भारतीय भूवैज्ञानिक सर्वेक्षण

GEOLOGICAL SURVEY OF INDIA

GLOF susceptibility study of Panikhar Pro-glacial lake in Suru Basin, Kargil district, UT Ladakh.

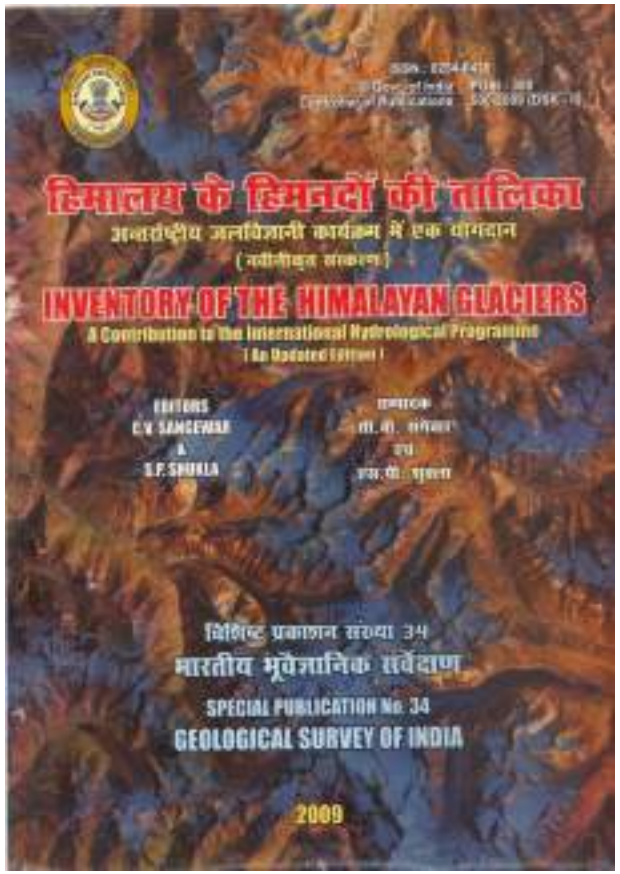


Panikhar Lake

Presented by
Ajai Kumar, Director
GSI, Northern Region, Lucknow

1. Assessment of Glacier Resources: Compilation of glacier inventory of the Indian Himalaya as per the International guidelines.

Previous Publication: 'Inventory of the Himalayan Glacier'. Published in 2009 as Special Publication No. 34.



New Publication: Updated 'Inventory of the Himalayan Glaciers' based on Remote Sensing Multi-Spectral Data.

Released on 4th December 2025.



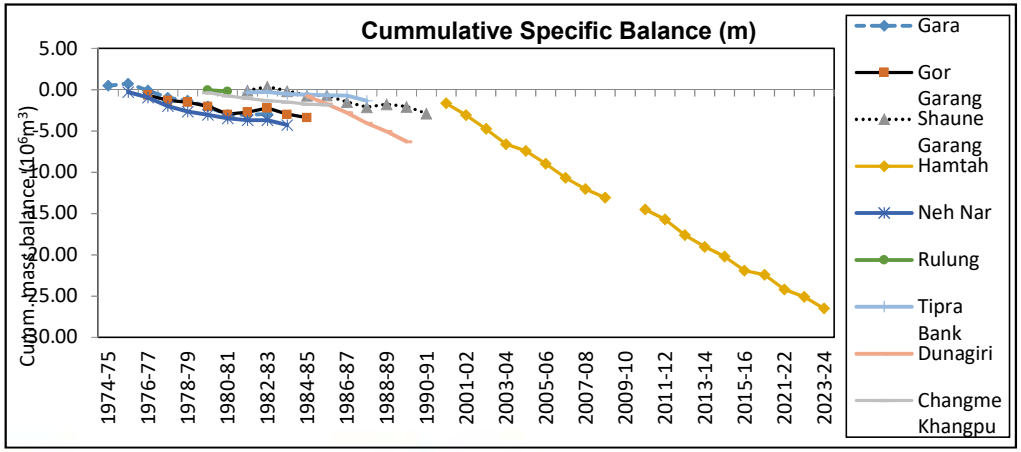
Follow us on:

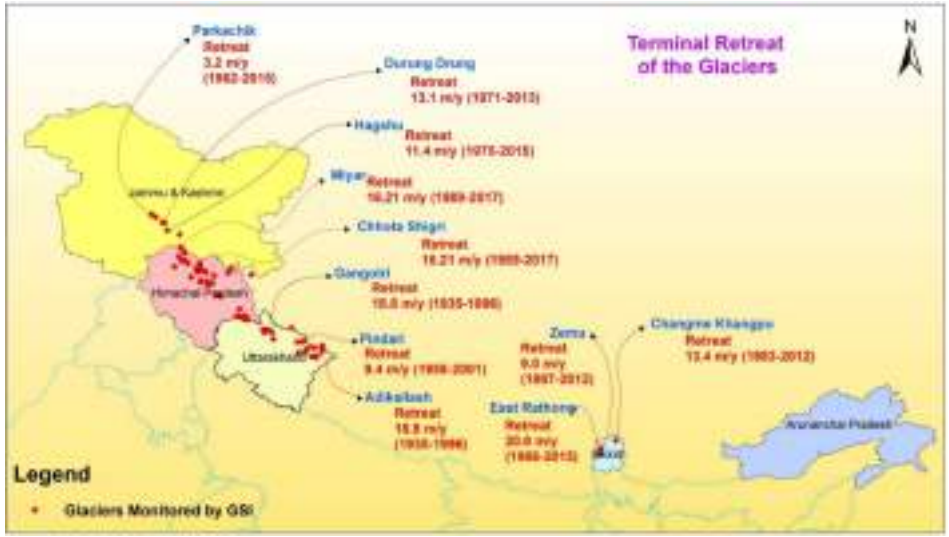
www.gsi.gov.in

2. Glacier Regimen Studies: Assessment of glacier mass balance, glacier dynamics, measurement of water discharge, suspended sediment load and Ice depth measurement using Ground Penetrating Radar etc.

- So far, GSI has conducted **Mass Balance studies on Nine glaciers** and secular movement study of more than 100 glaciers located in different climatic zones of Indian Himalaya.
- Since the 1984-85 hydrological year, **no positive mass balance** has been recorded on any studied benchmark glacier.







Recent Disasters in Indian Himalaya

1. Kedarnath Disaster- 2013: Main Cause- Extreme rainfall, moraine/lake breach, flash floods & debris flow, Impact- Massive destruction around Kedarnath valley, roads, bridges, pilgrim infrastructure, villages and tourism economy devastated.

2. Chamoli Disaster-2021: Rock-ice avalanche transforming into debris flow/flood, Impact- Rishiganga hydel project destroyed, major damage to Tapovan-Vishnugad project, bridges and roads washed away.

3. South Lhonak Lake GLOF-2023: Main Cause- Glacial Lake Outburst Flood (GLOF) from South Lhonak Lake, Impact- Teesta-III hydropower project destroyed, 13 bridges washed away, roads and settlements damaged, >60,000 affected





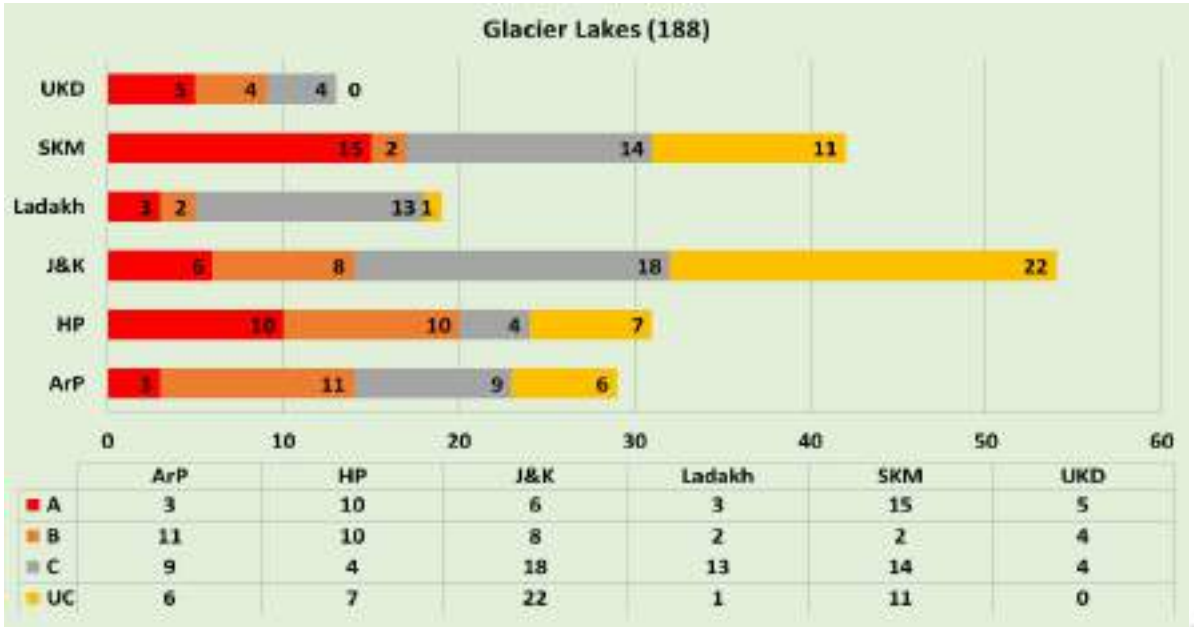


Follow us on:
www.gsi.gov.in

- **After Sikkim South Lhonak lake GLOF disaster (Oct, 2023), Pro-activeness has been shown by NDMA and various Departments of Govt. of India.**
- **NDMA has conducted number of coordination committee meetings to mobilize the technical agencies and Himalayan State Government's for systematic GLOF studies in India.**
- **NDMA has compiled a list of 188 high risk glacial lakes in India, based on studies carried out by GSI, NRSC, C-DAC, SDC and CWC, and classified them into four categories i.e. A-High Vulnerability, B-Moderate Vulnerability, C-low Vulnerability and UC- Unclassified.**



