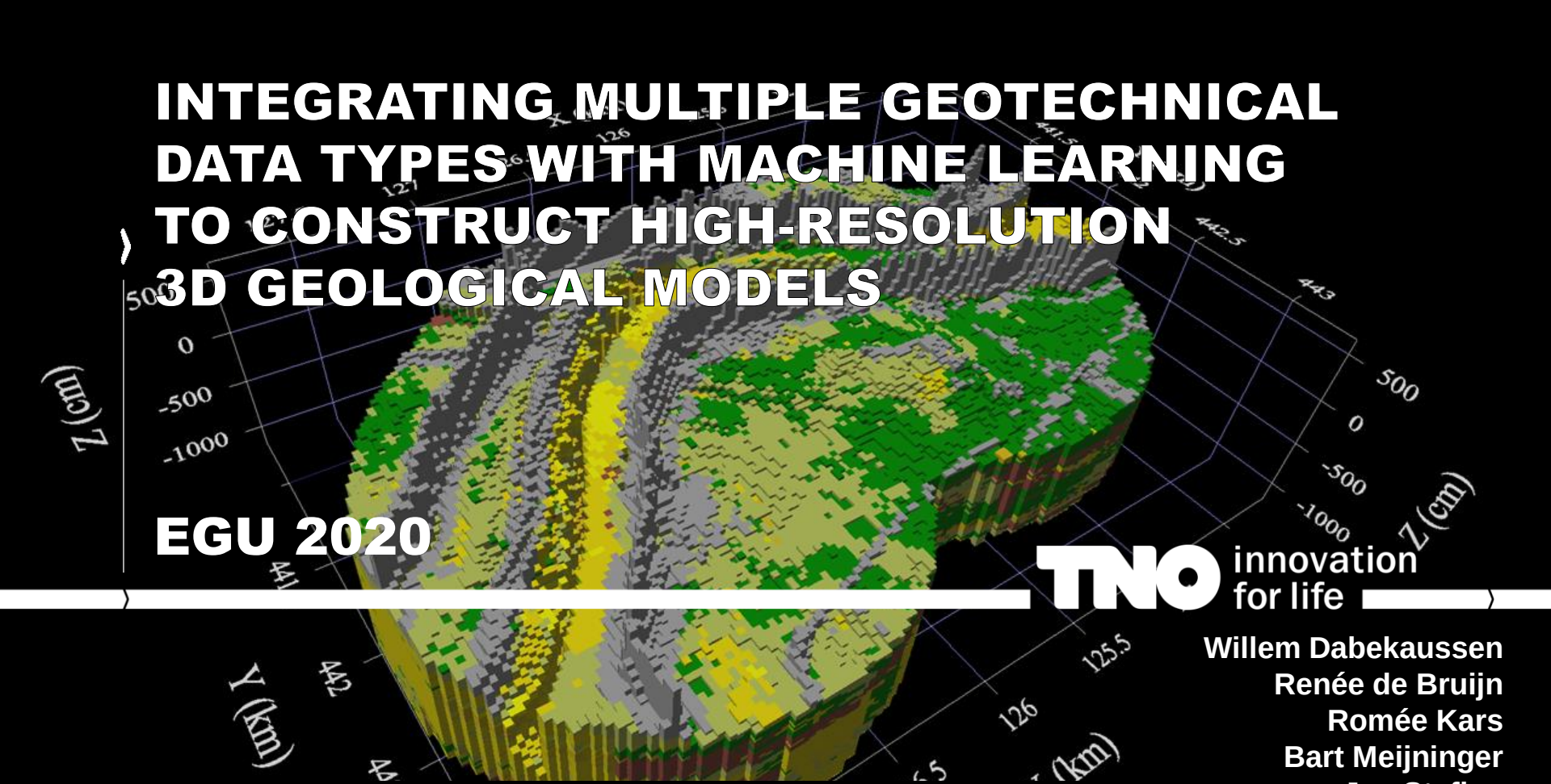
INTEGRATING MULTIPLE GEOTECHNICAL DATA TYPES WITH MACHINE LEARNING TO CONSTRUCT HIGH-RESOLUTION 3D GEOLOGICAL MODELS



EGU 2020

TNO innovation for life

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TNO – Geological Survey of the Netherlands

