



A catastrophic multi-hazard event in 2020 in Kali Gandaki valley, Nepal Himalaya

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Multiple hazards (e.g. floods, landslides, earthquakes, glacial and landslide lake outburst floods) are threatening people, their goods and infrastructures in the high mountains of Nepal Himalaya. Floods and landslides are mainly driven by monsoonal precipitation. However, human impact often increases natural risks, like in the Kali Gandaki (KG) valley, the deepest valley (>5500 m) on earth, where the new two-lane road construction (since 2017) has caused many undercut and instable slopes.

In the light of previous events, we intend to assess the cascading multi-hazard events of 2020 in three tributary catchments of KG.

We adopted a pluri-disciplinary approach: interpretation of Sentinel-2 satellite images (March and November 2020), analysis of precipitation (stations of Lete and Tatopani, GPM satellite precipitation measurements), hydrologic and seismic data (Beni), geomorphological mapping, hydrological modelling in HEC-RAS, and field visits in July and November 2020, including interviews with locals.

On 20 July 2020 major hyper-concentrated flood events and landslides occurred in the Rupse, Thaplyang and Kahiku catchments (between Tatopani and Lete) destroying parts of the KG road, road bridges and a hotel (Rupse site). We focus on the Rupse River entering the KG valley at Rupse waterfall (height 108 m; kyanitic gneisses) then flowing down to the KG road and to KG River 200 m below. The major flood event lasted two hours and reached a max. flood level of 35 m at the edge of the waterfall. Upstream of the waterfall, four landslides (each about 250m wide, 200 m high) were triggered. Due to cloud coverage satellite scenes are missing to unravel whether the landslides caused the damming of the river and a landslide lake outburst flood or if the landslides were mainly triggered by the flood and increased sediment input to it.

Floods from these tributary catchments caused a major KG flood especially south of the Rupse catchment, which led to severe erosion and sedimentation in the channel; i.e. destruction of a pole of the national electricity grid, reactivation of the Kham Bhatta deep-seated landslide, destruction

of the KG road (the construction of which probably contributed to this reactivation).

Seismic data from Beni, approximately 27 km downstream of the affected catchments, provide constraints on the timing and relative magnitude of the flood in the KG. The data show that a short duration high magnitude flood with a very rapid rise and recession passed through Beni on the afternoon of 20 July. In addition, station data of Lete and Tatopani shows that yearly rainfall totals of 1839.5 and 2140.2 mm, respectively, were the highest since 1970. March and April were already very wet, followed by extremely monthly rainfall totals of 499.7 mm and 551.5 mm at Lete and Tatopani, respectively.

Assessing the 2020 events demonstrates how important localized events in relatively small areas are to understand cascading multi-hazard processes in Himalayan mountain regions. In addition, such hydro-geomorphic functioning and related hazards should be carefully considered when planning road design and bridge sites together with landslide and water level monitoring, for a better traffic maintenance and safety.