**BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL,
PRINCIPAL BENCH, NEW DELHI**

ORIGINAL APPLICATION NO. 1156/2024

IN THE MATTER OF:

News item titled "Glacial lakes multiply in Himachal Pradesh and Tibet posing a threat to lives and infrastructure downstream" appearing in The Hindu dated 11.08.2024

NDOH- 07.01.2026

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NEW DELHI
DATE- 05/01/2026

**BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL,
PRINCIPAL BENCH, NEW DELHI**

ORIGINAL APPLICATION NO. 1156/2024

IN THE MATTER OF:

News item titled "Glacial lakes multiply in Himachal Pradesh and Tibet posing a threat to lives and infrastructure downstream" appearing in The Hindu dated 11.08.2024

REPLY/RESPONSE ON BEHALF OF RESPONDENT NO. 06 i.e NATIONAL INSTITUTE OF HYDROLOGY (NIH)

MOST RESPECTFULLY SHOWETH:-

1. That the present reply is being filed through by Dr. Surjeet Singh, presently posted as Scientist 'G' & Head Centre for Cryosphere & Climate Change Studies (C4S), National Institute of Hydrology (NIH), Jal Vigyan Bhawan, Roorkee-247667 (Uttarakhand).

2. That the I, in my official capacity at the NIH, am well conversant with the facts of the case and circumstances of the case, on the basis of the official records available in the office and as such authorised and competent to file the present reply.

3. That this Hon'ble Tribunal has registered the present matter suo-moto on the basis of the news item titled "Glacial lakes multiply in Himachal Pradesh and Tibet posing a threat to lives and infrastructure downstream" appearing in The Hindu dated 11.08.2024. That this Hon'ble Tribunal is

considering the issue of reduction of glacier size leading to an increase in moraine-dammed lake in Himachal Pradesh and Trans Himalayan Region of Tibet.

4. That this Hon'ble Tribunal has directed the respondent no. 06 to file their reply/response by way of affidavit, vide order dated 14/07/2025.

5. That it is most respectfully submitted that the National Institute of Hydrology (NIH), Roorkee is an autonomous institute under the Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India, mandated to undertake research, capacity building and scientific studies in the domain of hydrology, water resources and allied areas.

6. That following the Chamoli disaster (Uttarakhand) in February 2021 and the South Lhonak GLOF event (Sikkim) in October 2023, the Government of India has taken several proactive measures to assess and mitigate GLOF-related risks across the Indian Himalayan Region (IHR).

7. That the Central Water Commission (CWC) has initiated a comprehensive review of design floods, including Probable Maximum Flood (PMF), Standard Project Flood (SPF) and GLOF components, for all existing and under-construction dams vulnerable to such events. GLOF studies have been made mandatory for all new dams planned in catchments having glacial lakes. Glacier lakes inventory of Himachal Pradesh is annexed as **ANNEXURE - A**

8. That the CWC is presently monitoring 902 glacial lakes and water bodies in the Himalayan region, including 477 lakes larger than 50 ha and 425 lakes between 10–50 ha, on a monthly basis during June–October. This monitoring enables detection of changes in lake extent and identification of potentially hazardous lakes. CWC Criteria for risk indexing of glacial lakes in Indian Himalayan Region is annexed as **ANNEXURE - B**

9. That the National Disaster Management Authority (NDMA), through its Committee on Disaster Risk Reduction (CoDRR), has identified high-risk glacial lakes for field expeditions and preparation of mitigation strategies, including early warning systems and structural/non-structural measures. NDMA has also issued Guidelines on the Management of Glacial Lake Outburst Floods (GLOFs). A High-Level Committee chaired by the Union Home Minister has approved a dedicated GLOF Risk Mitigation Project of Rs. 150 crores for the States of Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh to support the efforts of state government to take up various mitigation measures related to GLOFs.

10. That the Centre for Cryosphere and Climate Change Studies (C4S) was established in May 2023 at the National Institute of Hydrology (NIH) by the Ministry of Jal Shakti to undertake scientific research on climate–cryosphere interactions and their impact on water availability in the Indian Himalayan Region. The Centre focuses on mapping and monitoring of snow, glaciers, glacial lakes and springs, and on developing a coordinated knowledge base on the Himalayan cryosphere in collaboration with national institutions. At present, C4S is monitoring six glaciers located in Ladakh, Himachal Pradesh and Uttarakhand. A Steering Committee on Monitoring of Glaciers, chaired by the Secretary, Ministry of Jal Shakti, has been constituted to guide and coordinate cryosphere research across

concerned ministries and scientific organisations including NIH, CWC, NRSC, GSI, NCPOR, WIHG and others.

11. That the NIH has also contributed to national studies under the National Mission on Himalayan Studies (NMHS), including assessment of glacial lakes and climate change impacts in Himalayan river basins, as reflected in responses placed before Parliament.

12. That it is respectfully submitted that the reports regarding a sharp increase in the number of glacial lakes in Himachal Pradesh, including those cited in media articles, are primarily based on studies conducted using satellite datasets of differing spatial resolutions and methodologies.

Studies by Randhawa et al. (2005, 2021) using LISS-III data and those by Bhambri et al. (2018) using higher-resolution LISS-IV data. The first study identified 22 and 31 moraine-dammed lakes, while the second study identified 391 and 116 lakes in Satluj and Chenab basins respectively. Another detailed study on glacial lakes in Himachal Pradesh by Wadia Institute of Himalayan Geology (WIHG) an autonomous institute of the Department of Science and Technology (DST) utilizes LISS-IV data (spatial resolution: 5.8 m) for the years 2011-2013 (~ same as Randhawa et al., 2021) indicates 35 & 76 moraine-dammed lakes in Satluj and Chenab basins, respectively (Bhambri et al., 2018).

Further Randhawa et al., 2021 indicates 118, 15 & 258 lakes in sub-basin 1 (Spiti), sub-basin 2 (lower Satluj) & sub-basin 3 (Tibet), respectively. Bhambri et al., (2018) identified 25 & 10 moraine-dammed lakes in Spiti and lower Satluj sub-basin, respectively.

Similarly, for the Chenab Basin Randhawa et al. (2021) identified 19, 14 and 83 lakes in Chandra, Bhaga and Miyar sub-basins, respectively. While Bhambri et al., (2018) identified 28, 48, & 43 moraine-dammed lakes in

Chandra, Bhaga & Miyar sub-basins, respectively. The moraine dammed lakes inventory in Satluj, Ravi, Chenab and Beas Basins of Himachal Pradesh, India is annexed as **ANNEXURE - C**

Moraine- dammed lakes study in the Chenab and the Satluj river basins using IRS data is annexed as **ANNEXURE - D**

13. That the apparent discrepancies in reported lake numbers arise due to:
    (a) Climate change and rising temperatures in the Indian Himalayan Region (IHR) and other mountainous regions of the world are reported by various national and international studies.
    (b) Differences in classification, wherein some studies include all water bodies while others restrict analysis to moraine-dammed lakes;
    (c) Variations in spatial resolution of satellite data used;
    (d) Methodological differences in mapping and interpretation.

It is scientifically acknowledged that glacier retreat and formation of new glacial lakes is a natural process, which has been accelerated in recent decades due to climate change and rising regional temperatures.

14. That the continuous long-term monitoring of glacial lakes in the IHR is being undertaken by NDMA, NRSC and CWC. Glacial lakes are being categorised into hazard categories A, B and C based on risk indexing criteria developed by CWC and released in September 2024. Standardisation of methodologies for glacier and glacial lake monitoring is currently under process through the Bureau of Indian Standards (BIS). Detailed field investigations, including bathymetry and moraine stability studies, are proposed initially for high-risk (Category-A) lakes under the National GLOF Risk Mitigation Programme, followed by medium- and low-risk lakes. Development and deployment of Early Warning Systems

(EWS) for vulnerable Himalayan basins is being prioritised in coordination with State Disaster Management Authorities. National Disaster Management Authority Guidelines Management of Glacial Lake Outburst Floods (GLOFs) is annexed as **ANNEXURE - E**

15. That it is most respectfully submitted that NIH is primarily a scientific and a research institution and does not have a regulatory or enforcement mandate. And NIH remains committed to supporting the Government of India, State Governments and statutory authorities by providing scientific inputs, research findings and technical guidance related to cryosphere dynamics, glacial lakes and climate change impacts. The measures already undertaken at the national level demonstrate a coordinated and proactive approach towards understanding and mitigating GLOF-related risks in Himachal Pradesh and the wider Himalayan region.

16. That it is respectfully submitted that glacier retreat and the consequent formation of new glacial lakes are natural processes, which have been accelerated due to climate change and rising temperatures. While such processes cannot be prevented, the associated risks can be effectively assessed and mitigated through scientific monitoring, preparedness and coordinated institutional action. Addressing climate change through reduction of global carbon emissions, in line with India's commitments under the Paris Agreement, remains imperative.

17. That in order to understand, assess and reduce the risks arising from increasing glacial lakes in the Indian Himalayan Region (IHR), the following measures are recommended and are being pursued:

    (i) Continuous long-term monitoring of glacial lakes and water bodies in the IHR through satellite-based mapping and

analysis, being undertaken by the National Disaster Management Authority (NDMA) in coordination with the National Remote Sensing Centre (NRSC) and the Central Water Commission (CWC).

(ii) Hazard-based categorisation of glacial lakes into Category A, B and C (Category A being the most hazardous), in accordance with the "Criteria for Risk Indexing of Glacial Lakes in the Indian Himalayan Region" developed by CWC in consultation with concerned agencies and released in September 2024.

(iii) Standardisation of methodologies for mapping and monitoring of glaciers and glacial lakes across the IHR, which is presently under process through the Bureau of Indian Standards (BIS) under its Sectional Committee WRD-32.

(iv) Detailed field investigations, including bathymetric surveys, assessment of moraine stability and other relevant parameters, to be undertaken initially for Category-A glacial lakes, followed by Category-B and Category-C lakes, under the National GLOF Risk Mitigation Programme (NGRMP) being implemented by NDMA in coordination with the respective State Disaster Management Authorities (SDMAs). GLOF RiskMitigation programme is annexed as **ANNEXURE – F**

(v) Development and deployment of Early Warning Systems (EWS) in Himalayan river basins having potentially hazardous glacial lakes, to enhance preparedness and minimize loss of life and property.

18. That the present reply may kindly be taken on record and into consideration and the Hon'ble Tribunal may pass appropriate order(s)/direction(s) as deem fit and proper under the facts and circumstance of the present case.

NEW DELHI
DATE- 05/01/2026

RESPONDENT

THROUGH-

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ANNEXURE- A

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Glacier Lake inventory of Himachal Pradesh

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Abstract: The flash flood occurring due to glacier lake outbursts (GLOFs) are usually catastrophic to the human lives and infrastructure in the downstream areas. It is therefore, important to map and frequently monitor glacier lakes of Himalaya not only to know the impact of climate change on glacier lakes but also to mitigate hazards that may cause loss to the society. In the present study, we have generated a glacier lake inventory of Himachal Pradesh using high resolution Resourcesat 2 LISS IV satellite images. A total of 958 glacier lakes (size > 500 m^2) of Himachal Pradesh (covering an area of 9.6±0.3 km^2) have been mapped using high resolution images. Out of these, 345 were classified as moraine-dammed lakes having a total area of 5.1±0.2 km^2 (53.1 % of the total glacier lake area). Altitude wise distribution of glacier lakes in Himachal Pradesh range from 3001 m a.s.l. to 5614 m a.s.l. The maximum glacier lakes area is seen in Chandra basin (2.7±0.09 km^2). Sissu, an artificial lake (area, 1900±66 m^2) is situated at the minimum elevation (~3100 m) in the Chandra basin. A supra-glacial lake in the Spiti basin is located at the maximum mean elevation of the study area (5614 m). The largest lake in the Himachal Pradesh has been classified as other moraine-dammed lake (1.0±0.03km^2) is sited at frontal of Samundra Tapu Glacier in the Chandra basin. The maximum number of glacier lakes are seen in the Miyar basin (156 counts), whereas minimum lakes are located in the Siul basin (06). The present study will provide a reference database to quantify impact of climate change on glaciers and glacial lakes in the region and will allow identification of potentially dangerous lakes in the state in conjunction with detailed ground investigations.

Key words: Glacier Lake Outburst Flood (GLOF), Himalaya, Moraine-dammed lake, Remote Sensing

सारांशः हिमनदों द्वारा निर्मित झीलों के फटने (विस्फोट) से आकस्मिक बाढ़ के प्रकोप से निचले भागों में रहने वालों के जीवन, मकानों और सड़कों इत्यादि पर विनाश की सम्भावना बनी रहती है। इसलिए हिमालय की इन झीलों का मानचित्रण करना तथा इन झीलों पर जलवायु परिवर्तन के असर एवं आपदा निवारण द्वारा समाज की रक्षा करना आवश्यक है। प्रस्तुत अध्ययन में, हमने हिमाचल प्रदेश की हिमनद झीलों को संसाधन उपग्रह–2 के लिस–IV से प्राप्त चित्रों द्वारा चिन्हित किया है। 500 वर्गमीटर से विशाल, कुल 958 झीलों, जोकि हिमाचल प्रदेश के 9.6± 03 वर्ग किलोमीटर क्षेत्र मे विस्तृत हैं, का मानचित्रण किया गया है। इनमें से 345 झील, हिमनद द्वारा एकत्रित मोरेन द्वारा निर्मित है तथा 5.1±02 (53-1%) क्षेत्र में विस्तृत हैं। ये झीलें 3001 मीटर से 5614 मीटर के बीच की ऊँचाईयों में स्थित हैं। चन्द्रा द्रोणी में सबसे अधिक झीले हैं तथा 2.7± 0.09 वर्ग किलोमीटर क्षेत्र में स्थित हैं। इनके अतिरिक्त मानव निर्मित सिसु झील सबसे अधिक ऊँचाई पर चन्द्रा द्रोणी में स्थित है। स्पीति द्रोणी में, हिमनद के ऊपर स्थित झील (सुप्रा ग्लेशियर) सबसे अधिक औसत ऊँचाई (5614 मीटर) पर स्थित है। चन्द्रा द्रोणी में, समुद्र टापू हिमनद के समक्ष मोरेन से निर्मित सबसे विशाल झील स्थित (1.0± 0.03 वर्ग किलोमीटर) है। मियार द्रोणी में सबसे अधिक झीलें (156) है जबकि सबसे कम झीलें (06), सियूल द्रोणी में चिन्हित की गयी है। इस प्रकार वर्तमान अध्ययन में, हिमनद झीलों की संख्या के संदर्भ आँकडों द्वारा जलवायु परिवर्तन एवं सम्भावित आपदाओं को अनुमानित करने तथा विस्तृत अध्ययन में क्षेत्र अध्ययन के द्वारा सहयोग मिलेगा।

संकेत शब्दः हिमनद झील विस्फोट बाढ़ (जी.एल.ओ.एफ.), हिमालय, मोरेन द्वारा निर्मित झील, सुदूर संवेदन।

INTRODUCTION

All lakes originating from present or past glaciers, in both continental ice sheets and mountain glaciers, are described as glacial lakes (Fairbridge 1968). A glacial lake can form on the surface of the glacier itself (supra-glacial), within the glacier ice (englacial), below the glacier ice (subglacial), in front of a glacier (proglacial), inside/surrounding of glaciers (periglacial) or in relict cirques (tarn or cirque) and is also dammed by glacier moraine or ice (moraine-dammed or ice-dammed). These lakes are good source of fresh water. Climate change studies in the Himalaya during the twentieth century have shown significant impact on glaciers and surrounding environments (Shrestha *et al*. 2015). Instrumental weather records from the northwestern Himalayan region for the past century suggest an increase in temperature of around 1.6°C/100 year (Bhutiyani *et al*. 2007), which matches closely with the prediction of AR5 of IPCC for the global average temperature increases (IPCC 2013). Numerous studies on Himalayan glaciers indicate that several of these glaciers have exhibited an increased recession rate over the past few decades in response to climatic warming (Kulkarni *et al*. 2011; Bhambri *et al*. 2011). Such climatic warming has caused an increase in number and volume of potentially hazardous moraine-dammed lakes in the Himalaya (Richardson & Reynolds 2000; Quincey *et al*. 2005; Fujita *et al*. 2008; Gardelle *et al.* 2012; Raj *et al*. 2013; Nie *et al*. 2013). These lakes usually form beside the lateral moraines and/or at the front of terminus. Glacier and snow melt water coupled with sporadic heavy rainfall in a short span of time (e.g. cloud bursts) pose potential threat to the stability of moraine dams, which appear to be otherwise stable owing to their existence over hundreds of years. The rapid accumulation of water in

these lakes can lead to unexpected breach of the moraine dam. The resultant rapid discharge of huge amount of water and debris is known as a glacial lake outburst flood (GLOF). The results of GLOF can be catastrophic to the human lives and infrastructure in the downstream areas (Richardson & Reynolds 2000; Huggel *et al*. 2002; Kääb *et al*. 2005). For instance, a moraine-dammed Chorabari lake (Gandhi Sarovar) at the periphery of Chorabari Glacier burst in the morning of 17th June, 2013 and released enormous volume of water that caused flash floods in the Kedarnath town leading to heavy devastation in the Mandakini valley downstream (Bhambri *et al*. 2016). Therefore, it is essential to map and frequently monitor Himalayan glacier lakes not only to understand the impact of climate change on glacier lakes but also to mitigate hazards that may cause loss to the society.

The conventional field surveys are laborious, time consuming and can be dangerous in high mountainous regions, whereas multi-spectral and multi-temporal satellite data offer great potential to monitor these glacier lakes at regular intervals (e.g., yearly or decadal). Kulkarni (1996) began research on glacier lake monitoring in India using remote sensing data and estimated peak discharge for the Samudra Tapu Lake in Himachal Pradesh. A few noteworthy studies have generated glacier lake inventory of Himachal Pradesh based on Landsat ETM+, OLI images or LISS III (Bhagat *et al*. 2004; Randhawa and Sharma 2014; Allen *et al.* 2016). However, these images contain information at medium scale (cell size 30m or 23.5 m) and it is difficult to map smaller glacier lakes on these images due to coarse resolution. Therefore, available glacial lake inventories need urgent updation. It has now become imperative to revisit these dataset and update and upgrade glacier lakes in the Himachal Himalaya using latest high resolution satellite datasets (cell size 5m). This new inventory would not only allow comparative decadal changes in lake area and their numbers but also lay down foundation of glacial lake inventory database creation complying with international standards. Therefore, the present study identifies and maps glacier lakes based on high resolution remote sensing data in Himachal Pradesh and classifies glacier lakes (types) with inventory parameters.

STUDY AREA

The state of Himachal Pradesh is situated in the Western Himalaya that covers an area of ~55,673 km^2. It is bounded by the Indo-China international boundary on its eastern margin, Jammu and Kashmir on its north and northwest, Uttarakhand on its south-east and Punjab on its southwest (Fig. 1). The elevation of Himachal Pradesh ranges from ~250 to 7026 m a.s.l. Himachal Pradesh is drained mainly by Beas, Chennab, Indus, Ravi and Satluj Rivers along with their tributaries.

Himachal Pradesh comprises of 2100 glaciers, covering an area of ~3799 km^2 or ~6.8% of the state (Sangewar 2004-05). Bada Shigri is the longest glacier (~26 km) in the state. Himachal Himalaya glaciers are fed by the Indian summer monsoon (ISM) in summer and westerlies in winter (Thayyen & Gergan 2010). Maximum snowfall in the area occurs from December to March, mostly due to western disturbances. Several studies suggest that glaciers of Himachal Himalaya have been receding since the end of the Little Ice Age (Mayewski & Jeschke 1979; Bhambri & Bolch 2009). In response, glacier lakes significantly expanded their area due to melting of ice and vacated glacierized region. However, knowledge of changes in glacier lake area in Himachal Himalaya is limited in terms of their dimension.

DATA SOURCES AND METHODS

Satellite data

High resolution multi-spectral and panchromatic satellite imageries from different Indian sensors such as Resourcesat-2 Linear Imaging Self-Scanning sensor (LISS) IV were evaluated for the end of ablation season (Table 1). We preferred multi-spectral Resourcesat-2 LISS-IV images that have 5.8 m resolution with 70 km swath as compared to shorter swath (23 km) of Resourcesat 1 LISS-IV for glacier lake inventory. The images were acquired from National Remote Sensing Centre (NRSC, http://www.nrsc.gov.in/). The Resourcesat-1 LISS-IV has three radiometric bands from green to near infrared. In order to interpret complex polygenetic glacier landscape, 10-bit radiometric resolution dataset of Resourcesat-2 LISS-IV sensors, which show better contrast were preferred over 7 bit lesser contrast IRS-IC and ID PAN data, specially for glaciers and glacier lakes. Cloud cover has been reported as one of the major challenges to map glaciers and high altitude lakes (e.g., Frey *et al*. 2012). Therefore, seven Landsat 8 images were also acquired from the United States Geological Survey (USGS) (http://earthexplorer.usgs.gov/) to ensure complete coverage. High resolution Google Earth satellite images were also used to classify glacier lake types.

Glacier lake mapping

The band ratio of LISS band 1/LISS band 3 (GREEN/NIR) was used to map automatically the glacier lakes in Himachal Pradesh as Resourcesat-2 LISS-IV lacks blue band. The band ratio GREEN/NIR method (e.g. ASTER image) has also been successfully utilized for the mapping of glacier lakes of Mt. Everest Region (Wessels *et al*. 2002). However, this method misclassifies shadow areas as glacier lakes (Fig. 2). Therefore, hill shade maps were generated using the SRTM DEM based on exact time of the LISS IV data acquisition parameters (e.g., sun elevation angle and azimuth) (cf. Huggel *et al*. 2002). We used 14 LISS-IV images of different time period. Difference in surface conditions (e.g., frozen lakes and fresh snow) of glacier lakes could not be distinguished from snow covered glaciers using automatic classification. Moreover, ice cliff and walls of supra-glacial lakes also get misclassified as glacier lakes in some cases. Therefore, we identified glacier lakes based on visual interpretation. Pan-sharpened products were generated by merging Cartosat and LISS-IV images. The

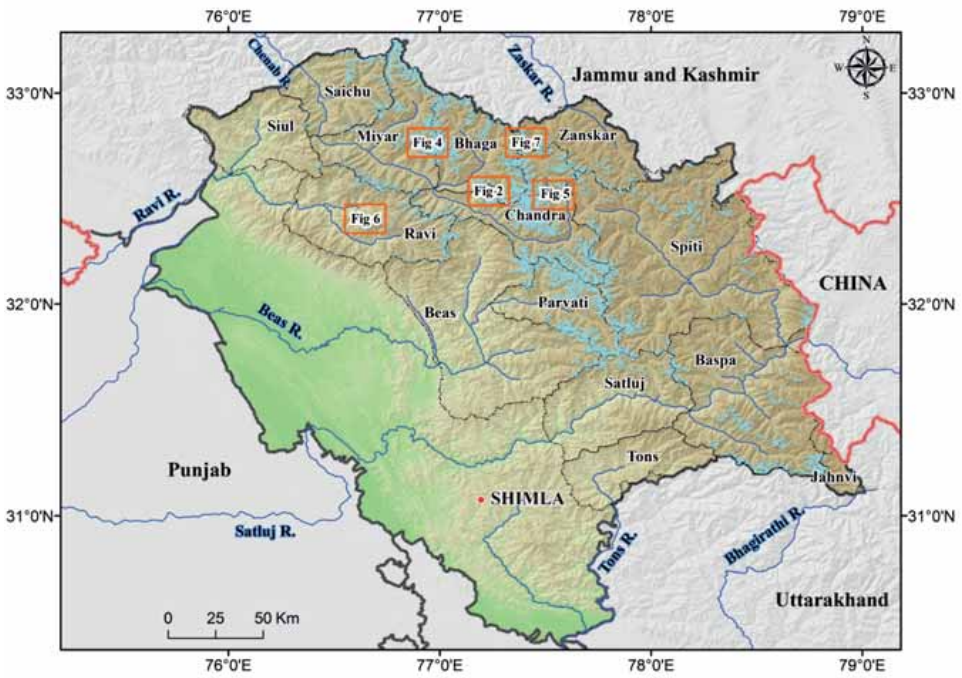

Fig. 1. Overview map of the study area.

Table 1. *Satellite data used in present study.*

Date	Satellite /Sensor	Resolution (m)
01.10.2011	RS 2/LISS IV	
15.10.2011	RS 2/LISS IV	
20.10.2011	RS 2/LISS IV	
08.11.2011	RS 2/LISS IV	
13.11.2011	RS 2/LISS IV	
27.11.2011	RS 2/LISS IV	
02.12.2011	RS 2/LISS IV	5.8
17.08.2012	RS 2/LISS IV	
07.11.2012	RS 2/LISS IV	
11.09.2013	RS 2/LISS IV	
20.09.2013	RS 2/LISS IV	
09.10.2013	RS 2/LISS IV	
02.11.2013	RS 2/LISS IV	
20.11.2013	RS 2/LISS IV	
28.08.2014	Landsat/OLI & Panchromatic	
19.09.2014	Landsat/OLI & Panchromatic	
28.09.2014	Landsat/OLI & Panchromatic	
08.08.2015	Landsat/OLI & Panchromatic	30 OLI; 15 Pan
28.09.2015	Landsat/OLI & Panchromatic	
08.09.2015	Landsat/OLI & Panchromatic	
17.10.2015	Landsat/OLI & Panchromatic	

glacier lake boundaries derived using semi-automatic method had to be reshaped manually using high resolution pan-sharpened images. Since in the present study high resolution satellite data (cell size 5 m) was used, 500 m^2 (0.0005 km^2or 20 pixels) was selected as minimum size of the lake. We estimated the mapping uncertainty for each glacier lake based on a buffer around the glacier lake margins as suggested by Granshaw and Fountain (2006).

Glacier lake classification

A glacier lake can form at front and surface or periphery of a glacier. Glacier lakes may also exist beneath or within the glacier mass, but do not show any surface signature on satellite images, hence can not be mapped. Therefore, such lakes are not considered in the present study. Glacier lake classification (type) is essential to know the position, source and process involved in the formation and evolution of lake. In the present study, ICIMOD (2011) and Bhambri *et al.* (2015) classification of glacier lake scheme with slight modifications has been adopted and the lakes have been classified based on glacier process in four major types: (1) moraine-dammed lake, (2) ice-dammed lake, (3) glacier erosion lake, and (4) other glacier lake (Fig. 3).

Moraine-dammed lake

A *moraine* is an accumulation of unconsolidated and unsorted glacial material, which is often referred to as till (e.g., clay, sand, gravel, and boulders) deposited by glacier movement in currently glacierized and formerly glaciated regions on Earth (e.g., Last Glacial Maximum). Moraines can be classified based on their location with respect to a current or former glacier extent. *End moraines* are ridges of glacial till that form at the margin of a glacier. These moraines indicate extension of past glaciations. In numerous cases, lakes develop in-between the end moraine and the glacier tongue. These lakes are called *end-moraine* glacier lakes. Gepang Gath (4069 m a.s.l.) is an example of such lake from Himachal Pradesh. A *lateral moraine* consists of unconsolidated glacial sediments in the form of a ridge along the sides of an alpine glacier. Sometimes,

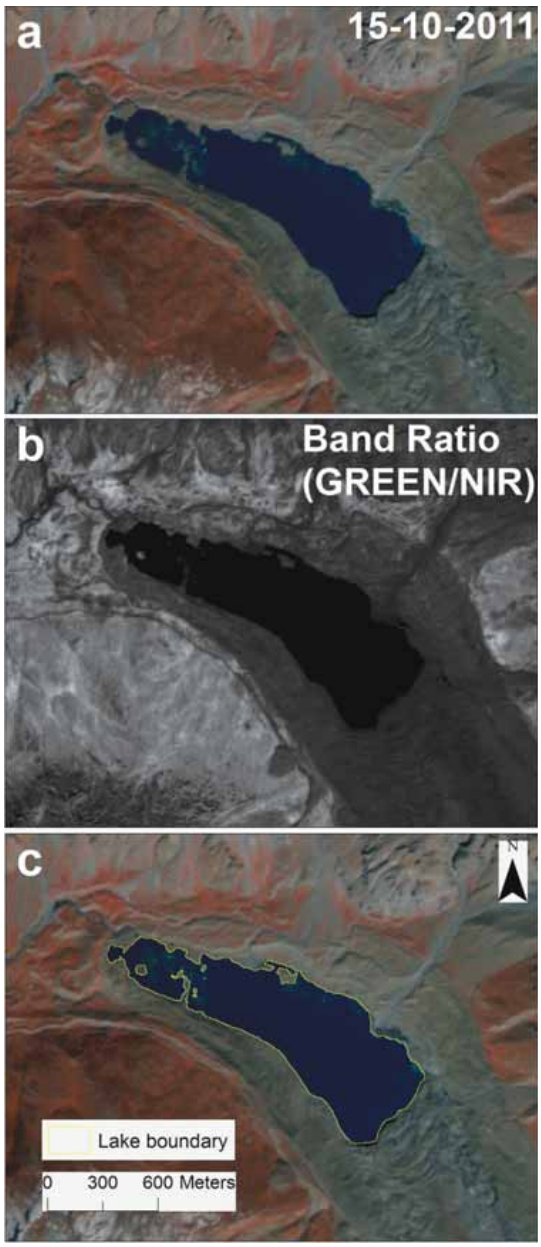

Fig. 2. Glacier lake mapping using remote sensing images: (a) FCC of Resourcesat-2 LISS IV 15-10-2011 image with band combination 3-2-1, (b) Band ratio (GREEN/NIR) image,(C) FCC of Resourcesat-2 LISS IV 15-10-2011 image with Yellow vector outline of Gepang Gath lake. See Fig. 1 for location.

a lake can develop between a lateral moraine and the valley wall. Such lakes are known as *lateral* moraine-dammed lakes (e.g. Neelkanth lake, Fig. 4). These lakes accumulate maximum water from the lateral basin (snow melt and precipitation) with little contribution from the glacier melt. In addition, *lateral* moraine-dammed lakes can be with or without ice. However, identification of iced and ice free lateral moraine-dammed lakes based merely on remote sensing is rather difficult owing to seasonal snow on satellite images. A *recessional moraine* forms at the end of the glacier across the valley direction. Such moraines develop where a retreating glacier remained stationary for a sufficient duration of time to form a crescent shape ridge of unconsolidated glacial material. These ridges may obstruct the glacier and/or snow melt water and form a small lake in frontal part of the glacier. These lakes are known as *recessional* moraine-dammed lakes. *Medial moraine* is formed from two glacier *lateral moraines*. Once two glaciers meet, the two edges form a joint moraine (*medial moraine*) in the middle of the glacier. Occasionally, lakes form between the confluences of lateral moraines of two glaciers. These lakes are known as *medial moraine* lakes. In many cases, it is difficult to recognize a particular type of moraine-dammed lake on the satellite images due to seasonal snow. Such lakes are therefore mapped under the other moraine-dammed lake (Fig. 5).

Ice-dammed lake

An ice-dammed lake forms when water accumulates behind the blockage of ice. Ice-dammed lakes are often formed when a large glacier blocks a river and forms a lake. This type of lake is known as a glacier ice-dammed lake. Chong Kumdan Glacier blocked the Shyok River and formed Gapshan lake in eastern Karakoram during 1929 (Mason 1930). Glacier melting is the most dominating process in the ablation zone and often forms ponds over the glacier surface. These ponds are covered by ice in all the directions and are known as supra-glacial or ephemeral lakes. Conditions of long periods of recession and negative mass balance generally result in the formation of supra-glacial ponds in the ablation zone of debris-covered glaciers, and these ponds join together to form a larger lake (Richardson & Reynolds 2000; Bolch *et al*. 2008; Benn *et al*. 2012).

Glacier erosion lake

Glacier *erosion* lakes are often formed in depressions generated by glacial erosion processes. Manimahesh (4189 m a.s.l.) is the example of such lake from Himachal Pradesh (Figs. 6, 7). Some lakes usually occur in armchair shaped hollow (*cirque*) consisting of steep head and side wall. Such *erosion* lakes are called *cirque* lakes, which form by the plucking and erosion of the glacier bed rock. In the Himalaya, *cirque* lakes are often found above 4000 m a.s.l, which are partially filled by snow in winter and by water during rest of the year. Glacier trough valley lake is another type of *erosion* lake in a glacier terrain. These lakes are formed when a glacier moves over an area, which contains alternate bands of hard and soft bed rocks. The glacier erodes soft rocks more quickly by erosion and creates a hollow surface. After retreat of the glacier, the rain water and glacier melt water are accumulated and form a *trough* lake. However, identification of such lakes based merely on remote sensing is rather difficult.

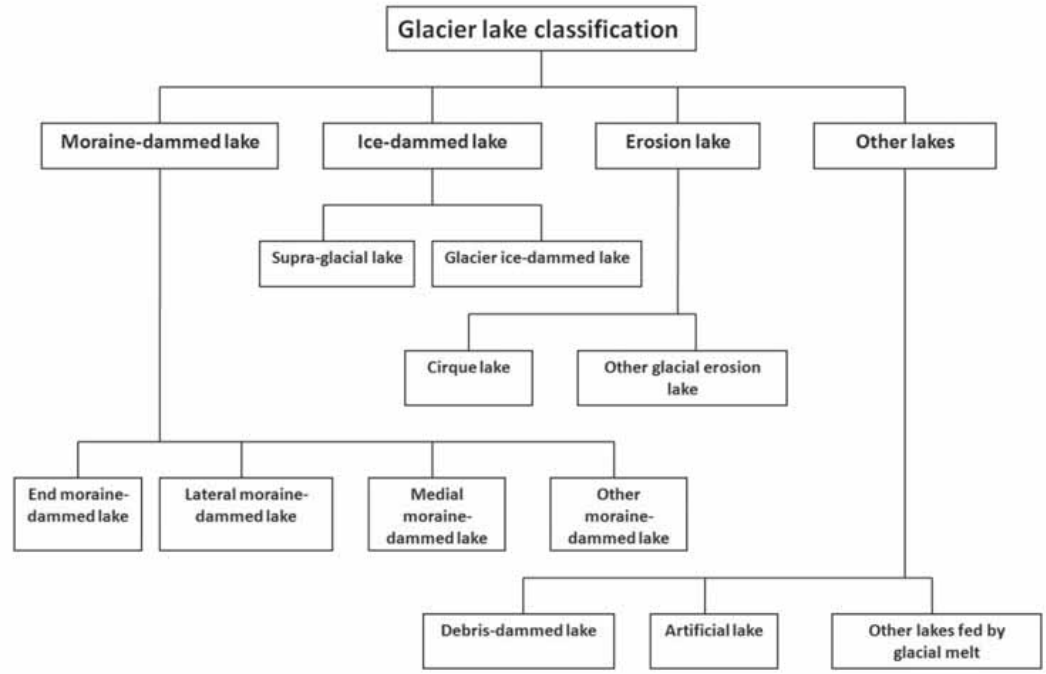

Fig. 3. Glacier lake classification scheme (modified after ICIMOD 2011; Bhambri *et al.* 2015).

Fig. 4. A *lateral* moraine-dammed lake (Neelkanth lake) in the Miyar basin (© Sanjay Deswal).

Fig. 5. Another moraine-dammed lake at the front of Samudra Tapu Glacier in the Chandra basin (© Pritam Chand Sharma).

Fig. 6. Manimahesh (4189 m a.s.l.) is an example of erosional lake in Ravi basin (© Pritam Chand Sharma).

Other lakes

Many lakes are not directly linked with glacier erosion and deposition processes. These lakes generally form due to blockade of local streams by rock falls, debris flows, and landslides in the glacier terrain. Such lakes are called *debris-dammed* lakes. Manmade lakes (*artificial*) are also categorized in this group. Sissu lake (3001 m a.s.l.) is one example of *artificial* lake in Himachal Pradesh.

Glacier lake inventory parameters

A basin-wise inventory is important to know the number and area of glacier lakes in respective basins. The Geological

Fig. 7. An erosional lake (Suraj Tal) in Bhaga basin (© Sanjay Deswal).

Survey of India (GSI) compiled names of fifth order basins and their respective codes based on UNESCO and TTS guidelines for glacier inventory (Raina & Srivastava 2008; Sangewar and Shukla 2009). We classified Himachal Pradesh in 14 fifth order basins for lake inventory with slight modification as suggested by the Geological Survey of India: Tons basin (5O12301), Jahnvi Ganga basin (5O13105), Zanskar basin (5Q13205), Siul basin (5Q21104), Ravi, Budhil basins (5Q21106,07), Saichu basin (5Q21208), Miyar basin (5Q21210), Bhaga basin (5Q21211), Chandra basin (5Q21212), Beas basin (5Q22108), Parvati basin (5Q22109), Kurpan, Nogri, Kut, Soldan, Sorang-Wanger Basins (5Q22208,09,10,11,12), Baspa, Tirung Khad, Tagla, Ropa Gad, Taiti and Hojis basin (5Q22213,14,15,17,18) and Spiti basin (5Q22219) (Fig. 1).

We generated glacial lake inventory for Himachal Pradesh in the shape file format, which included attributes - ID (code), glacier lake type, coordinates in terms of latitude and longitude, area, basin and elevation as non-spatial data. The ID allocation embeds the location address and type to facilitate future updation and comply with the international standards (Annexure 1).We allocated unique ID to each lake based on the latitude and longitude of the lake center (centroid) as suggested by the Global Land Ice Measurements from Space (GLIMS; http://www.glims.org/) (Annexure 1).

GLACIER LAKE DISTRIBUTION IN HIMACHAL PRADESH

We identified 958 glacier lakes (size >500 m^2) in Himachal Pradesh using satellite images (2011-2013), covering an area of 9.6±0.3 km^2 (Annexure 1). Out of these, 345 have been classified as moraine-dammed lakes (end moraine-dammed, lateral moraine-dammed, medial moraine-dammed, other moraine-dammed), having a total area of 5.1±0.2 km^2 (53.1 % of the total glacier lake area) (Table 2). The maximum number of glacier lakes (345 counts) are grouped under moraine-dammed lake category, while minimum number of glacier lake is occupied by the other lake group (37 counts and total area of 0.3±0.02 km^2) (i.e., debris-dammed lake, artificial lakes). Altitudinal distribution of glacier lakes in Himachal Pradesh varies from 3001 m to 5614 m. An artificial lake, Sissu lake (1900±66 m^2) is situated at the minimum elevation (~3100 m) in the Chandra basin. A supra-glacial lake of Spiti basin shows maximum mean elevation (5614 m) in the study area. The largest lake classified as *other* moraine-dammed lake (1.0±0.03km^2) in Himachal Pradesh is located at front of the Samundra Tapu Glacier in the Chandra basin. The maximum numbers of glacier lakes are seen in the Miyar basin (156 counts), whereas minimum number of lakes are seen in the Siul basin (06). In addition, maximum area of glacier lake is distributed in the Chandra basin (2.7±0.09 km^2).

The Beas basin

The Beas basin is located in the middle of Himachal Pradesh and shares western and eastern boundaries with Ravi and Satluj basins, respectively. The maximum numbers of lakes are mapped in other glacier erosion lakes (51 counts) category which occupy ~57% of the total glacier lake area (Fig. 8). Moraine-dammed lakes cover ~28% of total glacier lake area in this basin. Only three lakes are seen in other lake category (Table 3).

The Baspa, Tirung Khad, Tagla, Ropa, Taiti and Hojis basins

The Baspa, Tirung Khad, Tagla Ropa, Taiti and Hojis basins

Table 2. *Glacier lake distribution in the Himachal Pradesh.*

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	65	6.8	2284636	23.8	35148
	Lateral moraine-dammed lake	36	3.8	321685	3.4	8936
	Medial moraine-dammed lake	3	0.3	21339	0.2	7113
	Other moraine-dammed lake	241	25.2	2514578	26.2	10434
Ice-dammed lake	Supra-glacial lake	228	23.8	439442	4.6	1927
	Glacier ice-dammed lake	50	5.2	269549	2.8	5391
Glacier erosion lake	Cirque lake	7	0.7	316576	3.3	45225
	Other glacier erosion lake	291	30.4	3126277	32.6	10743
Other lakes	Debris-dammed lake	28	2.9	220309	2.3	7868
	Artificial lake	9	0.9	79703	0.8	8856
	Total	958		9594094		

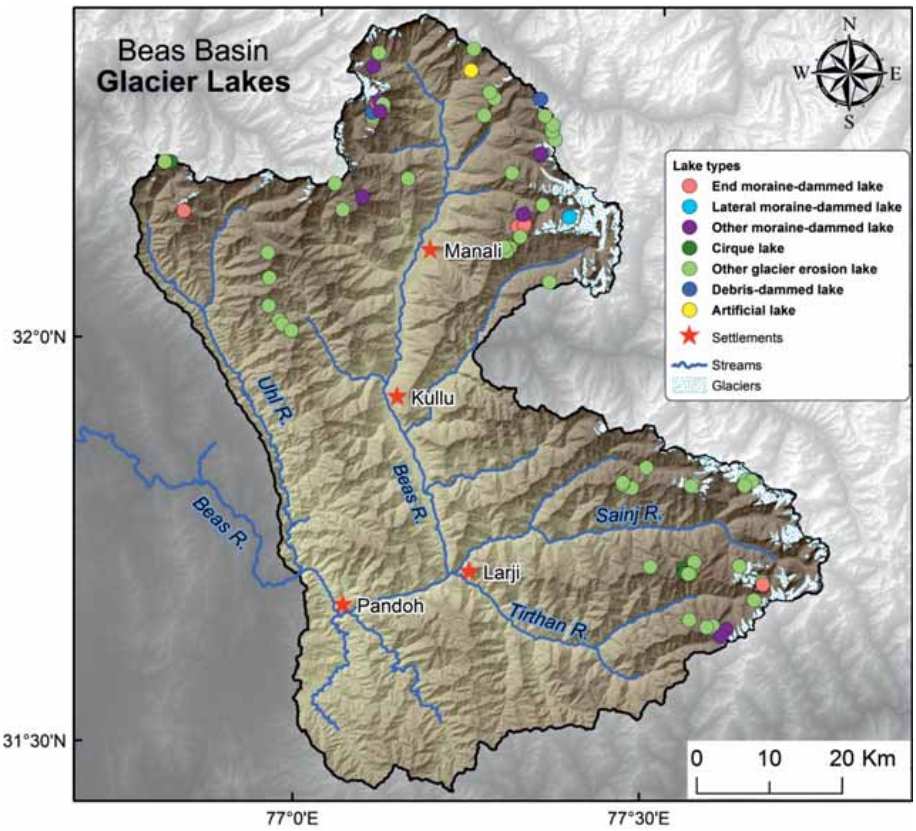

Fig. 8. Overview map of glacier lakes in the Beas basin.

Table 3. *Glacier lake inventory of the Beas basin.*

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	8	10.8	149100	16.7	18637
	Lateral moraine-dammed lake	1	1.4	16880	1.9	16880
	Other moraine-dammed lake	8	10.8	80701	9.1	10088
Glacier erosion lake	Cirque lake	3	4.1	84599	9.5	28200
	Other glacier erosion lake	51	68.9	512135	57.5	10042
Other lakes	Debris-dammed lake	2	2.7	42905	4.8	21452
	Artificial lake	1	1.4	4220	0.5	4220
	Total	74		890539		

Table 4. *Glacier lake inventory of the Baspa, Tirung Khad, Tagla Ropa, Taiti and Hojis basins*.

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	3	2.2	207030	23.4	69010
	Lateral moraine-dammed lake	1	0.7	3589	0.4	3589
	Other moraine-dammed lake	39	28.3	249717	28.3	6403
Ice-dammed lake	Supra-glacial lake	38	27.5	65539	7.4	1725
	Glacier ice-dammed lake	34	24.6	236271	26.7	6949
Glacier erosion lake	Other glacier erosion lake	22	15.9	119850	13.6	5448
Other lakes	Debris-dammed lake	1	0.7	1332	0.2	1332
	Total	138		883328		

are situated in between the Spiti basin (west) and Jahnvi Ganga (east). It consists of 138 lakes out of which 43 are moraine-dammed lakes (Table 4). This category of lakes covers ~52% of the total glacier lake area. The maximum number of glacier lakes are seen in ice-dammed lake group (72 counts), but occupy only ~34% of the total area (Fig. 9).

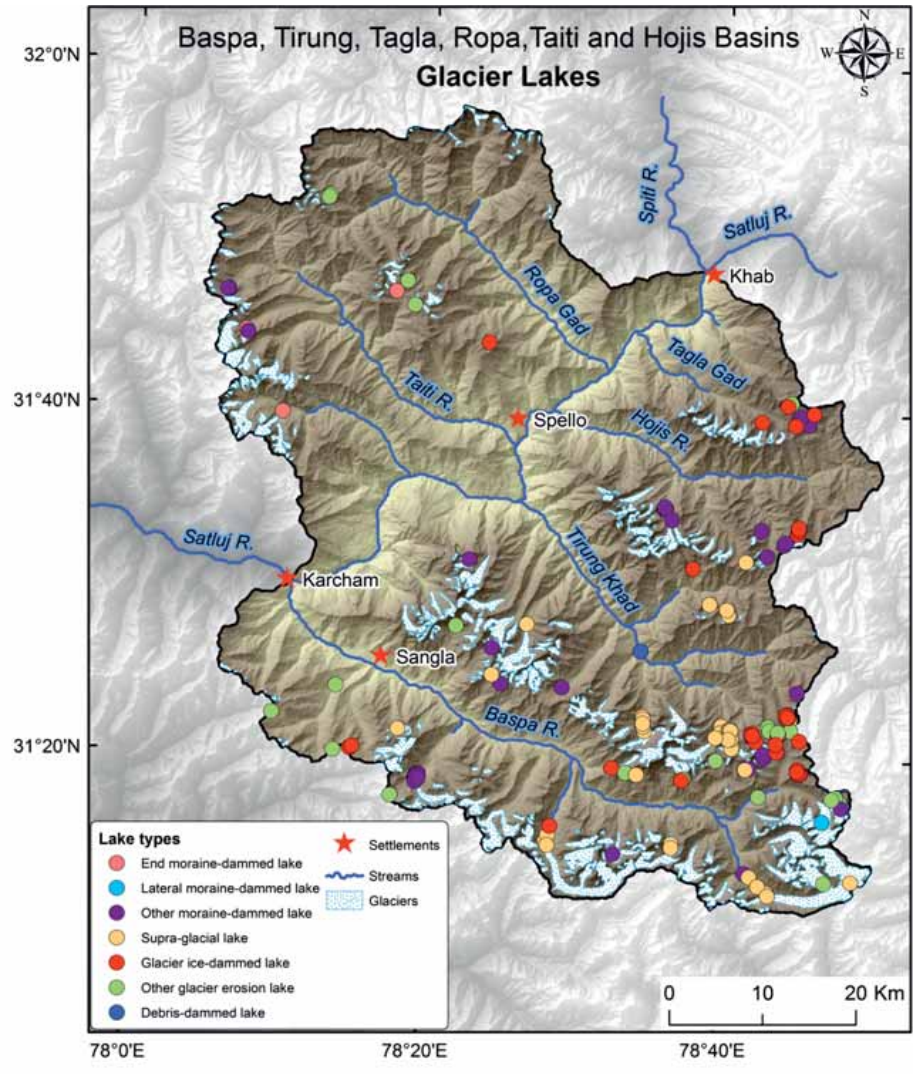

Fig. 9. Overview map of glacier lakes in the Baspa, Tirung, Tagla, Ropa, Taiti and Hojis basins.

The Bhaga basin

The Bhaga basin is situated in between the Miyar and Chandra basins. It contains a total of 125 lakes covering an area of 0.6±0.02 km^2. Out of this, ~0.4 km^2 (62% of total lake area) is covered by the moraine-dammed lakes in this basin (Table 5). About 23% area is covered by the other glacier erosion lake. There is no lake mapped in the cirque category in this basin (Fig. 10).

The Chandra basin

The Chandra basin is bounded by Bhaga on its west, Spiti in on

Table 5. *Glacier lake inventory of the Bhaga basin*.

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	15	12.0	218894	34.6	14593
	Lateral moraine-dammed lake	7	5.6	80867	12.8	11552
	Other moraine-dammed lake	26	20.8	93251	14.7	3587
Ice-dammed lake	Supra-glacial lake	40	32.0	50991	8.0	1275
	Glacier ice-dammed lake	2	1.6	2459	0.4	1229
Glacier erosion lake	Other glacier erosion lake	28	22.4	144103	22.7	5147
Other lakes	Debris-dammed lake	7	5.6	42904	6.8	6129
	Total	125		633470		

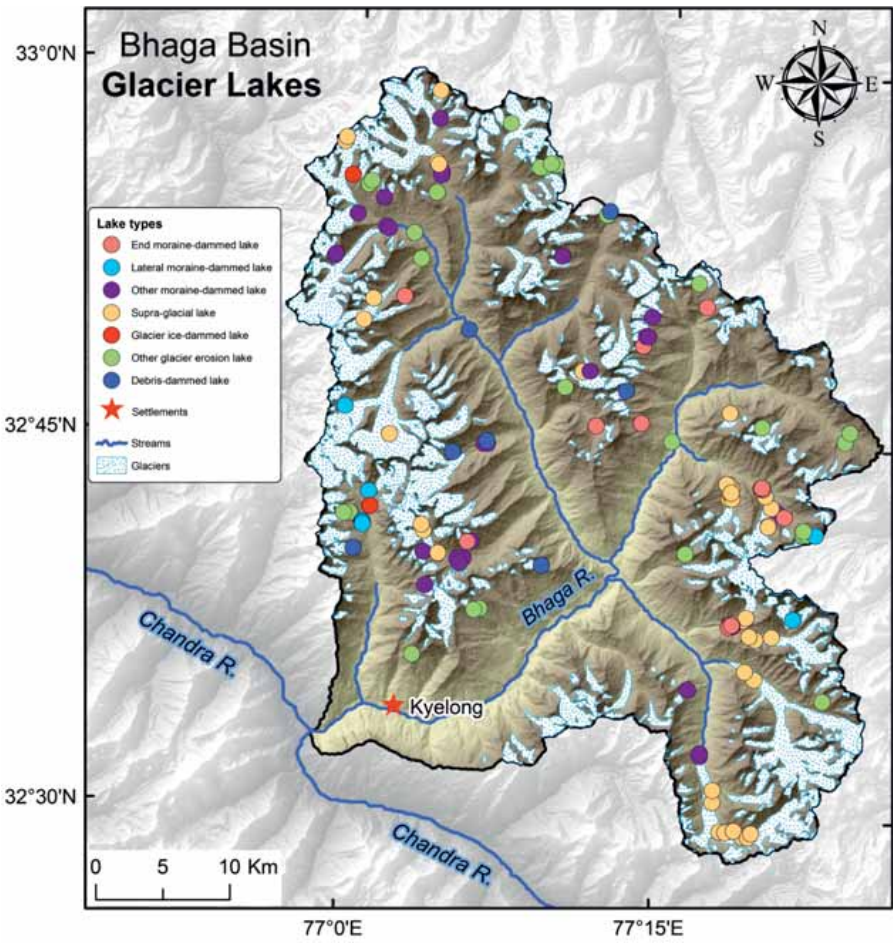

Fig. 10. Overview map of glacier lakes in the Bhaga basin.

its east, Zanskar in its north and Beas basins in its south. This basin consists of 60 lakes and maximum number (28) of these lakes belongs to moraine-dammed lake category (Table 6). This category covers 77% of the total lake area. The 9 other glacier erosion lakes cover ~18.5% area of total lakes whereas 20 supra-glacial lakes cover only 2.2 % area of total lakes (Fig. 11).

The Zanskar basin

The Zanskar basin shares northern boundary with Jammu and Kashmir, eastern, southern and western with Spiti, Chandra and Bhaga basins, respectively. This basin houses 16 lakes (Table 7). The two glacier erosion lakes cover maximum area (~48%) of lakes in the basin. The other moraine-dammed lakes are prominent glacier lakes in this basin and cover 50%

Table 6. *Glacier lake inventory of the Chandra basin.*

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	5	8.3	944209	34.8	188842
	Lateral moraine-dammed lake	2	3.3	3332	0.1	1666
	Medial moraine-dammed lake	1	1.7	16542	0.6	16542
	Other moraine-dammed lake	20	33.3	1138903	41.9	56945
Ice-dammed lake	Supra-glacial lake	20	33.3	60384	2.2	3019
	Glacier ice-dammed lake	1	1.7	911	0.0	911
Glacier erosion lake	Other glacier erosion lake	9	15.0	501596	18.5	55733
Other lakes	Debris-dammed lake	1	1.7	1107	0.0	1107
	Artificial lake	1	1.7	50157	1.8	50157
	Total	60		2717140		

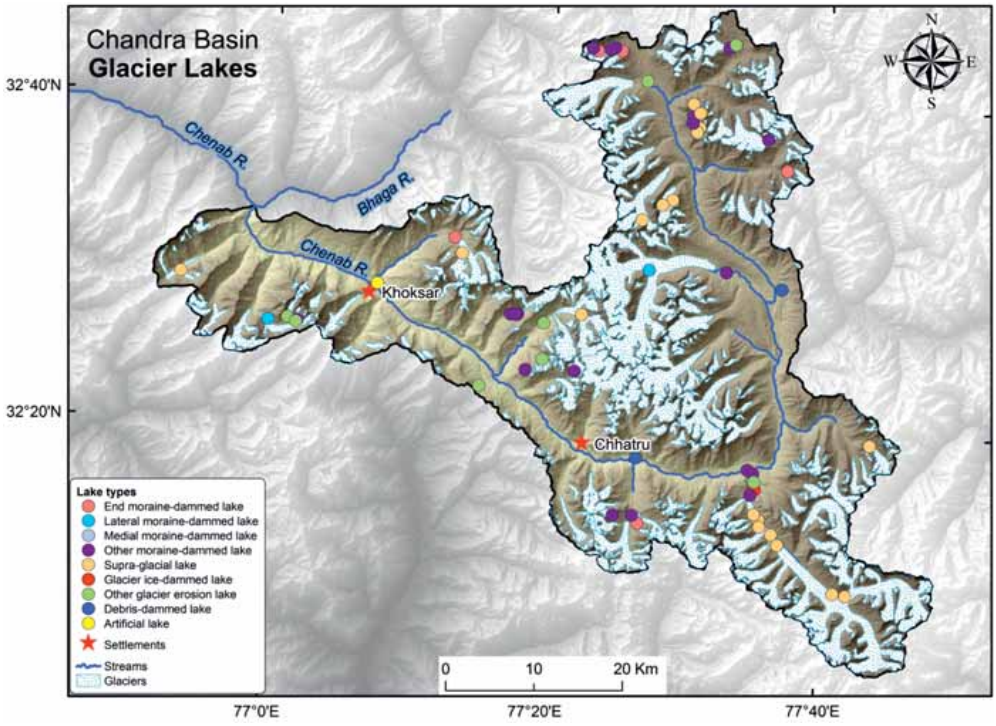

Fig. 11. Overview map of glacier lakes in the Chandra basin.

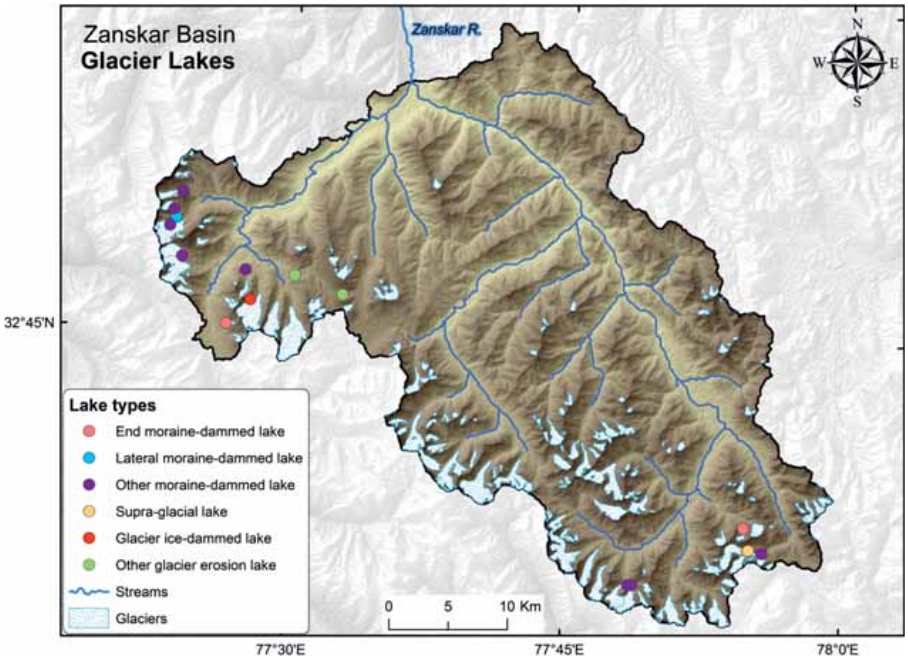

Fig. 12. Overview map of glacier lakes in the Zanskar basin.

of total number of glacier lakes but occupy ~25% area of total lakes (Fig. 12).

The Jahnvi Ganga basin

The Jahnvi Ganga basin shares western boundary with Baspa while maintaining eastern boundary with the Bhagirathi basin (Uttarakhand). Major part of Jahnvi Ganga basin is located and drained in the state of Uttarakhand. This basin comprises of 30 lakes. The maximum number of lakes is grouped under other moraine-dammed lake category (21), which covers

Table 7. *Glacier lake inventory of the Zanskar basin.*

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	2	12.5	21627	13.5	10814
	Lateral moraine-dammed lake	1	6.3	14490	9.1	14490
	Other moraine-dammed lake	8	50.0	40359	25.2	5045
Ice-dammed lake	Supra-glacial lake	2	12.5	3976	2.5	1988
	Glacier ice-dammed lake	1	6.3	2818	1.8	2818
Glacier erosion lake	Other glacier erosion lake	2	12.5	76634	47.9	38317
	Total	16		159905		

Table 8. *Glacier lake inventory of the Jahnvi Ganga basin.*

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	1	3.3	4563.76	19.0	4564
	Other moraine-dammed lake	21	70.0	6688	27.9	318
Ice-dammed lake	Supra-glacial lake	3	10.0	5958	24.9	1986
	Glacier ice-dammed lake	1	3.3	997	4.2	997
Glacier erosion lake	Other glacier erosion lake	3	10.0	4226	17.6	1409
Other lakes	Debris-dammed lake	1	3.3	1541	6.4	1541
	Total	30		23975		

~70%, of the total number of lakes but occupied only ~28% area (Table 8). About 47% area is covered by all the moraine-dammed lakes (Fig. 13).

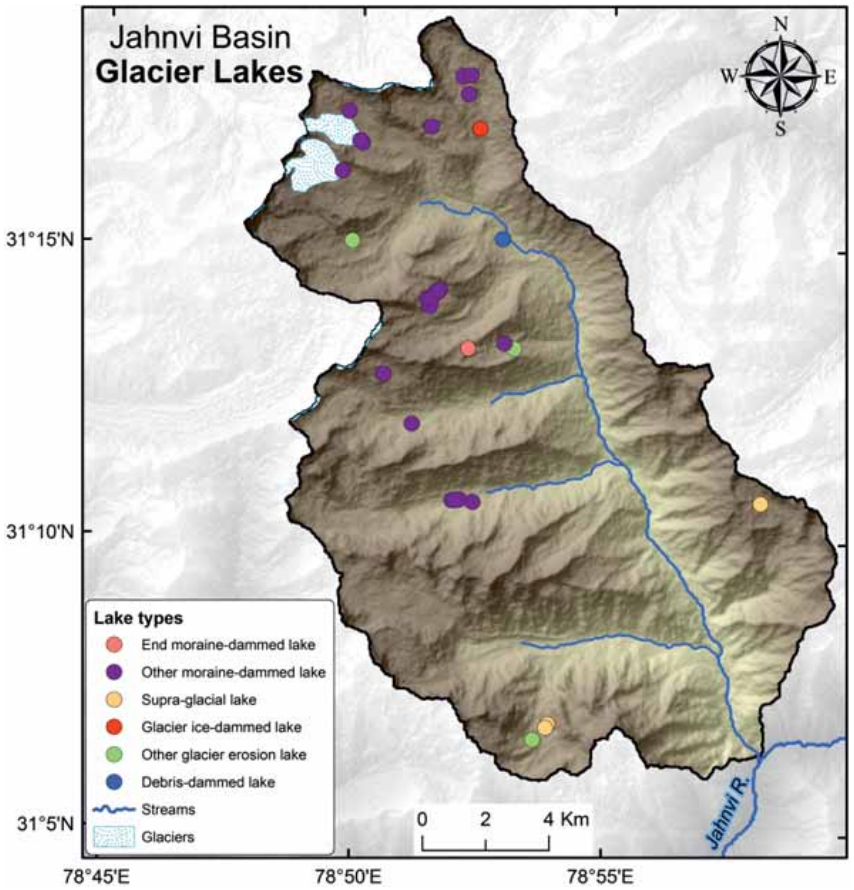

Fig. 13. Overview map of glacier lakes in the Jahnvi Ganga basin.

The Kurpan, Nogri, Kut, Soldan and Sorang-Wanger basins (Satluj)

The Kurpan, Nogri, Kut, Soldan and Sorang-Wanger basin (Satluj) is situated in between the Tons and Beas basins. It has 22 lakes; out of which10 are moraine-dammed lakes that cover ~84% of total glacier lake area (Table 9). The 9 other glacier erosion lakes cover only ~12% of the total glacier lake area (Fig. 14).

The Miyar basin

The Miyar basin is located in between the Bhaga and Saichu basins. The maximum number of glacier lakes are

Table 9. *Glacier lake inventory of the Kurpan, Nogri, Kut, Soldan and Sorang-Wanger basins* (*Satluj*).

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	1	0.5	37805	12.7	37805
	Lateral moraine-dammed lake	1	0.5	2749	0.9	2749
	Other moraine-dammed lake	8	3.6	209937	70.4	26242
Ice-dammed lake	Supra-glacial lake	2	0.9	5967	2.0	2983
Glacier erosion lake	Other glacier erosion lake	9	4.1	37163	12.5	4129
Other lakes	Artificial lake	1	0.5	4510	1.5	4510
	Total	22		298133		

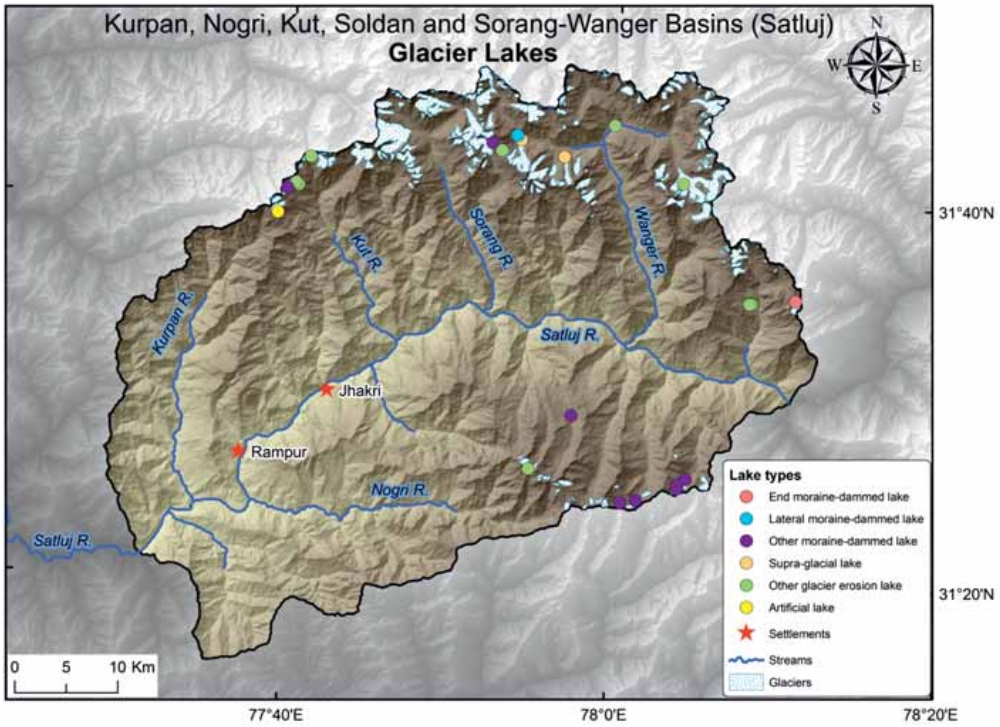

Fig. 14. Overview map of glacier lakes in the Kurpan, Nogri, Kut, Soldan and Sorang-Wanger basins (Satluj).

Table 10. *Glacier lake inventory of the Miyar basin*.

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	Lateral moraine-dammed lake	11	7.1	135884	25.0	12353
	Other moraine-dammed lake	32	20.5	142020	26.2	4438
Ice-dammed lake	Supra-glacial lake	83	53.2	155083	28.6	1868
	Glacier ice-dammed lake	7	4.5	12433	2.3	1776
Glacier erosion lake	Other glacier erosion lake	22	14.1	86544	15.9	3934
Other lakes	Debris-dammed lake	1	0.6	10790	2.0	10790
	Total	156		542755		

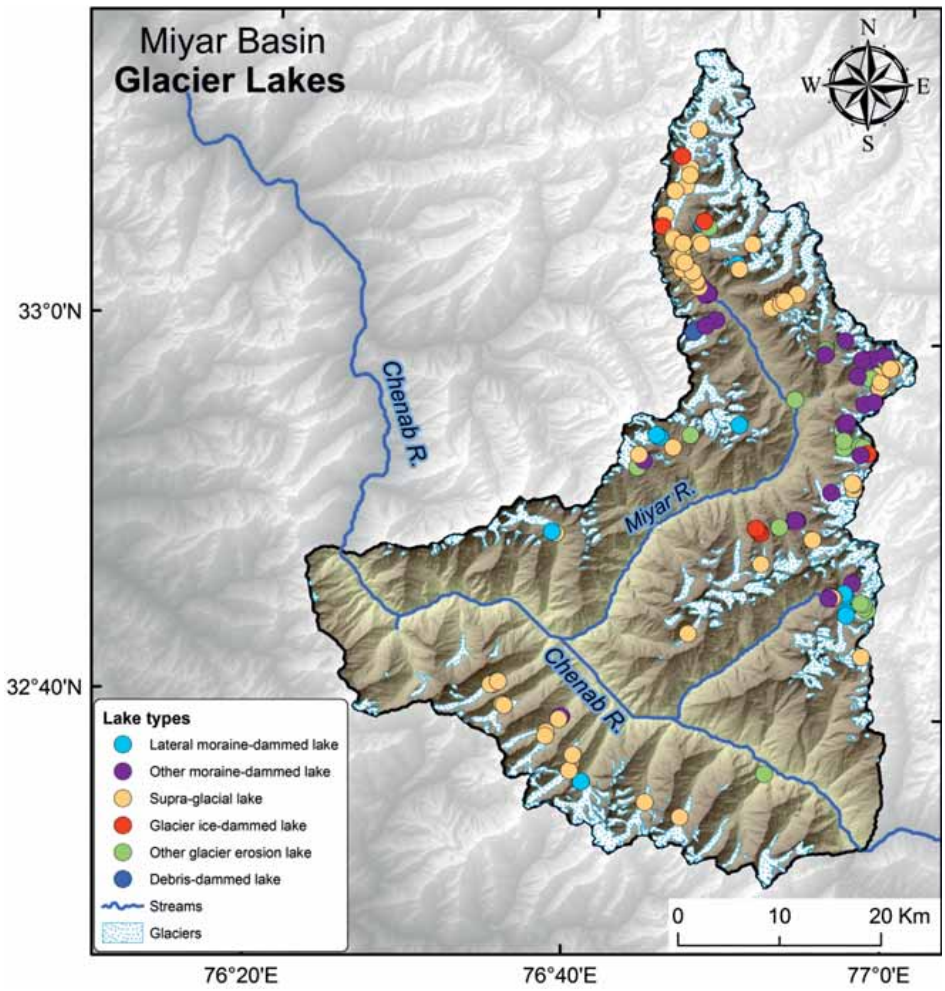

Fig. 15. Overview map of glacier lakes in the Miyar basin.

distributed in the Miyar basin (156 counts). Out of these, 83 are supra-glacial lakes, which cover ~29% of the total area (Fig. 15). The 43 moraine-dammed lakes cover ~51% of the total lake area (Table 10). The 22 other glacier erosion lakes cover ~16% of total lake area. Cirque lakes do not show any signature on satellite images in the Miyar basin.

The Parvati basin

The Parvati basin is bounded by Spiti in its east; Chandra in its north, Satluj in its south and Beas basins in its west. The Parvati is a tributary of the Beas River. This basin has 42 lakes and maximum lakes (26 counts) are grouped under other moraine-dammed lake category (Table 11). These lakes cover 32% of the total lake area whereas 10 other glacier erosion lakes cover 44% of the total lake area (Fig. 16).

Table 11. *Glacier lake inventory of the Parvati basin.*

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	1	2.4	104575	21.0	104575
	Lateral moraine-dammed lake	2	4.8	7656	1.5	3828
	Medial moraine-dammed lake	1	2.4	3584	0.7	3584
	Other moraine-dammed lake	26	61.9	157315	31.6	6051
Ice-dammed lake	Supra-glacial lake	1	2.4	1058	0.2	1058
	Glacier ice-dammed lake	1	2.4	2652	0.5	2652
Glacier erosion lake	Other glacier erosion lake	10	23.8	220478	44.3	22048
	Total	42		497317		

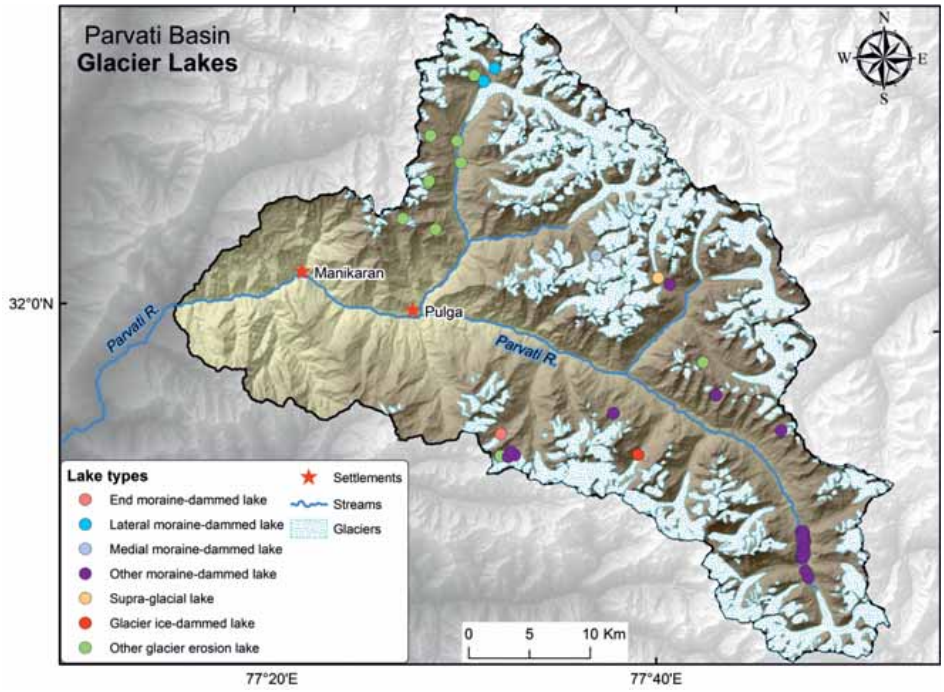

Fig. 16. Overview map of glacier lakes in the Parvati basin.

The Ravi and Budhil basins

The Ravi and Budhil basins consist of 127 lakes (Fig. 17). Out of this, 71 other glacier erosion lakes cover ~64% of total glacier lake area (Table 12). The 13 supra-glacial lakes cover

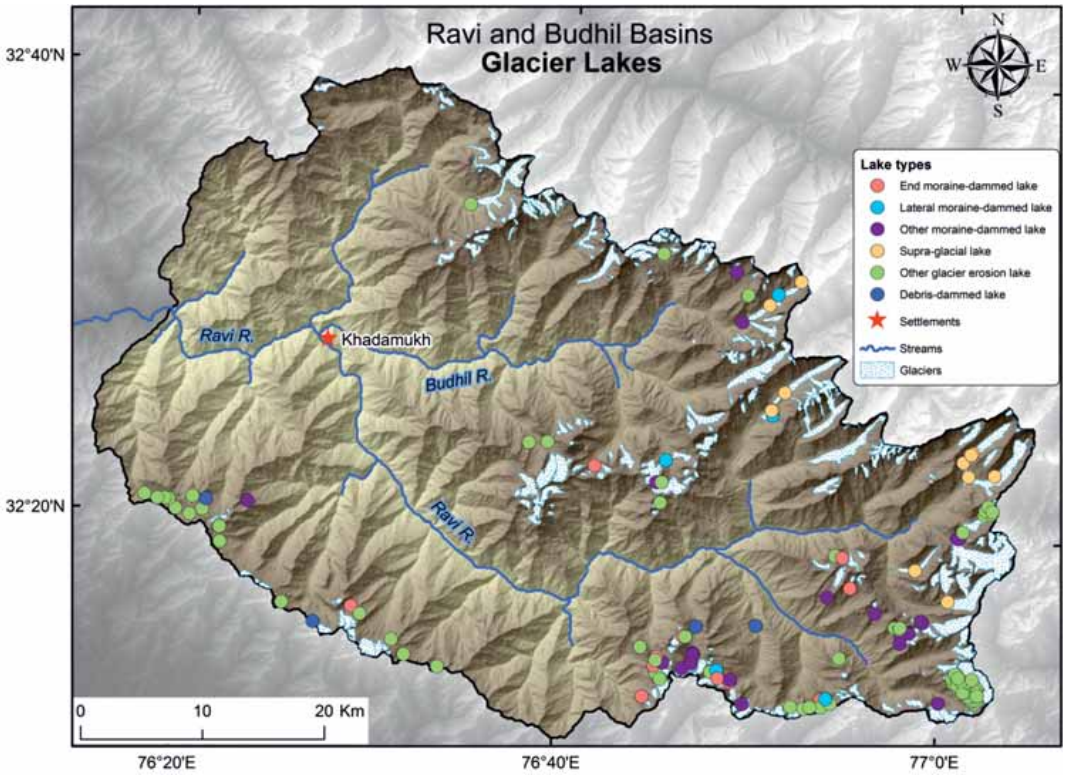

Fig. 17. Overview map of glacier lakes in the Ravi and Budhil basins.