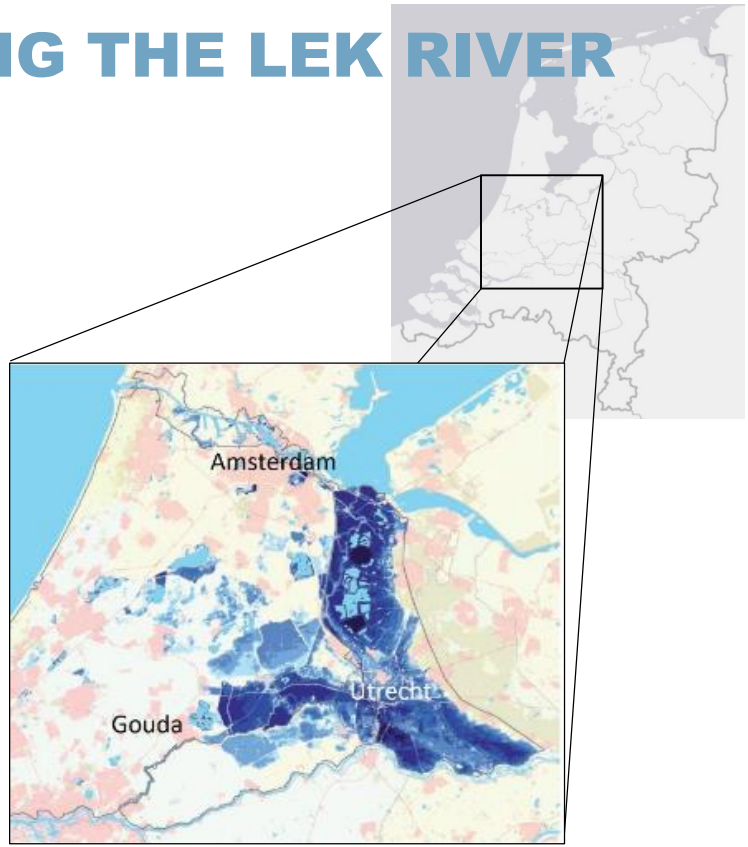
HOOGHEEMRAADSCHAP DE STICHTSE RIJNLANDEN
Geodan
Ministerie van Binnenlandse Zaken en Koninkrijksrelaties

DIKE REINFORCEMENTS ALONG THE LEK RIVER

The Northern Lek River dike protects a large and densely populated area of the Netherlands, including the cities Utrecht and Amsterdam.

Water Authority Hoogheemraadschap De Stichtse Rijnlanden (HDSR) maintains the dike and launched the project ‘Sterke Lekdijk’ for large scale reinforcements.

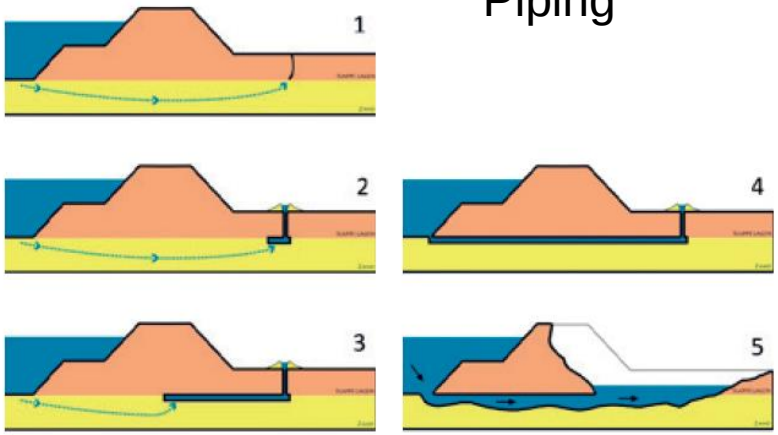
The strength and stability of the dike depends
- on its design
- the composition of the subsurface



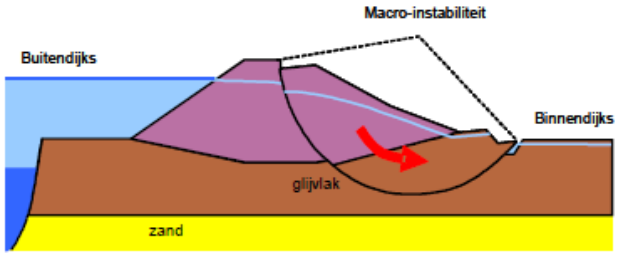
Source: Veiligheid Nederland in Kaart, 2014; Brochure Sterke Lekdijk, Geodan, 2018