- **GSI has prepared Glacial Lake inventory of Uttarakhand, Himachal Pradesh and J&K including Ladakh.**
- **So far , GSI has carried out GLOF susceptibility study of 14 glacial lakes lying in different Himalayan states/UTs (UK, J&K, Ladakh & HP).**



	ArP	HP	J&K	Ladakh	SKM	UKD
A	3	10	6	3	15	5
B	11	10	8	2	2	4
C	9	4	18	13	14	4
UC	6	7	22	1	11	0

www.gsi.gov.in

Follow us on:

Glacial Lake Outburst Floods: A Growing Threat

Objective/s

i. Estimation of lake expansion using field and satellite data.

ii. Detailed mapping of glacial lake and glacier snout.

iii. Identification and demarcation of potential rock fall zone and avalanche zone and other triggering factor for lake burst.

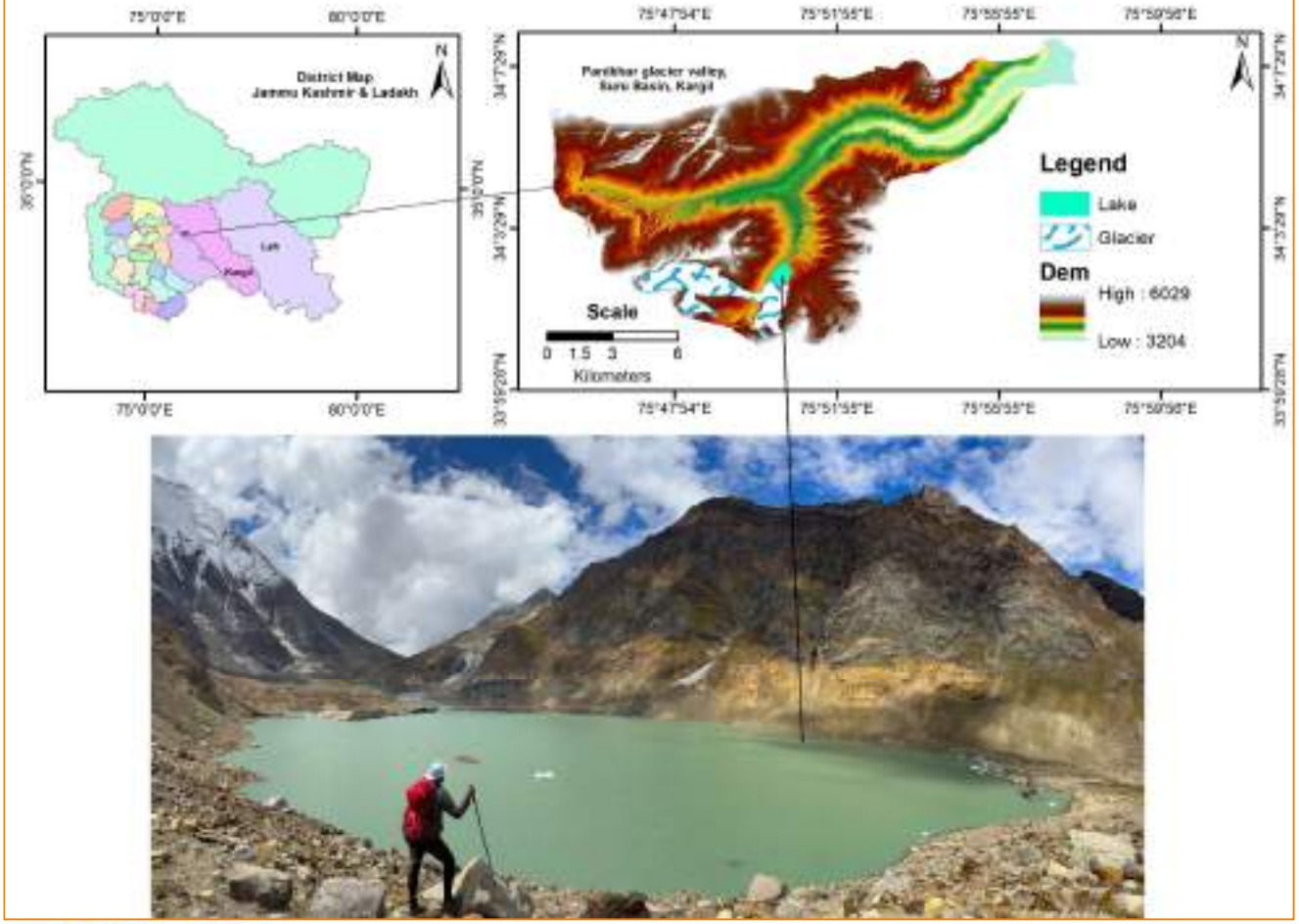
iv. Evaluation of potential risk of GLOF

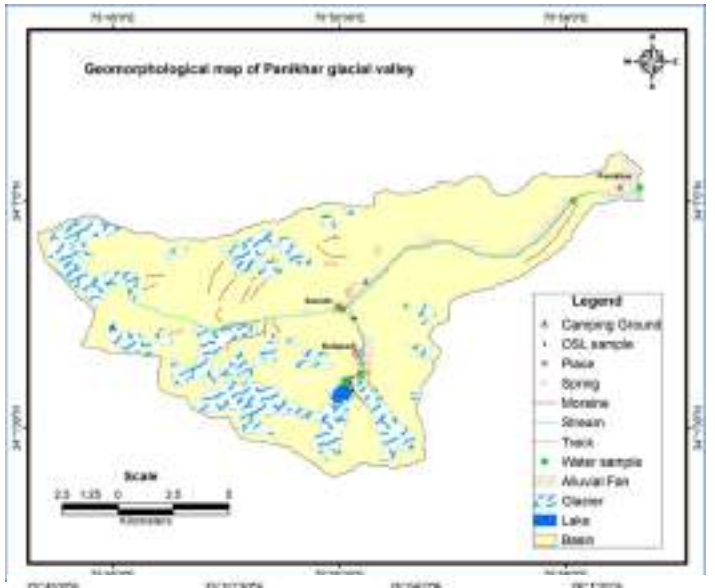
v. To suggest appropriate remedial measures.

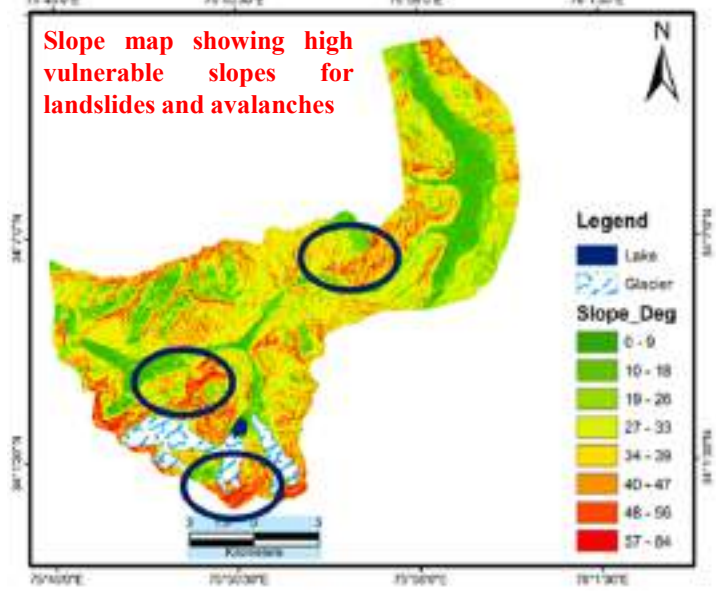


www.gsi.gov.in

Study area and geomorphological map showing the location of Panikhar Pro-Glacial Lake (Category-A high Risk) in Suru Basin, district Kargil, UT Ladakh.



