ABSTRACT

Dams are constructed along river systems to control flooding, supplying of drinking water, irrigation purposes and generation of power. For Himalayan country like Bhutan, river flowing from high mountains are exclusively harvested for production of hydropower. Hence, dams are built to store the flowing water. However, the consequences of dam failures can be devastating, with impacts varying widely depending on the size of the inundation area and the number of people at risk. This study presents a hypothetical dam breach modelling and Emergency Action Plan (EAP) development for the Mangdechhu Hydropower Plant (MHP) in Bhutan. The objective was to simulate a potential dam breach scenario and assess downstream flood risks to support emergency preparedness and infrastructure protection.

A two-dimensional unsteady flow model was developed using HEC-RAS 6.0, utilizing a 12.5-meter resolution Digital Elevation Model (DEM) to accurately represent the topography from the dam site to the powerhouse, covering approximately 48 km of the river stretch. The dam breach scenario was modelled using Froehlich's empirical equations, with a trapezoidal breach geometry and a breach formation time of 1.11 hours. The resulting peak breach outflow was computed at 2,397.6 m^3/s, which is significantly lower than the site's Probable Maximum Flood (PMF) of 6,218.8 m^3/s, yet sufficient enough to cause downstream impacts due to the sudden release and high velocity of floodwaters.

Simulation results revealed that the initial velocity at the dam toe reached 3.83 m/s, increasing sharply to 19.5 m/s near the powerhouse due to channel constriction and terrain slope. Inundation mapping indicated that multiple low-lying areas and critical infrastructures, including three key bridges—dam bypass bridge would be submerged in less than minute and flood would reach Trongsa-Kela feeder road bridge and the PH access bridge within 35 to 60 minutes of breach initiation. Maximum flood depths ranged from 47.84 m near the dam to 15 m at the powerhouse.

Based on these findings, a site-specific EAP was developed, integrating flood wave travel times, inundation extents, and stakeholder-specific response protocols. Priority zones for evacuation were identified, and communication strategies were established for effective early warning dissemination.

Keywords: Dam break modelling; HEC-RAS, Emergency Action Plan, MHP Dam.