Lumu Chimi Lake, Poiqu/Sun Koshi Basin, China and Nepal

Glacial lake outburst flood modelling

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Modelling based on secondary data indicates that a glacial lake outburst flood from Lumu Chimi Lake could release a peak flow of over 7,500 m^3 per second at the trading centre of Barhabise with catastrophic impacts on the settlements and infrastructure downstream including two hydropower plants and two major bridges. This peak flow would be three times greater than the GLOF of 1981, which caused significant loss of property and life, swept away two highway bridges, and damaged 27 km of highway and transmission lines.

Introduction

Himalayan glaciers have experienced rapid retreat in the past few decades. This has resulted in the formation and growth of many glacial lakes. These lakes are retained by unstable moraine materials, which can break leading to a type of flash flood known as a glacial lake outburst flood (GLOF). It is estimated that there are around 200 potentially dangerous glacial lakes in the HKH region (Ives et al. 2010).

This case study was conducted in the Poiqu/Sun Koshi basin, a transboundary basin that spans the Tibet Autonomous Region of China and Nepal (Figure 16). Nine potentially dangerous lakes have been identified in terms of GLOF risk on the Chinese side of the basin (Mool et al. 2005).

The basin covers an area of 3,393 km^2; 60 per cent of the area is in China and 40 per cent in Nepal. The river that runs through the basin is called the Poiqu in Tibet and the Bhote Koshi and then the Sun Koshi in Nepal. The basin has experienced at least three GLOF events in the past, all originating in the Chinese part of the basin, but causing damage in both countries.

Over the last four decades, with the construction of the Kathmandu-Kodari Highway, many settlements in the basin have moved from the hilltops to the roadside and the number of settlements and population has increased. Roads, bridges, and hydropower stations have also been constructed. This development in the flood plain has exposed more elements to risk from a GLOF event.

Figure 16: **Poiqu/Sun Koshi basin**

Lumu Chimi Lake is the second largest end moraine dammed lake in the Poiqu/Sun Koshi basin and a potential dangerous lake. The lake surface area is expanding: the total surface area increased from 1.67 km^2 in 1977 to 3.64 km^2 in 2003 (Mool et al. 2005). From the latest satellite image, the total lake surface area is estimated to be about 3.84 km^2 and average length is 3.2 km. The present study was conducted along a 104 km section of the river corridor from the lake's end in China to a town called Dolalghat in Nepal (45 km in the Tibet Autonomous Region of China and 59 km in Nepal).

The main objective of the study was to model a GLOF from Lumu Chimi Lake and simulate the propagation of the flood downstream along the river valley to develop flood inundation maps and assess the potential impact of the GLOF.