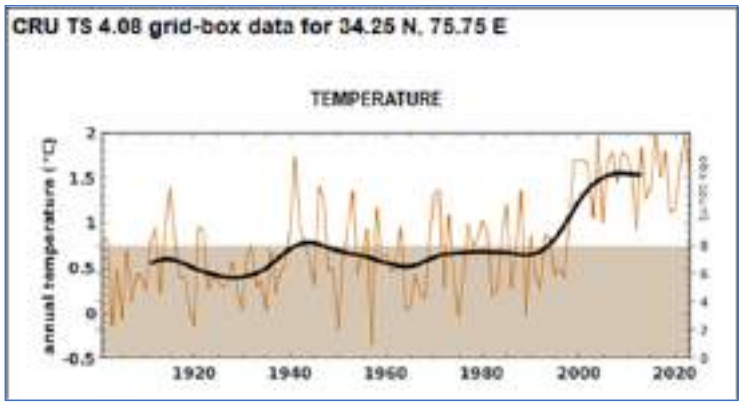


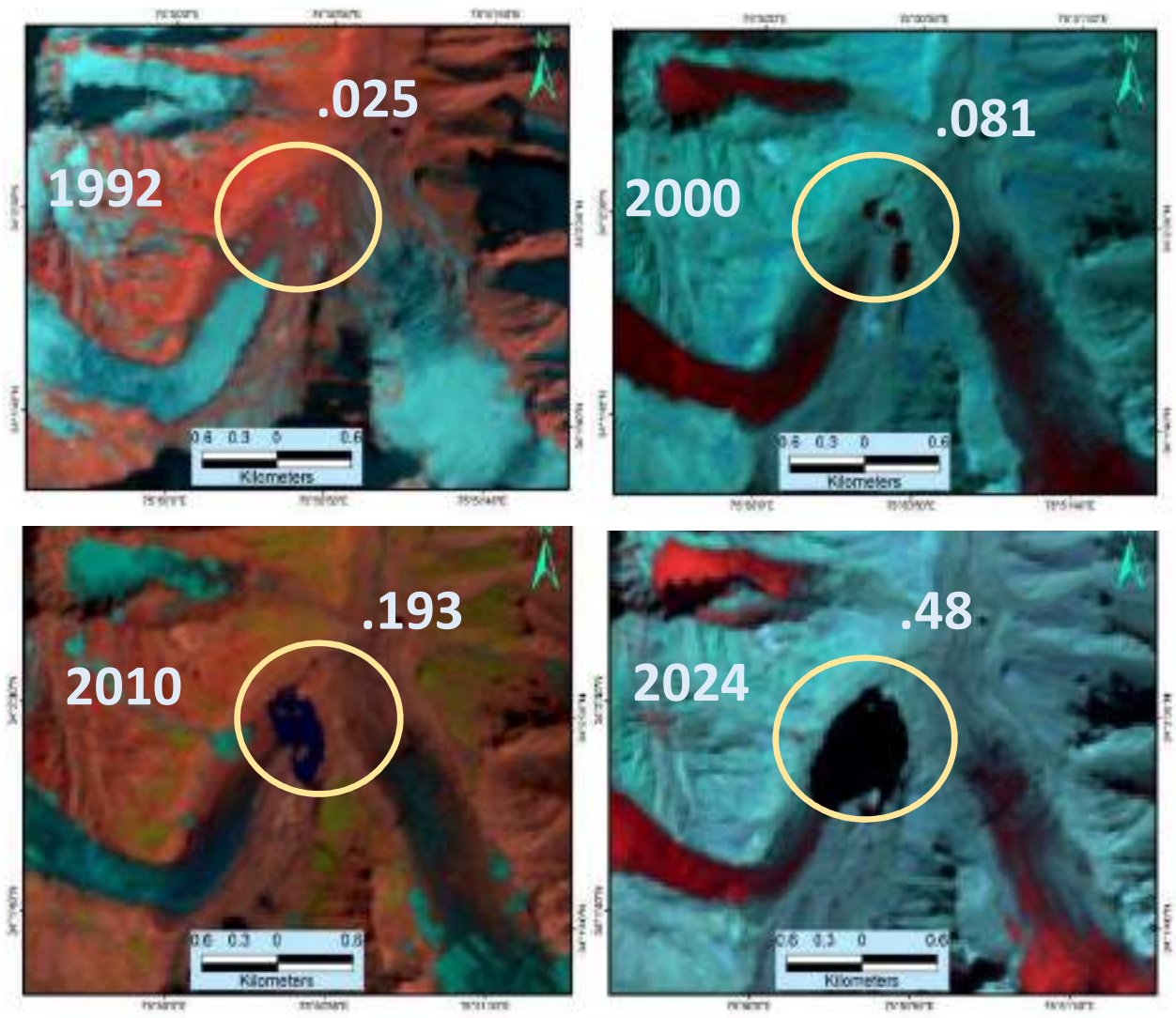


1. **Estimation of lake expansion using field and satellite data.**

- **Recessional history and pattern of Lake Expansion over time**

Used Landsat past and latest images



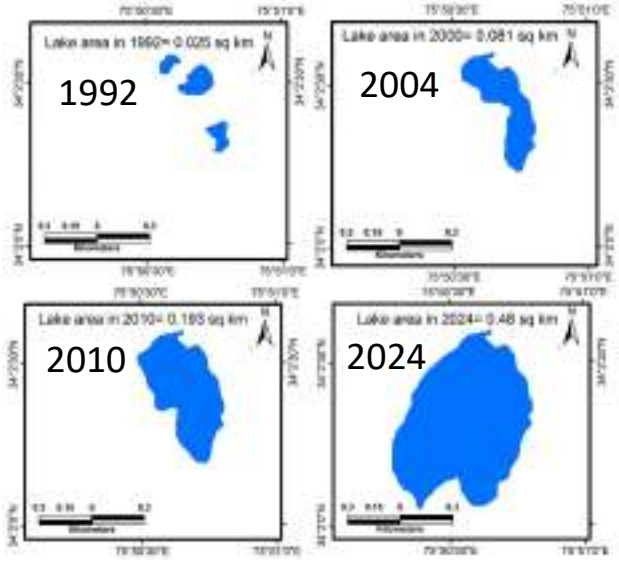


Panikhar Lake



Evidences of Lake expansion and calving nature of snout







Area of glacial lake

- 2 hectares in 1992
- 13 hectares in 2004
- 38 hectares in 2017
- 48 hectares in 2024

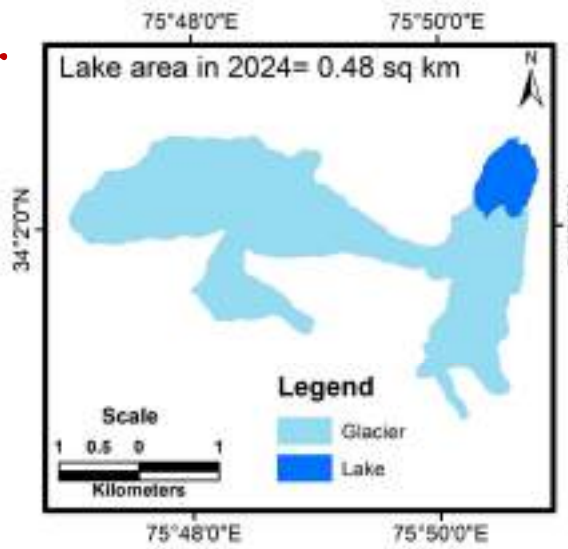


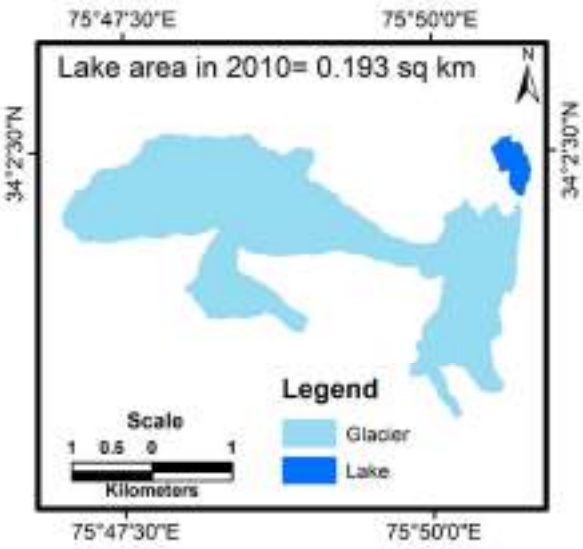
Time series Map of Panikhar Glacial Lake from 1992 to 2024

