Rapid Field Assessment of Sintaphu Glacial Lake Outburst Flood



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National Centre for Hydrology and Meteorology
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Assessment Summary

A technical team inspected the upper and lower Sintaphu lakes on 4th November 2026, six days after the glacial lake outburst flood (GLOF) of 29 October 2026. Photographs, visual observations, and laser range-finder measurements documented substantial outlet erosion and approximate lake-level lowering of 5.5 m in the upper lake and 36 m in the lower lake. Satellite-image and bathymetric analysis indicate storage reductions of 0.805 million m³ (36.1%) in the upper lake and 5.272 million m³ (90.1%) in the lower lake: about 6.1 million m³ was released in total and about 2.0 million m³ remains impounded.

Ice detachment into the upper lake is the most probable trigger, followed by a cascading failure of the lower lake. No direct observation confirms the initiating process or the order of drainage. The remaining lakes and outlets cannot be considered stable: the glacier still adjoins the upper lake, the breached lower moraine was sliding during the visit, and before the event neither lake had real-time water-level sensors. The priorities are outlet surveys, repeat bathymetry, reconstruction of the trigger and timeline, and sensor-based monitoring with lake-specific alert thresholds.

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1. Background

A GLOF was reported at the Sintaphu glacial lakes on 29 October 2026. Preliminary remote-sensing analysis of pre- and post-event optical and radar imagery was undertaken to examine lake changes and possible causes. As imagery alone could not establish the initiating process or event sequence, a field team visited the lakes on 4th November 2026 to document post-event conditions, measure visible outlet and lake-level changes, assess possible trigger evidence, and identify follow-up requirements.

This is a rapid assessment, not a detailed dam-stability evaluation, flood-hydrograph reconstruction, or downstream hazard assessment.

1.1. Study area

The Sintaphu glacial lake is a moraine-dammed glacial lake complex at about 4,480 m above sea level, below Wakila mountain in Laya Gewog, Gasa Dzongkhag, at the headwaters of the Mochhu. It consists of an upper lake in contact with a glacier terminus and a larger lower lake, and it is listed among Bhutan's 17 potentially dangerous glacial lakes (PDGLs).

1.2. Objectives

The following are the objectives of the field visit:

1. Document the condition of both lakes, their outlets, and the surrounding glacier margins after the event.
2. Measure the visible breach widths and heights and estimate lake-level lowering using laser observations.
3. Examine evidence for a possible trigger and an upper-to-lower lake cascade.
4. Identify residual hazards and information gaps, and recommend further investigations and monitoring.

2. Assessment Method

2.1. Remote Sensing Analysis

A preliminary analysis of satellite imagery was carried out immediately after the event. Because of weather and cloud cover over the region, the first clear post-event imagery was acquired on 1 November 2026, three days after the GLOF. High-resolution pre- and post-event images were provided by Newcastle University under the Education and Research Program (Planet Labs PBC imagery). Lake-area time series for 2013–2026 were derived from Landsat and Sentinel-2 imagery using the Normalized Difference Water Index (NDWI).

Pre-event Lake volume and depth were taken from 2023 bathymetric data. Post-event volume and depth were obtained by applying the post-event water surface to the pre-event bathymetric surface; the post-event depth distribution of the lower lake is a reconstruction. Upper-lake

bathymetric coverage is incomplete, so its volume figures are less certain than those for the lower lake.

2.2. Field Verification and Assessment

2.2.1. Visual inspection and photographic documentation

The team visually inspected the lake margins, exposed banks, outlet breaches, and glacier ice visible from the observation locations. Photographs documented outlet erosion, lake-level indicators, the glacier front, and ice blocks in the lakes and on exposed ground. The team examined the upper lake, the suspected source area, for evidence of a recent large ice detachment, and considered whether other visible slope failures could explain the event.