Table 12. *Glacier lake inventory of the Ravi and Budhil basins.*

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	11	8.7	198066	15.4	18006
	Lateral moraine-dammed lake	5	3.9	41667	3.2	8333
	Other moraine-dammed lake	23	18.1	175580	13.6	7634
Ice-dammed lake	Supra-glacial lake	13	10.2	27473	2.1	2113
Glacier erosion lake	Other glacier erosion lake	71	55.9	823308	63.9	11596
Other lakes	Debris-dammed lake	4	3.1	22190	1.7	5548
	Total	127		1288283		

only ~2% of total lake area. Cirque lakes do not show any signature on satellite images in the Ravi and Budhil basins.

The Saichu basin

The Saichu basin is bounded by the state of Jammu Kashmir in its north and the Miyar basin in its south and east. The Saichu is a tributary of the Chenab River. This basin has 72 lakes and maximum lakes (33 counts) are occupied by other glacier erosion lake category (Table 13). This group covers 56% of the total lake area while 17 other moraine-dammed lakes cover only 3.3% of the total lake area (Fig. 18).

Table 13. *Glacier lake inventory of the Saichu basin.*

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	5	6.9	88917	26.5	17783
	Lateral moraine-dammed lake	5	6.9	14570	4.3	2914
	Other moraine-dammed lake	17	23.6	11018	3.3	648
Ice-dammed lake	Supra-glacial lake	12	16.7	32021	9.5	2668
Glacier erosion lake	Other glacier erosion lake	33	45.8	189549	56.4	5744
	Total	72		36075		

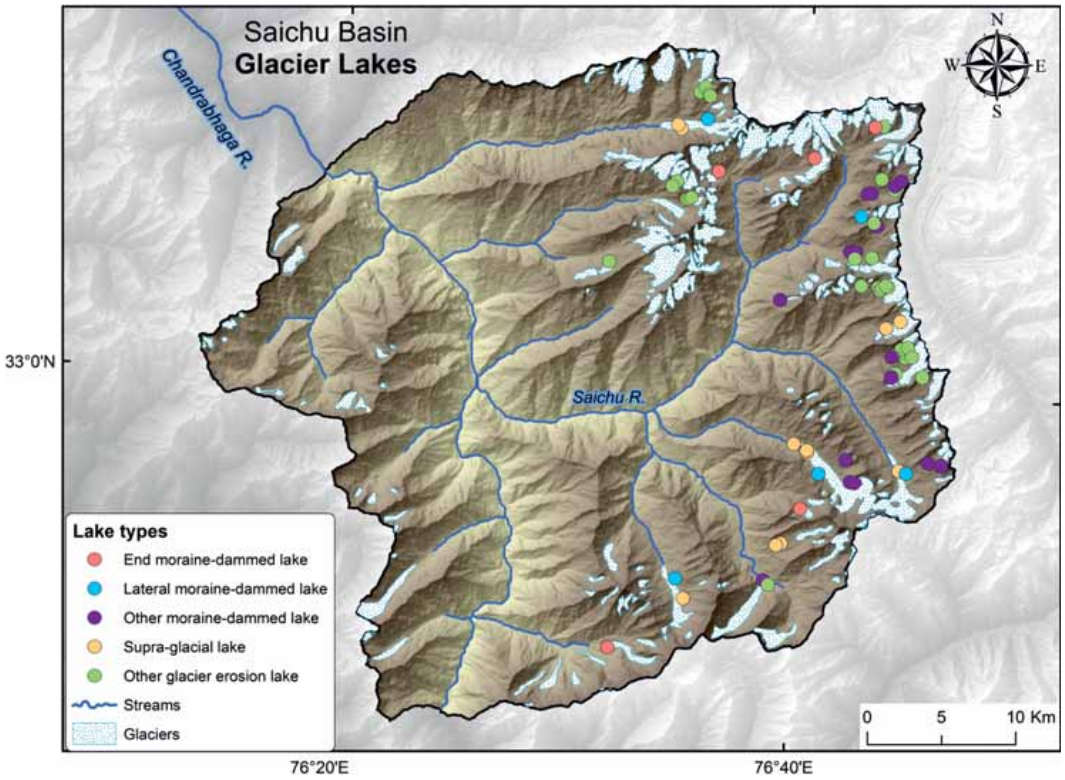

Fig. 18. Overview map of glacier lakes in the Saichu basin.

The Siul basin

The Siul basin shares western boundary with the state of Jammu and Kashmir while maintaining eastern boundary with the Ravi basin. This basin comprises only 06 lakes. The maximum number of lakes is grouped under other glacier erosion lake category (04), which covers only ~8%, of the total area of lakes (Table 14). About 53% area is covered by single end moraine-dammed lake (Fig. 19).

The Spiti basin

The Spiti basin is bounded by the Indo-China international boundary on its eastern margin, Jammu and Kashmir on its north and northwest, Chandra and Parvati on its western and Baspa on its southern margin. This basin contains 77 lakes. Out of this, the maximum number of lakes is mapped in moraine-dammed lakes (25 counts) category and they occupy ~53% of total glacier lake area (Fig. 20). Other glacier erosion lakes cover ~25% of total glacier lake area in this basin (Table 15).

Table 14. *Glacier lake inventory of the Siul basin.*

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	1	16.7	47297	52.8	47297
Glacier erosion lake	Other glacier erosion lake	4	66.7	7617	8.5	1904
Other lakes	Debris-dammed lake	1	16.7	34604	38.7	34604
	Total	6		89518		

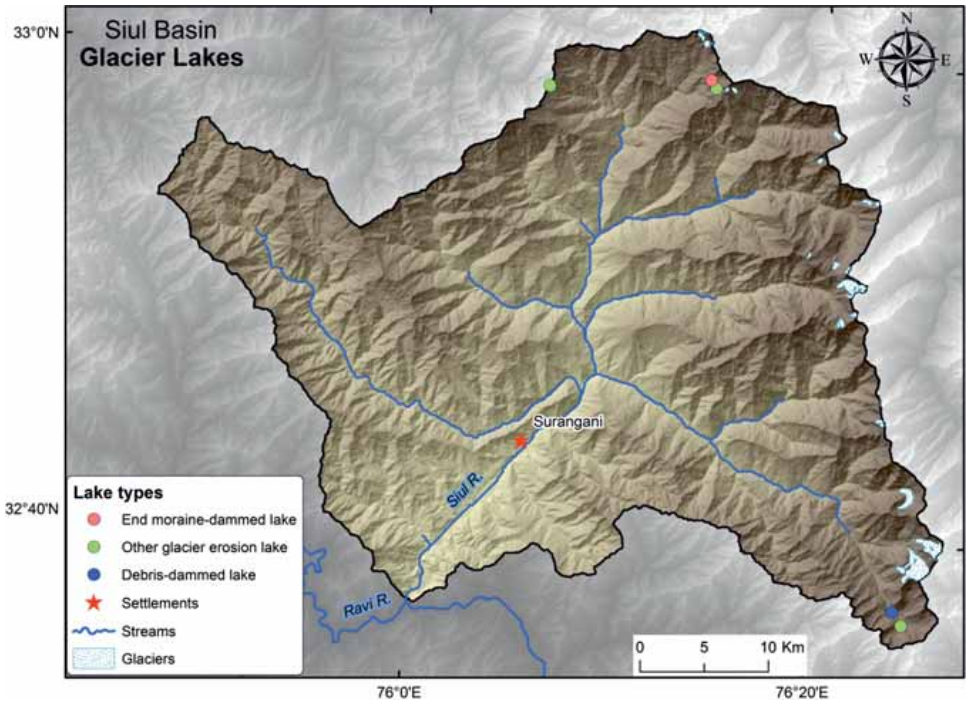

Fig. 19. Overview map of glacier lakes in the Siul basin.

Table 15. *Glacier lake inventory of the Spiti basin.*

Main type	Type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	End moraine-dammed lake	12	15.6	262543	45.3	21879
	Medial moraine-dammed lake	1	1.3	1213	0.2	1213
	Other moraine-dammed lake	12	15.6	48539	8.4	4045
Ice-dammed lake	Supra-glacial lake	14	18.2	30992	5.3	2214
	Glacier ice-dammed lake	3	3.9	10980	1.9	3660
Glacier erosion lake	Other glacier erosion lake	19	24.7	141868	24.5	7467
Other lakes	Debris-dammed lake	10	13.0	62935	10.9	6294
	Artificial lake	6	7.8	20816	3.6	3469
	Total	77		579885		

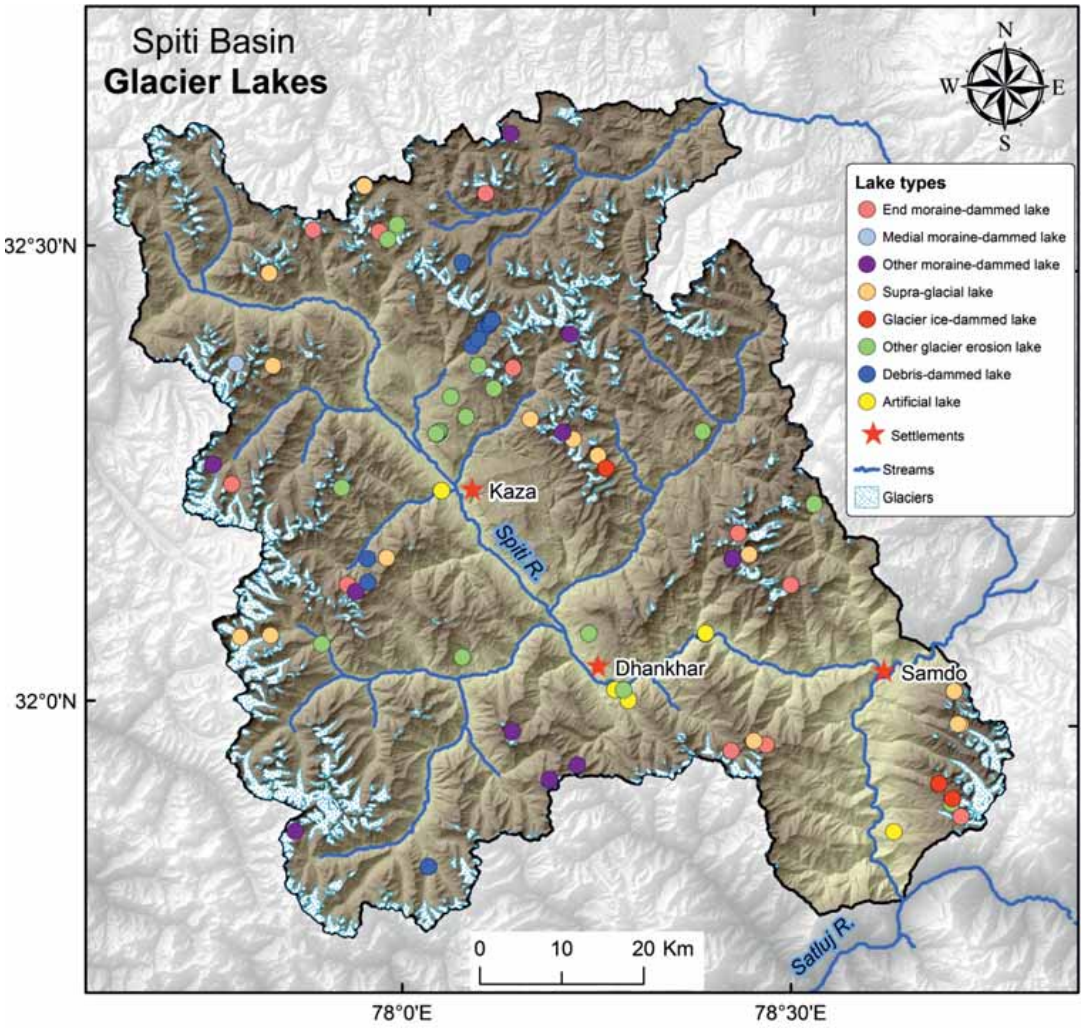

Fig. 20. Overview map of glacier lakes in the Spiti basin.

The Tons basin

The Tons basin shares western boundary with the Sutluj River while maintaining eastern boundary with the Yamuna basin (Uttarakhand). The Tons is the tributary of Yamuna River. Major part of the Tons basin is located and drained in Uttarakhand. This basin comprises of 11 lakes. The maximum number of lakes are grouped under other glacier erosion lake category (06), which cover ~55%, of the total number of lakes occupying ~50% area (Table 16). About 49% area is covered by all the cirque lakes (Fig. 21).

DISCUSSION

Overall, 958 glacier lakes (size > 500 m^2) were identified in Himachal Pradesh from satellite images (2011-2013) covering an area of 9.6±0.3 km^2 (Annexure 1). We also arranged glacier lake inventory using minimum size of lakes >0.01km^2 to compare with previous studies. The result suggests 174 lakes (size > 0.01km^2) covering an area of 7.5±0.3 km^2 in our glacier lake database. However, previous studies by Worni *et al.* (2013) reported only 45 glacier lakes (size > 0.01km^2), and Bhagat *et al.* (2004) identified 156 lakes in the same region

Table 16. *Glacier lake inventory of the Tons basin.*

Main type	Sub type	Total number	%	Total area (m^2)	%	Mean area (m^2)
Moraine-dammed lake	Other moraine-dammed lake	1	9.1	1250	0.3	1250
Glacier erosion lake	Cirque lake	4	36.4	231977	49.5	57994
	Other glacier erosion lake	6	54.5	235546	50.2	39258
	Total	11		468773		

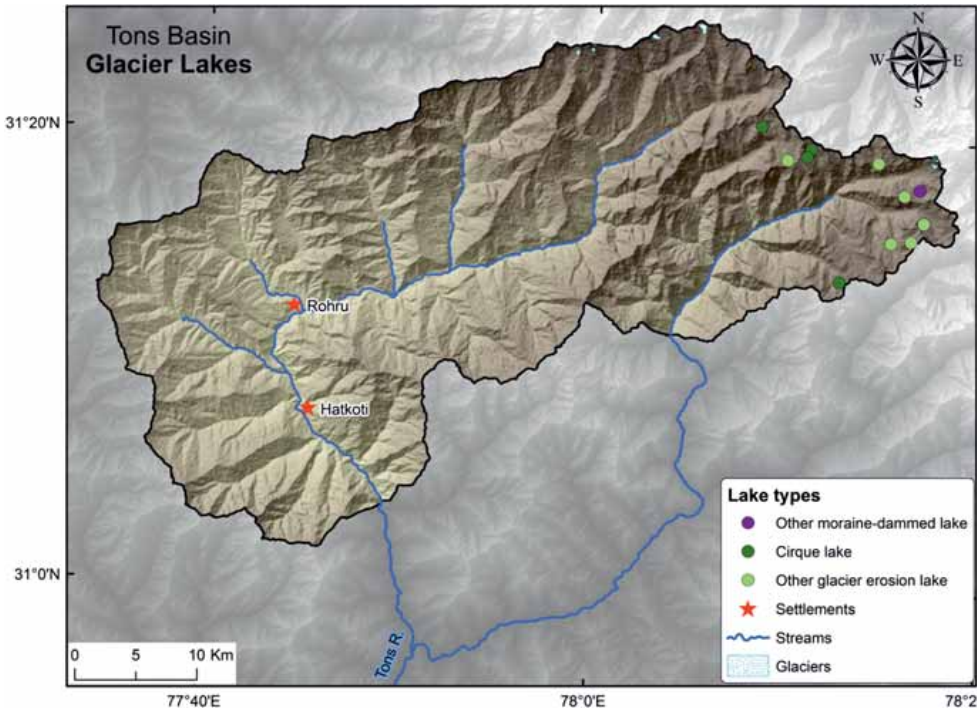

Fig. 21. Overview map of glacier lakes in the Tons basin.

Table 17. *Glacier inventory studies in the Indian Himalaya.*

S.No.	Study	Minimum size of lakes (km^2)	Satellite/Sensor resolution (m)	Area	No of lakes	Area (km^2)
1.	Bhagat *et al.* (2004)	-	IRS1D LISS3/23.5	Himachal Pradesh	156	385.22
2.	Randhawa & Sharma (2014)	0.05	Resourcesat-2 LISS III/23.5	Himachal Pradesh	779	-
3.	Worni *et al*. (2013)	0.01	Landsat ETM+/30	Himachal Pradesh	45	-
4.	Present study	0.01	Resourcesat-2 LISS IV/5	Himachal Pradesh	147	5.12
5.	Present study	0.0005	Resourcesat-2 LISS IV/5	Himachal Pradesh	958	9.6
6.	Gardelle *et al*. (2010)	0.0036	Landsat ETM+/30	Hindu Kush Himalaya	-	-
7.	Nie *et al*.(2013)	0.0081	Landsat ETM+/30	Central Himalaya	-	-

(Table17). This difference can be attributed to utilization of medium resolution Landsat ETM+ and IRS 1D LISS3 satellite images (cell size 30 and 23.5 m) by the previous studies. In addition, shadow and cloud cover have been identified as major challenges to identify glacier lakes on satellite images (e.g. Frey*et al*. 2012). Therefore, we overlaid glacier lake outlines derived from Resourcesat-2 LISS IV data on Landsat 8 to ensure complete coverage. In the present study out of 958 lakes, we mapped only 62 glacier lakes from Landsat 8 multispectral and panchromatic images (Annexure 1) and remaining from the Resourcesat-2 LISS IV images.

The selection of minimum size of glacier lake depends mainly on the spatial resolution of utilized satellite data. There are no standards available in the literature for the selection of thresholds for any minimum size of glacial lake. Previous studies on glacier lake mapping of the Himalaya based on Landsat TM/ETM+ (cell size 30 m) images have proposed threshold for minimum size of lake boundaries such as 3600 m^2 (0.0036 km^2) (Gardelle *et al*. 2010). In addition, Worni *et al*. (2013) and Nie *et al*. (2013) have used 10,000 m^2 (0.01km^2) and 8100 m^2 (0.0081 km^2) respectively for minimum size of lake. In the present study high resolution satellite data (cell size 5 m) were used and 500 m^2 (0.0005 km^2) was selected as minimum size of lake. The selection of this threshold is justified by the fact that small supra-glacial ponds usually join together to form a much larger lake in due course of time (e.g., Khumbu Glacier) (Bolch *et al*. 2008; Benn *et al*. 2012). The mapping of small lakes will facilitate to monitor the evolution process of these lakes in years to come.

Glacier lake classification (type) is essential to know the position, source and processes involved in the formation and evolution of a lake. Previous studies classified glacier lakes into erosion, valley, cirque, blocked, moraine-dammed (lateral moraine-dammed lake), and supra-glacial lakes (e.g. Bhagat *et al.* 2004). In this study, the classification of glacier lake type is based on the combination of two criteria: (1)

glacier process and (2) location of lakes. However, blocked lakes can be formed by the tributary glacier blocking the main valley glacier, and by snow avalanche and/or landslides damming. Therefore, this category can misclassify moraine-dammed, ice-dammed and debris-dammed lakes as blocked lakes. Randhawa and Sharma (2014) identified 779 lakes in Himachal Pradesh and referred all the lakes as moraine-dammed lake. This study also included lakes situated in Tibet. Conversely, our study included only lakes located in Himachal Pradesh. We adopted ICIMOD (2011) and Bhambri *et al.* (2015) classification of glacier lake scheme with slight modifications and classified lakes based on glacier process in four broad categories: (1) moraine-dammed lakes, (2) ice-dammed lakes, (3) glacier erosion lakes and (4) other glacial lakes. Our study mapped semi-automatically glacier lakes in the study area using band ratio of LISS band 1/LISS band 3 (GREEN/NIR). The use of Green band of Resourcesat-2 LISS-IV in the absence of blue was appeared to be very useful for automatic extraction of glacier lakes. However, shadow and walls of ice cliff of supra-glacial lakes get misclassified as glacier lakes. The fresh snow also generated problem to discriminate glacier lakes from snow covered glaciers using automatic classification. We visually checked and manually improved the resultant glacier lakes to eliminate misclassified seasonal snow cover, shadow areas and walls of ice cliff (Fig. 2).

CONCLUSIONS

Our inventory of 958 glacier lakes (size > 500 m^2) of Himachal Pradesh (covering an area of 9.6±0.3 km^2) using Resourcesat-2 LISS-IV satellite images not only fills gaps in the Himalayan glacier lake database but also supports further detailed studies related to lake area changes with time. Out of the 958 glacier lakes, 345 have been classified as moraine-dammed lakes (end moraine-dammed, lateral moraine-dammed, medial moraine-dammed, other moraine-dammed), having a total area of 5.1±0.2 km^2 (53.1 % of the total glacier lake area). The minimum number of glacier lakes are occupied by the other lake group (38 counts and total area of 0.7±0.02 km^2) (i.e., debris-dammed lake, artificial lakes). Altitudinal distribution of glacier lakes in Himachal Pradesh varies from 3001 m to 5614 m. An artificial lake, (Sissu lake, 1900±66 m^2) is mapped at the minimum elevation (~3100 m) in the Chandra basin. A supra-glacial lake in the Spiti basin shows maximum mean elevation in the study area (5614 m). The largest lake classified as *other* moraine-dammed lake (1.0±0.03km^2) is located at front of the Samudra Tapu Glacier in the Chandra basin. The maximum number of glacier lakes are seen in the Miyar basin (156 counts), whereas minimum lakes are seen in the Siul basin (06). The maximum area of glacier lakes is distributed in the Chandra basin (2.7±0.09 km^2).

The present inventory has great socio-economic importance as it will contribute valuable information to evolve policy framework for disaster management and mitigation in the Himachal Pradesh. The data base of lakes (e.g. supra-glacial lakes) will help to understand the dynamics of glaciers. The inventory will also provide reference data base to quantify impact of climate change on glacier recession and expansion of glacial lake in the region and will allow to identify potentially dangerous lakes in the state using ground investigations.

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Annexure 1

Glacier lake inventory of Himachal Pradesh by Rakesh Bhambri *et al.* 2018 (this issue)

GLIMS lake ID	GSI basin ID	Lake name	Lake type	Longitude	Latitude	Basin(s)	Mean Elevation (m)	Area (m^2)	Satellite/ Sensor	Satellite acquisition date
G078751E31553N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.751	31.553	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5301	63534	RS 2/LISS IV	20.09.2013
G078762E31658N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.762	31.658	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5423	11738	RS 2/LISS IV	20.09.2013
G078750E31661N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.750	31.661	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5462	4060	RS 2/LISS IV	20.09.2013
G078742E31678N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.742	31.678	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5568	3024	RS 2/LISS IV	01.10.2011
G078722E31366N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.722	31.366	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5266	2895	RS 2/LISS IV	20.09.2013
G078724E31363N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.724	31.363	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5261	2937	RS 2/LISS IV	20.09.2013
G078704E31360N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.704	31.360	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5074	5650	RS 2/LISS IV	20.09.2013
G078703E31359N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.703	31.359	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5081	1217	RS 2/LISS IV	20.09.2013
G078718E31336N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.718	31.336	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5231	3118	RS 2/LISS IV	20.09.2013
G078717E31339N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.717	31.339	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5265	1916	RS 2/LISS IV	20.09.2013
G078702E31326N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.702	31.326	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5282	3623	RS 2/LISS IV	20.09.2013
G078669E31366N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.669	31.366	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4774	897	RS 2/LISS IV	20.09.2013
G078744E31379N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.744	31.379	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5194	1421	RS 2/LISS IV	20.09.2013
G078747E31373N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.747	31.373	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5236	935	RS 2/LISS IV	20.09.2013
G078760E31322N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.760	31.322	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5240	10370	RS 2/LISS IV	20.09.2013
G078757E31321N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.757	31.321	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5239	6311	RS 2/LISS IV	20.09.2013
G078758E31322N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.758	31.322	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5211	4819	RS 2/LISS IV	20.09.2013
G078756E31326N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.756	31.326	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5180	2389	RS 2/LISS IV	20.09.2013
G078756E31324N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.756	31.324	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5225	1944	RS 2/LISS IV	20.09.2013
G078785E31275N	5Q22213,14,15,17,18	-	Lateral moraine-dammed lake	78.785	31.275	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5324	3589	RS 2/LISS IV	20.09.2013
G078804E31294N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.804	31.294	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5398	2510	RS 2/LISS IV	20.09.2013
G078799E31299N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.799	31.299	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	476	1854	RS 2/LISS IV	20.09.2013
G078806E31289N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.806	31.289	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	353	926	RS 2/LISS IV	20.09.2013
G078697E31225N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.697	31.225	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4327	62189	RS 2/LISS IV	20.09.2013
G078704E31221N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.704	31.221	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4391	1467	RS 2/LISS IV	20.09.2013
G078723E31206N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.723	31.206	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4561	1970	RS 2/LISS IV	20.09.2013
G078788E31216N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.788	31.216	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5188	2114	RS 2/LISS IV	20.09.2013
G078615E31249N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.615	31.249	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5002	1782	RS 2/LISS IV	20.09.2013
G078616E31252N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.616	31.252	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4964	606	RS 2/LISS IV	20.09.2013
G078474E31253N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.474	31.253	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4485	3623	RS 2/LISS IV	20.09.2013
G078477E31258N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.477	31.258	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4425	961	RS 2/LISS IV	20.09.2013
G078476E31248N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.476	31.248	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4529	748	RS 2/LISS IV	20.09.2013
G078600E31574N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.600	31.574	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4870	2770	RS 2/LISS IV	20.09.2013
G078601E31575N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.601	31.575	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4864	4035	RS 2/LISS IV	20.09.2013
G078602E31575N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.602	31.575	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4859	3808	RS 2/LISS IV	20.09.2013
G078601E31576N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.601	31.576	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4859	1093	RS 2/LISS IV	20.09.2013
G078609E31564N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.609	31.564	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5076	1784	RS 2/LISS IV	20.09.2013
G078653E31484N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.653	31.484	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4839	1783	RS 2/LISS IV	20.09.2013
G078668E31360N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.668	31.360	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4865	1174	RS 2/LISS IV	20.09.2013
G078583E31360N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.583	31.360	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4754	1112	RS 2/LISS IV	20.09.2013
G078580E31367N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.580	31.367	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4680	852	RS 2/LISS IV	20.09.2013
G078581E31374N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.581	31.374	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4631	1449	RS 2/LISS IV	20.09.2013
G078581E31364N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.581	31.364	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4705	1328	RS 2/LISS IV	20.09.2013
G078547E31324N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.547	31.324	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4668	644	RS 2/LISS IV	20.09.2013
G078818E31218N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.818	31.218	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5116	2631	RS 2/LISS IV	20.09.2013
G078753E31557N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.753	31.557	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5308	1116	RS 2/LISS IV	20.09.2013
G078709E31660N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.709	31.660	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5145	664	RS 2/LISS IV	20.09.2013
G078710E31556N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.710	31.556	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5100	3796	RS 2/LISS IV	20.09.2013
G078718E31531N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.718	31.531	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5227	6171	RS 2/LISS IV	20.09.2013
G078733E31358N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.733	31.358	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5313	1313	RS 2/LISS IV	20.09.2013
G078747E31363N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.747	31.363	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5378	622	RS 2/LISS IV	20.09.2013
G078732E31342N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.732	31.342	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5330	2432	RS 2/LISS IV	20.09.2013
G078627E31315N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.627	31.315	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5173	1796	RS 2/LISS IV	20.09.2013
G078479E31267N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.479	31.267	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4325	2463	RS 2/LISS IV	20.09.2013
G078678E31363N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.678	31.363	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4843	754	RS 2/LISS IV	20.09.2013
G078682E31346N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.682	31.346	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4969	596	RS 2/LISS IV	20.09.2013
G078168E31661N	5Q22213,14,15,17,18	-	End moraine-dammed lake	78.168	31.661	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4259	178521	RS 2/LISS IV	20.10.2011
G078382E31523N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.382	31.523	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5231	19221	RS 2/LISS IV	02.12.2011
G078448E31461N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.448	31.461	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4744	1614	RS 2/LISS IV	02.12.2011
G078233E31336N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.233	31.336	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4570	3260	RS 2/LISS IV	02.12.2011
G078681E31345N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.681	31.345	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4975	1184	RS 2/LISS IV	20.09.2013
G078329E31315N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.329	31.315	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4401	2854	RS 2/LISS IV	02.12.2011
G078329E31312N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.329	31.312	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4404	11996	RS 2/LISS IV	02.12.2011
G078326E31311N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.326	31.311	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4426	2912	RS 2/LISS IV	02.12.2011
G078328E31309N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.328	31.309	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4404	2823	RS 2/LISS IV	02.12.2011
G078326E31310N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.326	31.310	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4407	1133	RS 2/LISS IV	02.12.2011
G078329E31311N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.329	31.311	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4403	2859	RS 2/LISS IV	02.12.2011
G078328E31314N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.328	31.314	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4401	4503	RS 2/LISS IV	02.12.2011
G078328E31312N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.328	31.312	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4403	1012	RS 2/LISS IV	02.12.2011
G078327E31313N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.327	31.313	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4402	1305	RS 2/LISS IV	02.12.2011
G078329E31313N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.329	31.313	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4402	860	RS 2/LISS IV	02.12.2011
G078330E31313N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.330	31.313	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4402	713	RS 2/LISS IV	02.12.2011
G078327E31312N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.327	31.312	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4402	938	RS 2/LISS IV	02.12.2011
G078753E31666N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.753	31.666	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5524	2131	RS 2/LISS IV	11.09.2013
G078577E31437N	5Q22213,14,15,17,18	-	Debris-dammed lake	78.577	31.437	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	3564	1332	RS 2/LISS IV	02.12.2011

GLIMS lake ID	GSI basin ID	Lake name	Lake type	Longitude	Latitude	Basin(s)	Mean Elevation (m)	Area (m^2)	Satellite/ Sensor	Satellite acquisition date
G078235E31398N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.235	31.398	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	3382	2591	RS 2/LISS IV	13.11.2011
G078420E31403N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.420	31.403	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5029	19992	LANDSAT/OLI	08.09.2015
G078124E31740N	5Q22213,14,15,17,18	-	End moraine-dammed lake	78.124	31.740	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4791	24692	RS 2/LISS IV	20.10.2011
G078126E31737N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.126	31.737	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4855	1184	RS 2/LISS IV	20.10.2011
G078314E31767N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.314	31.767	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5028	6520	RS 2/LISS IV	20.10.2011
G078216E31871N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.216	31.871	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5078	1686	RS 2/LISS IV	20.10.2011
G078214E31869N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.214	31.869	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5110	897	RS 2/LISS IV	20.10.2011
G078738E31676N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.738	31.676	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5564	639	RS 2/LISS IV	01.10.2011
G078767E31669N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.767	31.669	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5541	832	RS 2/LISS IV	01.10.2011
G078747E31657N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.747	31.657	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5454	858	RS 2/LISS IV	01.10.2011
G078634E31518N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.634	31.518	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4975	2213	RS 2/LISS IV	01.10.2011
G078675E31474N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.675	31.474	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5086	1233	RS 2/LISS IV	01.10.2011
G078673E31479N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.673	31.479	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5048	690	RS 2/LISS IV	01.10.2011
G078754E31400N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.754	31.400	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5296	650	RS 2/LISS IV	01.10.2011
G078745E31376N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.745	31.376	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5212	1735	RS 2/LISS IV	01.10.2011
G078744E31376N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.744	31.376	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5206	1040	RS 2/LISS IV	01.10.2011
G078742E31378N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.742	31.378	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5221	1026	RS 2/LISS IV	01.10.2011
G078734E31359N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.734	31.359	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5313	1600	RS 2/LISS IV	01.10.2011
G078733E31361N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.733	31.361	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5316	2976	RS 2/LISS IV	01.10.2011
G078708E31352N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.708	31.352	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5197	1000	RS 2/LISS IV	01.10.2011
G078581E31372N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.581	31.372	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4650	4879	RS 2/LISS IV	01.10.2011
G078581E31368N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.581	31.368	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4685	2551	RS 2/LISS IV	01.10.2011
G078562E31320N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.562	31.320	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5264	1952	RS 2/LISS IV	01.10.2011
G078575E31318N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.575	31.318	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5289	3901	RS 2/LISS IV	01.10.2011
G078713E31299N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.713	31.299	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4572	841	RS 2/LISS IV	20.09.2013
G078615E31248N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.615	31.248	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5001	1586	RS 2/LISS IV	01.10.2011
G078681E31354N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.681	31.354	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4920	911	RS 2/LISS IV	01.10.2011
G078664E31333N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.664	31.333	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5242	7472	RS 2/LISS IV	01.10.2011
G078714E31212N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.714	31.212	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4490	1139	RS 2/LISS IV	01.10.2011
G078725E31203N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.725	31.203	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4576	1016	RS 2/LISS IV	01.10.2011
G078757E31353N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.757	31.353	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5385	5823	RS 2/LISS IV	01.10.2011
G078731E31350N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.731	31.350	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5325	862	RS 2/LISS IV	01.10.2011
G078679E31363N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.679	31.363	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4823	1054	RS 2/LISS IV	01.10.2011
G078680E31362N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.680	31.362	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4835	1986	RS 2/LISS IV	01.10.2011
G078744E31376N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.744	31.376	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5206	635	RS 2/LISS IV	01.10.2011
G078626E31313N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.626	31.313	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5163	1166	RS 2/LISS IV	20.09.2013
G078795E31297N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.795	31.298	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5472	10759	RS 2/LISS IV	01.10.2011
G078293E31779N	5Q22213,14,15,17,18	-	End moraine-dammed lake	78.293	31.779	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4968	3817	RS 2/LISS IV	20.10.2011
G078696E31325N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.696	31.325	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5232	637	RS 2/LISS IV	20.09.2013
G078753E31559N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.753	31.559	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5310	1006	RS 2/LISS IV	01.10.2011
G078694E31525N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.694	31.525	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5256	1340	RS 2/LISS IV	01.10.2011
G078705E31358N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.705	31.358	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5084	554	RS 2/LISS IV	01.10.2011
G078677E31354N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.677	31.354	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4927	559	RS 2/LISS IV	01.10.2011
G078663E31355N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.663	31.355	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4911	1494	RS 2/LISS IV	20.09.2013
G078697E31325N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.697	31.325	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5231	745	RS 2/LISS IV	01.10.2011
G078550E31241N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.550	31.241	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5286	1137	RS 2/LISS IV	01.10.2011
G078252E31339N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.252	31.339	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4730	47108	LANDSAT/OLI	08.09.2015
G078254E31340N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.254	31.340	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4691	33658	LANDSAT/OLI	08.09.2015
G078163E31371N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.163	31.371	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4723	31318	LANDSAT/OLI	08.09.2015
G078489E31401N	5Q22213,14,15,17,18	Lalan Ti	Other moraine-dammed lake	78.489	31.401	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4723	19114	LANDSAT/OLI	08.09.2015
G078409E31438N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.409	31.438	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5091	13485	LANDSAT/OLI	08.09.2015
G078305E31790N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.305	31.790	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5221	14759	LANDSAT/OLI	08.09.2015
G078399E31732N	5Q22213,14,15,17,18	-	Glacier ice-dammed lake	78.399	31.732	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4820	24168	LANDSAT/OLI	08.09.2015
G078369E31458N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.369	31.458	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4811	12358	LANDSAT/OLI	08.09.2015
G078410E31412N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.410	31.412	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5033	7131	LANDSAT/OLI	08.09.2015
G078104E31778N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.104	31.778	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4740	7356	LANDSAT/OLI	08.08.2015
G078102E31778N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.102	31.778	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4705	5808	LANDSAT/OLI	08.09.2015
G078736E31542N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.736	31.542	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5343	9600	RS 2/LISS IV	20.09.2013
G078738E31545N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.738	31.545	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	5314	4886	RS 2/LISS IV	20.09.2013
G078298E31294N	5Q22213,14,15,17,18	-	Other glacier erosion lake	78.298	31.294	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4879	4710	RS 2/LISS IV	02.11.2013
G078326E31307N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.326	31.307	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4432	2909	RS 2/LISS IV	02.12.2011
G078329E31310N	5Q22213,14,15,17,18	-	Other moraine-dammed lake	78.329	31.310	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4404	1371	RS 2/LISS IV	02.12.2011
G078305E31358N	5Q22213,14,15,17,18	-	Supra-glacial lake	78.305	31.358	Baspa, Tirung, Tagla, Ropa, Taiti and Hojis	4841	5221	LANDSAT/OLI	08.09.2015
G077298E32157N	5Q22108	-	End moraine-dammed lake	77.298	32.157	Beas basin	4393	67862	RS 2/LISS IV	15.10.2011
G077296E32157N	5Q22108	-	End moraine-dammed lake	77.296	32.157	Beas basin	4393	4066	RS 2/LISS IV	15.10.2011
G077307E32161N	5Q22108	-	End moraine-dammed lake	77.307	32.161	Beas basin	4547	30350	RS 2/LISS IV	15.10.2011
G077306E32159N	5Q22108	-	End moraine-dammed lake	77.306	32.159	Beas basin	4567	2666	RS 2/LISS IV	15.10.2011
G076788E32222N	5Q22108	-	Cirque lake	76.788	32.222	Beas basin	4572	67396	RS 2/LISS IV	15.10.2011
G077070E32187N	5Q22108	-	Other moraine-dammed lake	77.070	32.187	Beas basin	4326	6503	RS 2/LISS IV	15.10.2011
G077028E32202N	5Q22108	-	Other glacier erosion lake	77.028	32.202	Beas basin	4580	5142	RS 2/LISS IV	15.10.2011
G076780E32221N	5Q22108	-	Other glacier erosion lake	76.780	32.221	Beas basin	4569	35956	RS 2/LISS IV	15.10.2011
G077041E32170N	5Q22108	-	Other glacier erosion lake	77.041	32.170	Beas basin	4312	73681	RS 2/LISS IV	15.10.2011
G077080E32282N	5Q22108	-	End moraine-dammed lake	77.080	32.282	Beas basin	4532	9403	RS 2/LISS IV	15.10.2011
G077080E32285N	5Q22108	-	Other glacier erosion lake	77.080	32.285	Beas basin	4474	6042	RS 2/LISS IV	15.10.2011
G077079E32287N	5Q22108	-	Other glacier erosion lake	77.079	32.287	Beas basin	4458	5553	RS 2/LISS IV	15.10.2011
G077079E32292N	5Q22108	-	Debris-dammed lake	77.079	32.292	Beas basin	4345	41558	RS 2/LISS IV	15.10.2011
G077085E32304N	5Q22108	-	End moraine-dammed lake	77.085	32.304	Beas basin	4620	18518	RS 2/LISS IV	15.10.2011
G077089E32307N	5Q22108	-	Other moraine-dammed lake	77.089	32.307	Beas basin	4674	24456	RS 2/LISS IV	15.10.2011
G077095E32299N	5Q22108	-	Other glacier erosion lake	77.095	32.299	Beas basin	4496	2003	RS 2/LISS IV	15.10.2011
G077094E32303N	5Q22108	-	Other glacier erosion lake	77.094	32.303	Beas basin	4607	11149	RS 2/LISS IV	15.10.2011
G076810E32161N	5Q22108	-	End moraine-dammed lake	76.810	32.161	Beas basin	4417	6303	RS 2/LISS IV	15.10.2011

GLIMS lake ID	GSI basin ID	Lake name	Lake type	Longitude	Latitude	Basin(s)	Mean Elevation (m)	Area (m^2)	Satellite/ Sensor	Satellite acquisition date
G077304E32172N	5Q22108	-	Other moraine-dammed lake	77.304	32.172	Beas basin	4421	2845	RS 2/LISS IV	15.10.2011
G077332E32185N	5Q22108	-	Other glacier erosion lake	77.332	32.185	Beas basin	3801	5389	RS 2/LISS IV	15.10.2011
G077371E32171N	5Q22108	-	Lateral moraine-dammed lake	77.371	32.171	Beas basin	4606	16880	RS 2/LISS IV	15.10.2011
G077347E32266N	5Q22108	-	Other glacier erosion lake	77.347	32.266	Beas basin	4288	1393	RS 2/LISS IV	15.10.2011
G077341E32279N	5Q22108	-	Other glacier erosion lake	77.341	32.279	Beas basin	4566	24035	RS 2/LISS IV	15.10.2011
G077342E32277N	5Q22108	-	Other glacier erosion lake	77.342	32.277	Beas basin	4570	6907	RS 2/LISS IV	15.10.2011
G077343E32284N	5Q22108	-	Other glacier erosion lake	77.343	32.284	Beas basin	4624	4705	RS 2/LISS IV	15.10.2011
G077327E32248N	5Q22108	-	Other moraine-dammed lake	77.327	32.248	Beas basin	4460	7916	RS 2/LISS IV	15.10.2011
G077286E32223N	5Q22108	-	Other glacier erosion lake	77.286	32.223	Beas basin	4438	2033	RS 2/LISS IV	15.10.2011
G077242E32293N	5Q22108	Brighu	Other glacier erosion lake	77.242	32.293	Beas basin	4177	8196	RS 2/LISS IV	15.10.2011
G077256E32315N	5Q22108	-	Other glacier erosion lake	77.256	32.315	Beas basin	4408	1791	RS 2/LISS IV	15.10.2011
G077249E32322N	5Q22108	-	Other glacier erosion lake	77.249	32.322	Beas basin	4222	1459	RS 2/LISS IV	15.10.2011
G077091E32294N	5Q22108	-	Other moraine-dammed lake	77.091	32.294	Beas basin	4483	5147	RS 2/LISS IV	15.10.2011
G077135E32211N	5Q22108	-	Other glacier erosion lake	77.135	32.211	Beas basin	3759	1839	RS 2/LISS IV	15.10.2011
G077331E32295N	5Q22108	-	Other glacier erosion lake	77.331	32.295	Beas basin	4797	978	RS 2/LISS IV	15.10.2011
G077323E32316N	5Q22108	-	Debris-dammed lake	77.323	32.316	Beas basin	4524	1347	RS 2/LISS IV	15.10.2011
G077221E32348N	5Q22108	-	Artificial lake	77.221	32.348	Beas basin	3255	4220	RS 2/LISS IV	15.10.2011
G077077E32349N	5Q22108	-	Other moraine-dammed lake	77.077	32.349	Beas basin	3332	1704	RS 2/LISS IV	15.10.2011
G077085E32366N	5Q22108	Beas	Other glacier erosion lake	77.085	32.366	Beas basin	3658	3937	RS 2/LISS IV	15.10.2011
G077224E32375N	5Q22108	Dashir	Other glacier erosion lake	77.224	32.375	Beas basin	4225	7169	RS 2/LISS IV	15.10.2011
G077286E32131N	5Q22108	-	Other glacier erosion lake	77.286	32.131	Beas basin	4243	5702	RS 2/LISS IV	15.10.2011
G077282E32126N	5Q22108	-	Other glacier erosion lake	77.282	32.126	Beas basin	4268	5930	RS 2/LISS IV	15.10.2011
G076935E32114N	5Q22108	-	Other glacier erosion lake	76.935	32.114	Beas basin	4268	21677	RS 2/LISS IV	15.10.2011
G077345E32090N	5Q22108	-	Other glacier erosion lake	77.345	32.090	Beas basin	3608	5116	RS 2/LISS IV	15.10.2011
G077301E32144N	5Q22108	-	Other glacier erosion lake	77.301	32.144	Beas basin	4462	19546	RS 2/LISS IV	15.10.2011
G077657E31703N	5Q22108	-	Other glacier erosion lake	77.657	31.703	Beas basin	4292	1014	RS 2/LISS IV	08.11.2011
G077565E31676N	5Q22108	-	Other glacier erosion lake	77.565	31.676	Beas basin	4278	10122	RS 2/LISS IV	08.11.2011
G077470E31837N	5Q22108	-	Other glacier erosion lake	77.470	31.837	Beas basin	4338	15732	RS 2/LISS IV	08.11.2011
G077475E31838N	5Q22108	-	Other glacier erosion lake	77.475	31.838	Beas basin	4345	5936	RS 2/LISS IV	08.11.2011
G077554E31740N	5Q22108	-	Cirque lake	77.554	31.740	Beas basin	4400	9156	RS 2/LISS IV	08.11.2011
G077555E31734N	5Q22108	-	Cirque lake	77.555	31.734	Beas basin	4466	8047	RS 2/LISS IV	08.11.2011
G077495E31864N	5Q22108	-	Other glacier erosion lake	77.495	31.864	Beas basin	3680	1210	RS 2/LISS IV	08.11.2011
G077506E31741N	5Q22108	-	Other glacier erosion lake	77.506	31.741	Beas basin	4206	2334	RS 2/LISS IV	08.11.2011
G077569E31748N	5Q22108	-	Other glacier erosion lake	77.569	31.748	Beas basin	4279	1703	RS 2/LISS IV	08.11.2011
G077668E31726N	5Q22108	-	Other glacier erosion lake	77.668	31.726	Beas basin	4639	1476	RS 2/LISS IV	20.10.2011
G077669E31723N	5Q22108	-	End moraine-dammed lake	77.669	31.723	Beas basin	4622	9932	RS 2/LISS IV	20.10.2011
G077597E31668N	5Q22108	-	Other glacier erosion lake	77.597	31.668	Beas basin	4586	26263	RS 2/LISS IV	20.10.2011
G077599E31669N	5Q22108	-	Other glacier erosion lake	77.599	31.669	Beas basin	4583	1347	RS 2/LISS IV	20.10.2011
G077618E31666N	5Q22108	-	Other moraine-dammed lake	77.618	31.666	Beas basin	4606	26816	RS 2/LISS IV	20.10.2011
G077634E31745N	5Q22108	-	Other glacier erosion lake	77.634	31.745	Beas basin	4838	1798	RS 2/LISS IV	20.10.2011
G077640E31852N	5Q22108	-	Other glacier erosion lake	77.640	31.852	Beas basin	4757	33021	RS 2/LISS IV	20.10.2011
G077649E31851N	5Q22108	-	Other glacier erosion lake	77.649	31.851	Beas basin	4870	5606	RS 2/LISS IV	20.10.2011
G077638E31845N	5Q22108	-	Other glacier erosion lake	77.638	31.845	Beas basin	4593	3553	RS 2/LISS IV	20.10.2011
G076938E32082N	5Q22108	-	Other glacier erosion lake	76.938	32.082	Beas basin	3720	2103	RS 2/LISS IV	15.10.2011
G076939E32048N	5Q22108	-	Other glacier erosion lake	76.939	32.048	Beas basin	3453	2196	RS 2/LISS IV	15.10.2011
G076955E32030N	5Q22108	-	Other glacier erosion lake	76.955	32.030	Beas basin	3253	2178	RS 2/LISS IV	15.10.2011
G076960E32025N	5Q22108	-	Other glacier erosion lake	76.960	32.025	Beas basin	3368	1366	RS 2/LISS IV	15.10.2011
G076973E32018N	5Q22108	-	Other glacier erosion lake	76.973	32.018	Beas basin	3301	2279	RS 2/LISS IV	15.10.2011
G077563E31734N	5Q22108	-	Other glacier erosion lake	77.563	31.734	Beas basin	4491	13454	RS 2/LISS IV	20.10.2011
G077278E32131N	5Q22108	-	Other glacier erosion lake	77.278	32.131	Beas basin	4165	9098	RS 2/LISS IV	15.10.2011
G077561E31733N	5Q22108	-	Other glacier erosion lake	77.561	31.733	Beas basin	4509	18270	LANDSAT/OLI	17.10.2015
G077561E31843N	5Q22108	-	Other glacier erosion lake	77.561	31.843	Beas basin	4653	23924	LANDSAT/OLI	17.10.2015
G077461E31841N	5Q22108	-	Other glacier erosion lake	77.461	31.841	Beas basin	4369	9821	RS 2/LISS IV	08.11.2011
G077462E31844N	5Q22108	-	Other glacier erosion lake	77.462	31.844	Beas basin	4327	15728	RS 2/LISS IV	08.11.2011
G077589E31668N	5Q22108	-	Other glacier erosion lake	77.589	31.668	Beas basin	4561	33273	LANDSAT/OLI	17.10.2015
G077610E31657N	5Q22108	-	Other moraine-dammed lake	77.610	31.657	Beas basin	4638	5314	LANDSAT/OLI	17.10.2015
G077394E32756N	5Q21211	-	Other glacier erosion lake	77.394	32.756	Bhaga basin	4931	2381	RS 2/LISS IV	15.10.2011
G077397E32763N	5Q21211	Suraj Tal	Other glacier erosion lake	77.397	32.763	Bhaga basin	4785	19855	RS 2/LISS IV	15.10.2011
G077327E32764N	5Q21211	-	Other glacier erosion lake	77.327	32.764	Bhaga basin	5282	2909	RS 2/LISS IV	15.10.2011
G077231E32765N	5Q21211	-	End moraine-dammed lake	77.231	32.765	Bhaga basin	4736	2791	RS 2/LISS IV	15.10.2011
G077195E32762N	5Q21211	-	End moraine-dammed lake	77.195	32.762	Bhaga basin	4777	48625	RS 2/LISS IV	15.10.2011
G077106E32748N	5Q21211	-	Other moraine-dammed lake	77.106	32.748	Bhaga basin	4539	6521	RS 2/LISS IV	15.10.2011
G077109E32748N	5Q21211	-	Other moraine-dammed lake	77.109	32.748	Bhaga basin	4524	2395	RS 2/LISS IV	17.08.2012
G077218E32786N	5Q21211	-	Debris-dammed lake	77.218	32.786	Bhaga basin	5131	18820	RS 2/LISS IV	17.08.2012
G077280E32844N	5Q21211	-	End moraine-dammed lake	77.280	32.844	Bhaga basin	4879	35369	RS 2/LISS IV	15.10.2011
G077230E32817N	5Q21211	-	End moraine-dammed lake	77.230	32.817	Bhaga basin	5168	1806	RS 2/LISS IV	15.10.2011
G077306E32631N	5Q21211	-	End moraine-dammed lake	77.306	32.631	Bhaga basin	4396	49809	RS 2/LISS IV	15.10.2011
G077309E32630N	5Q21211	-	End moraine-dammed lake	77.309	32.630	Bhaga basin	4408	4510	RS 2/LISS IV	15.10.2011
G077317E32634N	5Q21211	-	Supra-glacial lake	77.317	32.634	Bhaga basin	4511	1214	RS 2/LISS IV	15.10.2011
G077319E32636N	5Q21211	-	Supra-glacial lake	77.319	32.636	Bhaga basin	4537	3378	RS 2/LISS IV	15.10.2011
G077306E32630N	5Q21211	-	End moraine-dammed lake	77.306	32.630	Bhaga basin	4431	1464	RS 2/LISS IV	15.10.2011
G077309E32631N	5Q21211	-	End moraine-dammed lake	77.309	32.631	Bhaga basin	4407	799	RS 2/LISS IV	15.10.2011
G077308E32631N	5Q21211	-	End moraine-dammed lake	77.308	32.631	Bhaga basin	4399	784	RS 2/LISS IV	15.10.2011
G077329E32721N	5Q21211	-	Supra-glacial lake	77.329	32.721	Bhaga basin	4593	2662	RS 2/LISS IV	15.10.2011
G077342E32707N	5Q21211	-	Other moraine-dammed lake	77.342	32.707	Bhaga basin	4673	26709	RS 2/LISS IV	15.10.2011
G077347E32705N	5Q21211	-	End moraine-dammed lake	77.347	32.705	Bhaga basin	4776	23641	RS 2/LISS IV	15.10.2011
G077363E32693N	5Q21211	-	Other glacier erosion lake	77.363	32.693	Bhaga basin	5087	1203	RS 2/LISS IV	15.10.2011
G077366E32693N	5Q21211	-	Other glacier erosion lake	77.366	32.693	Bhaga basin	5114	5840	RS 2/LISS IV	15.10.2011
G077372E32693N	5Q21211	-	Lateral moraine-dammed lake	77.372	32.693	Bhaga basin	5139	62625	RS 2/LISS IV	15.10.2011
G077363E32696N	5Q21211	-	Other glacier erosion lake	77.363	32.696	Bhaga basin	5064	1675	RS 2/LISS IV	15.10.2011
G077337E32710N	5Q21211	-	Supra-glacial lake	77.337	32.710	Bhaga basin	4687	1446	RS 2/LISS IV	15.10.2011

GLIMS lake ID	GSI basin ID	Lake name	Lake type	Longitude	Latitude	Basin(s)	Mean Elevation (m)	Area (m^2)	Satellite/ Sensor	Satellite acquisition date
G077331E32718N	5Q21211	-	Supra-glacial lake	77.331	32.718	Bhaga basin	4633	1296	RS 2/LISS IV	15.10.2011
G077256E32753N	5Q21211	Deepak Tal	Other glacier erosion lake	77.256	32.753	Bhaga basin	3750	10718	RS 2/LISS IV	15.10.2011
G077091E32824N	5Q21211	-	Debris-dammed lake	77.091	32.824	Bhaga basin	4046	6938	RS 2/LISS IV	15.10.2011
G077382E32581N	5Q21211	-	Other glacier erosion lake	77.382	32.581	Bhaga basin	5204	13081	RS 2/LISS IV	15.10.2011
G077357E32636N	5Q21211	-	Lateral moraine-dammed lake	77.357	32.636	Bhaga basin	5193	2954	RS 2/LISS IV	15.10.2011
G077301E32774N	5Q21211	-	Supra-glacial lake	77.301	32.774	Bhaga basin	4793	2299	RS 2/LISS IV	15.10.2011
G077269E32678N	5Q21211	-	Other glacier erosion lake	77.269	32.678	Bhaga basin	4961	1163	RS 2/LISS IV	15.10.2011
G077275E32587N	5Q21211	-	Other moraine-dammed lake	77.275	32.587	Bhaga basin	4518	1781	RS 2/LISS IV	15.10.2011
G077297E32511N	5Q21211	-	Supra-glacial lake	77.297	32.511	Bhaga basin	4232	1761	RS 2/LISS IV	15.10.2011
G077303E32716N	5Q21211	-	Supra-glacial lake	77.303	32.716	Bhaga basin	4494	1105	RS 2/LISS IV	15.10.2011
G077305E32716N	5Q21211	-	Supra-glacial lake	77.305	32.716	Bhaga basin	4491	1537	RS 2/LISS IV	15.10.2011
G077303E32720N	5Q21211	-	Supra-glacial lake	77.303	32.720	Bhaga basin	4438	916	RS 2/LISS IV	15.10.2011
G077305E32723N	5Q21211	-	Supra-glacial lake	77.305	32.723	Bhaga basin	4385	924	RS 2/LISS IV	15.10.2011
G077302E32725N	5Q21211	-	Supra-glacial lake	77.302	32.725	Bhaga basin	4347	1626	RS 2/LISS IV	15.10.2011
G077300E32726N	5Q21211	-	Supra-glacial lake	77.300	32.726	Bhaga basin	4332	783	RS 2/LISS IV	15.10.2011
G077273E32860N	5Q21211	-	Other glacier erosion lake	77.273	32.860	Bhaga basin	5156	4757	RS 2/LISS IV	15.10.2011
G077327E32621N	5Q21211	-	Supra-glacial lake	77.327	32.621	Bhaga basin	4631	849	RS 2/LISS IV	15.10.2011
G077340E32624N	5Q21211	-	Supra-glacial lake	77.340	32.624	Bhaga basin	4752	641	RS 2/LISS IV	15.10.2011
G077098E32682N	5Q21211	-	Other moraine-dammed lake	77.098	32.682	Bhaga basin	5073	1482	RS 2/LISS IV	15.10.2011
G077329E32723N	5Q21211	-	End moraine-dammed lake	77.329	32.723	Bhaga basin	4556	33464	RS 2/LISS IV	15.10.2011
G077304E32720N	5Q21211	-	Supra-glacial lake	77.304	32.720	Bhaga basin	4436	777	RS 2/LISS IV	15.10.2011
G077146E32935N	5Q21211	-	Other glacier erosion lake	77.146	32.935	Bhaga basin	5335	19012	RS 2/LISS IV	17.08.2012
G077143E32935N	5Q21211	-	Other glacier erosion lake	77.143	32.935	Bhaga basin	5459	1227	RS 2/LISS IV	17.08.2012
G077118E32964N	5Q21211	-	Other glacier erosion lake	77.118	32.964	Bhaga basin	5318	6538	RS 2/LISS IV	17.08.2012
G077061E32936N	5Q21211	-	Supra-glacial lake	77.061	32.936	Bhaga basin	4711	3431	RS 2/LISS IV	17.08.2012
G077007E32919N	5Q21211	-	Other glacier erosion lake	77.007	32.919	Bhaga basin	5263	1069	RS 2/LISS IV	17.08.2012
G076994E32925N	5Q21211	-	Glacier ice-dammed lake	76.994	32.925	Bhaga basin	5270	1559	RS 2/LISS IV	17.08.2012
G077108E32749N	5Q21211	-	Debris-dammed lake	77.108	32.749	Bhaga basin	4508	1357	RS 2/LISS IV	17.08.2012
G077081E32741N	5Q21211	-	Debris-dammed lake	77.081	32.741	Bhaga basin	5081	2413	RS 2/LISS IV	17.08.2012
G077016E32713N	5Q21211	-	Lateral moraine-dammed lake	77.016	32.713	Bhaga basin	4640	9759	RS 2/LISS IV	17.08.2012
G077001E32698N	5Q21211	-	Other glacier erosion lake	77.001	32.698	Bhaga basin	4875	1314	RS 2/LISS IV	17.08.2012
G076997E32698N	5Q21211	-	Other glacier erosion lake	76.997	32.698	Bhaga basin	4947	2105	RS 2/LISS IV	17.08.2012
G077005E32674N	5Q21211	-	Debris-dammed lake	77.005	32.674	Bhaga basin	4754	1246	RS 2/LISS IV	17.08.2012
G077061E32674N	5Q21211	-	Other moraine-dammed lake	77.061	32.674	Bhaga basin	5003	1102	RS 2/LISS IV	17.08.2012
G077093E32670N	5Q21211	-	Other moraine-dammed lake	77.093	32.670	Bhaga basin	4655	1752	RS 2/LISS IV	17.08.2012
G077088E32670N	5Q21211	-	Other moraine-dammed lake	77.088	32.670	Bhaga basin	4673	4318	RS 2/LISS IV	17.08.2012
G077155E32667N	5Q21211	-	Debris-dammed lake	77.155	32.667	Bhaga basin	4902	2269	RS 2/LISS IV	17.08.2012
G077063E32651N	5Q21211	-	Other moraine-dammed lake	77.063	32.651	Bhaga basin	5090	2154	RS 2/LISS IV	17.08.2012
G077031E32752N	5Q21211	-	Supra-glacial lake	77.031	32.752	Bhaga basin	5203	822	RS 2/LISS IV	17.08.2012
G077011E32693N	5Q21211	-	Lateral moraine-dammed lake	77.011	32.693	Bhaga basin	4546	1261	RS 2/LISS IV	17.08.2012
G077060E32688N	5Q21211	-	Supra-glacial lake	77.060	32.688	Bhaga basin	5054	845	RS 2/LISS IV	17.08.2012
G077073E32673N	5Q21211	-	Supra-glacial lake	77.073	32.673	Bhaga basin	4778	1277	RS 2/LISS IV	17.08.2012
G077107E32636N	5Q21211	-	Other glacier erosion lake	77.107	32.636	Bhaga basin	4909	1447	RS 2/LISS IV	17.08.2012
G077103E32635N	5Q21211	-	Other glacier erosion lake	77.103	32.635	Bhaga basin	5044	4227	RS 2/LISS IV	17.08.2012
G077061E32984N	5Q21211	-	Supra-glacial lake	77.061	32.984	Bhaga basin	5371	834	RS 2/LISS IV	17.08.2012
G076987E32948N	5Q21211	-	Supra-glacial lake	76.987	32.948	Bhaga basin	5365	904	RS 2/LISS IV	17.08.2012
G076988E32951N	5Q21211	-	Supra-glacial lake	76.988	32.951	Bhaga basin	5386	609	RS 2/LISS IV	17.08.2012
G077199E32904N	5Q21211	-	Other glacier erosion lake	77.199	32.904	Bhaga basin	5040	1330	RS 2/LISS IV	17.08.2012
G077198E32904N	5Q21211	-	Other glacier erosion lake	77.198	32.904	Bhaga basin	5043	1239	RS 2/LISS IV	17.08.2012
G076999E32900N	5Q21211	-	Other moraine-dammed lake	76.999	32.900	Bhaga basin	4860	6006	RS 2/LISS IV	17.08.2012
G076982E32871N	5Q21211	-	Other moraine-dammed lake	76.982	32.871	Bhaga basin	5200	3321	RS 2/LISS IV	17.08.2012
G076983E32872N	5Q21211	-	Other moraine-dammed lake	76.983	32.872	Bhaga basin	5183	2778	RS 2/LISS IV	17.08.2012
G077022E32892N	5Q21211	-	Other moraine-dammed lake	77.022	32.892	Bhaga basin	4603	1669	RS 2/LISS IV	17.08.2012
G077025E32890N	5Q21211	-	Other moraine-dammed lake	77.025	32.890	Bhaga basin	4615	1061	RS 2/LISS IV	17.08.2012
G077045E32888N	5Q21211	-	Other glacier erosion lake	77.045	32.888	Bhaga basin	4535	1009	RS 2/LISS IV	17.08.2012
G077051E32871N	5Q21211	-	Other glacier erosion lake	77.051	32.871	Bhaga basin	4626	1533	RS 2/LISS IV	17.08.2012
G077163E32875N	5Q21211	-	Other moraine-dammed lake	77.163	32.875	Bhaga basin	5311	16438	RS 2/LISS IV	17.08.2012
G077039E32845N	5Q21211	-	End moraine-dammed lake	77.039	32.845	Bhaga basin	5215	7315	RS 2/LISS IV	17.08.2012
G077007E32828N	5Q21211	-	Supra-glacial lake	77.007	32.828	Bhaga basin	5306	960	RS 2/LISS IV	17.08.2012
G077169E32787N	5Q21211	-	Other glacier erosion lake	77.169	32.787	Bhaga basin	5136	4969	RS 2/LISS IV	17.08.2012
G077062E32965N	5Q21211	-	Other moraine-dammed lake	77.062	32.965	Bhaga basin	5090	531	RS 2/LISS IV	17.08.2012
G077065E32930N	5Q21211	-	Other moraine-dammed lake	77.065	32.930	Bhaga basin	4609	1561	RS 2/LISS IV	15.10.2011
G077065E32927N	5Q21211	-	Other moraine-dammed lake	77.065	32.927	Bhaga basin	4587	815	RS 2/LISS IV	15.10.2011
G077061E32915N	5Q21211	-	Other glacier erosion lake	77.061	32.915	Bhaga basin	4907	646	RS 2/LISS IV	15.10.2011
G077200E32907N	5Q21211	-	Debris-dammed lake	77.200	32.907	Bhaga basin	5015	9862	RS 2/LISS IV	15.10.2011
G077236E32837N	5Q21211	-	Other moraine-dammed lake	77.236	32.837	Bhaga basin	5168	2725	RS 2/LISS IV	15.10.2011
G077232E32823N	5Q21211	-	Other moraine-dammed lake	77.232	32.823	Bhaga basin	5193	975	RS 2/LISS IV	15.10.2011
G077234E32823N	5Q21211	-	Other moraine-dammed lake	77.234	32.823	Bhaga basin	5169	974	RS 2/LISS IV	15.10.2011
G077014E32843N	5Q21211	-	Supra-glacial lake	77.014	32.843	Bhaga basin	5161	558	RS 2/LISS IV	15.10.2011
G077328E32724N	5Q21211	-	End moraine-dammed lake	77.328	32.724	Bhaga basin	4561	1034	RS 2/LISS IV	15.10.2011
G077304E32492N	5Q21211	-	Supra-glacial lake	77.304	32.492	Bhaga basin	4413	972	RS 2/LISS IV	15.10.2011
G077309E32491N	5Q21211	-	Supra-glacial lake	77.309	32.491	Bhaga basin	4440	1027	RS 2/LISS IV	15.10.2011
G077322E32489N	5Q21211	-	Supra-glacial lake	77.322	32.489	Bhaga basin	4526	769	RS 2/LISS IV	15.10.2011
G077297E32520N	5Q21211	-	Supra-glacial lake	77.297	32.520	Bhaga basin	4181	566	RS 2/LISS IV	15.10.2011
G077286E32542N	5Q21211	-	Other moraine-dammed lake	77.286	32.542	Bhaga basin	3968	906	RS 2/LISS IV	15.10.2011
G077286E32544N	5Q21211	-	Other moraine-dammed lake	77.286	32.544	Bhaga basin	3975	978	RS 2/LISS IV	15.10.2011
G077327E32595N	5Q21211	-	Supra-glacial lake	77.327	32.595	Bhaga basin	4229	1558	RS 2/LISS IV	15.10.2011
G077320E32600N	5Q21211	-	Supra-glacial lake	77.320	32.600	Bhaga basin	3749	807	RS 2/LISS IV	15.10.2011
G077335E32699N	5Q21211	-	Supra-glacial lake	77.335	32.699	Bhaga basin	4760	505	RS 2/LISS IV	15.10.2011
G077335E32698N	5Q21211	-	Supra-glacial lake	77.335	32.698	Bhaga basin	4772	1567	RS 2/LISS IV	15.10.2011
G077095E32681N	5Q21211	-	End moraine-dammed lake	77.095	32.681	Bhaga basin	5162	6608	RS 2/LISS IV	17.08.2012

GLIMS lake ID	GSI basin ID	Lake name	Lake type	Longitude	Latitude	Basin(s)	Mean Elevation (m)	Area (m^2)	Satellite/ Sensor	Satellite acquisition date
G077012E32692N	5Q21211	-	Lateral moraine-dammed lake	77.012	32.692	Bhaga basin	4494	996	RS 2/LISS IV	17.08.2012
G077012E32691N	5Q21211	-	Lateral moraine-dammed lake	77.012	32.691	Bhaga basin	4497	2562	RS 2/LISS IV	17.08.2012
G077017E32703N	5Q21211	-	Glacier ice-dammed lake	77.017	32.703	Bhaga basin	4490	927	RS 2/LISS IV	17.08.2012
G077315E32493N	5Q21211	-	Supra-glacial lake	77.315	32.493	Bhaga basin	4470	844	RS 2/LISS IV	15.10.2011
G077327E32488N	5Q21211	-	Supra-glacial lake	77.327	32.488	Bhaga basin	4544	669	RS 2/LISS IV	15.10.2011
G077329E32491N	5Q21211	-	Supra-glacial lake	77.329	32.491	Bhaga basin	4548	1057	RS 2/LISS IV	15.10.2011
G077322E32624N	5Q21211	-	Supra-glacial lake	77.322	32.624	Bhaga basin	4586	1145	RS 2/LISS IV	15.10.2011
G077329E32724N	5Q21211	-	End moraine-dammed lake	77.329	32.724	Bhaga basin	4543	875	RS 2/LISS IV	15.10.2011
G077020E32911N	5Q21211	-	Other moraine-dammed lake	77.020	32.911	Bhaga basin	5290	2521	RS 2/LISS IV	17.08.2012
G077183E32798N	5Q21211	-	Supra-glacial lake	77.183	32.798	Bhaga basin	5140	2257	RS 2/LISS IV	17.08.2012
G077188E32799N	5Q21211	-	Other moraine-dammed lake	77.188	32.799	Bhaga basin	5123	576	RS 2/LISS IV	17.08.2012
G077055E32604N	5Q21211	-	Other glacier erosion lake	77.055	32.604	Bhaga basin	4773	1101	RS 2/LISS IV	17.08.2012
G077090E32667N	5Q21211	-	Other moraine-dammed lake	77.090	32.667	Bhaga basin	4732	1202	RS 2/LISS IV	17.08.2012
G077059E32692N	5Q21211	-	Supra-glacial lake	77.059	32.692	Bhaga basin	5096	523	RS 2/LISS IV	17.08.2012
G076994E32770N	5Q21211	-	Lateral moraine-dammed lake	76.994	32.770	Bhaga basin	4977	710	RS 2/LISS IV	17.08.2012
G077062E32934N	5Q21211	-	Supra-glacial lake	77.062	32.934	Bhaga basin	4698	3271	RS 2/LISS IV	15.10.2011
G077156E32937N	5Q21211	-	Other glacier erosion lake	77.156	32.937	Bhaga basin	5412	8862	RS 2/LISS IV	17.08.2012
G077152E32937N	5Q21211	-	Other glacier erosion lake	77.152	32.937	Bhaga basin	5396	7721	RS 2/LISS IV	17.08.2012
G077009E32922N	5Q21211	-	Other glacier erosion lake	77.009	32.922	Bhaga basin	5266	15174	LANDSAT/OLI	28.09.2014
G077219E32526N	5Q21212	Gepang Gath	End moraine-dammed lake	77.219	32.526	Chandra basin	4069	687491	RS 2/LISS IV	15.10.2011
G077127E32476N	5Q21212	Sissu	Artificial lake	77.127	32.476	Chandra basin	3001	50157	RS 2/LISS IV	15.10.2011
G077384E32721N	5Q21212	-	End moraine-dammed lake	77.384	32.721	Chandra basin	5240	89013	RS 2/LISS IV	15.10.2011
G077413E32722N	5Q21212	-	End moraine-dammed lake	77.413	32.722	Chandra basin	5127	100660	RS 2/LISS IV	15.10.2011
G077454E32499N	5Q21212	-	Lateral moraine-dammed lake	77.454	32.499	Chandra basin	4803	1943	RS 2/LISS IV	15.10.2011
G077501E32657N	5Q21212	-	Other moraine-dammed lake	77.501	32.657	Chandra basin	5248	6908	RS 2/LISS IV	15.10.2011
G077445E32692N	5Q21212	-	Other glacier erosion lake	77.445	32.692	Chandra basin	4699	973	RS 2/LISS IV	15.10.2011
G077404E32725N	5Q21212	-	Other moraine-dammed lake	77.404	32.725	Chandra basin	5142	5112	RS 2/LISS IV	15.10.2011
G076890E32482N	5Q21212	-	Supra-glacial lake	76.890	32.482	Chandra basin	3443	12960	RS 2/LISS IV	15.10.2011
G077501E32670N	5Q21212	-	Supra-glacial lake	77.501	32.670	Chandra basin	5272	2725	RS 2/LISS IV	15.10.2011
G077511E32661N	5Q21212	-	Supra-glacial lake	77.511	32.661	Chandra basin	5446	5283	RS 2/LISS IV	15.10.2011
G077509E32661N	5Q21212	-	Supra-glacial lake	77.509	32.661	Chandra basin	5459	1426	RS 2/LISS IV	15.10.2011
G077510E32646N	5Q21212	-	Supra-glacial lake	77.510	32.646	Chandra basin	5456	2184	RS 2/LISS IV	15.10.2011
G077507E32640N	5Q21212	-	Supra-glacial lake	77.507	32.640	Chandra basin	5485	1090	RS 2/LISS IV	15.10.2011
G077506E32641N	5Q21212	-	Supra-glacial lake	77.506	32.641	Chandra basin	5484	2105	RS 2/LISS IV	15.10.2011
G077479E32571N	5Q21212	-	Supra-glacial lake	77.479	32.571	Chandra basin	5191	5904	RS 2/LISS IV	15.10.2011
G077467E32566N	5Q21212	-	Supra-glacial lake	77.467	32.566	Chandra basin	5290	939	RS 2/LISS IV	15.10.2011
G077443E32550N	5Q21212	-	Supra-glacial lake	77.443	32.550	Chandra basin	5202	1597	RS 2/LISS IV	15.10.2011
G077367E32393N	5Q21212	-	Other moraine-dammed lake	77.367	32.393	Chandra basin	4861	3779	RS 2/LISS IV	15.10.2011
G077329E32441N	5Q21212	-	Other glacier erosion lake	77.329	32.441	Chandra basin	3738	1716	RS 2/LISS IV	15.10.2011
G077253E32375N	5Q21212	-	Other glacier erosion lake	77.253	32.375	Chandra basin	3944	4213	RS 2/LISS IV	15.10.2011
G077308E32393N	5Q21212	-	Other moraine-dammed lake	77.308	32.393	Chandra basin	4550	15147	RS 2/LISS IV	15.10.2011
G077289E32449N	5Q21212	-	Other moraine-dammed lake	77.289	32.449	Chandra basin	4004	1903	RS 2/LISS IV	15.10.2011
G077329E32404N	5Q21212	-	Other glacier erosion lake	77.329	32.404	Chandra basin	4647	1821	RS 2/LISS IV	15.10.2011
G077374E32451N	5Q21212	-	Supra-glacial lake	77.374	32.451	Chandra basin	4429	1437	RS 2/LISS IV	15.10.2011
G077686E32174N	5Q21212	-	Supra-glacial lake	77.686	32.174	Chandra basin	4869	579	RS 2/LISS IV	09.10.2013
G077701E32172N	5Q21212	-	Supra-glacial lake	77.701	32.172	Chandra basin	5014	728	RS 2/LISS IV	09.10.2013
G077726E32326N	5Q21212	-	Supra-glacial lake	77.726	32.326	Chandra basin	5199	1976	RS 2/LISS IV	09.10.2013
G077020E32439N	5Q21212	-	Other glacier erosion lake	77.020	32.439	Chandra basin	4380	5317	RS 2/LISS IV	17.08.2012
G077032E32436N	5Q21212	-	Other moraine-dammed lake	77.032	32.436	Chandra basin	4258	1312	RS 2/LISS IV	17.08.2012
G077030E32434N	5Q21212	-	Other glacier erosion lake	77.030	32.434	Chandra basin	4208	768	RS 2/LISS IV	17.08.2012
G076997E32436N	5Q21212	-	Lateral moraine-dammed lake	76.997	32.436	Chandra basin	3815	1389	RS 2/LISS IV	17.08.2012
G077542E32728N	5Q21212	-	Other moraine-dammed lake	77.542	32.728	Chandra basin	5214	1563	RS 2/LISS IV	08.11.2011
G077595E32247N	5Q21212	-	Supra-glacial lake	77.595	32.247	Chandra basin	4204	7635	RS 2/LISS IV	08.11.2011
G077589E32278N	5Q21212	-	Glacier ice-dammed lake	77.589	32.278	Chandra basin	3942	911	RS 2/LISS IV	08.11.2011
G077586E32294N	5Q21212	-	Other moraine-dammed lake	77.586	32.294	Chandra basin	3906	3315	RS 2/LISS IV	08.11.2011
G077579E32298N	5Q21212	-	Other moraine-dammed lake	77.579	32.298	Chandra basin	3902	4436	RS 2/LISS IV	08.11.2011
G077447E32246N	5Q21212	-	Medial moraine-dammed lake	77.447	32.246	Chandra basin	4470	16542	RS 2/LISS IV	08.11.2011
G077449E32240N	5Q21212	-	End moraine-dammed lake	77.449	32.240	Chandra basin	4602	23364	RS 2/LISS IV	08.11.2011
G077445E32307N	5Q21212	-	Debris-dammed lake	77.445	32.307	Chandra basin	3492	1107	RS 2/LISS IV	08.11.2011
G077547E32499N	5Q21212	-	Other moraine-dammed lake	77.547	32.499	Chandra basin	4156	1020814	RS 2/LISS IV	08.11.2011
G077615E32483N	5Q21212	Chandra Tal	Other glacier erosion lake	77.615	32.483	Chandra basin	4304	481488	RS 2/LISS IV	08.11.2011
G077595E32240N	5Q21212	-	Supra-glacial lake	77.595	32.240	Chandra basin	4255	2085	RS 2/LISS IV	08.11.2011
G077610E32232N	5Q21212	-	Supra-glacial lake	77.610	32.232	Chandra basin	4338	7617	RS 2/LISS IV	08.11.2011
G077618E32222N	5Q21212	-	Supra-glacial lake	77.618	32.222	Chandra basin	4450	744	RS 2/LISS IV	08.11.2011
G077589E32253N	5Q21212	-	Supra-glacial lake	77.589	32.253	Chandra basin	4142	513	RS 2/LISS IV	08.11.2011
G077297E32450N	5Q21212	-	Other moraine-dammed lake	77.297	32.450	Chandra basin	4044	3110	RS 2/LISS IV	15.10.2011
G077296E32449N	5Q21212	-	Other moraine-dammed lake	77.296	32.449	Chandra basin	4049	800	RS 2/LISS IV	15.10.2011
G077294E32450N	5Q21212	-	Other moraine-dammed lake	77.294	32.450	Chandra basin	4016	4030	RS 2/LISS IV	15.10.2011
G077228E32510N	5Q21212	-	Supra-glacial lake	77.228	32.510	Chandra basin	4239	856	RS 2/LISS IV	15.10.2011
G077501E32650N	5Q21212	-	Other moraine-dammed lake	77.501	32.650	Chandra basin	5372	1248	RS 2/LISS IV	15.10.2011
G077588E32286N	5Q21212	-	Other glacier erosion lake	77.588	32.286	Chandra basin	3910	561	RS 2/LISS IV	08.11.2011
G077584E32272N	5Q21212	-	Other moraine-dammed lake	77.584	32.272	Chandra basin	3999	840	RS 2/LISS IV	08.11.2011
G077617E32604N	5Q21212	-	End moraine-dammed lake	77.617	32.604	Chandra basin	5203	43681	LANDSAT/OLI	28.09.2014
G077377E32724N	5Q21212	-	Other moraine-dammed lake	77.377	32.724	Chandra basin	5305	15826	LANDSAT/OLI	28.09.2014
G077399E32723N	5Q21212	-	Other moraine-dammed lake	77.399	32.723	Chandra basin	5136	4493	RS 2/LISS IV	15.10.2011
G077593E32636N	5Q21212	-	Other moraine-dammed lake	77.593	32.636	Chandra basin	5421	11184	LANDSAT/OLI	28.09.2014
G077550E32732N	5Q21212	-	Other glacier erosion lake	77.550	32.732	Chandra basin	5203	4739	LANDSAT/OLI	28.08.2014
G077442E32248N	5Q21212	-	Other moraine-dammed lake	77.442	32.248	Chandra basin	4314	9293	LANDSAT/OLI	17.10.2015
G077419E32248N	5Q21212	-	Other moraine-dammed lake	77.419	32.248	Chandra basin	5070	23790	LANDSAT/OLI	17.10.2015
G078893E31110N	5O13105	-	Other glacier erosion lake	78.893	31.110	Jahnvi Ganga basin	4784	1549	RS 2/LISS IV	20.09.2013
G078898E31114N	5O13105	-	Supra-glacial lake	78.898	31.114	Jahnvi Ganga basin	4689	1439	RS 2/LISS IV	20.09.2013

