The Nangama Glacial Lake Outburst Flood Occurred on 23 June 1980 in the Kanchanjunga Area, Eastern Nepal

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Key words : glacial lake outburst, Kanchanjunga Himal, Nangama Glacial Lake

I. Introduction

Glacial lake outburst floods (GLOFs) have occurred more than every three years since the 1960s in the Nepal Himalaya (Yamada and Sharma, 1993). In the far eastern Nepal Himalaya, a glacial lake on the Phucan Glacier was burst in 1980 (Yamada and Sharma, 1993). Eight persons were killed and 10 houses and 4 bridges were washed away by the GLOF (Khanal, 1996). The river water rose 20 m during the flood (Yamada and Sharma, 1993). In spite of the large damage, these are all information available so far; even the exact site or date of the occurrence is not known yet. This area, which is known as the Kanchanjunga area, was designated as a conservation area in 1997. Establishment of eco-tourism in this area is now attempted by some institutions, such as WWF Nepal Program, ICIMOD, foreign university, as well as Nepali NGOs.

Recent warmer climates have resulted in the general retreat of glaciers in the Himalaya and the formation of glacial lakes (e.g., Ives, 1986). Studies on the growth of the Imja Glacier Lake in Khumbu Himal, eastern Nepal, revealed that glacial lakes are very dynamic (Yamada and Sharma, 1993 ; Watanabe et al., 1994, 1995). Management of hazardous processes, such as GLOFs, therefore, will be very important for the establishment of eco-tourism. This study provides the basic information about the 1980 GLOF, and points out some measures to be discussed in the future to reduce the risk in the Kanchanjunga area.

II. Study area

Kanchanjunga Himal (Fig. 1), located in the eastern Nepal, has the world third highest mountain peak of Kanchanjunga (8,586 m). The study area, a western part of Kanchanjunga Himal, is in the basin of the upper Tamor Nadi (Nadi denotes a large river). The Tamor Khola (Khola denotes a river) and the Yanma Khola join at an altitude of 2,660 m. This study examines the area of the upper Tamor Nadi, covering the altitudes from 1,550 m near the confluence of the Ghunsa Khola to the peak of 6,839 m (Omikan Ri). Along the upper Tamor Nadi exist many settlements, such as Yanma (4,200 m), Chhija (4,100 m), Nup (4,000 m), Jaritar (3,850 m), Tarton (2,200 m), Kisonma (2,200 m), Iladada (2,180 m), and Lunthun (1,580 m). The Tamor Nadi flows in 18 VDCs (village development communities or the smallest unit of a local municipality) of the Taplejung District. Population of the Taplejung District was 120,780 in 1981 (Central Bureau of Statistics, 1981).