2.2.2. Laser measurements

A laser rangefinder was used to measure the visible breach widths and heights and the vertical separation between the interpreted pre-event and post-event lake levels. The reported dimensions represent the geometry visible during the visit. Breach height and lake-level lowering are different measurements and should not be used interchangeably.

Lake-level estimates depend on identifying the former shoreline correctly, and the breach observations describe selected visible dimensions rather than fully surveyed cross-sections. and repeated.

3. Findings from Post-event Assessment

3.1. Remote Sensing Analysis

3.1.1. Spatio-temporal changes of the Sintaphu lakes

We combined Landsat and Sentinel-2 imagery to establish time-series changes in the lakes, delineating lake areas from NDWI values. Figure 1 shows the change in lake area from 2013 to 2026 under pre-GLOF conditions.

The surface area of the lower lake showed no significant change over this period. In contrast, the upper lake evolved, with significant expansion where it contacts the terminal glacier. This contact matters for hazard: a lake that grows against a glacier front is exposed to ice detachment into the water. Across Bhutan, glacier-connected lakes account for most of the recent growth in glacial-lake area

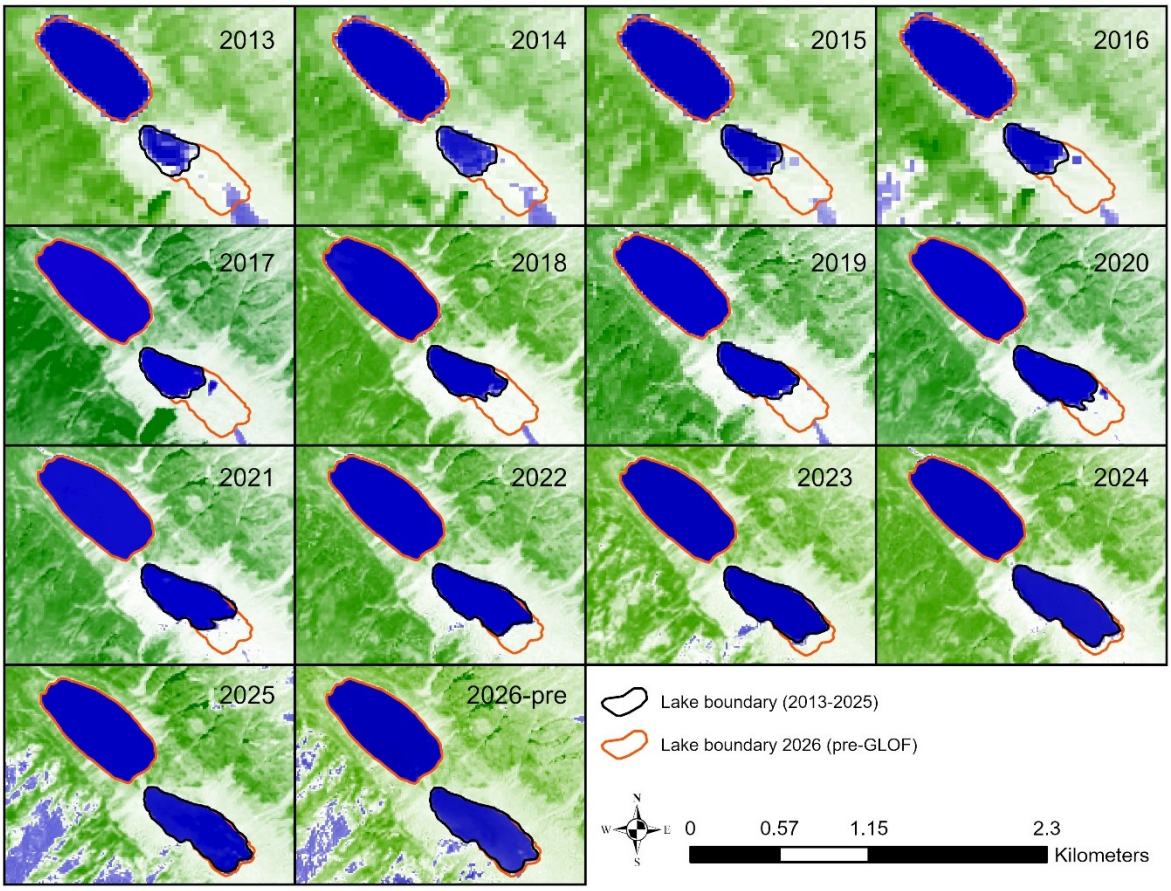

