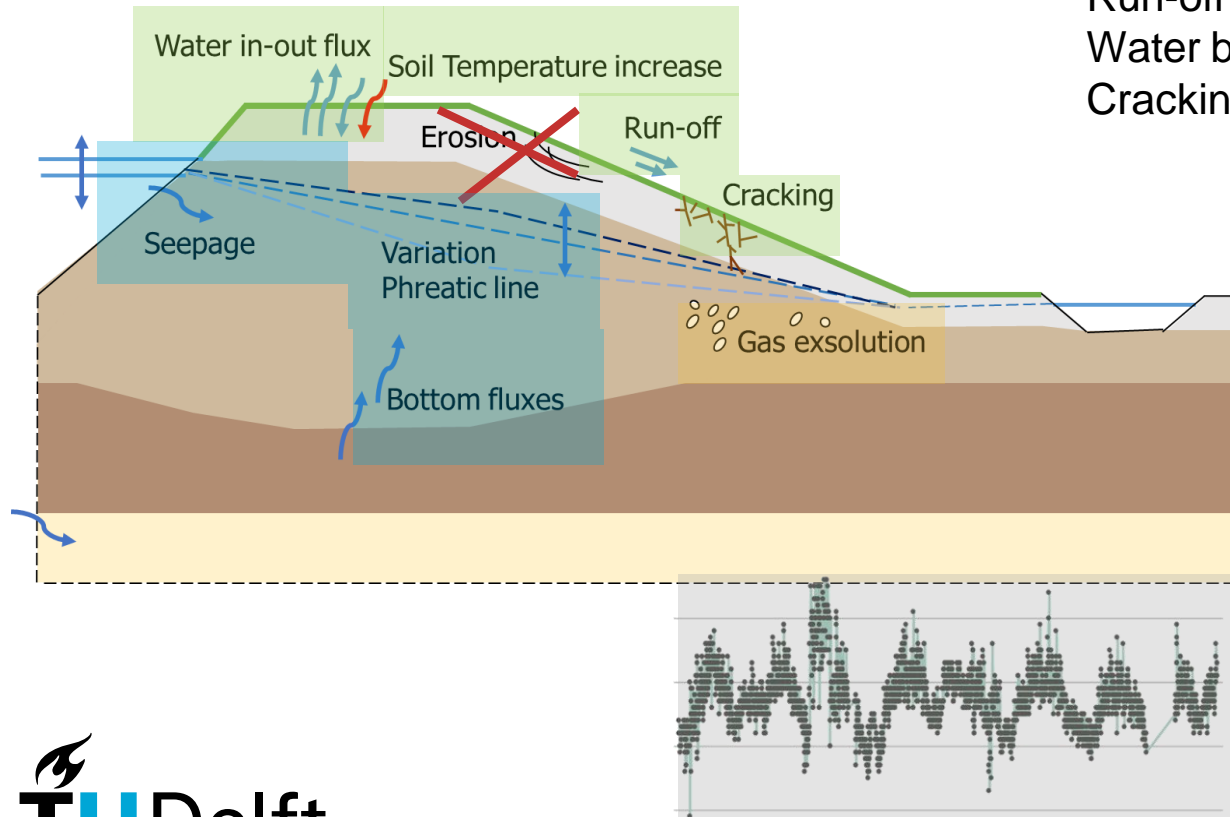
Boundary conditions
Public resources
Standpipe / Water pressure sensors

Soil storage capacity (unsaturated zone)
Vegetation
Moisture content
In-situ shrinkage, swelling
Run-off
Water balance
Cracking

Alterra (2022)
Moisture content sensors
Extenso/Inclino
Modelling
Modelling
Sensor signals/
observations