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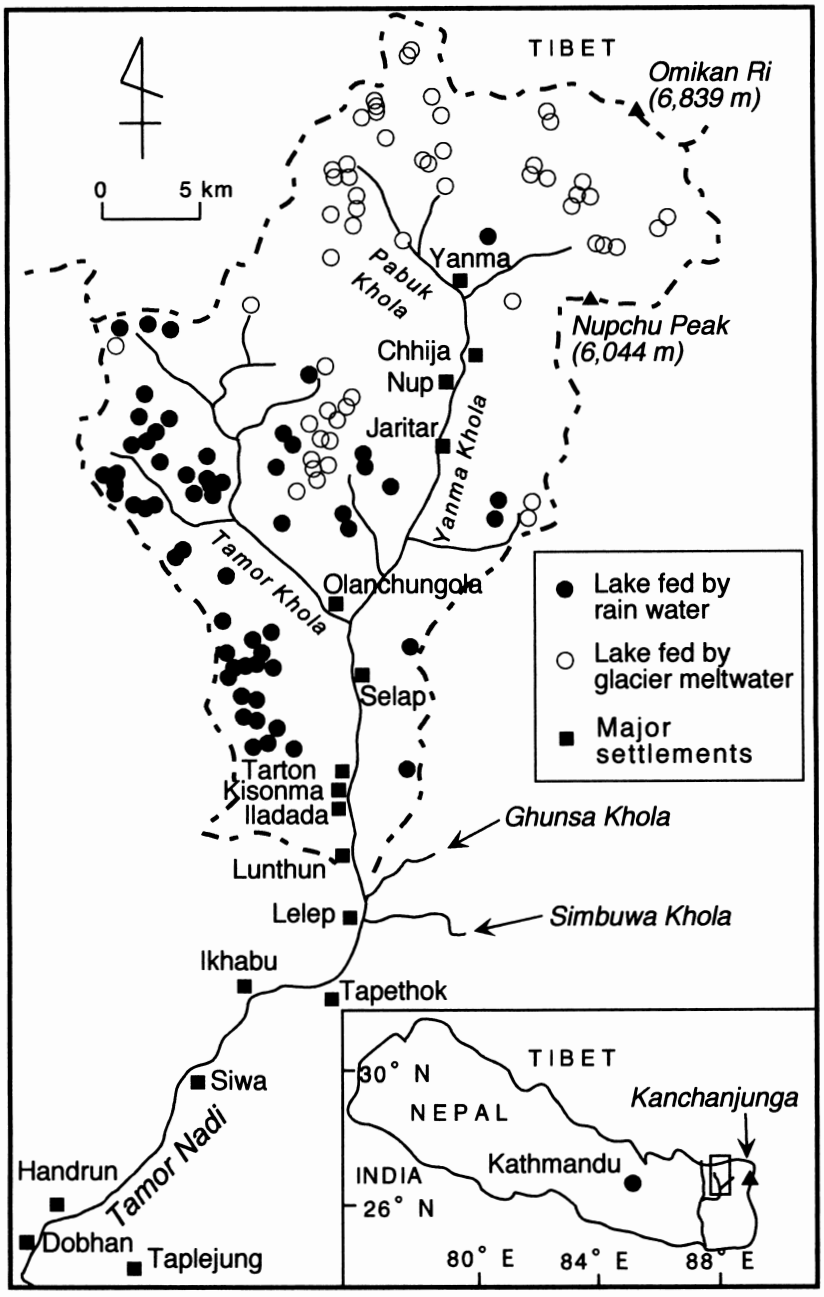


Fig. 1 Distribution of the glacial lakes in the watershed of the upper Tamor Nadi, Kanchanjunga area, eastern Nepal. Location names are based on the 1 : 50,000 topography maps.

III. Distribution of glacial lakes

The altitude and latitude of all lakes which are distributed in the watershed of the upper Tamor Nadi (Fig. 1) were examined by 1 : 50,000 topography maps and air photographs. The area has 118 lakes, which can be divided into two types : lakes with no present glaciers upstream ; and lakes on and by the present glaciers. Lakes with no present glaciers upstream are presently fed by rain water, whereas the others are fed by glacier meltwater.

Lakes fed by rain water are located from 3,960 to 5,460 m, and those fed by glacier meltwater are located from 4,460 to 5,450 m (Fig. 2). The average altitude of these lakes is 4,836 m and 4,996 m, respectively. Most locations of the lakes fed by rain water are on the cirques. These lakes may have been formed during the rapid melting of former glaciers after the Little Ice Age as observed in the Bhutan Himalaya (Takada, 1991, 1992). Lakes fed by glacier meltwater are most likely to have been formed in the last several decades.