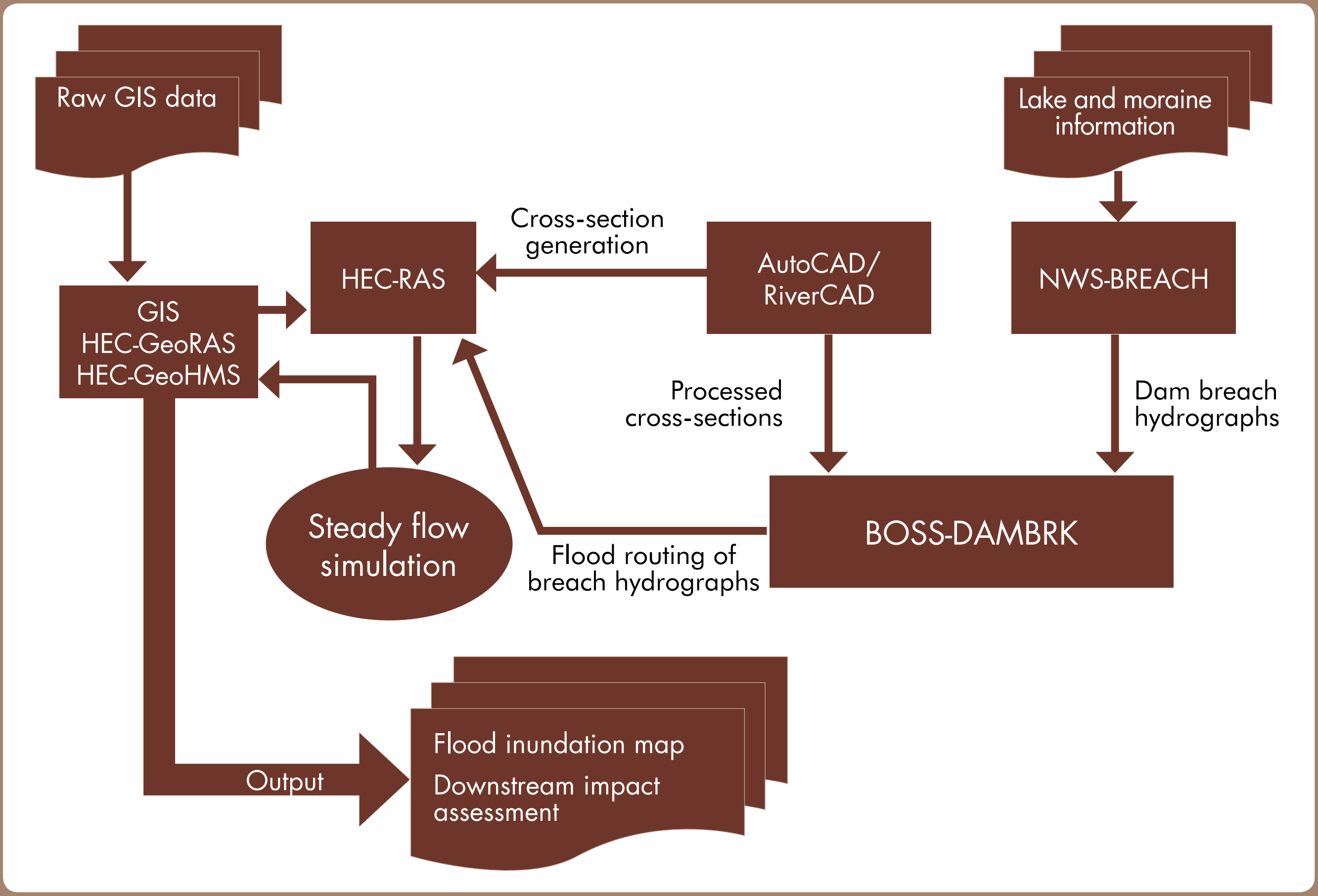
Methodology

The study was conducted in three stages: the modelling of outburst scenarios, the modelling of flood propagation along the Poiqu/Sun Koshi Valley, and flood hazard mapping with downstream impact assessment. A schematic diagram of the study methods is shown in Figure 17.

NWS-BREACH, a dam breach model developed by National Weather Services, was used to simulate the outburst hydrograph. After the GLOF hydrograph was derived from the breach model, flood propagation in the downstream areas was simulated using BOSS-DAMBRK (a software used to analyse dam failures and flood wave attenuation), which was used to simulate the failure of the dam, compute the resulting outflow hydrograph, and simulate the movement of the dam-break flood wave through the downstream river valley. NWS-BREACH is intended to be an auxiliary method for determining the breach parameters. In this study, NWS-BREACH results were used as a reference for inputs in BOSS-DAMBRK.

Twenty-nine runs of the BREACH model and 15 runs of the BOSS-DAMBRK model were carried out. Twenty-nine cross-sections of river reach were used in the BOSS-DAMBRK model to simulate dam break outflow and its impact from the lake downstream to Dolalghat. BOSS-DAMBRK was used to estimate flood wave travel time, time to flood stage, time to peak elevation, and corresponding water surface elevations.

Figure 17: **Schematic representation of the study methodology**



The output of the hydrographs at various cross-sections was used as input for steady flow data in HEC-RAS (software for River Analysis System). Results from HEC-RAS were used to prepare inundation maps after exporting them into HEC-GeoRAS (GIS tools for support of HEC-RAS) and using GIS. The final flood hazard maps were prepared in ArcGIS (GIS software). The land cover in flood hazard zones was quantified and mapped in ArcGIS. Specific sites at risk were identified and a field visit was conducted to check the results at certain vulnerable points.

