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Assessment of railway infrastructure slope failure by automated time-lapse ERT monitoring

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This study underscores the need for subsurface imaging and monitoring techniques to offer timely information on railway embankment condition and to contribute to the decision-making processes needed to minimise the risks of catastrophic slope failure. We investigate electrical resistivity tomography (ERT) as a means of providing railway earthwork asset condition assessment information through the deployment of a bespoke ERT monitoring system (PRIME – the Proactive Infrastructure Monitoring and Evaluation system), which has been specifically developed for geotechnical monitoring applications.

We focus on two test sites, Botley and Withy Beds, which are situated on mainline railway embankments in the UK near Southampton and London respectively. Both embankments have long histories of slope instability and are constructed from London Clay (a high plasticity clay widely associated with ground deformation problems). Long-term ERT monitoring infrastructure has been deployed across both sites to enable imaging of subsurface heterogeneity and to monitor subsurface moisture content variations. At Botley a grid of electrodes extending from the embankment shoulder to toe, over an area of ~20 by 30 m, was deployed to enable time-lapse 3D imaging of a progressive rotational failure at the site, whilst at Withy Beds a line of electrodes was deployed along the embankment toe to enable time-lapse 2D imaging for a ~300m length of susceptible embankment. Manual geodetic (total station and LiDAR) monitoring of the slope geometry and electrode positions, and conventional geotechnical monitoring using temperature, soil moisture and matric suction sensors have also been used at the sites to validate the results of the ERT monitoring. In additional, laboratory petrophysical testing of samples from the sites has been used to establish relationships between resistivity, moisture content and matric suction.

More than three-years of ERT monitoring data have been collected from the sites. Initial analyses of the results have shown strong correlations between the conventional geotechnical monitoring results and ERT derived estimates of soil moisture. At the site scale, a remarkably clear low-

resistivity layer can be seen in the middle embankment segment of Botley, which suggests a high clay content and likely limited hydraulic permeability. The properties of this layer, in conjunction with time-lapse ERT observations made during periods of heavy rainfall, have revealed the hydrological functioning of the slope and the strong influence of evapotranspiration associated with clusters of mature trees. On the other hand, the Withy Beds embankment shows less intense drying and wetting patterns, even though noticeable fluctuations in resistivity suggest the presence of localised zones of moisture build-up. The sandy sections at the Withy Beds site are consistently dry even after rainfall, which permits water to seep into the clay layer beneath. On the other hand, the clay lands have higher moisture content and exhibit summertime surface drying.

In this study we have provided unprecedented insights, in terms of ERT monitoring duration and spatiotemporal resolution, into the structure and moisture dynamics of mainline railway embankments. ERT has been demonstrated as novel means of providing operationally relevant condition monitoring information to support the management of vulnerable railway earthworks associated with complex ground conditions.