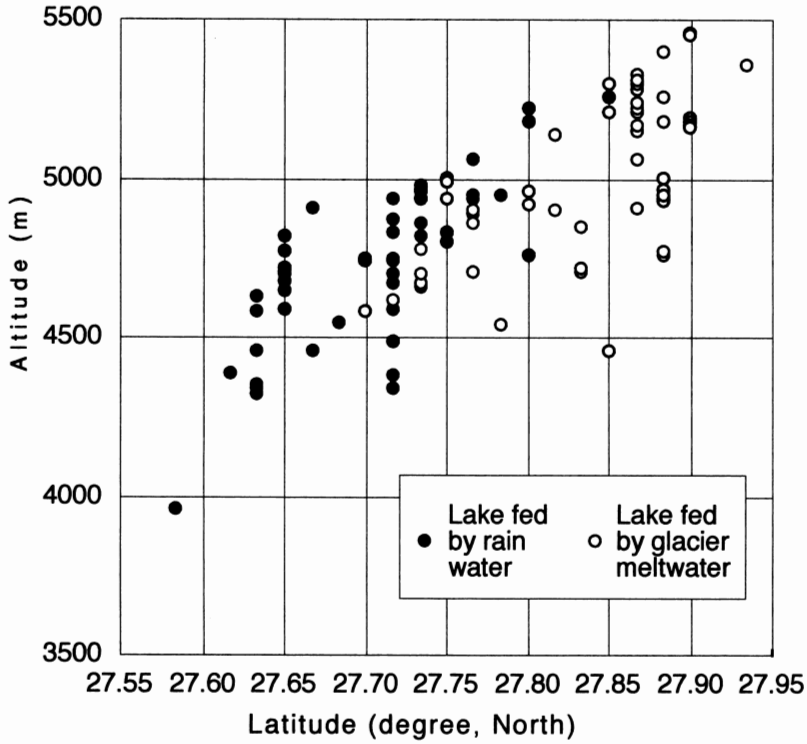


Fig. 2 Altitudes showing the distribution of two types of glacial lakes in the upper Tamor Nadi watershed. The number of the lakes fed by rain water is 62 and that by glacier meltwater is 56.

IV. The GLOF occurred in 1980

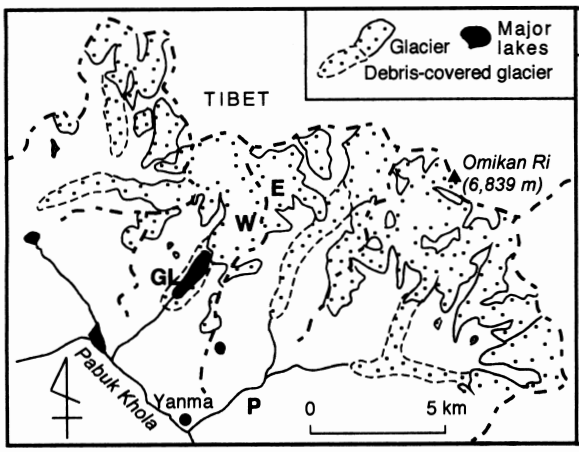
1. Identification of the date of the occurrence

Only information about the date of the occurrence of the 1980 GLOF that is available for researchers so far is "some time in 1980." The authors examined articles in newspapers and found one article about the GLOF, which was carried in *Rising Nepal* (1980) on 28 June 1980. The article

said that the flooded Tamor river swept away all the houses in Olangchung Gola village last Monday. This means that the incidence happened on 23 June 1980.

2. Identification of the triggered site

Topography maps (1 : 63,360 issued in 1975 and 1 : 50,000 issued in 1997) and air photographs taken in 1978 and 1992 were interpreted to find the site of the incidence. In addition, four kinds of trekking maps with different scales were examined to make sure names of glaciers, rivers, and lakes.



	E	W	P	GL
Map A	No name	No name	No name	No name
Map B	No name	No name	*Phujhan Khola*	*Nangama Pokhari*
Map C	*Phuchan Glacier*		*Syao Khola*	Not existed
Map D	*Phuchan Glacier*		*Shyo Khola*	Not existed
Map E	*Phuchan Glacier*	*Hidden Glacier*	*Syao Khola*	Not existed
Map F	*Phuchang Glacier*	No name	*Syao Chu*	Not existed

Fig. 3 A map to identify the 1980 GLOF site (GL) in the uppermost reaches of the Tamor Khola.
Map A : Topography map, 1 : 63,360, by Survey of India ; Map B : Topography map, 1 : 50,000, by Survey Department of Nepal ; Map C : Trekking map, 1 : 192,000, published by Mandala Productions ; Map D : Trekking map, 1 : 175,000, by Napa Maps ; Map E : Trekking map, 1 : 225,000, by Mandala Maps; Map F : Trekking map, ca. 1 : 210,000, by Yoshimi Yakushi.

Figure 3 shows the distribution of the present glaciers in the uppermost reaches of the Tamor Khola (Pabuk Khola), which was prepared to identify the triggered site of the 1980 GLOF. Yamada and Sharma (1993) report that the GLOF occurred from the "Phucan" Glacier. Therefore, the glacier named "Phucan" was first searched on the maps. Maps A (1 : 63,360) and B (1 : 50,000) have no glaciers named "Phucan" (Fig. 3). Maps C (1 : 192,000) and D (1 : 175,000) have the glaciers named "Phuchan." This name is collectively assigned to the east-facing and west-facing glaciers (E and W in Fig. 3). Map E (1 : 225,000) carries the "Phuchan" Glacier but it refers only to the east-facing glacier as the "Phuchan" Glacier (E). Map F (ca. 1 : 210,000) is essentially the same as map E, although the spelling is different. The river labelled "P" in Fig. 3 is named Syao Khola (maps C and E), Shyo Khola (map D), or Syao Chu (map F), but is named "Phujhan" Khola by the 1 : 50,000 topography map (map B). Glacier E in Fig. 3, therefore, is most likely to be the "Phuchan (Phucan)" Glacier. The problem, however, is that none of the maps/air photographs shows a lake on or near the glacier.