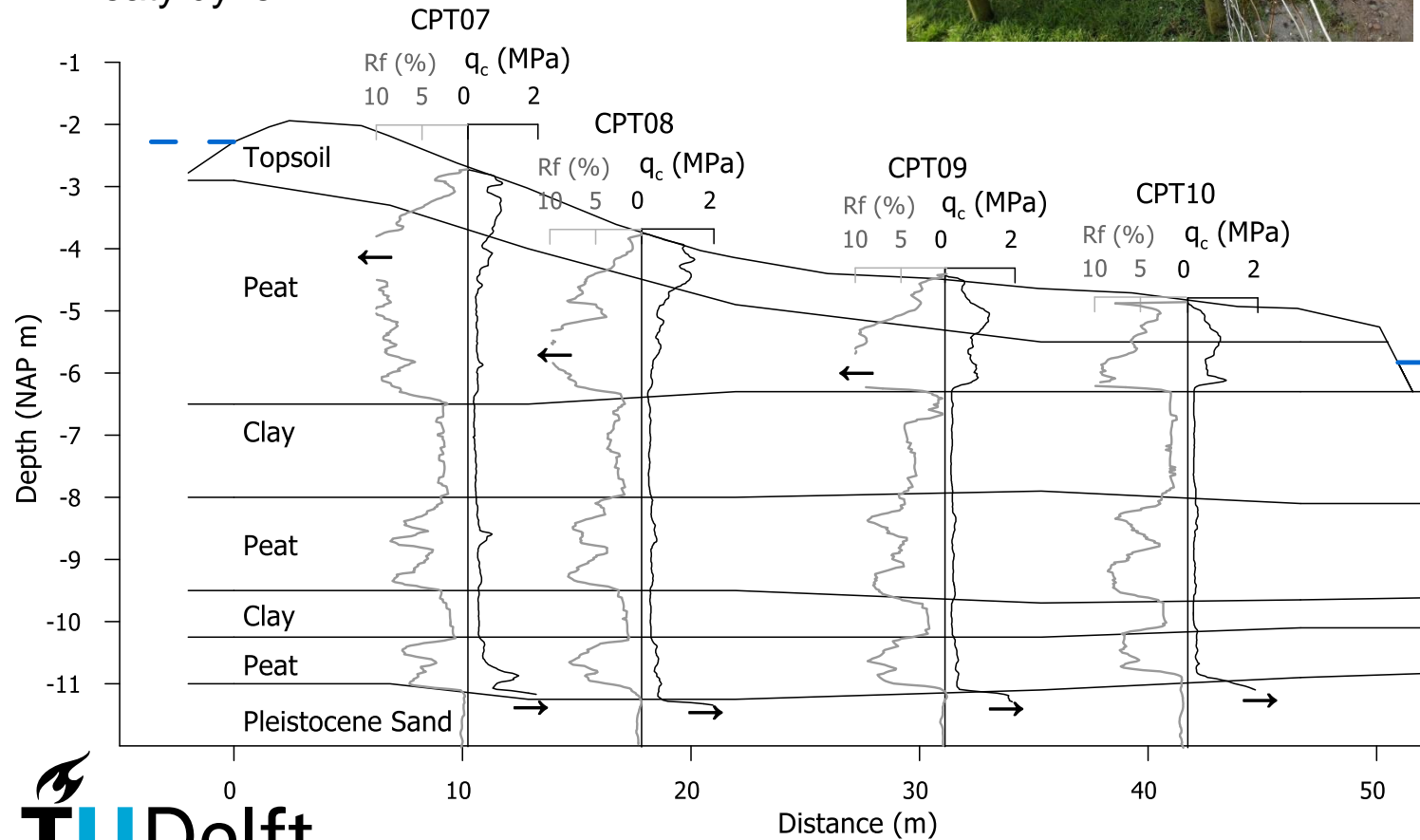
Biodegradation
Soil Temperature
Local pore water pressure
Temperature sensors
WSM

Dyke body & foundation layers
Stratigraphy
In-situ shrinkage, swelling
Hydraulic head
CPTu
Extenso/Inclino
WSM, Piezometers,
public resources,
modelling