DIKE FAILURE MECHANISMS RELATED TO SUBSURFACE CONDITIONS

Piping

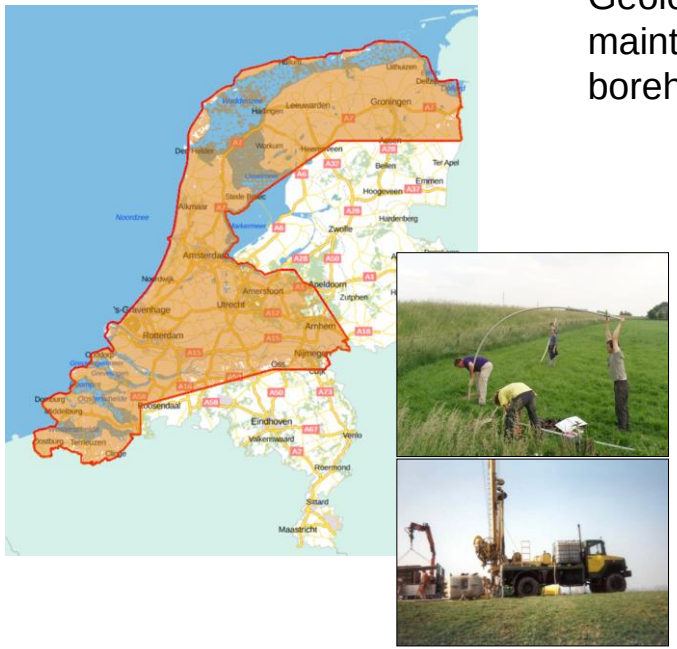


Macro-instability

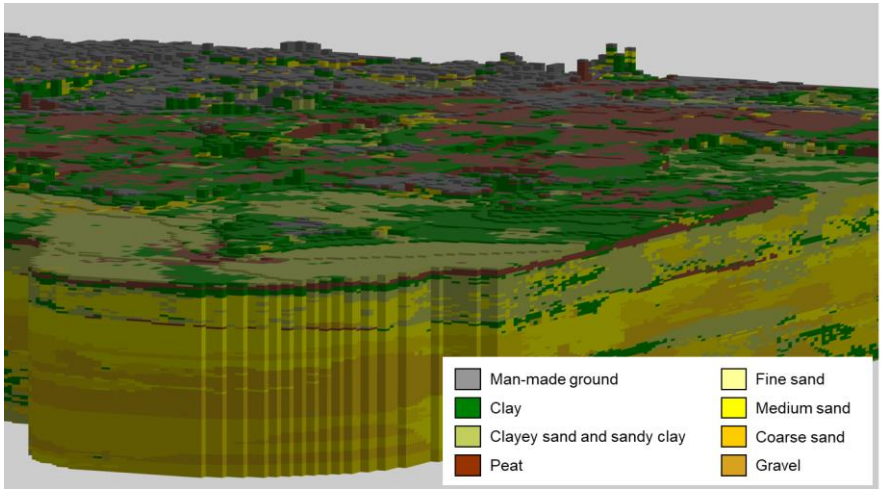


Detailed knowledge of the subsurface is essential!

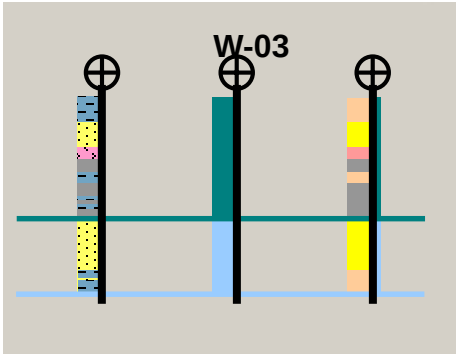
REGIONAL MODEL FOR SHALLOW SUBSURFACE



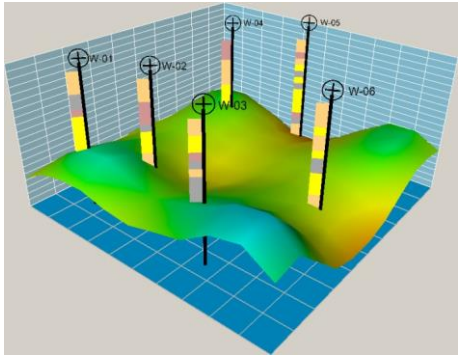
Geological Survey of The Netherlands develops and maintains GeoTOP model, based on ~ 580,000 boreholes.



