**Report**

**on**

# Field Expedition program on glacial lake outburst floods (GLOF), Sikkim

**Submitted by**

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## 1.0 INTRODUCTION

GLOFs refer to the sudden discharge of a water reservoir that has formed either underneath, at the side, in front, within, or on the surface of a glacier, and related dam structures can be composed of ice, moraine or bedrock.

A pilot project on study of glacial lake outburst floods (GLOF) is initiated in Sikkim with the collaboration of Sikkim State disaster management center and Swiss Government and funded by NDMA. This project in collaboration with a consortium (Geotest AG, UZH, University of Geneva) involves two sites in northern Sikkim, Shako Cho Lake and South Lhonak Lake satellite view of these are depicting in Fig1.

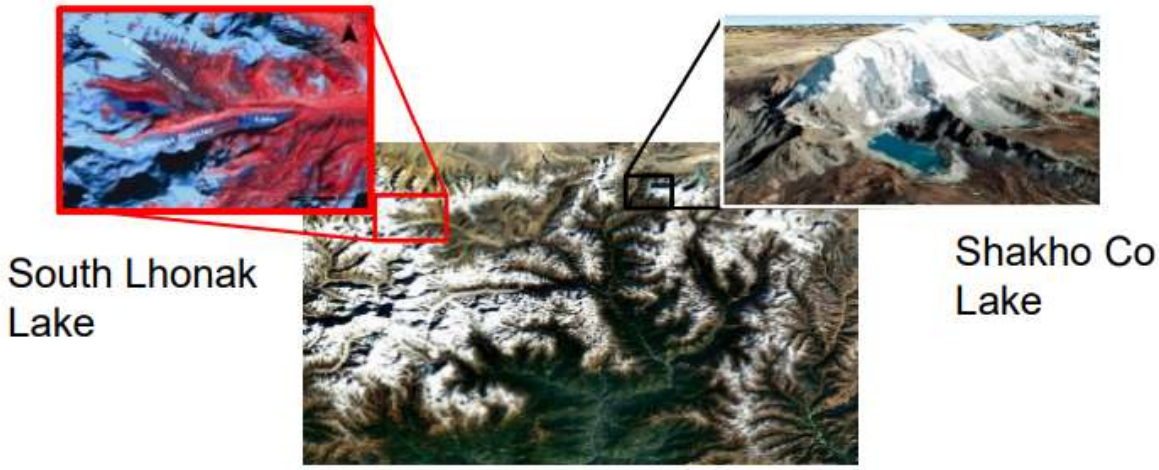


**Figure 1 depicting the satellite view of Shako cho and South Lhonak lake**

Both the lakes are at risk of glacial lake outburst floods (GLOF) and require long term monitoring. The South Lhonak lake is one of the largest and the fastest-growing lakes in Sikkim while Shako Cho Lake is comparatively smaller with high failure potential. While these lakes are mainly located in remote and unsettled mountain valleys, far-reaching glacial lake outburst floods (GLOFs) may claim lives and properties in the downstream area where many villages are located along with risk to hydropower plant. The settlement at Thangu is potentially exposed to GLOF from the Shako Cho Lake while Chungthang is exposed to GLOFs from both the lakes including the South Lhonak Lake (Fig. 2). Also, several other small settlements including Yathang, Talam, Latong, Yuigang, and Chuengtong are exposed to GLOF from the lakes

Therefore, in a preliminary phase, the project foresee visual monitoring of these glacier lakes with cameras and gathering meteorological information's of the region. The information about the lake volume, freeboard, discharge conditions, changes in morain dam geometry, movements in the slopes (rock, ice, snow), condition of the glacier tongue, etc. can be monitored through the install monitoring device. Based on this information, the local authorities can continuously estimate the hazard potential and imitate appropriate emergency measures in time of emergency. This data will also assist in improving process understanding and serve as a basis for the development of a GLOF early warning system for the region, which may be fulfill in next phase of the said project.