In the upper stream basins of the Tamor Khola (Figs. 1 and 3), only single site (27°52'N, 87°52' E) shows a great surface change, which was detected by the two topography maps (maps A and B).

A large glacial lake has a name "Nangama Pokhari (lake)" on the 1 : 50,000 topography map (map B). This should be the only possible site for the 1980 "Phucan" GLOF of Yamada and Sharma (1993). Because the name, "Phuchan (or Phucan)" Glacier, has been probably unofficially used by local residents, and because the governmental topography maps of 1 : 63,360 (map A) and 1 : 50,000 (map B) do not name the glacier, the triggered site should be called by the name of the lake that is printed on the newest 1 : 50,000 topography map (map B). After the topography map of 1 : 50,000, this study calls the incidence "Nangama GLOF."

3. Estimates of the lake size and impacted area

The Indian 1 : 63,360 topography map issued in 1975 shows that the Nangama Glacial Lake already had a certain extent of water surface (lake area : 0.14 km^2). The oblique air photograph taken by GEN in 1978 clearly shows that the lake expanded rapidly (Photo 1, left). The lake area in 1978 is estimated to be ca. 0.93km^2. By 1992 the lake had collected the large amount of water again (Photo 1, right). The lake water level today is estimated as ca. 4,950 m a.s.l.

On the air photographs the alternately deposited and eroded river bed can be easily traced downstream as low as ca. 3,040 m a.s.l. near the confluence of the Nurak Khola (Fig. 4). The length of the river bed directly impacted by the intensive deposition and erosion is ca. 23 km. Below the lowest site of the alternately deposited and eroded river bed, the river bed may also have been affected. The articles carried in the newspapers, *Rising Nepal* (1980) and *Gorkhapatra* (1980), state that the flood damaged the lower area including the settlements of Lunthun, Siwa, and Dobhan

