

Investigation of a breached levee

A multidisciplinary investigation involving visual, morphological, geophysical and geotechnical methods was applied to a previously breached levee in NW Belgium.

By **DAVY DEPREITER**, Flanders Hydraulics Research, Belgium with **Jeroen Vercruyse**, Patrik Peeters (Flanders Hydraulics Research, Belgium), **Leen De Vos**, Ivana Vukotic Hiskjere (Geotechnical Division Flemish Government, Belgium), **Timothy Saey** (3D-Soil BV, Belgium) and **Tinne Michielsen** (De Vlaamse Waterweg NV, Belgium).

A 20 km long 25 m wide levee situated in between two parallel discharge canals (and surrounded by 2 outer levees) in the northwest of Flanders, Belgium, has failed late 2018 for a reason unknown, yielding a breach of 25 m long. The canals and levees date from the 1860-1870'ies and are characterized by parallel rows of poplar trees, yielding a striking landscape feature. After repairs in 2019, a multidisciplinary study was conducted in 2020-2021 to identify drivers of the failure and prevent future events.



Figure 4: Breached central levee, end 2018.

The assessment involved a visual and morphologic analysis of the levee to describe the current state and localize anomalies, including animal burrows, erosion of the levee toe and vegetation anomalies. The inventory was based on visual inspections and 3D mobile mapping, including a high-density photographic dataset and LiDAR scanning from a 2015 region-wide survey and a local repeat survey in 2021. Also, a multibeam survey of the canal bottoms was conducted. Based on this, a geospatial anomaly dataset was built to localize damaged and anomalous zones.

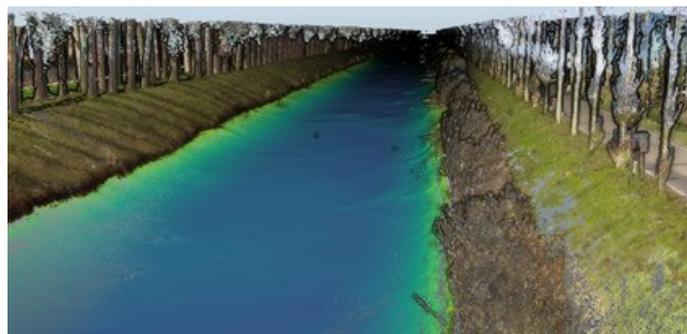


Figure 5: 3D LiDAR and multibeam point cloud visualization.

Because of the risk for the occurrence of unexploded ordnances (UXO) (left from World War II after shelling of the Zeebrugge port and other infrastructure) and to get an idea of the soil structure and presence of local anomalies, we applied geophysical methods to avoid extensive application of invasive techniques such as drilling and cone penetration testing (CPT). With the method of electromagnetic imaging (EMI), it became possible to better understand the internal structure of the levee (up to 5 m deep). A scan of the full levee crest was performed with different antenna configurations, so that simultaneously, shallow, and deep influences of soil variations on the EM signal could be detected. Repeated EMI scans during high and low hydraulic head difference between the canals did not indicate major differences and could thus not be used as a proxy for the presence of more versus less permeable zones or presence of piping zones across the levee. Through numerical inversion, a pseudo 2D profile of the levee core electrical conductivity was realized. The EMI interpretation led to identification and delineation of zones of similar levee structure and served to plan a geotechnical investigation less extensive than typical. Magnetometer cone penetration was performed prior to other invasive tests to prevent UXO related risks. Hydrogeologic and geotechnical modelling indicated that high hydraulic gradients (2 m head difference) between the two canals increased the risk for slope failure.

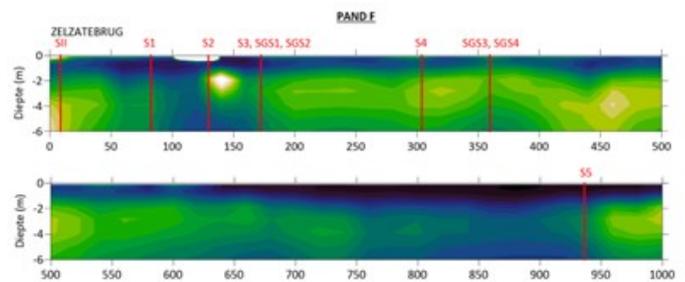


Figure 6: Example of the EM conductivity pseudo-2D profile.

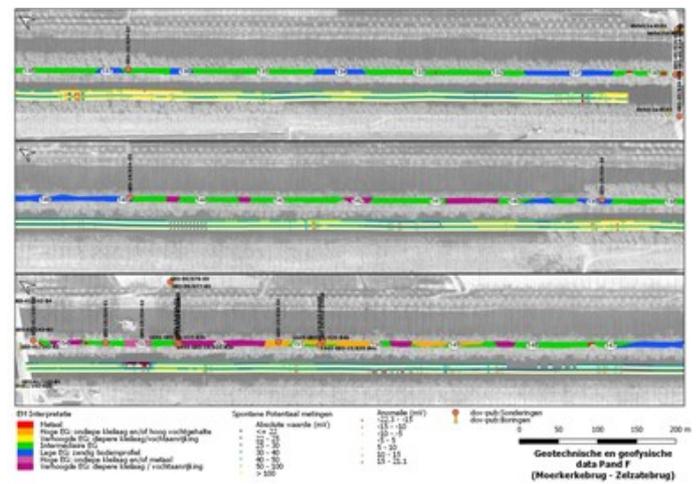


Figure 7: EM soil structure interpretation layer.

The investigation gave insight in the spatial extent of the (severity of) damage and its temporal evolution. Different factors contributing to the 2018 failure were identified: erosion of levee toe and slope, presence of burrows and old tree trunks, combined with an elevated hydraulic gradient between the canals leading to increased risk for piping and slope instability. Zones of increased vulnerability were identified based on the integration of all applied non-destructive methods and confirmed by limited drilling and CPTs.

After the investigation, restoration and strengthening works of the levee were planned and are currently underway.