ASSESSMENT REPORT OF SAMTELLING CHHU FOR FLOOD HAZARD AND ASSOCIATED RISKS

SUBMITTED BY

NATIONAL CENTRE FOR HYDROLOGY AND METEOROLOGY
ROYAL GOVERNMENT OF BHUTAN
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EXECUTIVE SUMMARY

Tserim Latso (Genyen Latso) and Dhuedrip Latso(Didrip Tso) are fresh water mountain lakes located at 4162 masl and 3928 masl with surface area measuring 0.098 km^2 and 0.039 km^2 respectively. There are no glaciers and lakes found to exist above these lakes. Tserim La Tso was found to be surrounded by solid bedrock consisting of granitic genesis, schist and quartzite on all sides. Dhuedrip Latso is a cirque lake surrounded by rock cliffs on three side and frontal moraines at the outlet area. Estimated water volume in Tserim Latso and Dhuedrip Latso are 5.595×10^5 m^3 and 2.699×10^5 m^3 respectively. Tserim Latso was found to be surrounded by solid rock on all sides. As for Dhuedrip Latso, since it is a cirque lake a frontal moraine dams the lake water at the outlet part and other three sides have solid rock cliffs.

Based on the physical observations on the surrounding materials damming the lakes, failure of the dam around the lakes by itself is found to be low. Since the volume of water stored in the lakes during the study period (September), which is still considered to be high flow season, is less than a million cubic meters, the flooding impact in the downstream even if a worst-case scenario of total emptying the lakes is considered was found to be insignificant.

However, the statement on the hazard and impact of flooding along Samteling Chu is purely based on the breaching scenario of Tserim Latso and Dhuedrip Latso. It is important to consider external factors such as unexpected meteorological conditions resulting in incessant precipitation phenomenon causing unexpected flooding. Any type of flooding in the upstream part of Samteling Chu has a chance to trigger mass movement along the thickly vegetated narrow valley which may result in huge debris flow.

Three flood hazard maps based on three flooding scenarios (flood from Tserim Latso, flood from Dhuedrip Latso and combined flood from Tserim Latso and Dhuedrip Latso) are prepared for the areas along Samteling Chu. Flood hazard maps prepared in this report are based on ground-based data from the lake sites (upstream) and global Digital Elevation Model (satellite DEM). To enhance the accuracy of such hazard maps, more ground-based data from the settlement area in the downstream along with high resolution satellite images for the upstream of Samteling chu are recommended.

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Annexures: Pictures from the sites.

1. Background

Based on the directive received from the Ministry of Energy and Natural Resources (MoENR), the National Center for Hydrology and Meteorology (NCHM) constituted a technical team lead by Mr. Karma, Specialist, Cryosphere Services Division for assessment of *Genyen Lkhatsho (Tserim Lhatsho)* and *Didrip Tso* for potential risk of outburst in the head water of Samtelling Chhu. Technical team traveled to the headwater of Samtelling Chhu from 3-10 September 2024 for field work.

The following are the Technical Team members who conducted the site assessment.

a. Mr. Karma, Specialist II (Glaciologist), Cryosphere Services Division, NCHM - Team Leader
b. Mr. Jamyang Zangpo, Sr. Hydro-met Officer Hydrology and Water Resources Services Division (HWRSD), NCHM
c. Mr. Sangay Tenzin, Assistant Engineer, Hydrology and Water Resources Services Division (HWRSD), NCHM
d. Mr. Tandin Wangchuk, Dy. Chief Hdyro-met Officer, Hydrology and Water Resources Services Division (HWRSD), NCHM
e. Mr. Sonam Dorji, Hydro-met Technician, Hydrology and Water Resources Services Division (HWRSD), NCHM
f. Mr. Sonam Tashi, Hydro-met Technician, Technical Standard and Research Division (TSRD), NCHM

Photo 1: Offering of Sang and Serkem at Tserim Latso

Prior to their departure for field work, the team visited the Dechengphug Lhakhang and offered prayers and sought guidance of the Dechenphu Lama for survey of lakes. Even at the site, the works on the lakes started only after offering Sang (Smoke offering) and Serkem (wine offering) by the team (Photo 1).

2. Objectives

The main objective of this study is to assess the status of two main fresh water mountain lakes Tserim Lhatsho (a.k.a Genyen Latsho) and Dhuedrip Lhatsho (a.k.a Didrip Tso) in the headwaters of Samteling Chu for flood hazard and associated risks in the downstream.

3. Study Area

Samelling chhu is one of the tributaries of Thimchu. The Samtenling catchment lies in the north Thimphu region with an area of approximately 50 km^2. Catchment altitude ranges from 2340 masl to more than 4700 masl in the mountain peak with good forest and vegetation coverage. Most of the settlement areas are located downstream in the alluvial fan of steam that includes Babena, Jungshia and India house area. There are more than 5 lakes in the headwater and Tserim Latso and Dhuedrip Latso are the larger ones. The Samtenling Chhu is primarily fed by more than 9 small tributaries. The three main tributaries of Samtelling chhu are the outflow tributaries from Tserim Latso and Dhuedrip Latso and other small lakes located high up in the mountains shown in Figure 1. Catchment has no glaciers and the streams are fed by rain and seasonal snow melt.

There is no river gauging station for monitoring the stream. The lean season flow measurements (2001-2024) of Samtenling Chhu varies between 0.06 m^3/s to 0.41 m^3/s with an average flow of 0.186 m^3/s. The length of the Samtenling Chhu from Genyen LaTsho to its confluence with Thimchhu is approximately 14 km long.