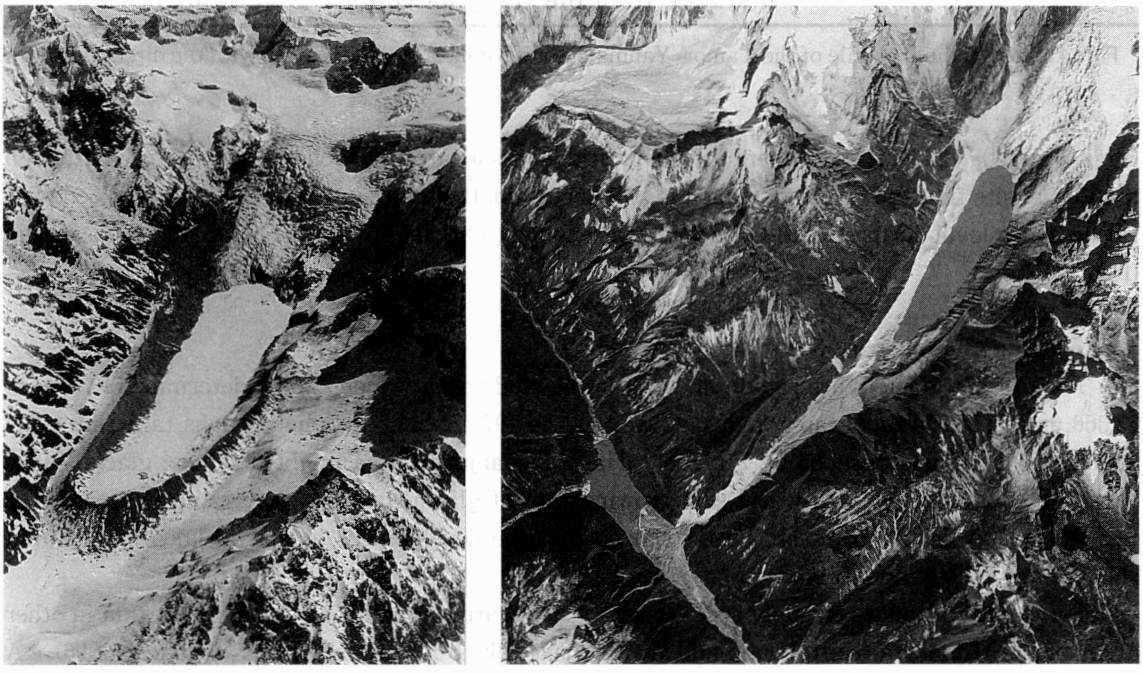


Photo 1 An oblique air photograph of the Nangama Glacial Lake before the outburst (left), and an air photograph of the same lake after the outburst (right)
Note that the lake before the outburst was surrounded by a large terminal moraine, which was breached when bursted. Left : taken on 27 April 1978 by GEN (Glaciological Expedition in Nepal), right : taken in December 1992 by Finland.

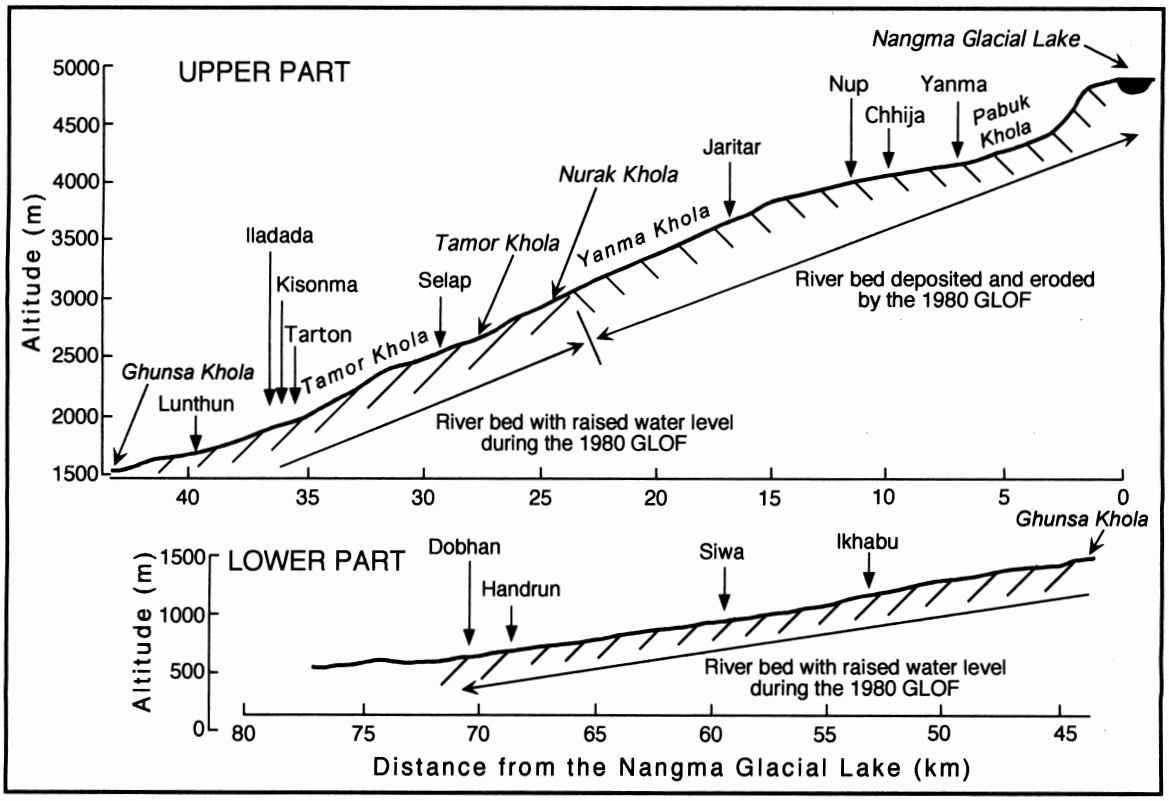


Fig. 4 Longitudinal profile of the Tamor-Yanma-Pabuk Khola showing the area with the direct impact by the 1980 GLOF.