Figure 1. Spatio-temporal analysis of lake area expansion at Sintaphu

3.1.2. Estimated area and depth reduction

Pre- and post-GLOF lake areas were extracted from the satellite images, and lake-level drawdown was calculated. The 2023 bathymetry was used to quantify the changes in lake area and volume following the GLOF of 29 October 2026 (Figure 2).

Table 1. Estimated lake surface area and maximum depth from satellite imagery analysis

Parameter	Upper Lake	Lower Lake
Pre-GLOF		
Lake surface area (m^2)	158,727	234,327
Maximum lake depth (m)	44.9	53.2
Post-GLOF		
Lake surface area (m^2)	143,574	63,195
Maximum lake depth (m)	39.4	17.2

The values were derived from pre- and post-event satellite images and the available bathymetry. They are preliminary, and the available data were not sufficient on their own to establish the

trigger or the processes preceding the event. Post-event depths are the field-checked values reported in Section 4.2.4.

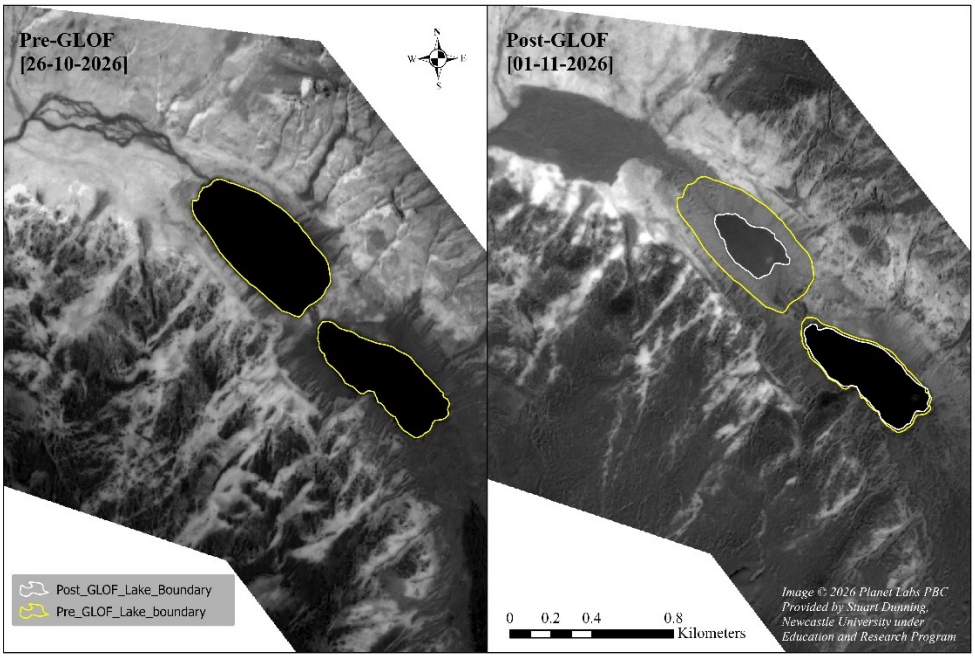

Figure 2. Changes in lake area pre- and post-GLOF event (Image © 2026 Planet Labs PBC. Provided by Stuart Dunning, Newcastle University, under the Education and Research Program)

3.2. Field Survey Assessment

The on-site assessment verified the remote-sensing results, assessed the likely trigger, recorded breach dimensions of the moraine dams, and estimated lake-level drawdown.