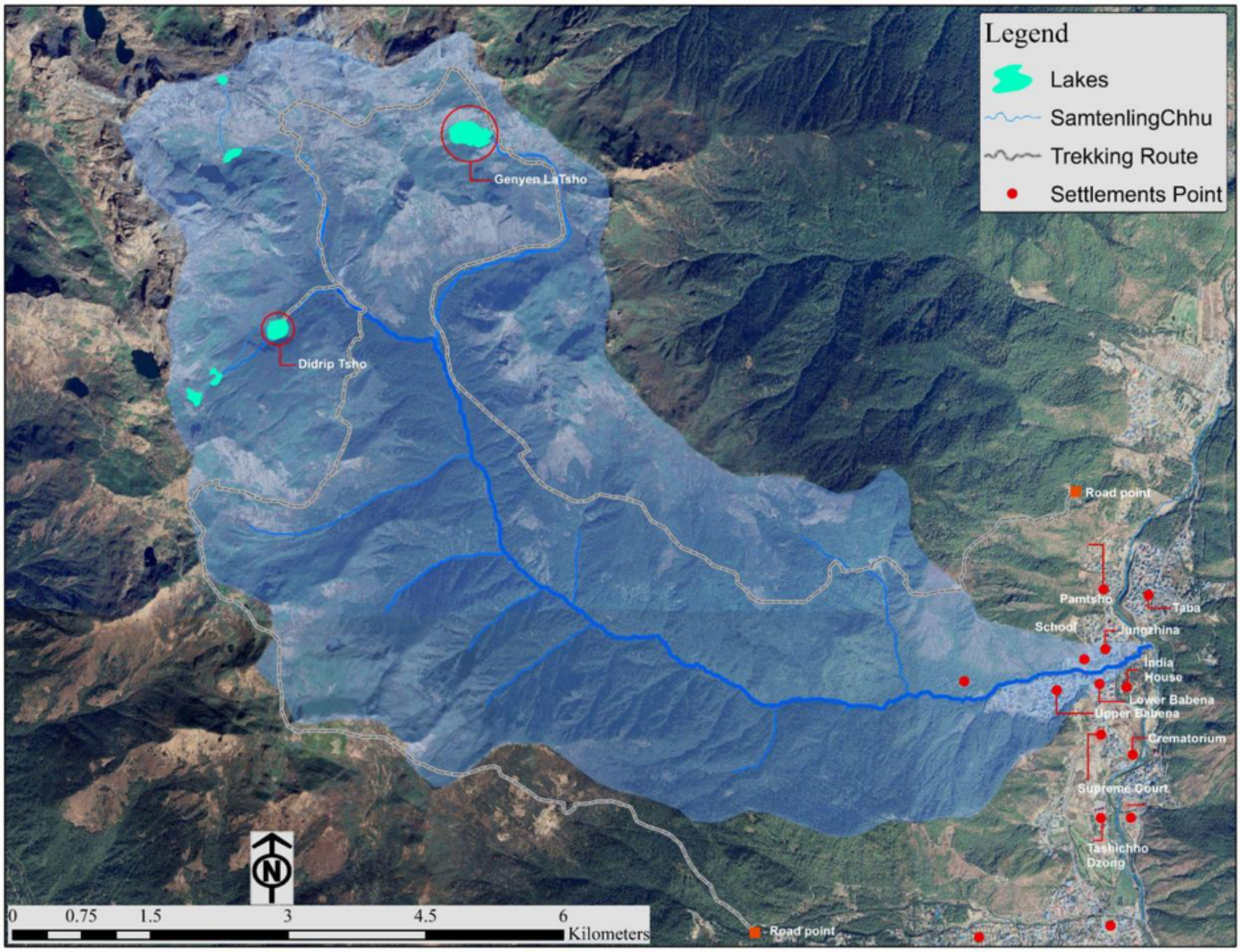


Figure 1: Location Map showing lakes, streams and settlement points along Samtenling Chhu.

4. Lakes

There are about 5 lakes in the watershed and only the two main larger lakes were assessed during this expedition. The location of the two lakes which were studied during this expedition are shown in Figure 1. The general description of the lakes along with the general geology of the surrounding area are given in the following section.

4.1 Tserim Latso (Genyen Latso)

Tserim Lhatsho (Genyen Lhatsho) is located at the source of the main eastern branch of Samteling Chu. The lake lies at a distance of two days trek from Dechen Goenpa, the nearest motorable road. Tserim Lhatsho is located at an elevation of 4162 masl and has a surface area of 98161.4 m^2 (0.098 km^2)

Photo 2: View of Tserim Latso (Genyen Latso)