GLIMS lake ID	GSI basin ID	Lake name	Lake type	Longitude	Latitude	Basin(s)	Mean Elevation (m)	Area (m^2)	Satellite/ Sensor	Satellite acquisition date
G078872E31177N	5O13105	-	Other moraine-dammed lake	78.872	31.177	Jahnvi Ganga basin	4466	10934	RS 2/LISS IV	01.10.2011
G078865E31178N	5O13105	-	Other moraine-dammed lake	78.865	31.178	Jahnvi Ganga basin	4459	3033	RS 2/LISS IV	20.09.2013
G078968E31178N	5O13105	-	Supra-glacial lake	78.968	31.178	Jahnvi Ganga basin	5287	3807	RS 2/LISS IV	20.09.2013
G078885E31221N	5O13105	-	Other glacier erosion lake	78.885	31.221	Jahnvi Ganga basin	4925	1884	RS 2/LISS IV	20.09.2013
G078870E31221N	5O13105	-	End moraine-dammed lake	78.870	31.221	Jahnvi Ganga basin	5202	4564	RS 2/LISS IV	20.09.2013
G078881E31252N	5O13105	-	Debris-dammed lake	78.881	31.252	Jahnvi Ganga basin	4490	1541	RS 2/LISS IV	20.09.2013
G078833E31279N	5O13105	-	Other moraine-dammed lake	78.833	31.279	Jahnvi Ganga basin	5259	2553	RS 2/LISS IV	20.09.2013
G078827E31271N	5O13105	-	Other moraine-dammed lake	78.827	31.271	Jahnvi Ganga basin	5295	3451	RS 2/LISS IV	20.09.2013
G078866E31298N	5O13105	-	Other moraine-dammed lake	78.866	31.298	Jahnvi Ganga basin	5269	8463	RS 2/LISS IV	20.09.2013
G078868E31293N	5O13105	-	Other moraine-dammed lake	78.868	31.293	Jahnvi Ganga basin	5209	2314	RS 2/LISS IV	20.09.2013
G078872E31284N	5O13105	-	Glacier ice-dammed lake	78.872	31.284	Jahnvi Ganga basin	5008	997	RS 2/LISS IV	20.09.2013
G078833E31280N	5O13105	-	Other moraine-dammed lake	78.833	31.280	Jahnvi Ganga basin	5251	2820	RS 2/LISS IV	20.09.2013
G078856E31284N	5O13105	-	Other moraine-dammed lake	78.856	31.284	Jahnvi Ganga basin	5235	1136	RS 2/LISS IV	20.09.2013
G078898E31113N	5O13105	-	Supra-glacial lake	78.898	31.113	Jahnvi Ganga basin	4710	713	RS 2/LISS IV	20.11.2013
G078851E31199N	5O13105	-	Other moraine-dammed lake	78.851	31.199	Jahnvi Ganga basin	4643	11765	RS 2/LISS IV	20.09.2013
G078868E31178N	5O13105	-	Other moraine-dammed lake	78.868	31.178	Jahnvi Ganga basin	4456	688	RS 2/LISS IV	01.10.2011
G078866E31178N	5O13105	-	Other moraine-dammed lake	78.866	31.178	Jahnvi Ganga basin	4457	723	RS 2/LISS IV	01.10.2011
G078829E31288N	5O13105	-	Other moraine-dammed lake	78.829	31.288	Jahnvi Ganga basin	5341	600	RS 2/LISS IV	01.10.2011
G078831E31251N	5O13105	-	Other glacier erosion lake	78.831	31.251	Jahnvi Ganga basin	5042	793	RS 2/LISS IV	01.10.2011
G078857E31233N	5O13105	-	Other moraine-dammed lake	78.857	31.233	Jahnvi Ganga basin	5268	8063	RS 2/LISS IV	20.09.2013
G078860E31238N	5O13105	-	Other moraine-dammed lake	78.860	31.238	Jahnvi Ganga basin	5251	2794	RS 2/LISS IV	20.09.2013
G078856E31235N	5O13105	-	Other moraine-dammed lake	78.856	31.235	Jahnvi Ganga basin	5280	960	RS 2/LISS IV	20.09.2013
G078858E31236N	5O13105	-	Other moraine-dammed lake	78.858	31.236	Jahnvi Ganga basin	5287	1146	RS 2/LISS IV	20.09.2013
G078857E31235N	5O13105	-	Other moraine-dammed lake	78.857	31.235	Jahnvi Ganga basin	5272	698	RS 2/LISS IV	20.09.2013
G078859E31237N	5O13105	-	Other moraine-dammed lake	78.859	31.237	Jahnvi Ganga basin	5265	788	RS 2/LISS IV	20.09.2013
G078842E31213N	5O13105	-	Other moraine-dammed lake	78.842	31.213	Jahnvi Ganga basin	5226	705	RS 2/LISS IV	20.09.2013
G078882E31222N	5O13105	-	Other moraine-dammed lake	78.882	31.222	Jahnvi Ganga basin	4923	895	RS 2/LISS IV	01.10.2011
G078869E31299N	5O13105	-	Other moraine-dammed lake	78.869	31.299	Jahnvi Ganga basin	5277	2159	RS 2/LISS IV	20.09.2013
G078140E31582N	5Q22208,09,10,11,12	-	Other glacier erosion lake	78.140	31.582	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	3571	1080	RS 2/LISS IV	07.11.2012
G077674E31677N	5Q22208,09,10,11,12	-	Other glacier erosion lake	77.674	31.677	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4613	7248	RS 2/LISS IV	08.11.2011
G077654E31652N	5Q22208,09,10,11,12	Sareolsar	Artificial lake	77.654	31.652	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4698	4510	RS 2/LISS IV	08.11.2011
G078185E31585N	5Q22208,09,10,11,12	-	End moraine-dammed lake	78.185	31.585	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4666	37805	RS 2/LISS IV	20.10.2011
G077686E31701N	5Q22208,09,10,11,12	-	Other glacier erosion lake	77.686	31.701	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4765	16083	RS 2/LISS IV	20.10.2011
G077901E31721N	5Q22208,09,10,11,12	-	Supra-glacial lake	77.901	31.721	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4062	3958	RS 2/LISS IV	20.10.2011
G077881E31711N	5Q22208,09,10,11,12	-	Other glacier erosion lake	77.881	31.711	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4647	2083	RS 2/LISS IV	20.10.2011
G078067E31686N	5Q22208,09,10,11,12	-	Other glacier erosion lake	78.067	31.686	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4447	761	RS 2/LISS IV	20.10.2011
G077897E31725N	5Q22208,09,10,11,12	-	Lateral moraine-dammed lake	77.897	31.725	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4075	2749	RS 2/LISS IV	20.10.2011
G077996E31735N	5Q22208,09,10,11,12	Kara	Other glacier erosion lake	77.996	31.735	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	3578	901	RS 2/LISS IV	20.10.2011
G077945E31707N	5Q22208,09,10,11,12	-	Supra-glacial lake	77.945	31.707	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4006	2009	RS 2/LISS IV	20.10.2011
G077672E31679N	5Q22208,09,10,11,12	-	Other glacier erosion lake	77.672	31.679	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4653	2940	RS 2/LISS IV	20.10.2011
G078138E31582N	5Q22208,09,10,11,12	-	Other glacier erosion lake	78.138	31.582	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	3611	721	RS 2/LISS IV	07.11.2012
G077959E31481N	5Q22208,09,10,11,12	-	Other moraine-dammed lake	77.959	31.481	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	3840	14534	RS 2/LISS IV	07.11.2012
G077871E31718N	5Q22208,09,10,11,12	-	Other moraine-dammed lake	77.871	31.718	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4721	31387	LANDSAT/OLI	08.09.2015
G078011E31406N	5Q22208,09,10,11,12	-	Other moraine-dammed lake	78.011	31.406	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4540	52730	LANDSAT/OLI	08.09.2015
G078027E31408N	5Q22208,09,10,11,12	-	Other moraine-dammed lake	78.027	31.408	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4443	43333	LANDSAT/OLI	08.09.2015
G078068E31419N	5Q22208,09,10,11,12	-	Other moraine-dammed lake	78.068	31.419	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4633	12473	LANDSAT/OLI	08.09.2015
G077663E31673N	5Q22208,09,10,11,12	-	Other moraine-dammed lake	77.663	31.673	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4714	36330	LANDSAT/OLI	08.09.2015
G077917E31434N	5Q22208,09,10,11,12	-	Other glacier erosion lake	77.917	31.434	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4992	5347	LANDSAT/OLI	08.09.2015
G078069E31423N	5Q22208,09,10,11,12	-	Other moraine-dammed lake	78.069	31.423	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4628	13459	LANDSAT/OLI	08.09.2015
G078077E31428N	5Q22208,09,10,11,12	-	Other moraine-dammed lake	78.077	31.428	Kurpan, Nogri, Kut, Soldan, Sorang-Wanger	4296	5692	LANDSAT/OLI	08.09.2015
G076749E32585N	5Q21210	-	Supra-glacial lake	76.749	32.585	Miyar basin	4199	1145	RS 2/LISS IV	15.10.2011
G076897E32840N	5Q21210	-	Other moraine-dammed lake	76.897	32.840	Miyar basin	4506	5220	RS 2/LISS IV	15.10.2011
G076895E32841N	5Q21210	-	Other moraine-dammed lake	76.895	32.841	Miyar basin	4513	3178	RS 2/LISS IV	15.10.2011
G076780E33004N	5Q21210	-	Debris-dammed lake	76.780	33.004	Miyar basin	4993	10790	RS 2/LISS IV	17.08.2012
G076749E32910N	5Q21210	-	Lateral moraine-dammed lake	76.749	32.910	Miyar basin	4621	7392	RS 2/LISS IV	17.08.2012
G076746E32911N	5Q21210	-	Lateral moraine-dammed lake	76.746	32.911	Miyar basin	4664	8022	RS 2/LISS IV	17.08.2012
G076727E32882N	5Q21210	-	Other glacier erosion lake	76.727	32.882	Miyar basin	4918	4569	RS 2/LISS IV	17.08.2012
G076941E32922N	5Q21210	-	Other glacier erosion lake	76.941	32.922	Miyar basin	5118	2098	RS 2/LISS IV	17.08.2012
G076944E32926N	5Q21210	-	Other moraine-dammed lake	76.944	32.926	Miyar basin	5188	9307	RS 2/LISS IV	17.08.2012
G076943E32927N	5Q21210	-	Other moraine-dammed lake	76.943	32.927	Miyar basin	5204	971	RS 2/LISS IV	17.08.2012
G076946E32929N	5Q21210	-	Other moraine-dammed lake	76.946	32.929	Miyar basin	5227	5625	RS 2/LISS IV	17.08.2012
G076963E32945N	5Q21210	-	Other moraine-dammed lake	76.963	32.945	Miyar basin	5121	6248	RS 2/LISS IV	17.08.2012
G076958E32971N	5Q21210	-	Other moraine-dammed lake	76.958	32.971	Miyar basin	4657	1405	RS 2/LISS IV	17.08.2012
G076958E32970N	5Q21210	-	Other moraine-dammed lake	76.958	32.970	Miyar basin	4657	1876	RS 2/LISS IV	17.08.2012
G076968E32968N	5Q21210	-	Other glacier erosion lake	76.968	32.968	Miyar basin	4836	1302	RS 2/LISS IV	17.08.2012
G076977E32960N	5Q21210	-	Supra-glacial lake	76.977	32.960	Miyar basin	5164	4450	RS 2/LISS IV	17.08.2012
G076978E32961N	5Q21210	-	Supra-glacial lake	76.978	32.961	Miyar basin	5161	3378	RS 2/LISS IV	17.08.2012
G076979E32966N	5Q21210	-	Supra-glacial lake	76.979	32.966	Miyar basin	5084	2031	RS 2/LISS IV	17.08.2012
G076993E32978N	5Q21210	-	Supra-glacial lake	76.993	32.978	Miyar basin	4966	876	RS 2/LISS IV	17.08.2012
G076989E32977N	5Q21210	-	Supra-glacial lake	76.989	32.977	Miyar basin	4955	1953	RS 2/LISS IV	17.08.2012
G076980E32980N	5Q21210	-	Supra-glacial lake	76.980	32.980	Miyar basin	4879	963	RS 2/LISS IV	17.08.2012
G076967E32986N	5Q21210	-	Other moraine-dammed lake	76.967	32.986	Miyar basin	5037	13895	RS 2/LISS IV	17.08.2012
G076968E32985N	5Q21210	-	Other moraine-dammed lake	76.968	32.985	Miyar basin	5014	1769	RS 2/LISS IV	17.08.2012
G076976E32986N	5Q21210	-	Other moraine-dammed lake	76.976	32.986	Miyar basin	5016	3867	RS 2/LISS IV	17.08.2012
G076959E32985N	5Q21210	-	Other moraine-dammed lake	76.959	32.985	Miyar basin	5207	1208	RS 2/LISS IV	17.08.2012
G076938E33000N	5Q21210	-	Other glacier erosion lake	76.938	33.000	Miyar basin	4984	621	RS 2/LISS IV	17.08.2012
G076921E32991N	5Q21210	-	Other glacier erosion lake	76.921	32.991	Miyar basin	4369	3313	RS 2/LISS IV	17.08.2012
G076920E32992N	5Q21210	-	Other glacier erosion lake	76.920	32.992	Miyar basin	4378	5984	RS 2/LISS IV	17.08.2012
G076888E33041N	5Q21210	-	Supra-glacial lake	76.888	33.041	Miyar basin	4664	2406	RS 2/LISS IV	17.08.2012
G076824E33066N	5Q21210	-	Lateral moraine-dammed lake	76.824	33.066	Miyar basin	5018	19668	RS 2/LISS IV	17.08.2012
G076824E33061N	5Q21210	-	Supra-glacial lake	76.824	33.061	Miyar basin	4982	2179	RS 2/LISS IV	17.08.2012

GLIMS lake ID	GSI basin ID	Lake name	Lake type	Longitude	Latitude	Basin(s)	Mean Elevation (m)	Area (m^2)	Satellite/ Sensor	Satellite acquisition date
G076825E33061N	5Q21210	-	Supra-glacial lake	76.825	33.061	Miyar basin	5001	949	RS 2/LISS IV	17.08.2012
G076826E33062N	5Q21210	-	Supra-glacial lake	76.826	33.062	Miyar basin	4999	1165	RS 2/LISS IV	17.08.2012
G076789E33043N	5Q21210	-	Other moraine-dammed lake	76.789	33.043	Miyar basin	4005	4887	RS 2/LISS IV	17.08.2012
G076791E33037N	5Q21210	-	Other moraine-dammed lake	76.791	33.037	Miyar basin	4004	2300	RS 2/LISS IV	17.08.2012
G076795E33039N	5Q21210	-	Other moraine-dammed lake	76.795	33.039	Miyar basin	3976	805	RS 2/LISS IV	17.08.2012
G076794E33039N	5Q21210	-	Other moraine-dammed lake	76.794	33.039	Miyar basin	3978	930	RS 2/LISS IV	17.08.2012
G076763E33065N	5Q21210	-	Supra-glacial lake	76.763	33.065	Miyar basin	4209	5346	RS 2/LISS IV	17.08.2012
G076786E33100N	5Q21210	-	Lateral moraine-dammed lake	76.786	33.100	Miyar basin	5080	15268	RS 2/LISS IV	17.08.2012
G076792E33098N	5Q21210	-	Other glacier erosion lake	76.792	33.098	Miyar basin	5053	16756	RS 2/LISS IV	17.08.2012
G076787E33103N	5Q21210	-	Glacier ice-dammed lake	76.787	33.103	Miyar basin	5087	2242	RS 2/LISS IV	17.08.2012
G076766E33134N	5Q21210	-	Supra-glacial lake	76.766	33.134	Miyar basin	4575	1070	RS 2/LISS IV	17.08.2012
G076755E33129N	5Q21210	-	Supra-glacial lake	76.755	33.129	Miyar basin	4547	980	RS 2/LISS IV	17.08.2012
G076770E33149N	5Q21210	-	Supra-glacial lake	76.770	33.149	Miyar basin	4662	740	RS 2/LISS IV	17.08.2012
G076761E33160N	5Q21210	-	Glacier ice-dammed lake	76.761	33.160	Miyar basin	4715	1436	RS 2/LISS IV	17.08.2012
G076764E32901N	5Q21210	-	Supra-glacial lake	76.764	32.901	Miyar basin	4432	1157	RS 2/LISS IV	17.08.2012
G076832E32923N	5Q21210	-	Lateral moraine-dammed lake	76.832	32.923	Miyar basin	4885	15992	RS 2/LISS IV	17.08.2012
G076784E33044N	5Q21210	-	Supra-glacial lake	76.784	33.044	Miyar basin	4023	1003	RS 2/LISS IV	17.08.2012
G076782E33049N	5Q21210	-	Supra-glacial lake	76.782	33.049	Miyar basin	4083	1007	RS 2/LISS IV	17.08.2012
G076781E33050N	5Q21210	-	Supra-glacial lake	76.781	33.050	Miyar basin	4083	1209	RS 2/LISS IV	17.08.2012
G076772E33055N	5Q21210	-	Supra-glacial lake	76.772	33.055	Miyar basin	4147	937	RS 2/LISS IV	17.08.2012
G076771E33057N	5Q21210	-	Supra-glacial lake	76.771	33.057	Miyar basin	4172	2250	RS 2/LISS IV	17.08.2012
G076771E33061N	5Q21210	-	Supra-glacial lake	76.771	33.061	Miyar basin	4176	678	RS 2/LISS IV	17.08.2012
G076768E33064N	5Q21210	-	Supra-glacial lake	76.768	33.064	Miyar basin	4202	4048	RS 2/LISS IV	17.08.2012
G076764E33062N	5Q21210	-	Supra-glacial lake	76.764	33.062	Miyar basin	4189	3896	RS 2/LISS IV	17.08.2012
G076765E33060N	5Q21210	-	Supra-glacial lake	76.765	33.060	Miyar basin	4171	1389	RS 2/LISS IV	17.08.2012
G076777E33058N	5Q21210	-	Supra-glacial lake	76.777	33.058	Miyar basin	4156	1155	RS 2/LISS IV	17.08.2012
G076762E33067N	5Q21210	-	Supra-glacial lake	76.762	33.067	Miyar basin	4216	2868	RS 2/LISS IV	17.08.2012
G076765E33068N	5Q21210	-	Supra-glacial lake	76.765	33.068	Miyar basin	4216	4844	RS 2/LISS IV	17.08.2012
G076762E33069N	5Q21210	-	Supra-glacial lake	76.762	33.069	Miyar basin	4222	3277	RS 2/LISS IV	17.08.2012
G076764E33072N	5Q21210	-	Supra-glacial lake	76.764	33.072	Miyar basin	4234	2776	RS 2/LISS IV	17.08.2012
G076762E33072N	5Q21210	-	Supra-glacial lake	76.762	33.072	Miyar basin	4236	1878	RS 2/LISS IV	17.08.2012
G076766E33072N	5Q21210	-	Supra-glacial lake	76.766	33.072	Miyar basin	4234	1541	RS 2/LISS IV	17.08.2012
G076764E33074N	5Q21210	-	Supra-glacial lake	76.764	33.074	Miyar basin	4236	1905	RS 2/LISS IV	17.08.2012
G076765E33077N	5Q21210	-	Supra-glacial lake	76.765	33.077	Miyar basin	4254	1381	RS 2/LISS IV	17.08.2012
G076761E33082N	5Q21210	-	Supra-glacial lake	76.761	33.082	Miyar basin	4287	1929	RS 2/LISS IV	17.08.2012
G076756E33085N	5Q21210	-	Supra-glacial lake	76.756	33.085	Miyar basin	4301	3735	RS 2/LISS IV	17.08.2012
G076766E33083N	5Q21210	-	Supra-glacial lake	76.766	33.083	Miyar basin	4276	2289	RS 2/LISS IV	17.08.2012
G076760E33068N	5Q21210	-	Supra-glacial lake	76.760	33.068	Miyar basin	4216	1565	RS 2/LISS IV	17.08.2012
G076762E33070N	5Q21210	-	Supra-glacial lake	76.762	33.070	Miyar basin	4222	958	RS 2/LISS IV	17.08.2012
G076783E33085N	5Q21210	-	Supra-glacial lake	76.783	33.085	Miyar basin	4410	3763	RS 2/LISS IV	17.08.2012
G076785E33083N	5Q21210	-	Supra-glacial lake	76.785	33.083	Miyar basin	4436	2217	RS 2/LISS IV	17.08.2012
G076746E33108N	5Q21210	-	Supra-glacial lake	76.746	33.108	Miyar basin	4419	1219	RS 2/LISS IV	17.08.2012
G076743E33097N	5Q21210	-	Glacier ice-dammed lake	76.743	33.097	Miyar basin	4453	1138	RS 2/LISS IV	17.08.2012
G076754E33088N	5Q21210	-	Supra-glacial lake	76.754	33.088	Miyar basin	4327	1602	RS 2/LISS IV	17.08.2012
G076755E33084N	5Q21210	-	Supra-glacial lake	76.755	33.084	Miyar basin	4291	1282	RS 2/LISS IV	17.08.2012
G076755E33086N	5Q21210	-	Supra-glacial lake	76.755	33.086	Miyar basin	4312	2563	RS 2/LISS IV	17.08.2012
G076681E32601N	5Q21210	-	Lateral moraine-dammed lake	76.681	32.601	Miyar basin	4121	761	RS 2/LISS IV	17.08.2012
G076668E32610N	5Q21210	-	Supra-glacial lake	76.668	32.610	Miyar basin	4328	1337	RS 2/LISS IV	17.08.2012
G076671E32625N	5Q21210	-	Supra-glacial lake	76.671	32.625	Miyar basin	4151	1991	RS 2/LISS IV	17.08.2012
G076642E32644N	5Q21210	-	Supra-glacial lake	76.642	32.644	Miyar basin	3880	1758	RS 2/LISS IV	17.08.2012
G076641E32641N	5Q21210	-	Supra-glacial lake	76.641	32.641	Miyar basin	3925	1162	RS 2/LISS IV	17.08.2012
G076585E32685N	5Q21210	-	Supra-glacial lake	76.585	32.685	Miyar basin	4053	5557	RS 2/LISS IV	17.08.2012
G076974E32763N	5Q21210	-	Other glacier erosion lake	76.974	32.763	Miyar basin	4996	858	RS 2/LISS IV	17.08.2012
G076970E32765N	5Q21210	-	Other glacier erosion lake	76.970	32.765	Miyar basin	5016	890	RS 2/LISS IV	17.08.2012
G076969E32721N	5Q21210	-	Supra-glacial lake	76.969	32.721	Miyar basin	5171	3477	RS 2/LISS IV	17.08.2012
G076582E32684N	5Q21210	-	Supra-glacial lake	76.582	32.684	Miyar basin	4076	3812	RS 2/LISS IV	17.08.2012
G076657E32658N	5Q21210	-	Other moraine-dammed lake	76.657	32.658	Miyar basin	3699	1827	RS 2/LISS IV	17.08.2012
G076657E32659N	5Q21210	-	Other moraine-dammed lake	76.657	32.659	Miyar basin	3699	2487	RS 2/LISS IV	17.08.2012
G076952E32761N	5Q21210	Neelkanth	Lateral moraine-dammed lake	76.952	32.761	Miyar basin	4507	1837	RS 2/LISS IV	17.08.2012
G076595E32667N	5Q21210	-	Supra-glacial lake	76.595	32.667	Miyar basin	4075	995	RS 2/LISS IV	17.08.2012
G076597E32666N	5Q21210	-	Supra-glacial lake	76.597	32.666	Miyar basin	4055	1496	RS 2/LISS IV	17.08.2012
G076655E32656N	5Q21210	-	Supra-glacial lake	76.655	32.656	Miyar basin	3714	3021	RS 2/LISS IV	17.08.2012
G076873E32614N	5Q21210	-	Other glacier erosion lake	76.873	32.614	Miyar basin	3004	1583	RS 2/LISS IV	17.08.2012
G076777E33184N	5Q21210	-	Supra-glacial lake	76.777	33.184	Miyar basin	4854	947	RS 2/LISS IV	17.08.2012
G076770E33144N	5Q21210	-	Supra-glacial lake	76.770	33.144	Miyar basin	4638	533	RS 2/LISS IV	17.08.2012
G076839E33084N	5Q21210	-	Supra-glacial lake	76.839	33.084	Miyar basin	4949	840	RS 2/LISS IV	17.08.2012
G076765E33083N	5Q21210	-	Supra-glacial lake	76.765	33.083	Miyar basin	4276	2621	RS 2/LISS IV	17.08.2012
G076872E33034N	5Q21210	-	Supra-glacial lake	76.872	33.034	Miyar basin	4539	1354	RS 2/LISS IV	17.08.2012
G076871E33035N	5Q21210	-	Supra-glacial lake	76.871	33.035	Miyar basin	4540	614	RS 2/LISS IV	17.08.2012
G076865E33031N	5Q21210	-	Supra-glacial lake	76.865	33.031	Miyar basin	4471	1000	RS 2/LISS IV	17.08.2012
G076861E33028N	5Q21210	-	Supra-glacial lake	76.861	33.028	Miyar basin	4429	790	RS 2/LISS IV	17.08.2012
G076804E33016N	5Q21210	-	Other moraine-dammed lake	76.804	33.016	Miyar basin	4374	6893	RS 2/LISS IV	17.08.2012
G076793E33010N	5Q21210	-	Other moraine-dammed lake	76.793	33.010	Miyar basin	4608	817	RS 2/LISS IV	17.08.2012
G076921E32989N	5Q21210	-	Other glacier erosion lake	76.921	32.989	Miyar basin	4375	1794	RS 2/LISS IV	17.08.2012
G076940E33002N	5Q21210	-	Other moraine-dammed lake	76.940	33.002	Miyar basin	4988	24860	RS 2/LISS IV	17.08.2012
G076984E32984N	5Q21210	-	Other glacier erosion lake	76.984	32.984	Miyar basin	4926	670	RS 2/LISS IV	17.08.2012
G076973E32948N	5Q21210	-	Other moraine-dammed lake	76.973	32.948	Miyar basin	5239	1956	RS 2/LISS IV	17.08.2012
G076947E32909N	5Q21210	-	Other glacier erosion lake	76.947	32.909	Miyar basin	5000	11843	RS 2/LISS IV	17.08.2012
G076943E32906N	5Q21210	-	Other glacier erosion lake	76.943	32.906	Miyar basin	4931	1344	RS 2/LISS IV	17.08.2012
G076943E32912N	5Q21210	-	Other glacier erosion lake	76.943	32.912	Miyar basin	4975	1566	RS 2/LISS IV	17.08.2012
G076960E32908N	5Q21210	-	Other glacier erosion lake	76.960	32.908	Miyar basin	5094	1669	RS 2/LISS IV	17.08.2012

GLIMS lake ID	GSI basin ID	Lake name	Lake type	Longitude	Latitude	Basin(s)	Mean Elevation (m)	Area (m^2)	Satellite/ Sensor	Satellite acquisition date
G076963E32907N	5Q21210	-	Other glacier erosion lake	76.963	32.907	Miyar basin	5090	7126	RS 2/LISS IV	17.08.2012
G076969E32902N	5Q21210	-	Glacier ice-dammed lake	76.969	32.902	Miyar basin	5121	1983	RS 2/LISS IV	17.08.2012
G076781E32912N	5Q21210	-	Other glacier erosion lake	76.781	32.912	Miyar basin	4898	1223	RS 2/LISS IV	17.08.2012
G076733E32888N	5Q21210	-	Other moraine-dammed lake	76.733	32.888	Miyar basin	4939	4444	RS 2/LISS IV	17.08.2012
G076932E32867N	5Q21210	-	Other moraine-dammed lake	76.932	32.867	Miyar basin	5001	23499	RS 2/LISS IV	17.08.2012
G076955E32870N	5Q21210	-	Supra-glacial lake	76.955	32.870	Miyar basin	5326	813	RS 2/LISS IV	17.08.2012
G076955E32875N	5Q21210	-	Supra-glacial lake	76.955	32.875	Miyar basin	5359	722	RS 2/LISS IV	17.08.2012
G076896E32838N	5Q21210	-	Supra-glacial lake	76.896	32.838	Miyar basin	4546	1841	RS 2/LISS IV	17.08.2012
G076895E32839N	5Q21210	-	Other moraine-dammed lake	76.895	32.839	Miyar basin	4541	799	RS 2/LISS IV	17.08.2012
G076878E32834N	5Q21210	-	Other glacier erosion lake	76.878	32.834	Miyar basin	4587	1671	RS 2/LISS IV	17.08.2012
G076859E32828N	5Q21210	-	Glacier ice-dammed lake	76.859	32.828	Miyar basin	4602	1495	RS 2/LISS IV	17.08.2012
G076856E32830N	5Q21210	-	Glacier ice-dammed lake	76.856	32.830	Miyar basin	4604	3538	RS 2/LISS IV	17.08.2012
G076854E32832N	5Q21210	-	Glacier ice-dammed lake	76.854	32.832	Miyar basin	4595	601	RS 2/LISS IV	17.08.2012
G076644E32821N	5Q21210	-	Supra-glacial lake	76.644	32.821	Miyar basin	4189	702	RS 2/LISS IV	17.08.2012
G076640E32822N	5Q21210	-	Lateral moraine-dammed lake	76.640	32.822	Miyar basin	4293	787	RS 2/LISS IV	17.08.2012
G076912E32824N	5Q21210	-	Supra-glacial lake	76.912	32.824	Miyar basin	4722	559	RS 2/LISS IV	17.08.2012
G076914E32824N	5Q21210	-	Supra-glacial lake	76.914	32.824	Miyar basin	4727	1739	RS 2/LISS IV	17.08.2012
G076861E32801N	5Q21210	-	Supra-glacial lake	76.861	32.801	Miyar basin	5052	3243	RS 2/LISS IV	17.08.2012
G076957E32787N	5Q21210	-	Other moraine-dammed lake	76.957	32.787	Miyar basin	4453	4429	RS 2/LISS IV	17.08.2012
G076951E32775N	5Q21210	-	Lateral moraine-dammed lake	76.951	32.775	Miyar basin	4412	13066	RS 2/LISS IV	17.08.2012
G076949E32777N	5Q21210	-	Lateral moraine-dammed lake	76.949	32.777	Miyar basin	4411	28657	RS 2/LISS IV	17.08.2012
G076935E32775N	5Q21210	-	Other moraine-dammed lake	76.935	32.775	Miyar basin	4268	1745	RS 2/LISS IV	17.08.2012
G076938E32773N	5Q21210	-	Supra-glacial lake	76.938	32.773	Miyar basin	4300	2594	RS 2/LISS IV	17.08.2012
G076935E32773N	5Q21210	-	Supra-glacial lake	76.935	32.773	Miyar basin	4278	1563	RS 2/LISS IV	17.08.2012
G076935E32774N	5Q21210	-	Supra-glacial lake	76.935	32.774	Miyar basin	4269	886	RS 2/LISS IV	17.08.2012
G076937E32773N	5Q21210	-	Supra-glacial lake	76.937	32.773	Miyar basin	4271	926	RS 2/LISS IV	17.08.2012
G076933E32772N	5Q21210	-	Other moraine-dammed lake	76.933	32.772	Miyar basin	4290	1618	RS 2/LISS IV	17.08.2012
G076970E32768N	5Q21210	-	Other glacier erosion lake	76.970	32.768	Miyar basin	5082	11067	RS 2/LISS IV	17.08.2012
G076967E32769N	5Q21210	-	Other glacier erosion lake	76.967	32.769	Miyar basin	5109	6532	RS 2/LISS IV	17.08.2012
G076952E32758N	5Q21210	-	Lateral moraine-dammed lake	76.952	32.758	Miyar basin	4519	24433	RS 2/LISS IV	17.08.2012
G076871E33032N	5Q21210	-	Supra-glacial lake	76.871	33.032	Miyar basin	4517	739	RS 2/LISS IV	17.08.2012
G076875E33035N	5Q21210	-	Supra-glacial lake	76.875	33.035	Miyar basin	4560	3318	RS 2/LISS IV	15.10.2011
G076955E32970N	5Q21210	-	Other moraine-dammed lake	76.955	32.970	Miyar basin	4629	1117	RS 2/LISS IV	15.10.2011
G076786E32573N	5Q21210	-	Supra-glacial lake	76.786	32.573	Miyar basin	4386	1201	RS 2/LISS IV	17.08.2012
G076890E32947N	5Q21210	-	Other glacier erosion lake	76.890	32.947	Miyar basin	3876	2066	RS 2/LISS IV	15.10.2011
G076768E33066N	5Q21210	-	Supra-glacial lake	76.768	33.066	Miyar basin	4200	1106	RS 2/LISS IV	17.08.2012
G076920E32988N	5Q21210	-	Other moraine-dammed lake	76.920	32.988	Miyar basin	4406	665	RS 2/LISS IV	17.08.2012
G076983E32989N	5Q21210	-	Other moraine-dammed lake	76.983	32.989	Miyar basin	5111	700	RS 2/LISS IV	17.08.2012
G076961E32900N	5Q21210	-	Other moraine-dammed lake	76.961	32.900	Miyar basin	5007	673	RS 2/LISS IV	17.08.2012
G076728E32893N	5Q21210	-	Supra-glacial lake	76.728	32.893	Miyar basin	5118	1131	RS 2/LISS IV	17.08.2012
G076954E32875N	5Q21210	-	Supra-glacial lake	76.954	32.875	Miyar basin	5347	702	RS 2/LISS IV	17.08.2012
G076787E32736N	5Q21210	-	Supra-glacial lake	76.787	32.736	Miyar basin	4525	1248	RS 2/LISS IV	17.08.2012
G076989E32978N	5Q21210	-	Supra-glacial lake	76.989	32.978	Miyar basin	4943	787	RS 2/LISS IV	17.08.2012
G076590E32687N	5Q21210	-	Supra-glacial lake	76.590	32.687	Miyar basin	4007	4004	LANDSAT/OLI	19.09.2014
G077492E32180N	5Q22109	-	Other glacier erosion lake	77.492	32.180	Parvati basin	4534	43539	RS 2/LISS IV	08.11.2011
G077501E32175N	5Q22109	-	Lateral moraine-dammed lake	77.501	32.175	Parvati basin	4306	6698	RS 2/LISS IV	08.11.2011
G077456E32134N	5Q22109	-	Other glacier erosion lake	77.456	32.134	Parvati basin	4558	100918	LANDSAT/OLI	17.10.2015
G077479E32131N	5Q22109	-	Other glacier erosion lake	77.479	32.131	Parvati basin	3900	1680	RS 2/LISS IV	08.11.2011
G077483E32115N	5Q22109	-	Other glacier erosion lake	77.483	32.115	Parvati basin	3837	2950	RS 2/LISS IV	08.11.2011
G077463E32065N	5Q22109	-	Other glacier erosion lake	77.463	32.065	Parvati basin	4313	7115	RS 2/LISS IV	08.11.2011
G077791E31837N	5Q22109	-	Other moraine-dammed lake	77.791	31.837	Parvati basin	4151	13272	RS 2/LISS IV	08.11.2011
G077792E31838N	5Q22109	-	Other moraine-dammed lake	77.792	31.838	Parvati basin	4149	1149	RS 2/LISS IV	08.11.2011
G077792E31842N	5Q22109	-	Other moraine-dammed lake	77.792	31.842	Parvati basin	4143	649	RS 2/LISS IV	08.11.2011
G077791E31845N	5Q22109	-	Other moraine-dammed lake	77.791	31.845	Parvati basin	4147	1937	RS 2/LISS IV	08.11.2011
G077658E32034N	5Q22109	-	Supra-glacial lake	77.658	32.034	Parvati basin	4641	1058	RS 2/LISS IV	08.11.2011
G077603E32049N	5Q22109	-	Medial moraine-dammed lake	77.603	32.049	Parvati basin	4736	3584	RS 2/LISS IV	08.11.2011
G077668E32029N	5Q22109	-	Other moraine-dammed lake	77.668	32.029	Parvati basin	4525	1901	RS 2/LISS IV	20.10.2011
G077797E31815N	5Q22109	-	Other moraine-dammed lake	77.797	31.815	Parvati basin	4217	1555	RS 2/LISS IV	20.10.2011
G077794E31820N	5Q22109	-	Other moraine-dammed lake	77.794	31.820	Parvati basin	4189	827	RS 2/LISS IV	20.10.2011
G077790E31829N	5Q22109	-	Other moraine-dammed lake	77.790	31.829	Parvati basin	4181	1471	RS 2/LISS IV	20.10.2011
G077792E31841N	5Q22109	-	Other moraine-dammed lake	77.792	31.841	Parvati basin	4148	8583	RS 2/LISS IV	20.10.2011
G077791E31844N	5Q22109	-	Other moraine-dammed lake	77.791	31.844	Parvati basin	4145	19582	RS 2/LISS IV	20.10.2011
G077789E31849N	5Q22109	-	Other moraine-dammed lake	77.789	31.849	Parvati basin	4153	35041	RS 2/LISS IV	20.10.2011
G077791E31848N	5Q22109	-	Other moraine-dammed lake	77.791	31.848	Parvati basin	4150	6433	RS 2/LISS IV	20.10.2011
G077791E31849N	5Q22109	-	Other moraine-dammed lake	77.791	31.849	Parvati basin	4142	1288	RS 2/LISS IV	20.10.2011
G077791E31847N	5Q22109	-	Other moraine-dammed lake	77.791	31.847	Parvati basin	4142	3540	RS 2/LISS IV	20.10.2011
G077791E31834N	5Q22109	-	Other moraine-dammed lake	77.791	31.834	Parvati basin	4177	1332	RS 2/LISS IV	20.10.2011
G077792E31834N	5Q22109	-	Other moraine-dammed lake	77.792	31.834	Parvati basin	4153	1819	RS 2/LISS IV	20.10.2011
G077793E31832N	5Q22109	-	Other moraine-dammed lake	77.793	31.832	Parvati basin	4165	924	RS 2/LISS IV	20.10.2011
G077790E31830N	5Q22109	-	Other moraine-dammed lake	77.790	31.830	Parvati basin	4163	957	RS 2/LISS IV	20.10.2011
G077790E31844N	5Q22109	-	Other moraine-dammed lake	77.790	31.844	Parvati basin	4142	2157	RS 2/LISS IV	20.10.2011
G077791E31830N	5Q22109	-	Other moraine-dammed lake	77.791	31.830	Parvati basin	4171	783	RS 2/LISS IV	08.11.2011
G077712E31948N	5Q22109	-	Other moraine-dammed lake	77.712	31.948	Parvati basin	4889	5898	RS 2/LISS IV	20.10.2011
G077623E31932N	5Q22109	-	Other moraine-dammed lake	77.623	31.932	Parvati basin	4547	1016	RS 2/LISS IV	20.10.2011
G077645E31902N	5Q22109	-	Glacier ice-dammed lake	77.645	31.902	Parvati basin	4213	2652	RS 2/LISS IV	08.11.2011
G077699E31972N	5Q22109	-	Other glacier erosion lake	77.699	31.972	Parvati basin	4800	9352	RS 2/LISS IV	20.10.2011
G077769E31924N	5Q22109	-	Other moraine-dammed lake	77.769	31.924	Parvati basin	5000	1218	RS 2/LISS IV	20.10.2011
G077510E32185N	5Q22109	-	Lateral moraine-dammed lake	77.510	32.185	Parvati basin	4438	958	RS 2/LISS IV	08.11.2011
G077526E31914N	5Q22109	-	End moraine-dammed lake	77.526	31.914	Parvati basin	4496	104575	LANDSAT/OLI	17.10.2015
G077455E32099N	5Q22109	-	Other glacier erosion lake	77.455	32.099	Parvati basin	4737	16293	LANDSAT/OLI	17.10.2015
G077456E32101N	5Q22109	-	Other glacier erosion lake	77.456	32.101	Parvati basin	4738	6624	LANDSAT/OLI	17.10.2015

GLIMS lake ID	GSI basin ID	Lake name	Lake type	Longitude	Latitude	Basin(s)	Mean Elevation (m)	Area (m^2)	Satellite/ Sensor	Satellite acquisition date
G077434E32072N	5Q22109	-	Other glacier erosion lake	77.434	32.072	Parvati basin	4857	8804	LANDSAT/OLI	17.10.2015
G077526E31898N	5Q22109	-	Other glacier erosion lake	77.526	31.898	Parvati basin	4708	23203	LANDSAT/OLI	17.10.2015
G077532E31898N	5Q22109	-	Other moraine-dammed lake	77.532	31.898	Parvati basin	4702	19038	LANDSAT/OLI	17.10.2015
G077538E31899N	5Q22109	-	Other moraine-dammed lake	77.538	31.899	Parvati basin	4634	19201	LANDSAT/OLI	17.10.2015
G077534E31902N	5Q22109	-	Other moraine-dammed lake	77.534	31.902	Parvati basin	4609	5743	LANDSAT/OLI	17.10.2015
G076755E32228N	5Q21106,07	-	Other glacier erosion lake	76.755	32.228	Ravi, Budhil basins	4526	6172	RS 2/LISS IV	15.10.2011
G077034E32214N	5Q21106,07	-	Other glacier erosion lake	77.034	32.214	Ravi, Budhil basins	4617	900	RS 2/LISS IV	15.10.2011
G077035E32216N	5Q21106,07	-	Other glacier erosion lake	77.035	32.216	Ravi, Budhil basins	4606	8740	RS 2/LISS IV	15.10.2011
G077034E32226N	5Q21106,07	-	Other glacier erosion lake	77.034	32.226	Ravi, Budhil basins	4694	13826	RS 2/LISS IV	15.10.2011
G076921E32296N	5Q21106,07	-	End moraine-dammed lake	76.921	32.296	Ravi, Budhil basins	4628	7820	RS 2/LISS IV	15.10.2011
G076753E32233N	5Q21106,07	-	End moraine-dammed lake	76.753	32.233	Ravi, Budhil basins	4359	85629	RS 2/LISS IV	15.10.2011
G076744E32210N	5Q21106,07	-	End moraine-dammed lake	76.744	32.210	Ravi, Budhil basins	4120	2729	RS 2/LISS IV	15.10.2011
G076759E32224N	5Q21106,07	-	Other glacier erosion lake	76.759	32.224	Ravi, Budhil basins	4605	1752	RS 2/LISS IV	15.10.2011
G076787E32244N	5Q21106,07	-	Other moraine-dammed lake	76.787	32.244	Ravi, Budhil basins	4339	74358	RS 2/LISS IV	15.10.2011
G076777E32256N	5Q21106,07	-	End moraine-dammed lake	76.777	32.256	Ravi, Budhil basins	4598	21432	RS 2/LISS IV	15.10.2011
G076803E32230N	5Q21106,07	-	Other glacier erosion lake	76.803	32.230	Ravi, Budhil basins	4631	8126	RS 2/LISS IV	15.10.2011
G076899E32213N	5Q21106,07	-	End moraine-dammed lake	76.899	32.213	Ravi, Budhil basins	4342	5641	RS 2/LISS IV	15.10.2011
G076899E32207N	5Q21106,07	-	Other glacier erosion lake	76.899	32.207	Ravi, Budhil basins	4396	6036	RS 2/LISS IV	15.10.2011
G076749E32369N	5Q21106,07	-	Other moraine-dammed lake	76.749	32.369	Ravi, Budhil basins	4722	5310	RS 2/LISS IV	17.08.2012
G076820E32223N	5Q21106,07	-	End moraine-dammed lake	76.820	32.223	Ravi, Budhil basins	4224	6441	RS 2/LISS IV	17.08.2012
G076812E32527N	5Q21106,07	-	Other moraine-dammed lake	76.812	32.527	Ravi, Budhil basins	4753	3696	RS 2/LISS IV	15.10.2011
G077007E32289N	5Q21106,07	-	Supra-glacial lake	77.007	32.289	Ravi, Budhil basins	4527	1970	RS 2/LISS IV	15.10.2011
G076808E32232N	5Q21106,07	-	Lateral moraine-dammed lake	76.808	32.232	Ravi, Budhil basins	4619	9215	RS 2/LISS IV	15.10.2011
G076884E32206N	5Q21106,07	-	Other glacier erosion lake	76.884	32.206	Ravi, Budhil basins	4571	1244	RS 2/LISS IV	15.10.2011
G076873E32207N	5Q21106,07	-	Other glacier erosion lake	76.873	32.207	Ravi, Budhil basins	4479	1320	RS 2/LISS IV	15.10.2011
G076741E32247N	5Q21106,07	-	Other glacier erosion lake	76.741	32.247	Ravi, Budhil basins	4471	747	RS 2/LISS IV	15.10.2011
G076944E32278N	5Q21106,07	-	Other moraine-dammed lake	76.944	32.278	Ravi, Budhil basins	4583	801	RS 2/LISS IV	15.10.2011
G076902E32289N	5Q21106,07	-	Other moraine-dammed lake	76.902	32.289	Ravi, Budhil basins	4452	1703	RS 2/LISS IV	15.10.2011
G077013E32336N	5Q21106,07	-	Other moraine-dammed lake	77.013	32.336	Ravi, Budhil basins	4520	9555	RS 2/LISS IV	15.10.2011
G077015E32335N	5Q21106,07	-	Other moraine-dammed lake	77.015	32.335	Ravi, Budhil basins	4521	2703	RS 2/LISS IV	15.10.2011
G077018E32341N	5Q21106,07	-	Other glacier erosion lake	77.018	32.341	Ravi, Budhil basins	4547	643	RS 2/LISS IV	15.10.2011
G076849E32421N	5Q21106,07	-	Lateral moraine-dammed lake	76.849	32.421	Ravi, Budhil basins	3611	21384	RS 2/LISS IV	15.10.2011
G076823E32509N	5Q21106,07	-	Other glacier erosion lake	76.823	32.509	Ravi, Budhil basins	4724	3320	RS 2/LISS IV	15.10.2011
G076823E32510N	5Q21106,07	-	Other glacier erosion lake	76.823	32.510	Ravi, Budhil basins	4687	3931	RS 2/LISS IV	15.10.2011
G076346E32345N	5Q21106,07	-	Other glacier erosion lake	76.346	32.345	Ravi, Budhil basins	4107	23610	RS 2/LISS IV	17.08.2012
G076332E32336N	5Q21106,07	-	Other glacier erosion lake	76.332	32.336	Ravi, Budhil basins	3978	294824	RS 2/LISS IV	17.08.2012
G076344E32332N	5Q21106,07	-	Other glacier erosion lake	76.344	32.332	Ravi, Budhil basins	4197	28066	RS 2/LISS IV	17.08.2012
G076326E32342N	5Q21106,07	-	Other glacier erosion lake	76.326	32.342	Ravi, Budhil basins	3943	22122	RS 2/LISS IV	17.08.2012
G076355E32336N	5Q21106,07	-	Other glacier erosion lake	76.355	32.336	Ravi, Budhil basins	4212	15666	RS 2/LISS IV	17.08.2012
G076358E32343N	5Q21106,07	-	Debris-dammed lake	76.358	32.343	Ravi, Budhil basins	3971	12345	RS 2/LISS IV	17.08.2012
G076322E32343N	5Q21106,07	-	Other glacier erosion lake	76.322	32.343	Ravi, Budhil basins	3915	12931	RS 2/LISS IV	17.08.2012
G076316E32342N	5Q21106,07	-	Other glacier erosion lake	76.316	32.342	Ravi, Budhil basins	3763	38711	RS 2/LISS IV	17.08.2012
G076371E32323N	5Q21106,07	-	Other glacier erosion lake	76.371	32.323	Ravi, Budhil basins	4378	6122	RS 2/LISS IV	17.08.2012
G076578E32569N	5Q21106,07	-	Other glacier erosion lake	76.578	32.569	Ravi, Budhil basins	3473	993	RS 2/LISS IV	17.08.2012
G076488E32269N	5Q21106,07	-	End moraine-dammed lake	76.488	32.269	Ravi, Budhil basins	4219	19666	RS 2/LISS IV	17.08.2012
G076496E32263N	5Q21106,07	-	Other glacier erosion lake	76.496	32.263	Ravi, Budhil basins	4386	6902	RS 2/LISS IV	17.08.2012
G076637E32395N	5Q21106,07	Manimahesh	Other glacier erosion lake	76.637	32.395	Ravi, Budhil basins	4189	7354	RS 2/LISS IV	17.08.2012
G076653E32396N	5Q21106,07	-	Other glacier erosion lake	76.653	32.396	Ravi, Budhil basins	4308	2836	RS 2/LISS IV	17.08.2012
G076565E32226N	5Q21106,07	-	Other glacier erosion lake	76.565	32.226	Ravi, Budhil basins	3573	1536	RS 2/LISS IV	17.08.2012
G076754E32369N	5Q21106,07	-	Other glacier erosion lake	76.754	32.369	Ravi, Budhil basins	4645	2049	RS 2/LISS IV	17.08.2012
G076757E32386N	5Q21106,07	-	Lateral moraine-dammed lake	76.757	32.386	Ravi, Budhil basins	4349	4663	RS 2/LISS IV	17.08.2012
G076908E32320N	5Q21106,07	-	Other glacier erosion lake	76.908	32.320	Ravi, Budhil basins	3874	10827	RS 2/LISS IV	17.08.2012
G076914E32318N	5Q21106,07	-	End moraine-dammed lake	76.914	32.318	Ravi, Budhil basins	4035	19065	RS 2/LISS IV	17.08.2012
G076978E32311N	5Q21106,07	-	Supra-glacial lake	76.978	32.311	Ravi, Budhil basins	4456	1363	RS 2/LISS IV	17.08.2012
G077036E32353N	5Q21106,07	-	Other glacier erosion lake	77.036	32.353	Ravi, Budhil basins	4732	8577	RS 2/LISS IV	17.08.2012
G077042E32355N	5Q21106,07	-	Other glacier erosion lake	77.042	32.355	Ravi, Budhil basins	4832	3333	RS 2/LISS IV	17.08.2012
G077037E32357N	5Q21106,07	-	Other glacier erosion lake	77.037	32.357	Ravi, Budhil basins	4797	2807	RS 2/LISS IV	17.08.2012
G077039E32360N	5Q21106,07	-	Other glacier erosion lake	77.039	32.360	Ravi, Budhil basins	4856	1907	RS 2/LISS IV	17.08.2012
G077043E32356N	5Q21106,07	-	Other glacier erosion lake	77.043	32.356	Ravi, Budhil basins	4843	7759	RS 2/LISS IV	17.08.2012
G076908E32210N	5Q21106,07	-	Other glacier erosion lake	76.908	32.210	Ravi, Budhil basins	4449	1876	RS 2/LISS IV	17.08.2012
G076789E32263N	5Q21106,07	-	Debris-dammed lake	76.789	32.263	Ravi, Budhil basins	4079	7112	RS 2/LISS IV	17.08.2012
G076535E32234N	5Q21106,07	-	Other glacier erosion lake	76.535	32.234	Ravi, Budhil basins	4243	25392	RS 2/LISS IV	17.08.2012
G076695E32379N	5Q21106,07	-	End moraine-dammed lake	76.695	32.379	Ravi, Budhil basins	4214	12513	RS 2/LISS IV	17.08.2012
G077014E32229N	5Q21106,07	-	Other glacier erosion lake	77.014	32.229	Ravi, Budhil basins	4633	657	RS 2/LISS IV	17.08.2012
G076819E32490N	5Q21106,07	-	Other moraine-dammed lake	76.819	32.490	Ravi, Budhil basins	3904	1368	RS 2/LISS IV	17.08.2012
G076842E32503N	5Q21106,07	-	Supra-glacial lake	76.842	32.503	Ravi, Budhil basins	4327	1130	RS 2/LISS IV	17.08.2012
G076858E32439N	5Q21106,07	-	Supra-glacial lake	76.858	32.439	Ravi, Budhil basins	3636	1743	RS 2/LISS IV	17.08.2012
G076848E32426N	5Q21106,07	-	Supra-glacial lake	76.848	32.426	Ravi, Budhil basins	4089	1198	RS 2/LISS IV	17.08.2012
G076847E32425N	5Q21106,07	-	Supra-glacial lake	76.847	32.425	Ravi, Budhil basins	4079	1172	RS 2/LISS IV	17.08.2012
G077022E32398N	5Q21106,07	-	Supra-glacial lake	77.022	32.398	Ravi, Budhil basins	4123	2810	RS 2/LISS IV	17.08.2012
G077024E32399N	5Q21106,07	-	Supra-glacial lake	77.024	32.399	Ravi, Budhil basins	4123	979	RS 2/LISS IV	17.08.2012
G077021E32381N	5Q21106,07	-	Supra-glacial lake	77.021	32.381	Ravi, Budhil basins	4168	1494	RS 2/LISS IV	17.08.2012
G077016E32392N	5Q21106,07	-	Supra-glacial lake	77.016	32.392	Ravi, Budhil basins	4123	991	RS 2/LISS IV	17.08.2012
G076394E32343N	5Q21106,07	-	Other moraine-dammed lake	76.394	32.343	Ravi, Budhil basins	4016	3050	RS 2/LISS IV	17.08.2012
G076753E32354N	5Q21106,07	-	Other glacier erosion lake	76.753	32.354	Ravi, Budhil basins	4574	4938	RS 2/LISS IV	17.08.2012
G076974E32264N	5Q21106,07	-	Other moraine-dammed lake	76.974	32.264	Ravi, Budhil basins	4684	1983	RS 2/LISS IV	17.08.2012
G076967E32263N	5Q21106,07	-	Other moraine-dammed lake	76.967	32.263	Ravi, Budhil basins	4619	11752	RS 2/LISS IV	17.08.2012
G076962E32268N	5Q21106,07	-	Other glacier erosion lake	76.962	32.268	Ravi, Budhil basins	4729	5934	RS 2/LISS IV	17.08.2012
G076966E32267N	5Q21106,07	-	Other glacier erosion lake	76.966	32.267	Ravi, Budhil basins	4751	1077	RS 2/LISS IV	17.08.2012
G076966E32268N	5Q21106,07	-	Other glacier erosion lake	76.966	32.268	Ravi, Budhil basins	4758	3225	RS 2/LISS IV	17.08.2012
G076985E32272N	5Q21106,07	-	Other moraine-dammed lake	76.985	32.272	Ravi, Budhil basins	4219	15329	RS 2/LISS IV	17.08.2012

GLIMS lake ID	GSI basin ID	Lake name	Lake type	Longitude	Latitude	Basin(s)	Mean Elevation (m)	Area (m^2)	Satellite/ Sensor	Satellite acquisition date
G076984E32274N	5Q21106,07	-	Other moraine-dammed lake	76.984	32.274	Ravi, Budhil basins	4205	14641	RS 2/LISS IV	17.08.2012
G076841E32266N	5Q21106,07	-	Debris-dammed lake	76.841	32.266	Ravi, Budhil basins	3387	1392	RS 2/LISS IV	17.08.2012
G076780E32256N	5Q21106,07	-	Other glacier erosion lake	76.780	32.256	Ravi, Budhil basins	4583	1020	RS 2/LISS IV	17.08.2012
G077024E32227N	5Q21106,07	-	Other glacier erosion lake	77.024	32.227	Ravi, Budhil basins	4734	13527	RS 2/LISS IV	17.08.2012
G077013E32232N	5Q21106,07	-	Other glacier erosion lake	77.013	32.232	Ravi, Budhil basins	4750	6001	RS 2/LISS IV	17.08.2012
G077018E32230N	5Q21106,07	-	Other glacier erosion lake	77.018	32.230	Ravi, Budhil basins	4674	4954	RS 2/LISS IV	17.08.2012
G077018E32227N	5Q21106,07	-	Other glacier erosion lake	77.018	32.227	Ravi, Budhil basins	4611	2405	RS 2/LISS IV	17.08.2012
G077031E32216N	5Q21106,07	-	Other glacier erosion lake	77.031	32.216	Ravi, Budhil basins	4552	23023	RS 2/LISS IV	17.08.2012
G077033E32217N	5Q21106,07	-	Other glacier erosion lake	77.033	32.217	Ravi, Budhil basins	4615	5283	RS 2/LISS IV	17.08.2012
G077033E32219N	5Q21106,07	-	Other glacier erosion lake	77.033	32.219	Ravi, Budhil basins	4610	4843	RS 2/LISS IV	17.08.2012
G077032E32220N	5Q21106,07	-	Other glacier erosion lake	77.032	32.220	Ravi, Budhil basins	4620	9585	RS 2/LISS IV	17.08.2012
G077031E32221N	5Q21106,07	-	Other glacier erosion lake	77.031	32.221	Ravi, Budhil basins	4615	4439	RS 2/LISS IV	17.08.2012
G077030E32221N	5Q21106,07	-	Other glacier erosion lake	77.030	32.221	Ravi, Budhil basins	4606	5835	RS 2/LISS IV	17.08.2012
G077032E32224N	5Q21106,07	-	Other glacier erosion lake	77.032	32.224	Ravi, Budhil basins	4680	10853	RS 2/LISS IV	17.08.2012
G077027E32219N	5Q21106,07	-	Other glacier erosion lake	77.027	32.219	Ravi, Budhil basins	4557	1271	RS 2/LISS IV	17.08.2012
G077024E32222N	5Q21106,07	-	Other glacier erosion lake	77.024	32.222	Ravi, Budhil basins	4636	955	RS 2/LISS IV	17.08.2012
G077023E32222N	5Q21106,07	-	Other glacier erosion lake	77.023	32.222	Ravi, Budhil basins	4606	2084	RS 2/LISS IV	17.08.2012
G077028E32230N	5Q21106,07	-	Other glacier erosion lake	77.028	32.230	Ravi, Budhil basins	4805	1524	RS 2/LISS IV	17.08.2012
G077026E32230N	5Q21106,07	-	Other glacier erosion lake	77.026	32.230	Ravi, Budhil basins	4793	808	RS 2/LISS IV	17.08.2012
G077021E32230N	5Q21106,07	-	Other glacier erosion lake	77.021	32.230	Ravi, Budhil basins	4698	1078	RS 2/LISS IV	17.08.2012
G077030E32232N	5Q21106,07	-	Other glacier erosion lake	77.030	32.232	Ravi, Budhil basins	4805	546	RS 2/LISS IV	17.08.2012
G076914E32244N	5Q21106,07	-	Other glacier erosion lake	76.914	32.244	Ravi, Budhil basins	4472	1333	RS 2/LISS IV	17.08.2012
G076787E32243N	5Q21106,07	-	Other moraine-dammed lake	76.787	32.243	Ravi, Budhil basins	4339	1766	RS 2/LISS IV	15.10.2011
G076787E32242N	5Q21106,07	-	Other moraine-dammed lake	76.787	32.242	Ravi, Budhil basins	4339	1024	RS 2/LISS IV	15.10.2011
G076787E32243N	5Q21106,07	-	Other moraine-dammed lake	76.787	32.243	Ravi, Budhil basins	4339	1454	RS 2/LISS IV	15.10.2011
G076778E32232N	5Q21106,07	-	Other moraine-dammed lake	76.778	32.232	Ravi, Budhil basins	4604	10094	RS 2/LISS IV	17.08.2012
G076785E32236N	5Q21106,07	-	Other moraine-dammed lake	76.785	32.236	Ravi, Budhil basins	4386	2256	RS 2/LISS IV	17.08.2012
G076761E32236N	5Q21106,07	-	Other moraine-dammed lake	76.761	32.236	Ravi, Budhil basins	4625	3937	RS 2/LISS IV	17.08.2012
G076755E32240N	5Q21106,07	-	End moraine-dammed lake	76.755	32.240	Ravi, Budhil basins	4447	1401	RS 2/LISS IV	17.08.2012
G076754E32237N	5Q21106,07	-	Other glacier erosion lake	76.754	32.237	Ravi, Budhil basins	4418	11379	RS 2/LISS IV	17.08.2012
G076455E32256N	5Q21106,07	-	Debris-dammed lake	76.455	32.256	Ravi, Budhil basins	4306	1341	RS 2/LISS IV	17.08.2012
G076524E32245N	5Q21106,07	-	Other glacier erosion lake	76.524	32.245	Ravi, Budhil basins	4307	4983	RS 2/LISS IV	17.08.2012
G076967E32257N	5Q21106,07	-	Other moraine-dammed lake	76.967	32.257	Ravi, Budhil basins	4662	1628	RS 2/LISS IV	17.08.2012
G076904E32214N	5Q21106,07	-	Lateral moraine-dammed lake	76.904	32.214	Ravi, Budhil basins	4416	5097	RS 2/LISS IV	17.08.2012
G076890E32207N	5Q21106,07	-	Other glacier erosion lake	76.890	32.207	Ravi, Budhil basins	4392	1309	RS 2/LISS IV	17.08.2012
G076831E32207N	5Q21106,07	-	Other moraine-dammed lake	76.831	32.207	Ravi, Budhil basins	4505	2865	RS 2/LISS IV	17.08.2012
G077002E32213N	5Q21106,07	-	Other moraine-dammed lake	77.002	32.213	Ravi, Budhil basins	4408	1046	RS 2/LISS IV	17.08.2012
G077035E32220N	5Q21106,07	-	Other glacier erosion lake	77.035	32.220	Ravi, Budhil basins	4635	2001	RS 2/LISS IV	15.10.2011
G077018E32235N	5Q21106,07	-	Other glacier erosion lake	77.018	32.235	Ravi, Budhil basins	4756	7998	RS 2/LISS IV	15.10.2011
G077016E32235N	5Q21106,07	-	Other glacier erosion lake	77.016	32.235	Ravi, Budhil basins	4757	2246	RS 2/LISS IV	15.10.2011
G077018E32233N	5Q21106,07	-	Other glacier erosion lake	77.018	32.233	Ravi, Budhil basins	4705	1406	RS 2/LISS IV	15.10.2011
G076809E32226N	5Q21106,07	-	End moraine-dammed lake	76.809	32.226	Ravi, Budhil basins	4426	15730	RS 2/LISS IV	17.08.2012
G076820E32225N	5Q21106,07	-	Other moraine-dammed lake	76.820	32.225	Ravi, Budhil basins	4209	3260	RS 2/LISS IV	17.08.2012
G077023E32398N	5Q21106,07	-	Supra-glacial lake	77.023	32.398	Ravi, Budhil basins	4123	2983	RS 2/LISS IV	15.10.2011
G077044E32383N	5Q21106,07	-	Supra-glacial lake	77.044	32.383	Ravi, Budhil basins	4354	3033	RS 2/LISS IV	15.10.2011
G076748E32538N	5Q21106,07	-	Other glacier erosion lake	76.748	32.538	Ravi, Budhil basins	4418	1652	RS 2/LISS IV	17.08.2012
G076869E32521N	5Q21106,07	-	Supra-glacial lake	76.869	32.521	Ravi, Budhil basins	4972	6607	RS 2/LISS IV	17.08.2012
G076850E32511N	5Q21106,07	-	Lateral moraine-dammed lake	76.850	32.511	Ravi, Budhil basins	4423	1307	RS 2/LISS IV	17.08.2012
G076304E32345N	5Q21106,07	Lam Dal	Other glacier erosion lake	76.304	32.345	Ravi, Budhil basins	3661	16526	LANDSAT/OLI	17.10.2015
G076371E32312N	5Q21106,07	-	Other glacier erosion lake	76.371	32.312	Ravi, Budhil basins	4173	31156	LANDSAT/OLI	17.10.2015
G076427E32270N	5Q21106,07	-	Other glacier erosion lake	76.427	32.270	Ravi, Budhil basins	4321	42499	LANDSAT/OLI	19.09.2014
G076587E33181N	5Q21208	-	Other glacier erosion lake	76.587	33.181	Saichu basin	4835	3202	RS 2/LISS IV	17.08.2012
G076591E33184N	5Q21208	-	Other glacier erosion lake	76.591	33.184	Saichu basin	4837	4968	RS 2/LISS IV	17.08.2012
G076593E33180N	5Q21208	-	Other glacier erosion lake	76.593	33.180	Saichu basin	4803	13839	RS 2/LISS IV	17.08.2012
G076594E33179N	5Q21208	-	Other glacier erosion lake	76.594	33.179	Saichu basin	4775	1100	RS 2/LISS IV	17.08.2012
G076593E33165N	5Q21208	-	Lateral moraine-dammed lake	76.593	33.165	Saichu basin	4339	2761	RS 2/LISS IV	17.08.2012
G076575E33158N	5Q21208	-	Supra-glacial lake	76.575	33.158	Saichu basin	4158	2300	RS 2/LISS IV	17.08.2012
G076573E33126N	5Q21208	-	Other glacier erosion lake	76.573	33.126	Saichu basin	4792	10405	RS 2/LISS IV	17.08.2012
G076570E33123N	5Q21208	-	Other glacier erosion lake	76.570	33.123	Saichu basin	4675	1113	RS 2/LISS IV	17.08.2012
G076580E33116N	5Q21208	-	Other glacier erosion lake	76.580	33.116	Saichu basin	4661	1253	RS 2/LISS IV	17.08.2012
G076582E33116N	5Q21208	-	Other glacier erosion lake	76.582	33.116	Saichu basin	4678	2851	RS 2/LISS IV	17.08.2012
G076584E33117N	5Q21208	-	Other glacier erosion lake	76.584	33.117	Saichu basin	4704	7008	RS 2/LISS IV	17.08.2012
G076527E33076N	5Q21208	-	Other glacier erosion lake	76.527	33.076	Saichu basin	4521	1458	RS 2/LISS IV	17.08.2012
G076743E33024N	5Q21208	-	Other glacier erosion lake	76.743	33.024	Saichu basin	4997	20062	RS 2/LISS IV	17.08.2012
G076741E33027N	5Q21208	-	Other glacier erosion lake	76.741	33.027	Saichu basin	4998	19058	RS 2/LISS IV	17.08.2012
G076740E33029N	5Q21208	-	Other glacier erosion lake	76.740	33.029	Saichu basin	5001	16821	RS 2/LISS IV	17.08.2012
G076734E33025N	5Q21208	-	Other glacier erosion lake	76.734	33.025	Saichu basin	4860	4178	RS 2/LISS IV	17.08.2012
G076744E33030N	5Q21208	-	Other glacier erosion lake	76.744	33.030	Saichu basin	5088	1728	RS 2/LISS IV	17.08.2012
G076748E33025N	5Q21208	-	Other glacier erosion lake	76.748	33.025	Saichu basin	5146	892	RS 2/LISS IV	17.08.2012
G076762E32961N	5Q21208	-	Other moraine-dammed lake	76.762	32.961	Saichu basin	4933	9726	RS 2/LISS IV	17.08.2012
G076721E33165N	5Q21208	-	Other glacier erosion lake	76.721	33.165	Saichu basin	4872	3315	RS 2/LISS IV	17.08.2012
G076714E33164N	5Q21208	-	End moraine-dammed lake	76.714	33.164	Saichu basin	4792	5161	RS 2/LISS IV	17.08.2012
G076721E33132N	5Q21208	-	Other glacier erosion lake	76.721	33.132	Saichu basin	4991	28620	RS 2/LISS IV	17.08.2012
G076714E33123N	5Q21208	-	Other moraine-dammed lake	76.714	33.123	Saichu basin	4621	24775	RS 2/LISS IV	17.08.2012
G076711E33123N	5Q21208	-	Other moraine-dammed lake	76.711	33.123	Saichu basin	4653	12722	RS 2/LISS IV	17.08.2012
G076732E33127N	5Q21208	-	Other glacier erosion lake	76.732	33.127	Saichu basin	4788	1825	RS 2/LISS IV	17.08.2012
G076730E33126N	5Q21208	-	Other glacier erosion lake	76.730	33.126	Saichu basin	4760	1008	RS 2/LISS IV	17.08.2012
G076731E33128N	5Q21208	-	Other moraine-dammed lake	76.731	33.128	Saichu basin	4795	1870	RS 2/LISS IV	17.08.2012
G076735E33132N	5Q21208	-	Other moraine-dammed lake	76.735	33.132	Saichu basin	4831	8055	RS 2/LISS IV	17.08.2012
G076700E33087N	5Q21208	-	Other moraine-dammed lake	76.700	33.087	Saichu basin	4645	17385	RS 2/LISS IV	17.08.2012
G076704E33087N	5Q21208	-	Other moraine-dammed lake	76.704	33.087	Saichu basin	4675	1048	RS 2/LISS IV	17.08.2012

