Comprehensive Report on

Survey of Shishper Glacier for the Assessment of Potential Lake Formation and Outburst

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Brief Summary

- Shishper Glacier is actively surging as estimated by in-situ data.
- With drop in temperature in winters, melt-water from Muchuchar will decrease.
- Surging Shishper glacier is highly likely to intercept the little amount of water in Muchuchar stream in winters, while resulting in formation of glacier dammed lake.
- In case of lake formation, its size and volume will keep on increasing till spring season.
- With increase in volume of "glacier dammed lake" there will be more pressure on Shishper glacier's ice walls.
- Due to high density of water and the low-density ice will easily rapture and this will result in a glacial lake outburst (GLOF) in spring season, next year (2021).

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Objective

Shishper Glacier is surging with a very high velocity and it obstructs meltwater from the neighboring Muchuhar glacier. That results in formation of glacier dammed lake. The glacier dam lake was outburst for first time in June 20th 2019, and for second time on May 29th 2020. The main objective of the survey of Shishper Glacier is to assess potential of lake formation in the future.

Background

Various glaciers in the central Karakoram, especially in Hunza (see Figure 1 for the location of Hunza catchment) are surging. Such surging glacier, sometimes, intercept its own meltwater or from another glacier and facilitates the development of glacier-dammed lake. Such glacier-dammed (or ice-dammed) lakes suddenly outbursts and may result in a catastrophic flood that affects infrastructure and destabilizes adjacent mountain slopes several kilometers downstream.

The size of the glacial lake varies considerably and a lake may hold tens of millions of cubic meters of water, which upon outburst produces flow of water (peak discharge) greater by an order of magnitude than rainfall accumulated peak flow. Such flow may persist from few hours to several days, and may affect and damage locations situated tens to hundreds of kilometers downstream. This phenomenon is termed as Glacial Lake Outburst Flooding (GLOF).

Glacial lakes generally impounds either by a glacier, or by a moraine, or they occur in proglacial depressions caused by glacial over-deepening in the bedrock or sediment. The source area of the lake water may be the meltwater of the damming glacier or any other adjacent glacier. At temperate glaciers, large amounts of meltwater originates from basal melting, as well.

Generally, glacier dammed lakes are more dangerous than moraine dammed lakes and Karakorum mountain range (Pakistan) is dominated by glacier dammed lakes mainly due to surging glaciers.

Shishper (Shispar) glacier situated at Hassanabad, Hunza is an example of a surging glacier that is intercepting glacier-meltwater from its neighboring glacier named Muchuhur and facilitating formation of a glacial lake that is at risk to GLOF in coming months.

Shishper is a surge-type glacier situated in central Karakoram. Once, together with Muchuhar Glacier it was part of great Hassanabad Glacier. However, due to fluctuating behavior of both Shishper Glacier and Muchuhar Glacier, now they are separated. Recent surge of Shishper glacier have caused troubles for local community by disrupting clean drinking water supply to Hunza, neighboring national Karakoram Highway (KKH) by damaging it partially, and it is a permanent threat to Reinforced Concrete Bridge on KKH. In its recent surge it obstructed the glacier-melt water from Muchuhar Glacier, resulting in formation of an Ice-Dammed Lake, that have outburst at least twice while damaging KKH, local under-construction hydropower plant and headwater sources of irrigation and clean drinking water to Hunza.

Surge-type glacier usually keep on fluctuating. Usually they are in quiescent phase when they experience stagnation or keep on retreating very slowly. Sometimes, within a relatively brief period of time they flow rapidly. It is simply re-distribution of ice mass from higher elevation (where snow keeps on accumulating for years) to lower elevations in a short span of time. In a similar manner, ice mass accumulated over upper reaches of (accumulation zone) Shishper Peak (7611 masl) is redistributed over a longer spatial area resulting in surge of Shishper Glacier, in which mass removed from top is distributed at the bottom (snout).