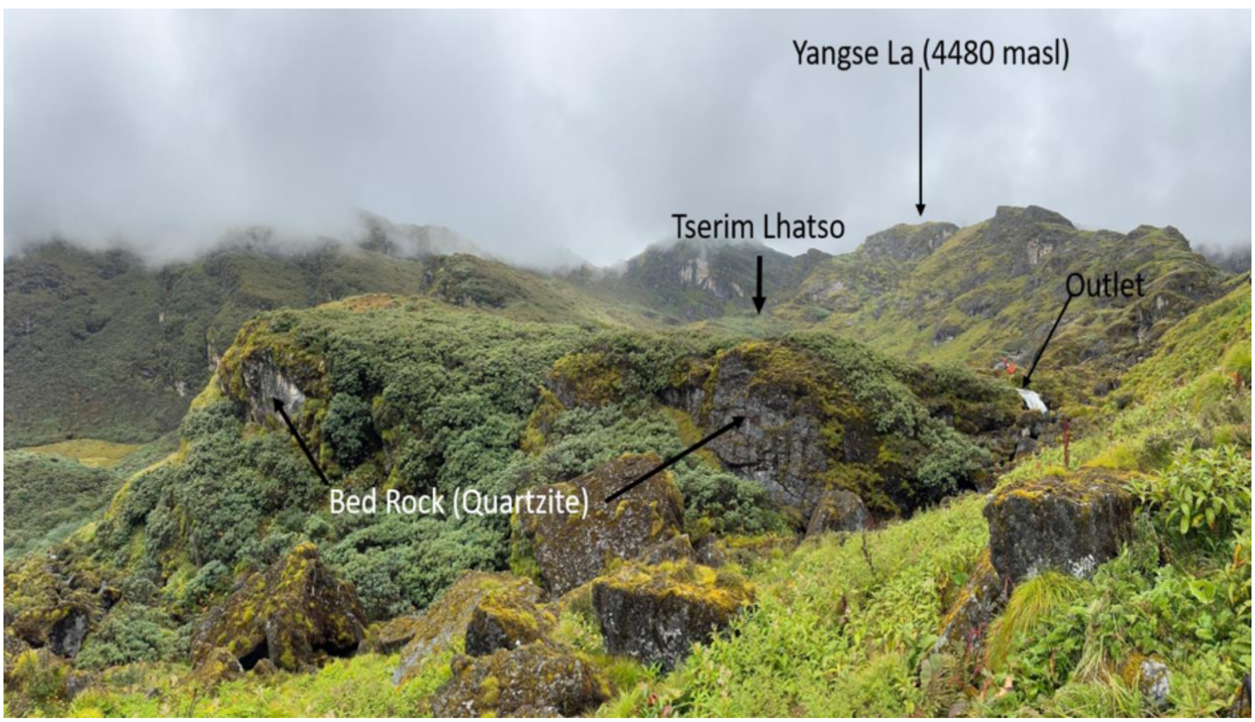


Photo 3: Solid bedrock surrounding Tserim Latso

Tserim Lhatsho was formed in a cirque-like landform towards the base of Yangse La (4480 masl) which now is surrounded by solid bed rocks belonging to Thimphu group mainly consisting of quartzite, schist intebedded with genesis and occasionally some mafic rocks towards the base of the valley. (Photo 2 and Photo 3). The details of the rock attitude is shown in Figure 2.

Figure 2: Image of Tserim Latso with Geological information.

4.2 Dhuedrip Lhatsho (Didrip Tso)

Dhuedrip Latso or Didrip Tso is the major lake lying in the headwaters of the main western branch of Samteling Chu. The lake is located at a distance of one day trek from Tserim Lhatsho crossing Yangse La (4480 masl). The lake is formed within a cirque landform at a tree line elevation of 3928 m.a.s.l. (Photo 4). Except at the outlet area, the lake is surrounded by solid rock mainly of Thimphu group; quartzite and geniess. Since it is formed in a cirque the lake is dammed by frontal moraine in the outlet area where the natural outlet exists at present. The lake measures 38744.4 m^2 (0.039 km^2) in surface area.

Photo 4: View of Dhuedrip Lhatsho

5. Data collection

5.1 UAV Survey

Considering the short duration of the field and also taking into account the difficulty in accessing the sites, UAV (DJI Matrice 300 RTK) was used to conduct aerial surveys on the lakes to collect topographic data. The high-resolution processed images of the lakes from the UAV survey are shown in Figure 3. The high-resolution products from aerial imageries such as orthomosaic photo and digital terrain model (DTM) are critical in deriving accurate physical parameters for lake breach modeling. Aerial survey using the UAV is shown in Photo 5.

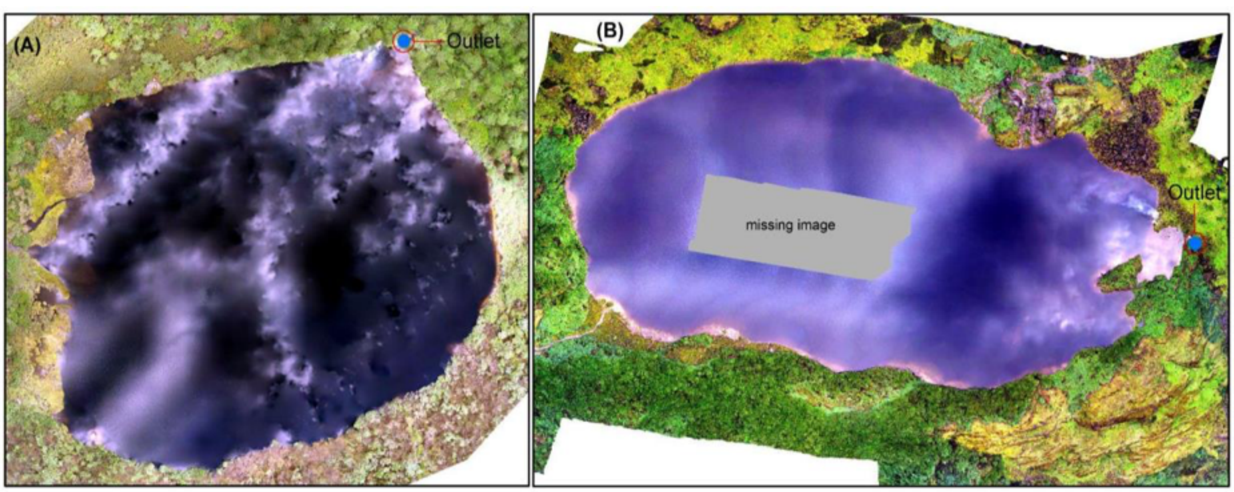


Figure 3: Aerial image of two lakes; (A) Dhuedrip Lhatsho and (B) Tserim Lhatsho

Photo 5: UAV survey on Tserim Latso

5.2 Bathymetry Survey

Bottom topography of the lake and volume of water stored in the lake plays an important role in assessing the flood hazard and its impact downstream from any type of lake. Bathymetry survey was conducted on both *Tserim Latso* and *Dhuedrip Latso* using a rubber inflatable boat mounted with SONAR GPS integrated sensors (FISH ELITE) as shown in Photo 6.