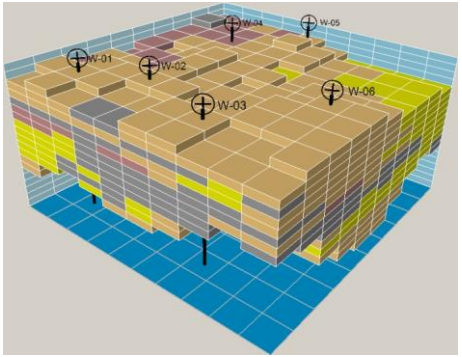
GEOTOP WORKFLOW



Lithostratigraphical interpretation of borehole logs



2D interpolation of stratigraphical surfaces

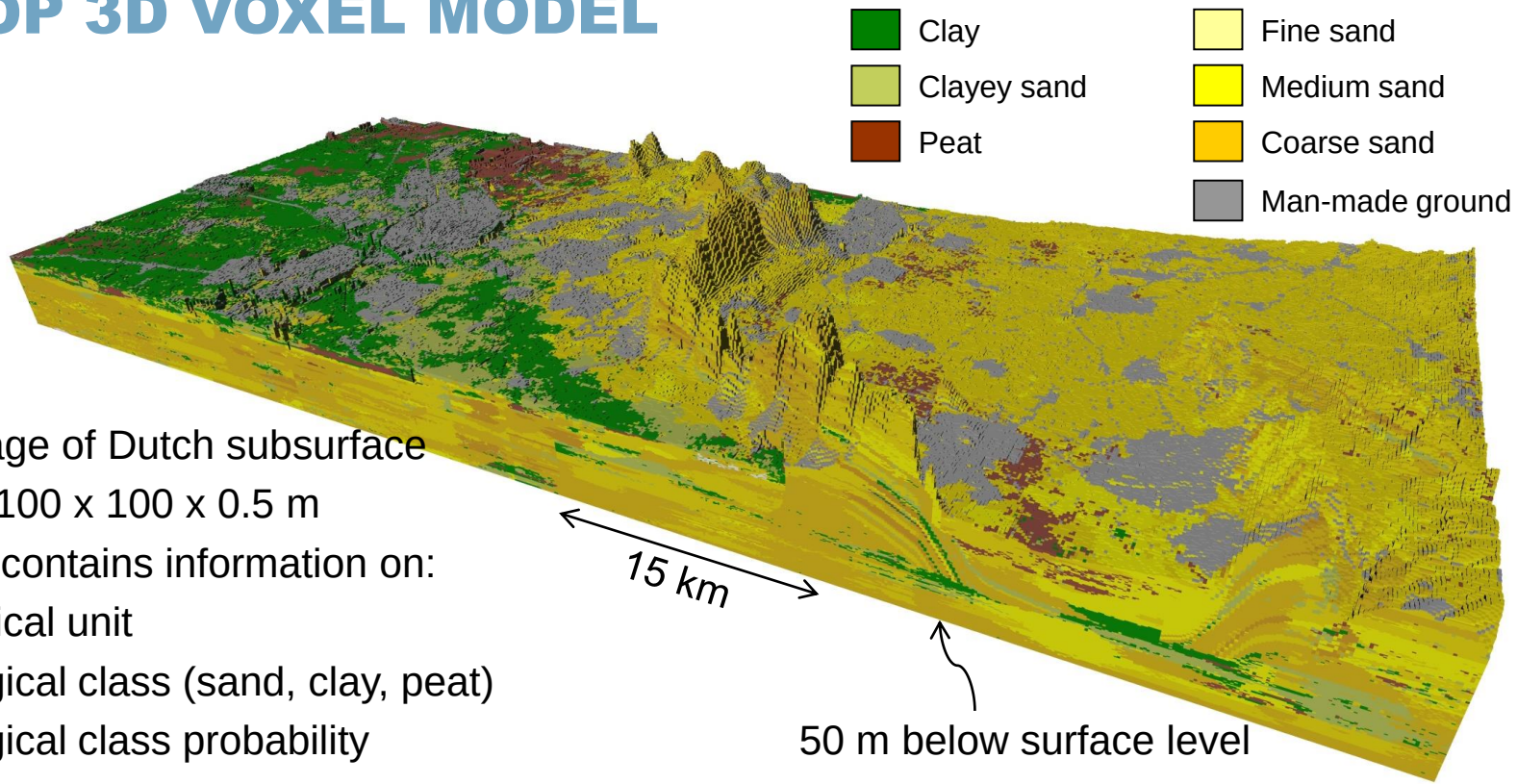


3D interpolation of lithological class within each stratigraphical unit

layer-based model **voxel model**

Stochastic simulation techniques allow quantification of uncertainty

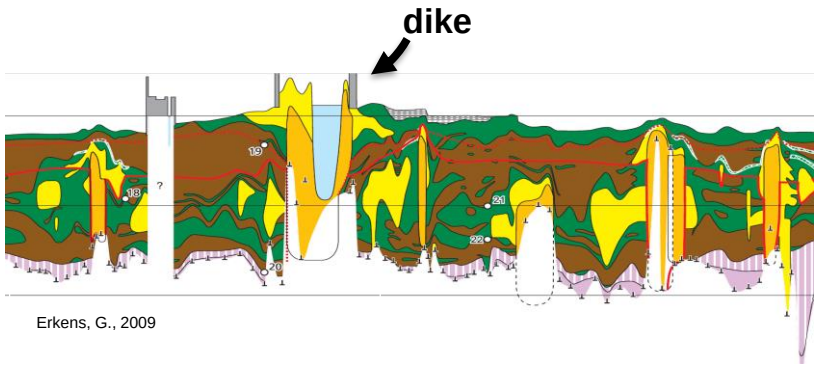
GEOTOP 3D VOXEL MODEL