GLIMS lake ID	GSI basin ID	Lake name	Lake type	Longitude	Latitude	Basin(s)	Mean Elevation (m)	Area (m^2)	Satellite/ Sensor	Satellite acquisition date
G076704E33083N	5Q21208	-	Other glacier erosion lake	76.704	33.083	Saichu basin	4722	2492	RS 2/LISS IV	17.08.2012
G076716E33084N	5Q21208	-	Other glacier erosion lake	76.716	33.084	Saichu basin	4785	3953	RS 2/LISS IV	17.08.2012
G076721E33067N	5Q21208	-	Other glacier erosion lake	76.721	33.067	Saichu basin	4934	9649	RS 2/LISS IV	17.08.2012
G076723E33065N	5Q21208	-	Other glacier erosion lake	76.723	33.065	Saichu basin	4933	5078	RS 2/LISS IV	17.08.2012
G076724E33066N	5Q21208	-	Other glacier erosion lake	76.724	33.066	Saichu basin	4939	6546	RS 2/LISS IV	17.08.2012
G076728E33067N	5Q21208	-	Other glacier erosion lake	76.728	33.067	Saichu basin	5008	7519	RS 2/LISS IV	17.08.2012
G076727E33068N	5Q21208	-	Other glacier erosion lake	76.727	33.068	Saichu basin	5006	3179	RS 2/LISS IV	17.08.2012
G076738E33046N	5Q21208	-	Supra-glacial lake	76.738	33.046	Saichu basin	4982	759	RS 2/LISS IV	17.08.2012
G076735E33015N	5Q21208	-	Other glacier erosion lake	76.735	33.015	Saichu basin	4906	590	RS 2/LISS IV	17.08.2012
G076736E33014N	5Q21208	-	Other glacier erosion lake	76.736	33.014	Saichu basin	4920	2431	RS 2/LISS IV	17.08.2012
G076675E32964N	5Q21208	-	Supra-glacial lake	76.675	32.964	Saichu basin	4282	8236	RS 2/LISS IV	17.08.2012
G076674E32965N	5Q21208	-	Supra-glacial lake	76.674	32.965	Saichu basin	4253	2167	RS 2/LISS IV	17.08.2012
G076665E32970N	5Q21208	-	Supra-glacial lake	76.665	32.970	Saichu basin	4159	2036	RS 2/LISS IV	17.08.2012
G076674E32966N	5Q21208	-	Supra-glacial lake	76.674	32.966	Saichu basin	4270	2232	RS 2/LISS IV	17.08.2012
G076684E32952N	5Q21208	-	Lateral moraine-dammed lake	76.684	32.952	Saichu basin	4510	583	RS 2/LISS IV	17.08.2012
G076658E32909N	5Q21208	-	Supra-glacial lake	76.658	32.909	Saichu basin	4543	821	RS 2/LISS IV	17.08.2012
G076590E32873N	5Q21208	-	Supra-glacial lake	76.590	32.873	Saichu basin	4298	8025	RS 2/LISS IV	17.08.2012
G076584E32885N	5Q21208	-	Lateral moraine-dammed lake	76.584	32.885	Saichu basin	4200	3370	RS 2/LISS IV	17.08.2012
G076647E32886N	5Q21208	-	Other moraine-dammed lake	76.647	32.886	Saichu basin	3924	16780	RS 2/LISS IV	17.08.2012
G076741E32956N	5Q21208	-	Supra-glacial lake	76.741	32.956	Saichu basin	4392	1901	RS 2/LISS IV	17.08.2012
G076747E32954N	5Q21208	-	Lateral moraine-dammed lake	76.747	32.954	Saichu basin	4479	2257	RS 2/LISS IV	17.08.2012
G076772E32960N	5Q21208	-	Other moraine-dammed lake	76.772	32.960	Saichu basin	5082	3148	RS 2/LISS IV	17.08.2012
G076709E33067N	5Q21208	-	Other glacier erosion lake	76.709	33.067	Saichu basin	4968	637	RS 2/LISS IV	17.08.2012
G076707E33109N	5Q21208	-	Lateral moraine-dammed lake	76.707	33.109	Saichu basin	4965	5600	RS 2/LISS IV	17.08.2012
G076719E33104N	5Q21208	-	Other moraine-dammed lake	76.719	33.104	Saichu basin	4974	987	RS 2/LISS IV	17.08.2012
G076655E32907N	5Q21208	-	Supra-glacial lake	76.655	32.907	Saichu basin	4515	886	RS 2/LISS IV	17.08.2012
G076537E32841N	5Q21208	-	End moraine-dammed lake	76.537	32.841	Saichu basin	3928	21441	RS 2/LISS IV	17.08.2012
G076603E33133N	5Q21208	-	End moraine-dammed lake	76.603	33.133	Saichu basin	4421	6919	RS 2/LISS IV	17.08.2012
G076716E33106N	5Q21208	-	Other glacier erosion lake	76.716	33.106	Saichu basin	5052	878	RS 2/LISS IV	17.08.2012
G076651E33056N	5Q21208	-	Other moraine-dammed lake	76.651	33.056	Saichu basin	4734	3147	RS 2/LISS IV	17.08.2012
G076728E33042N	5Q21208	-	Supra-glacial lake	76.728	33.042	Saichu basin	4867	1082	RS 2/LISS IV	17.08.2012
G076733E33024N	5Q21208	-	Other moraine-dammed lake	76.733	33.024	Saichu basin	4819	1100	RS 2/LISS IV	17.08.2012
G076756E33013N	5Q21208	-	Other glacier erosion lake	76.756	33.013	Saichu basin	5108	883	RS 2/LISS IV	17.08.2012
G076650E32883N	5Q21208	-	Other glacier erosion lake	76.650	32.883	Saichu basin	3951	1007	RS 2/LISS IV	17.08.2012
G076706E32948N	5Q21208	-	Other moraine-dammed lake	76.706	32.948	Saichu basin	4863	544	RS 2/LISS IV	17.08.2012
G076710E32947N	5Q21208	-	Other moraine-dammed lake	76.710	32.947	Saichu basin	4912	605	RS 2/LISS IV	17.08.2012
G076672E33144N	5Q21208	-	End moraine-dammed lake	76.672	33.144	Saichu basin	4908	13712	LANDSAT/OLI	28.09.2015
G076572E33161N	5Q21208	-	Supra-glacial lake	76.572	33.161	Saichu basin	4129	1574	RS 2/LISS IV	17.08.2012
G076733E33012N	5Q21208	-	Other moraine-dammed lake	76.733	33.012	Saichu basin	4904	3746	RS 2/LISS IV	17.08.2012
G076703E32961N	5Q21208	-	Other moraine-dammed lake	76.703	32.961	Saichu basin	4876	3969	RS 2/LISS IV	17.08.2012
G076772E32960N	5Q21208	-	Other moraine-dammed lake	76.772	32.960	Saichu basin	5103	711	RS 2/LISS IV	17.08.2012
G076671E32930N	5Q21208	-	End moraine-dammed lake	76.671	32.930	Saichu basin	4814	41684	LANDSAT/OLI	28.09.2014
G076405E32621N	5Q21104	-	Debris-dammed lake	76.405	32.621	Siul basin	3763	34604	RS 2/LISS IV	17.08.2012
G076413E32611N	5Q21104	-	Other glacier erosion lake	76.413	32.611	Siul basin	3926	2500	RS 2/LISS IV	17.08.2012
G076103E32979N	5Q21104	-	Other glacier erosion lake	76.103	32.979	Siul basin	3905	2519	RS 2/LISS IV	27.11.2011
G076102E32979N	5Q21104	-	Other glacier erosion lake	76.102	32.979	Siul basin	3929	880	RS 2/LISS IV	27.11.2011
G076241E32982N	5Q21104	-	Other glacier erosion lake	76.241	32.982	Siul basin	4267	1718	RS 2/LISS IV	27.11.2011
G076236E32988N	5Q21104	-	End moraine-dammed lake	76.236	32.988	Siul basin	4144	47297	LANDSAT/OLI	19.09.2014
G078411E32176N	5Q22219	-	Other moraine-dammed lake	78.411	32.176	Spiti basin	5258	3565	RS 2/LISS IV	09.10.2013
G077964E32167N	5Q22219	-	Supra-glacial lake	77.964	32.167	Spiti basin	5141	1711	RS 2/LISS IV	09.10.2013
G078121E32380N	5Q22219	-	End moraine-dammed lake	78.121	32.380	Spiti basin	4964	16380	RS 2/LISS IV	09.10.2013
G078121E32379N	5Q22219	-	End moraine-dammed lake	78.121	32.379	Spiti basin	4996	822	RS 2/LISS IV	09.10.2013
G078076E32381N	5Q22219	-	Other glacier erosion lake	78.076	32.381	Spiti basin	5239	1189	RS 2/LISS IV	09.10.2013
G077942E32525N	5Q22219	-	End moraine-dammed lake	77.942	32.525	Spiti basin	5287	21583	RS 2/LISS IV	09.10.2013
G077965E32530N	5Q22219	-	Other glacier erosion lake	77.965	32.530	Spiti basin	5353	1679	RS 2/LISS IV	09.10.2013
G077966E32533N	5Q22219	-	Other glacier erosion lake	77.966	32.533	Spiti basin	5219	7402	RS 2/LISS IV	09.10.2013
G078201E32302N	5Q22219	-	Supra-glacial lake	78.201	32.302	Spiti basin	5230	1935	RS 2/LISS IV	09.10.2013
G078187E32309N	5Q22219	-	Other moraine-dammed lake	78.187	32.309	Spiti basin	5359	2232	RS 2/LISS IV	09.10.2013
G078028E32307N	5Q22219	-	Other glacier erosion lake	78.028	32.307	Spiti basin	4403	1527	RS 2/LISS IV	09.10.2013
G078026E32306N	5Q22219	-	Other glacier erosion lake	78.026	32.306	Spiti basin	4377	1959	RS 2/LISS IV	09.10.2013
G078024E32304N	5Q22219	-	Other glacier erosion lake	78.024	32.304	Spiti basin	4325	820	RS 2/LISS IV	09.10.2013
G078024E32304N	5Q22219	-	Other glacier erosion lake	78.024	32.304	Spiti basin	4311	766	RS 2/LISS IV	09.10.2013
G077810E32374N	5Q22219	-	Supra-glacial lake	77.810	32.374	Spiti basin	5117	942	RS 2/LISS IV	09.10.2013
G078041E32345N	5Q22219	-	Other glacier erosion lake	78.041	32.345	Spiti basin	4705	4298	RS 2/LISS IV	09.10.2013
G078418E32204N	5Q22219	-	End moraine-dammed lake	78.418	32.204	Spiti basin	5604	32845	RS 2/LISS IV	09.10.2013
G078412E32177N	5Q22219	-	Other moraine-dammed lake	78.412	32.177	Spiti basin	5227	570	RS 2/LISS IV	09.10.2013
G078082E32422N	5Q22219	-	Debris-dammed lake	78.082	32.422	Spiti basin	4667	28817	RS 2/LISS IV	09.10.2013
G078088E32426N	5Q22219	-	Debris-dammed lake	78.088	32.426	Spiti basin	4734	9351	RS 2/LISS IV	09.10.2013
G078090E32428N	5Q22219	-	Debris-dammed lake	78.090	32.428	Spiti basin	4708	7730	RS 2/LISS IV	09.10.2013
G078092E32431N	5Q22219	-	Debris-dammed lake	78.092	32.431	Spiti basin	4729	3160	RS 2/LISS IV	09.10.2013
G077857E32524N	5Q22219	-	End moraine-dammed lake	77.857	32.524	Spiti basin	5237	3273	RS 2/LISS IV	09.10.2013
G077801E32476N	5Q22219	-	Supra-glacial lake	77.801	32.476	Spiti basin	5426	4327	RS 2/LISS IV	09.10.2013
G077954E32516N	5Q22219	-	Other glacier erosion lake	77.954	32.516	Spiti basin	5420	950	RS 2/LISS IV	09.10.2013
G078033E32242N	5Q22219	-	Artificial lake	78.033	32.242	Spiti basin	3663	3906	RS 2/LISS IV	09.10.2013
G078051E32494N	5Q22219	-	Debris-dammed lake	78.051	32.494	Spiti basin	5440	558	RS 2/LISS IV	09.10.2013
G078067E32402N	5Q22219	-	Debris-dammed lake	78.067	32.402	Spiti basin	4473	7671	RS 2/LISS IV	09.10.2013
G078079E32570N	5Q22219	-	End moraine-dammed lake	78.079	32.570	Spiti basin	5554	2513	RS 2/LISS IV	09.10.2013
G078097E32356N	5Q22219	-	Other glacier erosion lake	78.097	32.356	Spiti basin	5410	1400	RS 2/LISS IV	09.10.2013
G078109E32637N	5Q22219	-	Other moraine-dammed lake	78.109	32.637	Spiti basin	5514	5250	RS 2/LISS IV	09.10.2013
G078145E32323N	5Q22219	-	Supra-glacial lake	78.145	32.323	Spiti basin	5205	595	RS 2/LISS IV	09.10.2013
G078234E32285N	5Q22219	-	Supra-glacial lake	78.234	32.285	Spiti basin	5505	1326	RS 2/LISS IV	09.10.2013

GLIMS lake ID	GSI basin ID	Lake name	Lake type	Longitude	Latitude	Basin(s)	Mean Elevation (m)	Area (m^2)	Satellite/ Sensor	Satellite acquisition date
G078368E32314N	5Q22219	-	Other glacier erosion lake	78.368	32.314	Spiti basin	4824	15710	RS 2/LISS IV	09.10.2013
G078378E32093N	5Q22219	-	Artificial lake	78.378	32.093	Spiti basin	3264	1360	RS 2/LISS IV	13.11.2011
G078379E32093N	5Q22219	-	Artificial lake	78.379	32.093	Spiti basin	3262	1625	RS 2/LISS IV	13.11.2011
G078628E31880N	5Q22219	Nako	Artificial lake	78.628	31.880	Spiti basin	3651	8015	RS 2/LISS IV	13.11.2011
G078416E31965N	5Q22219	-	End moraine-dammed lake	78.416	31.965	Spiti basin	4881	50462	LANDSAT/OLI	08.09.2015
G078711E31999N	5Q22219	-	Supra-glacial lake	78.711	31.999	Spiti basin	5288	3876	RS 2/LISS IV	13.11.2011
G078708E32000N	5Q22219	-	Supra-glacial lake	78.708	32.000	Spiti basin	5268	2439	RS 2/LISS IV	13.11.2011
G078062E32324N	5Q22219	-	Other glacier erosion lake	78.062	32.324	Spiti basin	4745	2911	RS 2/LISS IV	09.10.2013
G078075E32409N	5Q22219	-	Debris-dammed lake	78.075	32.409	Spiti basin	4522	1373	RS 2/LISS IV	09.10.2013
G077939E32166N	5Q22219	-	Debris-dammed lake	77.939	32.166	Spiti basin	4535	953	RS 2/LISS IV	07.11.2012
G078488E32149N	5Q22219	-	End moraine-dammed lake	78.488	32.149	Spiti basin	5276	54096	LANDSAT/OLI	08.09.2015
G078685E31934N	5Q22219	-	Glacier ice-dammed lake	78.685	31.934	Spiti basin	5276	1157	LANDSAT/OLI	08.09.2015
G077915E32137N	5Q22219	-	End moraine-dammed lake	77.915	32.137	Spiti basin	5063	9078	RS 2/LISS IV	08.11.2011
G077925E32129N	5Q22219	-	Other moraine-dammed lake	77.925	32.129	Spiti basin	5225	11023	RS 2/LISS IV	08.11.2011
G077941E32140N	5Q22219	-	Debris-dammed lake	77.941	32.140	Spiti basin	5130	2468	RS 2/LISS IV	08.11.2011
G077778E32075N	5Q22219	-	Supra-glacial lake	77.778	32.075	Spiti basin	5090	894	RS 2/LISS IV	08.11.2011
G077817E32078N	5Q22219	-	Supra-glacial lake	77.817	32.078	Spiti basin	4715	2021	RS 2/LISS IV	08.11.2011
G077884E32070N	5Q22219	-	Other glacier erosion lake	77.884	32.070	Spiti basin	4163	693	RS 2/LISS IV	08.11.2011
G077761E32242N	5Q22219	-	End moraine-dammed lake	77.761	32.242	Spiti basin	5200	10482	RS 2/LISS IV	09.10.2013
G077736E32263N	5Q22219	-	Other moraine-dammed lake	77.736	32.263	Spiti basin	5206	1250	RS 2/LISS IV	09.10.2013
G077762E32375N	5Q22219	-	Medial moraine-dammed lake	77.762	32.375	Spiti basin	5222	1213	RS 2/LISS IV	09.10.2013
G078194E32418N	5Q22219	-	Other moraine-dammed lake	78.194	32.418	Spiti basin	5366	584	RS 2/LISS IV	09.10.2013
G077903E32242N	5Q22219	-	Other glacier erosion lake	77.903	32.242	Spiti basin	5394	754	RS 2/LISS IV	09.10.2013
G078264E32029N	5Q22219	-	Artificial lake	78.264	32.029	Spiti basin	3530	4135	RS 2/LISS IV	20.10.2011
G078281E32017N	5Q22219	-	Artificial lake	78.281	32.017	Spiti basin	4094	1774	RS 2/LISS IV	20.10.2011
G078275E32029N	5Q22219	-	Other glacier erosion lake	78.275	32.029	Spiti basin	3673	2797	RS 2/LISS IV	20.10.2011
G078228E32090N	5Q22219	Dhankar	Other glacier erosion lake	78.228	32.090	Spiti basin	4138	27230	RS 2/LISS IV	20.10.2011
G078183E31927N	5Q22219	-	Other moraine-dammed lake	78.183	31.927	Spiti basin	5224	1411	RS 2/LISS IV	20.10.2011
G078182E31928N	5Q22219	-	Other moraine-dammed lake	78.182	31.928	Spiti basin	5210	996	RS 2/LISS IV	20.10.2011
G078133E31980N	5Q22219	-	Other moraine-dammed lake	78.133	31.980	Spiti basin	5257	8616	RS 2/LISS IV	20.10.2011
G078065E32060N	5Q22219	-	Other glacier erosion lake	78.065	32.060	Spiti basin	4327	608	RS 2/LISS IV	20.10.2011
G078245E32271N	5Q22219	-	Glacier ice-dammed lake	78.245	32.271	Spiti basin	5100	941	RS 2/LISS IV	20.10.2011
G077922E32575N	5Q22219	-	Supra-glacial lake	77.922	32.575	Spiti basin	5531	1126	RS 2/LISS IV	17.08.2012
G078433E32181N	5Q22219	-	Supra-glacial lake	78.433	32.181	Spiti basin	5614	2688	RS 2/LISS IV	20.10.2011
G078029E31829N	5Q22219	-	Debris-dammed lake	78.029	31.829	Spiti basin	4243	853	RS 2/LISS IV	20.10.2011
G077856E31864N	5Q22219	-	Other moraine-dammed lake	77.856	31.864	Spiti basin	5137	2338	RS 2/LISS IV	20.10.2011
G078461E31972N	5Q22219	-	End moraine-dammed lake	78.461	31.972	Spiti basin	5283	53656	LANDSAT/OLI	08.09.2015
G078217E31945N	5Q22219	-	Other moraine-dammed lake	78.217	31.945	Spiti basin	4973	10704	LANDSAT/OLI	08.09.2015
G078701E31912N	5Q22219	-	Other glacier erosion lake	78.701	31.912	Spiti basin	5574	66485	LANDSAT/OLI	08.09.2015
G078702E31918N	5Q22219	-	Glacier ice-dammed lake	78.702	31.918	Spiti basin	5526	8883	LANDSAT/OLI	08.09.2015
G078714E31898N	5Q22219	-	End moraine-dammed lake	78.714	31.898	Spiti basin	5516	7353	LANDSAT/OLI	08.09.2015
G078702E32036N	5Q22219	-	Supra-glacial lake	78.702	32.036	Spiti basin	5385	2235	RS 2/LISS IV	13.11.2011
G078515E32238N	5Q22219	-	Other glacier erosion lake	78.515	32.238	Spiti basin	4861	2688	LANDSAT/OLI	08.09.2015
G078445E31976N	5Q22219	-	Supra-glacial lake	78.445	31.976	Spiti basin	5246	4877	LANDSAT/OLI	08.09.2015
G078255E31260N	5O12301	-	Other glacier erosion lake	78.255	31.260	Tons basin	4402	175867	RS 2/LISS IV	02.11.2013
G078265E31295N	5O12301	-	Other glacier erosion lake	78.265	31.295	Tons basin	4534	3596	RS 2/LISS IV	02.11.2013
G078242E31319N	5O12301	-	Other glacier erosion lake	78.242	31.319	Tons basin	4454	4866	RS 2/LISS IV	02.11.2013
G078283E31275N	5O12301	-	Other glacier erosion lake	78.283	31.275	Tons basin	4595	5265	RS 2/LISS IV	02.11.2013
G078142E31345N	5O12301	-	Cirque lake	78.142	31.345	Tons basin	4528	11529	RS 2/LISS IV	02.12.2011
G078184E31329N	5O12301	-	Cirque lake	78.184	31.329	Tons basin	4451	33055	RS 2/LISS IV	02.12.2011
G078181E31323N	5O12301	-	Cirque lake	78.181	31.323	Tons basin	4490	84610	RS 2/LISS IV	02.12.2011
G078278E31300N	5O12301	-	Other moraine-dammed lake	78.278	31.300	Tons basin	4433	1250	RS 2/LISS IV	02.12.2011
G078164E31320N	5O12301	-	Other glacier erosion lake	78.164	31.320	Tons basin	4425	32844	LANDSAT/OLI	08.09.2015
G078211E31231N	5O12301	-	Cirque lake	78.211	31.231	Tons basin	4265	102783	RS 2/LISS IV	02.12.2011
G078272E31262N	5O12301	-	Other glacier erosion lake	78.272	31.262	Tons basin	4806	13107	RS 2/LISS IV	02.11.2013
G076490E32233N		-	Other glacier erosion lake	76.490	32.233	Unidentified	3720	23900	RS 2/LISS IV	17.08.2012
G076487E32236N		-	Other glacier erosion lake	76.487	32.236	Unidentified	4136	1759	RS 2/LISS IV	17.08.2012
G077502E32792N	5Q13205	-	Other glacier erosion lake	77.502	32.792	Zanskar basin	5059	74289	RS 2/LISS IV	15.10.2011
G077458E32795N	5Q13205	-	Other moraine-dammed lake	77.458	32.795	Zanskar basin	4936	17160	RS 2/LISS IV	15.10.2011
G077394E32834N	5Q13205	-	Lateral moraine-dammed lake	77.394	32.834	Zanskar basin	5257	14490	RS 2/LISS IV	15.10.2011
G077546E32778N	5Q13205	-	Other glacier erosion lake	77.546	32.778	Zanskar basin	5423	2345	RS 2/LISS IV	15.10.2011
G077441E32754N	5Q13205	-	End moraine-dammed lake	77.441	32.754	Zanskar basin	5207	9498	RS 2/LISS IV	15.10.2011
G077809E32564N	5Q13205	-	Other moraine-dammed lake	77.809	32.564	Zanskar basin	5205	1120	RS 2/LISS IV	09.10.2013
G077813E32564N	5Q13205	-	Other moraine-dammed lake	77.813	32.564	Zanskar basin	5247	2811	RS 2/LISS IV	09.10.2013
G077912E32609N	5Q13205	-	End moraine-dammed lake	77.912	32.609	Zanskar basin	5373	12140	RS 2/LISS IV	09.10.2013
G077916E32592N	5Q13205	-	Supra-glacial lake	77.916	32.592	Zanskar basin	5480	2105	RS 2/LISS IV	08.11.2011
G077929E32591N	5Q13205	-	Other moraine-dammed lake	77.929	32.591	Zanskar basin	5293	1422	RS 2/LISS IV	08.11.2011
G077917E32593N	5Q13205	-	Supra-glacial lake	77.917	32.593	Zanskar basin	5479	1871	RS 2/LISS IV	09.10.2013
G077399E32854N	5Q13205	-	Other moraine-dammed lake	77.399	32.854	Zanskar basin	5275	2127	RS 2/LISS IV	15.10.2011
G077392E32840N	5Q13205	-	Other moraine-dammed lake	77.392	32.840	Zanskar basin	5333	664	RS 2/LISS IV	15.10.2011
G077400E32804N	5Q13205	-	Other moraine-dammed lake	77.400	32.804	Zanskar basin	5312	2863	LANDSAT/OLI	28.09.2014
G077388E32827N	5Q13205	-	Other moraine-dammed lake	77.388	32.827	Zanskar basin	5310	12192	LANDSAT/OLI	28.09.2014
G077463E32772N	5Q13205	-	Glacier ice-dammed lake	77.463	32.772	Zanskar basin	5336	2818	LANDSAT/OLI	28.09.2014

ANNEXURE- B

सत्यमेव जयते

Central Water Commission

Criteria for Risk Indexing of Glacial Lakes in Indian Himalayan Region

केन्द्रीय जल आयोग CENTRAL WATER COMMISSION आपो ज्योति रसोऽमृतम

September-2024

सत्यमेव जयते

Central Water Commission

Criteria for Risk Indexing of Glacial Lakes in Indian Himalayan Region

September-2024

अध्यक्ष, केंद्रीय जल आयोग एवं
पदेन सचिव, भारत सरकार

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Chairman, Central Water
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Foreword

As glaciers retreat, the lakes they leave behind grow larger, while the unstable moraine dams that hold them in place remain vulnerable to collapse. This poses a significant threat for downstream communities and ecosystems, where a sudden breach could result in catastrophic flooding. The Indian Himalayan region, with its densely populated valleys and crucial infrastructure, faces unique risks from these outbursts, making it vital to prioritize mitigation efforts and disaster preparedness. The need for "Criteria for Risk Indexing of Glacial Lakes in Indian Himalayan Region" arises from the increasing threat posed by Glacial Lake Outburst Floods (GLOFs), a consequence of climate change accelerating the melting of glaciers and expanding Glacial Lakes.

Different agencies have adopted various approaches to identify critical Glacial Lakes. There is a need to establish a common set of criteria for identifying these critical Glacial Lakes. In response, CWC has taken the initiative to bring together agencies such as National Remote Sensing Center (NRSC), Centre for Development of Advanced Computing (C-DAC), Defence Geoinformatics Research Establishment (DGRE), India Meteorological Department (IMD), Central Water and Power Research Station (CWPRS), Central Soil and Materials Research Station (CSMRS), Geological Survey of India (GSI), National Dam Safety Authority (NDSA), Wadia Institute of Himalayan Geology (WIHG), Central Electricity Authority of India (CEA), National Institute of Hydrology (NIH), National Disaster Management Authority (NDMA) and State Disaster Management Authority (SDMA) to collaborate on developing a unified framework for rapid risk assessment in the Indian Himalayan region.

The criteria for Risk Indexing of Glacial Lakes offer a structured approach to identifying and ranking Glacial Lakes based on their likelihood of failure and the potential damage they could cause. By evaluating key factors such as the Glacial Lake's Size, Change in Size of GL, Stability of Side Slope, Proximity to other Glacial Lakes as well as considering Downstream vulnerabilities like Habitation, Infrastructures like Dams, Bridges etc, Authorities can allocate resources efficiently for Monitoring, Early Warning Systems (EWS), and Mitigation measures. This method enhances decision-making and provide a guideline to allocate resources where they are most needed, reducing the overall risk of GLOF-related disasters in the region. I hope that use of this unified risk index by all agencies shall help in GLOF mitigation efforts in a long way.

(Kushvinder Vohra)

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Preface

The Himalayan Mountain region, often referred to as the "third pole," is home to a vast number of glaciers and Glacial Lakes. One significant concern in this region is the rapid accumulation of water in Glacial Lakes, particularly in those situated near retreating glaciers. When this happens, there is a higher risk of the unstable moraine dams that contain these lakes suddenly breaching. Such breaches can result in extremely high flood known as Glacial Lake Outburst Flood (GLOF), which can have devastating consequences for the areas downstream. Understanding these Glacial Lakes is therefore crucial for effective disaster risk management, as well as for assessing the impacts of climate change.

This criteria for Risk indexing is designed to provide a comprehensive methodology for identifying and categorizing Glacial Lakes based on factors such as Glacial Lake size, Glacial Lake type, Side slope, Snout distance from GL etc and the potential socio-economic impacts of an outburst. By developing this method, we aim to support policymakers, disaster management agencies, and scientists in their efforts to safeguard both lives and livelihoods. The purpose of this document is to facilitate informed decision-making and strategic planning in the face of a growing environmental challenge, ensuring that mitigation efforts are directed toward the most risky lakes within the Indian Himalayas regions.

Ashok

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Acknowledgement

Advent of an appropriate Criteria for Risk Indexing of Glacial Lakes has been an issue requiring not only broad basing the diverse and interdisciplinary input but also on boarding practical consideration in respect of monitorable destabilising factors. Accordingly efforts in this direction were initiated to assimilate views of various stockholders while also not losing the sight of present day limitation posed due to reasons of such Glacial Lakes being placed in inhospitable, high altitude remote location.

The Criteria for Risk Indexing of Glacial Lakes in Indian Himalayan Region has been arrived through the collaborative efforts of multiple agencies. Valuable Suggestions from organizations such as the National Remote Sensing Centre ,Centre for Development of Advanced Computing Defence Geoinformatics Research Establishment, India Meteorological Department ,Central Water and Power Research Station, Central Soil and Materials Research Station, Geological Survey of India, National Dam Safety Authority, Wadia Institute of Himalayan Geology, Central Electricity Authority of India , National Institute of Hydrology, National Disaster Management Authority and State Disaster Management Authority of Arunachal Pradesh, Himachal Pradesh, Jammu and Kashmir, Ladakh, Sikkim, Uttarakhand were helpful in formulation of criteria of Risk Indexing. A common set of criteria has now been formulated with the support of all the involved agencies, and their active participation is highly acknowledged and greatly appreciated.

The project team gratefully acknowledges the profuse guidance and continuous encouragement provided by Shri Kushvinder Vohra, Chairman, Central Water Commission & Ex-officio Secretary to the Government of India and Shri Ashok S. Goel, Member (River Management), Central Water Commission & Ex-officio Additional Secretary to Government of India. Shri Vishnu Deo Roy, in his earlier capacity as Director, Morphology & Climate Change Dte, CWC has been a key contributor of various ideas and concepts which crystalized in shape of these criteria. Furthermore, the valuable suggestions from Shri Sameer Kumar Shukla, Director, CWC, greatly enhanced the document. These contributions are sincerely appreciated.

We also extend our sincere thanks to our project team Shri Piyush Kumar, Director, Shri Piyush Kumar, Deputy Director; and Shri Rohit Kumar Yadav, Assistant Director, CWC, for their creative thinking with continuous effort. The team also expresses heartfelt gratitude to the colleagues of the Morphology & Climate Change Directorate for their cooperation and assistance.

(D.P. Mathuria)

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Executive Summary

Central Water Commission (CWC) acts as the nodal agency for Glacial Studies in India, playing a pivotal role in guiding states on critical aspects related to glacial hazards. As a leading organization, CWC provides expertise in monitoring Glacial Lakes, conceptualizing and installing Early Warning Systems and conducting hazard risk mapping.

In order to conduct a rapid risk assessment of Glacial Lakes, CWC has initiated collaboration among concerned stakeholders to develop a unified framework for risk assessment in the Indian Himalayan region. Through multiple meetings and discussions with stakeholders, it has been identified that criteria for Glacial Lake assessments should prioritize those that can be monitored through remote sensing due to the inaccessibility of many lakes and the substantial resources required for conducting physical studies on each one.

There are 12 criteria identified for the risk assessment of which 4 are for Glacial Lake itself, 3 for upstream of Glacial Lake, 3 for downstream of Glacial Lake and 2 for others. Out of total 100 marks, 45 is allocated to the Glacial Lake itself, upstream 15, downstream 30 and other 10. The weightage for these criteria ranges between 5 and 15 marks. Among the criteria, Glacial Lake size, Changes in Glacial Lake size, and Proximity to the nearest dam are particularly emphasized due to their potential severity, each receiving a maximum of 15 marks.

This methodology has been applied to assess 100 Glacial Lakes spread across four States (Arunachal Pradesh, Himachal Pradesh, Sikkim and Uttarakhand) and two Union Territories (Jammu & Kashmir and Ladakh) in the Indian Himalayan Region, at elevations ranging from 3,000 to 6,000 meters. These lakes include moraine-dammed lakes, ice dammed lake and Glacial erosion lakes, with moraine-dammed lakes considered most vulnerable in Indian Himalayan Region.

The assessment categorizes Glacial Lakes into four risk categories, with Category 1 (Score above 70) indicating the highest risk, and Category 4 (Score below 50) representing the lowest risk. Generally, Glacial Lakes classified under Category 1 are deemed the most risky, while those in Category 4 pose the least risk. However, it is possible that a single parameter with a lower weightage could still significantly influence the overall risk of a Glacial Lake, potentially outweighing other factors in the assessment.

The physical monitoring of each glacial lake in the Indian Himalayan Region (IHR) demands considerable financial and logistical resources, making it impractical to assess all glacial lakes comprehensively. Criteria for Risk Indexing of Glacial Lakes in Indian Himalayan Region will act as a crucial guide for stakeholders and the academic community, helping to prioritize monitoring efforts and interventions where they are most needed. By streamlining the assessment process, it supports more effective resource allocation and disaster preparedness.

1.0 Introduction:

The Indian Himalayan region, an integral part of the world's highest mountain range, is home to thousands of Glaciers that play a vital role in the hydrological cycle and serve as a crucial water source for the region. Glaciers in this region, particularly those located in the upper reaches of river basins such as the Ganges, Brahmaputra, and Indus, store large volumes of freshwater, gradually releasing it to feed rivers and streams. However, in recent decades, glaciers have been rapidly retreating due to global warming, leading to the formation and expansion of Glacial Lakes. These lakes, formed by melt water accumulating behind natural moraine or ice dams, are highly sensitive to climatic changes and pose a growing threat to downstream communities.

A significant concern associated with Glacial Lakes is the potential for sudden and catastrophic events known as Glacial Lake Outburst Floods (GLOFs). These occur when the natural dam holding the lake fails, either due to increased water pressure, seismic activity, landslides, or avalanche into the lake. The resulting floodwaters can cause massive destruction, with devastating impacts on life, property, and infrastructure downstream.

It is crucial to establish a framework for the rapid risk assessment of Glacial Lakes that provides a structured and systematic method for identifying and ranking these lakes. This approach enables authorities to prioritize resources for monitoring, mitigation and reducing the risk of catastrophic Glacial Lake Outburst Floods (GLOFs).

This framework assesses critical factors such as the Glacial Lake size, Changes in Glacial Lake size over time, Stability of side slopes, Proximity to other Glacial Lakes etc. It also considers downstream vulnerabilities, including nearby Habitations and key infrastructures like dams, bridges, roads etc. By evaluating these parameters, authorities can prioritize which lakes pose the greatest threat, ensuring that limited resources are used efficiently for monitoring, Early Warning Systems (EWS), and preventive measures.

1.1 Glacial Lake Outburst Floods (GLOFs):

Glacial Lake Outburst Floods (GLOFs) have occurred in various parts of the world. Indian Himalayan region is also vulnerable due to the presence of a large number of Glacial Lakes and the growing influence of Climate Change. These floods can have significant socio-economic consequences, as many communities in the region depend on the rivers fed by glacial melt water for agriculture, drinking water, and energy generation. Additionally, critical infrastructure, including dams, roads, bridges, and hydropower plants, is often located in the river valleys, putting them at risk from GLOFs.

Several GLOF events in the past have underscored the dangers posed by these floods. Notable GLOF occurrences in the Indian Himalayan region include the 1929 GLOF in the Shyok River basin and the 1985 Dig Tsho outburst in Nepal, which resulted in significant loss of life and property. Recently, the breach of the moraine dam embankment at Chorabari Lake in 2013 triggered by heavy rainfall and South Lhonak Lake in 2023, triggered by a landslide, exemplifies the complex interplay between climate change, glacial dynamics, and extreme weather events. These events have highlighted the urgency of monitoring and managing Glacial Lakes to mitigate the risks associated with GLOFs.

1.2 Importance of Risk Indexing:

The importance of risk indexing for Glacial Lakes lies in its ability to systematically assess and manage the hazards associated with Glacial Lake outburst floods (GLOFs), particularly in regions like the Himalayas where these lakes are becoming increasingly unstable. As glaciers retreat and melt water accumulates in Glacial Lakes held back by fragile moraine or ice dams, the risk of sudden and catastrophic floods grows. Risk indexing provides a method for identifying which Glacial Lakes are most likely to experience such outbursts and prioritizing them for monitoring and intervention.

By evaluating key factors such as the Glacial Lake size, type, Stability of the side slope etc. and its potential impact on downstream habitations and infrastructure, risk indexing assists authorities focus resources on most risky Glacial Lake. This proactive approach is critical for minimizing the loss of life, reducing economic damage, and enhancing preparedness efforts. It also assists the development of Early Warning Systems (EWS) and long-term climate adaptation strategies, making it a crucial tool in mitigating the impacts of Glacial Lake hazards in vulnerable regions.

1.3 Factors for Risk Assessment of Glacial Lake:

Glacial Lakes are situated in high-altitude regions with harsh climatic conditions and challenging terrain, making them generally inaccessible. This inaccessibility is a key factor contributing to the lack of monitoring capabilities for these lakes. Therefore, when considering the wide range of factors influencing Glacial Lakes, it is essential to account for practical constraints. These constraints must be weighed carefully when selecting the factors to be included in any risk assessment framework.

Among the factors influencing the risk associated with Glacial Lakes, some can be measured or monitored, while others cannot. Additionally, some factors are predictable, while others are sudden. This document focuses on factors that are measurable uniformly for remotely located Glacial Lakes and are known in advance. Certain factors that apply equally to all lakes, and thus do not differentiate risk levels, have been excluded from the criteria. For a more detailed risk analysis, additional lake-specific information may be considered for priority lakes. Instantaneous factors can be incorporated into an Early Warning System through systematic and continuous monitoring of high-risk lakes.

The NRSC's Glacial Lake ranking procedure involves a two-step methodology. First, a preliminary screening is conducted using four criteria. Then, six parameters are assigned to the Glacial Lakes, normalized, and weighted. The normalized scores are multiplied by the weights and summed for each Glacial Lake, with the highest total score indicating the most vulnerable Glacial Lake. C-DAC has separately identified 35 criteria with varying weights to assess the risk of glacial lakes in Sikkim. The overall score is determined by adding the points assigned

in each category, resulting in a total score where the highest value indicates the most vulnerable lake.

Risk associated with Glacial Lakes is determined by evaluating several key factors that influence the likelihood of a Glacial Lake Outburst Flood (GLOF) and the potential impact on downstream areas. The Glacial Lake size, type, Change in Size, Stability of side slope, Snout to Glacial Lake distance, Snout to Glacial Lake Slope, Glacial Lake in vicinity and connected are some of the important remotely measurable parameters on upstream of Glacial Lake and Glacial Lake itself.

Downstream parameters, including proximity to human settlements and infrastructures like dams, roads and bridges, are crucial for assessing the potential damage if a GLOF occurs. Glacial Lakes closer to infrastructure and populated areas poses a higher risk of catastrophic impacts. Additionally, historical GLOF events and the location of Glacial Lakes in seismic zones further elevate the risk, as past events and seismic activity may destabilize the Glacial Lakes triggering outbursts.

Factors for Risk Assessment of Glacial is divided into four categories which are as follows:

(i) **Glacial Lake:** This category examines factors that directly impact the stability and integrity of the Glacial Lake. Several key factors are considered to assess the potential hazard:

1. **Size of Glacial Lake** – Larger Glacial Lake tend to hold more water, increasing the potential for catastrophic flooding if they burst.
2. **Type of Glacial Lake** – The Glacial Lake's formation (moraine-dammed, ice-dammed, etc.) influences its structural stability.
3. **Change in Size of Glacial Lake over Time** – Rapid expansion of the Glacial Lake indicates growing instability and increased risk of an outburst.
4. **Stability of Lake Side Slope** – The condition of the surrounding slopes is crucial, as unstable slopes can lead to landslides that may trigger a dam breach.

(ii) **Upstream of Glacial Lake:** This section assesses conditions and parameters upstream (u/s) of the lake that could influence its stability and risk level.

1. **Snout to Glacial Lake Distance** – The distance between the glacier's snout and the Glacial Lake helps determine how glacial meltwater might affect the lake.
2. **Snout to Glacial Lake Slope** – The gradient between the glacier and the Glacial Lake can affect water flow dynamics and stability.
3. **Glacial Lakes in the Vicinity and Connected (>1 ha) within 1 Km in same Valley** – The presence of nearby connected Glacial Lake(s) increases the overall water volume and complexity, which can heighten the risk of chain-reaction events.

(iii) **Downstream of Glacial Lake:** This focuses on the parameters downstream (d/s) of the Glacial Lake to assess the potential impact on human life and infrastructure.

1. **Distance from Nearest Habitation likely to be affected** – The Glacial Lake located closer to populated areas poses higher risk to human casualties in the event of an outburst.
2. **Distance from Nearest Dam** – The proximity to critical infrastructure like dams is important, as a GLOF could lead to secondary disasters if the dam fails or opens gates suddenly.
3. **Distance from Nearest Bridge** – Assessing the risk to transportation infrastructure such as bridges helps gauge the potential for widespread disruption.

(iv) **Other Parameters:** Additional factors that can affect the overall risk are considered in this section.

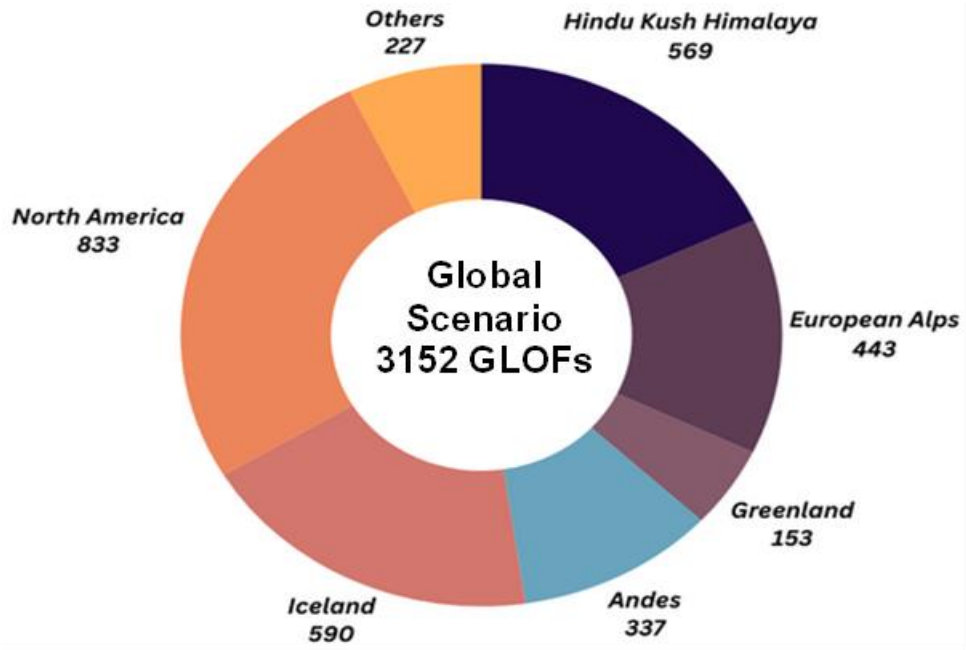
1. **Historical GLOF Events** – Previous GLOFs in the area offer insights into patterns of Glacial Lake instability and potential recurrence.
2. **Seismic Zones** – Glacial Lakes situated in active seismic zones are at higher risk of dam failure due to earthquake-induced destabilization.

2.0 Criteria for Risk assessment through indexing

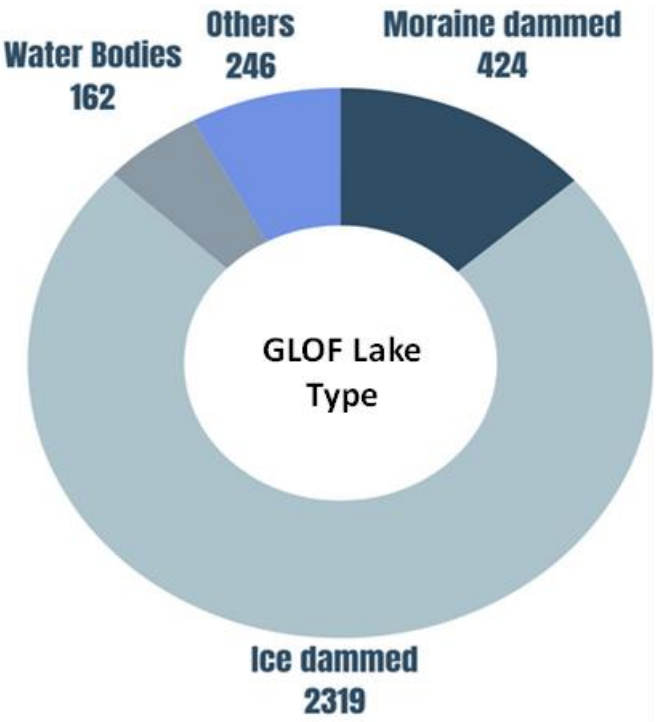
The basic concept behind shortlisting of Index for Risk associated with Glacial Lakes is to prescribe common criteria for studies being/proposed to be taken in this area of concern as mentioned above.

2.1 Background:

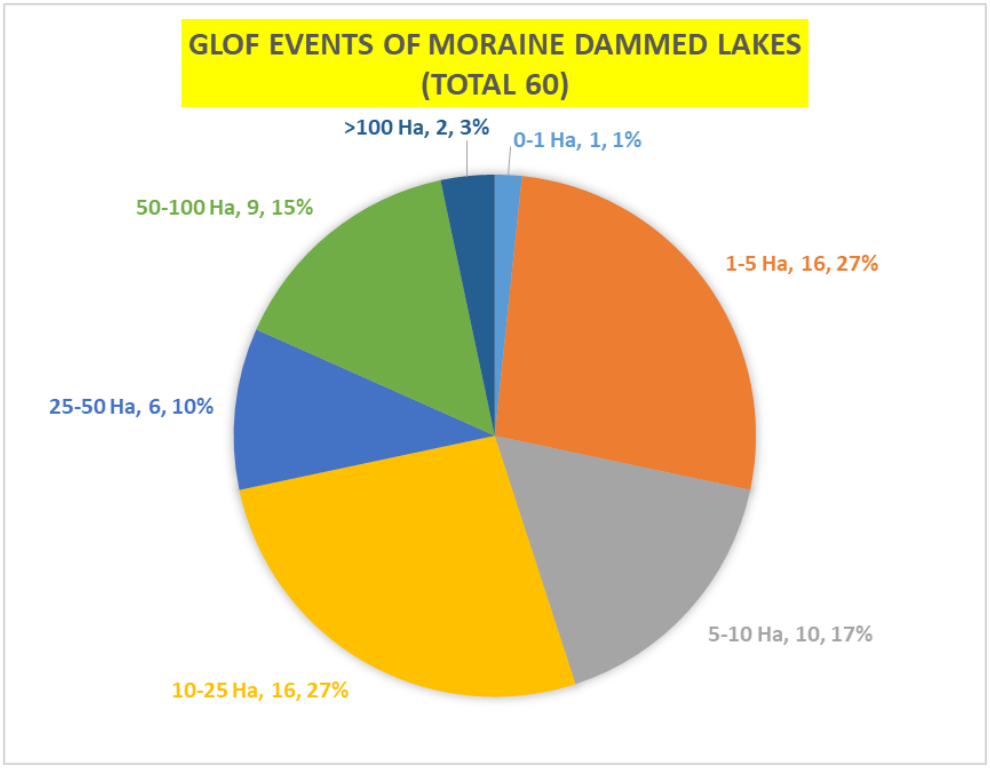
To develop the criteria for risk indexing, it was deemed essential to study the global scenario of Glacial Lake Outburst Floods (GLOFs). A search revealed a historical GLOF events database from a study titled "A Global Database of Historic Glacier Lake Outburst Floods," published on July 12, 2023. This database identified 3,152 GLOF events that occurred across 27 countries from 850 to 2022 CE, with 569 of these events reported in the Hindu Kush Himalaya region. The database includes 2,319 ice-dammed lakes and 424 moraine-dammed lakes. According to the findings, there have been 60 reported failures of moraine-dammed lakes and 394 failures of ice-dammed lakes in the Hindu Kush Himalaya. The size-related details for failures of moraine and ice-dammed lakes are as follows:



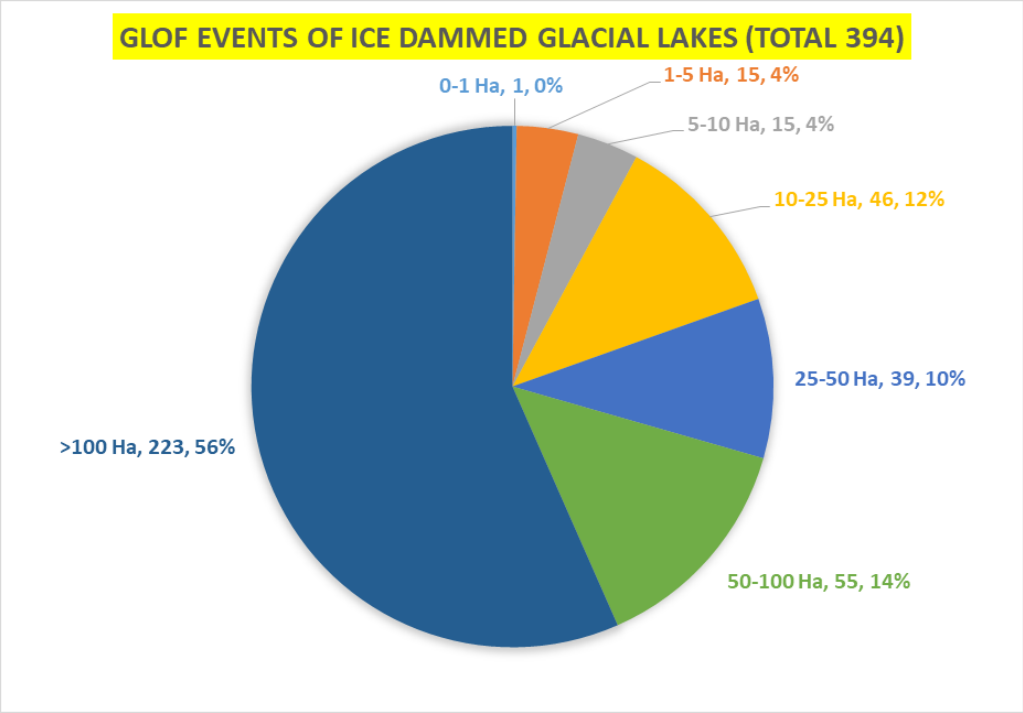
Graph 1: Location-wise past GLOF events



Graph 2: Lake Type GLOF events



Graph 3: GLOF events of Moraine Dammed Lakes (Sizewise)



Graph 4: GLOF events of Ice Dammed Lakes (Sizewise)

Therefore, susceptibility for failure of ice dammed lakes are higher than the moraine dammed lake. Similarly, larger Glacial Lakes are more prone to outburst than small lakes. Glacial Erosion lakes are mostly stable in nature.

However, as per article namely *"Increasing risk of Glacial Lake Outburst Floods from future Third Pole deglaciation"* published in nature climate change by Guoxiong Zheng, most past GLOF sources were related to moraine dammed Glacial Lakes.

2.2. Measurable factors and their priority:

GLOF is the primary hazard associated with the Glacial Lake. It's the potential for a sudden and catastrophic release of water from a Glacial Lake, causing widespread destruction downstream. The following criteria proposed/identified for Glacial Lakes:

2.2.1 Size of Glacial Lake: The size of a Glacial Lake provide fundamental insights into its water storage capacity. In the event of a GLOF, this characteristic becomes a critical factor. Normally, larger Glacial Lakes have a greater potential for catastrophic outbursts compared to smaller ones due to the volume of water they contain. However, the smaller Glacial Lakes can also pose risks. Lakes with larger sizes should be given higher priority.

2.2.2 Type of Glacial Lake: The diversity of Glacial Lakes necessitates a differentiated approach to risk assessment. Different types of Glacial Lakes exhibit distinct characteristics, formation processes, and potential hazards. Broadly Glacial Lakes are divided into four major types as per NRSC inventory:

i. **Moraine-dammed lake:** When glaciers melt, the water in these Glacial Lakes accumulates behind loose naturally formed glacial/moraine dams made of ice, sand, pebbles and ice residue. This is the another most common type of outburst due to failure of unstructured end moraine material on account of spillage due to flood surge or heavy inflow into the lake /seepage due to high hydraulic head or disappearance of permafrost condition with rise in temperature.
ii. **Ice-dammed lake:** An Ice-dammed Lake is created when a glacier blocks the flow of a river or stream, forming a lake behind the ice. Outburst of such glaciers are the most common due to melting of ice with rise in temperature in addition to other factors like sudden fall of ice/rock/moraine material in the lake.
iii. **Glacier Erosion lake:** These are the water bodies formed in a depression after the glacier has retreated in a form of cirque or trough valley, might be isolated and far away from the present glaciated area, and mostly stable in nature.
iv. **Other Glacial Lake**

2.2.3 Change in Size of Glacial Lake: The change in size of a Glacial Lake refers to increase or decrease in the lake's surface area and volume over time. A lake that rapidly increases in size is often a sign of accelerated glacier melting or instability in the surrounding terrain. This rapid growth can exert immense pressure on the natural or artificial dams containing the lake, increasing the risk of breach. Changes in lake size will be determined by analysing data from the preceding five years/ available data from monitoring reports or base year data from inventory reports. Lakes size increasing at higher rates needs more attention and therefore higher weightage.

2.2.4 Stability of Glacial Lake side slope (surrounding topography): The Glacial Lake side slopes influences erosion, landslides, avalanche and other forms of mass movement. Steeper slopes are more prone to failure and vice versa. Factors such as slope angle, material composition, vegetation cover and water content are important for assessment of surrounding topography of Glacial Lakes. Landslide susceptibility maps of lake's surroundings as available or to be prepared by GSI may be of use for scoring. Avalanche prone maps or similar database, as available with DGRE for the lakes area may also be of use in this context. Pending availability of desired information from GSI & DGRE, average slope of the surrounding area of the lake derived from publicly available DEM generated from remote sensing data may be used for analysis.

2.2.5 Glacial Lake inlet to snout distance: The snout of a glacier refers to its lower, terminal end where the glacier meets its surrounding environment. A shorter distance between the Glacial Lake inlet and the glacier snout implies a shorter pathway for melt water to reach the lake. This can lead to rapid lake level rise and increased pressure on the lake's dam, enhancing the risk of a GLOF whereas a longer distance can provide a buffer zone, allowing for some attenuation of the water flow before it reaches the lake. Therefore, longer distances between the lake inlet and glacier snout may indicate a lower risks and vice versa. Such data can be derived from publicly available DEM generated from remote sensing data.

2.2.6 Glacial Lake inlet to snout slope: The "Glacier Lake Inlet to Snout slope" refers to the gradient or incline from where a glacier feeds into a lake (the inlet) down to the glacier's terminus (snout). For risk assessment of Glacier Lake Outburst Floods (GLOFs), analysing this slope is crucial. A steep glacier slope accelerates the flow of melt water towards the lake, increasing the rate of lake level rise and pressure on the dam. A gentler slope reduces the velocity of melt water, allowing for more gradual lake level rise and potentially reducing the risk of a sudden outburst. Therefore, gentle slopes may indicate a lower risk and vice versa. Such data can be derived from publicly available DEM generated from remote sensing data.

2.2.7 Glacial Lake in the vicinity and connected (>1 ha) within 1 Km: The Indian Himalayan region is characterized by a high density of Glacial Lakes, many of which are in close proximity to each other. This clustering increases the risk of cascading failures. Global warming has accelerated the formation of new Glacial Lakes in recent years, exacerbating the situation. Interconnected lakes within this region pose a significant threat as the breach of one can trigger a chain reaction, leading to catastrophic GLOFs. Such information can be derived from analysing the inventory of Glacial Lakes in any GIS platform along with DEM and drainage network of the area.

2.2.8 Nearest downstream Habitation Distance (likely to be affected): The assessment of proximity of human settlements to the Glacial Lakes means distance of population and their livelihood in the path of the floodwaters from the lake. The floodwaters from a GLOF can carry debris, boulders, and ice, further increasing the destructive power of the flood. Settlements that are closer to the Glacial Lake are more likely to experience severe and immediate consequences, while those farther away may be less affected or have more time to respond. As first estimate, such data can be generated from Google Earth along with draining network of the area covering lakes. Subsequently, such data can be refined in consultation with local authority or any other source.

2.2.9 Distance to nearest downstream Dam: Downstream dams are particularly vulnerable to the destructive force of a GLOF. These massive surges of water, often carrying significant sediment loads, can overwhelm dam structures, leading to catastrophic consequences. Closer distances between the Glacial Lake and Dam indicates floodwaters will reach the dam more quickly, reducing the time available for early warning & response and vice

versa. Such data can be generated from Goole Earth or GIS along with drainage network covering the lake in GIS environment.

2.2.10 Distance to nearest downstream Bridge: Bridges are crucial components of transportation infrastructure, acting as vital lifelines connecting communities and facilitating the movement of people, goods, and emergency services. It plays a significant role in emergency response in the event of GLOF. Bridges located close to Glacial Lakes are at a higher risk of damage or destruction from GLOFs and vice versa. As first estimate, such data can be generated from Google Earth along with draining network of the area covering lakes. Subsequently, such data can be refined in consultation with local authority or any other source.

2.2.11 Historical GLOF events: Historical GLOF events are crucial for understanding the potential magnitude, frequency, and impacts of the hazards. Past occurrences where Glacial Lakes have burst, leading to sudden and catastrophic flooding. Evaluating the frequency of past GLOF events in the region helps identify trends and recurring risks. *Initially, such information may be taken from the historical database from a study titled "A global database of historic glacier lake outburst floods" published on 12th July 2023 identified 3151 GLOF events occurred in 27 countries between 850 and 2022 CE. Subsequently, the same can be refined in consultation with local authority of literatures.*

2.2.12 Seismic Zones: Seismic zones are categorized based on the likelihood and intensity of earthquakes occurring in a specific area. These classifications are crucial for understanding the seismic hazards in regions prone to earthquakes. Identifying and mapping these zones allows for the assessment of risks associated with natural disasters, such as GLOFs. Higher magnitude earthquake in the vicinity of the lakes may cause outburst of frontal dams releasing water from lakes or landslide of surrounding slopes resulting fall of mass into the lake leading to spilling of water or avalanche leading to fall of ice mass into the lake. It is to be noted that Indian Himalayan Region (IHR) includes four states—Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh and two Union Territories, Jammu & Kashmir and Ladakh, which fall under Seismic Zones IV and V.

Based on the above identified criteria, a matrix for risk identification has been prepared and placed at **Annexure-I.**

3.0 Criteria classification: The score for classification of the risky Glacial Lakes is as under (**Table 1**):

Table 1: Risk Score Classification

Risk Score Classification			Remarks
Sl No	**Score (S)**	**Category**	In general, Category 1 lakes are considered to be the most risky and category 4 is the least risky
1	**S>70**	**Category-1**	
2	**60<S<=70**	**Category-2**	
3	**50<S<=60**	**Category-3**	
4	**S<=50**	**Category-4**	

However, the identification of different categories is not intended to suggest that Category-1 lakes, being the most at risk, will necessarily fail, while Category-4 lakes will not. Categorization is meant as a tool for assessment of risk associated with a Glacial Lake only. The failure of a Glacial Lake depends on the interaction of various factors, which can trigger such events depending on the intensity of destabilizing forces.

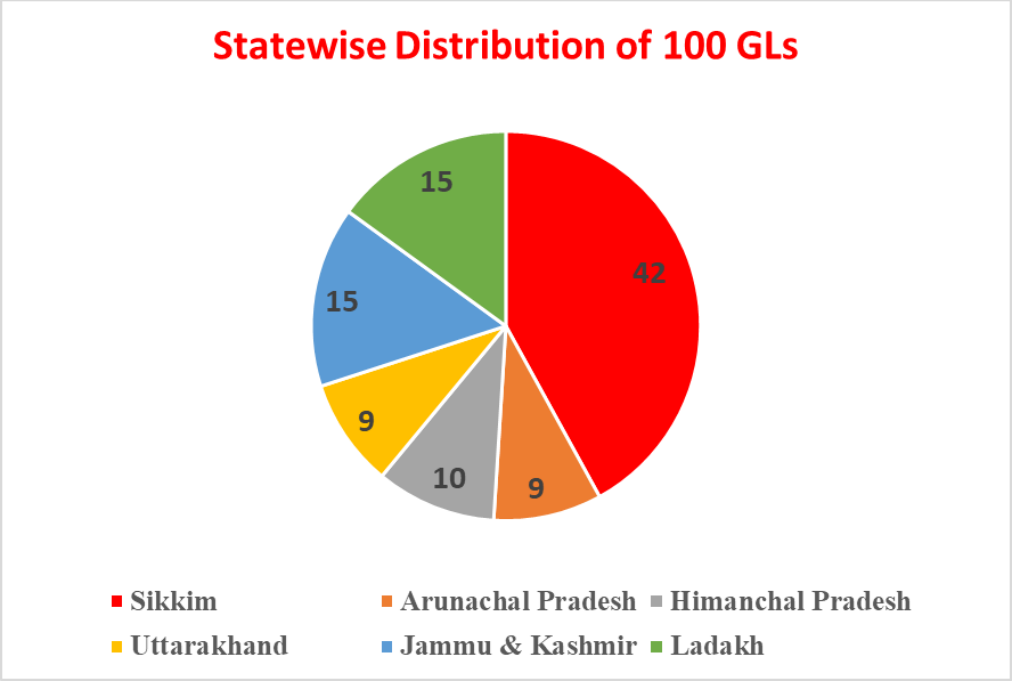
4.0 Result of application of criteria on 100 Glacial Lakes in India

4.1 Statewise Distribution of 100 Glacial Lakes:

The above criteria has been applied on 100 GLs in 4 States and 2 UTs of India in the Indian Himalayan Region. List of these 100 lakes is attached at **Annexure-II**. The details may be seen as per the following **Table 2**.

Table 2: Statewise Distribution of Glacial Lakes

State	No of GLs
Sikkim	42
Arunachal Pradesh	9
Himanchal Pradesh	10
Uttarakhand	9
Jammu & Kashmir	15
Ladakh	15
Total	**100**

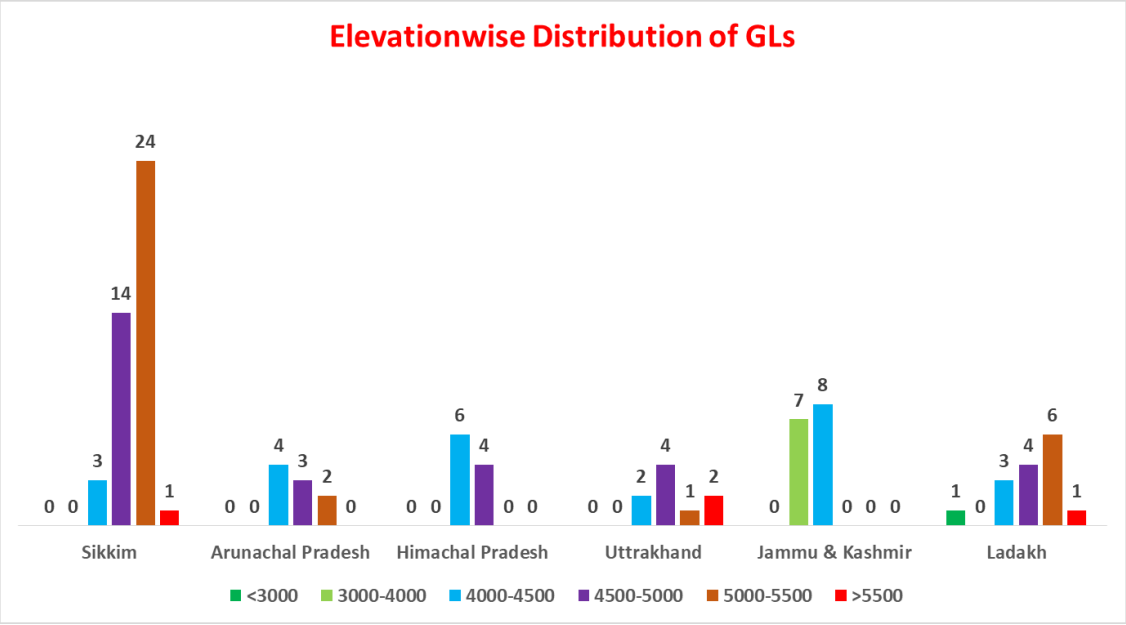


Graph 5: Statewise Distribution of Glacial Lakes

4.2 Elevationwise Distribution of 100 Glacial Lakes:

Table 3: Elevationwise Distribution of Glacial Lakes

Elevation (m)	Sikkim	Arunachal Pradesh	Himachal Pradesh	Uttrakhand	Jammu & Kashmir	Ladakh	Total
<3000	0	0	0	0	0	1	**1**
3000-4000	0	0	0	0	7	0	**7**
4000-4500	3	4	6	2	8	3	**26**
4500-5000	14	3	4	4	0	4	**29**
5000-5500	24	2	0	1	0	6	**33**
>5500	1	0	0	2	0	1	**4**
Total	**42**	**9**	**10**	**9**	**15**	**15**	**100**

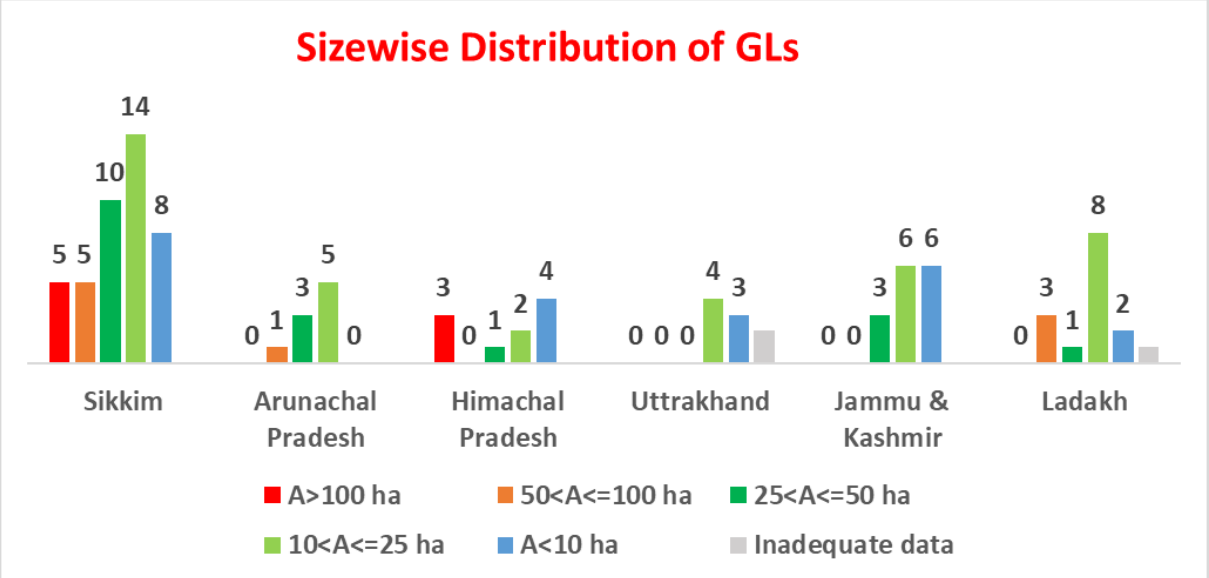


Graph 6: Elevationwise Distribution of Glacial Lakes

4.3 Water Spread area (Size) wise Distribution of 100 Glacial Lakes:

Table 4: Sizewise Distribution of Glacial Lakes

Glacial Lakes Size Distribution							
Area (Ha)	Sikkim	Arunachal Pradesh	Himachal Pradesh	Uttrakhand	Jammu & Kashmir	Ladakh	Total
A>100 ha	5	0	3	0	0	0	8
50<A<=100 ha	5	1	0	0	0	3	9
25<A<=50 ha	10	3	1	0	3	1	18
10<A<=25 ha	14	5	2	4	6	8	39
A<10 ha	8	0	4	3	6	2	23
Inadequate data	0	0	0	2	0	1	3
Total	**42**	**9**	**10**	**9**	**15**	**15**	**100**

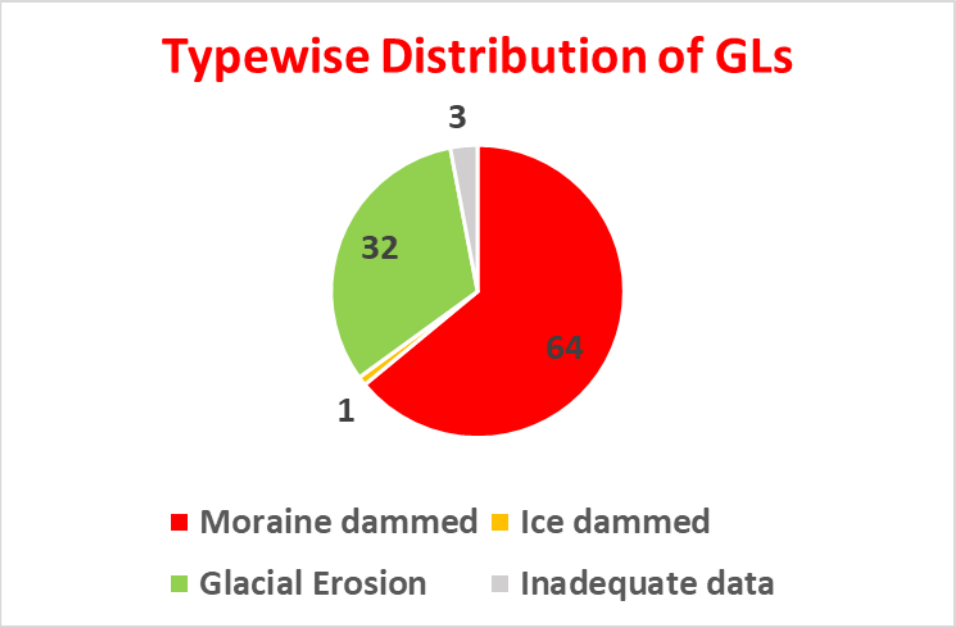


Graph 7: Sizewise Distribution of Glacial Lakes

4.4 Typeswise Distribution of 100 Glacial Lakes:

Table 5: Typewise Distribution of Glacial Lakes

Type of GL	No of GLs
Moraine dammed	64
Ice dammed	1
Glacial Erosion	32
Inadequate data	3
Total	**100**

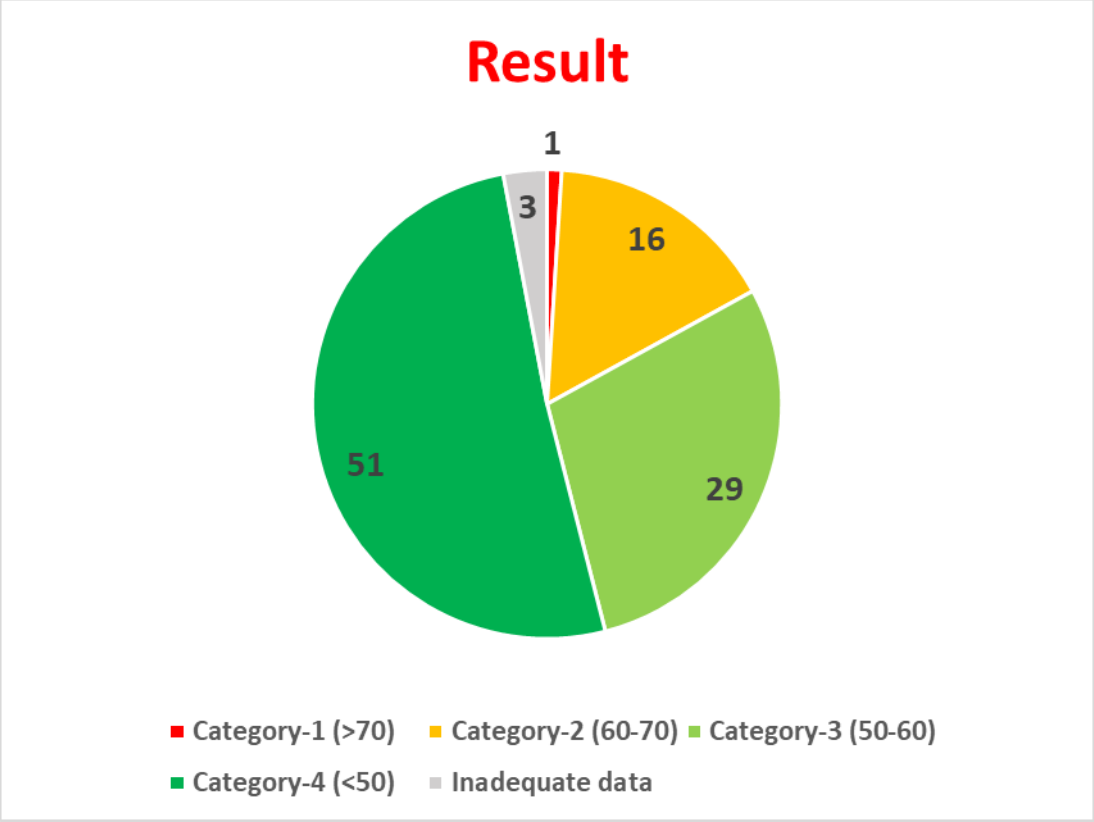


Graph 8: Typewise Distribution of Glacial Lakes

4.5 Result of Criteria application for 100 Glacial Lakes:

Table 6: Result of criteria on 100 GLs in India

Result of criteria on 100 GLs in India			
Category	**Score (S)**	**No of GLs**	**State-wise break up**
Category-1	S>70	1	SK-1
Category-2	60<S<=70	16	SK-12,HP-4
Category-3	50<S<=60	29	SK-11, AP-1, HP-4, UK-3, J&K-8, Ladakh-2
Category-4	S<=50	51	SK-18, AP-8, HP-2, UK-4, J&K-7, Ladakh-12
Inadequate Data	-	3	UK-2, Ladakh-1



Graph 9: Result of criteria on 100 GLs in India

5.0 Limitations and Assumptions:

1. **Data Dependency:** Glacial Lakes are situated in remote, high-altitude regions with challenging terrain and harsh climatic conditions which makes physical monitoring infrequent. Therefore, the risk assessment criteria rely heavily on remote sensing data, which may not capture all relevant parameters with the required precision.
2. **Field Verification Requirement:** Some parameters cannot be measured remotely and require on-the-ground verification, which may be time-consuming and resource-intensive.
3. **Interdependence of Criteria:** Some of the factors are independent and other are dependent. Attempts has been made to consider measurable independent factors only to keep minimum no of factors.
4. **Potential for Criteria Overpowering:** The proposed criteria is for rapid risk assessment assigning certain score to each factor. However, on ground, factors with low score may play more important role in certain condition. This needs to be considered whenever felt necessary as special cases.
5. **Evolving Criteria:** The criteria are indicative and may need revision as new technologies or environmental conditions emerge, potentially altering risk assessments.
6. **Uniform Impact of Criteria:** It is assumed that all criteria have been appropriately weighted, and their impact on the overall risk score is proportionate and balanced.
7. **Stable Environmental Conditions:** The criteria assume relatively stable environmental conditions, though future changes may require reassessmen

6.0 Conclusion:

The finalization of the criteria for assessing Glacial Lakes involved extensive input from various stakeholders, ensuring that the criteria are both comprehensive and effective in addressing the relevant challenges. The risk assessment criteria were systematically applied to evaluate 100 Glacial Lakes across the Indian Himalayan region, which encompasses four states and two Union Territories, each exhibiting diverse elevations and topographical features. This comprehensive assessment leveraged remote sensing technology to gather vital data, given the challenging accessibility of many of these lakes.