__Photo 6: Bathymetry Survey on Tserim Latso and Dheudrip Latso__

5.3 Discharge measurement

Equally important is the data on discharge from the lakes. Discharge measurement on both Tserim Latso and Dhuedrip Latso was conducted using a current meter (OTT MF Pro-water flow meter) by Wading method at the natural outlet of the lakes (Photo 7).

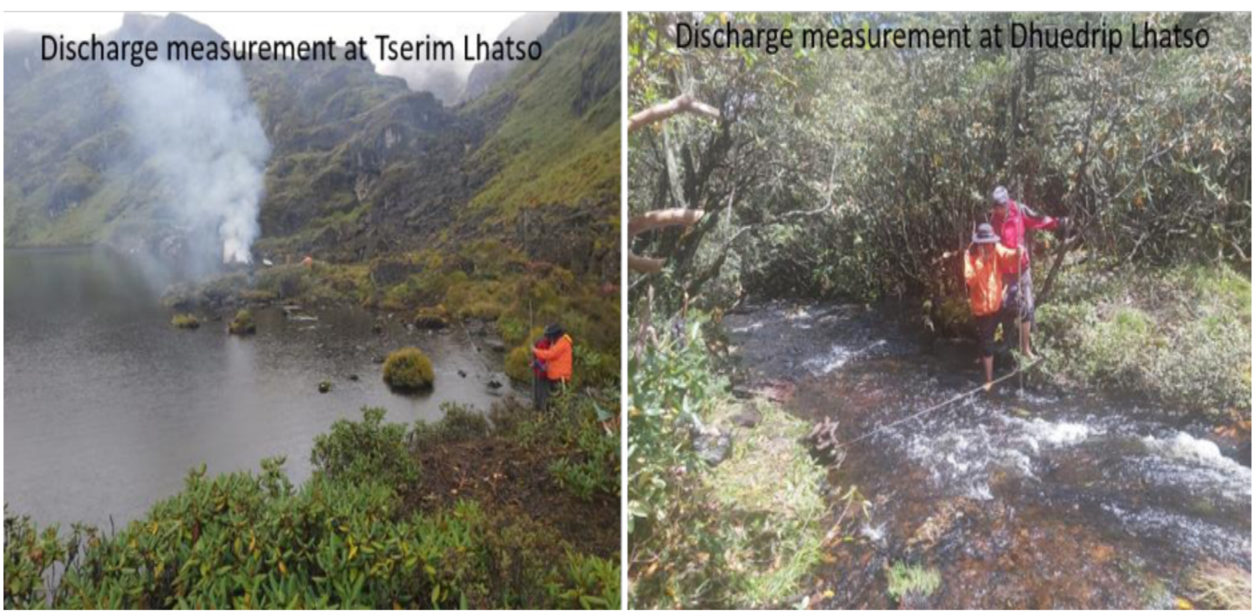


__Photo 7: Discharge measurement at the outlet of Tserim Latso and Dheudrip Latso__

6. Results and Findings

The findings from the analysis of the data collected are presented in the following section.

6.1 Lake volume

Based on the detailed bathymetry survey conducted on both Tserim Latso and Dhuedrip Latso, bathymetric maps of the lakes were prepared using Dr. Depth software. The bathymetric maps of Tserim Latso and Dhuedrip Latso are shown in Figure 4 and Figure 5 respectively.