Shisper Glacier has been surging since early 2018 while obstructing the river of Muchuhar Glacier and forming a glacier-dammed lake. The latest early summer outburst was likely triggered by an anomalous temperature rise, which caused significant glacier melt and consequently engorged the lake. The Hunza meteorological station recorded a significant temperature rise in late May 2020.

Shisper Glacier's surge is unprecedented, unpredictable and sporadic, that makes it vulnerable and risky toward flooding. Beginning in January 2018, the surging continued rapidly, till today. It was surging with a velocity of around 43 meters/day in the month of June 2019. This surge velocity is unusual for glaciers in Karakorum. Usually such surge behavior is called "classical surge" in which a surge onset with maximum velocity followed by low velocities and rapid termination of surge. The surge continued at a stable speed through 2019, then slowed down, and appeared to completely stop in June 2020. During its active surge phase, the glacier's snout advanced more than 2600 meters.

Methodology

In-situ measurement of glacier surge is usually performed by installation of stakes network on various locations of glacier from snout to upper reaches of the glacier. Bamboo sticks of lengths

4 - 4.5 meters were insert in the holes made by thermal ice drill (see Figure 2 & Figure 3). Since Shishper Glacier is surging actively, therefore, it is highly risky to walk over glacier. Nevertheless, 10 stakes were installed at the snout of the glacier (July 20th 2020) and a set of another 10 stakes were installed relatively upstream by the distance of 1250 meters on July 21st 2020. The position of the stakes were estimated with Differential GPS (DGPS) with the error margin of 3 cm. The stakes were again visited on August 08th 2020, and their updated positions were recorded. Afterwards, due to melting of the glacier, the stakes came out of the ice and they were not useable anymore.

In addition to stakefarm establishment, Ground Penetrating Radar (GPR) was utilized to assess the depth of Shishper Glacier (see Figure 6).

Results and Discussion

Shishper Glacier is actively surging with a southward velocity (downslope) of around 0.41 meters/day from Jul 20, 2020 to Aug 07, 2020 (around 18 days) on the snout of the glacier (see Figure 4). Meanwhile, it is moving eastward with the velocity of 0.1 m/days on same location as presented in Figure 4. Similarly, around 1.2 km above the snout the southward surging velocity of the Shishper Glacier is ~ 0.12 meter/day, whereas eastward velocity is ~0.11 meters/day (see Figure 5).

Predominantly Shishper glacier is moving southward under the influence of gravity (downslope). However, its eastward moment is response to inertial westward surge in which Shishper Glacier went upslope (westward) previously, and now it is settling itself in the main gorge of the Hassanabad Valley.

GPR scans revealed that Shishper Glacier is around 48 meters thick on its snout (Figure 6). Regular monitoring of Shishper Glacier depth through GPR will help to assess its future behavior. In case of retreat, the depth of glacier will decrease, whereas, in case of surge it either will accumulate more mass, or may sustain same depth.

Conclusion

Since, Shishper Glacier is actively surging as assessed by in-situ data collected from movement of Stakes installed on the Glacier through DGPS. Therefore, upon decrease in ambient temperature in winters of 2020, the glacier melt from Muchuchar Glacier will decrease to the seasons minimum, and actively surging Shishper Glacier is expected to close down the existing pathway that allows water from Muchucher Glacier to pass on to the Hunza River. With the

closing of pathway, Shishper Glacier is likely to obstruct a little water available in Muchuchar Glacier (winter's seasonal flow) and will facilitate the formation of glacier dammed lake. The size and volume of the lake will keep on increasing gradually until spring. With an increase in water of the glacier dammed lake there will be more pressure on Shishper glacier ice walls. Due to high density of water and the low-density ice (of Shishper Glacier) will easily rapture and this will result in a glacial lake outburst (GLOF) in spring season.