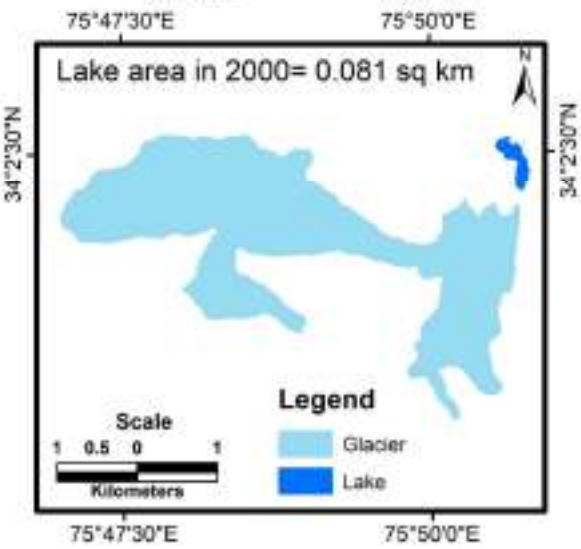
Glacier Attributes

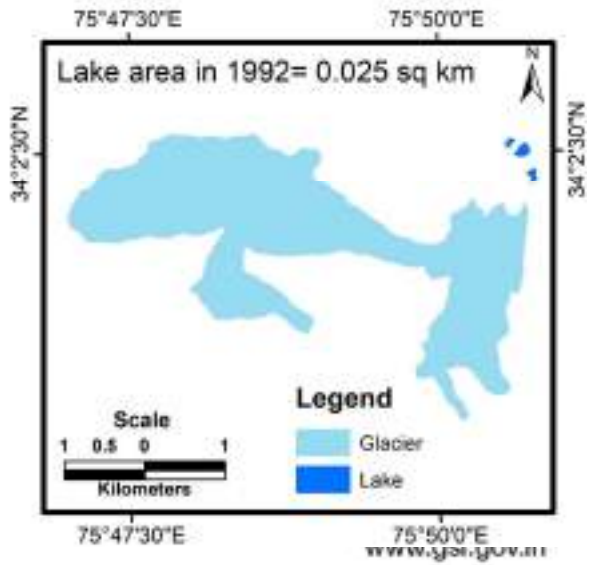
Glacier No. 5Q132 02 201	Attribute
Mean Length	5.79 km
Area	7.23 km^2
Debris cover	0.01 km^2
Mean Width	643 m
Snout/Lowest Elevation	4140 m asl
Highest Elevation	5316 m asl
Slope	12 degree
Orientation	NE





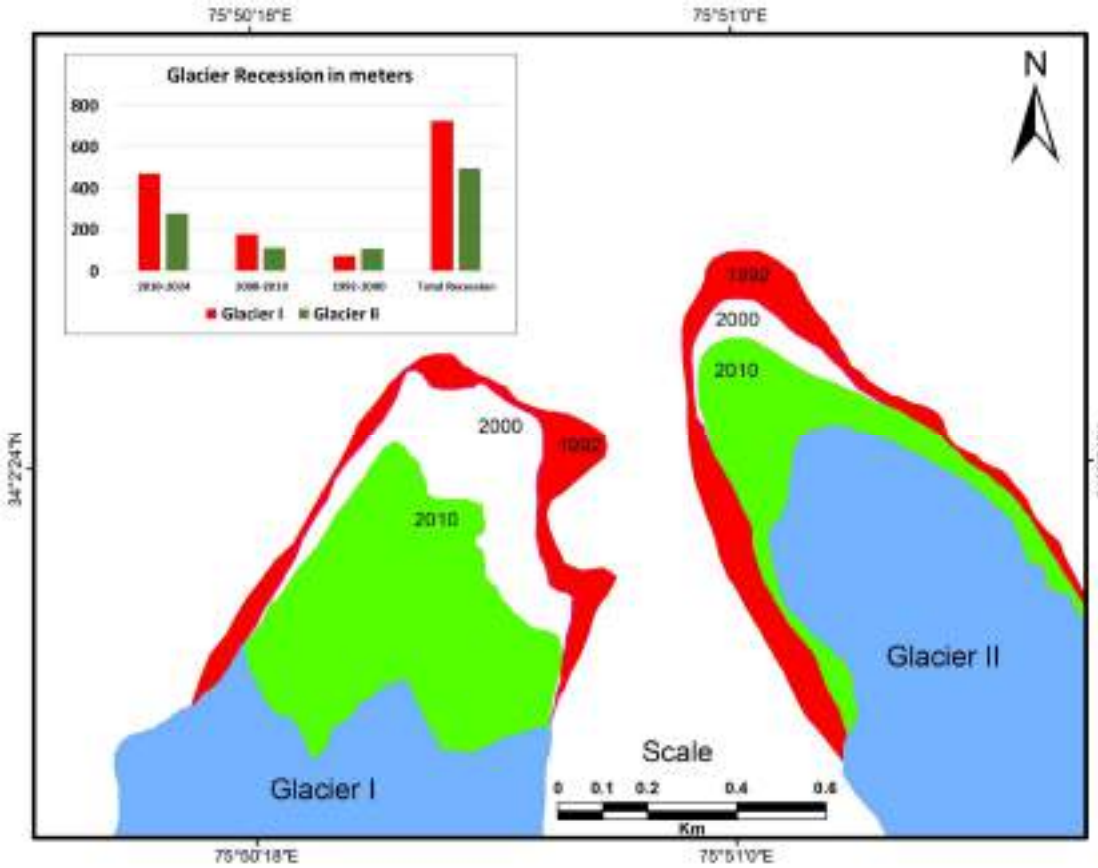




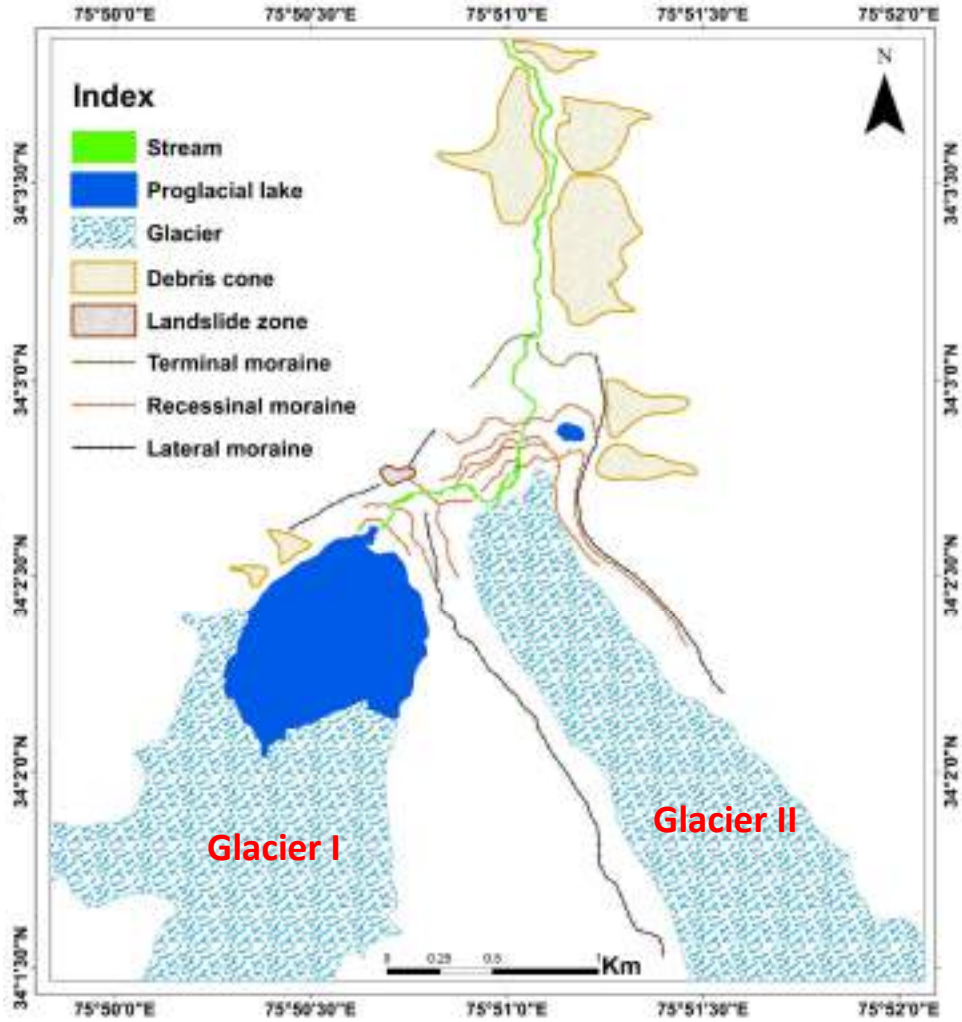


Follow us on:

2. Detailed mapping of glacial lake and glacier snout.

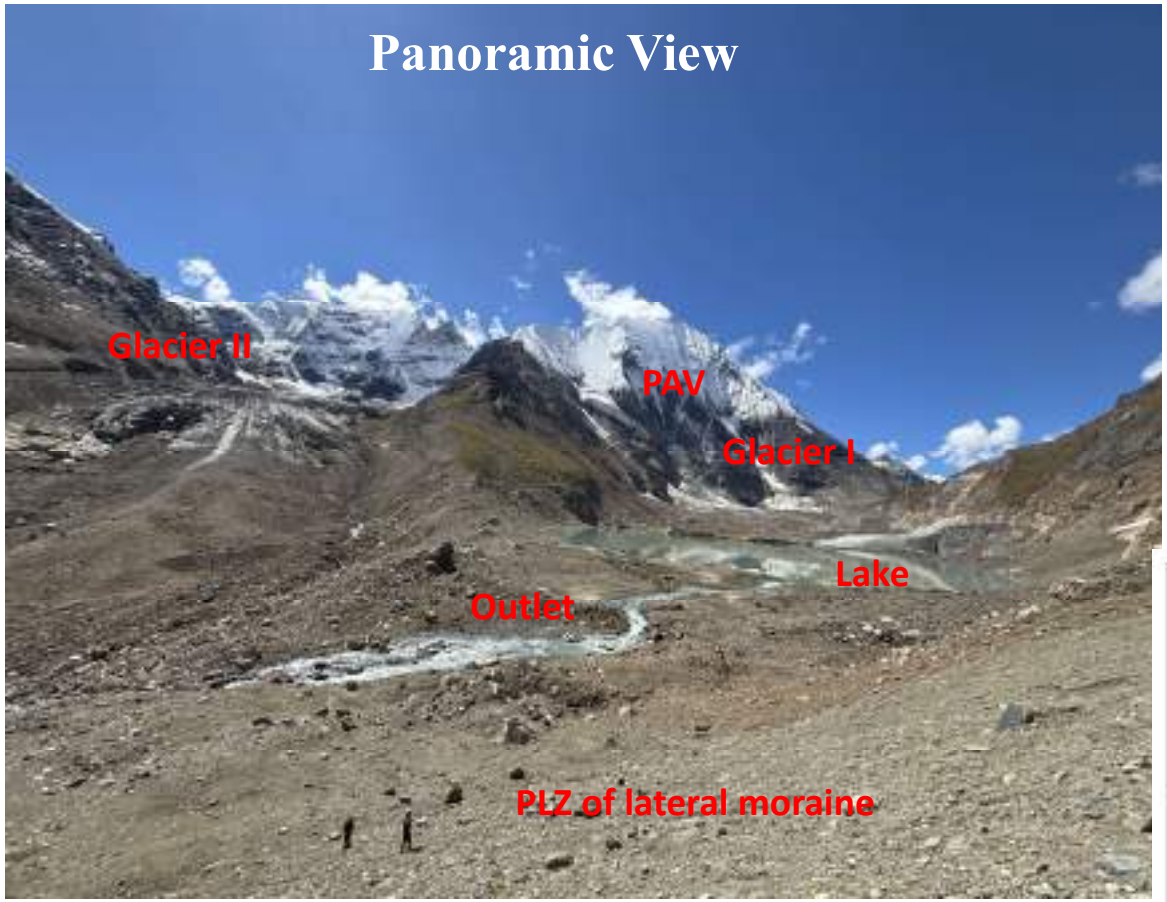


Time Series Glacier Recession, Panikhar Lake



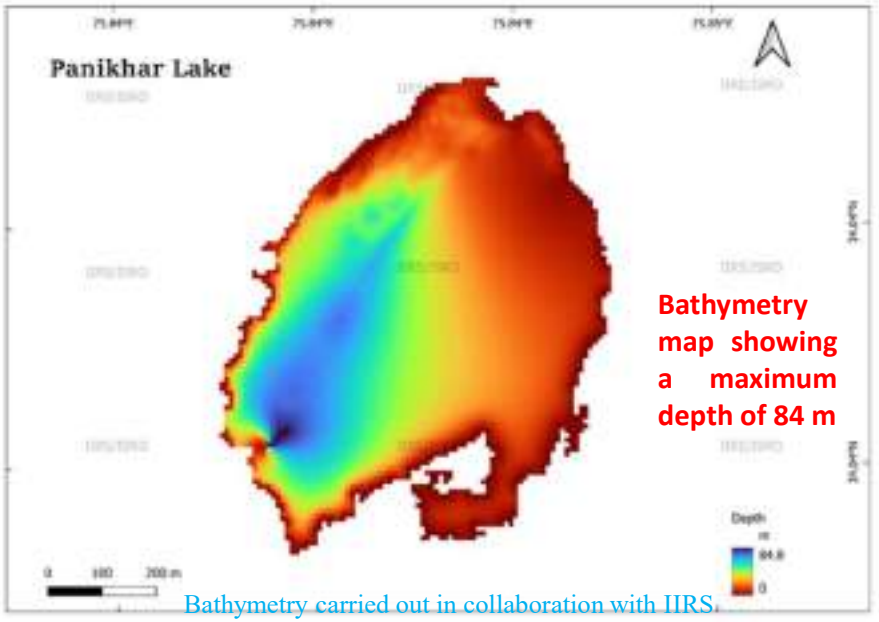
Large Scale Mapping (1:10,000)

हमें फॉलो करें / Follow us on:





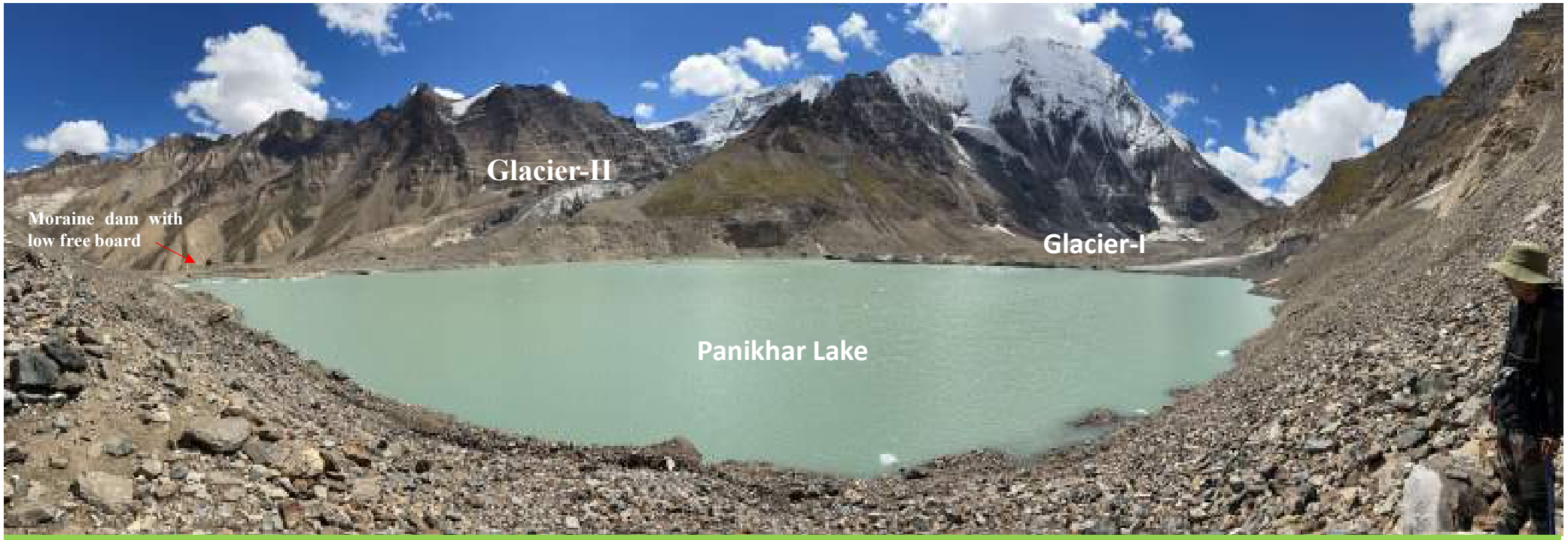
Attribute (Lake area-0.48 km²)	Huggel	Fujita	Bathymetry	Average
Mean Depth	25 m	46 m	26 m	38 m
Volume million m³	22	12	16.5	17 mcm



Lake Attributes

Lake attribute	Value
Area	0.48 km^2
Lake Volume	16.5 MCM
Lake Altitude	4106 m
Mean Freeboard	5.2 m
Mean Depth m	26
Glacier snout	4143 m

Mean Length	893 m
Mean Width	620 m
Dam Type	Moraine
Dam material	Loose Glacier Debris
Lake terminating	Calving glacier
Landslide probability	Moraine



Salkhala Fm: Highly deformed and metamorposed rocks including carbonaceous slates, graphitic phyllites, mica schists, marble, quartzites, and gneisses. **Sangra Fm**. The Sangra Formation is primarily composed of middle amphibolite facies rocks. It consists heavily of garnet schists and garnet-staurolite schists



