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Post-earthquake modification of 2015 Gorkha Earthquake landslides in the Bhote Koshi River valley

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Large earthquakes trigger widespread mass failures, and the estimated volumes of landslide material are often used to estimate seismically triggered erosion, assuming that all landslide material is transported out of the affected area. The expectation that earthquakes can generate a pulse of sediment output from the affected area can also potentially be used to recognize large seismic events in the sedimentary record. However, in order to properly understand the relationship between earthquake triggered landslides, sediment flux, and erosion, we need to consider how and when the landslide debris is mobilized in the fluvial system and exported from the catchment. We present observations from three field excursions to the upper Bhote Koshi River following the April 25 2015 Gorkha earthquake, which triggered extensive landsliding in this region. Our observations, from early June, late July, and Oct 2015, cover the pre-monsoon, mid-monsoon, and post-monsoon periods, allowing us to constrain monsoon-driven changes to seismically triggered landslides.In order to quantify post-earthquake modification of individual landslides and of the transport of landslide materials to the main trunk rivers, we conducted surveys using both terrestrial lidar and SfM. Immediately following the earthquake, a large number of landslides were disconnected from the channels, with significant amounts of material stored on the hillslopes. This was facilitated by the widespread presence of a two-step topography, with steep slopes adjacent to the main river channels and a section of lower gradient hillslope above. The landslides above this step typically did not reach the channel, or only delivered material via preexisting narrow debris flow chutes. As expected, the monsoon caused new landslides, the expansion of existing landslides, and the modification of coseisimic landslide deposits. In late July we observed ongoing mobilization of this stored material, with repeated downslope delivery of material from multiple landslides during a several day period. The mobilization of landslide debris continued through the monsoon, with greater change observed in the second half the monsoon. However, in October a significant amount of debris remained stored on hillslopes above the main channel, as well as in the upper parts of small tributaries. These deposits represent a major potential hazard during the next monsoon, and infrastructure in this area remains particularly vulnerable. We have also installed hourly time-lapse cameras in several locations along the Bhote Koshi to observe changes in the river channel. Aside from local perturbations due to individual landslides and debris flows, the river showed negligible change from June to October, indicating that the earthquake has not yet resulted in an increase of coarse sediment that exceeds transport capacity in the river. Continued monitoring of the landslides in this region over the next years will help us better constrain the timescales of export of coarse landslide material from the affected region.