Figures

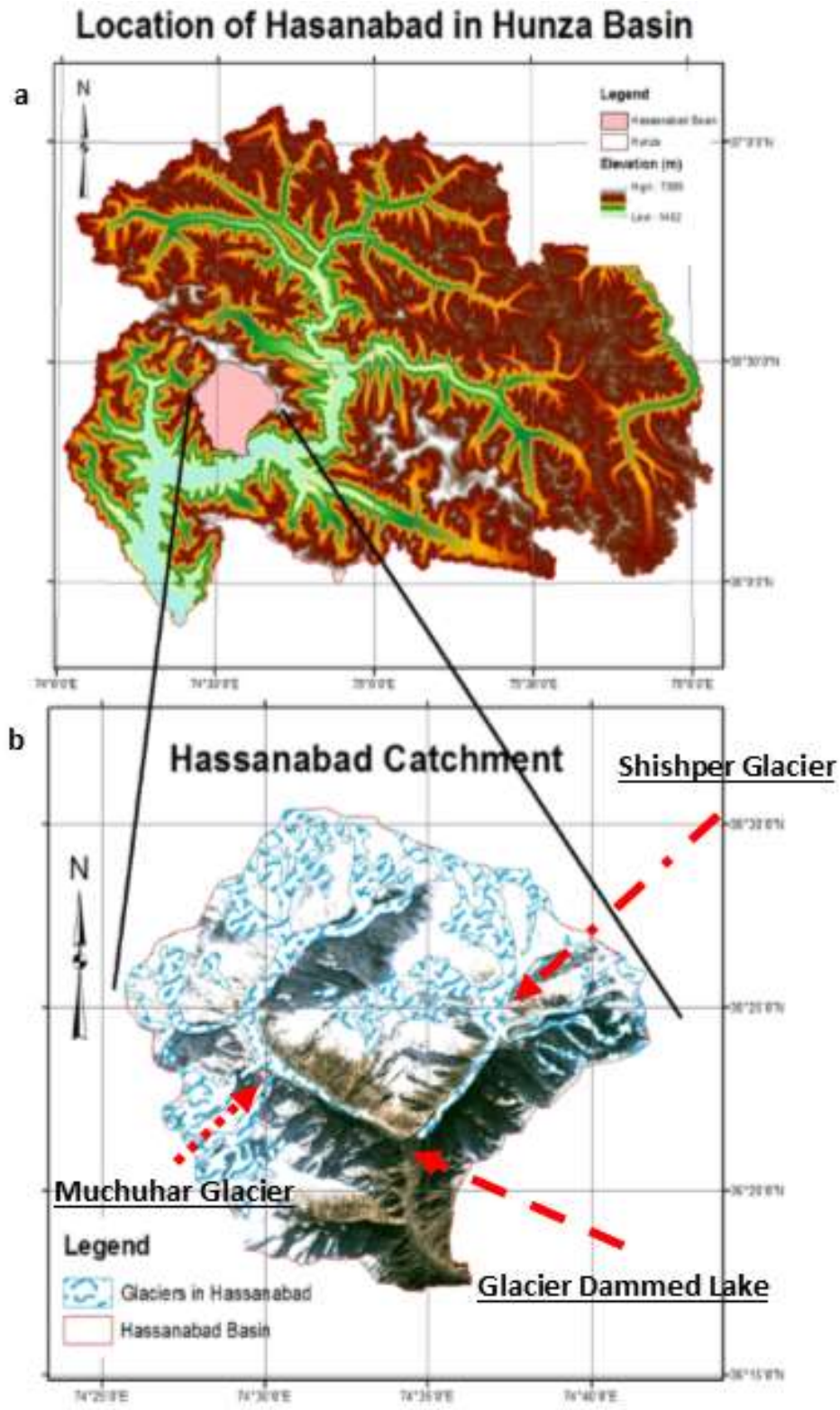

Figure 1: a) Location of Hassanabad in Hunza Basin, b) Location of Shishper Glacier, Muchuhar Glacier and Lake in Hassanabad Catchment are presented.