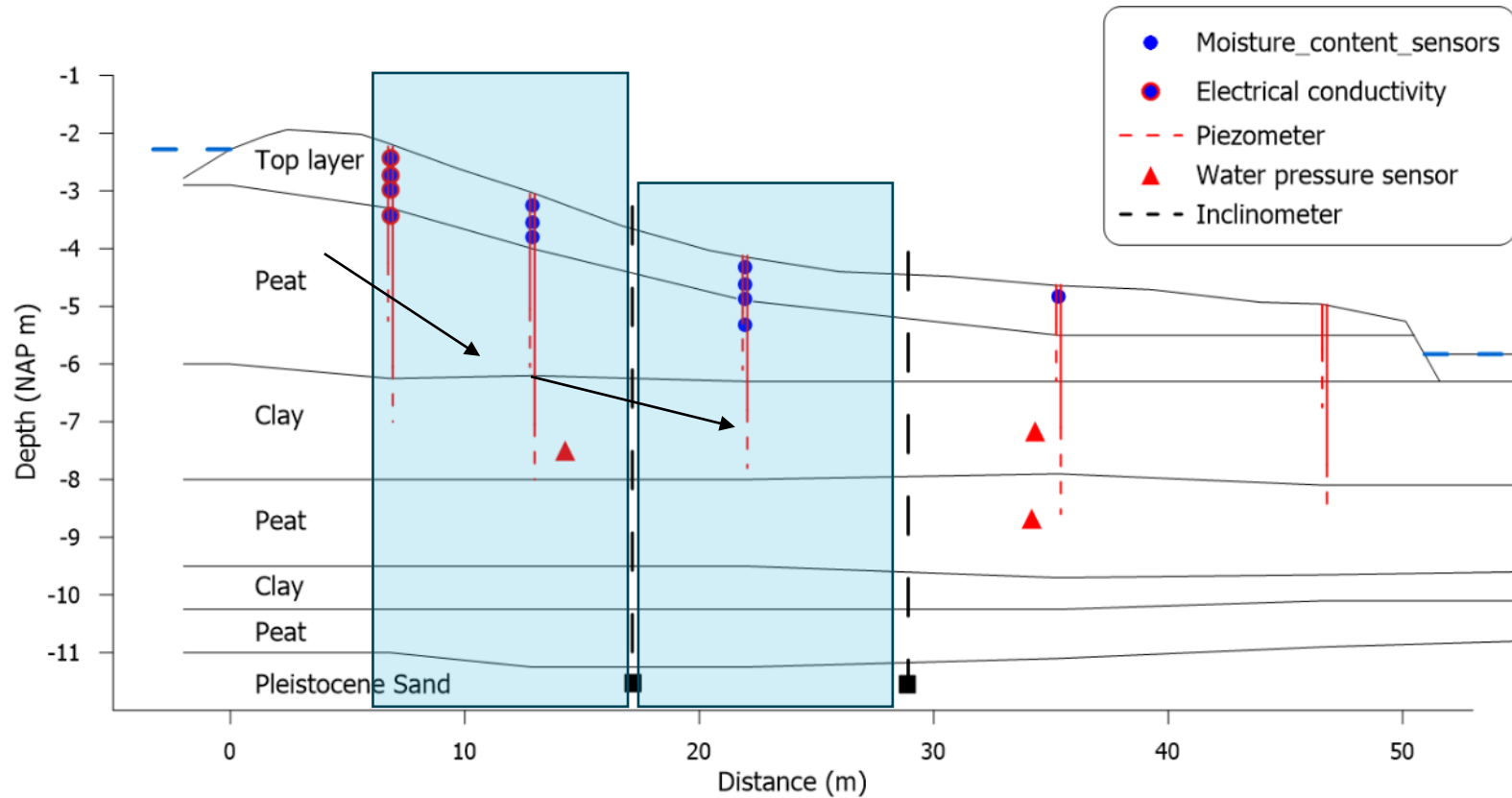


MT-Polder

- Stability issues
- Shallow Pleistocene sand layer