- ~2/3 coverage of Dutch subsurface
- Resolution 100 x 100 x 0.5 m
- Each voxel contains information on:
  - Geological unit
  - Lithological class (sand, clay, peat)
  - Lithological class probability

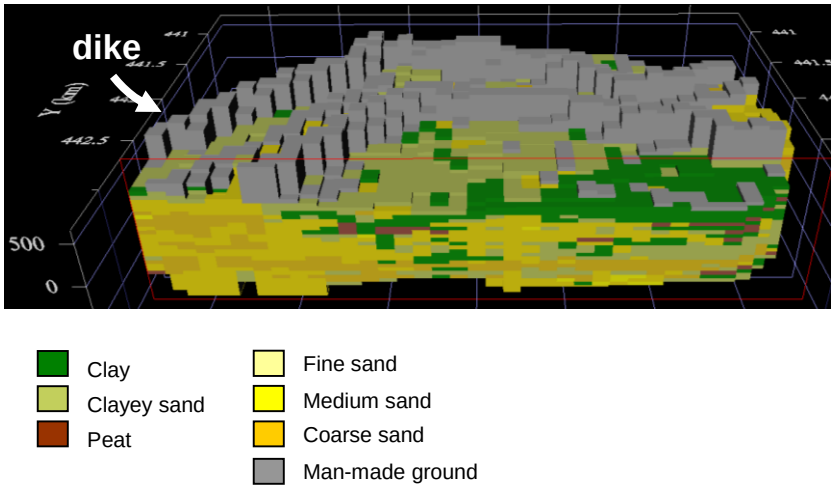
COMPLEX HOLOCENE GEOLOGY

- Lek river dike built on complex Holocene geology
- Regional GeoTOP model provides 100 m horizontal resolution
- Dike reinforcement projects require more detailed subsurface model