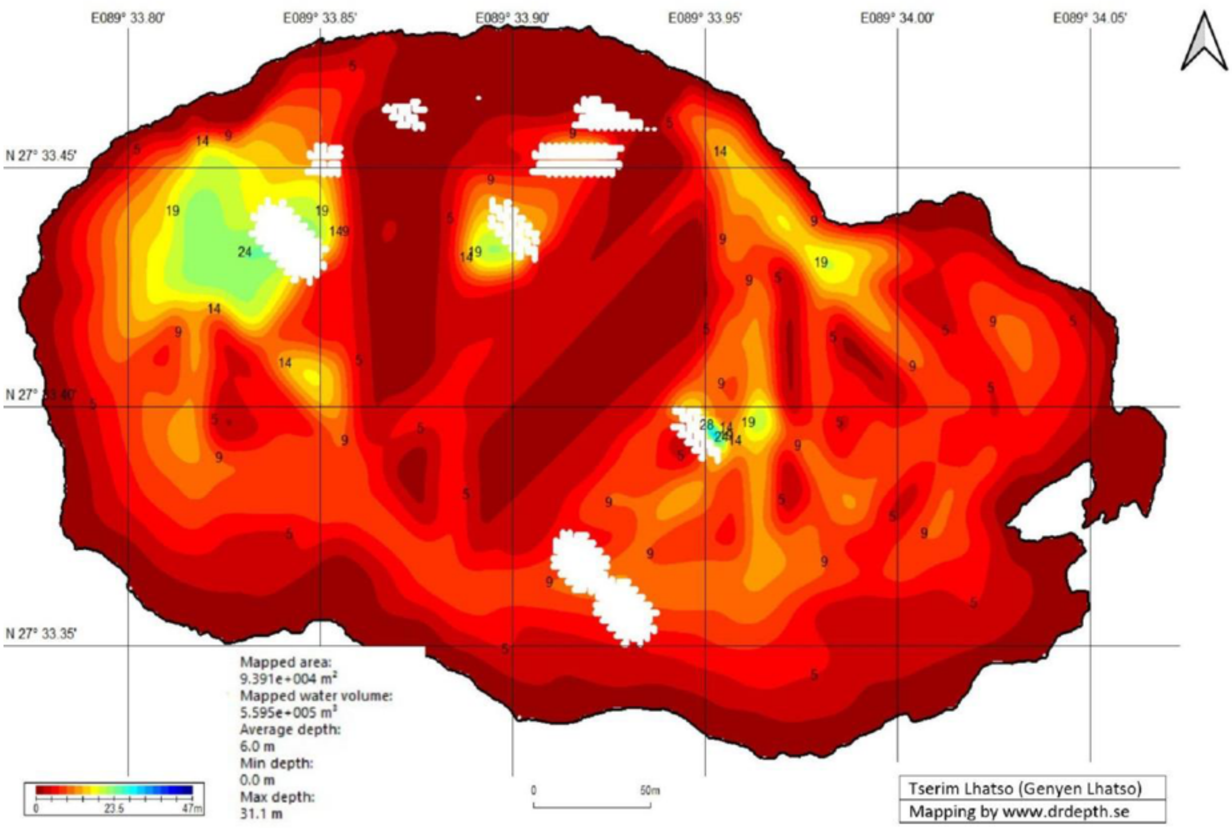


Figure 4: Bathymetric map of Tserim Latso (Genyen Latso)

The estimated water volume in Tserim Latso based on the bathymetric map is 5.595 X 10^5 m^3 with the deepest part of the lake measuring about 31.5 m. The average depth of the lake was found to be about 6 m. However, due to the topographic and environmental condition (deep gorge and narrow valley) in which Tserim Latso is located , the SONAR instrument missed some part of the data recording during the bathymetry survey.The white patches and sharp dark brown patches in figure 4 are the areas in the lake with missing data and not being able to extrapolate from the nearby data points. The bathymetric map was created using the recorded available data. Therefore, it is to be noted that the volume estimated and presented in this report is little underestimated due to partial missing data.

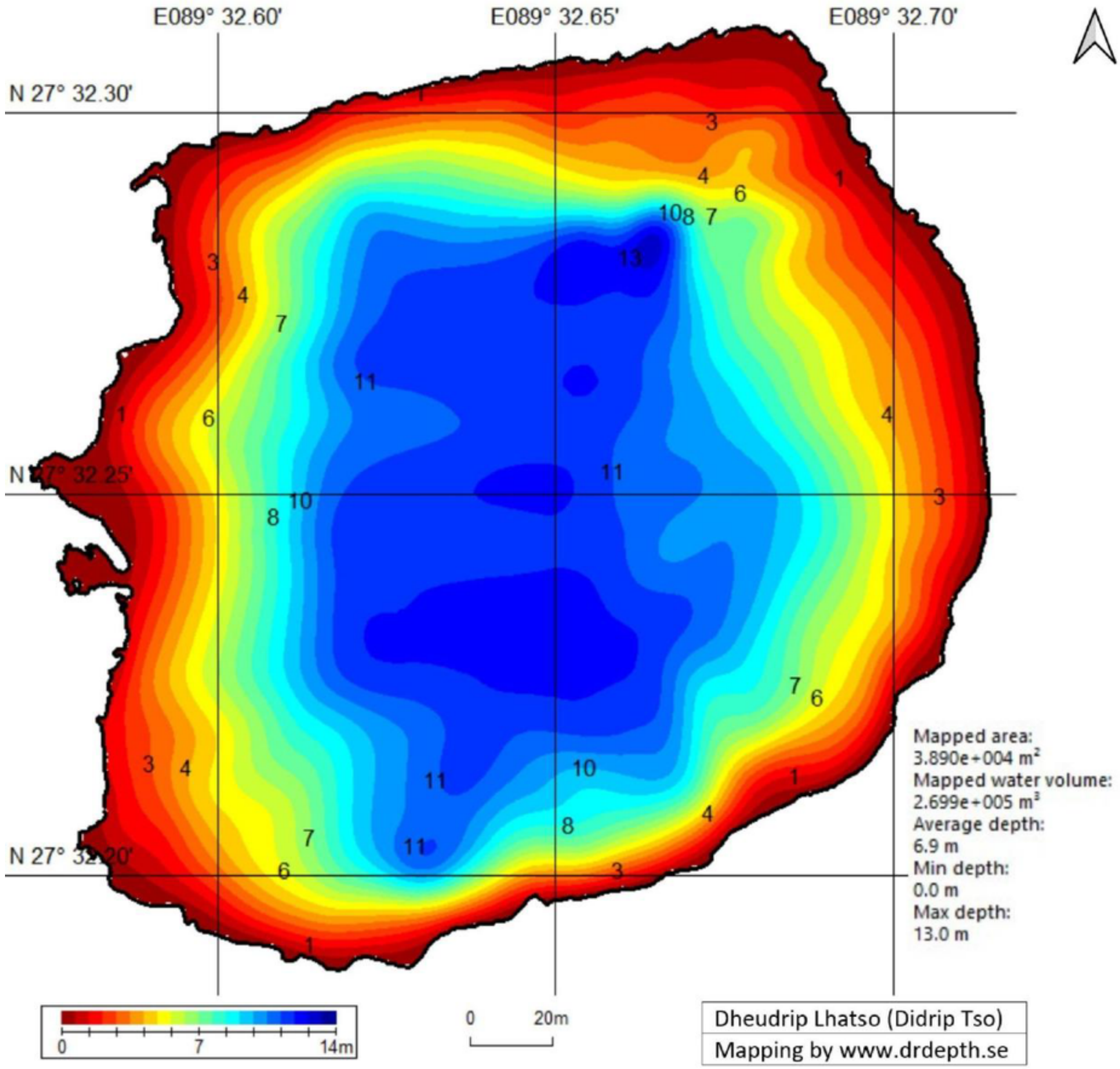


Figure 5: Bathymetric map of Dheudrip Latso (Didrip Tso)

The bathymetric map of Dhuedrip Latso is shown in figure 5. The estimated water volume in Dheudrip Latso is 2.699 X 10^5 m^3 with the deepest part of the lake measuring around 13 m. The average depth of the Dhuedrip Latso was found to be around 6.9 m.