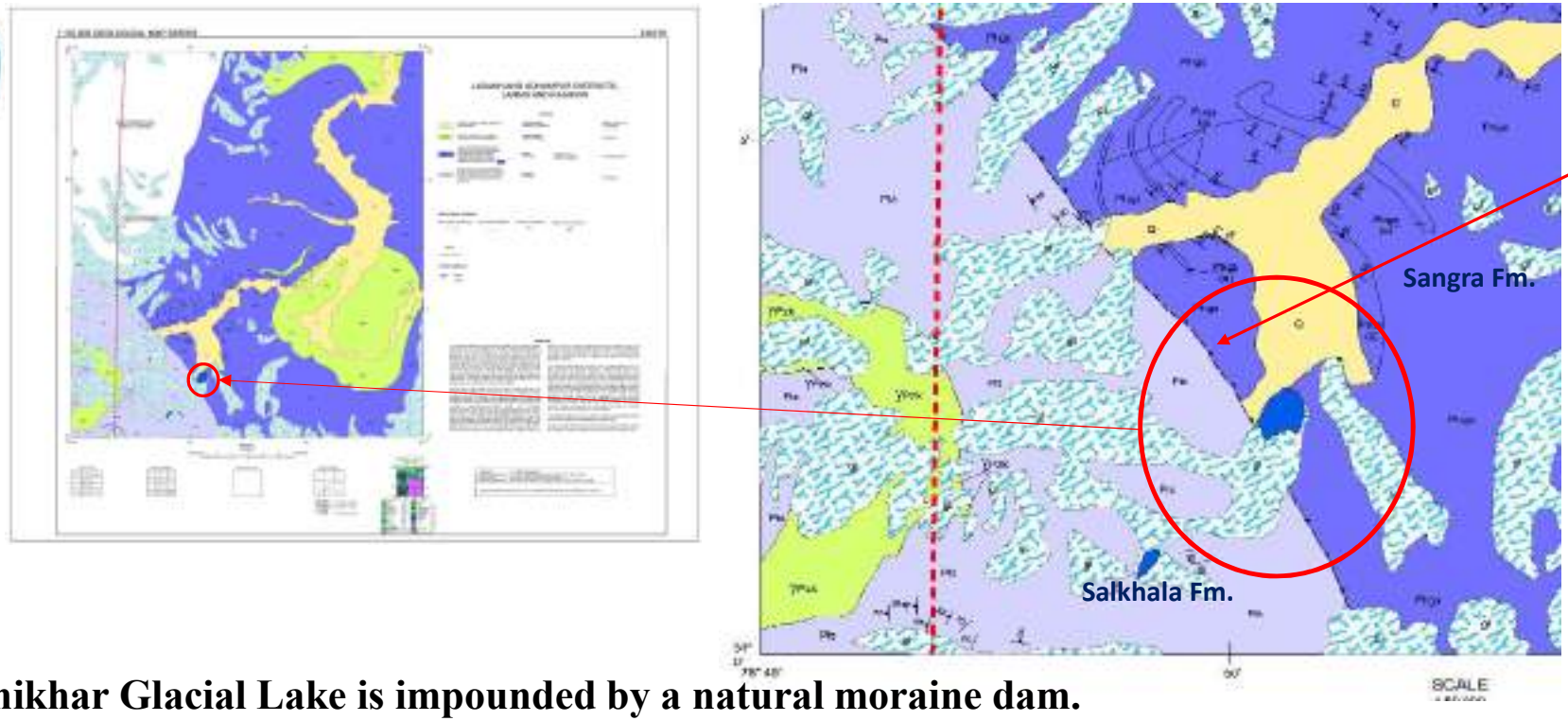
a. Establishment of discharge site b. Surveying of the lake and glacier c. glacial polishing d. Bathymetry of lake e. Floating icebergs c. Highly crevassed snout of associated glacier

3. Identification and demarcation of potential rock fall & avalanche zones and other triggering factor for lake burst.





Lake outlet of Panikhar glacial lake. The Panikhar glacial lake breach can be triggered by an avalanche/icefall as shown in the video.



Atholi thrust between Salkhala and Sangra formations

- **Panikhar Glacial Lake is impounded by a natural moraine dam.**
- **The stability and integrity of the moraine dam are influenced by the underlying geological and geomorphological conditions.**
- **The presence of active or potentially active faults in the vicinity of the glacial lake may increase the susceptibility of the moraine dam to failure due to seismic activity.**
- **Earthquakes or even minor tremors can destabilize moraine dams, especially if they are already weakened by erosion, internal piping or hydrostatic pressure from the glacial lake.**

4. Evaluation of potential risk of GLOF:



Risk indexing criteria (CWC, 2024)

Risk Index Criteria for Glacial Lakes

	Glacial lake (45)							U/s of GL (15)						D/s of GL (30)						Other (10)			
1	2		3		4		5	6		7		8		9		10		11		12		13	
Parameters	Size (ha) of GL		Type of GL		Change in size (in last 5 years/available data)		Stability of lake side Slope (Degree)	Snout to GL distance (Km)		Snout to GL slope (Degree)		Glacial Lake in the vicinity and connected (>1 ha) within 1 Km in same valley		Distance from nearest Habitation likely to be affected (Km)		Distance from nearest Dam (Km)		Distance from nearest Bridge(RCC/Bailey/Rope) (Km)		Historical GLOF events		Seismic Zones	
Total Score	15		5		15		10	5		5		5		10		15		5		5		5	
Score break-up	Size (ha)	Score	Type	Score	Status	Score	Side Slope	Score	Distance	Score	Slope	Score	Draining	Score	Distance	Score	Distance	Score	Distance	Score	Yes/No	Score	Zone	Score
	A>100	15	Moraine dammed	5	Increasing (>25%)	15	S>30	10	D<=0.5	5	S>30	5	Yes	5	D<=25	10	D<=25	15	D<=10	5	Yes	5	V	5
	50<A<=100	12	Ice dammed	3	Increasing (20-25%)	12	20<S<=30	7	0.5<D<=1	3	20<S<=30	3	No	0	25<D<=50	8	25<D<=50	12	10<D<=25	4	No	0	IV	3
	25<A<=50	8	Glacial Erosion	2	Increasing (15-20%)	9	10<S<=20	5	1<D<=2	2	10<S<=20	2			D>50	5	50<D<=100	8	25<D<=50	3				
	10<A<=25	5	Other	1	Increasing (10-15%)	7	S<=10	2	D>2	1	S<= 10	1					D>100	5						
	A<=10	3			Change(within +/- 10%)	3																		
					Decrease (>10%)	0																		

Risk Score Classification (CWC, 2024)

S. No	Score (S)	Category
1	S>70	Category-1
2	60<S <=70	Category-2
3	50<S <=60	Category-3
4	S<=50	Category-4

Follow us

Central Water Commission (CWC) Risk Index Criteria for glacial lakes applied on Panikhar proglacial lake.

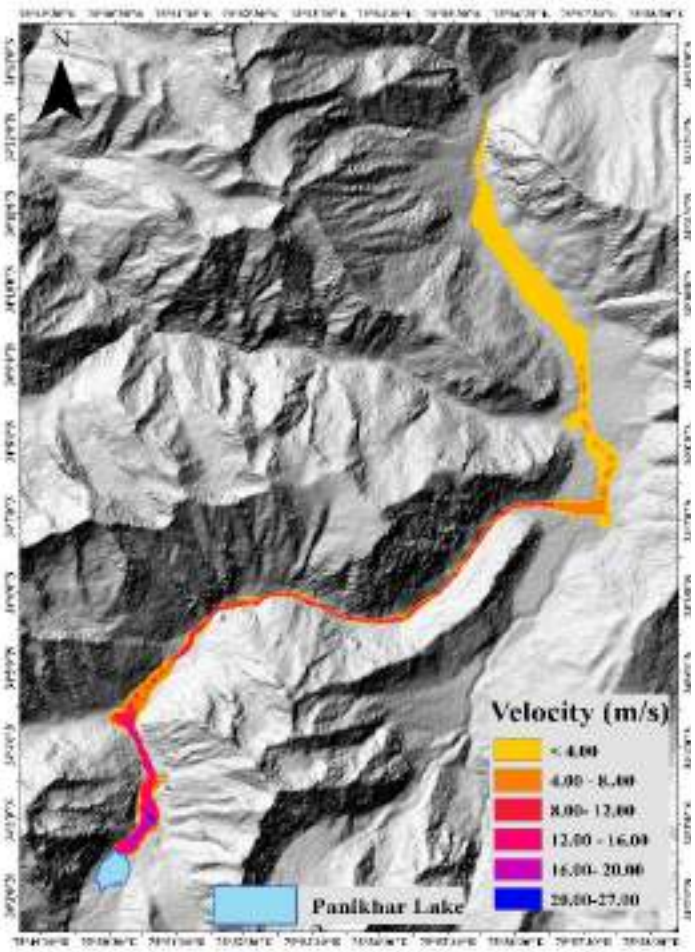
S. No.	Parameter	Lake Value	Score
1	Size (ha)	48 ha	8/15
2	Type	Moraine-dammed	5/5
3	Change in size (5-year)	19%	9/15
4	Side slope stability (°)	>30°	10/10
5	Snout to lake distance (km)	0 m	5/5
6	Snout to lake slope (°)	20-30°	5/5
7	Glacial lake in vicinity (>1 ha)	No	0
8	Distance to nearest habitation (km)	15 km	10/10
9	Distance to nearest dam (km)	>50 km	8/15
10	Distance to nearest bridge (km)	15 km	4/5
11	Historical GLOF events	No	0
12	Seismic zone	Zone V	5/5
Total Score	(>70 = High Risk)	69	

