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Hydrological Response to the Earthquake of 27 February 2010 in small Upland Catchments in the Chilean Coastal Range, Bío-Bío Region

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Hydrologic response to earthquakes has been observed for a long time yet. Increase in streamflow can be attributed to co-seismic elastic strain and/or changes in hydraulic head and/or enhanced hydraulic permeability. Hence, increased streamflow can occur due to liquefaction caused by ground shaking, fractures or cracks in the rock strata or deformation of the aquifers. However, earthquake hydrology still remains little decoded mainly due to the limitations of the observed phenomena in space and time. In this study we present the hydrologic response to a high magnitude earthquake even in small upland headwaters for the first time.

The silviculturally used catchments are located on the eastern slopes of the Coastal Range in Southern Chile near the city of Nacimiento at a distance of about 170 km to the epicenter. The base flow and diurnal runoff oscillation of small upland catchments showed similar but not uniform hydrologic response to the earthquake of 27 February 2010. Eight catchments out of ten experienced a decrease in base flow immediately after the earthquake followed by an increase reaching up to a four fold rise. In late May, and despite the lack of rainfall, most streams had not yet returned to the pre-seismic flow conditions. Runoff analysis indicates unchanged horizontal permeability. Increased recharge of shallow aquifers due to enhanced vertical permeability by subvertical fracturing is probable. This leaves the recession unaffected but enhances the transport of groundwater into the saprolith as the most permeable member of the geological layers. Rapid response, unchanged water temperature and a simple diffusion model showed the zone in transition of soil and weathered rock as the shallow origin of the excess flow. Patchy liquefaction of saturated near-surface saprolith contributes additional excess flow as empirical relations of magnitude, distance and seismic energy density indicate.

Parts of near-surface groundwater were injected by liquefaction from saturated areas into the drier upper soil layer where it was retained reducing the streamflow in short terms. The cross-section of subsurface flow expanded after a new hydraulic equilibrium between the saturated zone and the now moist soil has been established. Hence, a greater amount of water began to move towards the stream. The duration and amount of excess flow depend on the distances to the stream channels and the aquifers' dimensions. Consequently, the greater persistence of seismically induced excess flow is observed in the catchment with the largest spatial extent. Here, the excess-flow equalled approx. 8 mm during the study period.

The retained water was additionally available for root water uptake and intensified the transpiration of the riparian buffer strips. Since no water input from rainfall occurred for several weeks, the increased transpiration is the only process that can explain the post-seismic intensification of the diurnal oscillation.