The finalized criteria for Glacial Lake risk assessment are based on easily measurable, independent parameters, and are intended to be updated as new technologies or conditions emerge. While the criteria prioritize risk across multiple factors, certain parameters may disproportionately influence the overall score, requiring adjustments. These criteria enable rapid risk assessments to identify high-risk lakes, helping agencies allocate resources efficiently and initiate appropriate monitoring. This process is crucial for planning and implementing Early Warning Systems and mitigation measures for Glacial Lakes identified as having higher risk.

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Annexure I

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	D>50	0				
	A<=10	3			Change(within +/- 10%)	3											No Dam	0						
					Decrease (>10%)	0																		

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

Annexure II

State	District	Old Lake ID	New Lake ID	Name	Lat	Long	Type	River	Basin	Elevation (m)	Category
Sikkim	North Sikkim	03_78A_009	07478A050213	Khola Chhobuh	27.9466	88.3316	M(o): Other Moraine Dammed Lake	Khara Chu	Teesta	5034	Category-4
	North Sikkim	03_78A_014	07478A010059	South Lhonak Lake	27.9126	88.1955	M(e): End-moraine Dammed Lake	Gama Chu	Teesta	5194	Category-2
	North Sikkim	03_78A_021	07478A050272	NA	27.8245	88.2492	M(e): End-moraine Dammed Lake	Rhuling Chu	Teesta	5414	Category-3
	North Sikkim	03_77D_005	07477D120030	Lakes of Kangchengyao	28.0075	88.6981	M(e): End-moraine Dammed Lake	Teesta	Teesta	5209	Category-2
	North Sikkim	03_78A_001	07478A130523	Khangchung Tso	27.9902	88.8158	M(e): End-moraine Dammed Lake	Teesta	Teesta	5303	Category-2
	North Sikkim	03_78A_020	07478A050249	NA	27.881	88.2504	M(e): End-moraine Dammed Lake	Gama Chu	Teesta	5198	Category-4

State	District	Old Lake ID	New Lake ID	Name	Lat	Long	Type	River	Basin	Elevation (m)	Category
Sikkim	North Sikkim	03_78A_010	07478A050211	NA	27.9489	88.3052	M(e): End-moraine Dammed Lake	Khara Chu	Teesta	5049	Category-3
	North Sikkim	03_78A_035	07478A050208	Khola Chhamna	27.9513	88.3549	M(o): Other Moraine Dammed Lake	Khara Chu	Teesta	4989	Category-4
	North Sikkim	03_78A_008							Teesta	4989	Category-4
	North Sikkim	03_78A_005	07478A050186	NA	27.9736	88.4224	M(o): Other Moraine Dammed Lake	Nakul Chu	Teesta	5185	Category-4
	North Sikkim	03_78A_006	07478A050193	NA	27.969	88.4296	M(o): Other Moraine Dammed Lake	Nakul Chu	Teesta	4974	Category-3
	North Sikkim	03_78A_002	07478A090358	NA	27.982	88.5084	M(e): End-moraine Dammed Lake	Teesta	Teesta	4917	Category-3
	North Sikkim	227	07478A090355	NA	27.9924	88.5453	M(e): End-moraine Dammed Lake	Teesta	Teesta	5161	Category-2
	North Sikkim	03_77D_006	07477D120025	Lu tso	28.0143	88.5612	E(c): Cirque Erosion Lake	Teesta	Teesta	5073	Category-2
	North Sikkim	03_77D_004	07477D120034	Lakes of Kangchengyao	28.0056	88.7129	M(e): End-moraine Dammed Lake	Teesta	Teesta	5238	Category-3
	North Sikkim	295	07478A090403	Subu Chho	27.9203	88.6723	M(e): End-moraine Dammed Lake	Laehung Chu	Teesta	4827	Category-2

State	District	Old Lake ID	New Lake ID	Name	Lat	Long	Type	River	Basin	Elevation (m)	Category
Sikkim	North Sikkim	237	07478A130519	NA	27.9934	88.8014	M(o): Other Moraine Dammed Lake	Laehung Chu	Teesta	5299	Category-4
	North Sikkim	260	07478A130553	NA	27.8947	88.7614	M(e): End-moraine Dammed Lake	Laehung Chu	Teesta	5232	Category-3
	North Sikkim	03_78A_012	07478A130550	Penbawa Khangse	27.901	88.7819	M(o): Other Moraine Dammed Lake	Penbawa Chu	Teesta	5118	Category-3
	North Sikkim	03_78A_015	07478A130563	NA	27.8731	88.7893	M(e): End-moraine Dammed Lake	Sebozung Chu	Teesta	4962	Category-4
	North Sikkim	515	07478A130576	NA	27.8539	88.8059	E(o): Other Glacial Erosion Lake	Sebozung Chu	Teesta	5051	Category-4
	North Sikkim	312	07478A100485	NA	27.7003	88.5138	E(o): Other Glacial Erosion Lake	Teesta	Teesta	4491	Category-2
	North Sikkim	03_78A_023	07478A100495	Shingo Chho	27.6712	88.5125	E(c): Cirque Erosion Lake	Nathang Chu	Teesta	4525	Category-1
	West Sikkim	03_78A_027	07478A020131	Tikip Chu Lake	27.5331	88.0856	M(e): End-moraine Dammed Lake	Tikip Chu	Teesta	4860	Category-3
	West Sikkim	03_78A_031	07478A030158	Lachmi Pokhari	27.4373	88.0831	E(c): Cirque Erosion Lake	NA	Teesta	4280	Category-3
	West Sikkim	03_78A_026	07478A020123	Bhale Pokhari	27.563	88.1233	M(o): Other Moraine Dammed Lake	Choktsering Chu	Teesta	4710	Category-2

State	District	Old Lake ID	New Lake ID	Name	Lat	Long	Type	River	Basin	Elevation (m)	Category
Sikkim	North Sikkim	599	07478A100486	Chhumzomo Chhokha	27.6951	88.7165	E(o): Other Glacial Erosion Lake	Teesta	Teesta	4207	Category-2
	North Sikkim	03_78A_016	07478A010062	NA	27.8933	88.2123	I(s): Supra-Glacial Lake	Gama Chu	Teesta	5433	Category-4
	North Sikkim	03_78A_003	07478A090361	Gyapu Chho	27.9751	88.6161	M(e): End-moraine Dammed Lake	Lasha Chu	Teesta	4960	Category-3
	North Sikkim	03_78A_017	07478A010063	Green Lake	27.893	88.1909	M(o): Other Moraine Dammed Lake	Gama Chu	Teesta	5496	Category-4
	North Sikkim	03_78A_013	07478A010058	NA	27.9195	88.159	M(e): End-moraine Dammed Lake	Gama Chu	Teesta	5441	Category-4
	North Sikkim	03_77D_008	07477D080005	NA	28.0062	88.4935	M(e): End-moraine Dammed Lake	Nakul Chu	Teesta	5023	Category-4
	North Sikkim	03_77D_007	07477D120032	NA	28.0073	88.5714	M(o): Other Moraine Dammed Lake	Teesta	Teesta	4998	Category-4
	North Sikkim	03_77D_002	07477D120019	Gurudongmar Lake	28.0258	88.7104	M(e): End-moraine Dammed Lake	Teesta	Teesta	5148	Category-3
	North Sikkim	293	07478A090383	NA	27.9509	88.7043	M(o): Other Moraine Dammed Lake	Laehung Chu	Teesta	5030	Category-4
	North Sikkim	298	07478A090425	NA	27.8729	88.6379	M(e): End-moraine Dammed Lake	Kalep Chu	Teesta	5118	Category-2

State	District	Old Lake ID	New Lake ID	Name	Lat	Long	Type	River	Basin	Elevation (m)	Category
Sikkim	North Sikkim	256	07478A090447	NA	27.8156	88.6565	E(o): Other Glacial Erosion Lake	Lako Chu	Teesta	4603	Category-4
	North Sikkim	345	07478A090432	Khangpup Khangse	27.8636	88.7468	M(e): End-moraine Dammed Lake	Khangpup Chu	Teesta	5084	Category-4
	North Sikkim	03_78A_019	07478A130571	NA	27.8645	88.8629	M(e): End-moraine Dammed Lake	Sebozung Chu	Teesta	4781	Category-2
	North Sikkim	292	07477D120035	NA	28.0055	88.6546	M(o): Other Moraine Dammed Lake	Teesta	Teesta	5550	Category-4
	North Sikkim	569	07477D120039	NA	28.0019	88.6391	M(e): End-moraine Dammed Lake	Teesta	Teesta	5424	Category-2
	North Sikkim	03_78A_007	07478A090375	Yulhe khang	27.9609	88.65	M(e): End-moraine Dammed Lake	Lasha Chu	Teesta	4964	Category-4
Arunachal Pradesh	West Kameng	03_83A_004	08683A050830	NA	27.7633	92.4248	M(o): Other Moraine Dammed Lake	Dungma Chu	Manas	5094	Category-4
	Tawang	03_83A_003	08683A050827	NA	27.7706	92.435	M(o): Other Moraine Dammed Lake	Dungma Chu	Dangme Chu	5179	Category-4
	Tawang	03_83A_005	08683A050836	NA	27.7558	92.4011	E(o): Other Glacial Erosion Lake	Dungma Chu	Dangme Chu	4967	Category-4
	Dibang Valley	03_91D_075	10391D060672	NA	28.6078	96.3205	E(c): Cirque Erosion Lake	Thangkung Chu	Dibang	4239	Category-3
	Tawang	129	08683A050825	NA	27.7742	92.3147	E(o): Other Glacial Erosion Lake	Dungma Chu	Dangme Chu	4870	Category-4

State	District	Old Lake ID	New Lake ID	Name	Lat	Long	Type	River	Basin	Elevation (m)	Category
Arunachal Pradesh	West Kameng	03_83A_007	09383A060091	NA	27.7276	92.4362	M(l): Lateral Moraine Dammed Lake	Bichom	Jia Bharali	4995	Category-4
	Siang	03_82L_007	09682L050102	NA	28.8374	94.4514	E(o): Other Glacial Erosion Lake	Slke	Siyom	4136	Category-4
	Dibang Valley	03_91C_026	10391C030254	NA	29.3381	96.0821	M(o): Other Moraine Dammed Lake	Jairu Chu	Dibang	4290	Category-4
	Anjaw	03_91H_073	10591H081931	NA	28.0541	97.3296	E(o): Other Glacial Erosion Lake	NA	Lohit	4424	Category-4
Himachal Pradesh	Lahul & Spiti	01_52H_002	0152H0203651	NA	32.5255	77.2197	M(e): End-moraine Dammed Lake	Gepang Gath (Sissu)	Chenab	4069	Category-3
	Lahul & Spiti	01_52H_004	0152H1103771	NA	32.4987	77.5467	M(e): End-moraine Dammed Lake	Chandra	Chenab	4150	Category-4
	Lahul & Spiti	01_52H_003	0152H1103771	NA	32.4987	77.5467	M(e): End-moraine Dammed Lake	Chandra	Chenab	4150	Category-3
	Kangra	1774	0152D1603265	NA	32.2219	76.789	E(o): Other Glacial Erosion Lake	Uhl	Beas	4577	Category-4
	Lahul & Spiti	1805	0152H0103646	NA	32.7623	77.1955	M(e): End-moraine Dammed Lake	Dudha Khol	Chenab	4766	Category-3
	Kangra	1998	0152D1503248	NA	32.32	76.908	M(e): End-moraine Dammed Lake	Ravi	Ravi	4401	Category-2

State	District	Old Lake ID	New Lake ID	Name	Lat	Long	Type	River	Basin	Elevation (m)	Category
Himachal Pradesh	Kangra	1936	0152D1503254	NA	32.2561	76.7778	M(o): Other Moraine Dammed Lake	Thamsar Nala	Ravi	4563	Category-2
	Kullu	1847	0153E0904453	NA	31.9147	77.5258	M(e): End-moraine Dammed Lake	NA	Beas	4462	Category-2
	Kinnaur	01_53I_002	0153I0204530	NA	31.661	78.1677	M(e): End-moraine Dammed Lake	NA	Satluj	4255	Category-3
	Kinnaur	2031	0153I0704552	NA	31.3394	78.2535	M(o): Other Moraine Dammed Lake	Hurba Khad	Satluj	4676	Category-2
Uttarakhand	Pithoragarh	02_62B_005	0262B0700349	NA	30.4458	80.3875	M(e): End-moraine Dammed Lake	NA	Sarda	4306	Category-3
	Chamoli	2108	0253N0500173	NA	30.976	79.4597	M(e): End-moraine Dammed Lake	NA	Alaknanda	5537	Category-4
	Pithoragarh	02_62B_004	0262B0200331	NA	30.5645	80.1785	M(e): End-moraine Dammed Lake	NA	Sarda	4872	Category-4
	Pithoragarh	01_62B_003	0162B1104954	NA	30.4766	80.5923	M(e): End-moraine Dammed Lake	Darma Yankti	Satluj	5263	Inadequate Data
	Uttarkashi	2207	0253J1300055	NA	30.9122	78.9581	M(l): Lateral Moraine Dammed Lake	NA	Bhagirathi	4707	Category-3
	Chamoli	2147	0253N0500169	NA	30.9807	79.4881	M(o): Other Moraine Dammed Lake	NA	Alaknanda	5656	Category-4

State	District	Old Lake ID	New Lake ID	Name	Lat	Long	Type	River	Basin	Elevation (m)	Category
Uttarakhand	Chamoli	02_53N_001	0253N1300271	Basudhara Tal	30.9009	79.7543	M(e): End-moraine Dammed Lake	Dhauli Ganga	Alaknanda	4677	Category-3
	Bageshwar	2299	0253N1600329	Nag Kund	30.1835	79.8757	E(c): Cirque Erosion Lake	NA	Alaknanda	4462	Category-4
	NA	02_62B_007	NA	NA	30.2786	80.1305	NA	NA	NA	4830	Inadequate Data
Jammu & Kashmir	Anantnag	958	0143N0802057	NA	34.1377	75.4167	E(o): Other Glacial Erosion Lake	NA	Jhelum	4083	Category-3
	Muzaffarabad	01_43J_003	0143J0101344	NA	34.9262	74.1555	E(c): Cirque Erosion Lake	NA	Jhelum	3926	Category-4
	Bandipore	27	0143J1501501	NA	34.3796	74.8762	E(o): Other Glacial Erosion Lake	NA	Jhelum	3738	Category-3
	Bandipore	1037	0143N0301929	Gadsar lake	34.4217	75.0578	E(c): Cirque Erosion Lake	Gadsar Nala	Jhelum	3570	Category-3
	Ganderbal	182	0143N0802046	NA	34.2338	75.3248	E(o): Other Glacial Erosion Lake	Durin Nar	Jhelum	4279	Category-4
	Anantnag	963	0143N0802055	NA	34.1389	75.377	E(o): Other Glacial Erosion Lake	Daphhinpar Nar	Jhelum	3709	Category-3
	Anantnag	938	0143O0502269	Sorus Nag	33.9534	75.378	E(o): Other Glacial Erosion Lake	Sorus Nag	Jhelum	3644	Category-3
	Anantnag	931	0143O0502273	NA	33.9287	75.3891	E(c): Cirque Erosion Lake	Lanaihal Nala	Jhelum	4048	Category-4
	Ganderbal	1032	0143N0301938	NA	34.3864	75.0642	E(o): Other Glacial Erosion Lake	NA	Jhelum	4006	Category-4

State	District	Old Lake ID	New Lake ID	Name	Lat	Long	Type	River	Basin	Elevation (m)	Category
Jammu & Kashmir	Bandipore	98	0143N0301935	NA	34.3918	75.0848	E(o): Other Glacial Erosion Lake	Raman Nala	Kishan ganga	4072	Category-3
	Ganderbal	1014	0143N0301959	NA	34.2986	75.0607	E(o): Other Glacial Erosion Lake	NA	Jhelum	3975	Category-4
	Anantnag	993	0143N0401963	Doda Sar	34.2272	75.2223	E(o): Other Glacial Erosion Lake	NA	Jhelum	4137	Category-4
	Anantnag	976	0143N0802050	NA	34.1844	75.3728	E(c): Cirque Erosion Lake	Daphhinpar Nar	Jhelum	4276	Category-4
	Anantnag	951	0143N0802066	NA	34.0668	75.4754	E(o): Other Glacial Erosion Lake	Sonasar Nala	Jhelum	3724	Category-3
	Kishtwar	01_52C_002	0152C0102950	NA	33.8683	76.1208	M(e): End-moraine Dammed Lake	Tanak Nala	Chenab	4071	Category-3
Ladakh	Kargil	01_52C_003	0152C1603156	NA	33.1586	76.9839	M(e): End-moraine Dammed Lake	Katkar Nala	Indus Upper	4479	Category-4
	Kargil	01_52C_001	0152C0102941	NA	33.9453	76.2302	M(e): End-moraine Dammed Lake	Ringdom Sankpo	Indus	4357	Category-4
	Leh	01_52B_012	0152B1602938	NA	34.0056	76.7876	M(e): End-moraine Dammed Lake	Photang	Indus	5126	Category-4
	Leh	01_42H_002	0142H0600150	Ghamu Bar Lake	36.6421	73.4068	M(e): End-moraine Dammed Lake	Darkot Bar	Gilgit	2748	Category-4
	Kargil	180	0152B0302731	NA	34.3513	76.0753	M(e): End-moraine Dammed Lake	Katpachan Lungpa	Indus	4435	Category-3

State	District	Old Lake ID	New Lake ID	Name	Lat	Long	Type	River	Basin	Elevation (m)	Category
Ladakh	Leh	1360	0143M1201790	NA	35.0273	75.7255	E(o): Other Glacial Erosion Lake	Indus	Indus	4647	Category-4
	Leh	01_52A_002	0152A0402408	NA	35.0965	76.2337	E(o): Other Glacial Erosion Lake	Shyok	Indus	4512	Category-4
	Leh	01_52A_003	0152A0802503	NA	35.092	76.2523	M(e): End-moraine Dammed Lake	Shyok	Indus	4533	Category-3
	Leh	01_52A_004	0152A0802509	NA	35.0743	76.2928	E(c): Cirque Erosion Lake	Shyok	Indus	4599	Category-4
	Leh	173	0152B0902855	NA	34.7649	76.7109	E(o): Other Glacial Erosion Lake	Shyok	Indus	5123	Category-4
	Leh	01_52E_001	NA	NA	35.418	77.6046	NA	Shyok	Indus	5122	Inadequate Data
	Leh	01_52J_001	0152J0303811	NA	34.4565	78.1364	M(o): Other Moraine Dammed Lake	Kunzang Lungpa	Shyok	5295	Category-4
	Leh	01_52B_010	0152B1202878	NA	34.0512	76.7178	M(e): End-moraine Dammed Lake	Spang	Indus	5093	Category-4
	Leh	01_52L_006	0152L1504080	NA	32.4406	78.9249	M(e): End-moraine Dammed Lake	Miksadiu	Indus	5680	Category-4
	Leh	01_52L_007	0152L1504092	NA	32.4093	78.8997	M(e): End-moraine Dammed Lake	Nalung	Indus	5468	Category-4

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8 Moraine Dammed Lakes Inventory in Satluj, Ravi, Chenab and Beas Basins of Himachal Pradesh, India

Surjeet Singh Randhawa, Sunil Dhar, Bhanu Prakash Rathore, Rajesh Kumar, Neha Thakur, Pooja Rana, Duni Chand Rana, and Ajay Kumar Taloor

Abstract

Multispectral satellite imageries analyzed that the Himalayan region reflected the fast retreat of most of the glaciers. This further showed that especially the moraine-dammed proglacial lakes are also increasing. Those lakes are a major threat to property and life to downstream locations. Numerous research carried out in the Himalayan region under the changing climate and glacier status has indicated an alarming rise in the number and sizes of the glacial lakes that may be potentially disastrous when converts into the glacial lake outburst flood (GLOF). This study focusses on the glacial lakes mapping at the different time frame in the basins of Chenab, Ravi, Satluj and Beas of Himachal Himalaya using LISS III. The remotely sensed imageries on the GIS platform helped in preparing the moraine dammed glacial lake inventory and assessing the potentiality of becoming the GLOF in these basins. This is of prime importance for preparedness against disasters due to GLOFs. This requires a continuous observation for the pre-disaster preparedness.

Keywords

Climate change · Glaciers · Himalayas · Lake inventory · Moraine dammed lake · Remote sensing

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8.1 Introduction

A huge natural reserve of natural resources is found in the mountain ecosystems which governs the economic well-being of the region. The degradation of the mountain ecosystem is responsible for the landslides, desertification GLOF, etc. in the mountain region. The increased rate of disturbances in the mountain ecosystem and related issues of landslides, desertification, GLOF, etc. are the major challenges due to natural and anthropogenic factors (Bhat et al. 2019; Haque et al. 2020).

The Himalayas have a glaciated area of 33000 km^2 comprising the largest freshwater reserves in the form of frozen water other than the Polar Regions (Bahuguna et al. 2003). The increased average temperature of the earth has significantly increased the rate of loss of the glaciated areas since Little Ice Age (Denton and Hughes 1981) and resulted in a loss of glacial cover and its volume. A large number of glaciers in the Himalaya are under retreat in the last few decades (Bhardwaj et al. 2016; Singh et al. 2017, 2020; Kumar et al. 2018, 2020a, b; Bisht et al. 2019; Taloor et al. 2019; Khan et al. 2020; Sood et al. 2020a; Sarkar et al. 2020). Hence, a consistent observation of the glaciers helps address the time series of the retreat of glacier surface area and the mass loss of the glaciers in the Himalaya (Bisht et al. 2019, 2020; Sood et al. 2020b). Besides, the knowledge of meltwater hydrochemistry is very important to address the issues related to the quality of water that is the lifeline for the downstream communities for their livelihood (Bisht et al. 2018).

The Satluj valley witnessed a disastrous flood in the years 2000 under the cloud bursts and induced GLOF, causing severe damage to downstream. Hence, the region requires to have continuous monitoring concerning lakes in the high mountain region with its potentiality of becoming GLOF. An attempt has been made in this work to map the glacierized areas of Chenab, Ravi, Satluj and Beas basins with the help of LISS III for the year 2013 and its physical verification to some of the region. An inventory of moraine dammed glacial lake has been prepared, which can be used as a baseline data for understanding the potential hazards in downstream.

8.2 Study Area

The investigation of the lakes has been carried out in the basin within the Satluj, Chenab, Ravi and Beas of Himachal Pradesh. The rivers Chenab, Ravi and Beas originate from Himachal Himalaya while the river Satluj originates (4500 m) near Rakas and Manasarovar lakes of Tibetan plateau and all these major rivers contribute to the Indus River. For the detailed study, the Satluj basin is divided into three sub-basins (Spiti: sub-basin-1, Lower Satluj: sub-basin-2, Upper Tibet: sub-basin-3). Similarly, the other basins have been divided as Ravi, Beas (Jiwa, Parbati), Chenab (Chandra, Bhaga and Miyar sub-basins) for preparing the lake inventory of the moraine dammed lakes (Fig. 8.1).

8.3 Satellite Data Used

The moraine-dammed glacial lakes inventory of Satluj, Ravi, Beas and Chenab has been carried out by using the satellite data of Indian Remote Sensing (IRS), LISS-3 was used for delineation of all such lakes in the different basins. The details of the satellite imageries used for the analysis have been presented in Table 8.1.

8.4 Methodology

The IRS, LISS-3 imageries were used for the identification of glacial lakes and understanding the potentiality of becoming GLOF in the basins of the study area. The Satluj basin has been covered for its entire region including the

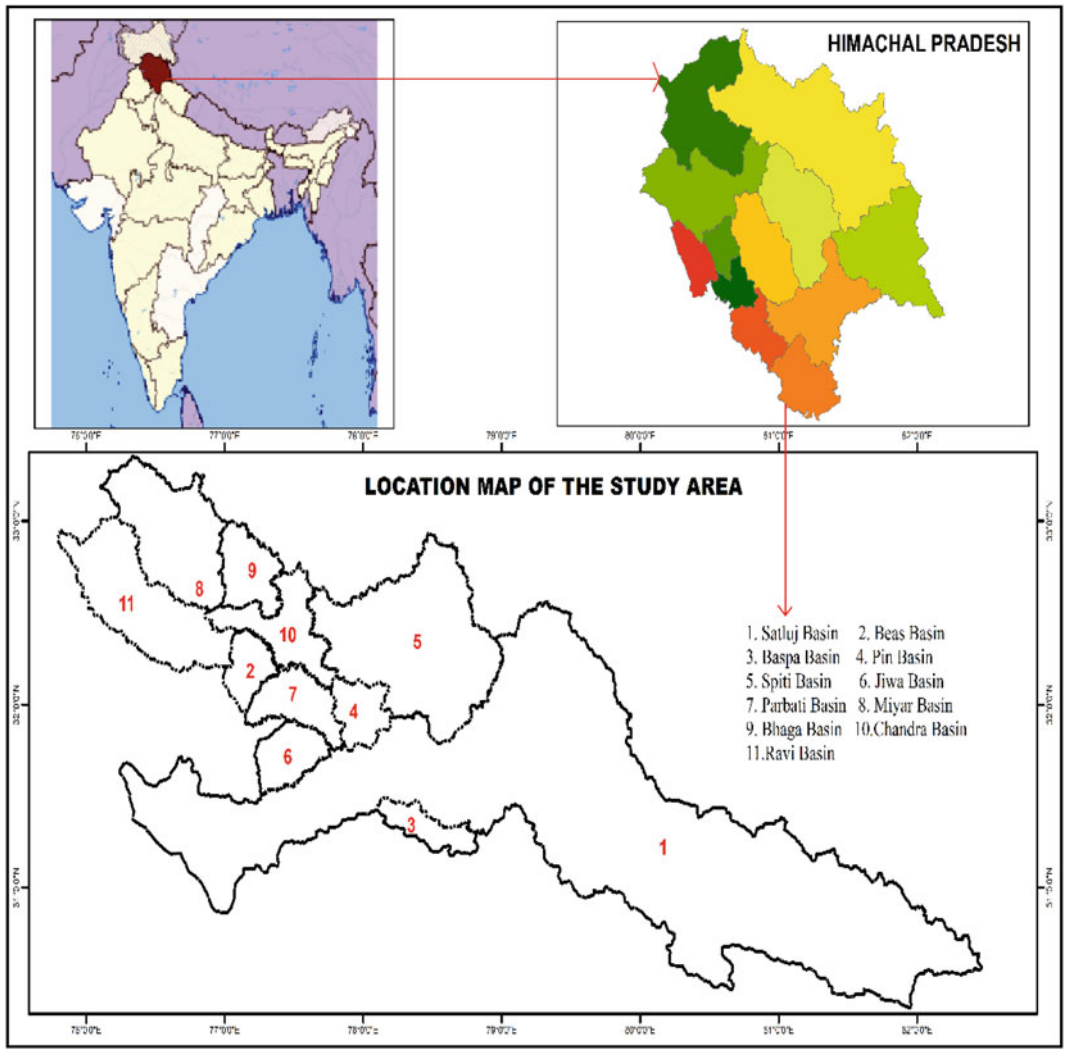

Fig. 8.1 Showing the study area of the different basins (*Source* IRS, LISS-3)

Mansarovar Lake. The better image quality having no cloud cover was used in the interpretation of the lake features. The geometric corrections were performed through a polynomial transformation of third-order. The boundary of basins was overlaid on the imageries. The boundary of lakes was delineated in the respective basins using ERDAS imagine. The deduced polygons were cleaned and polygon layers were built. For the identification, the polygons were assigned different ids for discussion of results. The process flow for the analysis of the data has been presented in Fig. 8.2.

8.5 Results and Discussions

8.5.1 Moraine Dammed Lakes Inventory of Chenab, Ravi, Satluj and Beas Basins in Himachal Pradesh by Using LISS III

Based on the visual interpretation techniques, satellite imageries analysis was carried out to generate updated information on moraine dammed glacier lakes in all the basins in Himachal

Table 8.1 The details of the satellite imageries used for lakes identification (*Source* IRS LISS-3 satellite imageries)

S. No.	Date of Pass	Path-Row	Sensor type
1	03-9-2013	96-48	Resourcesat-2/LISS-3
2	29-7-2013	96-49	Resourcesat2/LISS-3
3	20-9-2013	97-48	Resourcesat-2/LISS-3
4	20-9-2013	97-49	Resourcesat2/LISS-3
5	20-7-2012	98-48	Resourcesat-2/LISS-3
6	20-7-2012	98-49	Resourcesat2/LISS-3
7	01-7-2012	99-49	Resourcesat-2/LISS-3
8	09-10-2013	96-48	Resourcesat2/LISS-3
9	12-7-2013	94-47	Resourcesat-2/LISS-3
10	12-7-2013	96-48	Resourcesat2/LISS-3
11	31-7-2013	94-47	Resourcesat-2/LISS-3
12	29-7-2013	96-48	Resourcesat2/LISS-3
13	12-7-2013	95-48	Resourcesat-2/LISS-3
14	04-7-2013	94-48	Resourcesat2/LISS-3

(*Source* IRS, LISS–3) HWL: High Altitude Wetlands

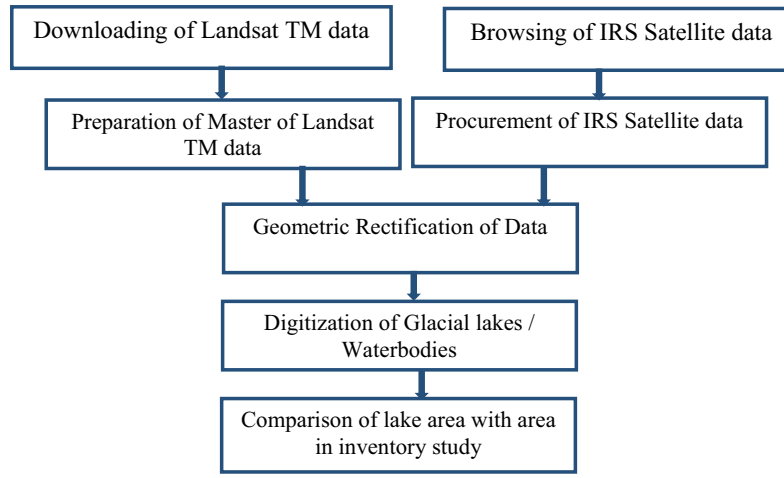

Fig. 8.2 Methodology implemented and its process flow in the interpretation of the satellite imageries (*Source* Authors)

Himalaya. All the delineated lakes have been assigned lake id's (Randhawa and Sharma 2013). The lakes have been further classified based on their aerial distribution such as lakes with area more than 10 hectares (ha), between 5–10 ha and less than 5 ha and all such lakes with area more than 5 ha have been taken into consideration for the tabulation purpose of the inventory of lakes in the present study.

8.5.2 Lakes Inventory of Chenab Basin

The Chenab basin instigates from the Baralacha region of Himachal Pradesh. Two major tributaries Chandra and Bhaga instigate from this region and flows in the reverse direction before meeting at Tandi near Keylong The Chandra, Bhaga and Miyar sub-basins has been analyzed

through the satellite image of 12 July 2013, and a total of 116 lakes were identified. The number of lakes identified in the basin using satellite data for 2001 and 2003 was only 55 (Randhawa et al. 2005), suggesting an increase of 61 lakes during the last decade. The distribution of these 116 lakes further suggests that 19 lakes fall in the Chandra sub-basin, 14 in the Bhaga sub-basin, and a maximum of 83 falls in the Miyar sub-basin (Fig. 8.3).

Further analyses revealed that in the Chandra sub-basin, 2 lakes are having area more than 10 ha, another 2 lakes are within the aerial range of 5 ha to 10 ha and 15 lakes were <5 ha. Likewise, Bhaga sub-basin, the aerial distribution of 14 lakes suggests that only one lake is having area more than 10 ha, 3 lakes are within the aerial range of 5 to 10 ha, and the remaining 10 lakes are having an area less than 5 ha. Similarly, in the sub-basin having a maximum number of lakes, i.e. the Miyar Sub-basin, only 3 lakes are having an area between 5 to 10 ha, and the remaining 80 lakes are of area <5 ha. As far as the vulnerable lakes in the Chenab basin are concerned, the lakes with id 1and 3 (Table 8.2) having an area of 80.12 ha and 146.31 ha seems to be extremely susceptible, particularly the lake with ID 1 appears to be quite deep. This is attached with the snout of the glacier under which the aerial extent is gradually increasing, i.e. from 27.0 ha (1976) to 55.4 ha (2001) and 80.12 ha in 2013. Likewise, the other lake with

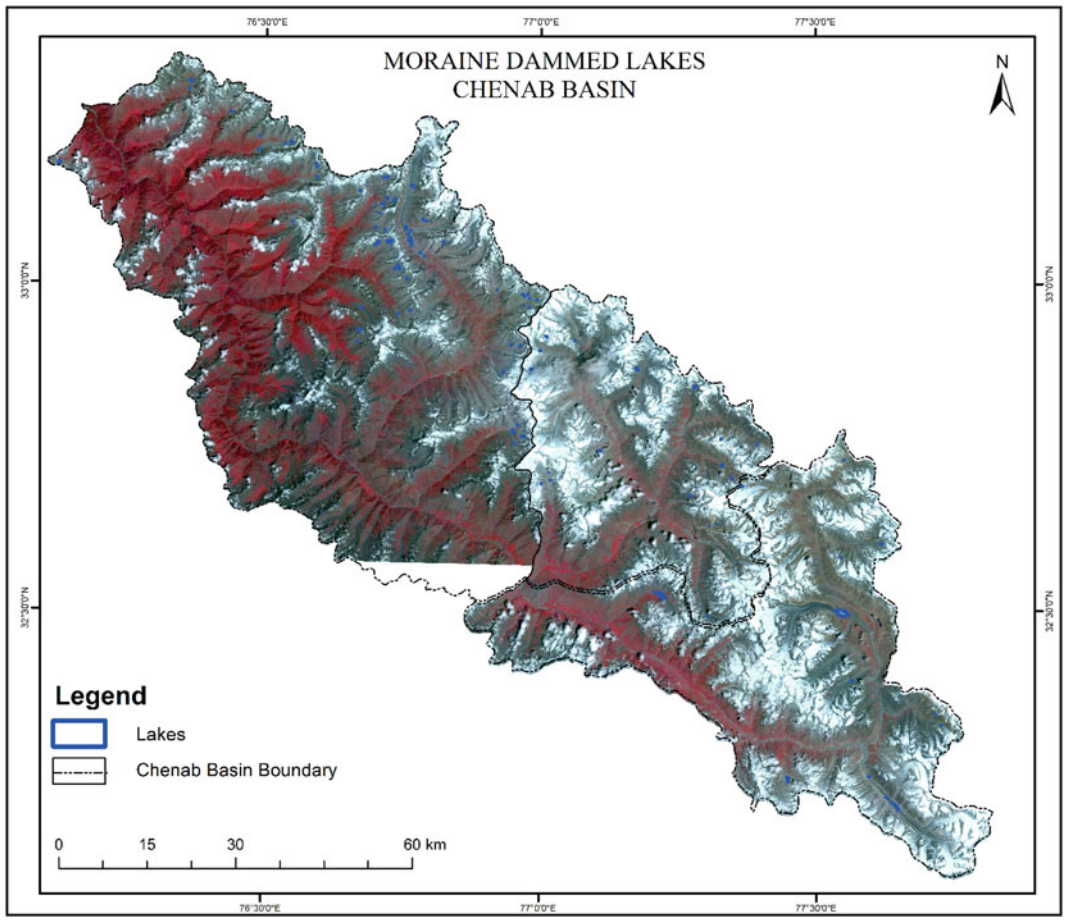

Fig. 8.3 Moraine dammed lakes in Chenab basin as delineated from IRS, LISS-3 image of 12 July 2013 (*Source* IRS, LISS-3)

ID 3 whose area has increased from 30 ha (1972) to 105.3 ha (2001) and 146.31 ha in 2013. Based on field evidence and paleo-history, a large moraine dammed lake at the snout Samundra Tapu glaciers in the Chenab basin has increased at a faster rate during the last three decades (Dhar et al. 2010). Thus, the whole Table 8.2 reflects that in the Chenab basin, 3 lakes having >10 ha area and 8 lakes with ranging from 5 to 10 ha area, due to that these warrant for regular monitoring.

8.5.3 Lakes Inventory in the Beas Basin

Beas basin instigates from the Rohtang region of Kullu district and the river emerging from this basin is named as Beas River. This basin has been studied in three parts as Jiwa, Parbati and the Beas. The Parbati River acts as the main tributary and joins the Beas River at Bhuntar in Kullu district. The analysis of IRS LISS III image dated 29 July 2013, showed 28 lakes in Parbati sub-basin and 39 lakes in the Jiwa sub-basin further downstream in the catchment. Because of the dense cloud cover, no information could be retrieved from the image in the upper catchment of the Beas basin (Fig. 8.4).

Further spreading of lakes in other sub-basins suggests that out of 28 lakes identified in the Parbati sub-basin, 2 lakes are having an area of more than 10 ha and the remaining 26 lakes are such which have an area less than 5 ha. Likewise, in the Jiwa sub-basin, 02 lakes show an area ranging from 5 to 10 ha, and the remaining 37 lakes are with an area <5 ha (Table 8.3).

8.5.4 Lakes Inventory of Ravi Basin

The LISS III data of 04 October 2013, reflected 22 lakes in the whole Ravi basin (Fig. 8.5).

A good quality cloud-free image of October has been used which showed 22 lakes in the Ravi basin and most of the lakes exist along the natural geomorphic depressions of the prominent Dhauladhar range. Further, the distribution of these 22 lakes suggests that there are 2 lakes which have an area of more than 10 ha and only 1 lake is with an aerial range between 5 to 10 ha, whereas the remaining lakes (19) in the Ravi basin are of lesser size with an area <5 ha (Table 8.4).

8.5.5 Lakes Inventory of Satluj Basin

Satluj basin having a large spatial extent has been studied using satellite data during the period July–September 2012/2013 in different path rows viz. 96–48, 96–49, 97–48, 97–49, 98–48, 99–49, respectively. The analysis reveals the presence of 391 moraine-dammed lakes in the entire catchment of the Satluj right from its origin in the Tibetan Himalaya (Fig. 8.6).

Table 8.2 Areal range of moraine-dammed lakes in Chenab basin (based on the analysis of IRS, LISS–3 data)

Sl.	Name of sub-basin	Lake ID (Number)	Longitude	Latitude	Area (ha)
1	Bhaga	11	77.306289	32.630207	10.20
2	Bhaga	3	77.398433	32.761989	6.71
3	Bhaga	6	77.329385	32.722573	7.73
4	Bhaga	8	77.347478	32.705244	5.13
5	Chandra	1	77.222620	32.524214	80.12
6	Chandra	3	77.546984	32.499906	146.31
7	Chandra	6	77.617488	32.604030	5.00
8	Chandra	13	77.447949	32.245131	7.44
9	Miyar	6	76.546224	33.216837	8.33
10	Miyar	43	76.671748	32.929764	5.91
11	Miyar	83	76.123668	33.182620	8.56

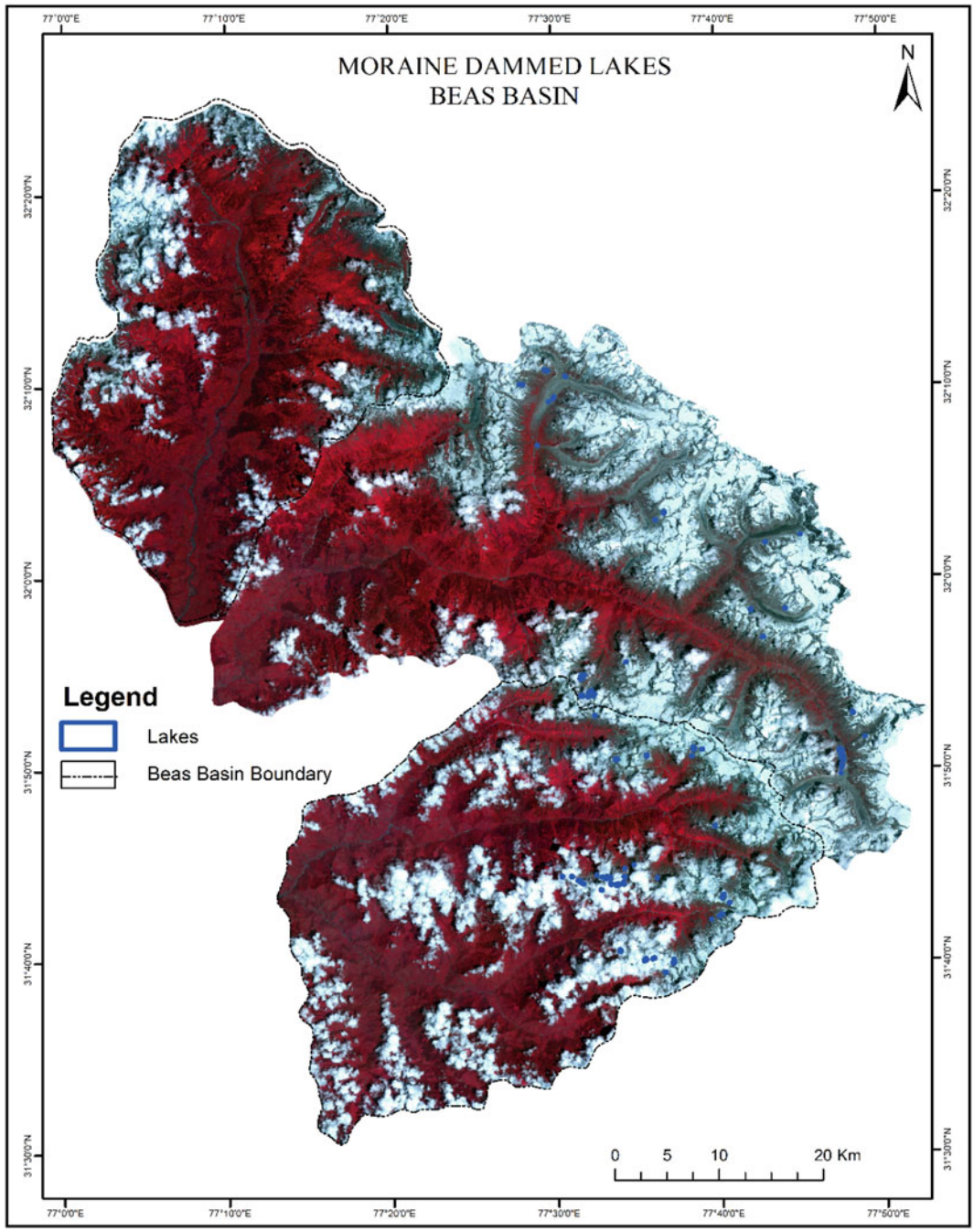

Fig. 8.4 Moraine dammed lakes in Beas basin as delineated from the image of 29 July 2013 (*Source* IRS, LISS-3 image)

Table 8.3 Areal spread of moraine dammed lake in Beas basin (*Source* IRS LISS–3 image)

Sl.	Basin name	Sub basin	Lake ID number	Longitude	Latitude	Area (ha)
1	Beas	Parbati	21	77.572690	31.926278	13.58
2	Beas	Parbati	26	77.526890	31.897405	13.08
3	Beas	Jiwa	9	77.668512	31.721823	5.07
4	Beas	Jiwa	34	77.618027	31.665046	6.07

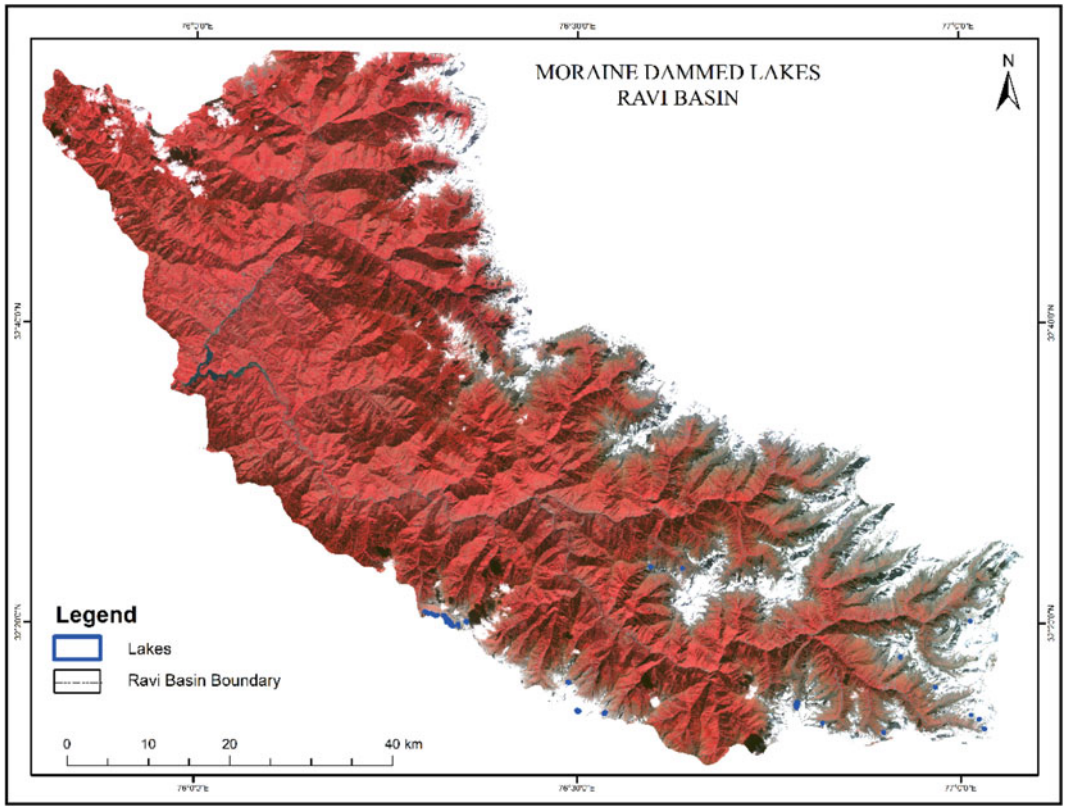

Fig. 8.5 Moraine dammed lakes in Ravi basin as delineated from the image of 4 October 2013 (*Source* IRS, LISS-3)

Table 8.4 Areal extent of moraine dammed lake in Ravi basin (*Source* IRS, LISS–3 image)

Sl.	Basin	Lake id number	Longitude	Latitude	Area (ha)
10	Ravi	10	76.787141	32.244530	14.87
12	Ravi	12	76.500869	32.237279	7.09
16	Ravi	14	76.330737	32.337624	33.51

The supplementary, analysis revealed that out of 391 lakes, 118 lakes are in sub-basin 1 (Spiti sub-basin), 15 lakes in sub-basin 2 (lower Satluj) and the 258 lakes in the sub-basin 3 (upper Satluj) in the Tibetan Himalayan region. As far as the aerial distribution of the lakes is concerned, 40 lakes in the entire Satluj basin having an area of more than 10 ha, 75 lakes are having

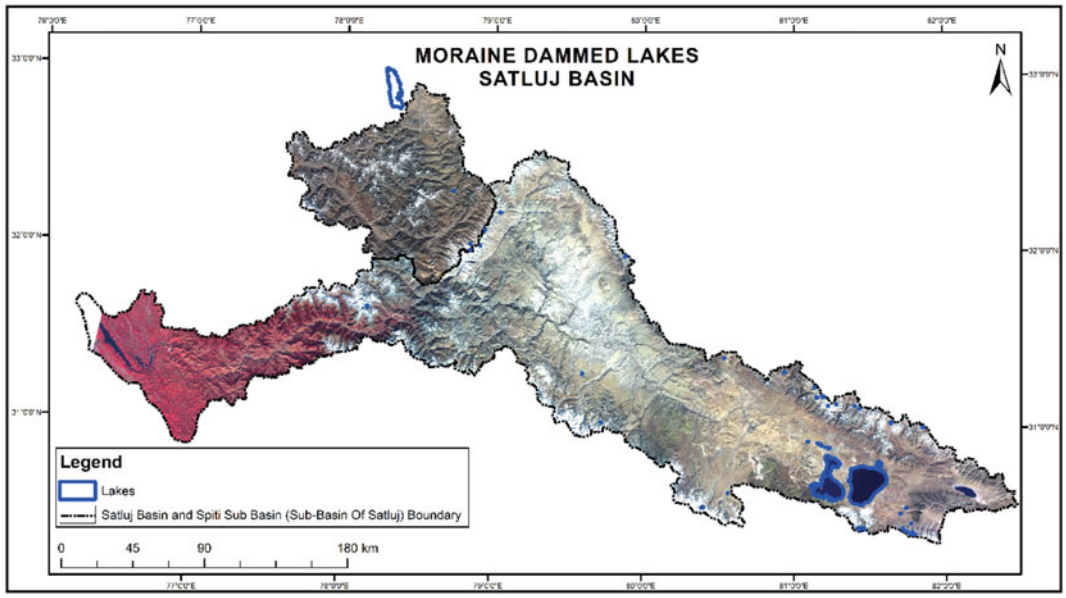

Fig. 8.6 Moraine dammed lakes as delineated in Satluj basin (*Source* IRS, LISS-3)

an area ranging from 5 to 10 ha and 276 lakes are of the lesser size of <5 ha (Table 8.5).

The results related to the lakes from all the basins have been summarized and the category wise distribution of lakes has been presented through Table 8.6. The aerial distribution of the lakes suggests that the Satluj basin possesses 391 lakes, from which 275 are of smaller size (less than 5 ha), 75 lakes range between 5 to 10 ha and 40 lakes are of size greater than 10 ha. Similarly, the Chenab basin (Chandra, Bhaga, Miyar) possesses 116 lakes which are approximately double than (55) lakes identified in 2001 satellite imageries (Randhawa et al. 2005). Out of the total 105 lakes are in the range of area <5 ha, 8 lakes are in the range of 5 to 10 ha and only 3 lakes are of area >10 ha. In the Beas basin (Jiwa, Parbati), out of 67 lakes 63 lakes of area <5 ha, 2 lakes of area 5 to10 ha and the remaining 2 lakes are of area >10 ha. The cloudy image of the upper part of the Beas basin put the constraints so no lake identification has been made. In Ravi basin, out of 22 lakes, 2 lakes are of area >10 ha, only 1 lake is with area ranging from 5 to 10 ha and remaining 19 lakes are with area <5 ha.

8.6 Conclusions

The status of lakes in the basins and sub-basins of Chenab (Bhaga, Chandra, Miyar), Beas (Jiwa, Parbati), Ravi, Satluj have been analyzed based on LISS III of the year 2013 and compared with the earlier lake inventories in these basins. The results disclosed a substantial increase in the numeral of moraine dammed lakes in all the basins mentioned above. The comparison with the earlier reported inventory of lakes in these basins based on the IRS IA & IB satellite imageries in the years 1993 disclosed about 38 lakes in Satluj basin (Kulkarni et al. 1999) having 14 lakes in the Himachal Pradesh while 24 lakes in the Tibetan region. The same basin in 2013 has been covered with 391 lakes including the Baspa and Spiti basins. Similarly, the basin Chenab has been reported to have 55 lakes based on the IRS IC/ID satellite imageries of the year 2003, which has been increased to 116 in LISS III satellite image of the year 2013.

This temporal variation of lakes in these basins is very clearly indicating the increasing

Table 8.5 Areal distribution of all moraine-dammed lakes in Satluj Basin

S. No.	Lake id	Basin ID	Longitude	Latitude	Area (ha)	S. No.	Lake id	Basin No	Longitude	Latitude	Area (ha)	S. No.	Lake id	Basin No	Longitude	Latitude	Area (ha)
1	37	1	78.70461	32.69416	5.4	41	560	3	79.12591	32.321	5.95	81	680	3	80.18395	31.44718	19.79
2	47	1	78.49398	32.44269	6.61	42	562	1	78.9954	32.23965	8.77	82	681	3	80.19622	31.44245	17.71
3	49	1	78.74175	32.31269	20.3	43	567	3	78.95518	32.10657	5.23	83	683	3	80.22435	31.43245	17.2
4	58	3	79.01097	32.32503	9.93	44	568	3	78.95625	32.09329	6.44	84	684	3	80.23391	31.43146	18.24
5	62	3	78.98791	32.30671	8.8	45	571	3	78.93541	32.001	9.59	85	685	3	80.29606	31.45177	8.56
6	63	3	78.99401	32.28709	9.57	46	573	1	78.84455	32.02254	7.67	86	686	3	80.26917	31.45958	6.28
7	67	3	79.05035	32.19611	23.74	47	576	1	78.76645	32.03093	7.85	87	687	3	80.18071	31.40144	7.49
8	68	3	79.03454	32.21077	8.53	48	580	3	78.85223	31.90085	22.32	95	98	3	81.0332	31.28473	14.95
9	74	1	78.98079	32.17743	5.31	49	581	3	78.79443	31.91341	6.59	96	107	3	81.0845	31.23876	5.85
10	77	3	78.9864	32.14782	9.17	50	585	1	78.71304	31.89844	7.92	97	109	3	81.13771	31.23316	11.01
11	82	3	78.95104	32.10916	5.26	51	587	1	78.73075	31.88669	5.84	98	112	3	81.14911	31.1978	12.15
12	86	3	78.94946	32.09378	10.12	52	590	2	78.74747	31.52819	6.03	99	113	3	81.19457	31.18094	52
13	87	3	78.9417	32.09407	11.46	53	595	2	78.14109	31.73377	6.97	93	114	3	81.15269	31.17821	23.25
14	88	3	78.95636	32.07898	5.02	54	597	2	78.20633	31.90931	6.49	94	116	3	81.38243	31.1381	9.21
15	89	3	78.93825	32.07883	8.14	55	601	1	78.45281	32.16677	5.64	95	134	3	81.85202	31.00371	24.36
16	93	3	78.95291	32.04592	7.59	56	605	1	78.50053	32.362	7	96	140	3	81.531	30.82868	6.57
17	94	3	78.92	32.00424	5.67	57	173	2	78.69657	31.22521	11.86	97	142HWL	3	81.56941	30.80125	364.14
18	97	1	78.88407	32.00381	8.33	58	177	2	78.3288	31.31149	24.84	98	145HWL	3	81.54085	30.7279	41066.37
19	99	1	78.85532	32.01603	17.36	59	180	2	78.25397	31.34068	5.94	99	148HWL	3	81.59198	30.7591	194.77
20	101	1	78.85464	31.97947	22.81	60	614	2	77.87832	31.69373	10.84	100	172	3	81.71995	30.44545	7.12
21	102	3	78.87972	31.95617	7	61	615	2	78.16767	31.66174	27.7	101	173	3	81.67561	30.44572	9.89
22	106	3	78.8476	31.96766	6.59	62	639	2	78.01247	31.40694	7.87	102	179	3	81.71341	30.42744	25.09
23	109	1	78.77321	32.02695	8.6	63	184	3	79.39264	32.37784	27.63	103	184	3	81.71968	30.41953	16.95
24	111	1	78.76805	32.03095	6.54	64	190	3	79.68327	32.25382	6.96	104	187	3	81.77671	30.40834	7.28
25	113	1	78.76372	32.02884	6.63	65	201	3	79.84579	31.99178	5.43	105	203	3	81.09009	31.26536	5.06
26	117	3	78.83234	31.91934	5.53	66	202	3	79.87211	31.97695	10.78	106	210	3	81.55487	30.77131	53
27	118	3	78.8365	31.91645	5.28	67	203	3	79.87563	31.96732	8.5	107	223	3	81.42486	31.1366	5.46
28	119	3	78.83168	31.91673	9.61	68	207	3	79.87748	31.95564	5.17	108	228	3	81.43578	31.11286	7.25
29	121	3	78.82885	31.91557	8.04	69	209	3	79.86544	31.92432	34.57	109	233	3	81.50399	31.09335	5.5

(continued)

Table 8.5 (continued)

S. No.	Lake id	Basin ID	Longitude	Latitude	Area (ha)	S. No.	Lake id	Basin No	Longitude	Latitude	Area (ha)	S. No.	Lake id	Basin No	Longitude	Latitude	Area (ha)
30	122	3	78.79484	31.90425	11.65	70	645	3	78.79411	31.44988	10.61	110	235	3	81.50304	31.11081	7.5
31	131	1	78.71485	31.90381	5.2	71	647	2	78.75113	31.55366	8.66	111	237	3	81.54287	31.116	11.88
32	133	2	78.76188	31.5392	7.32	72	652	3	79.59381	32.35287	6.2	112	242	3	81.54608	31.10174	6.81
33	135	3	78.8036	31.4354	7.48	73	656	3	79.78836	32.02724	10.35	113	253	3	81.72296	31.06934	8.6
34	154	1	78.81737	32.04471	10.5	74	662	3	79.85466	31.97757	7.21	114	607	3	81.16383	30.91277	14.7
35	155	1	78.81706	32.06681	8.21	75	664	3	79.85751	31.96684	5.37	115	608	3	81.09476	30.92422	15.97
36	551	1	78.70612	32.71675	8	76	96	3	79.60051	31.30347	24.34	116	692	3	81.1102	31.26913	5.24
37	553	1	78.72321	32.69407	7	77	171	3	79.514	31.13195	6.7	117	731	3	80.40077	30.55246	37.88
38	554	1	78.72233	32.69336	7.53	78	178	3	79.41423	31.05959	6.22	118	142HWL	3	81.56941	30.80125	364.14
39	556	1	78.84073	32.40785	7.9	79	399	3	79.72944	31.02881	6.04	119	145HWL	3	81.54085	30.7279	41066.37
40	557	1	78.90868	32.31144	8.02	80	669	3	79.4774	31.3577	11.92	120	148HWL	3	81.59198	30.7591	194.77

Table 8.6 Lakes spreading in the basins/sub-basins of Himachal Pradesh analyzed from the IRS, LISS-3 image (2013)

Sl.	Basin/sub-basin	No. of lakes with area >10 ha	No. of lakes with an area between 5–10 ha	No. of lakes with area <5 ha	Number of lakes in total
1	**Chenab**	**3**	**8**	**105**	**116**
	Bhaga	1	3	10	14
	Chandra	2	2	15	19
	Miyar	0	3	80	83
2	**Beas**	**2**	**2**	**63**	**67**
	Jiwa	0	2	37	39
	Parbati	2	0	26	28
3	**Ravi**	**2**	**1**	**19**	**22**
4	**Satluj**	**40**	**75**	**276**	**391**

trend of the lakes in the higher Himalaya of Himachal Pradesh. The results of 2013 indicated that the rise in the number of lakes are much higher for smaller sized lakes having an area less than 5 ha and formed mostly related to the snout retreat and moraines damming that may be an indication of a noticeable impact of changing climate in these regions.

One of the disastrous incidents of 2013, in the Kedarnath region of Uttrakhand, was also related to the bursting of a lake at the snout of the Chorabari in association with cloud burst causing a catastrophe in the downstream region (Dobhal et al. 2013). Hence, the importance of lake monitoring should not be ignored to have preparedness against the likely disaster due to GLOF. The lake formation and swelling of the lake are dynamic and its stability depends on the stability of the damming materials, as well as the variability of the impounded water quantity in lakes. The increased water volume in lakes may induce dam breaching and consequential situation of a flash flood in the downstream.

The reported lakes in the present study having an area >10 ha are highly potential, while the lakes with an area between 5–10 ha are moderately potential towards becoming GLOF in case of higher meltwater intrusion in the lakes and associated cloud burst disorder in the basins of Chenab, Beas, Ravi and Satluj. Thus, regular monitoring of existing and new formation of lakes are indispensable to avoid any possibility of catastrophe due to GLOF in the region.

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MORAINE–DAMMED LAKES STUDY IN THE CHENAB AND THE SATLUJ RIVER BASINS USING IRS DATA

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ABSTRACT

Moraine-dammed lakes are normally formed near glacier terminus. These lakes can burst due to excessive melting and can cause floods in the valleys. Many such floods have been reported in the Himalayas and other parts of the World. In this paper, an inventory of these lakes in the Satluj and the Chenab basins has been reported. During the investigation, 22 lakes in the Satluj and 31 lakes in the Chenab basin were mapped. In the Chenab basin, two lakes are of very large size, their areal extent is 105 and 55 ha, located in toposheet number 52 H11 and 52H02, respectively. These lakes were selected for detail monitoring.

The lake near the Geepang glacier, is located in toposheet number 52H 02 and its area was 27 ha in 1976. Using the satellite data, areal extent of the lake was monitored. The lake area was almost doubled to 55 ha in 2001. This suggested that, lake size is constantly increasing and it can cause outburst flood. The maximum possible depth of lake was estimated by taking the average difference of maximum and minimum height of moraine dam from the Survey of India toposheet. By considering the average depth, the volume of the lake water and the instantaneous discharge of 350 m^3/sec were estimated. This is large discharge for a small stream like the Geepang Gath and it can damage many civilian and defense establishments. Therefore, further detail field investigations of this lake are needed to assess threat potential and to develop strategy to avoid this flash flood.

Introduction

Glacier Lake Outbursts Floods (GLOF) caused by the moraine-dammed lakes is a common phenomenon in the glaciated terrains of the world. These floods can cause extensive damage to the natural environment and human property as it can drain extremely rapidly and relatively small lake can cause dramatic floods (Deslognes *et al.*, 1989).

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These events could be cyclic and can occur periodically. Many events of outbursts floods are reported in North America, Europe and in the Himalaya (Clarke and Mathews, 1981, Hewitt, 1985, Deslognes *et al.*, 1989). In the Himalayas, outbursts floods from glacial lakes are reported in Central Nepal and Bhutan (Gansser, 1983). On Sept. 3, 1977, an outbursts from a moraine-dammed lake occurred in the Mingbo valley, Dudh Kosi region, East Nepal. The flood was recorded at 70 km downstream from the Mingo valley (Fushimi *et al.*, 1985). But in the Indian segment of the Himalayas, no systematic records of floods due to outbursts of moraine-dammed lakes are available.

Remote sensing technique has been extensively used for delineation and mapping of moraine-dammed lakes in the Himalayas (Kulkarni, 1996; Kulkarni *et al.*, 1999). False color composite can be used to identify moraine-dammed lakes due to its dark-blue to black color and characteristic shape. This investigation is carried out in the glaciated terrain of the Chenab and the Satluj river basins.

Moraine Dammed Lakes in the Satluj and the Chenab Basin

Satellite images have shown a total of 22 lakes in the Satluj basin. Location of these lakes is given in Fig. 1 and areal extent of individual lakes is given in Table 1. The largest lake was almost 28 ha located in the Survey of India (SOI) toposheet number 52L16. The smallest lake was located in toposheet number 53I07. Similar investigation was carried out in the Chandra and the Bhaga (Chenab basin) river basins. In these basins satellite data of LISS-III of year 2001 was used. Investigation has shown presence of 31 lakes in the basin. Location and areal extent of lakes in the Chenab basin is given in Fig. 2 and Table 2, respectively. Areal extent of these lakes is varying from 0.3 to 105 ha. In the basin, two lakes are of very large size, their areal extent is 105 and 55 ha, located in toposheet number 52 H11 and 52H02, respectively. These lakes were selected for detail monitoring.

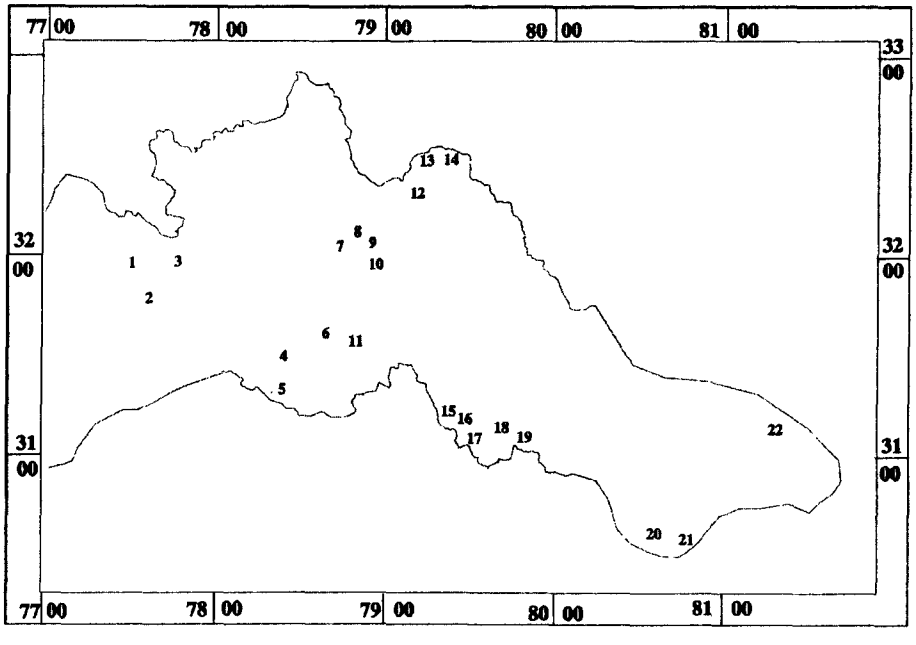

Fig. 1. Map showing location of lakes in the Satluj basin

Table 1: Areal extent of moraine dammed lakes in the Satluj basin

Lake number	Toposheet number	Areal extent (ha)
1	53E 09	10.2
2	53E 09	7.7
3	53E 09	3.3
4	53I 07	1.6
5	53I 07	19.9
6	53I 07	9.3
7	52L 16	12.4
8	52L 16	6.8
9	52L 16	27.9
10	52L 16	5.3
11	53I 14	15.4
12	53P 03	3.9
13	52P 06	7.8
14	52P 06	4.0
15	53M 08	6.2
16	53M 08	7.9
17	53M 08	10.6
18	53M 12	5.4
19	53M 12	5.6
20	62B 10	5.8
21	62B 10	5.7
22	62E 04	4.9

The lake formed near the glacier snout of the Geepang Gath glacier was monitored using 4 satellite images from 1990 to 2001 (Table 3; Fig. 3). Earliest record of lake extent is available from the topographic map of Survey of India. This was surveyed from areal photographs of 1976. The areal extent in 1976 was 27 ha and it has changed to 55.4 ha by year 2001 (Table 3). Satellite data of 1990, 1998, 2000 and 2001 indicates constant increase in areal extent. In addition, color of water body in standard FCC is black, indicating deep-water body. Therefore, this lake is selected to estimate lake volume and possible discharge of outburst flood.

Table 2: Areal extent of moraine dammed lakes in the Chenab basin

Lake number	Toposheet number	Areal extent (ha)
1	52C 16	1.3
2	52D 13	1.0
3	52D 13	1.2
4	52D 13	0.6
5	52D 13	1.9
6	52H 01	1.2
7	52H 01	0.3
8	52H 01	3.6
9	52H 01	1.4
10	52H 02	0.3
11	52H 02	55.4
12	52H 06	5.4
13	52H 06	0.5
14	52H 06	5.1
15	52H 06	1.0
16	52H 06	10.5
17	52H 06	10.3
18	52H 06	0.2
19	52H 06	0.2
20	52H 06	0.2
21	52H 06	0.4
22	52H 06	6.7
23	52H 08	4.5
24	52H 08	6.3
25	52H 08	2.3
26	52H 10	1.7
27	52H 10	4.9
28	52H 11	105.3
29	52H 11	0.3
30	52H 11	0.4
31	52H 11	0.4

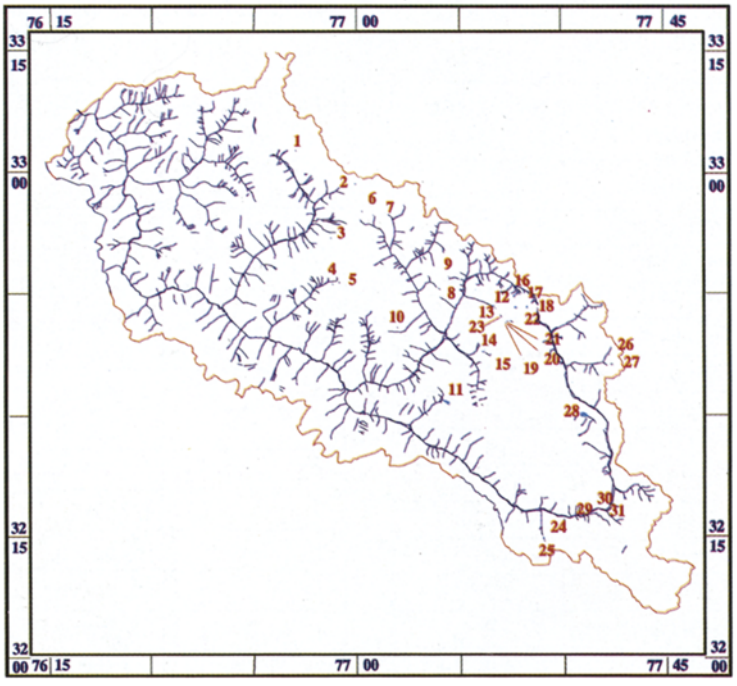

Fig. 2. Map showing location of lakes in the Chenab basin

Table 3: Changes in lake dimensions located near the Geepang Gath glacier in the Chenab basin (Lake number 11)

Year	Areal extent (ha)
1976	27.0
1990	42.0
1998	43.2
2000	51.1
2001	55.4

Another moraine-dammed lake number 28 (Fig. 2) is monitored using satellite images. A total of 7 images from 1972 to 2001 were used in the investigation. In 1972, areal extent of lake was observed as 30 ha and this was constantly increased up to 104 ha till 1993 (Table 4). The satellite image of 1998 indicate reduction of area extent to 94 ha, suggesting possibility of dewatering in between 1993 and 1998. The lake area remained relatively stable up to 2000 and it again increased in 2001. In addition, color of water body in standard FCC is sky blue, indicating shallow-water body. Satellite images showing areal extent of lake is given in Fig. 4.