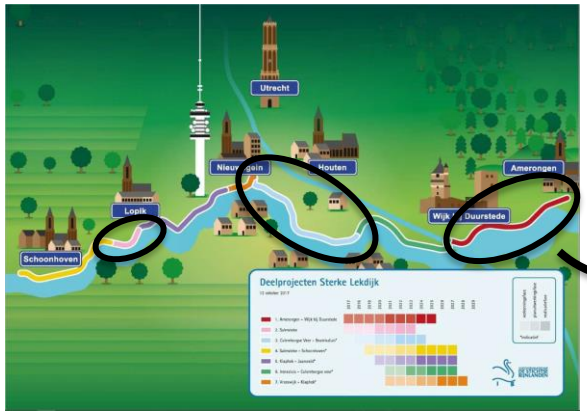


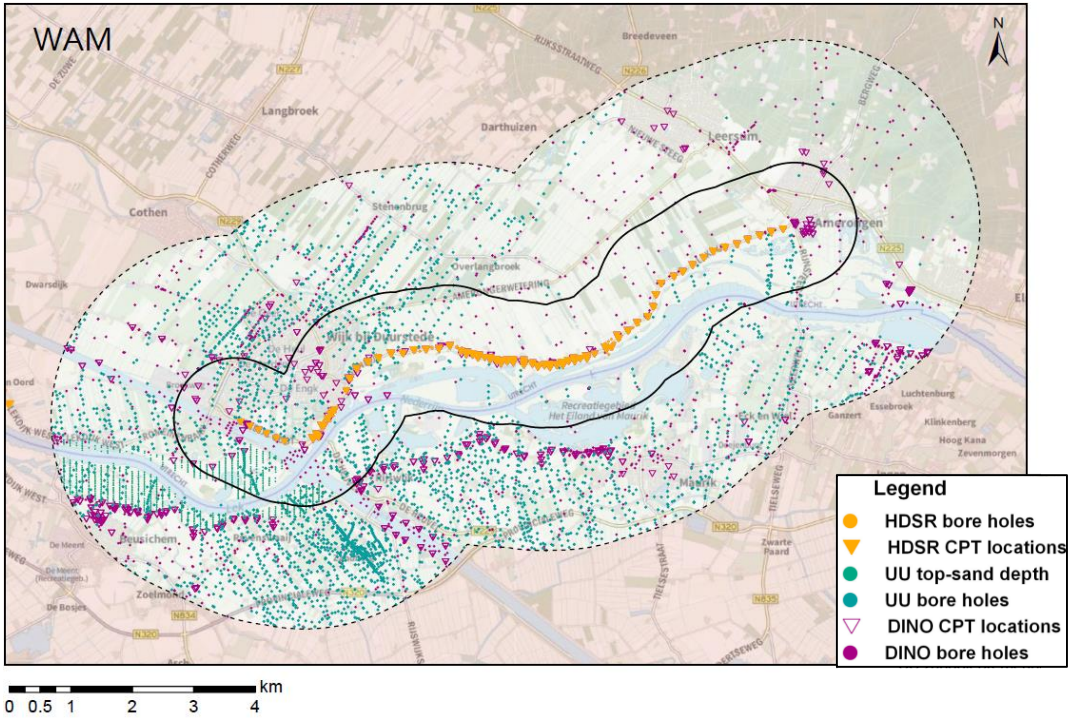
Erkens, G., 2009

GeoTOP

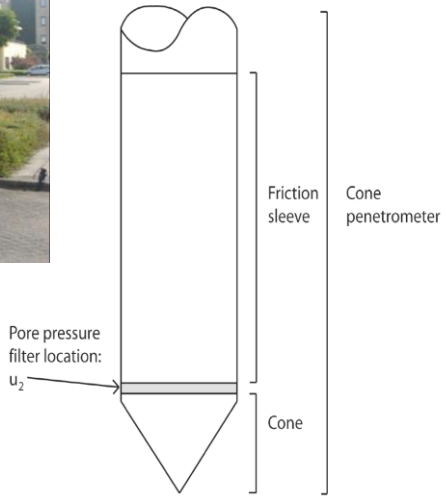


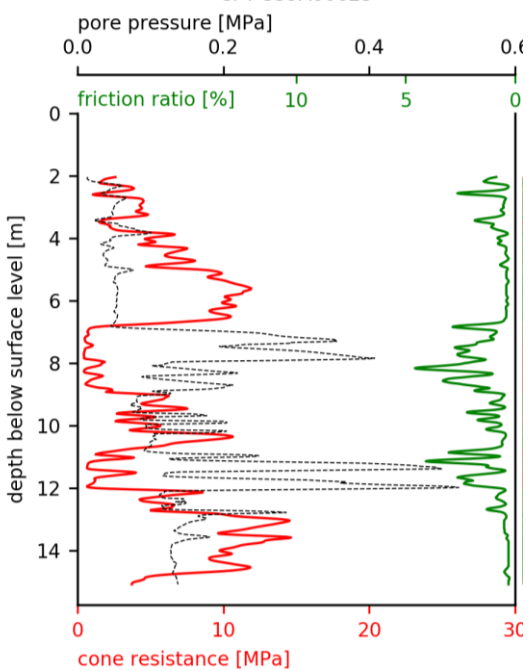
AVAILABLE BOREHOLE AND CONE PENETRATION TESTS





CONE PENETRATION TEST (CPT)



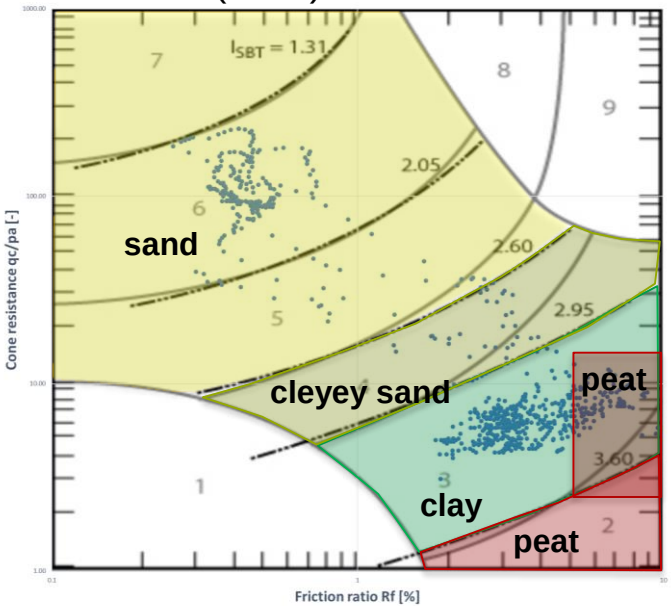


FROM CONE PENETRATION TEST TO LITHOLOGY

Lithological classification adapted from Robertson (2010) classification chart to identify GeoTOP lithological classes