The study relies mostly on secondary data and information for modelling. In hydrodynamic modelling, the quality of the topographic information determines the accuracy and reliability of the model. In this case, part of study area is in the Tibet Autonomous Region of China and information about the lake, moraine, topography, and socioeconomic conditions was difficult to acquire.

Results

Dam breach erosion model

Various scenarios were developed for the dam breach erosion model in NWS-BREACH using varying values of vulnerable dam height, piping failure at different heights, particle size 50 per cent finer (D_{50}), porosity, uniformity coefficient (D_{90}/D_{30}), dam upstream side slope, dam downstream side slope, and internal friction angle. The sensitivity analysis was done to evaluate the role of these input parameters in peak discharge (Q_p), time to peak flow (T_p), and top width of trapezoidal shape breach. The sensitivity results are shown in Table 5.

Table 5: **Summary of sensitivity analysis, dam breach erosion model**

Input parameter	% Variation	% Variation in output parameters (sensitivity in brackets[a])		
		Breach peak flow	Time to peak	Breach top width
Average particle size	100	+1.7 (NS)	-1.2 (NS)	+1.8 (NS)
Uniformity coefficient of dam material	60	+4.6 (SS)	-1.0 (NS)	+4.0 (SS)
Porosity	40	+10.0 (S)	-5.6 (S)	+7.2 (S)
Upstream side slope	75	-9.0 (S)	+3.0 (SS)	+7.0 (S)
Downstream side slope	29	-1.8 (S)	+1.0 (SS)	–
Internal friction angle	0	-2.0 (S)	+3.0 (SS)	+4.0 (S)

[a] NS = not sensitive; SS = slightly sensitive; S = sensitive.

Dam break analysis

Various scenarios were developed for the BOSS-DAMBRK model using depth of 20 m, time of failure of 0.75 hours, side slope of 1:1.15 (vertical:horizontal), Manning's *n* of 0, and varying values for the width (Table 6). However, only a few

Table 6: **Results of dam break analysis**

Location	Distance from Dolalghat (km)	Distance from dam (km)	Scenario 1 (width = 41 m)			Scenario 2 (width = 82 m)			Scenario 3 (width = 0 m)			Scenario 4 (width = 56 m)		
			Peak flow (m^3/s)	Peak depth (m)	Peak time (hr)	Peak flow (m^3/s)	Peak depth (m)	Peak time (hr)	Peak flow (m^3/s)	Peak depth (m)	Peak time (hr)	Peak flow (m^3/s)	Peak depth (m)	Peak time (hr)
Downstream of dam	104	0	7,909	5,014.3	0.3	12,286	5,015.4	0.2	2,677	5,012.2	0.5	9,611	5014.2	0.3
Near Chuhsiang	80	24	6,983	3,778.4	0.8	10,564	3,779.3	0.8	2,469	3,776.7	1.1	8,387	3778.8	0.8
Friendship Bridge	60	45	6,712	2,124.8	1.1	10,051	2,126.1	1.1	2,408	2,122.3	1.4	8,040	2125.3	1.1
Panlan	42	62	6,499	1,191.9	1.4	9,651	1,193.9	1.4	2,360	1,187.9	1.7	7,746	1192.8	1.4
Barhabise	30	75	6,319	861.1	1.7	9,328	863.8	1.5	2,322	858.1	2	7,513	862.7	1.6
Balefi	14	90	5,886	708.8	2.1	8,334	711	2	2,236	704.2	2.6	6,804	709.7	2
Dolalghat Bridge	0	104	5,492	641.4	2.6	7,599	643.3	2.4	2,138	637.4	3.2	5,967	641.9	2.5