3.2.1. Potential trigger event

The primary suspected trigger is ice detachment into the upper lake. A mass of ice detached from the glacier could have entered the lake and generated a displacement wave. This mechanism is consistent with the proximity of the glacier front to the lake and with the ice blocks observed.

However, no fresh source scar was identified, and no direct observation shows that a detachment occurred immediately before the drainage.

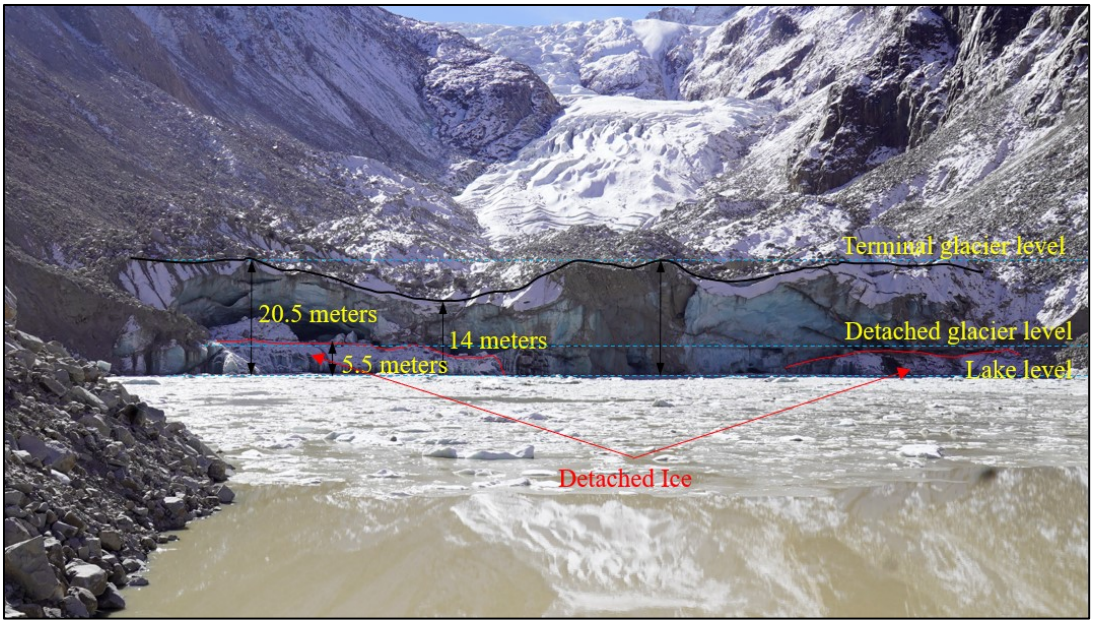

Figure 3. Glacier front adjoining the upper lake. Ice detachment from this setting is the primary suspected trigger

Minor sliding from the upper-right slope of the upper lake (Figure 4) was identified in satellite imagery and suspected as a potential trigger. Field verification showed that the slide was very minor and that its volume was probably too small to generate a wave large enough to breach the moraine. It may have been a precursor to the actual trigger (ice detachment), but the sequence of these events cannot be determined.

