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High-resolution 3D geological modelling of the Lek River dike for enhanced flood protection

Romée H. Kars, Renée de Bruijn, Willem Dabekaussen, Bart M. L. Meijninger, and Jan Stafleu
TNO - Geological Survey of the Netherlands, Utrecht, the Netherlands (romee.kars@tno.nl)

The Netherlands is a low-lying country: a large, densely populated and urbanised part lies below mean sea-level. The risk of flooding is therefore omnipresent and flood protection measures, such as dikes along rivers, are vital for the safety of the population and their economy. The regional water authorities apply high safety standards when monitoring and maintaining the dikes.

The water authority Hoogheemraadschap Stichtse Rijnlanden (HDSR) has launched a maintenance program to investigate and reinforce the northern Lek River dike between Schoonhoven and Amerongen. The geology of this area has been shaped by fluvial activity during the Holocene, resulting in a heterogeneous composition of the shallow subsurface. The strength and stability of the dike depend on both its design and the geology in its subsurface. A sandy channel deposit may lead to piping and undercutting of the dike while weak (e.g. peat) or layered strata under certain hydraulic pressures could potentially lead to collapse and catastrophic failure of the dike. Detailed knowledge of the subsurface in the area is therefore essential to design fit-for-purpose reinforcement measures.

The national GeoTOP model, built and maintained by TNO - Geological Survey Netherlands, is a 3D stochastic geological voxel model that provides insight in the lithostratigraphy and lithology up to a depth of 50 meters below MSL with voxels (3D cells) measuring 100x100x0.5 m. However, to estimate the risk of piping and other forms of instability, HDSR needs a higher level of detail. In this study we therefore constructed a high-resolution voxel model for three sections along the Lek River dike.

To model the lithology of each voxel we used borehole descriptions, cone penetration test (CPT) data and paleogeographic maps of the Rhine-Meuse Delta. Using CPT data as well as borehole descriptions allowed for higher-resolution modelling. To use the CPT's for calculation of the lithology, the CPT measurements were translated into lithological classes using an Artificial Neural Network. Special attention was paid to the shape and position of the buried paleo channels, as their presence is a potential risk for piping, and to the mapping of man-made features in the landscape. The resulting 3D geological model has a voxel cell size of 25x25x0.25 m, a resolution that is 32x higher than the GeoTOP model.

The new high-resolution model is now used by HDSR for:

- identification of dike segments that need further investigation
- designing location-specific and fit-for-purpose dike reinforcement measures
- explaining proposed measures to local stakeholders.

The first two applications potentially reduce costs significantly; whereas the third application aids creating social foundation for reinforcement measures. Most importantly, the new high resolution model helps HDSR to enhance safety behind the dikes.