- Classification chart designed for geotechnical classes
- Lithological classes clayey sand and peat hard to identify
- Needs tuning based on local geology

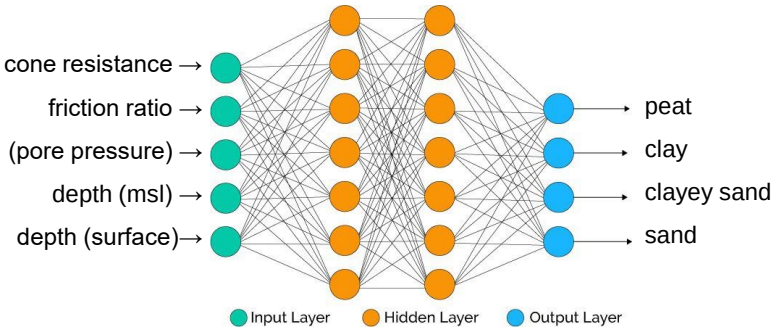
Robertson (2010) classificatie schema



FROM CONE PENETRATION TEST TO LITHOLOGY: ARTIFICIAL NEURAL NETWORK

Network design

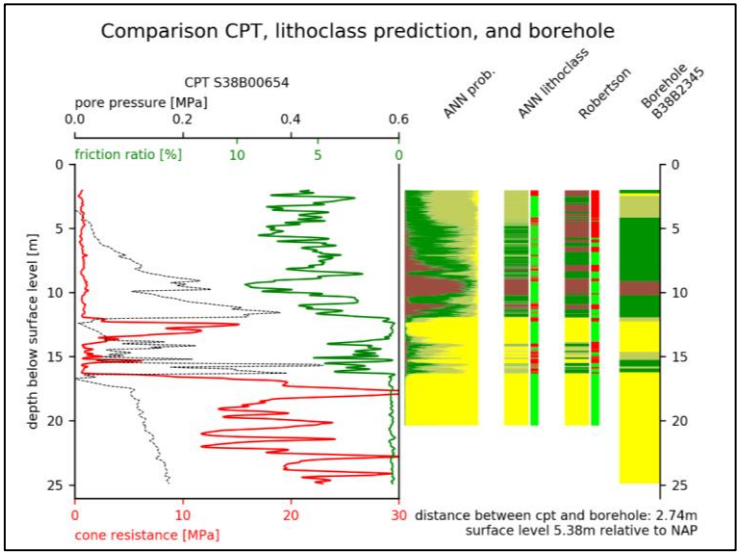
- 2 Dense hidden layers
- Classify CPT parameters to lithological classes



Train with local data

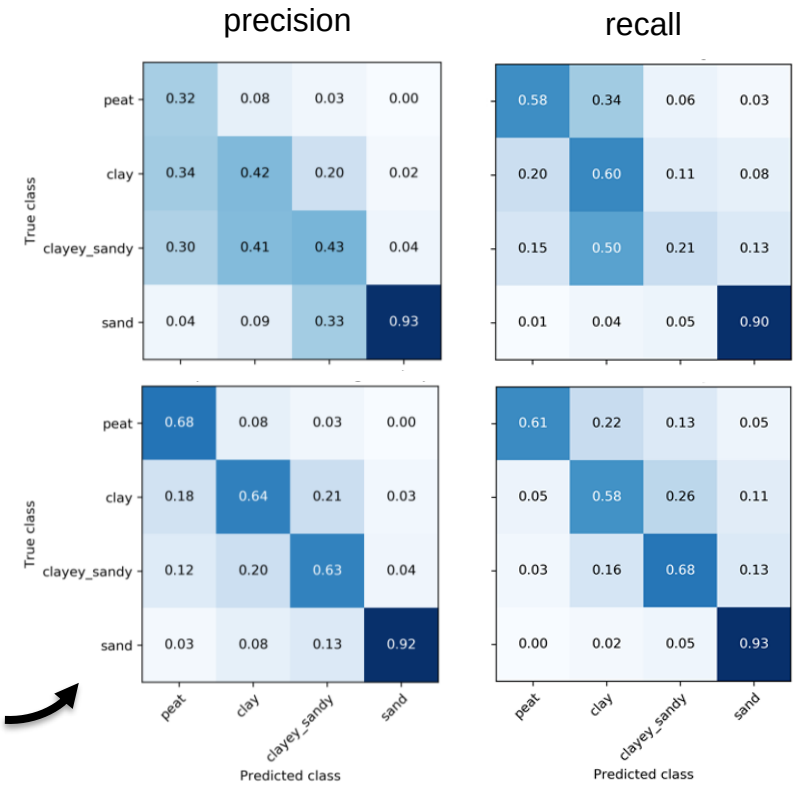
- 231 pairs of closely spaced boreholes and CPT's were available