6.2 Outflow discharge from the lakes

The discharge measurement at the outlets of Tserim Lhatsho and Dhuedrip Lhatsho was conducted on 5th and 7th September 2024 respectively. The measured data are given in the table 1 below.

Table 1: Discharge data from Tserim Latso and Dhuedrip Latso

Sl. No	Lake	Outlet Discharge (m^3/s)	Date of measurement
1	Tserim Lhatsho	0.25	5^{th} September 2024
2	Dhuedrip Lhatsho	0.29	7^{th} September 2-24

6.3 Potential Lake breach hydrograph

The potential flow hydrograph from the lake is estimated using the BREACH model. BREACH is a numerical model describing the dam breach process and the resulting outflow hydrograph which is based on fundamental principles of hydraulics, sediment transport, soil mechanics, and the physical properties of dam materials and the reservoir. The model is physically based and was designed to predict the size, shape, and time of dam breach development, as well as the resulting flow rate and the volume of water released. The peak from the Tserim Latso and Dhuedrip Latso, considering the worst-case scenario (total breach of the lakes) is approximately 146 m^3/s and 57 m^3/s respectively. The breach flow hydrograph from the lakes is illustrated in Figure 6.

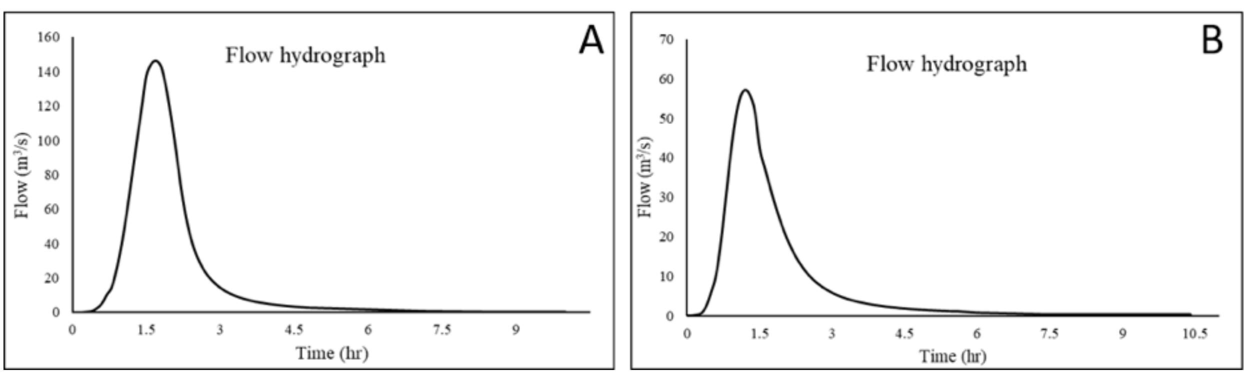


Figure 6: Breach flow hydrograph from lakes; A) Tserim Latso B) Dhuedrip Latso .

6.3 Inundation Extent of potential flood

A hydrodynamic model is essential for understanding the characteristics of a flood wave caused by a flood propagating downstream, as well as for quantitatively evaluating the potential impact.

HEC-RAS, a commonly used hydrodynamic model was used to route the flow under unsteady flow conditions. Three different scenarios were simulated; outburst from Tserim Latso, outburst from Dhuedrip Latso and a worst-case scenario of a combined outburst where both the lakes assumed to breach at the same time. Inundation extent for these three scenarios are illustrated in Figure 7 and highlighted for the Samtenling, Babena and Jungzhina area. The results are based on globally available terrain models (10m resolution).