Figure 18: Attenuation of flood at selected locations

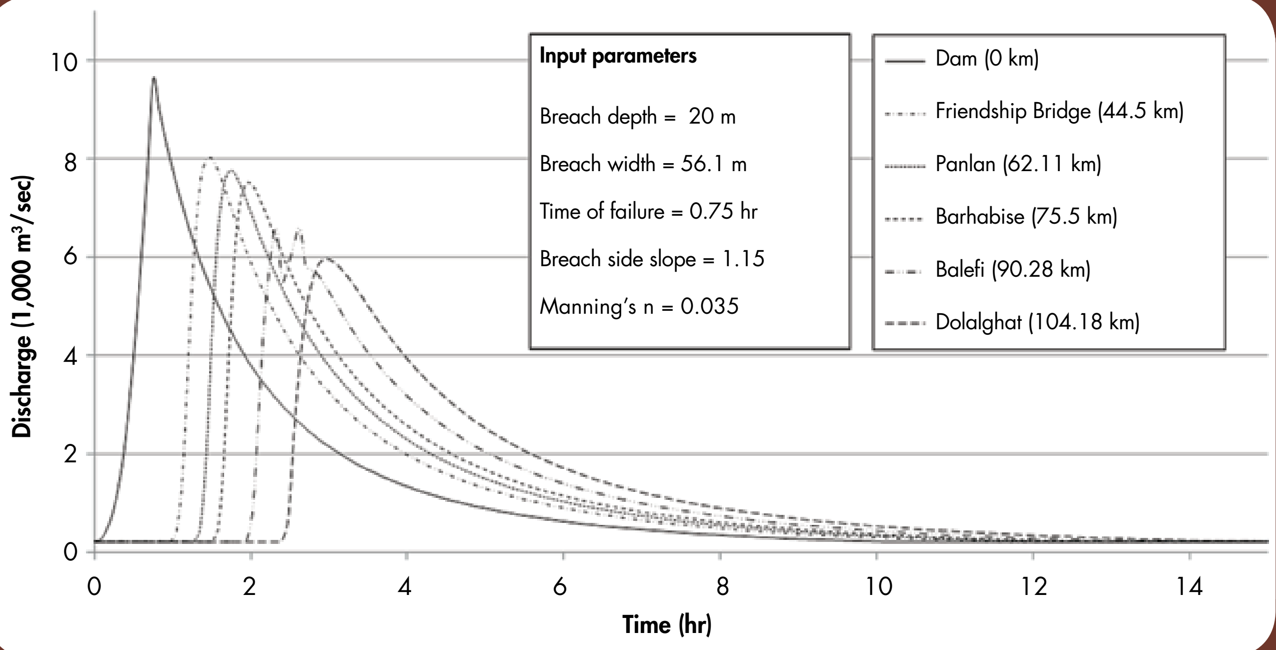
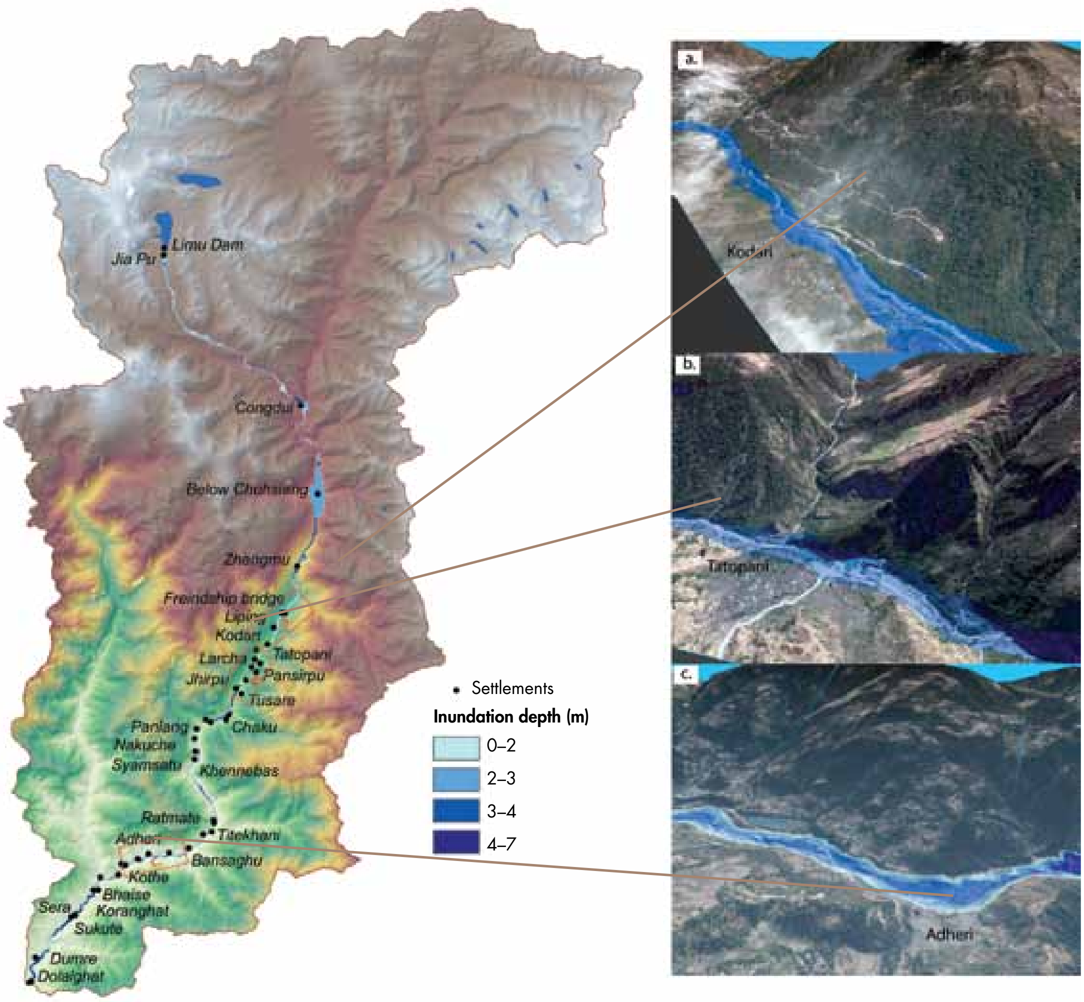