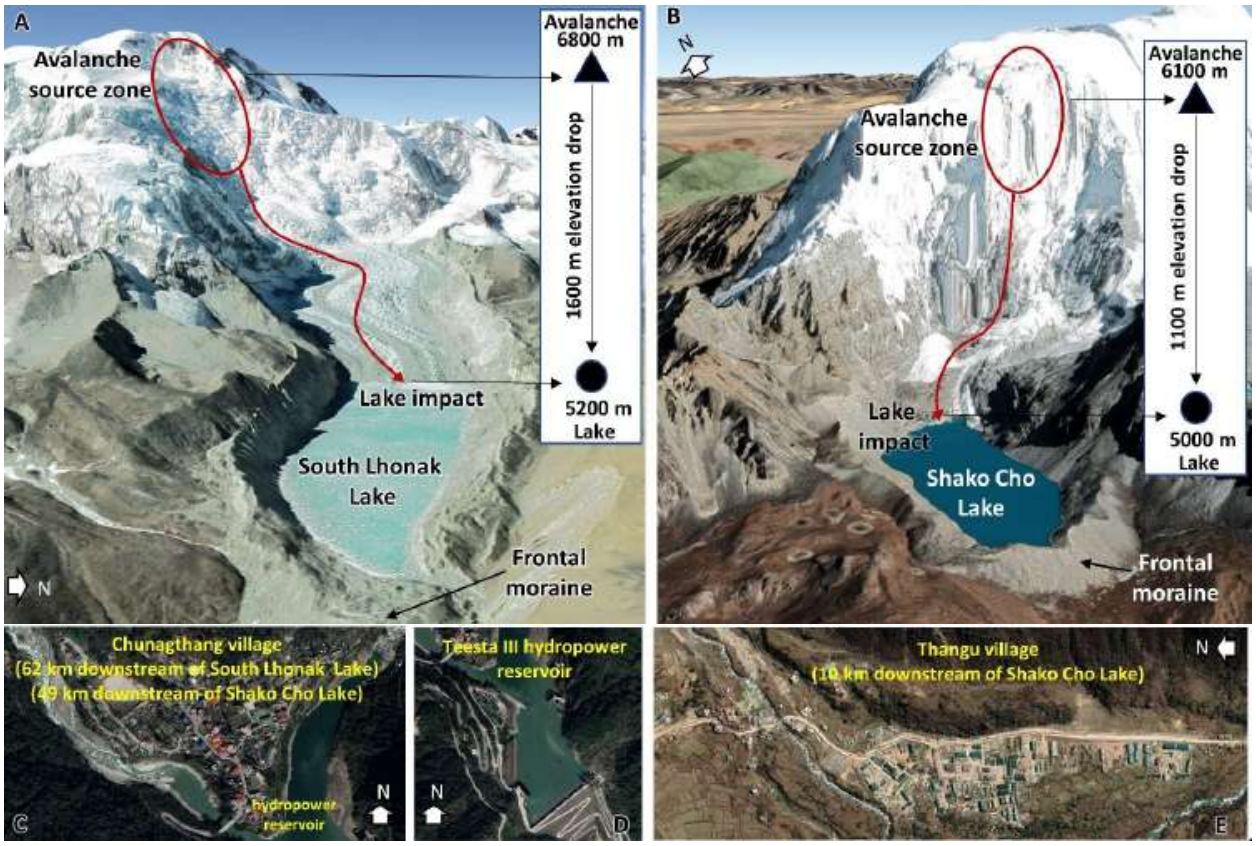


Figure 2A) possible avalanche source zone above South Lhonak Lake and surrounding slopes (B) possible avalanche source zone above Shako Cho Lake and surrounding slopes; (C-D) the Chungthang village and the Teesta III hydropower reservoir located 62 km and 49 km downstream of South Lhonak Lake and Shako Cho Lake respectively; (E) Thangu village located 10 km downstream of the Shako Cho

As a first phase, a field expedition program was scheduled during 6th - 21st September 2023 in order to install the monitoring devices in two lakes at Sikkim. The Indian participants of this program are from various research institute as well as state authorities working in the field of disaster management.

## 2.0 Scope of the Work:

A field expedition to the two glacial lakes named South Lhonak and Shako Cho in Sikkim is planned with following goals

(1) assessment of moraine dam stability and potentially of the slopes surrounding the lake

(2) field validation of installation sites for installation of monitoring devices

(3)geological and geotechnical understanding for moraine dams and slopes (stability evaluation) experience in high mountain environment.

(4) develop the Early warning system

These goals are long term and can be achieved in various phases. In this current and first phase of expedition, the installation of the monitoring devices by swiss expert has been done whereas in the second phase, EWS will develop after the holistical study of the area and data interpretation. The Indian participants and Swiss experts were divided into two teams. Each of the team has a Swiss Geologist and Instrumentation Engineer, involved in the installation of the monitoring device in Shako Cho Lake and the South Lhonak Lake along with Indian Participants/Scientists.

## 3.0 Location of Glacial Lakes:

The Sikkim Himalaya hosts numerous glacial lakes in the high-altitude glacierized region, including the two most dangerous lakes: South Lhonak Lake and the Shako Cho Lake.

The **South Lhonak lake** is morain dammned lake (27°54'20"N and 88°10'20"E) and located at an elevation of 5,200 m (17,100 ft) above sea level in the Teesta Basin, Sikkim, Himalaya (Fig. 2). It formed due to the melting of the Lhonak glacier. The lake is rapidly growing in size in an

abnormally rapid manner due to the melting of the lake's associated South Lhonak glacier and additional melt water from the adjacent North Lhonak and main Lhonak glaciers. The frontal moraine damming the lake has a width of approximately 500 m and it gets narrow towards the north, where a surface outflow from the lake is located. The surficial outflow channel cuts the moraine dam in the north-northeast direction while the main valley is oriented towards the east . The crest height of the frontal part of the damming moraine (south from the outflow channel) is 7 m above lake.