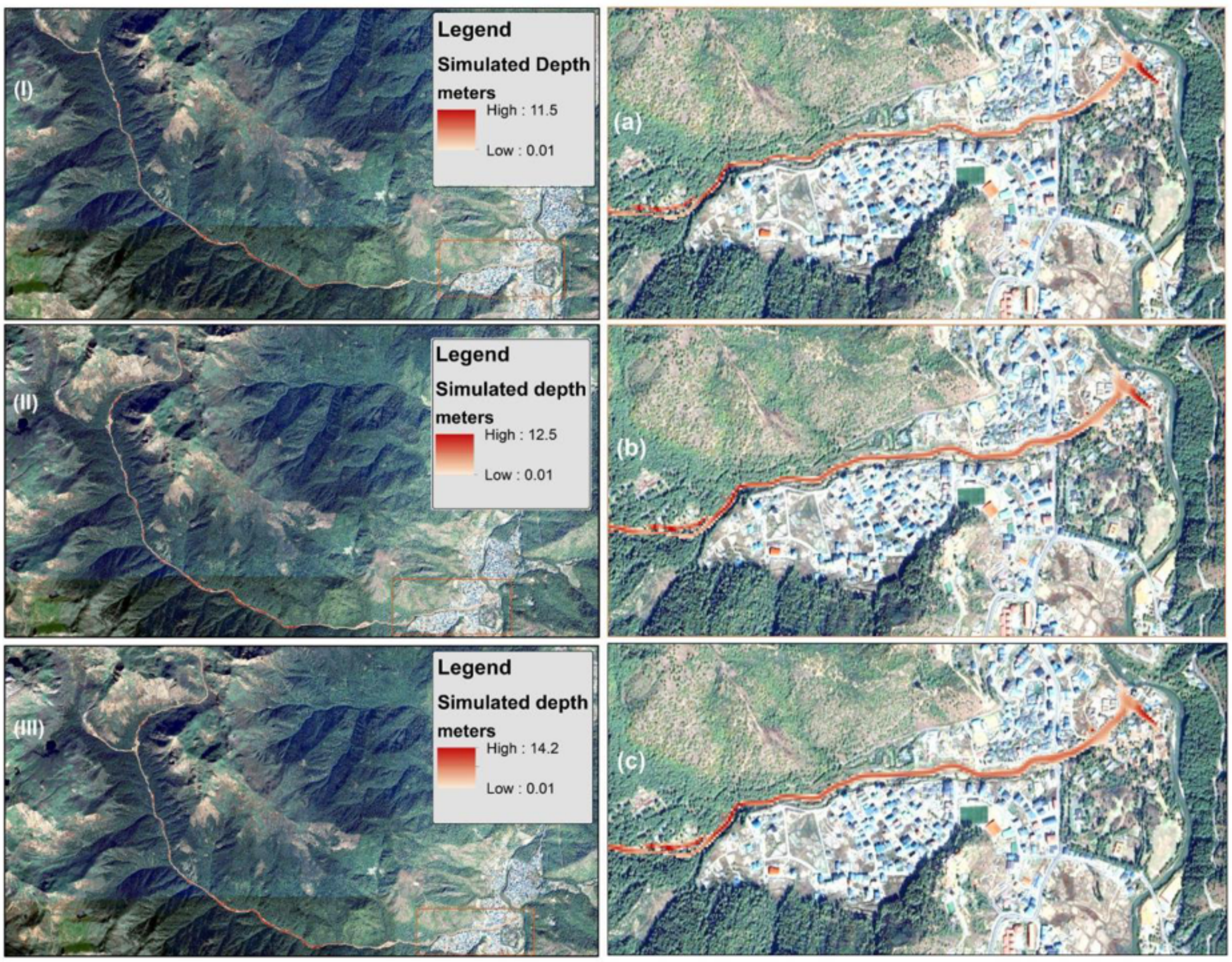


Figure 7: Simulated flood depth for the Samtenling chu catchment for various scenarios. I,II & III shows the simulated results for outburst from Dhuedrip Latso, Tserim Latso and combined respectively; a,b & c show the corresponding flood depths and extent in settlement area downstream.

7. Discussion

7.1 Stability of the lakes and surrounding area

As shown in Photo 2 and Photo 3, Tserim Latso is located in a landform resembling a cirque near to the base of Yangse La. There are no glaciers or lakes above Tserim Latso feeding the lake. The lake is completely surrounded by solid high grade metamorphic bed rocks mainly consisting of granitic gneiss and schist at the top (near the outlet) which is underlined by quartzite and a thin band of mafic rock towards the valley bottom. The dip amount of the rocks ranges from 12 degree to 37 degree with dip direction towards NW (into the slope) and striking NE. The dip direction towards NW coincides with the direction of rocks dipping into the slope which is a good indicator of stable slope. As such no major fracture or shear zones are observed on the rock face surrounding the lake. There were also no major seepages observed downstream of the natural outlet of the lake. All these features indicate that Tserim Latso is quite stable and it is very unlikely that the damming materials surrounding the lake will fail and breach resulting in an instantaneous flooding situation.

Dheudrip Latso is a cirque lake indicating that the lake was formed through collection of water in a cirque which was created through glacial activity in the past. Due to the past glacial activity there is a presence of frontal moraine which is damming the lake and on which the present natural outlet exists. Except for the outlet area, all other sides surrounding the lake are observed to have presence of insitu rock. Although the outlet of the lake lies on the frontal moraine, the downslope from the crest of the terminal moraine was found to be thickly vegetated with trees and bushes. Huge boulders of granitic gneiss and quartzite were also seen on the outer slope of the moraine which are covered with thick lichens and mosses. No major mass movements and seepages were observed on the moraine daming the lake. Presence of thick vegetation and under growth, absence of mass movement and seepage are all indicative of highly stable moraine dam. Similar to Tserim Latso no glaciers and lakes were observed above Dheudrip Latso feeding the lake.

7.2 Size and volume of the lake

Normally fresh water mountain lakes exist as water bodies with shallow depth unlike other glacial lakes. The surface area varies from lake to lake which is mainly determined by the shape and extent of the area in which the lakes were formed. Tserim Latso and Dheudrip Latso are typical fresh water mountain lakes (Photo 2 and Photo 4).

The surface area of Tserim Latso as determined from the image taken through drone survey and was found to be 0.098 km^2. The deepest part of the lake based on the bathymetry survey result was found to be about 31.1 m. The estimated volume of Tserim Latso was estimated to be around 5.595 X 10^5 m^3 (0.559 million cubic meters). Similarly, the surface area of Dheudrip Latso as determined from the drone image was found to be 0.039 km^2 and the deepest part of the lakes was measured to be around 13 m. Total volume of water stored in Dheudrip Latso was estimated at around 2.699 X 10^5 m^3 (0.269 million cubic meters).

Total volume of water stored in both Tserim Latso and Dhuedrip Latso are found to be less than a million cubic meters which is insignificant in terms of flood volume even if we consider a worst-case scenario of totally breaching the lake. However, this statement is entirely based on the stored water in the individual lakes only. In the flooding scenario along Samteling Chu, it is important to consider mass movement triggered by the flood along the river channel resulting in debris flow which will have greater impact downstream.