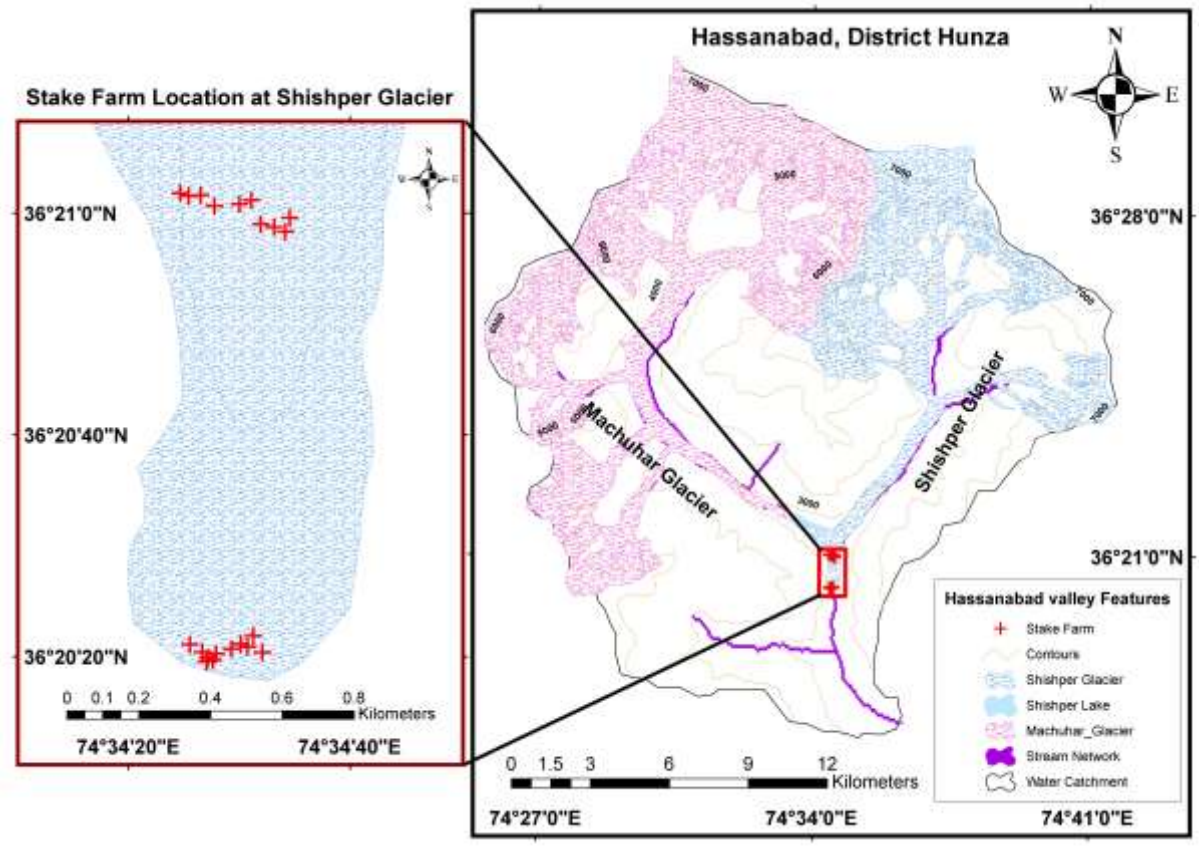

Figure 2: Schematic diagram of both Muchuhur and Shishper Glacier (once jointly called Hassanabad Glacier) are presented (right). Location of Stakefarm established at Shishper Glacier for assessment of its surge is presented (left).

Figure 3: a) Stake 15 installed for assessment of surge in Shishper Glacier on July 21st, 2020. b) Hole on Shishper Glacier is being drilled using Thermal Ice Drill.