Estimation of Lake Volume

In order to estimate present volume of lake, field investigation may be needed. However, maximum possible lake volume can be estimated using the Survey of India toposheets. Maximum possible lake volume is important because lake can cause outburst flood, if water level rises to maximum moraine dam. The difference between maximum and minimum height of moraine is estimated as 18 m. The lake volume estimated using average lake depth as 9.9 million m^3 by considering areal extent of lake as 55.4 ha in the year 2001.

Fig. 3. Satellite images showing a moraine-dammed lake near the Geepang Gath glacier

Fig. 4. Satellite images showing a moraine-dammed lake near the glacier number 28

Table 4: Changes in dimensions of the glacier number 28

Year	Areal extent (ha)
1972	30.0
1984	60.0
1987	76.0
1993	104.0
1998	94.2
2000	95.3
2001	105.3

Estimation of Peak Runoff

A simple empirical formula suggested by Clague and Mathews (1973) to estimate peak run off was used in the investigation. In this method, the maximum instantaneous discharge can be estimated by using the volume as an input. The equation used for the estimation of peak runoff is as under:

$$Q_{MAX} = 75(V/10\,00000)^{0.67}$$

Where,

Q_{MAX} = Maximum instantaneous discharge (m^3/s)

V = Lake volume (million m^3)

Subsequently to the development of the above-mentioned formula, many physically based models were developed to estimate the peak discharge. But due to non-availability of other information such as thickness, length of the drainage, lake temperature, etc., it is difficult to apply such models at this stage of investigation. Therefore the formula suggested by Clague and Mathews (1973) was simply used to make the initial assessment of the potential hazards.

Therefore as discussed above, by taking the maximum lake volume in the 1998, the peak discharge can be estimated as 350 m^3/sec. This discharge is very large in comparison to the summer discharge estimated of many glaciated streams in the region. For example, the Chotta Sigri nala in the same basin, which is only 10 m^3/sec. Therefore, this flood can cause significant increase in the river discharge and it can cause extensive damage in the region.

Conclusion

The application of remote sensing technology has made possible to map small lakes formed at the higher altitudes, which would have not been possible by field investigations. During the investigation a total of 22 lakes in the Satluj and 31 lakes in the Chenab basin were mapped. Systematic analysis of satellite images has provided information about formation of these lakes. The monitoring of two lakes has suggested that one lake (58 H11) has natural mechanism of dewatering and it may not cause large outburst flood. The other lake (58 H02) formed at the snout of the Geepang Gath glacier showed a gradual increase in its size over the years. The instantaneous discharge estimated using the volume input is 350 m^3/sec. This estimated discharge is much more than the summer discharge calculated for many small streams in the basin. Thus bursting of such lakes can cause flash floods in the downstream areas resulting in damage to roads, life and property. Therefore in order to assess the hazards from such lakes, it is important to study such lakes in detail by field investigations. This will help in making the assessment of possible hazards and to suggest the measures to avoid flash floods from the out bursts of moraine dammed lakes.

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ANNEXURE- E

सत्यमेव जयते

NATIONAL DISASTER MANAGEMENT AUTHORITY GUIDELINES

MANAGEMENT OF GLACIAL LAKE OUTBURST FLOODS (GLOFs)

October 2020

NATIONAL DISASTER MANAGEMENT AUTHORITY
MINISTRY OF HOME AFFAIRS
GOVERNMENT OF INDIA

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

National Disaster Management Authority Guidelines
Management of Glacial Lake Outburst Floods (GLOFs)

National Disaster Management Authority Guidelines
Management of Glacial Lake Outburst Floods (GLOFs)

A publication of:

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National Disaster Management Authority
Ministry of Home Affairs
Government of India

October, 2020

सत्यमेव जयते

Prime Minister

MESSAGE

It is heartening to learn that National Disaster Management Authority (NDMA) has prepared national guidelines on management of Glacier Lake Outburst Floods (GLOFs).

Global warming and climate change are among the major challenges the world faces today. The hazards associated with glacial formations in the Indian Himalayan Region (IHR) require an integrated strategy to minimize disaster risks. The national guidelines will increase awareness about different aspects of GLOFs to further efficient monitoring and effective response.

The document on instructions will facilitate a holistic mechanism from local to national level while ensuring valued participation of various stakeholders in IHR. Identification and standardisation of short-term, medium-term and long-term action plans will offer active roles and responsibilities to stakeholders and help build a robust and responsive way forward to deal with glacial risks.

May the national guidelines on GLOFs, the outcome of the collaborative effort of NDMA and Swiss Agency for Development and Cooperation, Embassy of Switzerland, prove to be a valuable asset in the hands of people to efficiently deal with glacial hazards and strengthen our preparedness and resilience.

Best wishes to NDMA for its future endeavours.

(Narendra Modi)

New Delhi
आश्विन 16, शक संवत् , 1942
08th October, 2020

अमित शाह
AMIT SHAH

सत्यमेव जयते

गृह मंत्री
भारत
HOME MINISTER
INDIA

संदेश

यह प्रसन्नता का विषय है कि **राष्ट्रीय आपदा प्रबंधन प्राधिकरण (NDMA)** ने **ग्लेशियल लेक आउटबर्स्ट फ्लड्स (ग्लॉफ)** के प्रबंधन पर राष्ट्रीय दिशानिर्देश विकसित किए हैं, जिसमें ग्लेशियल जोखिमों के सभी पक्षों का सामना करने के लिए दुनिया में उपलब्ध सर्वोत्तम विधाओं को शामिल किया गया है। मेरे लिए यह हर्ष का विषय है कि एन.डी.एम.ए., स्विस एजेंसी फॉर डेवलपमेंट एण्ड कोऑपरेशन (एस.डी.सी.), स्विट्जरलैंड दूतावास के साथ साझेदारी में यह दिशानिर्देश ला रहा है।

भारत के हिमालयन क्षेत्रों में ग्लेशियल लेक आउटबर्स्ट फ्लड्स (ग्लॉफ) की संभावना अधिक है। मुझे विश्वास है कि राष्ट्रीय दिशानिर्देशों के क्रियान्वयन से यथासमय स्थानीय प्रशासन और समुदाय को प्रारम्भिक चेतावनी देने एवं आपदा जोखिम न्यूनीकरण में हमें सफलता मिलेगी।

मैं एन.डी.एम.ए. को ग्लेशियल लेक आउटबर्स्ट फ्लड्स (ग्लॉफ) के प्रबंधन के बारे में राष्ट्रीय दिशानिर्देश तैयार करने के लिए बधाई देता हूँ और प्राधिकरण को सभी भविष्य के प्रयासों में सफलता की कामना करता हूँ।

शुभकामनाओं सहित !

(अमित शाह)

PREFACE

Mountain regions are characterized by sensitive ecosystems, enhanced occurrences of extreme weather events and natural hazards; they are also regions of conflicting interests between economic development and environmental conservation. With rapid global warming, fragile mountain cryosphere and landscapes are evolving and new threats of landslides, Glacial Lake Outburst Floods (GLOFs), avalanches, cloud burst, drought and flash floods are posing serious risks to the vulnerable mountain communities.

The Indian Himalayan Region (IHR) is facing critical challenges while coping with the adverse effects of climate change. The disappearance of mountain glaciers, expansion of large glacial lakes and the formation of new glacial lakes are amongst the most recognizable impacts of global warming in this environment. IHR lies in Seismic Zones IV and V making the region highly prone to earthquakes. This combined with other disturbances such as avalanches and falling boulders is making the glacial lakes vulnerable to breaches, unleashing sudden, potentially disastrous floods in the nearby communities.

People residing at considerable distances downstream from unstable glacial lakes are facing serious threats to their lives and property. Flash floods and GLOFs have killed thousands in many parts of the world. Some of the largest events have occurred in the Indian Himalayas, such as the Kedarnath disaster in Uttarakhand (2013) and Parechu river flash floods in Himachal Pradesh (2005). Despite these losses, disaster risk management related to GLOFs has not been mainstreamed into development policies and programmes.

In this context, the National Disaster Management Agency (NDMA) has partnered with the Swiss Agency for Development and Cooperation (SDC) along with national experts from concerned Indian institutions for the development of the National Guidelines on Management of Glacial Lake Outburst Floods (GLOFs). These guidelines aim to enable concerned ministries or departments of State/UT, central governments and other stakeholders to take concerted action for preparedness, prevention, mitigation, and response to GLOFs. These Guidelines also emphasize awareness and capacity building of the relevant stakeholders.

For further study, Summary of Guidelines for Policy Makers and a detailed compendium may be referred.

Sh. Kamal Kishore	Sh. Krishna S. Vatsa	Sh. Rajendra Singh	Lt. Gen. Syed Ata Hasnain (Retd.)	Sh. G.V.V. Sarma
Member	Member	Member	Member	Member Secretary

Acknowledgement

Formulation of Guidelines for Management of Glacial Lake Outburst Floods (GLOFs) could be accomplished through constitution of Task Force of inter-disciplinary experts. The Task Force comprised of sub-groups of experts addressing different components for glacial lake disaster risk reduction. Besides members of the Task Force, experts from various National and State Government Departments/ Institutions provided useful inputs towards formulation of this document viz. the Ministry of Environment, Forest and Climate Change (MOEFCC), National Institute of Hydrology, Roorkee, Central Water Commission (CWC), Geological Survey of India (GSI), National Remote Sensing Centre (NRSC), National Institute of Disaster Management (NIDM), Snow and Avalanche Study Establishment (SASE) – DRDO, Defence Terrain Research Laboratory (DTRL) - DRDO, Indian Institute of Remote Sensing (IIRS), National Centre for Polar and Ocean Research (NCPOR), Border Roads Organisation (BRO), Wadia Institute of Himalayan Geology (WIHG), Kashmir University, Indian Institute of Technology (IIT) Bombay, Indian Institute of Technology (IIT) Mandi, G.B. Pant National Institute of Himalayan Environment (NIHE), Nehru Institute of Mountaineering (NIM) and University of Zurich, Switzerland.

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The effortless contribution by Dr. Sanjay K Jain and Dr. A K Lohani Scientist–G, National Institute of Hydrology (NIH), Roorkee is much appreciated in compilation and shaping of the guidelines.

We would like to humbly thank the Government of Switzerland acting through the Swiss Agency for Development and Cooperation (SDC), especially Ms. Divya Kashyap, Senior Thematic Advisor of SDC, for partnering with NDMA and extending support throughout the process of guideline development. These guidelines have especially benefitted from the extensive technical inputs provided by Dr. Simon Allen and Dr. Holger Frey from the University of Zurich, Switzerland. Their engagement, which also brought on-board the international scientific perspective through links to the GAPHAZ working group, was possible through the support extended by the SDC.

Efforts of Mitigation Division especially Dr. Ravinder Singh, Senior Consultant (Landslide & Avalanche), NDMA and Ms. Priyanka, Junior Consultant, are highly acknowledged in bringing comprehensiveness and finalization of these guidelines.

Also, contributions of Ms. Sweksha Gupta and Shri Akshay Rai Bansal, former Junior consultants at NDMA are acknowledged in assisting during the initial stages of guidelines preparation.

It is hoped that the sincere efforts that have been put in bringing this document on the frontline will prove useful to the concerned States/ Union Territories, Departments and other stakeholders in formulating projects and plans that will lead to effective and holistic hazards and risks reduction due to GLOFs and LLOFs in future.

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Abbreviations & Acronyms

APN	Asia-Pacific Network for Global Change Research
ASTER	Advanced Space-borne Thermal Emission and Reflection Radiometer
ATIs	Administrative Training Institutes
BIS	Bureau of Indian Standards
CD	Civil Defence
CBOs	Community Based Organisations
CWC	Central Water Commission
CAPF	Central Armed Paramilitary Forces
CPF	Central Police Force
DEM	Digital Elevation Model
DEOC	District Emergency Operating Centre
DoT	Department of Telecommunication
DPDC	District Planning and Development Council
EMS	Electromagnetic Spectrum
ESCAP	Economic and Social Commission for Asia and the Pacific
ENVI	Environment for Visualizing Images
EOC	Emergency Operations Centre
EOS	Earth Observation System
ETH	Swiss Federal Institute of Technology
EWS	Early Warning System
FCC	False Colour Composite
GAPHAZ	Glacier and Permafrost Hazards in Mountains
GCP	Ground Control Point
GIS	Geographic Information System
GLIMS	Global Land Ice Measurements from Space
GLOF	Glacial Lake Outburst Flood
GoI	Government of India

GoS	Government of Sikkim
GSI	Geological Survey of India
HKH	Hindu Kush Himalaya
IAHS	International Association of Hydrologists
ICIMOD	International Centre for Integrated Mountain Development
IDRN	India Disaster Resource Network
IHR	Indian Himalayan Region
IIRS	Indian Institute of Remote Sensing
IMCT	Inter-Ministerial Central Team
IRMSS	Infrared Multi-spectral Scanner
IRS	Indian Remote Sensing
ITBP	Indo Tibetan Border Police
RS-2	ResourceSat-2
ITC	International Institute for Geo-Information Science & Earth Observation
LLOF	Landslide Lake Outburst Flood
LISS	Linear Imaging and Self Scanning Sensor
MSL	Meter above Sea Level
MoD	Ministry of Defence
MoEFCC	Ministry of Environment, Forest and Climate Change
MSS	Multi Spectral Scanner
NASA	National Aeronautics and Space Administration
NCC	National Cadet Corps
NCPOR	National Centre for Polar and Ocean Research
NDRF	National Disaster Response Force
NGO	Non-Governmental Organisation
NDMA	National Disaster Management Authority
NDSI	Normalized Difference Snow Index
NDWI	Normalized Difference Water Index

NLRTI	National Level Research and Training Institute
NIDM	National Institute of Disaster Management
NIH	National Institute of Hydrology
NIM	National Institute of Mountaineering
NIR	Near Infra-Red
NMSHE	National Mission on Sustainable Himalayan Ecosystem
NRSC	National Remote Sensing Centre
NSS	National Service Scheme
NTRO	National Technical Research Organisation
NYKS	Nehru Yuva Kendra Snagathan
PAN	Panchromatic Mode Sensor System (SPOT)
RAMMS	Rapid Mass Movement Simulation
RMS	Root Mean Square
RS	Remote Sensing
SDMA	State Disaster Management Authority
SEOC	State Emergency Operating Centre
SRSAC	State Remote Sensing Application Centre
SMPDBK	Simplified Dam-Break
SPOT	Satellite Pour l'Observation de la Terre
SoI	Survey of India
SOPs	Standard Operating Procedures
SWIR	Short Wave InfraRed
TCPO	Town and Country Planning Organization
TIR	Thermal Infrared
TIN	Triangular Irregular Network
TM	Thematic Mapper
UAVs	Unmanned Aerial Vehicles

UT	Union Territory
UNESCO	United Nation Education Scientific Cultural Organization
UNDRR	United Nations office for Disaster Risk Reduction
UNISDR	United Nations International Strategy for Disaster Reduction
VCA	Vulnerability Capacity Assessment
VIS	Visible
VNIR	Visible and Near InfraRed
WIHG	Wadia Institute of Himalayan Geology
WWF	World Wildlife Fund

Executive Summary

Glacial retreat due to climate change occurring in most parts of the Hindu Kush Himalaya has given rise to the formation of numerous new glacial lakes, which are the major cause of Glacial Lake Outburst Floods (GLOFs). A GLOF is a type of flood occurring when water dammed by a glacier or a moraine is released suddenly. When glaciers melt, the water in these glacial lakes accumulates behind loose naturally formed 'glacial/moraine dams' made of ice, sand, pebbles and ice residue. Unlike earthen dams, the weak structure of the moraine dam leads to the abrupt failure of moraine dam on top of the glacial lake, which holds large volume of water. A catastrophic failure of the dam can release the water over periods of minutes to days causing extreme downstream flooding. Such outbursts known as GLOF have the potential of releasing millions of cubic metres of water in a short period causing catastrophic flooding downstream. Peak flows as high as 15,000 cubic metre per second have been recorded in such events. As a result, the threat of GLOFs is receiving increased attention and awareness for glacial lake monitoring and hazard mitigation has increased recently.

Since glaciers in the Himalayas are in a retreating phase, glacial lakes are growing and pose a potentially large risk to downstream infrastructure and life. As glaciers retreat, the formation of glacial lakes takes place behind moraine or ice 'dam'. Different types of lakes may have different levels of hazard potential. For instance, moraine-dammed lakes located at the snout of a glacier have a high probability of breaching with high hazard potential whereas erosion lakes have little chance of breaching. These floods pose severe geomorphologic hazards and can wreak havoc on all manmade structures located along their path. Much of the damage caused during GLOF events are associated with large amounts of debris that accompany the floodwaters. GLOF events have resulted in many deaths, as well as the destruction of houses, bridges, forests, and roads. Unrecoverable damage to settlements and farmland can take place at large distances from the outburst source with longer term disturbance to the livelihoods.

The potentially dangerous lakes can be identified based on the condition of lakes, dams, associated mother glaciers, and topographic features around the lakes and glaciers. The criteria used to identify these lakes are based on field observations, processes and records of past events, geomorphologic and geotechnical characteristics of the lake/dam and surroundings, and other physical conditions.

Structure of the Guidelines

In these Guidelines, **Chapter 1** provides a general outline of glaciers and glacial lakes in the IHR including factors contributing to glacial hazards. **Chapter 2** covers the Himalayan geo-environment, topographic and geomorphological set up as well as hydrological setup. **Chapter 3** presents hazards and risk zonation mapping with details of the hazard and risk assessment. Risk reduction and mitigation measures which are an important

part of the report are covered in **Chapter 4**. **Chapter 5** summarises the aspect of awareness and preparedness including community, medical preparedness. Capacity building has been described in brief in **Chapter 6**. Response such as emergency search and rescue, emergency relief, post-disaster damage, and need assessment, etc. have been given in **Chapter 7**. Research and development in the GLOF are described in **Chapter 8**. Regulation and enforcement covering planning, legal regime, and technical audits, etc. have been discussed in **Chapter 9**. Finally, **Chapter 10** enumerates the action plan and implementation of the guidelines.

Except guidelines, other main outcomes and efforts of Task Force are listed as under:-

a.) Comprehensive Mitigation Projects on Glacial Lake Outburst Flood (CMP-GLOF).

b.) Pilot Project on Reducing Glacial Outburst and Flood Risk in Lhonak Lake & Shako-Cho Lake of North District of Sikkim

Chapter 1: The Context

1.1 Glacial Lake Outburst Flood (GLOF) and Landslide Lake Outburst Flood (LLOF) Hazards — An Introduction

The climate changes, which have set in after little Ice Age, have led to regional challenges and local impact on the mountain eco-systems, including increased instances of Glacial Lake Outburst Floods (GLOFs). A GLOF is created when water dammed by a glacier or a moraine is released suddenly. Some of the glacial lakes are unstable and particularly moraine dammed lakes are potentially susceptible to sudden discharge of large volumes of water and debris which causes floods downstream i.e. GLOF (Xu Jianchu et al., 2007). The ongoing climate change is expected to alter and potentially increase the probability of lake outbursts in the future. To meet related disaster management challenges, the present document presents a framework for the management of glacial hazards and risks, especially focusing on risks of glacial lake outburst floods (GLOFs) and also landslide lake outburst floods (LLOFs) in the IHR.

1.2 Factors Contributing Glacial Hazards (GLOF & LLOF)

Factors contributing to the hazards / risks of moraine-dammed glacial lakes include: (a) large lake volume; (b) narrow and high moraine dam; (c) stagnant glacier ice within the dam; and (d) limited freeboard between the lake level and the crest of the moraine ridge. Potential outburst flood triggers include avalanche displacement waves from (i) calving glaciers; (ii) hanging glaciers; (iii) rock falls; (iv) settlement and/or piping within the dam; (v) melting ice-core; and (vi) catastrophic glacial drainage into the lake from sub-glacial or englacial channels or supraglacial lakes.

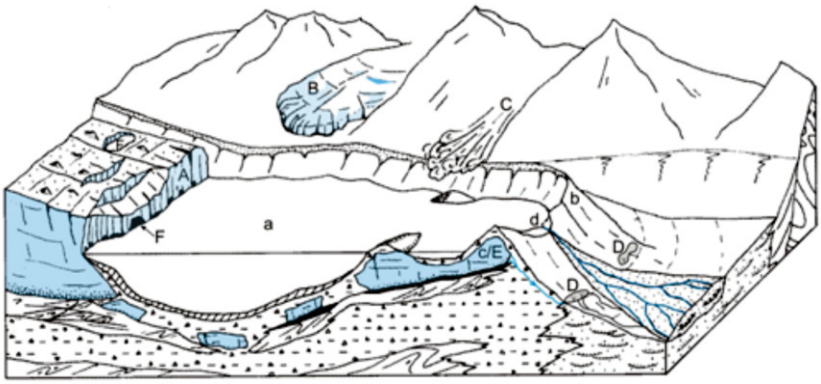

Figure 1.1: Schematic diagram of a hazardous moraine-dammed glacial lake
[**Source:** Richardson, S.D. and J.M. Reynolds (2000)]

Triggering Mechanism

Different triggering mechanisms of GLOF events depend on the nature of the damming materials, the position of the lake, the volume of the water, the nature and position of the associated mother glacier, physical and topographical conditions, and other physical conditions of the surroundings. Interaction between the above-mentioned risk factors and triggering processes like ice avalanches,

debris flows, rockfall, earthquake or landslides reaching a lake strongly affect the risk of a lake outburst.

Moraine dam formation process

End and lateral moraines are created from material pushed and piled from glacier movement till released when a glacier melts and recedes and act as an unstable dam to ice melting from the glacier. End moraines are formed at the farthest limit reached by a glacier. Lateral moraines are formed along the sides of a glacier. Both terminal and lateral moraines may act as dams.

Mechanism of moraine-dammed lake failure

In addition to, earthquakes being one of the causes for moraine dam failure (Clague 2003), the frequency and magnitude of moraine dam failures and GLOFs will continue to increase with the current and continued scenario of global warming (RGSL 2003) and present one of the greatest threats to people and property in mountainous regions. The unstable nature of moraine dams greatly increases the chances of dam failure. Large lake volume above the moraine dam increases pressure against the dam. Large wave caused from calving glaciers or ice or rock avalanches into the lake may overtop the moraine dam. Melting of stagnant glacier ice in the moraine dam may also reduce the freeboard or create passageways for piping to occur. Catastrophic glacial drainage may raise the lake level quickly and overtop the dam (RGSL 2003; Hambrey and Alean 2004).

Initiation of opening within or under the ice dam (glacier) occurs in six ways:

- Floatation of the ice dam (a lake can only be drained sub-glacially if it can lift the damming ice barrier sufficiently for the water to find its way underneath);
- Pressure deformation (plastic yielding of the ice dam due to a hydrostatic pressure difference between the lake water and the adjacent less dense ice of the dam; outward progression of cracks or crevasses under shear stress due to a combination of glacier flow and high hydrostatic pressure);
- Melting of a tunnel through or under the ice;
- Drainage associated with tectonic activity; and
- Water overflowing the ice dam generally along the lower margin.

The bursting mechanism for ice-dammed lakes can be highly complex and involve some or most of the above-stated processes. A landslide adjacent to the lake and subsequent partial abrasion on the ice can cause the draining of ice core-moraine-dammed lakes by overtopping as the water flows over, the glacier retreats, and the lake fills rapidly. A mechanical failure of the ice dam can result in extreme discharge and is the most critical outburst mechanism.

1.3 PRESENT MECHANISM FOR EARLY WARNING SYSTEM

The Early warning system (EWS) is an integral component of risk management for natural disaster. It has been listed as one of the five priorities under Hyogo Framework for Action (HFA) for building disaster resilient nations and communities and is one of the seven global targets of its succeeding document, the Sendai Framework for Disaster Risk Reduction (SFDRR).

The traditional framework of early warning systems is composed of **three phases**: i) monitoring of precursors; ii) forecasting of a probable event; and iii) the notification of a warning or an alert before an event take place (see figure 1.2). Thereafter, the emergency response system becomes active. The purpose is to recognize the fact that there needs to be a response to the warning, where the initial responsibility relies on emergency response agencies. International standards set by the United Nations office for Disaster Risk Reduction (UNDRR) formerly

United Nations International Strategy for Disaster Reduction (UNISDR) encompasses the four key components of EWS. Effective early warning systems require strong technical foundations and good knowledge of the risks. At the same time, they must be embedded in an understandable manner and relevant to the communities which they serve (Villagran de León et al., 2007) with clear messages, dissemination systems that reach those at risk, and practiced and knowledgeable responses by risk managers and the public. A detailed discussion on early warning systems is covered in section 4.6 of these guidelines.

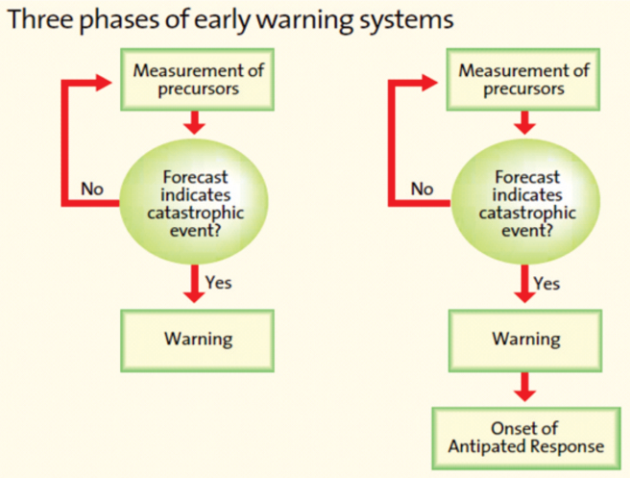

Figure 1.2: Three phase early warning system.

1.4 KEY RISK PARAMETERS

Risks are considered key when there is a high probability that the hazard will occur under circumstances where societies or social-ecological systems exposed are highly susceptible and have limited capacities to cope or adapt and as a result potential consequences are severe. Both the timing of the hazard and the dynamics of vulnerability and exposure contribute to disaster impacts. Risks that materialise in the near term may be evaluated differently than risks that materialise in the distant future, as the time available for building up adaptive capacities is different (Fig. 1.3)

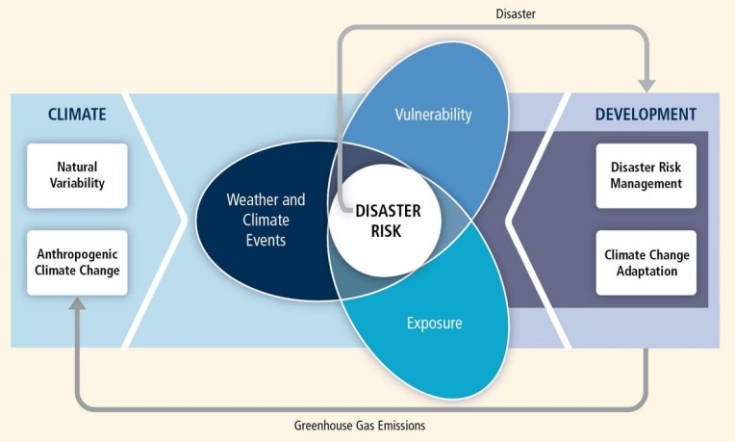

Figure 1.3: Risk Concept of IPCC (IPCC, 2012)

1.5 GLOF MANAGEMENT STRATEGIES

There are several possible methods for mitigating the impacts of GLOFs, for monitoring and for early warning systems (cf. Chapter 4). The most important structural mitigation measure for reducing GLOF risk is to reduce the volume of water in the lake in order to reduce the peak surge discharge. In general, any one or combination of the following methods may be applied for reducing the volume of water in the lake: controlled breaching, construction of an outlet control structure, pumping or siphoning out the water from the lake, and making a tunnel through the moraine barrier or under an ice dam. Careful evaluation with detailed studies of the lake, mother glaciers, damming materials, and the surrounding conditions are essential in choosing an appropriate mitigation measure. Any existing and potential source of a larger snow and ice avalanche, slide, or rock fall around the lake area, which has a direct impact on the lake and dam has to be studied in detail.

Non-structural and organizational mitigation measures can be complementary to structural measures. In particular, in remote and inaccessible regions, non-structural mitigation measures such as NGOs and other social societies in the region often provide more cost-efficient options compared to structural measures.

There should be monitoring systems prior to, during, and after construction of infrastructure and settlements in the downstream area. It will be necessary to build bridges with appropriate flow capacities and spans at elevations higher than those expected under GLOF events.

1.6 NATIONAL DISASTER MANAGEMENT POLICY AND GUIDELINES

As per Disaster Management (DM) Act 2005 and National Disaster Management Policy 2009; NDMA, as the apex body for disaster management headed by the Prime Minister, has the responsibility for laying down policies, plans and guidelines for the disaster management and coordinating their enforcement and implementation for ensuring timely and effective response to disasters in India.

The possibility of GLOF and LLOF in Indian Himalayan Region (IHR) are escalating very rapidly and pose a threat to the lives of millions of people living in this region. Preparation of these guidelines is an utmost need to mitigate the impacts of glacial hazards and risks, to develop disaster resilient communities and significantly reduce the loss of lives and assets. These guidelines will assist the Central Ministries, Departments and States to formulate their respective DM plans and extend necessary cooperation/assistance to NDMA for carrying out its mandate.

1.6.1 Approach to the Guidelines

The main objective of the guidelines is to generate awareness of various aspects of dam failure hazards in India and to implement suitable actions to reduce both the risk and costs associated with these hazards. The Guidelines envision to improve administrative response, bringing together the relevant scientific capabilities of the nation to eliminate the losses from glacial and landslide hazards.

The main aim and objectives of these Guidelines is to develop a strategy that encourages the use of scientific information, maps, methodology, guidance for early warning system, response management, development and implementation of initiatives to reduce losses from glacial hazards. These Guidelines also describes the awareness, preparedness, capacity development, research and development, regulations and enforcements and roles and responsibilities of the local, state and national ministries/ departments along with the various scientific organizations and institutions to reduce the potential risks.

Chapter 2: Himalayan Geo-Environment and Cryosphere

2.1 INTRODUCTION

The Himalayan arc is young and tectonically active, formed as a result of massive collision between Eurasia and the northward-drifting Indian plate about 50 million years ago (Patriat and Achach,1984). It forms the northern limit of India. The Hindukush-Karakoram-Himalaya hosts the largest and most important glacier systems outsides the poles and is commonly referred to as **the third pole** on the earth. The changing climate associated with increased run-off and less infiltration coupled with the removal of forest cover has resulted in the depletion of the hill aquifer system in the region. Variability of monsoon rains and seasonal snow-glacier melt have often led to unpredictable flash floods, rock-falls, debris flows, avalanches, GLOFs, landslides, soil erosion resulting in the loss of human lives and property.

2.2 GEOLOGICAL SETUP

The Himalaya is a classic example of an orogenic system created by continent–continent collision (e.g., Dewey and Bird, 1970; Dewey and Burke, 1973).The Himalayan mountain range is subdivided into four principal tectonic zones, from south to north these are: the Sub-Himalaya (Shiwalik Range), the Lesser Himalaya, the Higher Himalayan Crystalline, complex and the Tethyan Himalaya (Fig. 2.1& 2.2).

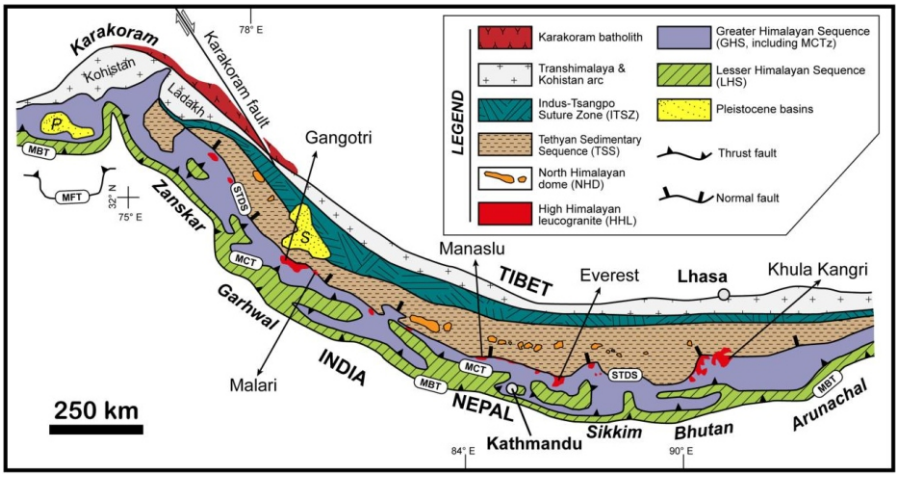

Figure 2.1: Schematic geological map of the Himalayan belt showing the main units and tectonic boundaries (modified after Law et al., 2004 and Weinberg, 2016). MFT: Main Frontal Thrust; MBT: Main Boundary Thrust; MCT: Main Central Thrust; STDS: South Tibetan Detachment System; P: Peshawar basin; S: Sutlej basin. (*Source: Carosi et al., 2018)*

2.3 TOPOGRAPHIC AND GEO-MORPHOLOGICAL SETUP

The most characteristic features of the Himalayas are their soaring height, steep-sided jagged peaks, valley and alpine glaciers, topography deeply cut by erosion, seemingly unfathomable river gorges, complex geologic

structure, and series of elevation zones that display different ecological associations of flora, fauna, and climate. The regional geomorphology of the Himalaya reflects the interaction of mountain building and precipitation setup from the south. The Himalayas appear as a gigantic crescent with the main axis rising above the snow line, where snowfields, alpine glaciers, and avalanches all feed lower-valley glaciers that in turn constitute the sources of most of the Himalayan rivers. The greater part of the Himalayas, however, lies below the snow line. The mountain-building process that created the range is still active. As the bedrock is lifted, considerable stream erosion and gigantic landslides occur.

2.4 HYDROLOGICAL SETUP

The Himalaya is the water tower of the Asian continent, characterized by high precipitation and little evaporation because of lower air temperatures and longer snow coverage, resulting in large contributions of snowmelt and ice melt to the runoff of lowland areas (Viviroli et al., 2007). Himalayan glaciers are drained by 19 major rivers that form the Indus, the Ganges and the Brahmaputra river systems flowing throughout the Himalayan regions, each having a defined catchment area. These rivers rise north of the mountain ranges and flow through deep gorges that generally reflect some structural control, such as a fault line. All the major rivers like the Ganga, Indus, and Brahmaputra originate from the glacierized

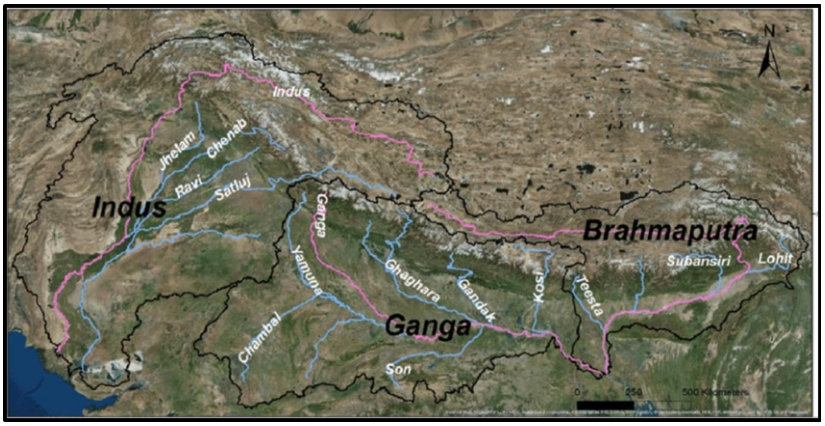

Figure 2.2: Three major river systems emerged from snow/glaciers bound area in the Himalaya.

2.5 CRYOSPHERE SYSTEM

In India 35% of the geographical area is mountainous, of which 58% is covered under the Himalayas. This area covers about 20.3% of India's total geographical area. The Himalaya consist a large area of snow/ice and snow cover after the Polar Regions, hence, studies are largely focused on snow and glaciers due to its visible impact on the environment and resources. The water flowing in the Himalayan Rivers is the combined drainage from rainfall, snowmelt and glacier-melt runoff. In the Himalayan region, several water resources projects are under operation and many more are coming up. These projects are of considerable national and local importance in terms of hydropower generation, irrigation, flood control and subsequent socio-economic development of the region. Proper planning and management of these projects depends on the correct assessment of stream flow generated from snow and glacier melt.

About 10 percent of the Himalaya is covered with glaciers and additional area of nearly 30 to 40 percent supports the snow cover. In total, there are about 9,575 glaciers (37,500 km^2) in the Indian Himalayan Region (IHR), spread across 6 states and union territories i.e.,

Jammu-Kashmir, Ladakh, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh (Raina and Srivastva, 2008). These glaciers form the perennial source for three great rivers: viz, the Indus, the Ganga and the Brahmaputra. The three basins (India and Environs) put together have 71182.08 km^2 of glaciated area with 32392 glaciers. The Indus basin (including Tibet, Karakoram, Great Himalaya) has 16049 glaciers occupying 32246.43 km^2 of glaciated area. The 18 glaciated sub-basins in Indus basin are mapped. The Ganga basin (Including Nepal) has 6237 glaciers occupying 18392.90 km^2 of glaciated area. There are 7 glaciated sub-basins in Ganga basin. The Brahmaputra basin (including Bhutan and south Kailash range in Tibet), has 10106 glaciers occupying 20542.75 km^2 of glaciated area. The 27 glaciated sub-basins in Brahmaputra basin are mapped. Basin wise glacier summary for Indus, Ganga and Brahmaputra basin is provided in table 2.1 and Fig. 2.3.

Table 2.1: Summary of glacier and lake inventory of Indus, Ganga and Brahmaputra basins.

Sr. No.	Basin Characteristics	Indus Area (in km^2)	Ganga Area (in Km^2)	Brahmaputra Area (in Km^2)	Total basin Area of all three (in Km^2)
1	Sub-basins (Nos.)	18	7	27	52
2	Accumulation Area	19265.98	10884.6	12126.35	42276.94
3	Ablation Area Debris	6650.95	4844.7	5264.90	16760.55
4	Ablation Ice Exposed	6310.58	2663.5	3081.48	12055.56
5	Total no. of glaciers	16049	6237	10106	32392
6	Total glaciated area	32246.43	18392.9	20542.7	71182.08
7	No. of Permanent Snow fields and Glaciers	5117	641	3651	9409
8	Area under of Permanent Snow fields and Glaciers	991.68	198.70	1282.9	2474.3
9	No. of Supra-glacier lakes	411	87	474	972
10	Area of Supra-glacier lakes	18.92	15.20	70.0	104.13
11	No. of Moraine dam /Glacial lakes	469	194	226	889
12	Area of Moraine dam /Glacial lakes	33.82	64.10	70.2	168.07

*Source: ISRO, 2010. Snow and Glaciers of the Himalayas: Inventory and Monitoring, Discussion Paper II, Space Application Centre (SAC) Ahmedabad and Ministry of Environment and Forests, New Delhi. (*http://www.moef.nic.in/downloads/public-information/Discussion_Paper%20-%2013th%20June.pdf*)*

The distribution of glaciers in the Himalayas is uneven, with higher concentration of glaciers in the North-Western part as compared to North-Eastern part. Such complexity is due to criss-cross mountain chain, altitude variation and different climatic conditions. Vohra (1996) stated that the glaciers are found in all those areas which attain or exceed the heights necessary for glacier generation. Most of the glaciers are situated on

the main Himalayan range, but other ranges, such as the Pir Panjal, Dhauldhar and Ladakh ranges also support glaciers.

It has been estimated by various researchers that about 17 percent of the Himalaya and 37 percent of the Karakoram are covered by glacier ice. The major clusters of glaciers occur in and around the following ten Himalayan peaks and massifs: Nanga Parbat, the Nanda Devi group, the Dhaulagiri massif, the Everest-Makalu group, the Kanchenjunga, the Kula Kangri area, and Namche Barwa.

The principal glaciers of the Himalaya are Siachen (72 km^2), Gangotri (30 km^2), Zemu (26 km^2), Milam (19 km^2), and Bara Shigri (30.5 km^2).

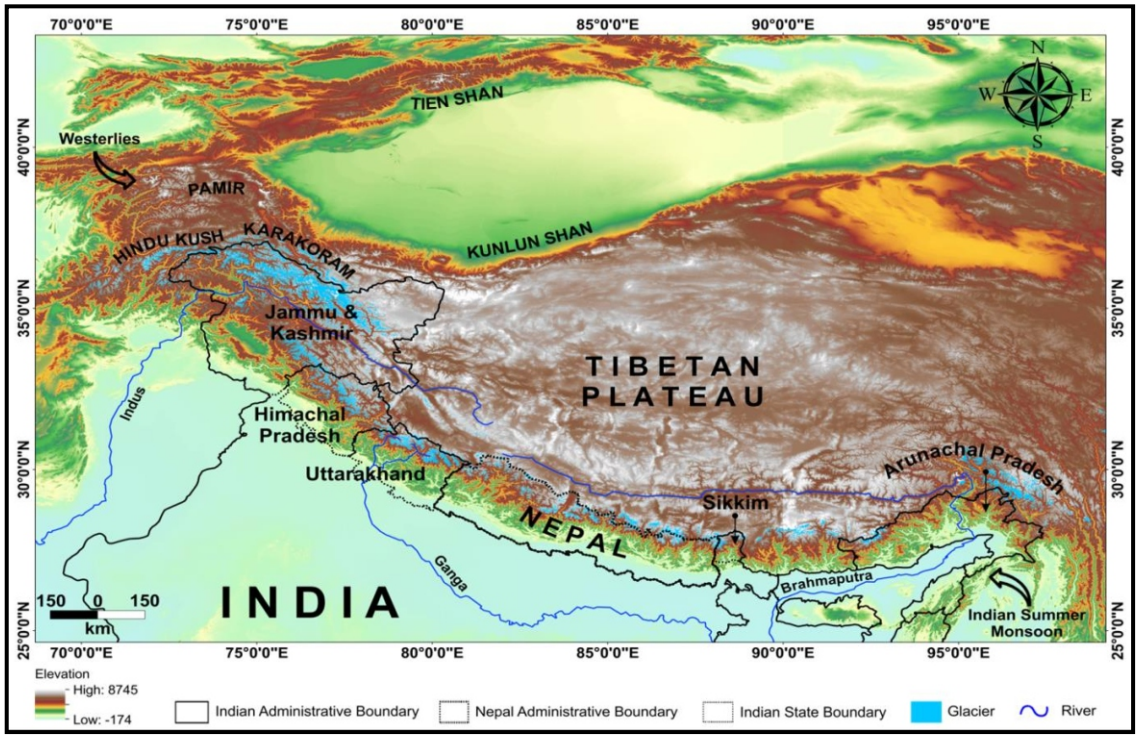

Figure 2.3: Glaciers cover and the major river systems (the Indus, the Ganga and the Brahmaputra) over the Indian Himalayan range.

2.5.1 Permafrost

Permafrost and frozen grounds are key elements of the terrestrial cryosphere that will be strongly affected by a warming climate. Permafrost is defined as sub-surface earth materials that remain continuously at or below the freezing temperature of water for at least two consecutive years (Harriset al., 1988). The permafrost evidences in the IHR was available from Tso Kar lake area way back in 1975-76 from a study conducted by the Geological Survey of India (GSI). Initial modelling assessment on a regional scale suggests that the permafrost area in the Hindu Kush Himalaya (HKH) region could extend up to 1 million km^2, which roughly translate into 14 times the area of glacier cover in the region. The permafrost covered glacial mountains in Sikkim are shown in Fig. 2.4.

Fig.: 2.4 The Permafrost covered glacial mountains in Sikkim (Eastern Himalayas, Indian Himalayan Region)

The monitoring of permafrost and surface conditions is necessary to understand the permafrost distribution in a certain area and includes, i) compilation of information from detailed field soil surveys and mapping; ii) Historical data (maps and literature), photographs and, satellite imageries; iii) spatially explicit thermal modelling of ground temperatures. This information can be used for the design of a monitoring network, and assessment of regional ecosystems.

Permafrost thaw in the high mountain areas, especially in drier climatic zones such as the Upper Indus basin (UIB) could increase the probability of GLOF and LLOF occurrences. Most of the glacial lakes in this region are formed by melting of the ground ice left by the receding glacier and surrounded by ice cored moraine. Identification of shallow permafrost in the glacier elevations of cold-arid region of Ladakh in the Upper Indus basin recently (Schmidt et al., 2016, Wani et al., 2019, Thayyen, 2020) suggests serious implications of possible permafrost thaw on glacial lakes. As warming occurs in the region, the ice core within the moraine that holds the glacial lake water can lose its strength leading to its eventual collapse leading to GLOF. A number of GLOFs are reported from the region but no study has been conducted to assess the causative factors. Furthermore, thawing of permafrost in steep mountain slopes can increase the likelihood of rockfalls and large rock avalanches that can enter a lake and trigger GLOFs.

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CHAPTER 3: HAZARD & RISK ZONATION MAPPING

3.1 INTRODUCTION

The hazard and risk assessment provide the basis for prioritising, designing, and implementing risk management strategies, and is therefore considered as a cornerstone of Disaster Risk Management (DRM). Given the complexity of interacting surface processes and landforms in high mountain environments, integrative, forward-looking and comprehensive system-wide approaches to hazard modelling are required, going beyond traditional modelling of single processes.

This chapter provides guidance on a systematic approach to the assessment of glacial and permafrost-related hazards and risk, and in particular Glacial Lake Outburst Floods (GLOFs), drawing upon latest international best practices (GAPHAZ, 2017). Following an introduction to the overarching hazard and risk assessment framework, the chapter focuses on two levels of assessment, firstly to identify potentially dangerous lakes, and then to undertake detailed hazard and risk assessment for such lakes, and downstream areas.

3.2 HAZARD AND RISK ASSESSMENT FRAMEWORK

The hazard and risk assessment framework follows the concept of climate risk, an integrative concept gaining increasing importance in international climate change policy (IPCC, 2014). Integrating the traditionally diverging perspectives from the disaster risk management and climate adaptation communities, climate risk is conceptualized by IPCC (Figs. 1.3 and 3.1). Figure 3.1 describes the first order risk assessment, to be applied to larger regions (e.g. national or state level) in order to identify hotspots of risk and helps prioritising sites or regions where detailed risk assessments need to be focussed. Based on the detailed risk assessment various risk management options can be effective in reducing underlying vulnerabilities, exposure, or the hazard itself as a physical event (hazard) intercepting with an exposed and vulnerable system (e.g., community, industry, or ecosystem). The assessment framework distinguishes between two primary levels of assessment: 1) First-order assessment at a national or regional scale to provide a preliminary overview of risk hot-spots where further investigation and prioritization can be focused; and 2) the detailed hazard and risk assessment for a specific location or community that then provides the basis for decision-making, design, and implementation of risk management strategies (see section 5).

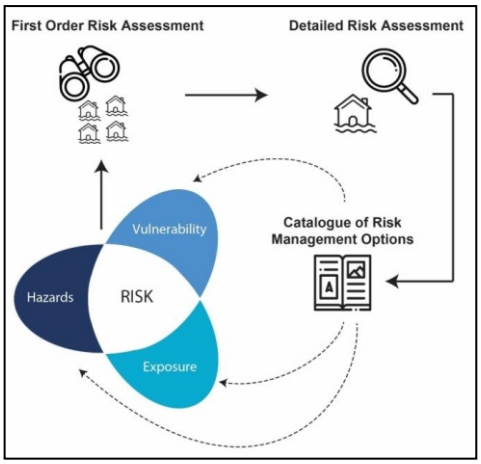

Figure 3.1: Glacial and Permafrost-related Risk Management within the broader Climate Risk framework of IPCC (2014).

3.2.1 Hazard

Hazard in the context of these guidelines refers to the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. The component of the assessment of GLOF builds on from internationally accepted best practices in hazard assessment recently published by the International Association of Cryospheric Sciences and International Permafrost Association (IACS/IPA) Standing Group on Glacier and Permafrost Hazards (GAPHAZ, 2017).

Two core components (or outcomes) of the hazard assessment process include:

1. *Susceptibility and stability assessment*: Identifying where from and how likely hazard processes are to initiate, based on an assessment of wide-ranging triggering and conditioning factors
2. *Hazard mapping:* Identifying the potential threat from the hazard for downslope and downstream areas, and providing the scientific basis for decision making and planning.

Typically, hazard is then quantified and communicated in the form of classified hazard maps, defined on the basis of the probability (or likelihood) that an event will occur and the expected intensity (or magnitude) of the given event.

3.2.2 Exposure

For glacial and permafrost related risks, exposure is typically assessed based on an inventory of anthropogenic elements that could be adversely affected by hazard (villages, habitations, roads, bridges, critical lifelines, hydropower stations, heritage sites, sacred places, schools, hospitals, military infrastructure etc.) located within the runout path of potential flood and mass movement events.

3.2.3 Vulnerability

Vulnerability is highly context specific, and can vary significantly as physical vulnerability (housing-infrastructure), social vulnerability (age, gender, education, etc.) and economic vulnerability.

3.3 DISASTER CATALOGUING AND LAKE INVENTORIES

Cataloguing of past GLOFs or other disasters is to be distinguished from a glacial lake inventory that literally maps all glacial lakes in a given region.

The cataloguing of past catastrophic mass movements is a fundamental pre-requisite for the assessment of hazards and risks. Through investigation of the distribution, type, and pattern of past hazard events, understanding of triggering and conditioning processes can be improved. When physical access or remotely sensed imagery allows detailed investigation of an outburst event, main physical parameters to be considered are:

- Lake name
- coordinates (longitude, latitude, altitude)
- location (mountain range, valley)
- lake type (supra-, pro-, peri-, sub-glacial, etc.)
- lake size (pre- and post- event)
- dam type (bedrock-dammed, moraine-dammed, ice-dammed, combined dam, landslide dammed)
- permafrost conditions (ice-cored moraine, rock glaciers, surrounding rock slopes)

- best estimate of date of lake formation (particularly for landslide-dammed lakes)
- date of outburst event
- probable trigger
- outburst mechanism(s)
- flood volume
- peak discharge at lake site
- downstream reach - the water levels and discharges along the reach at certain intervals
- flow type/sediment load
- downstream impacts

Key considerations for a glacial lake inventory concern the definition of what will be included as glacial lake, and the temporal and spatial scale at which the inventory will be undertaken. On these aspects the following factors may be considered:

- Lakes that remain in direct contact with a glacier
- Lakes which are formed within and/or dammed by glacial ice or debris (moraine)
- Lakes that are in contact with, or formed within creeping permafrost features.
- Bedrock dammed lakes occupying glaciated or former glaciated cirques.
- Other lakes that are in close proximity, and therefore directly threatened by unstable glaciers or permafrost zones.
- Have a minimum size of 1 hectare (0.01 km^2)
- Mapping all lakes within the catchment area of the district or state under consideration, including the ones whose catchment areas may extend beyond administrative boundaries.
- Undertake mapping in the post-monsoon window, when lakes will be at their largest, and conditions are most favorable for remote-sensing based analyses.

3.4 FIRST-ORDER HAZARD AND RISK ASSESSMENT

First order hazard and/or risk assessments are typically implemented at large-scale (e.g., National to State level), in order to establish an overview of potential risk hotspots and as a basis for prioritising further actions. Such assessments can extend across administrative boundaries, to consider far-reaching trans-boundary hazards and risks. For GLOFs, the starting point for any assessment is establishing a comprehensive and up-to-date lake inventory for the region of interest (Section 3.3), including existing information from studies that have assessed hazard and/or risk associated with the mapped lakes.

3.4.1 Large-Scale Assessment Methods

Large-scale assessment methods include a range of approaches that provide a first indication of the extent and threat of hazard and risk, but where hazard intensities and impacts are not physically modelled and field studies not undertaken.

At large scales, key factors that are considered in a remote-sensing based assessment of lake stability in the Himalayan context typically include as a minimum:

- The potential for ice and rock avalanche triggering of an outburst event (including the role of glacial de-buttressing and permafrost degradation)
- Climatological conditions (rainfall, snowfall, temperature)
- Lake area (as a proxy for lake volume)
- Lake watershed characteristics (e.g., favoring rainfall and snowmelt into the lake)
- Dam type (ice, rock, or debris)
- Steepness of the downstream slope of the dam

While other factors sometimes considered, depending on the availability of data and scale of the assessment include:

- Dam freeboard
- Dam width to height ratio
- Permafrost conditions – presence of an ice cored moraine

Note that a full explanation of the various predisposing and triggering factors that would be considered in a more detailed local assessment are outlined (see Section 3.5).

Available large-scale data for some or all states of the IHR that can be used to characterise exposure to GLOFs and other hazards includes:

- Population (population density grids or census data)
- Village locations (as points or outlines)
- Transport infrastructure, including strategically important roads
- Agricultural land area
- Forest areas
- Wetland areas
- Cultural heritage sites
- Tourism sites and hotels
- Hydropower stations.

Table 3.1: Indicators used in the flood vulnerability assessment for Himachal Pradesh, India. The main components of vulnerability represented by each indicator are listed, and the dependency of the relationship with vulnerability is given (after Allen et al., 2016).

S. No.	Indicator	Components represented	Dependency[1]
1.	Female population	sensitivity, capacity to prepare, respond and recover	+
2.	Population <6 years of age	sensitivity, capacity to prepare, respond and recover	+
3.	Population >60 years of age	sensitivity, capacity to prepare, respond and recover	+
4.	Literacy rate	capacity to prepare, respond and recover	-
5.	Unemployment	capacity to prepare, respond and recover	+
6.	Employment in farming	sensitivity, capacity to recover	+
7.	Disabled population	sensitivity, capacity to prepare, respond and recover	+
8.	Home renters	capacity to recover	+
9.	Derelict houses	sensitivity, capacity to respond and recover	+
10.	Water availability	capacity to prepare and respond	-
11.	Medical facilities	capacity to prepare and respond	-
12.	Education facilities	capacity to prepare, respond and recover	-
13.	Banking services	capacity to prepare and recover	-
14.	Access to radio	capacity to prepare and respond	-
15.	Access to TV	capacity to prepare and respond	-
16.	Access to internet	capacity to prepare and respond	-
17.	Access to mobile	capacity to prepare and respond	-
18.	Access to vehicle	capacity to prepare, respond and recover	-

(1) A positive (+) dependency means that an increase in the measured variable indicates an increase in vulnerability. A negative (-) dependency means that an increase in the measured variable indicates a decrease in vulnerability.

3.4.2 Potentially critical Lakes in the IHR

To identify potentially dangerous lakes, one should ideally draw upon multiple sources of information, combining large-scale first order assessment results (including trans-boundary threats), with knowledge available from previous state level investigations and studies. Such an approach is favoured because it emphasises those lakes that have been identified as critical in one or more studies, and therefore provides the most robust basis for prioritising where further local investigations, and potentially risk reduction strategies should be targeted. Importantly, the selection criteria should be based on mutually agreed and scientifically accepted criteria. A first-order assessment and listing of potentially dangerous lakes in support of this guidance document has been provided in Annex 1. It must be stressed however, that such listings of potentially dangerous lakes are merely a static snapshot, and first order hazard and risk assessments should be updated at regular intervals to keep pace with rapidly changing environmental and social landscapes.

Index-based approaches can be used by combining standardised indices (see Annex 1) for hazard, exposure, and vulnerability. Indices have the advantage that they remain objective, whereas decision-trees require a higher level of expert judgement.

Typically, first-order approaches focus on the threat to people and property, however, sector-based assessments are also recommended, as lakes that may pose a critical threat to one sector, e.g., the farming or transportation sector, may be different from those lakes that threaten populated areas, or another sector. General conclusions from the first order assessment and synthesis provided in Annex 1 include (see also Figures 3.2 and 3.3):

- Major roads and bridges across all states are threatened by potentially dangerous lakes.
- The threat to cropland is greatest in the union territory of Jammu and Kashmir & Leh-Ladakh, Sikkim, and Arunachal Pradesh.
- The threat to hydropower is the highest in Sikkim.
- GLOF risk to the population is the highest in Sikkim and Jammu and Kashmir, but a danger exists across all Himalayan states (note this does not consider seasonal variations in population as related to, e.g., tourism).

Annex -1: *Synthesis Report on current GLOF hazard and risk across IHR by University of Zurich. Available at: https://eclim-research.ch/synthesis-report-on-current-glof-hazard-and-risk-across-ihr-5/*

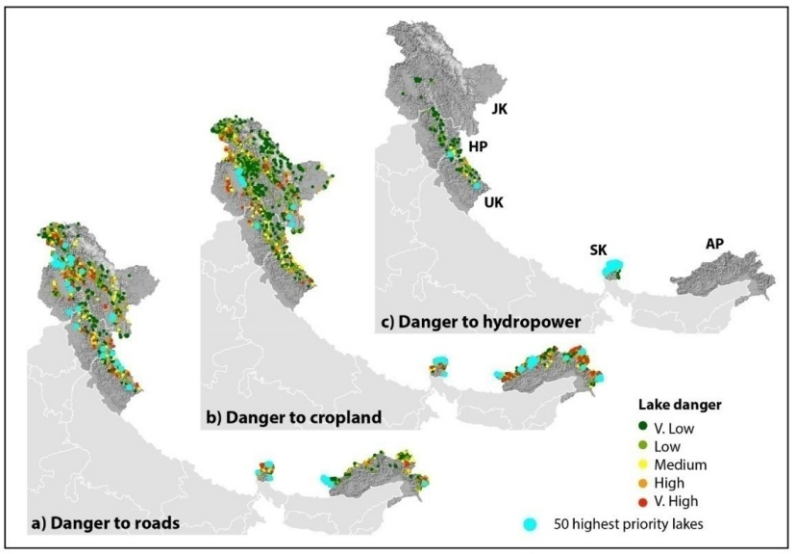

Figure 3.2: Lake danger levels assessed with a large-scale first-order approach, considering exposure of roads, crop land, and hydro-power stations.
(For full results & final listing based on comparison with other studies see Annex 1)

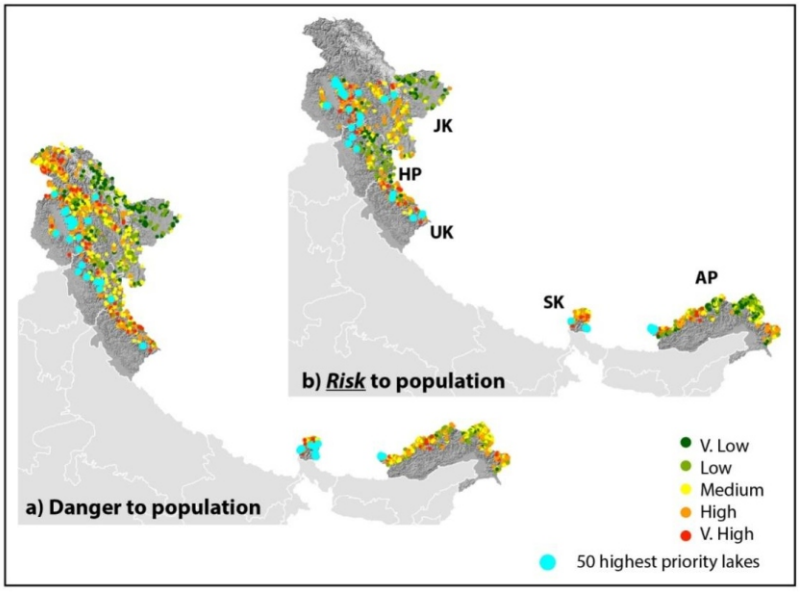

Figure 3.3 : Lake danger and risk levels assessed with a large-scale first-order approach. Danger considers lake hazard levels and population density. Lake risk includes social vulnerability (from IHCAP 2019)**, which as not available for all of J&K.**
(For full results & final listing based on comparison with other studies, see Annex 1)

Annex -1: *Synthesis Report on current GLOF hazard and risk across IHR by University of Zurich. Available at: https://eclim-research.ch/synthesis-report-on-current-glof-hazard-and-risk-across-ihr-5/*

3.5 DETAILED HAZARD AND RISK ASSESSMENT

Where critical situations are identified (e.g., where the large-scale assessment has revealed hotspots of risk), detailed hazard and risk assessments should be undertaken, combining sophisticated hazard modelling and mapping with on-ground assessment of vulnerability and exposure to generate local risk maps. A detailed risk assessment aligns to section 5.1.2 of the 2009 National Policy on Disaster Management, and institutional responsibilities for undertaking GLOF hazard and risk mapping are outlined under section 7.11.1 of the 2019 National Disaster Management Plan (NDMP). A prominent example of this level of assessment is at South Lhonak glacier lake in Sikkim, where major work was carried out by Geological Survey of India (GSI) and Defence Research & Development Organization (DRDO), including remote sensing and field observations to assess geotechnical and geomorphic factors.

3.5.1 Assessing susceptibility/stability

Wide-ranging atmospheric, cryospheric, and geotechnical factors can condition and trigger GLOFs and other glacial or permafrost-related hazards (see Appendices 1-3). The relevance of certain factors for susceptibility or stability will vary from one region to another, and expert judgement is needed to determine whether or not more emphasis (weight) should be applied to some factors. For example, in monsoon affected parts of the IHR, more emphasis might be given to the role of heavy precipitation in triggering GLOF events, while in drier permafrost-rich zones, degradation of buried ice in the moraine dam could be the most critical factor. Conditioning and triggering factors inform not only about the location and likelihood of an event, but also provide insights on the possible magnitude of the event. Appendix – 3 outlines the main factors to be considered, corresponding methodological approaches and assessment scale to be applied to assess the susceptibility and stability of a glacial lake.

3.5.2 Hazard mapping and zonation

Hazard mapping and zonation typically draws upon historical records to establish frequency – magnitude relationships that can then be used as a basis for scenario development and hazard modelling, e.g., hazard mapping for a given river floodplain might be conducted for flood event with an established peak discharge, which may vary from catchment to catchment depending upon the frequency-magnitude relationship. For hazards such as GLOFs that originate in high mountain environments, the ability to establish a reliable frequency – magnitude relationship is limited by three factors:

- Hazards originate often in remote, inaccessible locations, meaning even large events may have passed unnoticed and dates of previous events are missing or highly uncertain for the historical record.
- The cryosphere is changing rapidly and, in some cases, conditions are already beyond any historical precedence, meaning frequency – magnitude relationships are of decreasing significance.
- Many events can occur only once (e.g. complete incision of a moraine dam), and hence, frequency – magnitude relationships may not apply at all.

Given these limitations, a semi-qualitative approach to scenario development is

different magnitudes (small, medium, and large) are linked to corresponding best estimates of the likely probability of occurrence (e.g., low, medium, high). The fundamental basis for the scenario development is the information gathered during the susceptibility and stability assessment, augmented where possible with the best understanding of past events occurring in the region or other areas (Figure 3.4).

3.5.2.1 Scenario development

The goal is to establish three feasible scenarios based on the underlying lakes susceptibility assessment, where the potential mass or volume initiated in a small, medium, or large event is estimated, and a corresponding best estimate of the probability of such an event occurring is assigned.

For GLOFs, the following general approaches for scenario development are foreseen:

- Probabilities are specifically assigned based on careful consideration of the underlying lake susceptibility and stability assessment. All probability – magnitude combinations are possible.
- A simple inverse frequency-magnitude relationship is applied, with the large scenario assigned the lowest probability outburst event, and the small scenario as the highest probability outburst event.

Where there is an insufficient basis or reasoning to distinguish probabilities it may be feasible to maintain the same probability level across all 3 scenarios, i.e., all three outburst scenarios are considered equally likely.

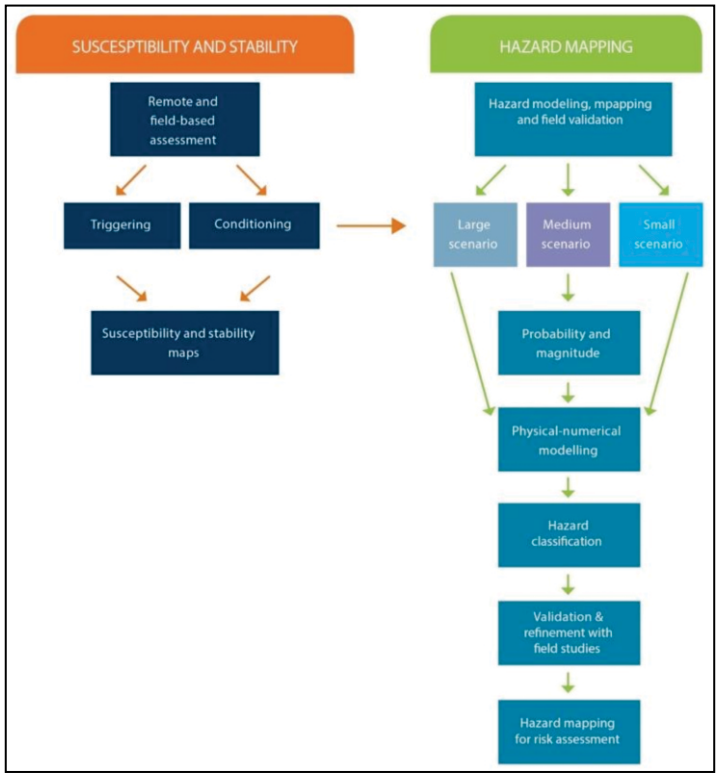

Figure 3.4: Framework for the assessment and mapping of glacial and permafrost-related hazards using a scenario-based approach (GAPHAZ 2017).

Scenarios for GLOFs are complex, owing to the various trigger mechanisms, lake types, and dam compositions. For bedrock-dammed lakes, where the only likely outburst mechanism is a mass movement triggered impact wave, a first approximation of the likely displaced water volume will be equal to the potential incoming mass. In this case, the associated probabilities will be linked to the ice and bedrock stability assessment for the surrounding slopes (see Appendices 1 and 2). For moraine-dammed lakes, the large scenario will involve complete incision of the dam and removal of the downstream slope of the dam, with steep, narrow dams most susceptible to irreversible erosion. Where the breach depth is greater than the mean depth of the lake, full release of the lake volume is possible. Due to the self-enhancing nature of dam incision, a large scenario may be considered equally probable as a small scenario for critical dam structures. For more favorable dam geometries, a reduction in outflow and cessation of erosion can occur well before the full lake volume has been emptied, making smaller scenarios more probable for impact-triggered events, and also events triggered by seepage and piping.

3.5.2.2 Hazard modelling and mapping

To link the results of scenario modelling with a corresponding hazard level, a matrix-based approach to hazard classification is typically used, for instance employed within the Swiss codes of practice. For each scenario, the 3-by-3 matrix links the modelled flood or mass movement intensities with the assigned probability level for that scenario, to establish a danger or hazard level (Figure 3.5 and 3.6). Multiple scenarios (e.g., small, medium, large scenarios) can then be overlaid and fine-tuned through field mapping to arrive at a final hazard map. This common framework can be applied for various processes occurring in glacial environments (GLOFs/debris flows, landslides, avalanches, etc.).

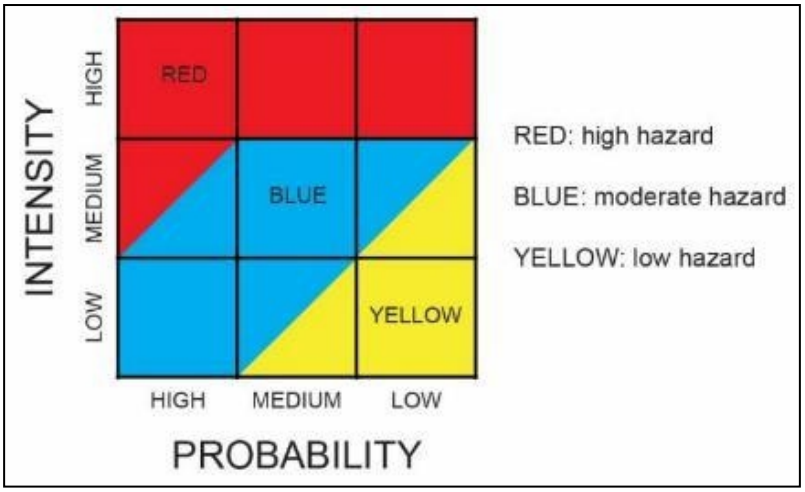

Figure 3.5: Matrix based approach for linking the susceptibility assessment (probability) with the scenario-based intensity modelling to arrive at a hazard classification.
(Colors are usually subject to nationally defined standards)

According to the Swiss practice, qualitative intensity relates to potential damage the event could cause to people and property (if they were present).

High intensity: people and animals would face the threat of injury inside buildings; heavy damage to buildings or even destruction of buildings would be possible.

Medium intensity: people and animals would face the threat of injury outside buildings, but would face low threat levels inside buildings; lighter damage to buildings should be expected.

Low intensity: people and animals would be slightly threatened, even outside buildings (except in the case of stone and block avalanches, which could harm or kill people and animals); superficial damage to buildings could be expected.

Note that for some processes not all three intensity classes are valid, e.g., in the impact zone of a rock avalanche the intensity is always considered *high*. Likewise, for debris flows, *low* intensities are not considered, according to the Swiss practice.

Table 3.2: Indicative values for the intensity classification for various high mountain hazards as used in Swiss practice *(after, Hürlimann et al., 2006; Raetzo et al., 2002)*.

Kinetic energy (E); Velocity (v); flow depth or height of the deposit (h).

Phenomena	Low intensity	Medium intensity	High intensity
Rockfall	E < 30 kJ	30 < E < 300 kJ	E > 300 kJ
Rock avalanche			E > 300 kJ
Landslide	v ≤ 2cm/year	v:dm/year (>2cm/year)	v > 0.1 m/day for shallow landslides; displacement > 1m per event
GLOF/ Debris flow (single parameter)		h < 1 m	h > 1 m
GLOF/ Debris flow (multiple parameter)		h < 1 m or v < 1m/s	h > 1 m and v > 1m/s

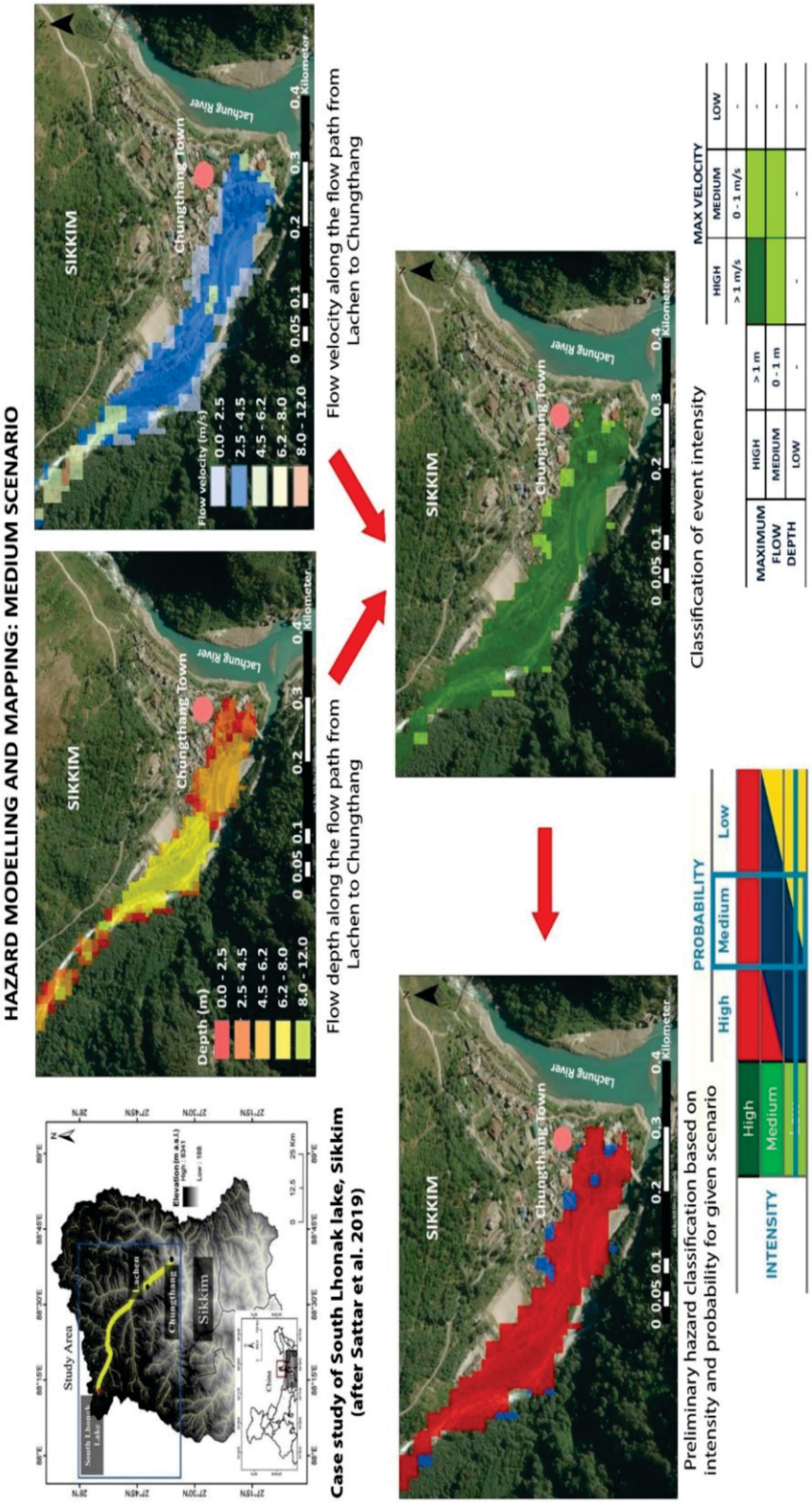

Figure 3.6: Illustrative example of GLOF hazard modelling and mapping for South Lhonak Lake, Sikkim (based on Sattar et al. 2019).