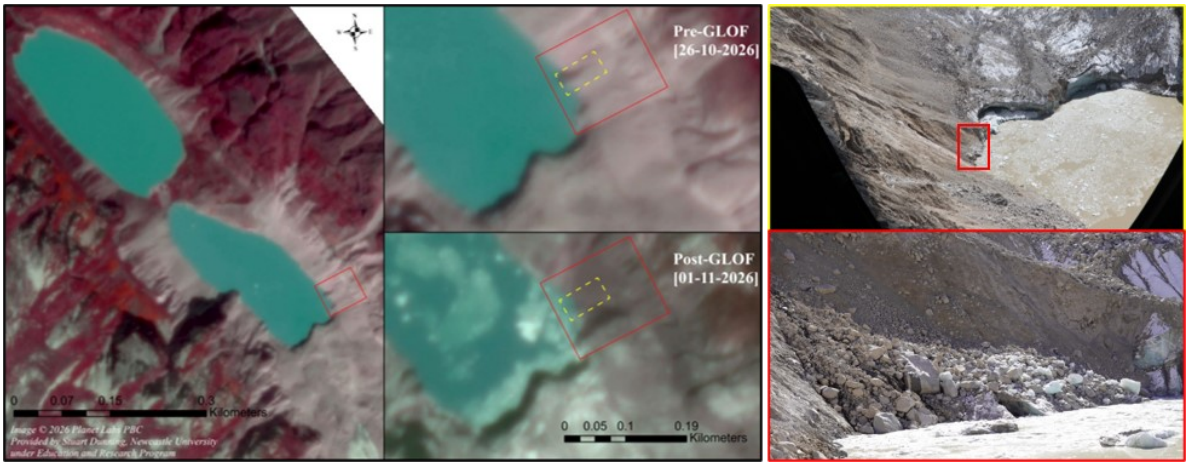

Figure 4. Left panel: location of the suspected minor landslide from satellite imagery. Right panel: image from the field. (Image © 2026 Planet Labs PBC. Provided by Stuart Dunning, Newcastle University, under the Education and Research Program)

3.2.2. Interpreted GLOF process: cascading event

The event is interpreted as a cascading GLOF in which both lakes drained. The sequence is assumed to have begun with an ice-related disturbance in the upper lake. A displacement wave from the impact of detached ice would have overtopped the upper-lake moraine and incised the

outlet, and the outflow was conveyed to the lower lake. The sudden surge of sediment-laden inflow would have raised the water level in the lower lake and increased the load on its moraine dam, leading to overtopping, rapid erosion, and ultimately failure, which sent the combined lake water and moraine material downstream.

The volumes add a caveat. The upper lake released at most 0.805 million m³, about 15% of the 5.272 million m³ released by the lower lake. The added inflow therefore did not account for most of the lower-lake release, which was mainly the lower lake's own stored water. This suggests that the surge, overtopping and erosion of the lower dam were what mattered, rather than the extra volume. Which failure mechanism dominated cannot be determined without surveyed breach cross-sections, information on the dam material, and timing data. The order of drainage was not recorded directly; it rests on field evidence and on general knowledge of cascading GLOFs, and it is consistent with NCHM's preliminary satellite analysis.

3.2.3. Assessment of breach and lake parameters

Breach dimensions were measured with laser equipment, and the values represent a single maximum point. Width may vary along the breach, and the recorded height depends on the upper and lower reference points used. The values are not average breach dimensions, the erosion depth since the event, or the maximum flood depth.

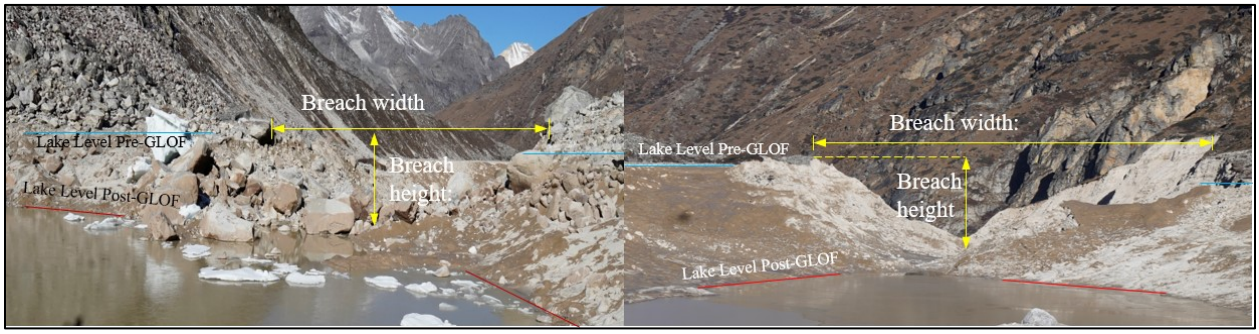

Figure 5. The breached moraine dams. The breach width and breach height, along with pre- and post-GLOF lake levels, are indicated. Left: upper lake; right: lower lake

The upper lake showed an approximate vertical water-level reduction of 5.5 m and an eroded outlet. The measured breach was approximately 39 m wide and 8.25 m high. The exposed margins and the current water surface are evidence of drainage, and the nearby glacier front remains a potential source of ice entering the lake.