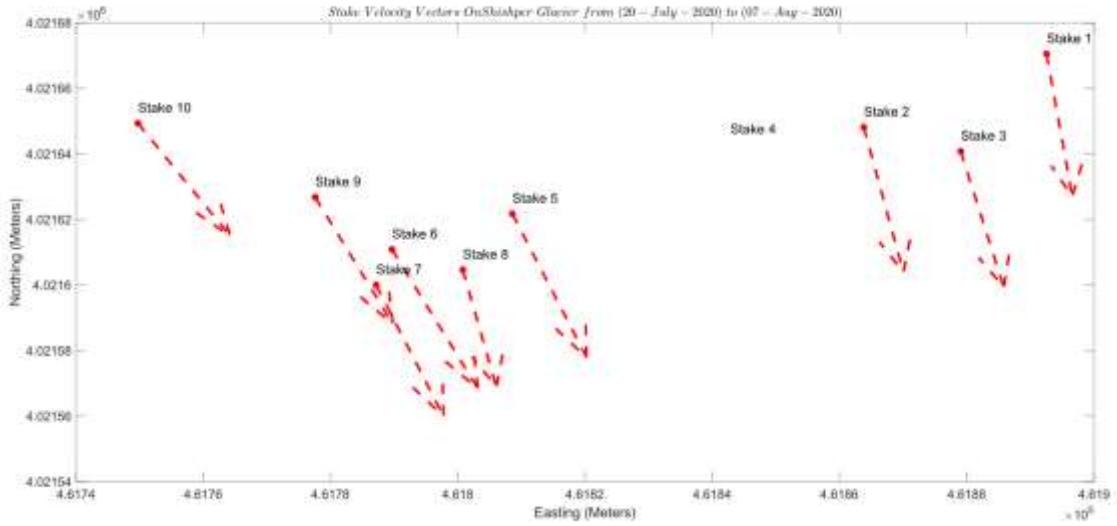

Figure 4: Velocity vectors of the stakes (Stake No. 1 to 10) at the snout of the Shishper Glacier are presented. Easting and Northing are presented with distance in meters from central meridian i.e., 75°E and from equator, respectively. The stakes have moved 7.4 meters from July 20th, 2020 to August 7th, 2020 (17 days) at the rate of ~43.6 cm/day in southward direction and 1.7 meters east ward at the rate of 10 cm /day.

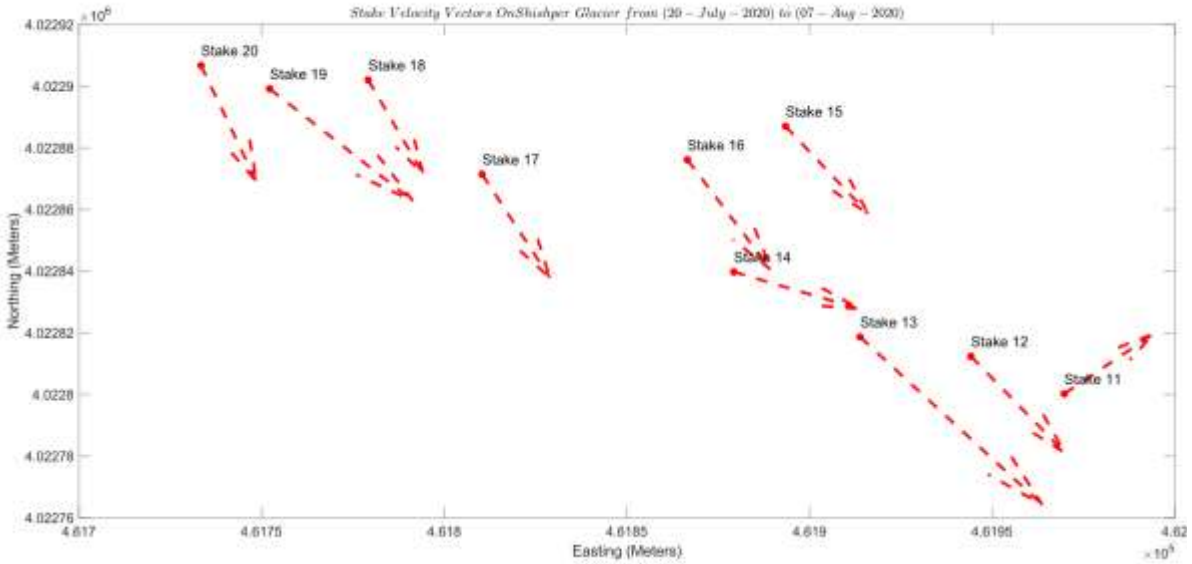

Figure 5: Velocity vectors of the stakes (Stake No. 11 to 20) installed averagely ~1229 meters above the snout of the Shishper glacier are presented. Easting and Northing are presented with distance in meters from central meridian i.e., 75°E and from equator, respectively. The stakes have moved around 2.05 meters from July 21st 2020 to August 7th 2020 at the rate of 12.8 cm/day in southward direction, and 2.05 meters eastward at the rate of 12.07 cm/day.