3.5.3 Risk Assessment

In order to advance from a hazard assessment to a risk assessment, results from the hazard mapping need to be combined with information on exposure (of people, assets, infrastructure and ecosystems), with information on the vulnerability.

3.5.3.1 Exposure

The most challenging aspect is to quantify the exposure of livelihoods, environmental services, and also to determine temporal dimensions of exposure. In high tourism areas, for example, many buildings located in a flood path may be unoccupied for much of the year, and in agricultural areas, families may migrate up or down the valley to different land holdings depending on the season.

3.5.3.2 Vulnerability

Community-level surveys and focus group meetings could bring together community leaders, farmer organizations, self-help groups, and other grass-roots organizations to explore local drivers of vulnerability, and undertake a qualitative Vulnerability Capacity Assessment (VCA). In particular, we highlight the importance of ensuring good representation of marginalized and disadvantaged groups in such participatory studies, including nomadic/seasonal populations, women, children, and people with disabilities. The 2009 National Policy on Disaster Management also underlines the importance of including these groups when undertaking a comprehensive assessment of vulnerability.

Important components that can be included in a VCA include: (a.) Historical timeline, (b.) Seasonal calendar, (c.) Patterns of vulnerability, (d.) Stakeholder mapping, and (e.) Coping mechanisms.

The results of participatory VCA's can be used to validate and refine large scale indicator-based assessments (see section 3.4.1), ensuring that the selected indicators adequately capture the perceived drivers and patterns of vulnerability in a community. Participatory VCA's are best led by institutions and agencies that have long-standing experience and established relationships within the communities.

3.5.3.2 Integrated Risk Mapping

Final risk maps can then be created by combining hazard mapping/zones, with vulnerability and exposure maps. Figure 3.7 provides an illustrative example of a GLOF risk assessment undertaken for the state of Himachal Pradesh, where standardised indices were multiplied to establish GLOF risk at the administration unit of a Tehsil.

As seen with the example of a local debris flow/flood risk assessment in Colombia, South America (Figure 3.8), risk assessment at this scale provides information on risk levels for specific dwellings and properties, providing a robust basis for the implementation of risk reduction strategies that aim to address those most affected by a potential event.

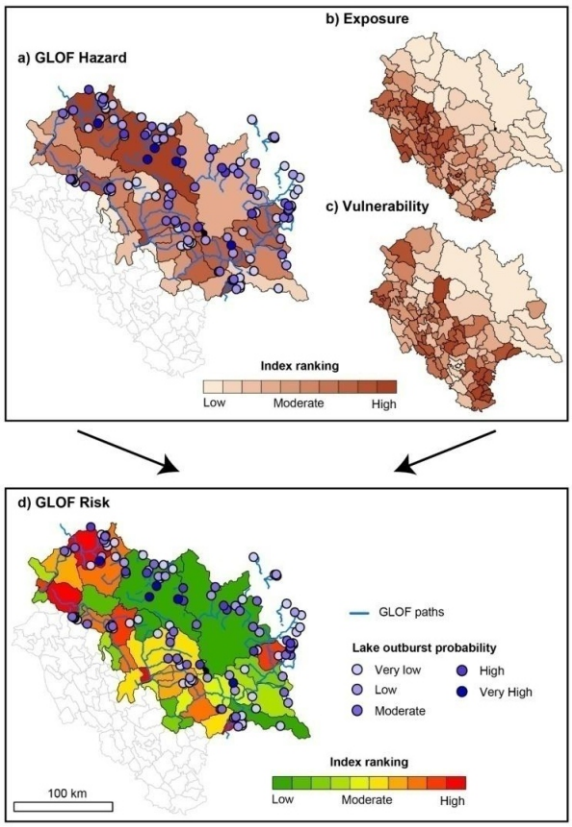

Figure 3.7: Large-scale GIS based assessment of GLOF risk, integrating mapped indices of GLOF hazard, exposure and vulnerability *(Source: Allen et al., 2016)*.

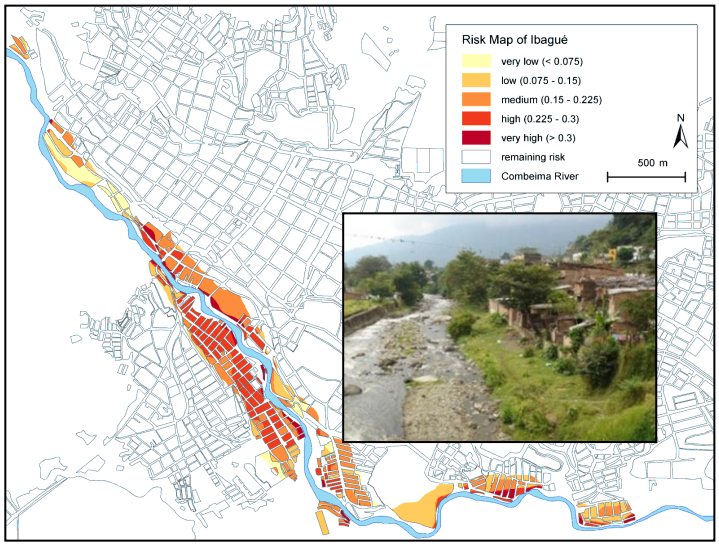

Figure 3.8: Flood and Lahar risk map for the Colombian city of Ibague, combining information on hazard, exposure and vulnerability *(Source: Künzler et al., 2012)*.

Chapter 4: Monitoring, Risk Reduction & Mitigation Measures

4.1 INTRODUCTION

A prerequisite for successful, effective and sustainable risk management and risk reduction is a comprehensive and detailed site-specific risk assessment (cf. Chapter 3). Only the information provided by such an assessment allows the relevant authorities to take informed decisions on the most suitable measure or measures for effective and sustainable reduction of risks in a given situation. For the identification of suitable risk management options, thus, a comprehensive, multi-risk approach should be followed. This is also important in order to avoid any unintended negative effects.

The involvement of the local stake holders in the planning of risk reduction measures is essential to guarantee an effective risk reduction strategy that is also supported by the local population. Ownership of risk reduction measures by the local population furthermore is important in view of maintenance and sustainability.

Risk reduction and mitigation measures may incur huge costs and may not be feasible to implement, therefore Central/State Governments should apply a cost-benefit analysis and focus on implementing the strategy part that covers up for the major percent of the risk.

4.2 CASE STUDIES IN THE HIMALAYAN REGION

India has a remarkable history of successful warnings in relation to LLOFs, dating back to the 19th century. In 1894, a landslide in Gohna, Uttarakhand (UK), dammed the main river. On 5 July that year, the engineer in charge estimated the lake to overflow the dam in mid-August, which eventually happened. Despite the devastating impact of the flood, including washing away most of the buildings along the river and severe destruction in the town of Srinagar, no victims were reported, thanks to the precise prediction of the event and related efficient dissemination of the early warning to the population (Nature, 1894). This was made possible by the installation of a telephone line between the lake and the towns of Chamoli, Srinagar, etc., located downstream (Dimri, 2013). This can be considered as the first Early Warning System (EWS) for lake outburst floods in the Himalayas.

One of the most promising options for efficient and effective disaster risk management, is the implementation of EWS. The number of implemented and operational GLOF EWS is still very small, even at the global scale. In the Himalayan region, three cases are reported, where sensor and monitoring based technical systems for GLOF early warning have been implemented (Table 4.1). In two of the three cases, at Tsho Rolpa and Imja Lake, these EWS were complemented by structural measures for lake level lowering.

Table 4.1: Selected Cases of GLOF EWS implementations in the Himalayan region.

Lake	Region	Year	Reference
Tsho Rolpa	Rolwaling Valley, Nepal	1998	Rana et al. (2000)
Imja Lake	Everest region, Nepal	2008	Fukui et al. (2008)
Kyagar glacial lake	Shaksgam Valley, PR China	2013	Haemmig et al. (2014)

However, today none of these systems is operational, mainly due to a lack of identification and ownership by the local population (c.f. Watanabe et al., 2016, for the Imja case). This emphasizes the importance of the involvement of the local population for a successful and sustainable implementation of EWS. Another example for a GLOF EWS from the Peruvian Andes is described in more detail below (Section 5.5.5)

4.2.1 The Operation Phuktal (2015)

In cases where the dammed obstruction needs to be removed like river blockage due to landslide, explosives are sometimes used to clear the way for effective drainage. One such landslide occurred along the Phuktal River (tributary to Zanskar River) on December 31, 2014 about 90 km from Padum in Kargil district of Ladakh, which led to blockage of the river and eventually led to a potential flood situation on May 7, 2015 (Fig. 4.1).

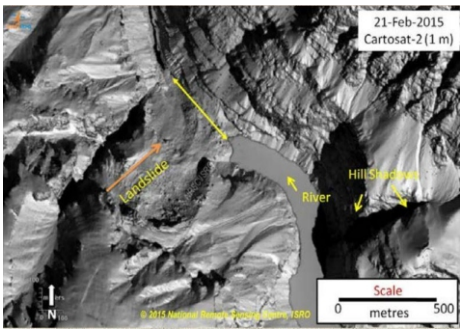

Figure 4.1: Blockage of Phuktal River due to landslide as can be seen from the image obtained through CARTOSAT- 2 *(Source: NRSC).*

It posed a major threat to life, property and infrastructure especially the Nimmo Bazgo dam.The NDMA created an Expert Task Force from various organisations. The Task force along with the Indian Army devised explosives for channelization of water from landslide dammed river through control blasting and manual excavation by clearing out the landslide debris (Fig. 4.2).

Figure 4.2: Indian Army installing a safety rope from camp base to the landslide location.

4.3 RISK REDUCTION TECHNIQUES AND MODELS

Risk reduction can be effective on each of the three components of risk (hazard, exposure, vulnerability). The selection of an adequate action depends on the urgency of the situation, the available resources as well as the specific characteristics of the site. In many cases, a combination of different measures will result in a more robust and effective reduction of disaster risk. A detailed hazard and risk assessment, according to the procedure described (Section 3.5), provides the information for a decision on (a) robust risk management option(s). Figure 4.3 gives an overview of such actions, which are further described below.

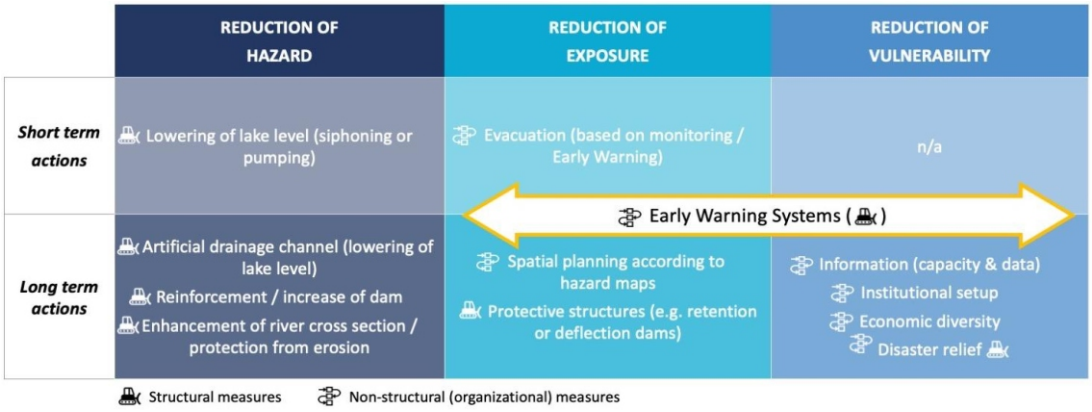

Figure 4.3: Overview of options for the risk management of glacial lakes.

These options can be discriminated by the risk element the actions are effective on (i.e. reduction of hazard, reduction of exposure or reduction of vulnerability). Also, these options can be distinguished into structural and non-structural (i.e. organizational). Structural measures (c.f. digger symbols in Figure 4.3) typically involve the construction of remediation structures, either at the lake itself, or at the settlements or infrastructure potentially affected. Such structural measures have the potential to be very effective for risk reduction, in particular when achieving a substantial reduction of the hazard. However, such actions are expensive, especially when implemented in remote regions, such as the IHR. Limited access for heavy machinery can be an impeding factor for such actions. Organizational, non-structural measures, on the other hand, in many cases can be cheaper and faster to implement. As they often aim at a reduction of exposure and/or vulnerability, they can be effective not only for GLOF and LLOF related risks, but for the reduction of multiple risks.

4.4 MANAGEMENT OPTIONS FOR GLOF & LLOF INDUCED HAZARDS AND RISKS

4.4.1 Hazard Reduction Options (Artificial Drainage System i.e., Siphoning Techniques, Control Blasting, etc.)

Actions aiming at a reduction of the hazard typically involve structural measures at the glacial lake itself and thus aiming at a reduction of the outburst susceptibility or a reduction of the magnitude of a potential event. Such measures have parallels with structural measures for floods outlined in the Section 3.3.3 of the National Disaster Management Plan (NDMA 2019), focussing on enhancing the safety of reservoirs and construction of embankments and levees.

Lowering the lake level directly influences the hazard potential of a lake, as it reduces the volume of the lake (and thus the potential flood volume and peak discharge) on the one hand, and on the other hand increases the freeboard of the dam, which is another

important factor of the lake outburst susceptibility. In the short-term and in emergency situations, the level of a lake can be lowered by siphoning or pumping. The effectiveness of such efforts depends on the characteristics of the site, as well as on the access to the lake, the availability of equipment for siphoning and/or pumping and the experience of the personnel involved in such actions. Grabs and Hanisch (1993) present experiences from the Himalayas, where lake level were lowered by about 5m.

At moraine dammed and landslide dammed lakes with a low freeboard and thus in a critical situation, highly susceptible for an outburst, it is in some cases possible to lower the lake level by lowering artificially the outlet point. However, such an action is extremely risky, as it might initiate the formation of a breach, by starting a self-reinforcing process of increased discharge and increased erosion, eventually causing a GLOF or LLOF. Such measures should only be undertaken with the utmost care, and have to be accompanied by measures to prevent erosion in the artificially created outlet channel.

Figure 4.4: Artificial Channel Enlargement of Imja Lake, Nepal, 26 September 2016 *(Source: UNDP). (Artificial channel enlargement for lake level lowering is a very critical moment, as it can lead to the formation of a breach and a GLOF/LLOF)*

Culverts and open spillways are introduced in the moraine crests generally at the lowest point to keep excavation volumes to a minimum. The construction is usually carried away in a cofferdam as to isolate the site from the lake. Culverts are generally reinforced with concrete or are made up of cast sheet metal. Geo-textile liners may also be used to line channels and protect the floor from erosion. Spillways are generally left open, but it is recommended to install gateways which can control downstream erosion during the initial phase of draw down e.g. Tsho Rolpa, Nepal (Rana et. al., 2000). Strong implementation and safety measures are required when dealing with critical lakes.

Reinforcing and/or increasing the dam is a suitable option for the hazard reduction of lakes dammed by moraine and other unconsolidated material. Raising the dam crest increases the dam freeboard and decreases the potential for overtopping of a large volume of water in case of a large displacement wave in the lake. Reinforcing the dam with a stone facade provides protection against erosion and the initiation of a breach formation.

Such measures have been successfully applied to more than 35 lakes in the Cordillera Blanca, Peru over the past seven decades. Portocarreo (2014) gives an overview of the typical steps involved in such works.

1. Establish logistical access to the site.
2. Lowering of lake level by pumping or siphoning. Successful applications of siphoning have been made at lakes at altitudes up to 4,500 m a.s.l. (Reynolds GS Ltd, 2003). Applications at higher lakes remain to be tested.
3. Permanent reduction of lake level
   a. For moraine dammed lakes:
      i. Cutting the downstream face of the moraine into a V shape
      ii. Installing a reinforced concrete pipe* of appropriate diameter
      iii. Building an earth dam with a stone facade over the pipes, restoring much of the original V- shaped cut in the moraine (protection against the hydrodynamic effects of big waves). Cf. Fig. 4.5, left)
      iv. Open cuts* are also an option (Fig. 4.5, right), c.f. remediation measures at Tsho Rolpa and Imja Lake. In these cases, the floor and the sides of the drainage channel need to be protected by concrete or geo-textile liners (Reynolds GS Ltd, 2003).
   b. For bedrock dammed lakes:
      i. Drilling of one or several drainage channels/tunnels* through the bedrock dam.
      ii. Tunnels in moraine dams have only been drilled above water level in order to limit any rise in water level (e.g. Safuna Alta Lake, Peru) (Reynolds GS Ltd, 2003).

* for pipes, cuts, channels and tunnels, measures have to be taken to prevent objects (blocks of ice or snow; driftwood; etc.) from entering the structure and cause a blockage of the drainage.

Figure 4.5 : (a) Outlet channel with reinforced dam reconstruction at the moraine dammed lake Laguna Cuchillacocha, Peru *(Photo: C. Portocarrero)*, **(b) Open channel at Imja Lake, Nepal, inaugurated in October 2016** *(Photo: UNDP).*

The major disadvantages of such structural measures are the related high costs. In particular, in remote regions of the IHR, with glacial lakes often located in rough and inaccessible terrain, such works are not feasible. An alternative to this are structural works implemented at locations between the lake and the settlements/infrastructure at risk. This can include retention basins, retention and/or deflection dams.

4.4.2 Exposure Reduction Options

Exposure can be reduced either (i) on the short term in the form of an evacuation in case of an event or (ii) on the long term, by considering hazard maps of all relevant processes for spatial planning. Restricting constructions and development in GLOF/LLOF prone areas is a very efficient means to reduce risks at no cost. Roles and responsibilities

concerning the regulation and enforcement around flood plain zoning and flood inundation management are outlined in Section 7.2.4 of the National Disaster Management Plan (NDMP, 2019)

For (i), information on imminent or ongoing events is needed, such as, for instance, provided by an Early Warning System (Section 5.5). Since GLOFs are very fast processes, an evacuation must be executed within a very short time, this requires an alarming infrastructure, clear protocols for all involved actors, and capacitation of the involved population and responsible authorities. Besides classical alarming infrastructure consisting of acoustic alarms by sirens, modern communication technology using cell and smart phones can complement or even replace traditional alarming infrastructure.

(ii). In contrast to other countries, there are no uniform codes for excavation, construction and grading codes in India. Nevertheless, a hazard map provides a solid basis for the consideration of hazards in the spatial planning:

In the high hazard zone, the construction of any habitation should be prohibited. Existing buildings are to be relocated to a safer nearby region and all the resources for the relocation have to be managed by Central/State governments. New infrastructuresin the medium hazard zone have to be accompanied by specific protection measures. Retrofitting techniques to strengthen the weak structures should be implemented in order to protect existing infrastructure.

Land use planning is the most effective and economical ways of reducing losses due to landslides by avoiding the hazard and minimizing the risk. There are no widely accepted procedures or regulation in India for landuse planning in the GLOF/LLOF prone areas. Such regulations need to be developed concerning the increased risk of future GLOF/LLOF events.

Figure 4.6 shows a hazard map with five levels of GLOF hazard, along with indicated evacuation routes (arrows) and safety zones (green rectangles with a white S). Such a hazard map with evacuation routes included, in combination with a spatial planning and building law, is a very effective tool for the reduction of exposure.

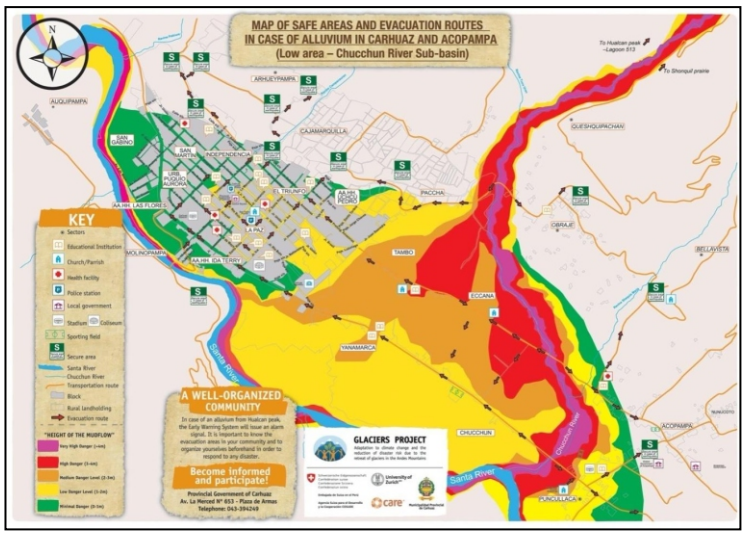

Figure 4.6: GLOF hazard map for the city of Carhuaz, Peru (Source: CARE Peru).
[Used as a tool for risk communication and reduction: Besides the hazard zones, evacuation routes (arrows) and safety zones (green rectangles with a white S) are indicated]

Locally and for particularly vulnerable infrastructures such as schools, hospitals, hydropower installations, pilgrim sites, major bridges, communication and energy lines, etc., protective structures like retention or deflection dams can significantly reduce the exposure of selected entities.

4.4.3 Vulnerability Reduction Options

Vulnerability can only be reduced in the long term. Based on the vulnerability assessment, weaknesses should be extenuated or eliminated. Capacity building with the population at risk is a crucial activity to reduce vulnerability on climate change, which also has a positive effect on most other risk management actions. Such capacity building should provide a relevant understanding of climate change and related impacts at both a regional and a local scale. Also, it should take into account cultural and traditions as well as local knowledge on experienced changes of the physical environment. Knowledge on the perception and prioritization of the different risks provides valuable information for the selection of site-specific and adequate risk management actions, which will be accepted by the local communities.

Insurances and compensation for losses are a further, efficient mean to reduce vulnerability. GLOF/LLOF insurance would be a logical means to provide compensation, and at the same time an incentive to avoid or mitigate the hazard. GLOF/LLOF insurance coverage could be made a requirement for mortgage loans. Controls on building, development, and property maintenance would need to accompany the mandatory insurance. Insurance and appropriate government intervention can work together, each complementing the other in reducing losses and compensating the victims.

Figure 4.7: Representation of a school where children were taking part in mock drill.

4.5 MONITORING TECHNIQUES

4.5.1 Introduction

Torrential rain or earthquakes may cause large-scale flank collapse damming the river channel. The collapse of such a landslide dam causes catastrophic downstream flooding. The biggest difference of such landslide-dammed lakes to glacial lakes is that glacial lakes can be identified and the risk assessed in a planned way, as the glaciers and moraines have a fixed position, unlike landslide dams which

are unpredictable. Thus, more time is available to plan and implement measures to reduce the likelihood of GLOF. This can be ensured through continuous monitoring. The various means and methods which can be adopted for monitoring are discussed below.

4.5.2 Monitoring Glacial Lakes

Between early warning (hours to minutes), and long-term monitoring of dangerous lakes (annual to biannual), there is a challenge to detect new threats that may emerge over the course of days, weeks, and months. This can include rapidly expanding glacial lakes in response to prolonged heavy rainfall, new glacial lakes as a result of blockages in the glacial hydrological system or associated with surging glaciers, and newly formed landslide lakes. As many of these processes are more likely to occur during the monsoon months, cloud cover can prevent the use of optical remote sensing. There are therefore opportunities to exploit Synthetic-Aperture Radar (SAR) imagery to automatically detect changes in water bodies, including new lake formations, during the monsoon months. Methods and protocols could be developed to allow year-round remote monitoring of lake bodies from space, as a compliment and precursor to ground-based early warning systems at critical lakes.

National Remote Sensing Centre (NRSC) had completed a project during 2011-15 on "Inventory and Monitoring of Glacial Lakes / Water Bodies in the Himalayan Region of Indian River Basins", sponsored by Climate Change Directorate, Central Water Commission (CWC), New Delhi, Govt. of India. Under this project, glacial lakes and water bodies located in all three major river basins viz., Indus, Ganga, and Brahmaputra including trans-boundary region were mapped with a water spread area of size greater than 10 ha using IRS-AWiFS sensor data of 56 m spatial resolution. A total of 2,028 features were mapped consisting of both glacial lakes (503) and water bodies (1,525). It was observed that there are 352, 283 and 1,393 glacial lakes and water bodies in Indus, Ganga and Brahmaputra river basins respectively. Glacial lake extent change monitoring for lakes of size greater than 50 ha (477 glacial lakes and water bodies) has been carried out by NRSC from 2011 to 2015 during monsoon period of June to October on monthly basis. The continuation of glacial lake monitoring is being carried out by CWC for 477 lakes from 2016 onwards (every year) on monthly basis during monsoon months using IRS-AWiFS satellite data. The entire GIS database on glacial lakes and water bodies over Himalayas mentioned above is available with CWC.

In addition to or instead of remote sensing approaches, a combination of precipitation thresholds and river stage monitoring can be considered for the monitoring of landslide dammed lakes, as described below:

4.5.2.1. Object-Based Image Analysis (OBIA) technique

Traditionally, supraglacial lakes SGLs (as small as 100 sqm) were mapped through field surveys which are laborious, risky and time consuming. The location of these glacial lakes in rugged and remote terrain makes it difficult to monitor them manually. There are alternative approaches to manual mapping of SGLs, for instance by using automated or semi-automated mapping approaches. Also, there are ways of processing remote sensing data using a technique called Object-Based Image Analysis (OBIA) technique.

4.5.2.2. Field investigation of critical lakes

Field investigations including topographical and bathymetric mapping, hydro-meteorological observations, and geological, geophysical and glaciological surveys may be carried out for high priority/vulnerable lakes. Drones and other unmanned aerial vehicles (UAVs) provide powerful tools for efficiently combining on-site field work and remote sensing techniques.

The selection of critical lakes should be done based on a first-order, regional assessment of hazards and risks of glacial lakes, based on remote sensing analyses.

4.5.2.3 Monitoring by trekking guides

The guides and porters employed by private/ semi-government agencies are regular visitors to the glacial lakes. This resource can be amalgamated into the monitoring grid after suitable training and registration, for effective surveillance and reporting of the glacial lakes.

4.5.3 Precipitation threshold for landslides

Rainfall is widely recognized as an important trigger for landslides, posing an increased threat to people and economies worldwide under climate change conditions. Rainfall thresholds, defined as the best separators for triggering and non-triggering known rainfall conditions, are the most used instrument in landslide hazard assessment and early warning tools. The most common parameters used to define empirical thresholds are the combinations of rainfall intensity duration, rainfall event-duration, and antecedent rainfall conditions.

Contingent upon the kind of available rainfall data, empirical thresholds can be summarized as follows:

(1) thresholds which combine rainfall data obtained from specific rainfall events,
(2) thresholds involving antecedent parameters, and
(3) alternating thresholds, like hydrological thresholds

For setting up an early warning system using empirical rainfall thresholds, various factors need to be taken care of:

- collection of reliable and large rainfall and landslide datasets,
- selecting threshold parameters depending on landslide characteristics and precipitation data,
- defining the events and using an objective and standardized methodology,
- validation of the thresholds determined.

4.5.4 Measurement of River and Lake Water Level

Water level or stage of the River is measured as its elevation above the GTS datum. Water level measurement was conducted by reading non-recording gauges. A series of vertical staff gauges as per the specifications laid down in IS 4080-1977 have to be fixed at three sections at each site i.e. upstream, station gauge and downstream.

There exist also water level recorders for continuous or distinct, automated measurements of water levels. Two types of water level recorders exist, (i) pressure sensors, which determine changes of the water level based on changes of water pressure, and (ii) contact-less sensors, using sonic waves to determine water level. Such automated devices for water level measurements and recording as well have the potential to be incorporated into an automated monitoring or early warning system.

Water level sensors installed along the banks of the river channel, immediately downstream of the lake outlet can be used in an Early Warning System (EWS) for GLOFs to detect the onset of a breach, cf. Section 5.7.

In addition to the traditional methods of water level sensors, the satellite altimeter and LIDAR can also be used for basin level WL monitoring of glacier lakes and downstream rivers (Thakur et al., 2020; Yuan et al., 2020).

4.6 EARLY WARNING SYSTEMS

Increasing the availability of EWS for disaster risk reduction is one of the seven targets of the Sendai Framework for Disaster Risk Reduction 2015-2030 (UNISDR, 2015).Monitoring, Early Warning and Alarming are key elements for an effective reduction of disaster risk, and the National Policy on Disaster Management (2009) emphasises the need to establish, upgrade and modernise forecasting and early-warning systems for all types of disasters. As indicated in Fig. 4.8, Early Warning Systems (EWS) can reduce both the exposure as well as the vulnerability of the potentially affected population. EWS are complex systems, involving not only technical, but also social, political and even juristic aspects. As defined by the United Nations International Strategy for Disaster Reduction (UNISDR, 2006), EWS consist of four key elements (Fig. 4.8):

- Risk Knowledge
- Monitoring and Warning Systems
- Dissemination and Communication
- Response Capability

Figure 4.8: Key elements of Early Warning Systems *(Source: UNDP 2018)*.

Till date there are a very limited number of GLOF EWS operational globally. This is due to the extremely challenging conditions, with short warning times, limited pre-event indicators, often combined with the necessity to evacuate a large number of persons.

4.6.1 Risk Knowledge

A detailed, site-specific risk assessment is a prerequisite for an effective design and successful implementation of an EWS. This includes a detailed assessment and mapping of hazard and a detailed evaluation of the vulnerabilities. Knowledge of the different types of vulnerabilities of the potentially affected population is needed for the development of a suitable communication and warning strategy.

4.6.2 Monitoring and Warning Services

The monitoring and warning services constitute the technical core component of an EWS. This element comprises the installation of adequate measurement devices to constantly observe the critical parameters. This potentially includes sensors at the lake, in the lake surrounding, at the dam/outlet, in the stream and at other sites potentially at risk. Also, remote information from other sources can be part of the monitoring strategy of an EWS, such as satellite observations, meteorological and hydrological prediction models etc.

4.6.3 Dissemination and Communication

The dissemination and communication element comprises the distribution of understandable alerts, warnings and alarms, including also preparedness information to the population at risk. In their recommendations for building functional EWS, UNDP notes that *"Historically, most failures in EWS occurred due to miscommunication – not equipment or infrastructure failure – further underscoring the gravity of this element"* (UNDP, 2018).

4.6.4 Response Capability

Response capability, the last element of EWS, consists of the centralised knowledge, plans, protocols and other inputs needed for timely and appropriate action by affected population and involved other stakeholders and authorities. Prerequisites for a successful response to EWS warnings are that the endangered population is aware of the looming risks and perceives them as relevant, and also that they have trust in the Early Warning System.

4.6.5 General Remarks

Due to the technical complexity of some systems, it is essential to have a calibration phase after the installation of an EWS. This time is needed to refine the warning thresholds, and for the personnel operating the EWS to familiarize with the system. This calibrations phase should be used for simulations and drills.

In order to guarantee a constant availability and operationality of an EWS, maintenance of all components of the system is indispensable. Sensors and hardware have a limited lifetime, in particular under harsh high-mountain conditions. Also, the software needs to be constantly updated to new technological standards. The costs of such maintenance work need to be considered in the budget of the authority or institution responsible for the operation and maintenance of the EWS.

4.6.6. Early warning system in the Sutlej river basin, India

Some measures have been put in place in the Sutlej River basin for monitoring, forecasting, and early warning to deal with flash floods, especially from cloudbursts. As GLOFs are one of the causative factors in propagating flash floods downstream, these measures also act as an early warning system for a GLOF. Telemetry stations set up by the Snow and Hydrology Division of the Central Water Commission in Sumdo, at the confluence of the Parechu and Spiti rivers, and Khaab, at the confluence of the Spiti and Sutlej rivers, and by the Naptha-Jhakri project at Dubling, are intended to monitor any increase in the water level and to relay information. They were introduced in response to the gap in early warning that was felt after the floods in 2000, and also for the protection of hydropower projects. Similarly, a wireless network at Reckong Peo, used by security personnel with connections to border outposts, and the Doordarshan Satellite Earth Station and All India Radio Relay Centre, have been very useful in generating warnings and in communicating during emergencies (UNDP 2008).

Chapter 5: Awareness & Preparedness

5.1 AWARENESS

Given the rarity of the events like GLOFs and LLOFs, local communities are not too aware about their disastrous effects. Since outburst floods are sudden, and cause disasters that affect localised areas resulting in segregated losses, they do not receive appropriate attention due to their transitory nature, and short-lived human memory. Hence, the level of awareness about GLOFs and LLOFs has been quite low compared to other disasters like earthquakes, cyclones, cloud bursts, Tsunamis, etc. While the Kedarnath Tragedy of 2013 in the state of Uttarakhand in Western Himalayas did bring about some awareness about GLOF in the IHR, there is still a long way to go.

5.2 CREATION OF COMMUNITY AWARENESS ON GLOFs AND LLOFs RISK REDUCTION

The following are the short, medium and long term strategies which may be adopted to create community awareness on GLOFs and LLOFs risk reduction:

A. Short Term

1. **Automated Alert Services:** In collaboration with the various government and private travel agencies including Indian Airlines, Indian Railways and mobile network operators, NDMA can send automated SMS and e-mail messages on precaution to be taken while travelling in the GLOF/LLOF vulnerable areas at the time of booking of travel tickets to these areas.
2. **Toll free number or smart-phone based application for GLOFs/ LLOFs reporting**: Each state in the very high and high-risk zones can initiate a mechanism for GLOFs/LLOFs reporting upon receiving reports of early signs of GLOFs and LLOFs from people. NDMA in collaboration with the leading technical institutions of the country like Indian Institute of Technology (IIT) can design a computer/smart-phone application for disaster management. The application can be used to know about the latest information on disasters (including GLOFs/LLOFs) across the country.
3. **Creation of common signage for GLOFs/LLOFs vulnerable areas:** A common signage (aligned with International systems) for GLOFs/ LLOFs vulnerable areas can be designed and displayed in GLOFs/ LLOFs vulnerable areas across the country, advising people to be aware of rapidly rising rivers, and where to find safe ground.
4. **Use of local mass media:** A well designed mass media campaign (both print & electronic) can be undertaken in the vulnerable and affected states. The campaign must be designed in the local languages. The local community radio can broadcast programmes on awareness. It can also transmit early warning messages regarding the occurrence of GLOFs/LLOFs in the area.
5. **Use of posters, wall paintings and hoardings:** Posters and hoardings on the various aspects of awareness regarding GLOFs/LLOFs can be designed and displayed at all important public places. Wall paintings depicting GLOF and LLOF vulnerable zones can be displayed at prominent public locations in order to increase the awareness among the locals. The campaign material should be translated into local languages.

6. **Use of Global Disaster Preparedness and Response Apps**: There are a number of globally recognized disaster preparedness and response apps serving the needs of people affected by disasters. These top mobile apps could prove fruitful in providing assistance to aid workers and volunteers (Aapda Mitra) in better preparedness and response to the disaster.

B. Medium Term

1. **Awareness through documentary**: NDMA should initiate a programme using documentaries/presentations for Government organisations, schools and hospitals, soldiers, NGOs, local nodal agencies, local community organisations and youth clubs, and local people focusing on the role and responsibility before, during and after the landslide or flood disaster.
2. **Creation of village task force:** The not-for profit and/or community-based organizations should constitute a village task force in each village of the vulnerable states. The members of the task force should be made aware of the various aspects of glacial landslide mitigation and post-glacial landslide activities.
3. **Creation of a citizen science application for environmental monitoring:** NDMA in collaboration with the leading technical institutions of the country like Indian Institutes of Technology (IITs) can design an application for smart-phones, allowing citizens to record key environmental parameters, such as lake or river levels. By engaging communities in scientific monitoring, they are more likely to respond positively to any warnings or alerts.

C. Long Term

1. **Awareness programme on GLOFs/ LLOFs hazard:** There is need for emphasis on a robust awareness programme for GLOFs/LLOFs hazard. There is a need for enhancing public awareness about signs and events that manifest that a GLOFs/LLOFs is imminent so that personal safety measures may be taken in a timely manner. Some of these signs include: (a.) fragments of ice/debris from moraines in the river waters, (b.) calm waters in the river showing and unusual turbid nature, (c.) damming/ blockage of the river body by local landslide or extra-large erratic boulders which may lead to rise in the level of river water, (d) cracking sounds from the glaciers upstream, (e.) change in the colour of river water showing suspension of sediments due to landslide/collapse of moraine dam upstream, (f.) cracks in Glacier/Moraine Dammed wall along the boundary of glacier lake, etc.
2. **Use of traditional art forms/ traditional knowledge:** Due to modernization and tech savvy nature of 21st century generation, traditional disaster management practices are dying /losing relevance. Therefore, it is necessary to document and disseminate traditional best practices available in mountainous regions of India through community participation in trainings. Traditional art forms are important media of awareness generation. Traditional knowledge and modern technologies can be combined to design glacial landslide and flood Early Warning System (EWS).
3. **Awareness through Participatory Approach:** A participatory planning and implementation process is recommended in order to maintain the sustainability of the programs launched by the administration for disaster management. It is necessary that the government and the communities together evolve a joint action plan aimed at enhancing community education and development of community leadership. The Community Based Family Disaster

Preparedness and mitigation (CBFDP) is one such process to capacitate communities to prevent, mitigate and cope with disasters effectively. The elements of participatory learning can be applied at different levels such as organizational level (headquarters, branches, schools, businesses, workplaces), community level (village, town, cities) and population level (marginalized, vulnerable sections).

4. **GLOFs/LLOFs education plan:** An illustrated booklet with information on GLOFs/LLOFs awareness can be prepared in local languages. This can be circulated among the Panchayati Raj Institutions (PRIs) members, Front Line Health Workers (FLHW), School Teachers, Youth Leaders, members and other important stakeholder groups in these areas.

5. **Involvement of Not-for-Profit Organisations**: Government agencies should identify not-for-profit organisations to undertake the awareness building activities in the vulnerable States. The organisation should be asked to submit a targeted awareness generation plan.

6. **Awareness among local youth:** The not-for-profit organisations can hold regular awareness generation camps with the members of National Cadet Corps (NCC), Scouts and Guides, and National Service Scheme (NSS) volunteers. These camps should be conducted in coordination with the state and district teams of these organisations.

7. **National Data Centre on GLOF/LLOF**: It would integrate various data sources, a geo-portal to address the data needs and thus, enable an effective response. A step towards building the same has been taken by the GIS team at NDMA.

8. **Awareness among policy makers and government officials:** The policy makers are key stakeholders in disaster management. State Disaster Management Authority (SDMA) can hold workshops with policy makers and government officials of all departments to reinforce their role in ensuring that people conform to the various land use policies.

5.3 AWARENESS DRIVE FOR SPECIFIC TARGET GROUP

Awareness drive for specific target groups including **communities residing in on the downstream areas; vulnerable groups including women, children and senior citizens**; **urban planners and architects, geologists and civil engineers** should be undertaken. **Administrative integration among the government departments, public sector agencies, NGOs and civil bodies** should be given special attention in order to integrate activities related to creation of awareness and preparedness. A holistic and collaborative approach towards trainings and awareness building should be adopted in order to develop action plans to spread awareness and preparedness measures to the last mile.

5.4 PREPAREDNESS

Disaster preparedness refers to measures taken to reduce and mitigate the effects of a disaster, and forms a core component of the proactive stage of disaster risk management. Preparedness can considerably relieve the severity of impact during the scenario of a disaster. Given the rarity of GLOF and LLOF events in the IHR, not much is known to the community. While structural support (embankments, artificial drainages, etc.) may be feasible to some extent, however it cannot be

widely replicated because of inadequate technology, financial and logistic constraints (inaccessibility to mountain reaches).Non-structural/institutional support is therefore, one of the key mechanisms to be strengthened in such contexts. For this Central and State Governments, in collaboration with various stakeholders and NGOs, need to work closely to implement measures of preparedness on the ground.

5.4.1 Government Agencies and other Stakeholders

SDMA/State Government is one among the early responders and must work in close cooperation with local government/non-government bodies and agencies in the region to provide aid and relief at the earliest. A network with additional responsibilities must be handed to the government officials in the region for decision and support for pre, during and post phase of the disaster. Generate awareness and provide training support on GLOF/LLOF preparedness and response to ITBP, local police and SDRF. As the community preparedness measures have been discussed in section 5.4.3. If the community at large is prepared, not only will it help reduce the impact of the disaster but will also contribute to the overall socio-economic development of the region helping the region at large to achieve resilience from GLOF and other disasters.

5.4.2 Medical Preparedness

Catastrophic natural disasters like GLOFs and LLOFs have a high potential to cause incidences of mass injuries, causalities and subsequent health outbreaks. Direct health effects of a flood may include: drowning; injuries like cuts, sprains, fractures, electric shocks; diarrhoea, vector and rodent borne diseases like malaria, lepto spirosis; skin & eye infections; and psychological stress. In order to respond to event related medical emergencies, a number of measures are required.

a) Creation of Trained Medical First Responders

The state governments/SDMAs must ensure creation of trained medical first responders for first aid and resuscitation measures for burying and drowning cases. Medical staff must know how-to pull-out water from the respiratory tract and how to carry out cardio-pulmonary resuscitation. A list of trained medical and paramedical staff must be made available to all the relevant agencies. Medical Stores and medical kits must be prepared for the management of GLOFs casualties. Intravenous (IV) fluid, ventilators, oxygen, dressing materials, tetanus toxoid, antibiotics, vaccines, anti-snake venom and anti-diarrhoea drugs will be the most commonly needed medical resources. Large-scale medical stores from where these materials can be procured in a timely manner must be identified. State governments/SDMAs must make available emergency medical equipment and drugs for resuscitation.

b) Patient Evacuation Plan

Heli-ambulances need to be deployed to aid in the evacuation of casualties from the affected region. Within identified risk hot-spots, safe zones should be established, where medical supplies can be stored, and Heli-landing sites demarcated. It is important that such safe zones are well outside the zone of residual risk, including from secondary hazards. The ambulances should have Standard Operating Procedures (SOPs) for treatment.

c) Emergency Routes and Medical Mock Drills

Since the areas vulnerable to GLOFs/LLOFs are often remote and rugged, providing immediate medical attention would

be a challenge in itself. Emergency routes should be demarcated based on the results of hazard mapping (see Chapter 3) and frequent medical mock drills by the trained medical professionals must be conducted.

d) Medical Disaster Management Plans

Disaster Management Plans need to be prepared by all hospitals. Medical facilities, training of medical personnel, creating awareness about drowning and its management should be a part of the plan. Hospitals must nominate an officer for coordinating management of casualties. Contingency plans must be prepared for providing additional beds. Oxygen cylinders, Continuous Positive Air Pressure (CPAP) ventilators, dressing materials, blood and IV fluid for transfusion must be stocked. The hospital casualty room must be equipped with resuscitation equipment like suction apparatus, airways laryngoscope, pulse oximeter, defibrillator and lifesaving drugs. In addition, the aftermath of GLOFs/LLOFs, public health response is one of the prime responsibilities of medical authorities. They will ensure safe water supply and clean food availability along with the maintenance of hygiene and sanitation by proper bio-waste disposal. Water testing and food inspection is required to be carried out regularly to prevent the outbreak of any epidemic. An effective communication system is an essential requirement for prompt medical response.

5.4.3 Community Preparedness

If the community facing the disaster or vulnerable to associated hazards is well prepared, it will greatly reduce the impact of the disaster. Simulation exercises, mock drills and awareness programmes for the GLOF/LLOF prone district need to be developed and made an essential part of the preparedness programme. The entire cycle of an exercise programme from orientation seminar to full scale exercise takes about 6 to 12 months. Complete exercises in disaster prone districts of the Himalayan states vulnerable to GLOF and LLOF events must be conducted at least once in three years after careful planning so that grey areas in the preparedness programme are identified and efforts are made to make the necessary modifications.

CHAPTER 6: CAPACITY DEVELOPMENT

6.1 INTRODUCTION

A successful and sustainable implementation of this framework for GLOF and LLOF risk assessment and management require different kinds of capacities, including engineering, scientific, socio-economic, organisational, and institutional in various forms. The complexity of task requires an interdisciplinary approach with a collaboration of engineers, hydrologists, geo-morphologists, modelling experts, remote sensing specialists, infrastructure planners and builders, environmentalists and sociologists, and authorities at local, state and national level. In addition, it is essential to develop experiences from events and situations and to document and analyse cases and extract lessons learnt to develop best practices.

In this section, aspects of education and capacity building at the university level, training of professionals involved in the assessment and management of GLOF and LLOF risks, and capacity building within local, potentially affected communities is discussed.

6.2 GLOFs AND LLOFs EDUCATION

University education is the foundation for the basic training of the different types of experts involved in GLOFs and LLOFs risk assessment and management.

For the assessment of GLOFs and LLOFs hazards and risks, a thorough understanding of natural processes and their complex interactions in glaciated high-mountain regions is required, including knowledge of the past and future developments at different spatio-temporal scales. This understanding needs to be complemented with technical skills, such as remote sensing, cartography, and development and application of numerical models for the simulation of these processes (Figure 6.1).

For the evaluation of the vulnerability, specialists from social sciences are needed to assess and understand the social, cultural and economic background of the potentially affected population.

In case of an emergency situation, engineering skills are needed for design and implementation of short, medium and long-term hazard and risk reduction. For the implementation of Early Warning Systems (EWS, cf. Section 5.5), electronic and communications engineers, and programming experts are required.

For response in case of catastrophic events, efficient relief capacities and resources are needed which requires managerial and response implementation capacities.

6.2.1. Education of Professionals

All glaciated regions and mountain/hill ranges are likely to be affected by GLOFs and LLOFs risks. Knowledge exchange and experience sharing with scientists and practitioners working on GLOFs and LLOFs issues across different mountain ranges and hilly regions of the world is, therefore, an important part of the continuous further education of professionals and experts. Organizing and participating at workshops and conferences, bringing together GLOFs and LLOFs risk assessment and management experts is a key means to benefit from experiences gained in other regions. Online resources like the Training modules relating to glacier hazards and disaster risk management developed under the Indo-Swiss Capacity Building Programme on Himalayan Glaciology can also support education of professional.

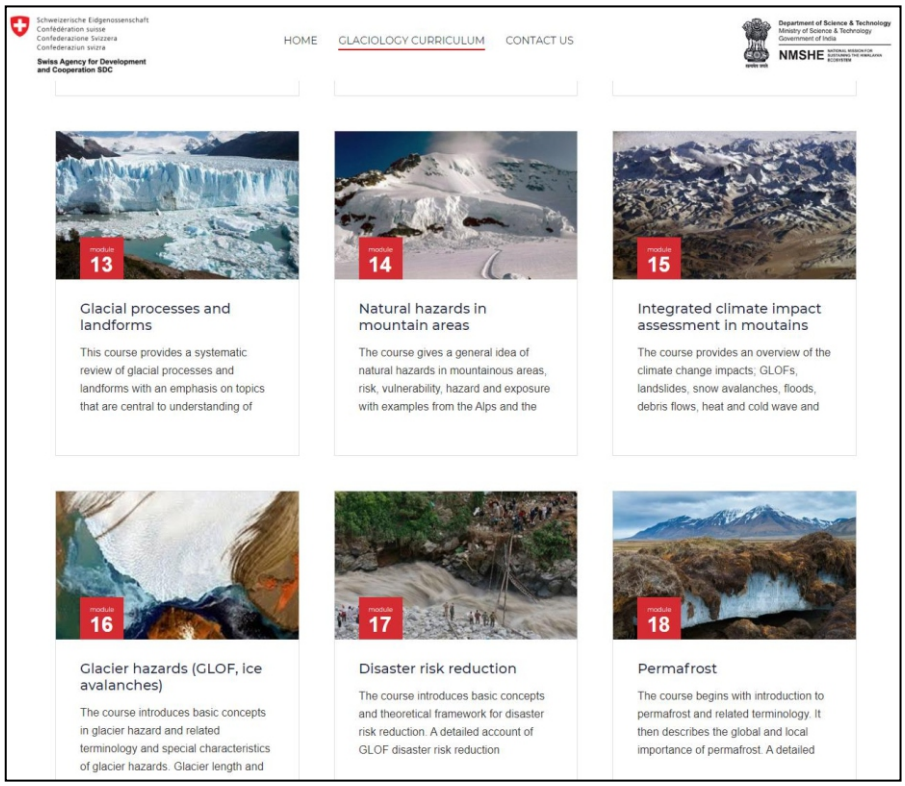

Figure 6. 1: Training modules relating to glacier hazards and disaster risk management.

(Produced under the Indo-Swiss Capacity Building Programme on Himalayan Glaciology, organised by The Department of Science and Technology (DST), Government of India and the Swiss Agency for Development and Cooperation in 2019- http://glaciology.in/curriculum/*)*

Further, to strengthen the education of professionals, there is a need for the documentation of past and recent events (cf. Section 7.5) and development of best practices. Such a database allows for constant development of expertise, based on the lessons learnt from past events.

6.2.2. Community Education

Building capacities in communities potentially threatened by GLOFs and LLOFs is important in order to improve response capacities in case of a catastrophic event. Such capacity development activities should involve the following aspects:

- Information of the reasons and causes of a potential risk, including changes in the environmental and climatic conditions over the past years.
- Current risk situation and potential scenarios of outburst events, including expected impacts at different sites relevant for the community.
- Development and implementation of a risk reduction strategy, including warning and alarming procedures, if available.
- Individual risk reduction measures (avoid unnecessary presence in the riverbed, location of immobile assets outside the hazard zone, etc.).
- Behaviour in case of an event, potentially involving drills and simulations of early warning and alarming systems.

Community education efforts should be embedded in a set of activities with the potentially affected communities, involving the evaluation of local knowledge and risk perceptions related to past and current GLOFs and LLOFs risk, surveys and interviews for the vulnerability assessment (cf. Section 3.5), the planning of risk management options (cf. Section 5.4.2 and 5.5.4), etc.

Education and awareness raising also needs to extend to reach transient populations, such as recreational and religious tourists (pilgrims) exposed to GLOFs and other associated hazards. This could be achieved, for instance, through information signs, infographics, and brochures.

6.3 TRAININGS

6.3.1. Training of Professionals

Regular workshops for professionals of institutions involved in the assessment and management of GLOFs and LLOFs risks should be held once the present guidelines are implemented. Such workshops will foster cross-organisational collaborations that are required for a comprehensive and strategic management of related risks.

Pilot studies developed to demonstrate the risk assessment and management strategies of these guidelines can be used to illustrate the approaches as practical examples. Over time, these pilot studies can be replaced by real cases that will emerge according to the present guidelines.

The mapping, monitoring and modelling of potential glacier or landslide lakes is usually done by various Earth Observation (EO) system such as polar orbiting satellites, aerial and UAV based platforms. Therefore, specialized training modules or online webinar for such basic and advanced topics can be organized for professionals/users working in this area, by the concerned institutes in India (IIRS, NIH, NRSC, SASE, WIHG, IITs), in collaboration with NDMA and NIDM. Such trainings can be used to get inputs from international experts and specialists for providing updated knowledge to the students and practitioners.

6.3.2. Training of Decision makers

As the policy and decision makers regulate and manage the disaster preparedness and response system, it is necessary that they are aware of the gaps in the disaster preparedness and what communities face during such disasters. For that, trainings and workshops for policy and decision makers should also be conducted periodically. This will enhance the efficiency and regularity in the system to mitigate the GLOF/ LLOF disaster risks and hazards.

6.4 CAPACITY UPGRADATION

6.4.1 Documentation

It is recommended to establish a systematic database of past GLOFs and LLOFs disasters and emergency situations developed according to the approaches presented in these guidelines. Such a database is important in order to extract best practices and lessons learnt from past events, which will contribute to further refining of these guidelines according to newer insights gained over time. NDMA is well placed to develop and host such a database, and moderate related educational efforts.

The GLOF and LLOF events database should include the following aspects for each case or lake:

- Observed environmental conditions, if available before, during and after an outburst, should be described
- Consequences of event.
- Assessment of outburst susceptibility and scenarios of possible future developments
- Institutional roles and responsibilities, as well as communications between institutions
- Risk reduction and mitigation measures taken
- Critical reflection and lessons learnt
- Actions to be taken further

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CHAPTER 7: RESPONSE

7.1 INTRODUCTION

Magnitude of disasters like GLOFs and LLOFs can vary from small to large scale and the response measures are required to be taken at the appropriate levels. Under response measures, there is an utmost need to provide immediate assistance to maintain life, improve health, provide initial repair to infrastructure and support the morale of the affected population.

7.2 EMERGENCY SEARCH AND RESCUE OPERATION

7.2.1 Local Community

Experience has shown that over 80 percent of search and rescue is carried out by the local community before the intervention of the state machinery and specialised search and rescue teams. Thus, trained and equipped teams consisting of local people must be set up in GLOF and LLOF vulnerable and prone areas to ensure immediate and effective response. Regular updating/revision of the training, and participation in mock drills will be important to ensure readiness to respond.

7.2.2 Search and Rescue Teams

On the ground, besides others, the NDRF battalions will assist the state government/district authorities in training the local communities. They will be further assisted by the ATIs, CD, Home Guards and NGOs. The state governments, through the ATIs, will develop procedures for formally recognizing and certifying such trained search and rescue team members; they will also provide suitable indemnity to community level team members for their actions in the course of emergency response following a flood. Youth organisations such as the NCC, NSS and NYKS will provide support services to the response teams at the local level, under the overall guidance and supervision of the local administration.

7.3 EMERGENCY RELIEF

Trained community level teams will assist in planning and setting up emergency shelters, distributing relief packages among the affected people, identifying missing people, and addressing the needs for food, health care, water supply and sanitation, education, etc. of the affected community. These teams will also assist the government in identifying the most vulnerable people who may need special assistance following the disaster. Emergency relief can only be effective if it is underpinned by effective disaster preparation (see chapter 6), and these components need to be closely linked.

7.3.1 Emergency Medical Response

7.3.1.1 Emergency Treatment at Site

Prompt and efficient emergency medical response will be provided by Quick Reaction Medical Teams (QRMTs), mobile field hospitals, Accident Relief Medical Vans (ARMVs) and heli-ambulances in areas inaccessible by roads . They will be activated to reach the affected areas immediately, along with dressing material, splints, portable X-ray machines, mobile operation theatres, resuscitation equipment and life-saving drugs, etc. Resuscitation, triage and medical evacuation of victims who require hospitalization will be done in accordance with SOPs. Heli access may be critical in remote mountain regions, and road access can be destroyed by the event itself. However, weather conditions, particularly during monsoon, can prevent safe helicopter access, and hence, alternative routes into affected areas should be identified in advance.

7.3.1.2 Medical Facilities and Medical Treatment at Hospital

A well-rehearsed medical preparedness plan is required to provide intensive care to cases rescued from drowning and those buried under the debris. An emergency medical plan will be triggered immediately on receiving information about imminent threat of GLOF/LLOF. The action will be immediately initiated for crisis expansion of required number of beds. The medical superintendent should be able to forecast the requirement of enhanced manpower and medical stores after knowing the number of causalities likely to be received at the hospital. Special efforts will be made for the availability of IV fluid, antibiotics vaccines etc. Children, women, elders and other vulnerable casualties will be attended on priority basis.

7.3.1.3 Mortuary Facilities and disposal of Dead Bodies

The state will develop contingency plans to have sufficient mortuaries to preserve the dead bodies. After proper identification, dead bodies will be immediately disposed of through district authorities, to prevent the outbreak of an epidemic and environmental pollution.

7.3.1.4 Public Health Issues in Aftermath

Safe and sufficient drinking water will be ensured. Protecting existing water sources from contamination, adding chlorine tablets in the water for residual disinfection effect and provision of latrine and proper waste disposal to avoid contamination through flies and other insects are important steps required immediately in the aftermath of a GLOF/LLOF. Vector control will be done by spraying of shelters with residual insecticides. Provision of insecticide treated mosquito nets is recommended.

7.3.1.5 Psychosocial Aspects

A large number of victims will suffer from psycho-social effects in the aftermath of the disaster event. The psycho-social impact of floods could manifest as a reaction in the form of post-traumatic stress disorders (PTSD) and other psychosocial ailments among the displaced populations. A team comprising of a social worker, a psychologist and a psychiatrist will provide counselling to such people.

7.3.1.6 Documentation of Medical Response

Documentation of the medical response provided after a GLOF/LLOF event will be done by a medical administrator. This documentation will be used as feedback for future improvement of the response strategies.

7.4 INCIDENT RESPONSE SYSTEM

All response activities will be undertaken at the local level through a suitably devised Incident Response System (IRS) coordinated by the local administration through the Emergency Operations Centers (EOCs). State governments will commission and maintain EOCs at appropriate levels for the coordination of human resources, relief supplies and equipment. Standard Operating Procedures (SOPs) for the EOCs will be developed by state governments and integrated within the framework of the IRS, which will take advantage of modern technologies and tools, such as GIS maps, scenarios and simulation models for effectively responding to disasters. GIS maps available from other sources, such as the city planning departments will be compiled considering their potential application after a disaster. The state governments/SDMAs will undertake the training of personnel involved in the IRS. Some of the state governments have already adopted this system.

7.5 COMMUNITY-BASED DISASTER RESPONSE

7.5.1 Institutionalizing the Role of Community Based Organisations, Non-governmental Organisations etc. in Incident Response System

A number of organisations, like NGOs, self- help groups, CBOs, youth organisations such as NCC, NYKS, NSS etc., women's groups, volunteer agencies, CD, Home Guards, etc. normally volunteer their services in the aftermath of any disaster. Village level task forces will also be constituted on a voluntary basis for better preparedness of the community including shepherds/Himalayan nomads. The state governments/ SDMAs and DDMAs will coordinate the allocation of these human resources for performing various response activities. State governments will work with these agencies to understand and plan their roles in the command chain of the IRS, and incorporate them in the DM plans.

7.5.2 Dissemination of Information

Soon after the disaster, accurate information will need to be provided on the extent of the damage and other details of the response activities through electronic and print media. The state governments will utilise different types of media, especially print, radio, television and internet, to disseminate timely and accurate information.

7.6 LOGISTICS

7.6.1 Emergency Logistics/Equipment:

Specialized heavy earthmoving and search and rescue equipment are required immediately after a GLOF/LLOF to help clear debris and carry out search and rescue operations of trapped people under huge masses of debris. Also, Motor launches, country boats, inflatable rubber boats, life jackets, lifebuoys and other equipment will be required immediately after floods to carry out search and rescue of trapped people. State governments will compile a list of such equipment, identify suppliers thereof and enter into a long-term agreement for their quick mobilization and deployment in the event of floods and a landslide disaster.

The IDRN, which is a web-based inventory of information on emergency equipment and response personnel available in every district, will be revised and updated every three months.

7.6.2 Relief Camps

The setting up of relief camps (Rahat Ghar) for the people whose houses have been damaged by floods/landslides and the provision of basic amenities in such camps involves complex logistics of mobilizing relief supplies, tents, water supply and sanitation systems, transport and communication systems, and medical supplies. Most importantly, site selection for relief camps based on best available scientific information (hazard mapping etc.) should be part of the disaster preparedness phase. Relief camps, and access corridors to these camps, should be outside of zones of residual risk, and safe from any potential secondary hazards.

A temporary shelter building, where the locals can find shelter during the times of disaster should be erected/ built in a raised location to ensure resilience to landslides and floods. The building will include a raised plinth which will safeguard it from flood waters and needs to be built with landslide resistance standards of the highest orders.

7.6.3 Establishing the Accessibility

The primary challenge in the response to natural calamity in the Himalayas is ensuring accessibility to the affected areas, due to likelihood of choking of the limited communication lines. In case of the Himalayas,

c) Preparation of Hazard Zonation Maps and mapping of unsafe areas for human settlements that are likely to be at risk from a susceptible GLOF/LLOF.

d) Ensure continuous monitoring of highly susceptible lakes followed by field survey in terms of change in the area of the lake, change in water level, position of a lake in relation to moraines and associated glaciers, the activity of lakes and condition of the dam.

e) Involvement of the shepherds/ guides/porters and local communities in monitoring of glacial/landslide lakes with high risk boundary conditions and discernible terrain changes.

f) Seek inputs from Indian Meteorological Division (IMD) and Snow & Avalanche Study Establishment (SASE), CWC, Survey of India (SOI) to ensure continuous weather monitoring and to facilitate decision making in case of emergency. **[Action:** State/UT Admin**]**

g) In case of abrupt expansion of the lake, ascertain the cause at the earliest through satellite/aerial and physical means. **[Action:** State/UT Admin/NRSC**]**

h) Ensure availability of satellite communications (SAT Comms.). **[Action:** State/UT Admin/DoT**]**

i) Convene a meeting at District/State level to tackle the issue. Inform NDMA and provide regular updates.**[Action:** State/UT Admin**]**

j) Refer the situation to the National Disaster Management Authority (NDMA) if it is beyond the capability/resources of State Govt. **[Action:** State/UT Admin/ NDMA**]**

k) National Crisis Management Committee (NCMC) to convene a meeting at the earliest depending upon the severity of the situation. Simultaneously, the Defence Crisis Management Group (DCMG) meeting may also be held, if required. **[Action:** Cabinet Secretariat/ NDMA/MoD**]**

l) NDMA / SDMA to activate the Control Rooms and update all records. Establish telephonic and video contact with all concerned officials including officials of the concerned State Control Room, IMD, CWC, NRSC and National Technical Research Organization (NTRO) obtain satellite images of the affected area. NDRF / SDRF alerted to be on standby. **[Action:** NDMA/ SDMA (State/UT Admin)/NDRF/SDRF/NRSC/ NTRO/ IMD/ CWC**]**

m) Based on the lessons learnt, the affected State to organize a Team of Experts from those agencies which are likely to be involved. These could be some or all of the following suggestive list of institutions:- **[Action:** State/UT Admin/NDMA**]**

(i) Central Water Commission (CWC)
(ii) India Meterological Department (IMD)
(iii) Survey of India (SOI)
(iv) Geological Survey of India (GSI)
(v) Central Institute of Mining & Fuel Research (CIMFR)
(vi) National Mission for Sustainable Himalayan Ecosystem (NMSHE)
(vi) National Institute of Hydrology (NIH)
(vii) Snow & Avalanche Study Establishment (SASE)
(viii) Border Roads Organization (BRO)
(ix) MoD / Integrated Defence Staff (IDS)
(x) Hydro Power Developers
(xi) Dept of Science & Technology (Suitable representative from State Govt.)
(xii) Official media personnel.
(xiii) Other Departments.

the heavy earth moving machinery might not be useful and relevant in the immediate response stage. Hence, innovative methods using locally available natural resources will have to be used and local agencies and population will have to be trained for the same. It is important to innovate and design lighter machinery, which are more suitable to be carried in the mountains in a disassembled form.

7.7 POST DISASTER DAMAGE AND NEED ASSESSMENT

Assessment of the damage, both direct and indirect, due to GLOF/LLOF as wells as secondary physical effects, such as landslide-caused flooding, is very important to understand whether it will be possible to treat it economically or not. While direct losses include the impact on infrastructure, vehicles, life loss, etc., indirect landslide losses could include:

i) The loss of industrial, agricultural, and forest productivity; and tourism sector revenues as a result of damage to land or facilities, or interruption of transportation systems.
ii) Reduced real estate values in areas threatened by GLOFs/LLOFs.
iii) The loss of tax revenues on properties devalued as the result of GLOFs/ LLOFs.
iv) Measures that are required to be taken to prevent or mitigate additional landslide damage.
v) Adverse effects on water quality in streams and irrigation facilities at and near the GLOFs/LLOFs affected region.
vi) The loss of human or animal productivity because of injury, death, or psychological trauma.

Indirect losses many a times exceed direct losses. Unfortunately, most indirect losses are difficult to evaluate and are therefore either ignored or estimated rather conservatively. Also, usually people and entities prefer to keep their financial losses discrete and not disclose these publicly. Restoration of direct assets will also lead to improvement in the indirect losses but much effort is required to be made by all the local organisations/ NGOs/ Communities to regain the indirect assets.

Physical damage assessment is done through airborne videography/ imagery, satellite data and field surveys. Much of the work on damage assessment nowadays is based on the Earth observation data i.e. optical and SAR satellite data. It is highly useful to identify places clogged with water and those hit by landslides. Precise measurements can give results of movement at millimeter (mm) scale.

7.8 STANDARD OPERATING PROCEDURE (SOP)

STANDARD OPERATING PROCEDURE (SOP) ON AVERTING THREATS EMANATING FROM GLACIAL LAKE OUTBURST FLOODS (GLOFs) AND LANDSLIDE LAKE OUTBURST FLOODS (LLOFs) IN HIMALAYAN REGION

The SOP lays down the guidelines and actions to be taken by the various agencies during the disaster event /crises. The standardized Incident Response System (IRS) for managing the GLOFs and LLOFs will be incorporated in line with these procedures. The SOP is implemented three stages as outlined below.

Pre-Operational Phase (Stage I)

a) Preparation of an inventory of the glacial/landslide lakes through remote sensing and GIS and prioritisation of the lakes according to the GLOF/LLOF risk assessment framework. **[Action:** State/UT Admin/District Admin/ NRSC/NTRO/ CWC/ National Mission for Sustaining the Himalayan Ecosystem (NMSHE)-DST**]**

b) Mapping of glacial/landslide lakes and relevant water bodies in IHR as well as classification of lakes based on the susceptibility as Highly Susceptible, Moderately Susceptible and Low susceptibility. **[Action:** NRSC/NTRO/ CWC/ NMSHE/ MOJS/ NLRTI**]**

n) State/ UT Admininstration to take immediate precautionary and preventive measures to ensure safety to life and property. These include: -

- **(i)** Informing the populace living both down/upstream of the impending danger.
- **(ii)** Installing water level monitoring gauges at suitable locations.
- **(iii)** Preparing (rehabilitation) relocation plans.
- **(iv)** Establishing communication facilities at the likely affected areas.
- **(v)** Alerting and preventing locals/ tourists from venturing into affected areas by establishing check posts/ check points.
- **(vi)** Erecting banners/ boards with warning signs.
- **(vii)** Taking immediate steps to relocate personnel from high risk zones.

o) The Expert Team / essential members to conduct an on the spot assessment of the GLOF/LLOF and carry out recce to ascertain: -

- **(i)** Free board available i.e. difference between current water level and dam height.
- **(ii)** Type and texture of the dam.
- **(iii)** Possible time available before a sudden dam break.
- **(iv)** Seepage towards downstream if any.
- **(v)** Any threat likely to develop due to impounded water.
- **(vi)** If physical intervention to drain the lake is required, then alignment and dimension of channel required to be created.
- **(vii)** How the channel is to be created, i.e. by using earth movers or manual clearing of debris (where earth movers cannot be deployed).
- **(viii)** Whether explosives can be used for creating a channel? If so, resources required i.e. manpower, equipment, explosives, etc.
- **(ix)** Any site-specific requirements.
- **(x)** Photography and videography of the site and surrounding areas.

p) Set up of Expert team by NDMA / SDMA to assist State in preparing a detailed action plan giving out: -

(i) Transportation

(ii) Communication

(iii) Medical

(iv) Safety

(v) Logistics stocking, replenishment and reserves

(vi) Induction, execution and de-induction phases

(vii) Media plan, photography & videography of events

Operational Phase (Stage II)

a) Installation of Automatic Water Level Recorders (AWLR) and Water Gauges at the susceptible lakes for continuous monitoring of water level in the lake.

b) Ensuring controlled breaching of the dam by reducing the volume of the water in the lake via construction of an outlet control structure, pumping or siphoning of the water from lake and tunneling through the moraine barrier or under an ice dam. **[Action:** State/UT Admin**]**

c) CWC to prepare pre-run scenarios and generate flood inundation/DEM Chart

to indicate level of potential threat in the event of the dam break/overflow scenario.

d) Planning of evacuation strategies on the basis of results from flood inundation modelling. **[Action:** State/UT Admin/CWC/CAPF/Local Police**]**

e) Ensure installation of Early Warning Systems (EWS) involving threshold based automatic alarm system monitored on a daily or weekly basis by State Emergency Operating Centre (SEOC) and managed by State Disaster Management Authority. **[Action:** SEOC-SDMA/DEOC-DDMA**]**

f) Securing and establishment of shelter homes, camp site and forward staging areas. **[Action:** State / UT Admin/ Army/ ITBP/ CAPF]

g) Establishing communication facilities (including HF/ VHF/ HAM/ satellite phones) at the site, staging areas and District Control Room. **[Action:** State/UT Admin/CAPF/ITBP/Army**]**

h) Installing safety devices like anchors, ropes, harnesses etc. where required.**[Action:** NDRF/ SDRF/ CAPF/ ITBP/Army/NIM**]**

i) Stocking of logistics like ration, equipment and machines, fuel, medicines, explosives and accessories, lighting arrangements. **[Action:** State/UT Admin/CAPF/ITBP/BRO/ Army**]**

j) Relocating the likely affected people from low lying areas at least 48 hours before actual commencement of work at the site. **[Action:** State/UT Admin/District Admin**]**

k) Detail a lookout team to alert members at the work site from falling stones, loose land mass etc. **[Action:** Expert team leader**]**

i) Marking the alignment of the channel to be created at the blockage site.**[Action:** Expert team leader**]**

m) Controlled use of explosives to break boulders/ dislodge compacted earthmass. Expertise of CIMFR, BRO & Army Engineers and others may be sought for use of explosives. **[Action:** Explosive Experts in State/UT Admin/ Army/ BRO**]**

n) Manual clearing of debris along the marked alignment. **[Action:** Expert team leader/CAPF/Army**]**

o) Manual clearing of debris and use of explosives can be alternately followed until the desired width, depth and length of channel is created for free flow of impounded water. **[Action:** Expert team leader/CAPF/Army**]**

p) Use of earth movers (JCB) if it is possible to reach them at the site. These can even be dismantled in parts, carried by helicopters under slung and assembled at the site (As done during River Sunkoshi blockage in 2014, Nepal). **[Action:** State/UT Admin/Airforce/ Army Engineers**]**

q) Loose debris can even be washed away using high pressure water jets at places subject to deployment of heavy-duty compressors. **[Action:** State/UT Admin/ Army**]**

r) Photography and videography of events for future reference. Representatives of media should be associated. **[Action:** State/UT Admin/ Expert Team Leader**]**

s) Heli-Ambulance/ air support to be requisitioned to National Emergency Response Centre (NERC) / Joint Secretary (Air). **[Action:** State / UT Admin/ MHA/MoD**]**

t) Bill for such air support to be raised against SDRF allocation**. [Action:** Air Force/ MHA**]**

u) Obtain daily weather reports to the plan for next day's activity. **[Action:** Team leader/Air Force/IMD**]**

v) Media briefing and press release at the end of the day's activity by the designated representative of State associated with the team. **[Action:** State/ UT Admin / District Admin/ NDMA/ Army PRO**]**

w) Ensure effective coordination and seamless communication among central and state agencies for quick, clear, effective dissemination of warnings, information and data. **[Action:** State / UT Admin/ District Admin**]**

Post Operational Phase (Stage III)

a) Round the clock monitoring from the Lookout Post till the situation normalises. **[Action:** State/UT Admin/ Army**]**

b) Obtain satellite imageries, from NRSC & NTRO to compare pre and post activity changes in volume of impounded water upstream, status of flow of water through channel and flow of water downstream. **[Action:** State/UT Admin/CWC/NRSC/ NTRO/NDMA**]**

c) Periodical aerial recee and videography of the sites without connectivity to know the latest status. **[Action:** State/UT Admin/ Army/ Air Force/ Expert Team**]**

d) Sectoral assessment of the damage such as infrastructure damage, livestock damage, agriculture damage. **[Action:** State / UT Admin/ IMCT**]**

e) Ensure calculation of the compensation required to be provided to the population exposed to the hazard. **[Action:** State / UT Admin**]**

f) Decide on rehabilitation of population once impounded water has drained out. CWC can assist in advising the safe levels. **[Action:** State/ UT Admin/ CWC/NRSC/NTRO**]**.

g) In cases where the dam has breached, Post Breach Analysis and Assessment by team of experts shall be carried out and further course of action recommended. **[Action:** State / UT Admin**]**

h) All concerned / involved Ministries and Govt. organizations must ensure they have adequate well-trained experts so that they can be speedily moved to the disaster site. **[Action:** State / UT Admin/ CWC/SASE/SOI/BRO/CIMFR/ ITBP**]**

i) Compendium of recommendations and lessons learnt shall be drawn and shared with all concerned agencies / Depts. **[Action:** State/ UT Admin/ Expert Team Leader**]**

Conclusion

The SOP on "Averting Threats Emanating from Glacial Lake Outburst Floods (GLOF) and Landslide Lake Outburst Flood (LLOFs) in Himalayan Region" gives out detailed actions /steps to be taken by respective authorities in the event of GLOF/LLOF. It is, by no means, exhaustive but a referral document which needs periodical modification with sharing of experiences and best practices across the country.

