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In situ geotechnical measurements and slope stability analyses in Lake Lucerne: From understanding of past to predictions of future slides

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Lakes can be used as model basins to analyse subaqueous slope stability under static and dynamic loading conditions. Here we present results from detailed case studies in Lake Lucerne (Central Switzerland) derived from (i) in situ measurements of the geotechnical properties of the normally consolidated subaquatic slope sediment, (ii) lithologic and petrophysical description of the cored sediment cover, and (iii) limit equilibrium modeling of subaqueous slope stability under static and dynamic loading conditions. In Lake Lucerne the historic 1601 A.D. Mw ˜ 6.2 earthquake triggered several translational slides on the sediment-covered slopes with inclination angles $>$ 12 degree, as by numerous slide scars and by coeval debris flows deposits in the basin plains (Schnellmann et al., 2006). High-resolution seismic data and short cores from the failure surfaces indicate that slip planes developed in the Late Glacial deposits that underlie the 4-6 m of Holocene drape. Long piston cores, in situ vane shear and freefall CPT (FF-CPT) testing combined with in situ pore pressure measurements in undisturbed slope sections adjacent to failure scars reveal lithological and geotechnical characteristics of the slope-covering sedimentary section. Recovered ltihologies indicate that the Late Glacial deposits consist of very fine clays with some angular gravel components and minor intercalated sand layers. This stratigraphic unit is characterized by low in situ shear strength values suggesting a potential zone of low stability conditions. Additionally, excess pore pressures in this interval, as measured using the CPT probe, suggest a potential for reducing effective shear strength when applying additional stresses (e.g. dynamic loading) to this material. Sedimentological

and geotechnical data were implemented into limit equilibrium slope stability models. Results indicate that the slopes are stable under static loading conditions with a factor of safety FS $>$ 2. Pseudostatic back analyses reveal critical horizontal seismic accelerations of ~0.13 g to trigger slope failures. This value is very similar to calculated peak ground accelerations at the study site during the 1601 A.D. Mw 6.2 event that had an epicentral distance of ~12 km (deduced from predictive ground motion models; Bay et al, 2003). This study on subaqueous slope stability assessment in the lacustrine model basin provides promising insights into the stability of subaqueous slopes covered by normally consolidated sediments. Furthermore, when being analyzed on a GIS-based basinwide scale, this study will eventually identify sites of potential future slope instabilities in perialpine lakes of central Switzerland yielding the means to assess relative intensities of paleoseismic events and contributing to a general slide-related hazard assessment.