The lower lake showed an approximate vertical water-level reduction of 36 m. Its outlet had a substantially larger breach than that of the upper lake, approximately 187 m wide and 50 m high. The lowered water surface and exposed banks indicate substantial drawdown.

Table 2. Field measurements of lake-level lowering and outlet breach dimensions

Breach parameters	Upper Lake	Lower Lake
Approximate water-level lowering	5.5 m	36 m
Recorded breach width	39 m	187 m
Recorded breach height	8.25 m	50 m

3.2.4. Estimation of lake volume

The upper lake retained most of its mapped surface area, while the lower lake lost most of its area and stored water. The mapped depth changes agree with the field estimates of lake-level lowering: maximum depth decreased by 5.5 m (44.9 m to 39.4 m) in the upper lake and by 36 m (53.2 m to 17.2 m) in the lower lake. Upper-lake bathymetric coverage is incomplete, so all volume estimates are preliminary and should be accompanied by uncertainty bounds.

Upper lake

The upper lake retained most of its surface extent after the event. Its area decreased from approximately 0.159 km² to 0.144 km², a reduction of 9.5%. Estimated water volume decreased from 2.230 million m³ to 1.425 million m³, a preliminary net storage decrease of 0.805 million m³ (36.1%). Maximum depth decreased from about 44.9 m to 39.4 m, consistent with the 5.5 m of lake-level lowering recorded in the field.

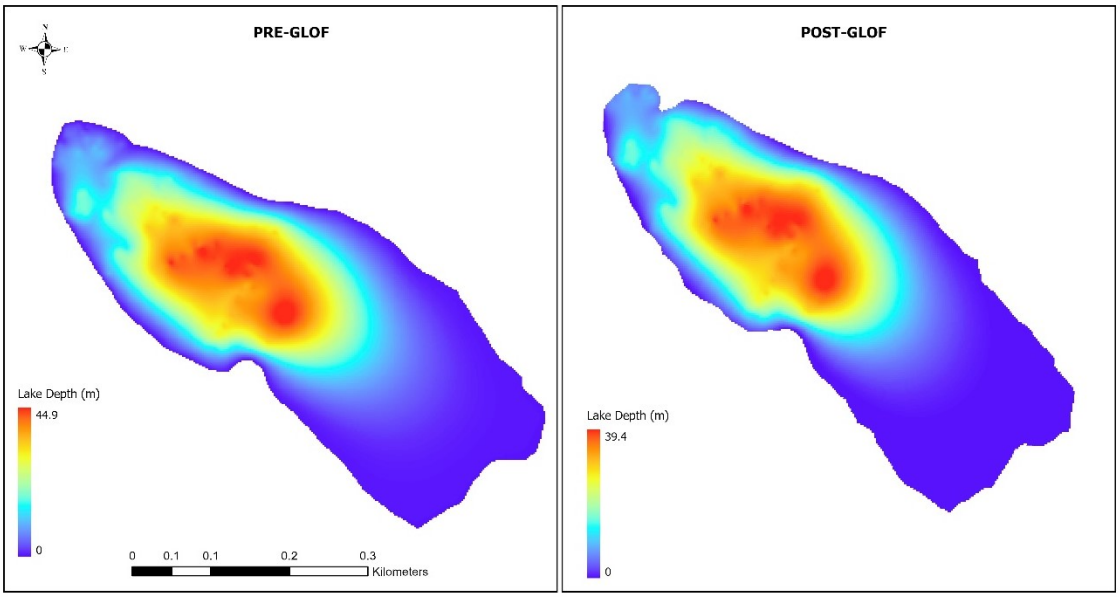

Figure 6. Upper lake pre-GLOF and post-GLOF depth distributions. Each panel uses its own depth scale; the colors should not be compared as identical absolute depths