7.3 Potential Flood Volume and Inundation Extent

The potential peak flood flow from Dhuedrip Latso and Tserim Latso are 146 m^3/s and 57 m^3/s respectively under complete breach scenarios. Under the worst-case scenario (combined flooding from Dhuedrip Latso and Tserim Latso), where there is a complete breach of lakes, an estimated combined peak flow of 203 m^3/s is expected to flow downstream. The peak flow from lake breach as it propagates downstream will attenuate and peak flow at the settlement area will be lower due to loss in storage areas and frictional losses although the flood volume would remain similar in accordance with laws of conservation of mass.

The simulated results show that the buildings and infrastructures in close proximity to Samteling Chu especially below Jungshina bridge areas are expected to be inundated during the events considered for this report. The modeled result is entirely based on the water volume in the assessed lakes and does not take into account abnormal precipitation phenomenon. The simulation results using a coarse resolution global terrain model in most cases does not represent the actual ground conditions and misrepresentation is more severe in small streams such as Samteling Chu. A higher resolution terrain model with field-based river cross sections and hydraulic structures along the rivers will significantly improve the results presented in this report and understand the conveyance capacity of the channel.

8. Conclusion

Based on physical verification of the lakes and the results obtained from analysis of the data collected from the lake sites and simulated results obtained through modeling, the following conclusions can be drawn.

- Tserim Latso in its current state was found to be stable considering that the entire lake is surrounded by solid rock.
- Dheudrip Latso is a cirque lake and found to be dammed by frontal moraine on which the natural outlet of the lake exists. In terms of stability of the moraine dam, no major signs of instability were observed during the site visit.
- In terms of volume of water stored, the quantity of water stored in the lakes was found to be less than a million cubic meters. This volume by itself is insignificant in terms of flood

impact downstream unless combined with other external factors such as abnormal rainfall.

- There are no glaciers or lakes found above both Tserim Latso and Dhuedrip Latso which may act as a triggering factor for flood from the two lakes.
- All along Samteling Chu, no indications of past major flooding are observed. The downstream part was found to be thickly vegetated with thick bushes and shrubs. Incase of any type of flood in the future a high concentration of debris should be expected.
- The simulated flood indicates that the settlements along the streams are expected to be inundated, especially the areas downstream of the Jungzhina bridge.

9. Recommendation

As a part of the findings from the present study, the following are the recommendations.

- Flood hazard from Tserim Latso and Dhuedrip Latso was found to be low considering the stability of damming materials around the lakes and total volume of water stored in the lakes. However, incessant precipitation phenomenon which are more common recently needs to be considered as a triggering factor for future flooding scenario along Samteling Chu.
- To enhance the quality of flood hazard maps along Samteling Chu, ground-based data especially in the settlement area (downstream) including river cross sections and high-resolution satellite image and digital elevation model for the upstream needs to be obtained.
- Samteling Chu watershed has thick forest and vegetation coverage along the stream course and banks. The stream channel may get blocked due to debris collection resulting in the formation of artificial lakes along the river course during the rainy season which are common phenomena in mountainous areas. It is recommended to monitor the upstream river course from time to time during the monsoon.

ANNEXURE: Pictures from the site

Bathymetry Survey

Close up of bathymetry Survey

Testing of Drone before the work

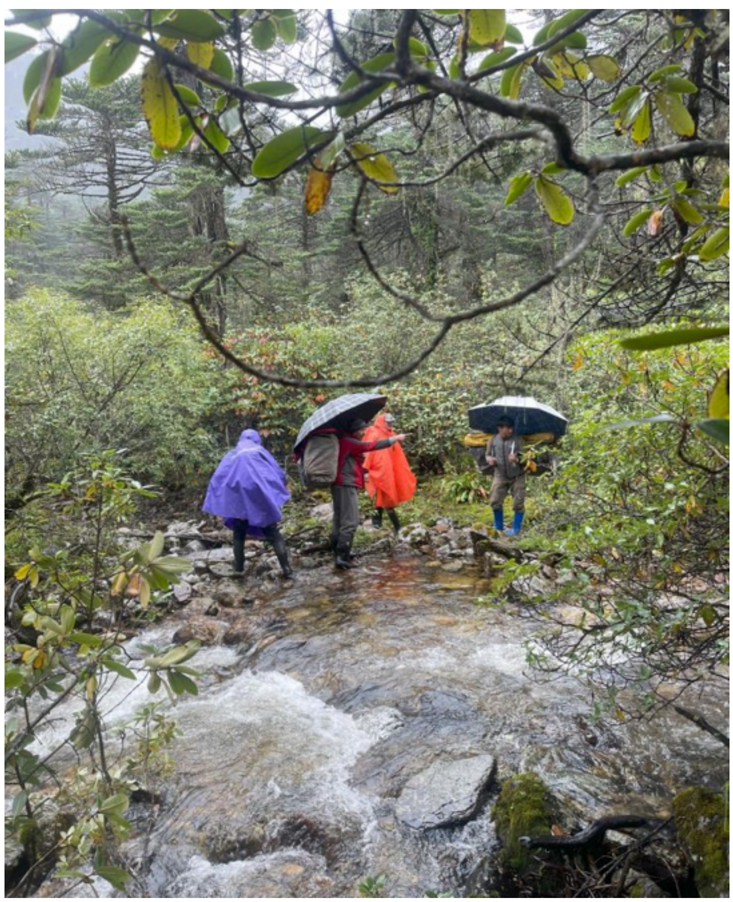
Checking the geology around the lake

Taking geological information of the rocks surrounding the lake

View of Tserim Latso

Measuring rock attitudes

Measuring Discharge at the outlet of Dhuedrip Latso



On the way to Dhuedrip Latso