CROSS VALIDATION RESULTS



Single CPT – borhole pair

Confusion matrix



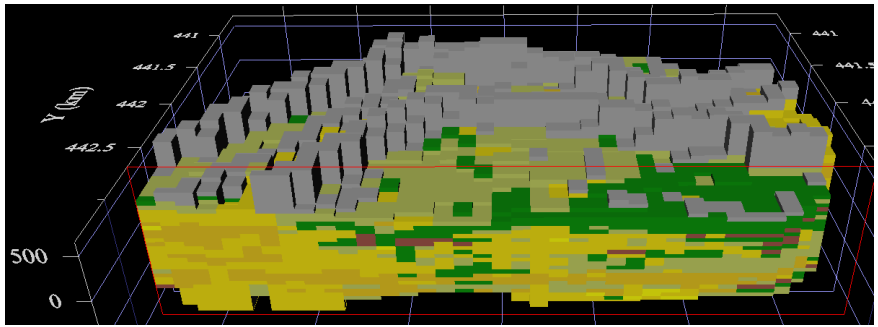
Based on Robertson (2010)

Artificial neural network

HIGH-RESOLUTION SUBSURFACE MODELLING

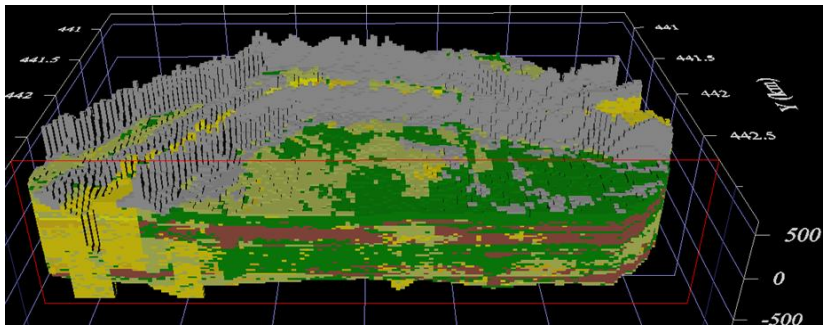
- Machine Learning techniques allow harmonization of multiple data types
- Using cone penetration tests together with borehole information greatly increased data density, justifying very detailed modelling
- High-resolution subsurface models facilitate new applications that need detailed information about local geology

‘normal’ GeoTOP (regional model)



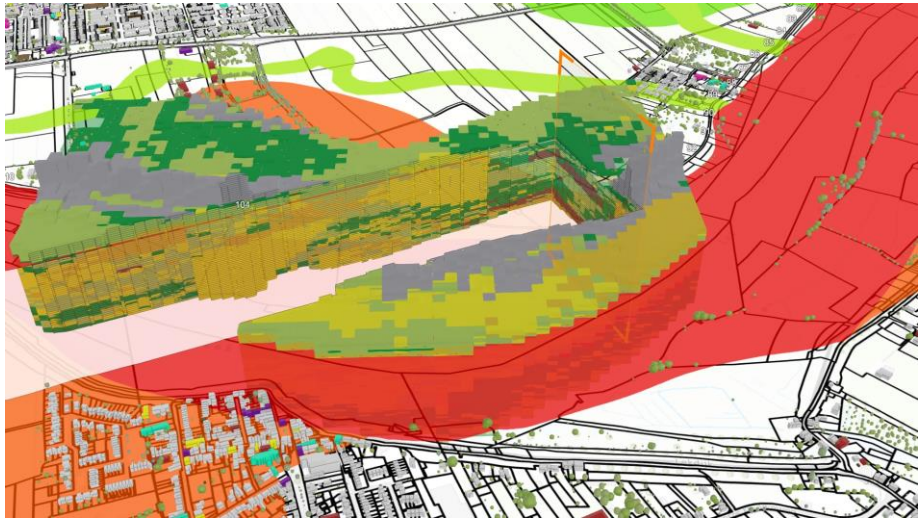
Voxel size 100 x 100 x 0.5 m

High resolution GeoTOP (local model)



Voxel size 25 x 25 x 0.25 m

COMMUNICATION & CONCLUSIONS



Combining information above & below the surface
in Digital Twin environment

- **Machine learning can help getting more out of available data**
- **More data enables detailed models**
  - **→ more specific for experts**
  - **→ brings geology closer to non-experts**