Table 3. Pre- and post-GLOF comparison of lake area, estimated water volume and maximum depth for the upper lake

Parameters	Upper Lake		
	Pre-GLOF	Post-GLOF	Changes (%)
Lake area (m^2)	158,727.2	143,574.5	−9.5
Lake volume (m^3)	2,230,028.5	1,425,010.8	−36.1
Maximum lake depth (m)	44.9	39.4	−12.2

Lower lake

The lower lake lost far more area and water. Its mapped area decreased from approximately 234,327 m² to 63,195 m², a reduction of 171,132 m² (73.0%). Estimated water volume decreased from 5.853 million m³ to 0.582 million m³, a storage loss of 5.272 million m³ (90.1%). Maximum depth decreased from about 53.2 m to 17.2 m, consistent with the 36 m of lake-level lowering recorded in the field. The visit found extensive exposed banks and an enlarged outlet breach.

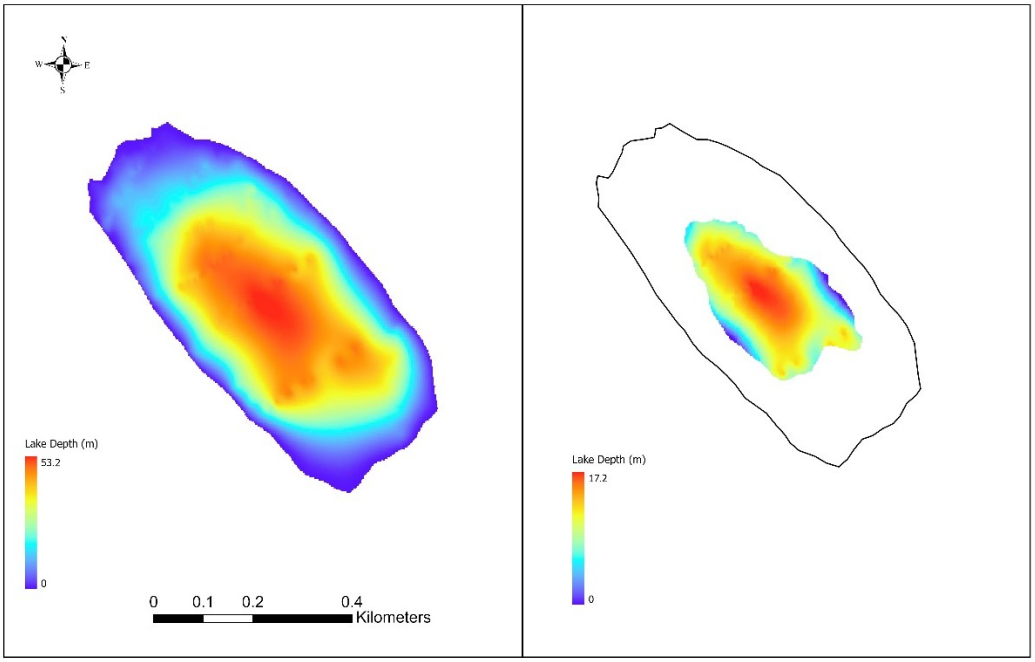

Figure 7. Lower lake pre-GLOF and reconstructed post-GLOF depth distributions. The black outline in the right panel shows the former extent. Maximum depths are 53.2 m and 17.2 m, with separate color scales

Table 4. Pre- and post-GLOF comparison of lake area, estimated water volume, and maximum depth for the lower lake

Parameters	Lower Lake		
	Pre-GLOF	Post-GLOF	Changes (%)
Lake area (m^2)	234,327.1	63,195.5	−73.0
Lake volume (m^3)	5,853,466.4	581,938.8	−90.1
Maximum lake depth (m)	53.2	17.2	−67.7

Combined

Together, the two lakes held about 8.083 million m³ before the event and about 2.007 million m³ afterwards, so about 6.1 million m³ (75.2%) was released (Table 1).