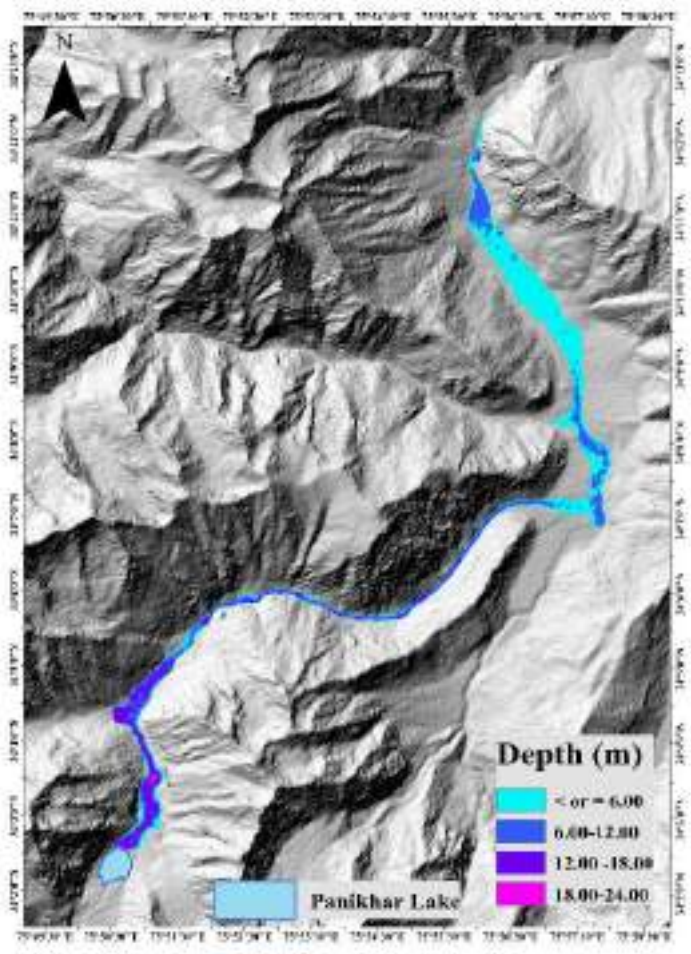


Follow us on:

GLOF Simulation by HEC-RAS Model

Spatial distribution of maximum depth and flow velocity for the breach scenario.

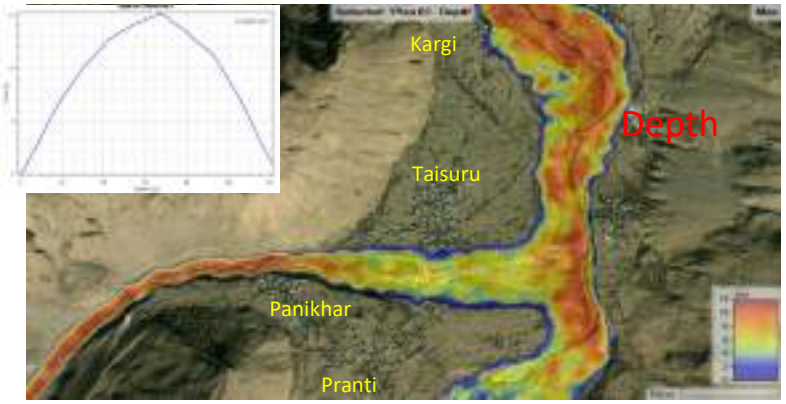


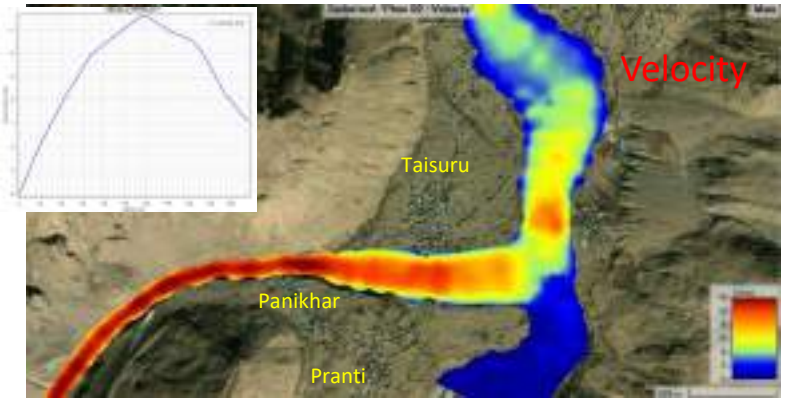


GLOF scenario modeled using HEC-RAS tool to assess flood level and velocity along a 26 km flow path.

