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Geometrical and hydrogeological impact on the behaviour of deep-seated rock slides during reservoir impoundment

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Given that there are still uncertainties regarding the deformation and failure mechanisms of deep-seated rock slides this study concentrates on key factors that influence the behaviour of rock slides in the surrounding of reservoirs. The focus is placed on the slope geometry, hydrogeology and kinematics. Based on numerous generic rock slide models the impacts of the (i) rock slide geometry, (ii) reservoir impoundment and level fluctuations, (iii) seepage and buoyancy forces and (iv) hydraulic conductivity of the rock slide mass and the basal shear zone are examined using limit equilibrium approaches.

The geometry of many deep-seated rock slides in metamorphic rocks is often influenced by geological structures, e.g. fault zones, joints, foliation, bedding planes and others. With downslope displacement the rock slide undergoes a change in shape. Several observed rock slides in an advanced stage show a convex, bulge-like topography at the foot of the slope and a concave topography in the middle to upper part. Especially, the situation of the slope toe plays an important role for stability. A potentially critical situation can result from a partially submerged flat slope toe because the uplift due to water pressure destabilizes the rock slide. Furthermore, it is essential if the basal shear zone daylights at the foot of the slope or encounters alluvial or glacial deposits at the bottom of the valley, the latter having a buttressing effect.

In this study generic rock slide models with a shear zone outcropping at the slope toe are established and systematically analysed using limit equilibrium calculations. Two different kinematic types are modelled: (i) a translational or planar and (ii) a rotational movement behaviour. Questions concerning the impact of buoyancy and pore pressure forces that develop during first time impoundment are of key interest. Given that an adverse effect on the rock slide stability is expected due to reservoir impoundment the extent of destabilisation is highly dependent on the ratio of the rock mass volume affected by buoyancy forces to the total volume of the rock slide. If a large rock mass volume ratio is submerged, huge buoyancy forces evolve and destabilize the slope significantly. Additionally, the influence of impoundment velocity on the rock slide behaviour and the impact of material properties of the rock masses are analysed. Reservoir water rapidly infiltrates into high-permeable rock slide masses evolving high pore pressures at the basal shear zone which leads to destabilisation. Conversely, reservoir water infiltrates slowly into low-permeable rock masses and the destabilizing effect of the pore water pressure might be compensated by a buttressing reservoir load over the low-permeable rock masses.

Preliminary steady state calculations show that the factor of safety decreases constantly with increasing reservoir level until a certain threshold reservoir level and minimum factor of safety is reached. After exceeding this threshold level a further increase in reservoir impoundment leads to an increase of the factor of safety. This threshold reservoir level is reliant on the rock slide geometry and rock mass volume affected by buoyancy. Upcoming research is expected to provide new fundamentals for a comprehensive understanding of deformation and failure processes of deep-seated rock slides in order to perform reliable forecasts.