3.3. Residual hazards and current condition

The event reduced the stored volume but did not remove the hazard. The upper lake adjoining the glacier terminus still holds significant lake volume. Further ice detachment could overtop the weakened outlet and release the remaining water. With continuous sliding observed on the breached moraine of the lower lake, temporary blockage of the outlet channel and a similar cascading event could release sediment-rich surges.

4. Limitations

This report is based on remote sensing and a rapid field assessment. The main limitations are:

- **Timing.** The inspection took place six days after the event. The photographs record conditions at the time of the visit, not at the moment of failure, and later erosion or sliding may have altered the geometry.
- **Trigger and sequence.** No direct record establishes the initiating ice movement or the order of drainage between the two lakes. The interpretation rests on field observation and on general knowledge of cascading GLOFs. Weather, seismic, and hydrological records were not reviewed.
- **Laser measurements.** The measurements give rapid dimensions but do not define complete breach cross-sections or an event hydrograph. Measurement uncertainty has not been quantified, and the lowering estimates depend on identifying the former shoreline correctly.
- **Volume estimates.** The estimates rely on the 2023 bathymetry, incomplete upper-lake coverage and a reconstructed post-event bed for the lower lake, and carry no uncertainty bounds.
- **Satellite imagery.** The first clear post-event image was acquired three days after the event.

- **Scope.** The assessment does not include a dam-stability analysis, flood-hydrograph reconstruction, or downstream hazard and impact assessment.

5. Conclusion

Based on the physical verification of the lakes, moraines, and surrounding area, and on the data collected during the assessment, the following conclusions are drawn:

- The GLOF of 29 October 2026 was a cascading event in which both Sintaphu lakes drained. Ice detachment into the upper lake is the most probable trigger, but it was not directly observed.
- The rapid field assessment documented substantial outlet erosion and approximate lake-level lowering of 5.5 m in the upper lake and 36 m in the lower lake.
- The upper lake lost approximately 9.5% of its mapped area and 36.1% of its estimated water volume; the corresponding reductions in the lower lake were approximately 73.0% and 90.1%. Estimated storage losses were approximately 0.805 million m^3 and 5.272 million m^3, respectively.
- A combined volume of about 6.1 million m^3 was released and about 2.0 million m^3 remains in the two lakes. The 90.1% loss from the lower lake is at the upper end of the scenarios modelled before the event.
- The remaining lakes and outlets cannot be considered stable. The breached lower moraine was sliding continuously during the visit; the glacier still adjoins the upper lake.
- The initiating process and the sequence of drainage require further investigation.

6. Recommendations

Immediate monitoring and communication

Continue observation of both lake levels, outlet flow, and visible glacier instability where safe access or remote viewing is possible. Record repeat photographs from fixed positions and establish stable reference marks for water-level observations. Communicate any abrupt water-level change, increased discharge, renewed outlet erosion, or major ice movement through the existing NCHM reporting and warning arrangements.

Enhancement of monitoring stations and EWS

Upgrade the existing monitoring stations with automated lake-level and outlet-flow sensors, supported by real-time data transmission and reliable power supply. Establish lake-specific monitoring thresholds and alert protocols, strengthen communication among relevant agencies and downstream communities, and improve community preparedness through awareness programs, evacuation planning, and periodic emergency drills.

Survey the outlets and connecting channels.

Carry out a georeferenced topographic survey of both breach areas and the channel linking the lakes. Obtain longitudinal profiles and representative cross-sections, and record crest, channel-bed, and water-surface elevations in a common vertical reference. Confirm whether each outlet consists of erodible sediment, bedrock, ice, or a combination, and identify remaining unstable material.