Mean Depth - 26 m
Volume – 16.5 m m^3
Peak discharge (Q-max) – 1625 m^3/s

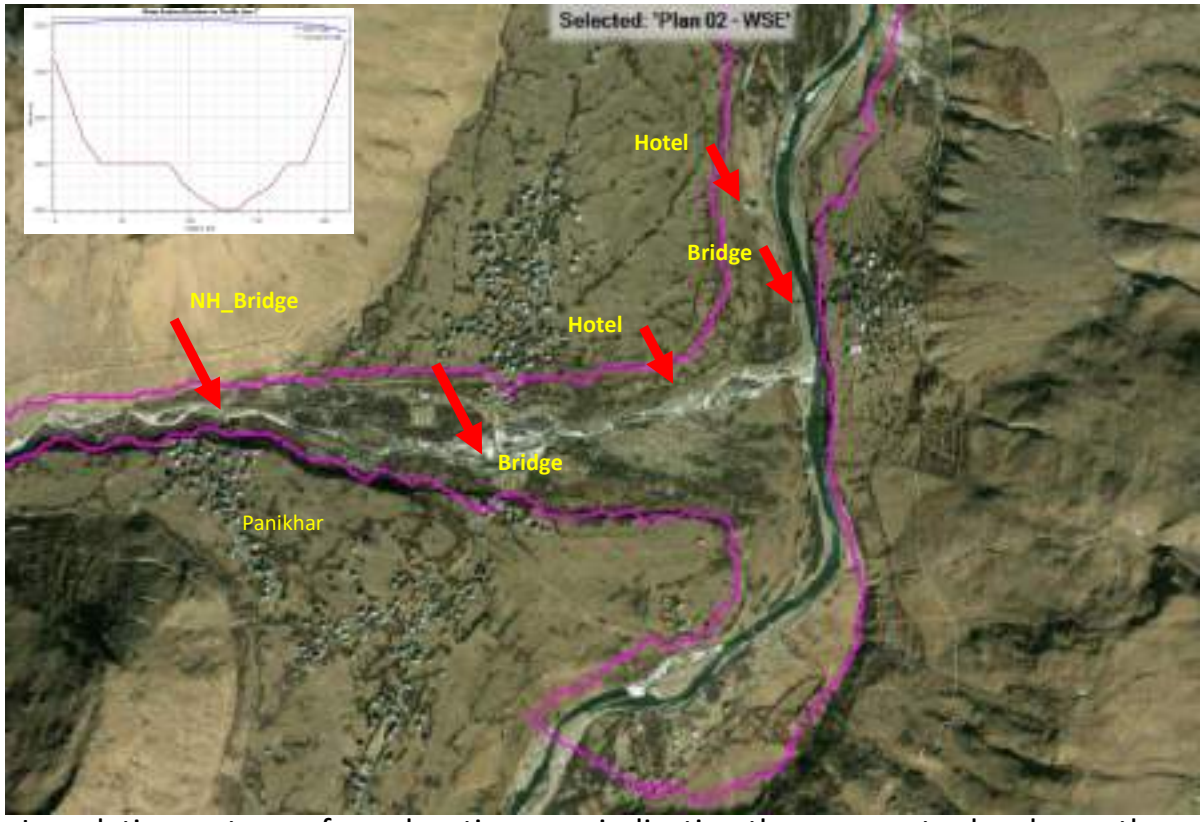
GLOF Simulation by HEC-RAS Model





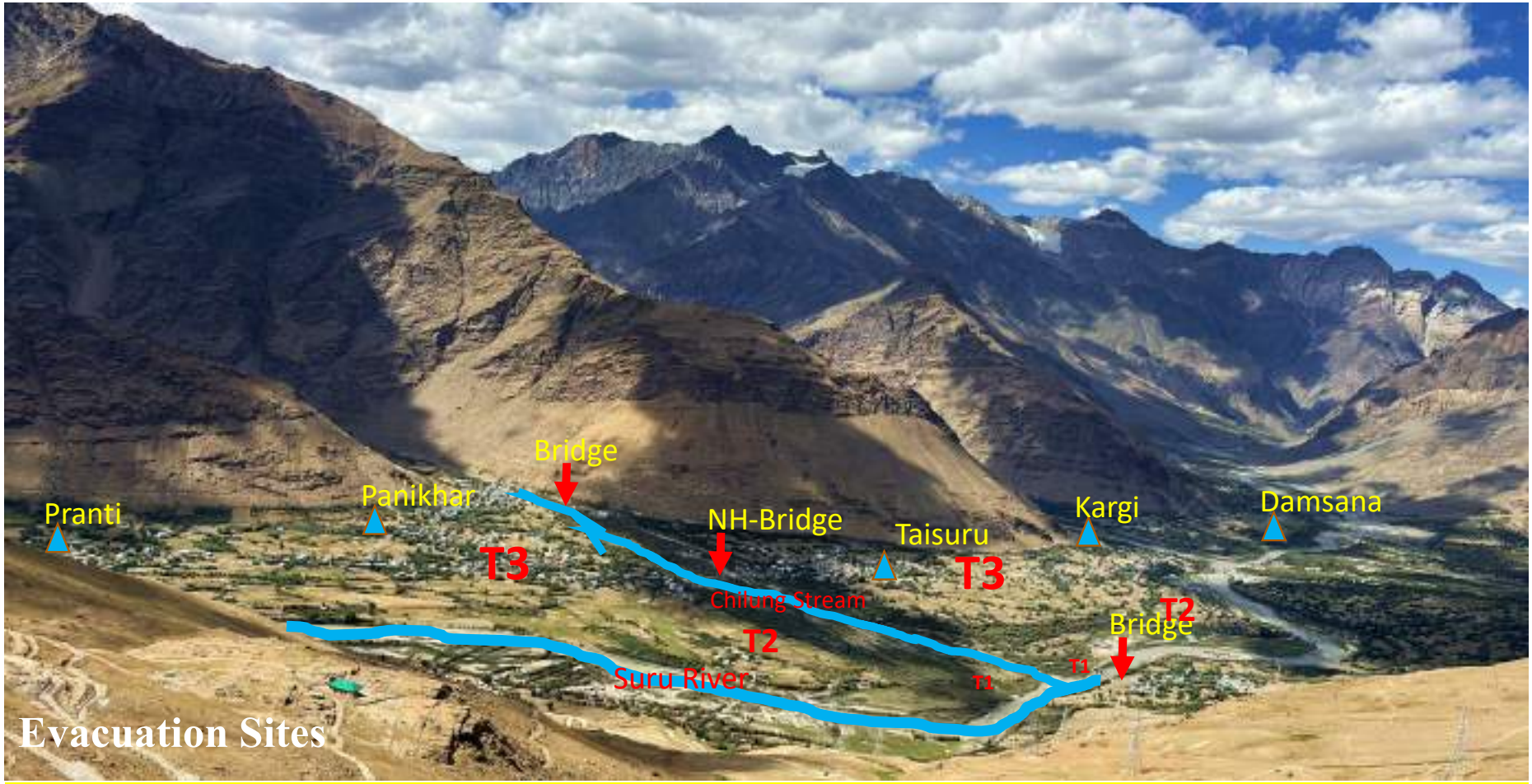
Depth and velocity profiles near the settlement

2D hydrodynamic modelling



Inundation water surface elevation map indication the max. water level near the affected area

- **An area of ~7 km², including critical infrastructure (settlements, bridges, roads etc.), is vulnerable in case GLOF scenario.**
- **Flood wave from the lake could reach the nearest settlement (Panikhar) within 50 minutes.**
- **Peak velocity of the flood wave estimated is about 15 m/s.**



- **River Terrace (T3)-Safer sites for evacuation >15 m higher than present stream**
- **T2 & T1-will be affected during the GLOF. Most of the bridges, houses, roads, hotels are constructed on T2 and T1.**

Follow us on

Mitigation:

Reducing the Volume of Lake Water: The first and foremost strategy to reduce the water level in the lake to reduce not only the overall threat but also the possible peak surge discharge from a GLOF.

This could be attained through-

- controlled breaching,
- construction of spillway or an outlet control structure,
- pumping or siphoning out the water from the lake, and
- making a tunnel through the moraine or under an ice dam.



Siphoning at Palcacocha glacial Lake, Peru



Spillway at Imja glacial lake, Nepal

Follow us on:

ov.in

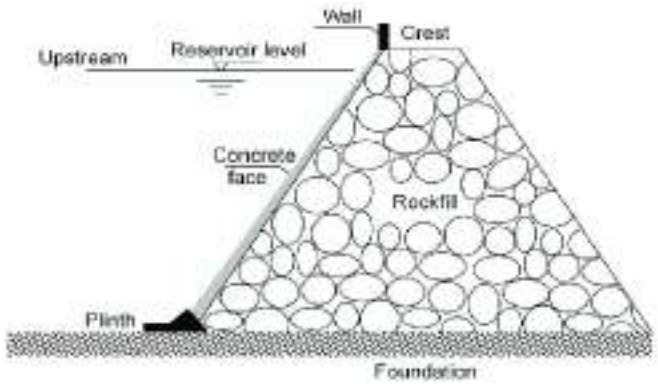
Suggested Retaining Structure Type at Dolma Sampa area, Lhonak valley.



Check dams as an immediate solution

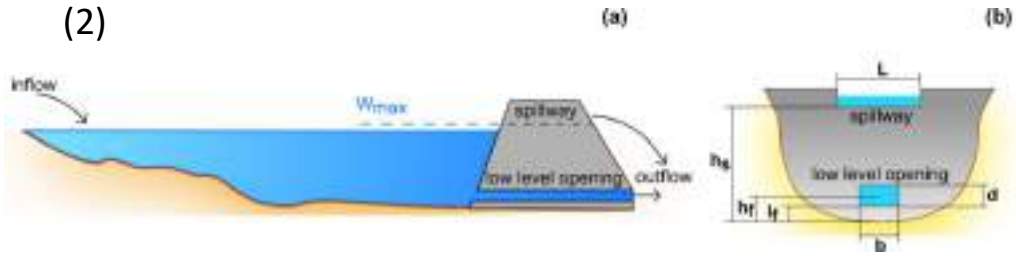
- ✓ **There are sites with wide valley.**
- ✓ **Construction of check dams (earth and rock fill dams) of low height at different locations will be very useful in preventing damage downstream to a great extent.**
- ✓ **Series of low height check dams with the help of local rocks available can limit the damage caused by sudden discharge.**

(1)



Concrete faced rockfill dam/retention structure

(2)



Flow-Through Dams/retention structure can be used for Flood Control

Slope Stabilization & Erosion Control on unstable slopes:

- **Gabion walls** help to retain soil and rock, reduce erosion, and improve slope stability, thereby reducing the risk of landslides and slope failure.
- **Retaining Walls** Retaining walls provide structural support by holding back soil and resisting lateral earth pressure, helping to prevent soil movement and slope instability.







हमें फॉलो करें / Follow us on:

Highlights

- **Lake characteristics: Panikhar Glacial Lake covers ~0.48 km², with a maximum depth of 84 m and an estimated volume of 18 million m³.**
- **Rapid expansion: Lake expanded from ~2 ha (1992) to ~48 ha (2024) i.e. increased 46 ha in just 32 years.**
- **High-risk factors: Rapid lake expansion, calving glacier snout, potential ice/snow avalanches, low freeboard, and landslide-prone areas near the outlet.**
- **GLOF modelling: indicates a potential flood path of ~26 km, with peak velocity up to 15 m/s and ~7 km² of downstream area vulnerable, including Panikhar village.**
- **Risk mitigation: Establish regular lake monitoring and an early warning system (EWS).**
- **Immediate safety measures: Relocate vulnerable infrastructure, including the police station, guesthouse, hotels and houses, and declare T1 and T2 terraces as unsafe zones.**
- **Engineering measures: Conduct detailed geotechnical assessment for controlled drainage/siphoning or an alternate outlet. Construction of retention structures in the downstream may help to attenuate flood energy and reduce damage.**
- **Preparedness: Identify and develop emergency evacuation routes and safe sites for downstream communities.**

Thank you