Figure 19: **Flood inundation map**



scenarios are realistic. It was assumed that the lower part of the dam is more stable due to its compactness and greater dam width. Thus, a 20 m breach of the dam was considered for the dam break analysis. The result shows that the peak outburst flood from a 20 m breach could be as high as 9,611 m^3 per second at the dam breach location (Figure 18). Under this scenario, the peak flood at Barhabise in Nepal (75 km downstream from the dam) would be 7,513 m^3 per second with 1.6 hours of lead time. This magnitude of flood at Barhabise is more than three times greater than the flood of 1981 from the outburst of Zhangzanbo Glacial Lake (Xu 1985).

The results from various scenarios developed in BOSS-DAMBRK indicate that the peak flood is determined by the dam breach width, time of failure, breach shape, and Manning's *n* as the flood propagates downstream from the dam.

Flood inundation and impact assessment

The outputs of the one-dimensional unsteady flow simulation and dam break analysis were used to prepare flood inundation maps. The impact of GLOF risk on the Nepal side was only estimated due to limited data availability.

The results show that the settlements along the river, such as Maghi Gaun and Belgaun near Dolalghat, and Sukute, Andheri, Khadichaur, Lamosangu, Barhabise, and Tatopani are at risk of GLOF. (Figure 19), It is also estimated that over 21 km of the Arnico Highway at various locations (from Dolalghat to the Friendship Bridge at the border of Nepal and China), the Khandichaur and Barhabise bridges, and many suspension bridges are also exposed to GLOF risk. Similarly, the Bhote Koshi and Sun Koshi hydropower dams and their powerhouses are exposed, as well as various land cover types (Table 7).

Table 7: **Land cover exposed to GLOF risk in Nepal**

Land cover type	Area (ha)
Agricultural land	234.8
Forest	161.3
Grass	60.2
Bush	123.4
River course	364.4
Cutting cliffs	0.2
Total	944.3

Recommendations

- The results of this study should be used to create land use and flash flood risk management plans.
- More modelling should be conducted with data of a greater degree of certainty for fuller understanding of flash flood risk and impacts based on field data and for enhanced flash flood risk management.
- The methodology in this study can be applied to other potentially dangerous glacial lakes in similar river valleys to understand the nature and extent of GLOF impacts for effective flash flood risk management.