- Peaty dyke

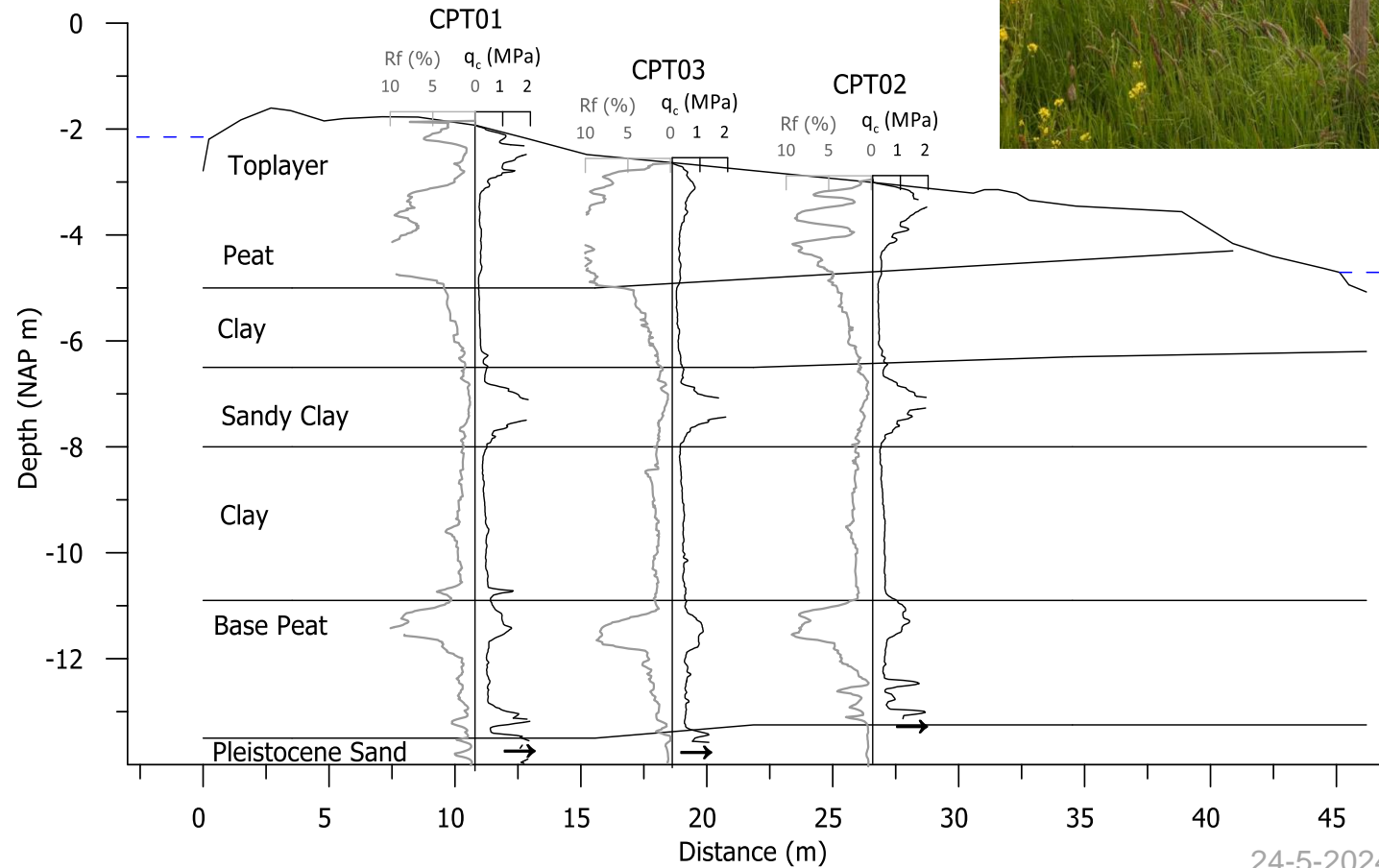
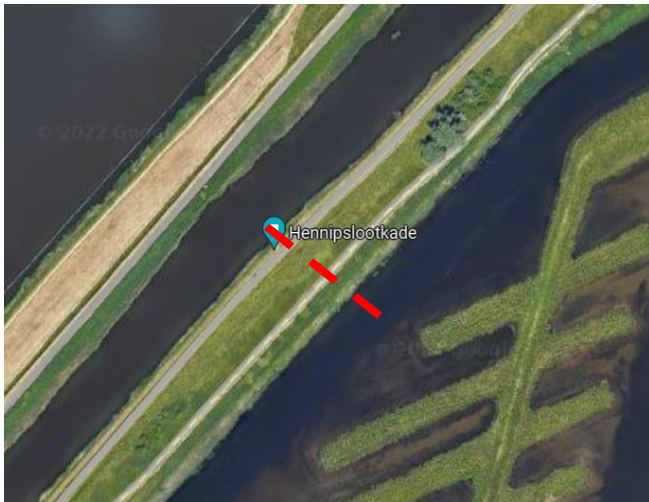