(Figs. 1 and 4). The altitude where the swept bridge was located in Dobhan is ca. 640 m. Although the lowest site that the GLOF damaged is still uncertain, the minimum length of the river bed with raised water level during the GLOF, which was enough to breach bridges, is estimated as ca. 71 km (Fig. 4).

V. Reducing the hazard

The present glaciers are rapidly melting in the study area, which can be determined by the 1 : 63,360 and 1 : 50,000 topography maps, as well as the 1978 oblique air photographs taken by GEN and the 1992 air photographs by Finland. The Kanchanjunga area might not have glacial lakes with immediate danger. However, the growing rate of glacial lakes is very rapid (Yamada and Sharma, 1993 ; Watanabe et al., 1994, 1995), so that the development of glacial lakes in the area should be urgently monitored.

These circumstances strongly urges to establish a warning system as is very important in other areas of the Himalaya (Kattelmann and Watanabe, 1996a, b ; Watanabe and Rothacker, 1996). A radio warning system can be effective means of reducing hazards by GLOFs as well as those by other processes. It has to be carefully organized not to fail to provide adequate warning to downstream residents and trekkers. Unfortunate improper operation is reported in the Bhutan Himalaya (Watanabe and Rothacker, 1996).

After the Mingbo, Langmoche, and Chubung outburst floods, residents of the Rolwaling and

Khumbu valleys were well aware of the hazard posed by glacial lakes (Kattelmann and Watanabe, 1996b). Local community members expressed concern about future possibilities in GLOFs, and some have been active in publicizing the hazard. Due to the difficulty in identifying the local names of the VDCs, population of 13 out of the 18 VDCs along the Tamor Nadi were able to be identified: it was 48,246 in 1981 (Central Bureau of Statistics, 1981). The number of residents of the 18 DVCs along the Tamor Nadi in the Taplejung District should be larger than 50,000 today. All residents and foreign trekkers stepping into the area have to be well aware of GLOFs.

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ネパール東部，カンチェンジュンガ地域で1980年6月23日に発生した，ナンガマ氷河湖決壊

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キーワード：氷河湖決壊，カンチェンジュンガ・ヒマール，ナンガマ氷河湖

ネパール最東部のカンチェンジュンガ・ヒマール地域では，1980年にプチャン氷河の氷河湖が決壊したという報告があるが，実際の発生地点や発生日など詳しいことはわかっていない。そこで，ここでは，地形図・空中写真判読および地元の新聞記事の調査によって，この氷河湖決壊の発生場所，発生日，湖の大きさ，下流への影響範囲などを調べた。

1997年に発行された5万分の1地形図と1992年撮影の空中写真を使って，タムール川上流部の湖の位置と高度を明らかにした。その結果，調査流域には118の湖が確認された。このうち62の湖は，氷河を上流に持たないタイプの湖で，かつて上流にあった氷河の融解時に形成されたものであると考えられる（分布高度：3,960-5,460m）。いっぽう56の湖は，現在も氷河の上やそばに位置しており，氷河の融け水によって涵養されている（分布高度：4,460-5,450m）。

問題の氷河湖決壊洪水については，これまでのところ，“1980年にタムール川上流のプカン氷河湖で決壊が生じ，河川では水位が20m上昇し，下流に被害を及ぼした”ということが報告されていたにすぎない。氷河湖決壊発生当時の2つの新聞記事を調べたところ，発生日は1980年6月23日であることがわかった。またこの氷河湖決壊洪水の前後の地形図と写真を比較した結果，この氷河湖決壊は，タムール川の支流のパブク川に注ぐナンガマ氷河湖（標高約4,950m）の決壊によることがわかった。ナンガマ氷河湖は，決壊する前の1978年には，およそ0.93km^{2}の湖水面積を持っていたと推定される。この氷河湖の決壊によって湖から23km下流までは著しい堆積と侵食が繰り返されている。また新聞記事によれば，洪水によって標高640mにあった橋が破壊されている。このことから，洪水は発生地点から下流方向に少なくとも71kmにわたって被害を与えたと考えられる。

この氷河湖の周辺のタムール川（パブク川）最上流域だけでも，小さな湖が多数形成され始めており，ネパール・ヒマラヤでの氷河湖の形成速度の大きさを考慮に入れると，今後の氷河湖の成長のモニタリングおよび警報伝達・避難体制の確立を急ぐ必要があるといえる。

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