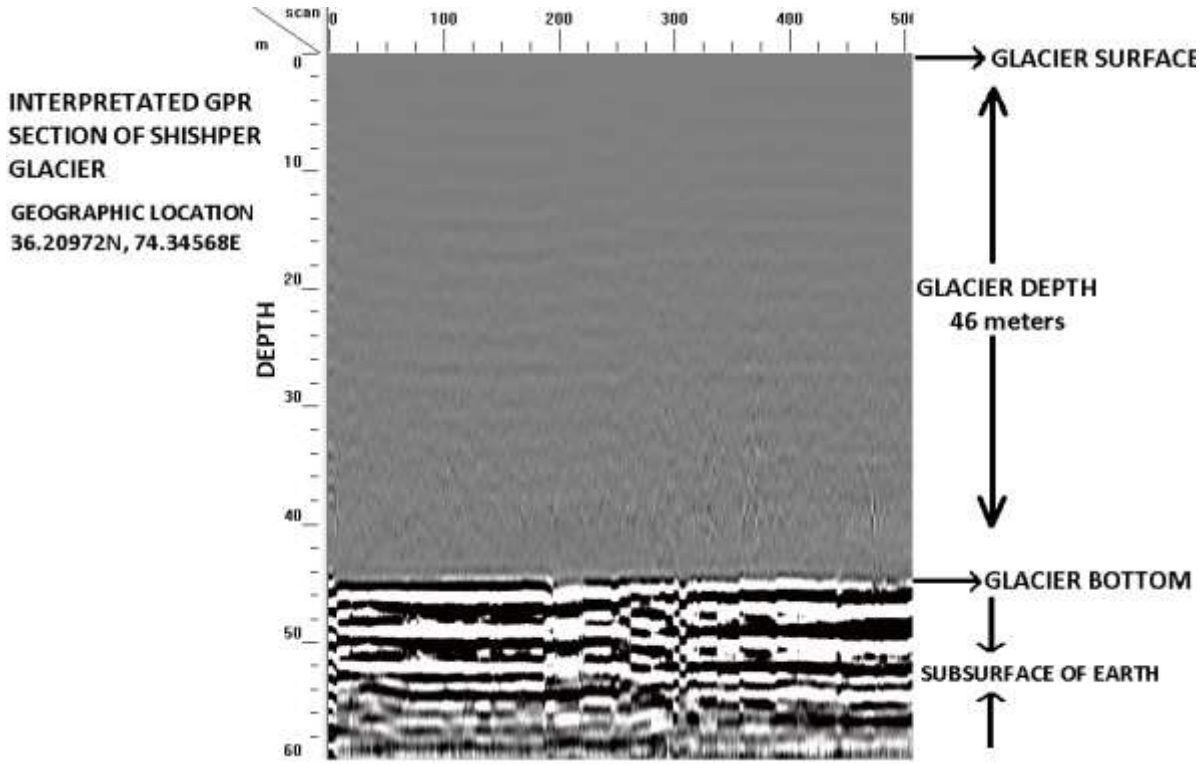

Figure 6: Depth of Shishper glacier was estimated on several locations near snout using Ground Penetrating Radar (GPR). It was around 46 meters deep. Regular monitoring of Shishper Glacier depth through GPR will help to assess its future behavior. In case of retreat, the depth is start decrease, whereas in case of surge it either will accumulate more mass, or may sustain same depth.

Figure 7: Principal Investigator Dr. Furrukh Bashir (PMD) is explaining experimental design and equipment functionality to community and Deputy Commissioner of Hunza.