MT-Polder

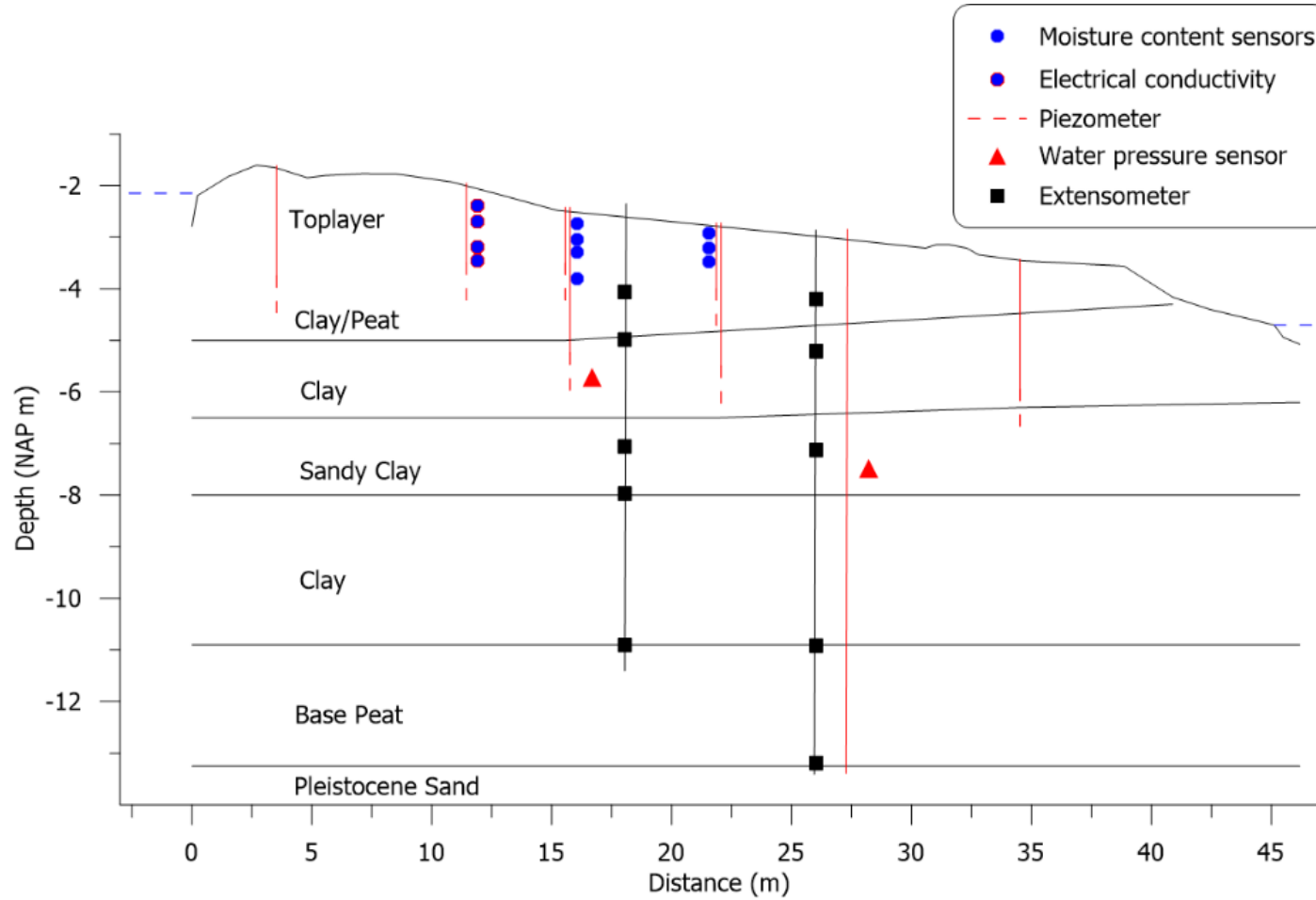


Hennipslootkade

- Gentle dyke
- Water rich area
- Highly vegetated
- Largest hydraulic variations