Figure 3 Schematic view of South Lhonak Lake

The **Shako Cho glacial lake** (27°58′29″N; 88°36′ 58″E) is located at 5000 m a.s.l. in the northern part of Thangu valley. The lake is located approximately 10 km upstream of the nearest settlement of Thangu village (3900 m a.s.l.). The Shako Cho Lake is a large proglacial in Sikkim and is highly critical due to various key indicators including low width-to-height ratio of the end moraine, steep damming moraine composed of loose granular material, the presence of a 1000-m high mountain slope rising above the lake, and the location of nearest Thangu village . Previous

studies reported that, as the freeboard of the damming moraine is 10 m, mass impacts into the lake from the mountain face above the lake can lead to dam overtopping waves (Worni et al., 2013). The dam is susceptible to erosion due to the sharp dam and weak dam structure (Worni et al., 2013). The flow channel originating at the lake is geometry characterized by steep side slopes and a lack of vegetation in the upper part till the nearest settlement at Thangu.

Figure 4 Schematic view of Shako Cho Lake

## 4.0 About Monitoring Instrument

The installed monitoring intruments consist of two webcameras (wide angle view and normal view), two solar panals and automatic weather station(AWS). The high definition images provided with web cameras, allow for automatic deformation analysis of the monitored area and allow to identify even small details within the monitored area. An AWS typically consist of a

enclosure containing the data logger, rechargeable battery, minicomputer/screen and the meteorological sensors with an attached solar panel. The two solar panals used are angled in such a way that dureing intense snowfall if one panal is covered with snow the vertical solar panal will work on reflected sunrays .As an advantage, If the areas doesnot get sun light for various days then the system may not charge but automatically started working when the panal receive sunrays. The meteorology sensors gives data on temperature, humidity, precipitation, wind Speed,Wind direction and radiation. All these data will be recorded and communicate through satellite in Geoprevent portal which will further examine and helpful to develop Early warning system. The online data portal connects, visualizes, and provides the relevant information up-to-date. Also the advantage in the swiss make monitoring device is its support of 2 way communication . if any error occur then it may possible to detect the problem remotely.

Figure 5 depicting the installation of monitoring instruments at Shako Cho and South Lhonak lake sites by Swiss Experts


Figure 6 depicting the portal and access of data after installation of device at lake site

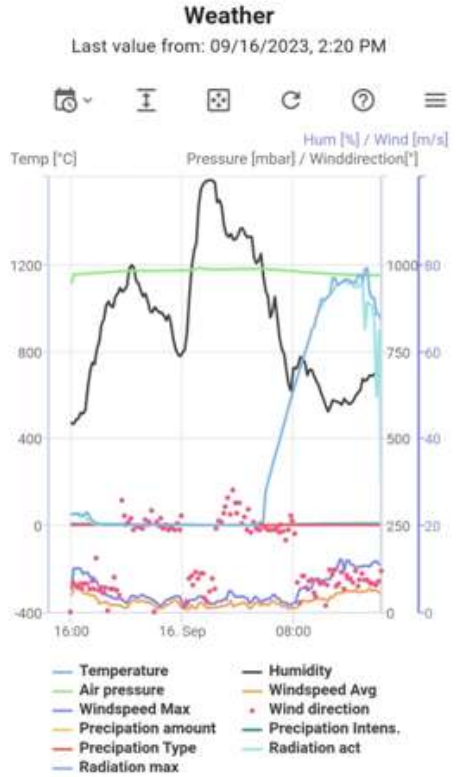


Figure 7 depicting the graph of various meterologyical data obtained on 16th Sept 2023after installation of monitoring device at the Geoprevent Portal.

## Summary

- Mass movements (ice / rock avalanches and landslides) from upstream and breach formation can cause a GLOF from South Lhonak and Shako Cho Lakes
- Future lake expansion will increase the probability of mass movement impacts
- The short response time at Thangu village is a big risk and could require design of mitigation measures.
- Floods can reach Chungthang and potentially beyond.
- It is of vital importance to monitor the lake sites and to develop Early warning system
- The installation of automatic Monitoring devices at both the lake sites was installed and data received in the Geoprevent portal
- In the present phase, the capacity building of other Himalayan States and transferring of knowledge of the GLOf were completed as of one of the objective of said pilot project
- In the next phase of the pilot project, the EWS will be initiated. The investigations and experience gained provide a basis for the further design of GLOF EWS for the upper Teesta basin.