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Assessing post-failure geomorphic impact of an earthquake-triggered landslide dam, Jhelum River, Pakistan

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The 8 October 2005 Kashmir Earthquake ($M = 7.6$) incurred substantial damage in northern Pakistan, causing widespread building collapse, destruction of roads and bridges, and an estimated 87000 fatalities. The earthquake also triggered several thousands of landslides, the largest of which obliterated a village and blocked two rivers in a tributary valley of the Jhelum River. Here we focus on the post–failure geomorphic impact of a $70 \times 10^6\ m^3$ landslide near Dana Hill, which has impounded a tributary of the Jhelum River 45 km southeast of Muzaffarabad using remote sensing data (ASTER, SRTM, IKONOS). A possible outburst flood from the dammed lake currently threatens several villages of the Jhelum valley above Muazaffarabad, e.g. Hatian 3 km, Dhallan 10 km and Khun 20 km downstream, just to name a few. We generated 30–m digital elevation models prior to and after the earthquake from ASTER satellite scenes and a SRTM DEM to investigate the Dana Hill landslide geometry and the morphology of the adjacent drainage network. Using additional geotechnical field data, we conducted a first–order probabilistic limit–equilibrium analysis to assess whether the dynamic loading required to trigger the landslide was solely the result of seismic ground shaking. Two scenarios were established assuming the hillslope to be either fully drained or fully saturated. Our model indicates a probability of failure of 8% under fully drained conditions, while seismic acceleration appearing to be the key control on reducing stability. We quantified the geometry of the landslide dam and lake as input to a 1D unsteady–flow routing model for simulating a possible outburst flood caused by a combination of overtopping and breaching. The maximum volume of the lake impounded by the 130–m high dam may rise up to $60 \times 10^6\ m^3$, which roughly corresponds to previous estimates. The modelled clear–water peak discharge of $8000\ m^3/s$ is likely to cause a 12–m high flood wave immediately below the dam. The estimated wave height is 9 m at the confluence of the Karli and Jhelum Rivers near the village of Hatian, and may decrease only gradually on its way to Muzaffarabad. We conclude that simplistic slope–stability analysis allows to reasonably constrain the most likely landslide trigger, and discuss the usefulness and limits of combining continuously updated remote sensing data with slope–stability and flood–routing models for future reconnaissance studies.