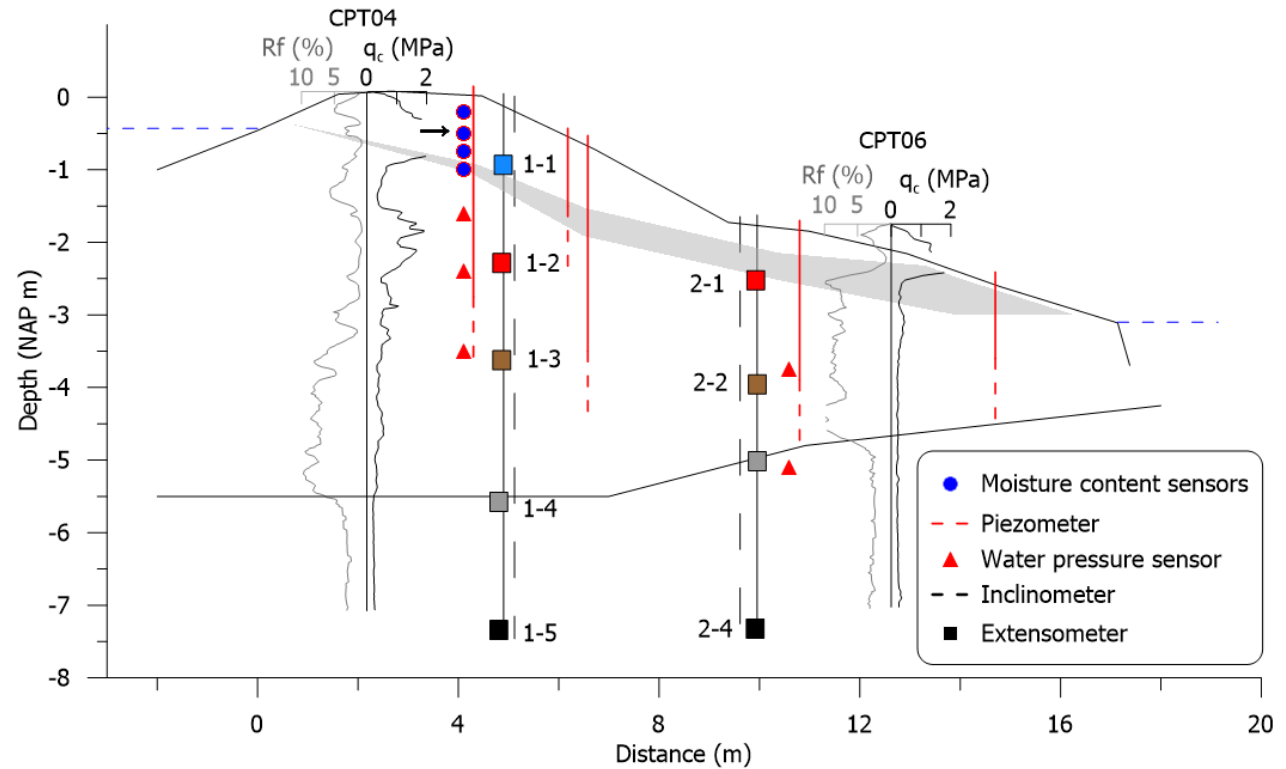


Hennipslootkade



Duifpolder

- Steep dyke
- Clayey dyke
- Strong heterogeneous top layer
- Double monitoring



Conclusion

- From literature... Multiple physical soil processes can be identified for climate-dyke interactions
 - Field observations allow to identify significance to the large scale
- Initial observations (droogtemonitor) allowed us to infer:
 - Interplay between boundary conditions
 - Importance of dyke characteristics (like geometry)
- To go from hydraulic variations towards geotechnical stability assessments:
 - Extension of deformation monitoring at 3 case studies
 - Correlating monitoring data with environmental conditions