Chapter 8: Research and Development

8.1 INTRODUCTION

Typically, GLOFs increase to peak flow then gradually or abruptly decrease to normal levels once the water source is exhausted. Therefore, outburst flood peak flow is directly related to lake volume, dam height and width, dam material composition, failure mechanism, downstream topography, and sediment availability. In order to get the maximum GLOF peak at any location, the breaching of moraine dams of above glacial lakes have to be considered along with channel routing. GLOFs tend to entrain large amounts of sediment, with the potential to transport massive boulders, particularly in the upper reaches where channel gradients in high mountain catchments are often steep. This is particularly true for floods from moraine dammed lakes, which frequently transform into debris or hyper concentrated flows following the entrainment of material from the moraine and immediate downstream channel. Due primarily to their large flow depths and locally high energy gradients, GLOFs produce erosive forces far greater than typical meteorological floods would for the same stream conditions.

In long stream channels such as in the Himalayas and the Andes, dynamic flow transitions are often observed for GLOFs, from initial debris flow types to hyper concentrated flows and possibly back to debris flows depending on channel slope and availability of erodible material. Flood paths extending up to 100 km and even more have been observed (Carey et al., 2012; Cenderelli and Wohl, 2003; Schwanghart et al., 2016). A time series water sampling of trans-boundary fluvial systems and their hydro-geochemical analyses has been done to trace the origin of the flash floods in the headwaters of Himalayan Rivers (Rai and Singh, 2007).Towards this, the collected discharge data of CWC may be used for the validation. Further, atmospheric phenomenon like cloud bursts and intense rainfall may be studied by establishing advanced instrumentation like Doppler RADAR systems and Automatic Weather Stations (AWS) at high altitudes.

8.2 RESEARCH ISSUES & CHALLENGES

The purpose of the modelling is to reconstruct a historical GLOF, or to investigate the impact of a potential future GLOF. The models are required to give the user an estimated peak breach discharge, and time to peak discharge, and require prior knowledge of the moraine geometry (e.g. its height, width, length) and/or the glacial lake (e.g. it's volume, depth, and surface area), which can be plugged into a simple equation.

Key challenges that modelers face here stem in large part from the incredible complexity of these flows. Assessment of the accuracy of such models also requires the availability of pre and post-flood DEMs, which allow the modeler to see whether the modelled patterns of erosion and deposition match those observed in reality for documented GLOFs. However, these data are rarely available due to the logistical (and financial) challenges associated with producing repeat topographic surveys of often remote and largely inaccessible valleys, as well as predicting if and when a given moraine will fail. Further, for most glacial lakes, a hazard assessment cannot rely on information from past GLOF events (such as observed erosion patterns, for instance), as lake outbursts often are single events, without historical precedence. Nevertheless, current scientific state-of-the-art techniques for GLOF hazard modelling relies on scenario-based, future-oriented numerical models, that are coupled

according to the chain of processes involved in a GLOF (cf. Chapter 3, as well as GAPHAZ 2017, Jain et al., 2012, Schneider et al. 2014, Frey et al. 2018, Mir et al., 2018). Recent efforts include modeling approaches that are able to simulate entire chains of mass movement processes within a single modeling framework (Mergili et al. 2017, 2020). There is still a large research potential both in the development of hazard scenarios and the estimation of related uncertainties, as well as the numerical modeling of mass movements involved in a GLOF.

A wider area of research is related to the use of local knowledge for disaster risk management. Local population in the IHR has a long-standing experience in dealing with hazards and risks from glacial lakes. In particular when considering the common lack of observational data in remote mountain regions, local knowledge can indeed provide valuable information on past conditions and events. Further, involvement of the local population in disaster risk reduction efforts is indispensable (cf. Chapter 4). Another area with research potential include the integration of socio-economic assessments and developments in risk assessments and management strategies, which requires the involvement of and collaboration with social scientists.

8.3 EFFECT OF FUTURE CLIMATE CHANGE

In relation to climate warming and cryospheric changes, a primary challenge concerns the anticipation and assessment of hazards resulting from a fundamental change from glacial to periglacial landscapes (Haeberli et al., 2016). Disappearance of glaciers, permafrost degradation, landscape evolution and corresponding changes in inter-connected surface processes are cumulative developments that lead far beyond historical precedence. Future conditions will in many places be far removed from the past and present and therefore limit the value of historical event inventories. Quantitative, future-oriented and scenario-based system approaches must therefore be applied (see Chapter 3). However, modelling future high-mountain landscapes with their complex systems of interacting surface processes and landforms is a young, emerging research field, and uncertainties are inherently large. Individual components within the complex system have strongly diverging characteristics in their response to climate change. By comparison, due to slow heat diffusion and retarding effects from latent heat exchange in subsurface ice, permafrost degradation is a slow process with long-term commitments. Corresponding deglaciated landscapes can therefore be expected to turn into periglacial landscapes characterised by slowly degrading permafrost, numerous new lakes and pronounced disequilibrium in conditions concerning vegetation cover, slope stability and sediment cascades.

In view of the large uncertainties involved with anticipating such conditions, focused monitoring using advanced space-borne and terrestrial technology is required in case of high hazard or risk levels, coupled with regular re-assessment of the general conditions and specific hazard situations. The formation of new lakes located within increasingly close proximity to steep and destabilizing mountain headwalls has the potential to greatly enhance regional risks from far-reaching flood waves. Corresponding hazard and risk management relating to low-probability events with extreme damage potential is especially difficult for planning, policymaking and decision taking. Furthermore, the expected penetration of humans with their infrastructure for tourism, traffic or hydropower, etc., into previously un-accessible or even avoided high mountain areas must be taken into account.

CHAPTER 9: REGULATION AND ENFORCEMENT

9.1 INTRODUCTION

The widespread loss of property and life during the recent GLOF events (such as the Kedarnath disaster) have shown that most construction plans are ill conceived and do not follow the building standards or design codes. Climate change is expected to alter and potentially increase the probability for lake outbursts in the future posing potential threats in the downstream settlements. Urban centers, towns and some villages in mountain areas are being burdened beyond their capacity by tourism and rural-to-urban migration while the loss of large areas of farmland has ruined livelihoods of rural communities and affected the food security in the mountains. New regulations need to be framed for the Himalaya keeping in mind the hazards due to GLOF/LLOF and the causative factors of cloud burst, flash flood, earthquakes. In the case of existing structures, as it is difficult or impossible to alter land use, specific construction codes are required to reach the desired protection level. Regulations and enforcement are required on two fronts - namely, (i) a no habitation/ construction zone in the GLOF hazard area as determined from flood plain zoning studies; and (ii) the strict enforcement of the existing building standards/regulations which have been derived from various laws pertaining to planning and development. Subsequently, it is necessary for their implementation by the multiple agencies in a holistic manner.

9.2 IDENTIFIED GAPS

There is a need for a Himalaya GLOF Mitigation Policy and a Himalaya GLOF/LLOF Mitigation Strategy. The following needs are identified for the Himalaya: -

(1) Himalaya GLOF/ LLOF Mitigation Policy (HGLMP) which is a must for Himalaya GLOF/ LLOF Mitigation Strategy (HGLMS) should be common all over the Indian Himalaya States. HGLMS must be developed by the States and be area/problem specific but must reflect the HGLMP. Emphasis must be given to prevention/ preparedness in HGLMP/HGLMS.

(2) The existing bye laws/regulations at the local body or state/central level should be incorporated in the HGLMP and HGLMS. They should not contradict each other. The HGLMS must focus on implementation and enforcement of laws/ regulations and accountability.

(3) Necessity of flood hazard zonation, slope and land-use maps to guide urban planners for clearing constructions. For this, cloud burst forecasting, flash flood modelling and slope instability analysis reflecting the potential for extreme rainfall, flooding, landslides representing the ongoing event/process are required and should be two separate components of HGLMS.

(4) HGLMP and HGLMS should not contradict National Environment Policy and therefore, they should be validated by the MoEFCC.

(5) Best practices which are used to mitigate floods and landslides at the local level and activities which can be

held responsible for the GLOF/ LLOF hazard should be documented in the HGLMP.

(6) There is a need to have specific land use policy for the Indian Himalaya Region for the regions facing GLOF/ LLOF hazard, especially at the micro-level under the jurisdiction of the local bodies. Coordination among the panchayats, line departments, forest department and municipal authorities for management of water bodies and drainage outside municipal limits is also required.

(7) State specific GLOF/ LLOF mitigation strategies to be formulated to address specific issues of each mountain state.

(8) The municipal bye-laws must provide for regulating construction activities in areas that fall in hazard zones or areas close to rivers, springs and watersheds of the towns. In many cases these provisions exist in the bye-laws but need to be strictly enforced.

(9) As there is no specific standards/ code(s) are available with respect to GLOF/LLOF hazards, the same must be developed by BIS.

9.3 TECHNO-LEGAL REGIME

To address the special problems of towns and villages located in GLOF/ LLOF susceptible areas, necessary modifications must be made to the Model Town and Country Planning Legislations (2016), Zoning Regulations, Development Control, Building Regulations/Bye-laws taking into consideration the special conditions of the Indian Himalaya Region. Such laws are mainly state legislations as the state is competent to legislate and make laws on such subjects. The Environmental Regulations and Environment Impact Assessment (EIA) according to the notifications of the MoEFCC must also be included in the techno-legal regime.

9.3.1 Model Building bye-laws 2016

Building bye-laws are legal tools used to regulate coverage, height, building bulk, and architectural design and construction aspects of buildings to achieve orderly development of an area. The Town and Country Planning Organization under the Ministry of Housing and Urban Affairs has recently prepared the "Model Building Bye-laws -2016" for the guidance of the State Governments, Urban Local Bodies, Urban Development Authorities, etc. Under the natural hazards, the committee has included the hazards due to earthquakes, cyclones, floods, and landslides. However, no specific mention of GLOF/ LLOF events is given in the bye-laws.

9.3.2 Regulations for Land Use Zoning for Natural Hazard Prone Areas

Zoning regulations are legal tools for guiding the use of land and protection of public health, welfare and safety. The regulations for land use zoning for natural hazard prone areas are notified under Town and Country Planning Act as applicable in the respective States as and when Master Plan/ Development Plan of different cities/towns/areas are formulated. These zoning regulations are implemented through the provisions of Development Control Regulation/Building Bye-laws, wherever the Master Plan are not in existence or not formulated.

A detailed guideline for land use zoning has been prepared with an objective to regulate land use in hazard prone areas to minimize the damage caused to the habitat, as a result of natural hazards viz. earthquakes, cyclonic storms, landslides and floods. These include prioritization of types of buildings for land use zoning.

9.3.3 Indian Standard Codes

The National Building Code published by the Bureau of Indian Standards in 2016 and subsequent revisions are advisory in nature and not mandatory. The code also covers aspects of administrative requirements and bye-laws including building services.

As landslides and GLOF are closely interrelated, for protection of landslide hazard, two IS codes are mentioned for ready reference- (i) IS 14458 (Part 1): 1998 Guidelines for retaining wall for hill area: Part 1 Selection of type of wall; and (ii) IS 14458 (Part 2): 1997 Guidelines for retaining wall for hill area: Part 2 Design of retaining/breast walls. (iii) IS 14458 (Part 3): 1998 Guidelines for retaining wall for hill area: Part 3 Construction of dry-stone walls, (iv) IS 14496 (Part 2): 1998 Guidelines for preparation of landslide – Hazard zonation maps in mountainous terrains: Part 2 Macro-zonation

9.3.4 Related NDMA Guidelines

The NDMA has also issued guidelines on landslides, floods and urban flooding and a National Landslide Risk Management Strategy (2019) which are relevant to GLOF/ LLOF. However, considering the special characteristics of the GLOF events, there is a need for special regulations for areas situated downstream of GLOF/ LLOF hazard areas.

9.3.5 Initiatives of the Ministry of Environment, Forest and Climate Change (MoEFCC)

The Ministry of Environment, Forest and Climate Change (MoEFCC) is the nodal agency in the administrative structure of the central government for planning, promotion, co-ordination and overseeing the implementation of environmental and forestry programs. Certain initiatives of MoEFCC are relevant in the context of flooding in hilly areas. The Environmental Impact Assessment (EIA) is one of the proven management tools for incorporating environmental concerns in development process and in improved decision-making. The EIAs were initiated with the appraisal of river valley projects and now includes other sectors like industrial projects, thermal power plants, mining schemes and infrastructure projects, etc. Guidelines will be issued to State EIA Authorities to subject even smaller projects to meet EIA norms.

9.3.6 State Level Legislation

The planning and development are state subjects and therefore, the development in the states is based on the legislative support as applicable in that state. The legislative support in the state is applicable to formulate Master Plans, Zonal Development Plans and Area Planning layouts for their implementation and enforcement.

9.3.7 Legislative Support at the Local/ Municipal Level

At the local level, the Municipal Authorities and Panchayats regulate the development/construction of buildings through the building bye-laws as followed in their respective areas. The State Governments/UTs from time to time issue directions/guidelines for safety against natural hazards, which are followed by local bodies while granting permission for construction of buildings/ structures.

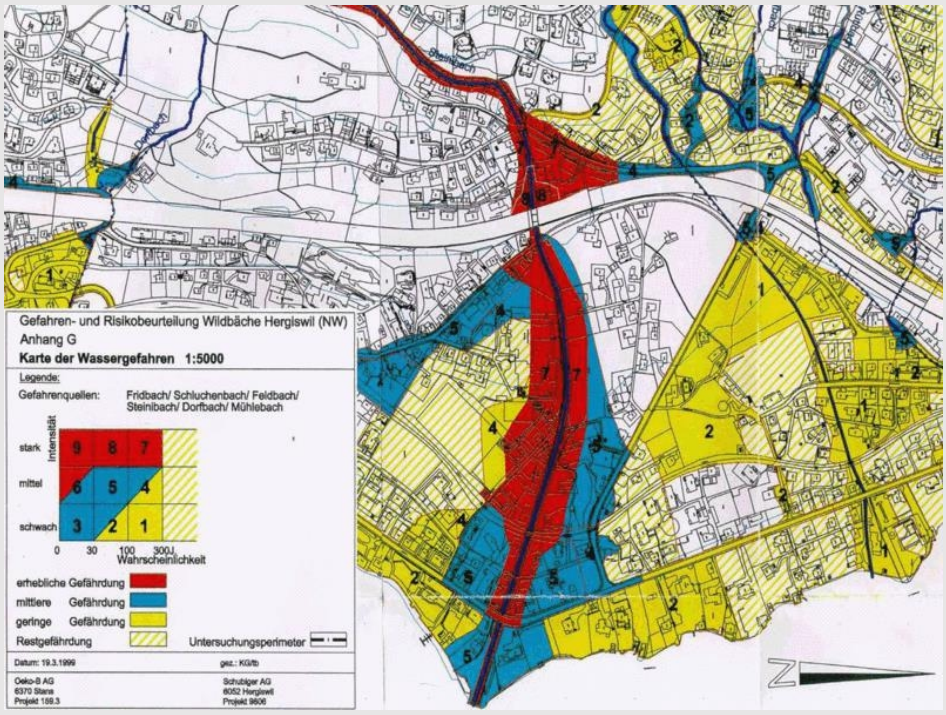
9.4 TECHNO-LEGAL REGIME AND RISK MANAGEMENT IN SWITZERLAND

Box 1: Example of Zoning Regulations and Hazard Assessment in Switzerland

Switzerland is a mountainous country that has a long history of living and responding to natural hazards, including GLOFs. The Federal Flood Protection Law and the Federal Forest Law came into force in 1991. The purpose of these laws is to protect the environment, human lives and property from the damage caused by water, mass movements, snow avalanches and forest fires. As a result of these regulations, greater emphasis has been placed on preventative measures, and cantons are legally required to establish registers and maps denoting areas of hazards and to take them into account in their guidelines for landuse planning.

Hazard maps, according to the federal guidelines express three degrees of danger, represented by corresponding colours: red, blue and yellow. This ensures homogeneous and uniform means of assessment of the different kinds of natural hazards affecting Switzerland. Within the **red** zone (high hazard), development is generally prohibited. In the **blue** zone (moderate hazard), development is strongly regulated, while in the yellow zone (low hazard), people need to be notified and alerted of possible hazards.

Importantly, hazard maps are compiled for all the different processes that are relevant for a specific site or settlement. This has important implications for spatial planning, since being outside the GLOF hazard zone, for example, does not necessarily imply to be safe from avalanches or other flood hazards. Hence, risk management follows a multi-risk approach.



Box 1: Example of a flood hazard map for the village of Hergiswil, central Switzerland (http://www.planat.ch/en/authorities/hazard-maps)

9.5 RECOMMENDATIONS

There are no widely accepted procedures or regulation in India for land use planning in the GLOF/LLOF prone areas. Therefore, a committee should be constituted to formulate specific land use zoning, development control and building construction regulations need to be developed concerning the increased risk of future GLOF/LLOF events and give its recommendations within a year. The following actions are recommended for preparing techno-legal regime for cities, towns and villages in GLOF hazard areas also considering the associated hazards of cloudburst, flashflood, earthquakes and landslides.

9.5.1 Policy Level Recommendations

The State Governments / Sanctioning authorities should have a panel of reputed and technical personnel including SDMA, who can assist the building sanctioning authority in formulating GLOF specific regulations. They should take into consideration the Government Orders issued by the various State Governments which contain a number of provisions to be followed while sanctioning the building plans by the Development Authority, Special Area Development Authority, Corporation, Municipal Board and also by the concerned government department while formulating the regulations. At present there are several Acts/Rules/ Regulations applicable in the states. There should be single legislation to control development and building activity which could be formed taking into consideration present legislative framework and incorporating the suggestions made and should follow strictly the provisions suggested for safety against natural hazards e.g. the provision of Indian Standards. EIA should also consider the expected GLOF event(s) for future projects in GLOF hazard areas.

9.5.2 Technical Level Recommendations

The regulations should make it mandatory for all buildings, especially hospitals, schools, community halls to be designed according to the latest specifications and codes, for example the National Building Code of India, 2016. The special technical committee should recommend additional measures to be included in GLOF hazard areas.

9.5.3 Community Level Recommendations

There is a need to bring awareness at all levels of society starting with a high-level awareness program for decision makers regarding safety against natural hazards and the techno-legal regime. Awareness/ training program is required for engineers/ officials working with local authorities regarding bye-laws, regulations, codes and manuals for disaster resistant construction.

9.5.4 Tourism Level Recommendations

The regulations should be made to create the buffer zone to restrict the tourism in GLOFs prone areas and nearby region to reduce the impact of pollution in those areas. This should be monitored by state tourism committee to reduce the frequency of GLOF occurrences and recommend additional measures to be included in GLOF hazard areas. Awareness programmes/ notices should be disseminated for instructions, in collaboration with local authorities for disaster resistant tourism services.

Chapter 10: Implementation of The Guidelines— Preparation of GLOF & LLOF Management Plans

10.1 PLAN OF ACTION

Comprehensive DM plans will be prepared at the National, State and District levels. At the National level, the DM plan will focus on various aspects of DM including preparedness, mitigation and response. These plans will clearly identify the roles of key stakeholders for each disaster level and also include assessments of their own response capacities.

There is no Nodal Ministry and Agency identified for the subject on glacial studies including Glacial Lake Outburst Flood (GLOF) and Landslide Lake Outburst Flood (LLOF). Although, Central Water Commission (CWC) was monitoring the glacial lakes including water bodies from the year 2009 onwards and also identified to provide mitigation measures for landslide dams in the NDMA Guidelines on Management of Landslides and Snow Avalanches (June, 2009). Therefore, it is proposed to identify the Ministry of Jal Shakti (MoJS) as Nodal Ministry and CWC as Nodal agency for the glacial studies including GLOF and LLOF.

[**Action:** The MoJS/CWC]

These plans will be subjected to approval from NDMA, will include various aspects of glacial and landslide hazard management especially GLOF and LLOF. The main features to be included in the plan are as follows:

i) Preparation of state and district level DM plans with the aim of managing GLOF and LLOF hazard events.

ii) Revision of town planning bye-laws and adaptation of model land use bye-laws in hilly areas.

iii) Wide dissemination of model land use planning practices in hilly areas.

iv) Establishing appropriate mechanisms for compliance review of all land use planning and building bye-laws in hilly areas.

v) Enforcing and monitoring the compliance of land use and town planning bye laws, and other safety regulation in areas vulnerable to GLOF/LLOF.

vi) Training of trainers in professional and technical institutions.

vii) Training of professionals like engineers and geologists for hazard assessment and mapping, investigation techniques, analysis and observational practices

viii) Launching Public awareness campaigns on GLOF & LLOF hazard and risk reduction, and sensitizing all stakeholders on hazard mitigation.

ix) Preparing an inventory of past and recent GLOF and LLOF events.

x) Developing an inventory of critical lakes including attributes based on Geospatial and on field analysis like topography, rock type etc.

xi) Assessing the status of risk (exposure and vulnerability) of the existing built environment.

xii) Preparation of the DM plans by educational and health institutes/ organisations, government offices, etc., and carrying out mock drills for enhancing preparedness in vulnerable

areas.

xiii) Strengthening the EOC network.

xiv) Streamlining the mobilization of communities, government agencies, the corporate sector, and other stakeholders.

xv) Preparing community and village level DM plans, with specific reference to the management of GLOFs and LLOFs.

xvi) Developing simple and effective information and warning dissemination systems that can reach affected communities in far flung areas clearly and in time.

xvii) Introducing GLOF and LLOF safety education (as a sub-group to Landslide and Flood education) in schools, colleges and universities.

xviii) Strengthening hazard safety R&D in professional technical institutions.

xix) Preparing document on the lessons learnt from previous GLOF and LLOF incidents, and their wide dissemination.

xx) Preparing an action plan for upgrading the capabilities of organisations and institutions involved in Glacial, Landslide and Flood disaster management studies with clear roadmap and milestones.

xxi) Developing appropriate risk transfer instruments by collaborating with insurance companies and financial institutions.

The proposed timeline for the implementation of the various activities in Guidelines are both important and very necessary especially in case of the non-structural measures for which no clearance is required from central and other agencies. Structural measures will be dealt with precise schedules evolved in the GLOF/LLOF management plans that will be followed at the central/state ministries, duly taking into account the availability of financial, technical and managerial resources. A strategy plan of implementation of various activities in the guidelines needs to be devised at the state and central level.

10.1.1 Short Term (1-2 years)

i) Formation of Specialized Committee under MoJS/CWC in consultation with NDMA involving expert agencies/institutes dealing with research and development on Glacial, Landslide and Flood Hazards to formulate specific land use zoning, development control, building construction regulations etc.

[**Action:** The MoJS/CWC in consultation with NDMA]

ii) Taking up pilot projects at least at 10 sites in the next two years to strengthen up the existing methodology right up to hazard and risk level.

[**Action:** The MoJS/CWC in consultation with concerned State/UT Disaster Management Authorities and other stakeholders]

iii) Hiring group of expert agencies to identify susceptible sites through Remote Sensing and GIS. Also, create a priority list by examining the vulnerability and associated risk for which immediate attention is required.

[**Action:** The MoJS/CWC in collaboration with NRSC and other stakeholders in consultation with NDMA]

iv) Development of Early Warning System (EWS) based on Ground Instrument, Water level sensors and Seismicity in consultation with Expert Institutes (such as NIH-Roorkee, C-DAC) and other nodal agencies.

[**Action:** The MoJS/CWC in consultation with concerned State/UT Disaster Management Authorities and other stakeholders]

v) Set up a regular monitoring system using remote sensing satellites and GIS.

[**Action:** The MoJS/CWC in collaboration with NRSC and other stakeholders]

10.1.2 Medium Term (3-4 years)

i) Already available BIS codes with respect to water projects are not sufficient for GLOF/LLOF; therefore, BIS needs to developed the same on different aspects of GLOF/LLOF in coordination/ collaboration with Nodal Ministry/ Agency.

[**Action:** The BIS in coordination with MoJS/CWC and other stakeholders in consultation with NDMA]

ii) **Improve and upgrade the current Early Warning System** keeping in view the validity and benefits of the results that were acquired during its active session.

[**Action:** The MoJS/CWC in consultation with concerned State/UT Disaster Management Authorities and other stakeholders]

iii) **Enhancing the mitigation measures by implementing the Risk Reductions Techniques namely:** Water lowering by Tunnel/ spillway and Hazard Reduction by Dam Construction.

[**Action:** The MoJS/CWC in consultation with concerned State/UT Disaster Management Authorities and other stakeholders]

iv) **Design of animated character for spreading awareness on disaster management (including GLOF/LLOF):** An animated character can be designed in partnership with computer animators.

[**Action:** The MoJS/CWC]

v) **Creation of a disaster management application:** NDMA in collaboration with the Indian Institute of Technology (IIT) can design a computer application for disaster management. The application can be used to know about the latest information on disasters (including GLOF/LLOF) across the country.

[**Action:** The NDMA in collaboration with MoJS/CWC and other Expert Institutions]

vi) **Awareness through documentary:** The National Disaster Management Authority (NDMA) should initiate a programme on power point documentary/presentation for Government organisation, School and Hospital organisation, Soldiers, NGOs, Local nodal agencies, Local club, and local people focusing on the role and responsibility before, during and after the GLOF/LLOF disaster.

[**Action:** The NDMA in collaboration with MoJS/CWC and concerned State/UT Disaster Management Authorities and other stakeholders]

vii) **Creation of village task force and volunteers:** The not-for-profit organizations should constitute a village task force and volunteers (Aapda Mitra) in each village of these states. The members of the task force should be made aware of the various aspects of GLOF/LLOF mitigation and post-disaster activities.

[**Action:** State/UT Disaster Management Authorities in consultation with NDMA]

10.1.3 Long Term (5-8 years)

i) **Use of web-based and app-based dissemination tools** for the preparation of maps for common use not only by the administrators but also by the community, tourists etc.

[**Action:** The MoJS/CWC in collaboration with Expert Institutions]

ii) **Wireless sensor network (WSN)** based ground instrumentation and real time monitoring of GLOF/LLOF.

[**Action:** The MoJS/CWC in collaboration with Expert Institutions and consultation with State/UT Disaster Management Authorities]

iii) **Incorporation of latest and advanced mitigation measures** to reduce the risk.

[**Action:** The MoJS/CWC in collaboration with Expert Institutions and consultation with State/UT Disaster Management Authorities]

iv) Incorporation of the advanced Evacuation and Emergency planning measures.

[**Action:** The MoJS/CWC in collaboration with Expert Institutions and consultation with State/UT Disaster Management Authorities]

v) **Awareness programme on GLOF/LLOF hazard:** Government (National/ State) has also emphasized on a robust awareness programme for GLOF/LLOF hazard. Public awareness is being enhanced about signs and events that manifests that a GLOF/LLOF is imminent so that personal safety measures may be taken.

[**Action:** The MoJS/CWC, NDMA and State/UT Disaster Management Authorities in consultation with Expert Institutions]

vi) **Use of traditional art forms/ traditional knowledge:** Due to modernization and tech savvy nature of 21stcentury generation, old traditions disaster management practices are dying up. Therefore, it is necessary to document and disseminate old traditional best practices available in mountain regions of India through community participation in trainings. Traditional art forms are important mediums of awareness generation. Traditional knowledge and modern technologies are also useful in designing Early Warning System (EWS).

[**Action:** The MoJS/CWC, NDMA and State/UT Disaster Management Authorities in consultation with Expert Institutions]

vii) **Awareness through Participatory Approach:** The planning and implementation process is recommended in order to maintain sustainability of the programs launched by the administration for disaster management. It is necessary that the government and the communities together evolve a joint action plan aimed at enhancing community education and the development of community leadership. The elements of participatory learning can be applied at different levels such as organizational level (headquarters,

branches, schools, businesses, work places), community level (village, town, cities) and population level (marginalized, vulnerable sections).

[**Action:** The MoJS/CWC, NDMA and State/UT Disaster Management Authorities in consultation with Expert Institutions]

viii) **Involvement of Not-for-Profit Organisations:** NDMA should identify not-for-profit organisations to undertake the awareness building activities in these States. The organisation should be asked to submit a targeted awareness generation plan.

[**Action:** The MoJS/CWC, NDMA and State/UT Disaster Management Authorities in consultation with Expert Institutions]

ix) **Awareness among school children, their parents and teachers:** The not-for-profit organisations can organise sessions for school children, their parents and teachers from Class IX onwards on various aspects of GLOF/LLOF occurrence and their mitigation. A one-day training module can be designed for the participants.

[**Action:** The MoJS/CWC, NDMA and State/UT Disaster Management Authorities in consultation with Expert Institutions]

x) **Awareness among local youth:** The not-for-profit organisation can hold a day long awareness generation camp with the members of the National Cadet Corps (NCC), Scouts and Guides, and National Service Scheme (NSS) volunteers. These camps should be conducted in coordination with the state and district teams of these organisations.

[**Action:** The MoJS/CWC, NDMA and State/UT Disaster Management Authorities in consultation with Expert Institutions]

xi) **Awareness among members of Panchayati Raj Institutions:** On similar lines; the not-for-profit organizations can also hold a one-day awareness generation workshop for the Panchyati Raj Institution (PRI) members of the various panchayats in the district in the district headquarter. The Community Based Family Disaster Preparedness and mitigation (CBFDP) is a process to capacitate communities to prevent, mitigate and cope with disasters effectively.

[**Action:** The MoRD and State/UT Disaster Management Authorities in consultation with Expert Institutions]

xii) **Awareness among policy makers and government officials:** The policy makers are key stakeholders in disaster management. State Disaster Management Authority (SDMA) can hold workshops with policy makers and government officials of all departments to reinforce their role in ensuring that people conform to the various land use policies.

[**Action:** The MoJS/CWC, NDMA and State/UT Disaster Management Authorities in consultation with Expert Institutions]

xiii) **National Data Centre on GLOF/LLOF:** It would integrate various data sources, a geo-portal to address the data needs and thus, enable an effective response.

[**Action:** The MoJS/CWC in consultation with NRSC-ISRO]

xiv) **Climate Change related GLOF/LLOF risk management:** The past incidences clearly indicate the high frequency as well as intensity of the hydro-meteorological hazards in the mountain region such as heavy rainfall, landslides, riverine floods, cloud burst, Glacial Lake Outburst Floods (GLOFs), droughts etc. Therefore, local communities require awareness, specialized training and right information to cope up with disasters in the mountains.

[**Action:** The MoJS/CWC, NDMA, NIDM and State/UT Disaster Management Authorities in consultation with Expert Institutions]

Section 7.11 of NDMP (2019) may also be referred for any other specific responsibilities of Central/ State agencies related to GLOF.

10.2 IMPLEMENTATION AND MONITORING

10.2.1 Institutional Mechanisms

The National Disaster Response Force (NDRF)/SDRF mandated by the DM Act, 2005, will address, in close collaboration with all other field level agencies, all concerns regarding the response to the threat of GLOF/LLOF disaster or other disasters if and when these arise or occur.

The NDRF/SDRF personnel will be equipped with the most modern search and rescue equipment and will undergo GLOF/LLOF specific training to be able to effectively deal with diverse types of GLOF/LLOF and other mass movements and familiarise themselves with the case records of some of the major GLOF/LLOF events.

The projects prepared by the central ministries, departments, state governments, district authorities, rural bodies, urban local bodies, and other stakeholders in accordance with these Guidelines will be implemented by them in accordance with in-built schedules. These plans will indicate clearly the structure of the monitoring as per Govt. of India norms and the reports to be generated at various levels together with the agency to which the report is to be sent, its format and the frequency/timing.

10.3 FINANCIAL ARRANGEMENTS

10.3.1 Mainstreaming of Disaster Management in Developmental Plans

The central and state ministries/ departments will mainstream disaster management efforts in their developmental plans. In the annual expenditure plans, specific allocations will be made for carrying out disaster awareness programmes, maintaining preparedness and for undertaking mitigation efforts. Wherever necessary and feasible, the corporate sector should also be involved in supporting risk management efforts as part of Corporate Social Responsibility (CSR).

10.3.2 Plans of Central Ministries/ Departments

The various measurement for GLOF management recommended in the Guidelines will be funded by the central ministries/ departments and state governments concerned by making provisions in their Five-Year and annual plans. Additional funds will also be made available through special mitigation projects to be formulated and implemented by the state governments/SDMAs under the overall guidance and supervision of the NDMA. Besides this, 10 per cent of the Calamity Relief Fund (CRF) could also be utilized for the purchase of equipment for GLOF preparedness and mitigation, and for rescue and relief operations.

[**Action:** SDMAs in collaborations with Central Ministries]

10.3.3 State Plans

GLOF management schemes would be

planned, funded, executed and maintained by the state government themselves as per their own priorities. Central plan assistance would be in the form of block loans and grants and would not be tied to any sector or project. Allocations for the GLOF sector within the overall plan outlay would have to be made by the state government themselves. The various measures for GLOF management recommended in these Guidelines will be included by the respective state government in their own plans.

[**Action:** State governments/SDMAs]

10.3.4 Centre for Glacial Research, Studies & Management (CGRSM)

A national level ***Centre for Glacial Research, Studies and Management (CGRSM)*** will be established by the MoJS under the umbrella of the National Institute of Hydrology (NIH), Roorkee as a premier centre with state-of-the art facilities, which would eventually grow into a national centre of excellence. It will be fully autonomous in its functioning, similar to that of the national laboratory of the Council of Scientific and Industrial Research with full operational freedom and an independent budget. It will operate within a framework of specified rules. The CGRSM will be headed by an eminent expert with a proven track record.

This initiative will help in ensuring a wider view of glacial studies as a component of the environment/climate change and bringing the existing pool of expertise in earth sciences including hydrology, geomorphology, seismology, meteorology, landslide, IT etc. to bear upon this new initiative.

The national centre will be serviced by a nation-wide chain of actual as well as virtual sub-centres (field offices) in high-altitude to ensure adequate national coverage, information flow, community participation, networking, feedback etc. It will also foster, promote and sustain a scientific culture in the glacial studies including GLOF/LLOF aiming for a paradigm shift in the culture of prevention and safety. It will aim to galvanise the existing scattered pool of scientific and technological expertise especially in subjects such as geomorphology, earth sciences, meteorology, seismology, space research, IT and communication technology, urban development, remote sensing etc. Other areas of concern to be addressed by the centre will be to learn lessons from past incidences and arranging for high quality education, research, training and documentation. To begin with sub-centres (field offices) will as far as possible, be located in one of the existing knowledge institutions to be identified in consultation with the State Government. The network could be gradually expanded in tune with the dynamics of felt needs. The establishment of virtual sub-centres will be encouraged to serve as clearing houses of information. The national capacity building initiative of the central and state governments would make adequate funding provisions to ensure a critical mass of staffing and infrastructure in the field offices, The CGRSM will nurture the field offices, eventually making them financially self-supporting within the time frame of one decade.

In the field of geotechnical investigation and research, the CGRSM will coordinate and collaborate with the national and international Institutions such as Wadia Institute of Himalayan Geology (WIHG), NCPOR-Goa, NRSC-ISRO, IIRS-ISRO, SASE-DRDO, Zurich University, SLF DAVOS, NGI etc, as well as scientific organizations such as the Standing Group on Glacier and Permafrost Hazards in Mountains (GAPHAZ) of the International Association of Cryospheric Sciences (IACS) and the International Permafrost Association (IPA).

[**Action:** The MoJS in consultation with NDMA]

10.3.5 Centrally Sponsored/Central Sector Schemes

The role of the central government is advisory, promotional and facilitative in nature. On specific requests from the state governments, the MoJS/CWC will include some of the works / schemes in consultation

with NDMA and Technical Advisory Committee (TAC) as recommended in the Guidelines for funding under these schemes, provided that sufficient funds are available. A high level scientific and TAC which will be chaired by the Secretary, MoJS will be constituted by the MoJS in consultation with the NDMA to serve as a think tank to nurse the glacial studies with cutting edge science and technology, fresh ideas and stimulus.

TAC will also make recommendations to the GoI on various aspects of the CGRSM including its formation, aims and objectives, funding, functioning and autonomy.

The Joint Secretary, NDMA; Joint Secretary, MoEFCC; Joint Secretary, MoES; Joint Secretary, MoJS; Joint Secretary, DST and Executive Director of the NIDM will be ex-officio members of both CGRSM and TAC.

[**Action:** The MoJS-CWC]

The TAC will comprise top professionals (either national or international) drawn from multi-specialty streams of Government, Private, Independent researchers connected with glacial studies including GLOF/LLOF and it will address research, human resource and capacity development, glacial mapping, investigation, mitigation, control, preservation and protection of glacier as a component of the environment.

It will also provide full support to the human resource development and training functions delegated to the NIDM and other national institutions.

[**Action:** The MoJS in consultation with the NDMA and MoEFCC]

10.3.6 District Planning and Development Council Funds

From the funds available with the District Planning and Development Council in GLOF prone areas, a part will be allocated for the implementation of GLOF management schemes in the districts.

[**Action:** State/UT Admin]

10.3.7 Comprehensive and Pilot National GLOF Mitigation Projects

The NDMA has proposed to take up a pilot and Comprehensive Mitigation Project on GLOF (CMP-GLOF) whose aims and objectives will be developed and finalized in due course. In a broader sense, it will consider the following issues:

i) Assessment of the risk and vulnerabilities associated with GLOF disasters.
ii) Reduction in the degree of the risk, severity or consequences of GLOF and improving their mitigation.
iii) Setting pace setter examples for geological and geotechnical investigations of GLOF and also for efficacy of GLOF treatment measures.
iv) Establishment of monitoring and early warning systems for susceptible glacial lakes.
v) Capacity development of institutes/ organizations enhancing the capabilities of communities and training of functionaries.
vi) Identification of institutes/ organizations and entrusting them with the implementation of R&D programs.
vii) Enhancing the promptness and efficacy of response to impeding threats of GLOF or their actual occurrence.
viii) Ensuring that proper arrangements are made for organizing rescue, relief and rehabilitation works.
ix) Improving the quality and increasing the speed of rehabilitation and reconstruction process.
x) Spreading awareness with a stress on preparedness and providing advice and training to the agencies involved in the management of GLOF.

[**Action:** The NDMA in collaboration with MoJS/CWC]

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Appendix 1

Factors to be considered under an assessment of ice avalanche susceptibility/stability (from GAPHAZ 2017)

Susceptibility factors for Ice Avalanches	Relevance			Key Attributes	Susceptibility		Assessment methods	Assessment scale
	Con.	Trig.	Mag.		Lower	Higher		
Atmospheric								
Temperature	+	+		Mean temperature	No trend	Strong trend	Station-based or gridded climate analyses	Basin
				Intensity and frequency of extreme temperatures	Low	High	Station-based or gridded climate analyses	Basin
Precipitation		+		Intensity and frequency of extreme precipitation events.	Low	High	Station-based or gridded climate analyses	Basin
Cryospheric								
Thermal conditions	+			Cold, polythermal or temperate glacier. Distribution and persistence of permafrost. Thermal anomalies due to hanging glaciers.	Expert judgement of implications for failure mechanisms and processes.		Model-based (indirect) Geophysical (semi-direct) Boreholes (direct)	Regional to basin. Site specific.
Glacier type	+		+	Cliff or ramp type situation.	Expert judgement of		Remote sensing	Regional

						implications for frequency/magnitude.			to basin
Crevasse density and orientation	+			+	Formation of cracks across glacier. Size and depth of crevasses.	Not evident	Large and widespread	Remote sensing	Basin to site specific
Bed topography	+				Steep slope angle and sudden breaks in topography. Convex slopes. Lack of frontal abutment.	Favorable	Unfavorable	Inferred or modelled from surface topography. Geophysical survey.	Regional to basin. Site specific.
Glacial hydrology	+	+			Distributed subglacial drainage system for ramp-type failures. Evidence of increased water pressure and or blockages (critical for polythermal glaciers), such as pooling at surface or sudden changes in discharge for large catastrophic failures.	Favorable	Unfavorable	Remote sensing, hydrological modelling, and field studies.	Basin to site specific.
Glacier velocity	+				Increase in surface velocity, particularly below crevasse zones.	No change	Rapid increase	Remote sensing, field studies	Basin to site specific
Glacier geometric change	+				Thickening towards base of hanging glacier. Thickening of valley glacier tongue as evidence for surging.	No change	Large thickening	Remote sensing	Basin to site specific
Glacier length change	+				Retreating or advancing towards steeper topography, and/or new thermal regimes.	Favorable	Unfavorable	Remote sensing, field studies, anecdotal evidence	Regional to basin
Ice avalanches	+	+		+	Frequency and magnitude of instabilities, including serac fall.	Not evident	Frequent and increasing	Remote sensing, field studies, anecdotal	Basin to site specific

evident						activity	evidence.	
Geotechnical and geomorphic								
Underlying bedrock stability	+	+	+	SEE ROCK AVALANCHE SUSCEPTIBILITY ASSESSMENT (Appendix 2)	Unstable	Stable	SEE ROCK AVALANCHE SUSCEPTIBILITY ASSESSMENT	Basin to site specific
Seismicity	+	+		Potential magnitude & frequency, ground acceleration	Low potential	High potential	Geological mapping & modelling.	Regional

Appendix 2

Factors to be considered under an assessment of rock avalanche susceptibility/stability (from GAPHAZ 2017)

Susceptibility factors for Rock Avalanches	Relevance			Key Attributes	Susceptibility		Assessment methods	Assessment scale
	Con.	Trig.	Mag.		Lower	Higher		
Atmospheric								
Temperature	+	+		Mean temperature	No trend	Strong trend	Station-based or gridded climate analyses	Basin
				Intensity and frequency of extreme temperatures	Low	High	Station-based or gridded climate analyses	Basin
Precipitation		+		Intensity and frequency of extreme precipitation events.	Low	High	Station-based or gridded climate analyses	Basin
Cryospheric								
Permafrost conditions	+		+	State of permafrost, distribution and persistence within bedrock slopes. Depth of active layer and unstable mass.	No permafrost or cold permafrost	Warm (melting) permafrost	Model-based (indirect) Geophysical (semi-direct)	Regional to basin. Site specific.
Glacier conditions	+		+	Retreat (thinning) from within or below rock slope.	No retreat	Significant retreat	Remote sensing, field studies, anecdotal	Regional to basin

Geotechnical and geomorphic							evidence	
Rock mass quality	+		+	Lithological characteristics Degree of weathering	Favorable	Unfavorable	Geological mapping (remote sensing or field)	Basin to site specific
Condition of Discontinuities	+			Degree of weathering, aperture, filling (e.g. breccia or gouge), seepage	Favorable	Unfavorable	Geological mapping (remote sensing or field)	Basin to site specific
Geometry of Discontinuities	+		+	Dip, orientation, spacing, persistence	Favorable	Unfavorable	Geological mapping (remote sensing or field)	Basin to site specific
Condition of slope	+			Overhanging, convexities, irregularities	Favorable	Unfavorable	Geological mapping (remote sensing or field)	Basin to site specific
Slope angle	+			Topographic slope angle. Critical range or threshold angle established from local inventories.	Low slope angle	Steep slope angle	Geological mapping (remote sensing or field)	Basin to site specific
Slope height	+		+	Relative relief of the face or slope	Small	Large	Geological mapping (remote sensing or field)	Basin to site specific
Seismicity	+	+		Potential magnitude & frequency, ground acceleration	Low potential	High potential	Geological mapping &modelling.	Regional
Rockfall evident	+	+	+	Frequency and magnitude of past activity	Not evident	Frequency and increasing activity	Geological mapping (remote sensing or field)	Basin to site specific

Appendix 3

Factors to be considered under an assessment of GLOF susceptibility (from GAPHAZ 2017). Factors may be relevant for conditioning (Con.), triggering (Trig.), and/or the magnitude (Mag.) of any GLOF. For many factors, relationships with suscep tibility or stability are not straightforward, and the expert must apply judgement across a range of attributes to determine whether conditions are favourable (low susceptibility) or unfavourable (high susceptibility)

Susceptibility factors for GLOFS	**Relevance**			**Key Attributes**	**Susceptibility**		**Assessment methods**	**Assessment Scale**
	Con.	Trig.	Mag.		**Lower**	**Higher**		
Atmospheric								
Temperature	+	+		Mean temperature	No trend	Strong trend	Station-based or gridded climate analyses (e.g. IMD)	Basin
				Intensity and frequency of extreme temperatures	Low	High		
Precipitation	+	+		Intensity and frequency of extreme precipitation events (inc. snowfall).	Low	High	Station-based or gridded climate analyses (e.g. IMD or GPM-IMERG)	Basin
Cryospheric								
Permafrost conditions	+			State of permafrost, distribution and persistence within lake dam area and bedrock surrounding slopes	No permafrost or cold permafrost	Warm (melting) permafrost in dam area and/or surrounding	Model-based (indirect) Geophysical (semi-direct)	Regional to basin. Site specific.

						debris or bedrock slopes		
Glacier retreat and downwasting	+		+	Enlargement of proglacial lakes, enhanced supraglacial lake formation, dam removal or subsidence	No retreat, lake expansion, or dam subsidence	Significant retreat, lake expansion, or dam subsidence	Remote sensing	Regional to basin
Advancing glacier(incl. surging)	+			Formation of ice-dammed lakes	No change evident	Advance and damming evident	Remote sensing	Regional to basin
Ice avalanche potential	+		+	SEE ICE AVALANCHE SUSCEPTIBILITY ASSESSMENT (Appendix 1)	Lower	Higher	SEE ICE AVALANCHE SUSCEPTIBILITY ASSESSMENT	Basin to site specific
Calving potential	+		+	Width of glacier calving front, activity, crevasse density	Not evident	Large and frequent	Remote sensing and field studies.	Basin to site specific
Lake size	+		+	Area or volume	Smaller	Larger	Remote sensing, modelling of bed topography, field studies	Regional to site specific
Lake bathymetry	+		+	Influence on dam hydraulics, influence on displacement wave propagation and run-up	Favorable	Unfavorable	field studies (sonar measurements)	Site specific
Sub- Supra- or englacial drainage	+	+		Connectivity of the lake to the glacial hydrological system	Not connected	Well connected	Field studies and modelling	Site specific

Geotechnical and geomorphic								
a) Dam characteristics								
Type	+		+	Bedrock, moraine, ice	Bedrock	Ice, (ice-cored moraine)	Remote sensing	Regional to basin
Ice-cored moraine	+			Thickness, persistence, and condition (linked to permafrost)	Absent	Large and thawing	Geophysical field studies	Site specific
Dam width to height ratio	+		+	Width across the dam crest relative to the dam height	Larger	Smaller	DTM analysis, field studies	Basin to site specific
Freeboard to dam height ratio	+		+	Elevation difference between lake surface and lowest point of moraine.	Larger	Smaller	Remote sensing, DTM analysis, field studies	Basin to site specific
Lithology	+		+	Coarseness of moraine material, presence of fine-grained material, volcanic material etc.	Coarse material predominant	Fine-grained or volcanic material predominant	Field studies	Site specific
Downstream slope	+			Mean slope on downstream side of lake dam.	More gentle	Steeper	DTM analysis, field studies	Basin to site specific
Vegetation and anthropogenic disturbance	+			Density and type of vegetation (grass, shrubs, trees). Destabilizing effects of anthropogenic activities.	Widespread	Absent	Remote sensing, field studies	Basin to site specific
b) Catchment topography and hydrology								
Catchment area	+			Total size of drainage area upstream of catchment, proportion	Smaller	Larger	DTM analysis	Regional to basin

				glaciated/non-glaciated				
Mean slope	+			Steepness of catchment area	More gentle	Steeper	DTM analysis	Regional to basin
Drainage density	+			Density of the stream network in catchment area	Lower	Higher	DTM analysis	Regional to basin
Stream order	+			Presence of large fluvial streams, facilitating rapid drainage into lake	No or low order only	Large high order streams evident	Remote sensing, DTM analysis	Regional to basin
Upstream lakes	+			Presence and susceptibility of upstream lakes.	Absent	Several lakes	Remote sensing	Regional to basin
c) Geotechnical stability								
Rock avalanche potential	+		+	SEE AVALANCHE SUSCEPTIBILITY ASSESSMENT (Appendix 2)	Lower	Higher	SEE ROCK AVALANCHE SUSCEPTIBILITY ASSESSMENT	Basin to site specific
Moraine instabilities	+		+	Potential for landslides from moraine slopes into the lake	No steep moraine slopes adjacent to lake	Steep, unstable moraine slopes adjacent to lake.	DTM analysis, remote sensing, field work, geophysical investigations	Basin to site specific
Seismicity	+			Potential magnitude & frequency, ground acceleration	Lower	Higher	Geological mapping & modelling (e.g. GSHAP)	Regional

Composition of Task Force

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NATIONAL DISASTER MANAGEMENT AUTHORITY
* INDIA *

ANNEXURE- F

सत्यमेव जयते
Goverment Of India

NATIONAL GLACIAL LAKE OUTBURST FLOODS (GLOF) RISK MITIGATION PROGRAMME

(NGRMP)

PHASE-1

National Disaster Management Authority (NDMA)
Government of India

1

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Executive Summary

Background

The receding and melting of mountain glaciers, the expansion of existing glacial lakes, and the formation of new glacial lakes are among the most recognizable impacts of global warming in the Indian Himalayan Region. As glaciers retreat, melt waters occupy depressions earlier occupied by glacier ice leading to the formation of glacial lakes or ice 'dams'. Because of the inherent instability of such "dams," they are prone to sudden failure or breach, which can be caused by various factors such as earthquakes, GLOFs, avalanches, overtopping, rock-fall, and slope failure. Such outbursts, which can discharge millions of cubic metres of water and debris in a few hours and cause catastrophic devastation and flood up to hundreds of kilometres downstream, are considered Glacial Lake Outburst Floods (GLOFs). The states and union territories of Jammu and Kashmir, Ladakh, Arunachal Pradesh, Sikkim, Himachal Pradesh, and Uttarakhand are particularly susceptible to GLOF hazard.

Objectives of the Programme

The primary objectives of the programme are:

- Prevent loss of life and reduce economic loss and damage to critical infrastructure due to GLOF and similar events.
- Strengthening the early warning and monitoring capacities based on last mile connectivity.
- Strengthen scientific and technical capabilities in GLOF risk reduction and mitigation at local levels through strengthening local level institutions and communities.
- Use of indigenous knowledge and scientific cutting-edgemitigation measures to reduce and mitigate GLOF risk.

Approach

This is essentially a National Programme, and it is the responsibility of the states to identify lakes, to plan mitigation, execute and implement the projects successfully at the regional and ground level. This programme also meets the risk reduction goals of the Sendai Framework for Disaster Risk Reduction (2015-2030). The national programme will be implemented in phases as GLOFs are site-specific, and their vulnerability varies according to the geographical, geological and geodynamic conditions and vulnerability of people and assets (infrastructure, settlements etc.) in the downstream areas. Four Himalayan states and two union territories have been identified for project implementation in Phase-I viz. Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Jammu & Kashmir, and Ladakh.

Components

In the National Programme on GLOF Risk Reduction and Mitigation,four components have been identified:

Component 1:GLOF Hazard and Risk assessment (elaboration of standardized assessment method and a lake inventory): A comprehensive risk and vulnerability assessment of GLOFs is of utmost importance in managing the risk of GLOFs. Creation of glacial lake inventory and recognizing their risks adopting a standardized method (Aligned with the NDMA GLOF guidelines 2020)is required for monitoring and to assess GLOF risks for all involved agencies, hazard susceptibility assessment of vulnerable glacial lake and risk evaluation of dangerous glacial lakes are the priority task under this component to prioritise the early warning system.

Component 2: GLOFMonitoring and Early Warning System (including remote sensing data, community involvement for monitoring, alerting/ dissemination): This component will harness the complementary strengthsof remote sensing techniques, with advanced technologies like seismometers to detect tremors at an early stage, water level sensors, cameras, trigger lines etc.,to monitor risk prone glacial lakes, design and implement codified warning system using smartphones and siren towers placed at strategic downstream locations of the risk prone lakes to avoid loss of life and property. The activities will also include promoting and implementing acommunity-centric glacial lake monitoring and early warning system.

Component 3:GLOF Mitigation Measures (Site-specific interventions combining technical expertise and community involvement): Based on field assessments undertaken for high-risk glacial lakes, and leveraging the indigenous knowledge, appropriate mitigation measures such as reinforcing or strengthening of unsafe moraine dams, draining of lake waters through siphoning, controlled blasting, excavation of artificial drainage channels, etc. may be designed and implemented.

Component 4: Awareness Generation & Capacity Building (involving stakeholders at multiple levels): This componententails raising awareness among relevant stakeholders about GLOF hazard, risk, and potential hazard mitigation measures. Comprehensive Community Based GLOF Risk Awareness Programme,Preparation of Contingency Action Plan to Reduce GLOF Risk and research and development are the major activities that are covered under this component.

Budget

The First Phase of the Programme will be implemented with a budget of ₹150 crores (comprising Rs. 135 crores from NDMF and 15 crores as States' share, excluding UTs budget) during April 2023 to March 2026 (Table A).It will be funded by NDMF for States whereas it will be funded by regular Union Territory (UT) Grants for two UTs. States' share will be applicable as per extant NDMF guidelines. Details of allocation for components of the programme are given in the following Table A:

Table A:Component and Activity-wise budget allocation for Phase-1 (FY 2023-24 to 2025-26):

	Component	Activities	Ratio in %	Budget (Ratio in %)
1	GLOF Hazard and Risk Assessment	A.Creation and Updation of glacial lake inventory and Classification	20	15
		B. Hazard, Vulnerability and Risk Assessment of Glacial Lakes	80	
2	Glacial Lake Monitoring &	A.Glacial Lake Monitoring	20	

	GLOF Early Warning System	B. Early Warning System	80	35
3	Site Specific Intervention	A.Structural measures	70	40
		B.Non-Structural Measures	30	
4	Awareness Generation and Capacity Building	A.Community Based GLOF Risk Awareness and Preparedness Programme	25	10
		B. Preparation of Contingency Action Plan to Reduce GLOF Risk	25	
		C. Research & Development (R&D) (Small Grant Window)	50	
	Total			100

Allocation of funds among components/sub-components have been mentioned in terms of percentage of gross allocation. State-wise distribution of funds is indicated in Table B. States will divide allocated fund among components and sub-components as per ratio shown in Table-A.There could be flexibility for re-allocation of fund across sub-components of a component by States as per respective requirement; however, the fund allocation across components may be inter-changeable only with approval of NDMA on reasonable ground shown by the State.

NRSC has identified total 7570 glacial lakes within Indian territory under National Hydrology Project funded by MoJS in 2017 (Table-1). Out of these lakes, though some risky glacial lakes have been identified NRSC, CWC, SDC (as mentioned at Para 1.3, 1.4, 1.5), this activity was done based on remote sensing. Also, this data does not cover all of 7570 glacial lakes. Hence, this data needs ground validation before taking up any mitigation activity for these risky lakes. Hence, total number of glacial lakes has been considered for budget allocation under this programme rather than number of risky glacial lakes in each State/UT (Table-11).

The state wise details of allocations for the period from FY 2023-24 to 2025-26 (Phase - 1) is given in Table B:

Table-B: State-wise Distribution of Budget

Sl. No	State/UT	Number of Glacial Lakes*	Centre share (Rs. in crore)	State share (Rs. in crore)	Total Budget
1	Himachal Pradesh	537	31.5	3.5	35
2	Uttarakhand	347	27	3	30
3	Sikkim	733	36	4	40
4	Arunachal Pradesh	2,188	40.5	4.5	45
	Total	**7570**	**135**	**15**	**150**
5	Jammu & Kashmir (UT)	546			15
6	Ladakh (UT)	3,219			15

[* Source of data – NRSC-ISRO (Table-1)]

Project appraisal, approval and monitoring

The technical, financial and social aspects of the DPRs of the mitigation project will be appraised and reviewed by the Technical Advisory Committee (TAC) and Project Appraisal Committee (PAC), which are constituted at the NDMA and SDMA levels. TAC will be established to appraise projects from the technical and social point of view; conduct a technical review of projects sanctioned from mitigation funds and recommend improvement. After the TAC has completed its technical evaluation, the Project Appraisal Committee (PAC) will appraise the project from an administrative and financial standpoint. NDMA will provide technical assistance to any project approved under NDMF/ SDMF and publish the finding on the mitigation portal.

NATIONAL GLACIAL LAKE OUTBURST FLOODS (GLOF) RISK MITIGATION PROGRAMME (NGRMP)

1. Background

1.1. **Glacial Lakes:**Glaciers are a common geomorphological feature in the snow-capped high mountain regions of the world. The Indian Himalayan region is home to over 5160 glaciers (WWF, 2009). Siachen, Gangotri, Zemu, Milam, Bhagirathi Kharak and Satopanth are some important mountain glaciers in the Indian Himalayan region.Glaciers are sensitive to changes in climate and are apparent indicators of climate warming (Zemp, 2019). The Indian Himalayan Region (IHR) is facing important challenges in view of coping with the adverse effects of climate change. Like many other mountain regions worldwide, the IHR is particularly sensitive to changes in global climate from both a physical and societal perspective (Allen et al. 2020). Physically, the disappearance of mountain glaciers and the expansion of large glacial lakes are amongst the most recognizable and dynamic impacts of climate warming in this environment.Across the IHR, the numbers and areas of glacial lakes have rapidly increased due to a warmer climate during the last century (Ives et al. 2010; Gardelle et al. 2013; Zhang et al. 2015; Carrivick and Tweed 2016). According to Nie et al. (2017), the number and area of glacial lakes in IHR have increased by approximately 8.8% and 14%, respectively, between 1990 and 2015.In the catchment area of the Himalayan region, there are 503 glacial lakes and 1525 water bodies with a water spread area of more than 10 ha situated between 500 and 4000 meters above mean sea level. The receding and melting of mountain glaciers, the expansion of large glacial lakes, and the formation of new glacial lakes are among the most recognizable impacts of global warming in the Indian Himalayan Region.

1.2. **High Risk Glacial Lakes:**As glaciers retreat, meltwater occupies the depression earlier occupied by glacier ice leading to the formation of glacial lakes or ice 'dams'.Because of the inherent instability of such "dams," they are prone to sudden

failure or breach, which can be caused by various factors such as earthquakes, GLOFs, avalanches, overtopping, rock-fall, and slope failure.Such outbursts, which can discharge millions of cubic metres of water and debris in a few hours and cause catastrophic devastation and flood up to hundreds of kilometres downstream, are consideredGlacial Lake Outburst Flood (GLOF). The GLOF can be formed either underneath, at the side, in front, within, or on the surface of a glacier and related dam structures and can be composed of ice, moraine, or bedrock, that can seriously damage the life, property, agriculture, livestock, forests, ecosystems and livelihoods of downstream communities of the glacial lake.

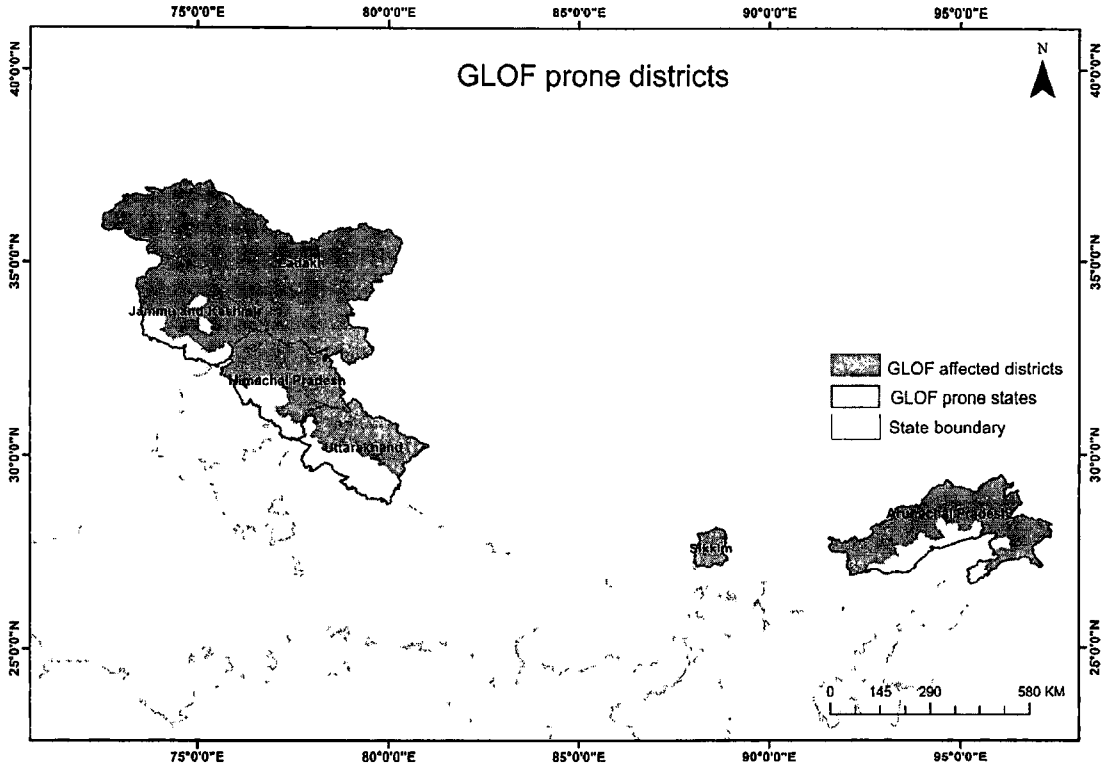

Figure 1: GLOF Prone areas

1.3. Inventory&Risk Ranking of Glacial Lakes under National Hydrology Project, 2017 by NRSC-ISRO:

A. Inventory

During 2017, NRSC has taken up National Hydrology Project (NHP) sponsored by Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga

Rejuvenation (DoWR, RD&GR), Govt. of India. As part of NHP, NRSC carried out inventory of Glacial Lakes of size ≥0.25ha for entire catchment area of Indian Himalayan River Basins (Indus, Ganga and Brahmaputra) covering ~9.6 lakhs sq.km using high resolution Resourcesat-2 LISS4 MX satellite data of (majorly from 2016-2017 period) and mapped 28,043 glacial lakes. Using the glacial lake database, basin-wise Glacial Atlases for Indus, Ganga and Brahmaputra Rivers and Integrated Atlas of Indian Himalayan River Basins were brought out and are web published for access & download (https://www.nrsc.gov.in/Atlas_Glacial_Lake). The atlases present the details of glacial lakes in terms of area, type and elevation and administrative unit wise (within India & Trans-boundary). Out of 28,043 glacial lakes inventoried in entire catchment area of Indian Himalayan River Basins (Indus, Ganga and Brahmaputra), about 7,570 glacial lakes are present within Indian administrative region and 20,473 glacial lakes are located in trans-boundary region.

Table 1: State/UT-wise list of Glacial Lakes in Indian Territory (NRSC, NHP, 2017)

S.No	State/UT	Number of Glacial Lakes
1	Arunachal Pradesh	2,188
2	Sikkim	733
3	Himachal Pradesh	537
4	Uttarakhand	347
5	Jammu & Kashmir (UT)	546
6	Ladakh (UT)	3,219
	Total	7,570

B. Ranking of Glacial Lakes (in descending order of **GLOF risk)**

The inventoried glacial lakes were ranked by NRSC based on the risk profile in two-step process, i.e. preliminary screening and ranking.

- Preliminary screening of glacial lakes was carried out based on four parameter criteria sequentially comprising lake type (moraine, ice-dammed & cirque-erosion types are considered), area of lakes above one ha, lakes associated with glacier and lakes with settlements enroute river reach.

- After preliminary screening, ranking is done based on the following set of parameters of glacial lakes:
    - Lake type
    - Lake area
    - Distance between glacier snout and glacial lake inlet
    - Slope between glacier snout and glacial lake inlet
    - Distance between glacial lake outlet and the nearest settlement/infrastructure
    - Slope between glacial lake outlet and the nearest settlement/infrastructure

  Using above parameters, weights were calculated and using statistical approach (unequal weight method) glacial lakes were ranked in descending order of risk.

- The above ranking process is completed for Indus and GangaRiver basins and for Brahmaputra Riverbasin it is in progress.
- The following 2 tables provide a list of ranked glacial lakes in Indus and Ganga River basins and their details (rank, coordinates and lake area) are given in AnnexureB. It is also mentioned that the same work for Brahmaputra Basin is under process.

Table 2:List of 614 ranked Glacial Lakes in Indus River Basin

S.No	State/UT	Ranking
1	Himachal Pradesh	90
2	Uttarakhand	1
3	Jammu & Kashmir (UT)	75
4	Ladakh (UT)	263
5	Transboundary Region	185
	Total	614

Source: NRSC

Table 3:List of 864 ranked Glacial Lakes in Ganga River Basin

S.No	State/UT	Ranking
1	Uttarakhand	61
2	Transboundary Region	803
	Total	864

Source: NRSC

A detailed list of the district-wise distribution of glacial lakes in India is enclosed in **Annexure-A.** A detailed list of the distribution of 614 risky glacial lakes in Indus River Basin and 864 risky glacial lakes in Ganga River basin is enclosed in **Annexure-B.**

1.4. High Risk Glacial Lakes– Collaborative Study by NDMA and Swiss Development Cooperation (SDC)

Govt. of India signed a Memorandum of Understanding for cooperation in disaster management with Govt. of Switzerland. Under this MoU, a report 'Synthesis Report on GLOF Hazard and Risk across the Indian Himalayan Region' has been prepared by University of Zurich, Switzerland. In this report, 56 glacial lakes have been identified as critical lakes in the country. The distribution of these high-risk glacial lakes is shown in Table-4. As per the report Sikkim has the maximum number of high-risk lakes (25) followed by Jammu & Kashmir (18). The details of the state-wise high-risk glaciers are annexed as Annexure-C.

Table 4. State-wise distribution of high-risk glacial lakes

States	No. of High-Risk Lakes
Jammu and Kashmir	18
Himachal Pradesh	8
Uttarakhand	4
Sikkim	25
Arunachal Pradesh	1
Total	**56**

Source: SDC

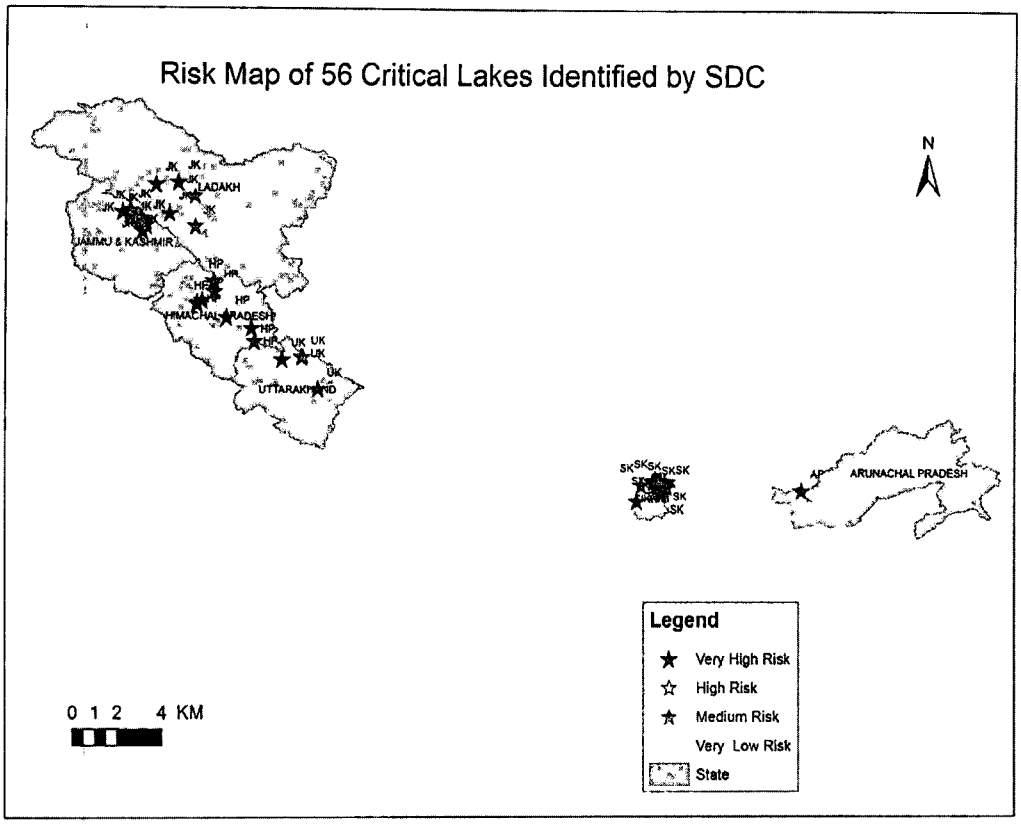

Figure 2: Map showing Risk Map of 56-Critical Lakes Identified by SDC

1.5. Assessment of Eight Glacial lakes by CWC:

As mentioned at Para 1.4, wherein 56 lakes in the 6 States/UTs in Indian Himalayan Region (IHR) have been identified as high priority lakes by Swiss agency for Development and Co-operation (SDC), these lakes are being monitored through remote sensing by CWC from 2022. The monitoring reports for the month of June-2022, July-2022 and August-2022 have already been shared on CWC website.

Further to assess the potential impact from these lakes in the downstream area, a first order hazard assessment has been undertaken by CWC. The methodology adopted is similar to that of SDC. Initially, eight lakes have been analysed on a 30m DEM (SRTM) in four States/UTs. The State-wise simulated flow propagation path from these lakes, which has been overlaid on

population density layer may be obtained from CWC. A summary of this assessment is attached as Annexure-D.

1.6. Glacial Lake Monitoring:

National Remote Sensing Centre (NRSC)/ISRO, Hyderabad carried out inventory of glacial lakes & water bodies of size greater than 10 hectares using Resourcesat-1 Advanced Wide Field Sensor (AWiFS) of 56 m spatial resolution satellite data of 2009 and 2,028 were mapped. Glacial lakes and water bodies of size > 50 ha(477 number) were monitored using AWiFS satellite data for the months of June to October from 2012 to2016. During 2015, NRSC imparted necessary training & technical handholding to Morphology & Climate Change Directorate, Central Water Commission (CWC)for monitoring of glacial lakes using satellite data. Since 2016, CWC is internally carrying out the monitoring Glacial lakes (>50ha) using satellite data and periodic monthly reports are web published (http://www.cwc.gov.in/glacial-lakeswater-bodies-himalayan-region). Now the Central Water Commission has reviewed its strategy and it ismonitoring glacial lakes of ten hectares and above.

1.7. Threat to Local People:

The presence of glacial lakes in the Himalayan region makes them a potential threat to the inhabitants of the Himalayas, particularly in the states and union territories of Jammu and Kashmir, Ladakh, Arunachal Pradesh, Sikkim, Himachal Pradesh, and Uttarakhand. The Indian Himalayan region has seen some of the worst events of disasters due to glacier and ice melt in the recent years, profoundly affecting the lives and livelihoods of people living in these regions. Despite these losses, disaster risk management related to GLOFs has not been mainstreamed into development policies and programmes.

1.8. Purpose of aMitigation Programme:

Currently, no Ministry or Department of the Government of India has any scheme for mitigating GLOF risks. Because of the rapidly growing number of glacial lakes, there is a need to prepare a comprehensive inventory of glacial lakes and catalogue all mass movements that can play a crucial role in hazard and risk assessment. Such an inventorization can be undertaken by selected institutions at the State / UT level, such as the Department of Geoinformatics, Kashmir University and DGRE-DRDO for J&K and Ladakh, HIMCOSTE for Himachal Pradesh, Uttarakhand Space Application Centre (USAC) / IIRS and NIH-Roorkee for Uttarakhand, Department of Science and Technology for Sikkim, NESAC and State Remote Sensing Application Centre (SRSAC) for Arunachal Pradesh to prepare a

comprehensive database of glacial lakes at State / UT level on GIS platform by taking inputs from work done by the NRSC-ISRO and Central Water Commission (CWC). Identification of vulnerable and potentially dangerous glacial lakes through remote sensing technology can be undertaken based on the condition of lakes, dams, associated parent glaciers, and topographic features around the lakes and glaciers. The methodology used to identify the vulnerable lakes may be based on field observations, processes, and records of past events, geomorphologic and geotechnical characteristics of the lake/dam and surroundings, and other physical conditions.

Due to a lack of initiative and resource crunch, most states have not undertaken any programme/ scheme for GLOF Risk Management as suggested in the Guidelines issued by NDMA on GLOF. As a result, the Government of India must take proactive measures since the problem of GLOF is focused primarily in backward and mountainous areas in North and North-Eastern India and states under special categories. Invariably, they do not have the resources to formulate GLOF risk management projects under the State Plan. Central agencies like BRO carry out mitigation activities regarding GLOF on their border roads. Similarly, individual Central Public Sector Units (CPSUs) of the power sector only take up mitigation projects in areas prone to GLOF within the power project area.

This programme has taken a holistic approach to mainstream GLOF Risk Reduction and Mitigation for implementation through identifying drivers/project proponents. This program is proposed to be driven by science and technology with local-level initiatives to strengthen the state machinery. It aims to provide all the necessary support to the concerned states and UTs for holistically and sustainably addressing the risk associated with GLOF. Participation of the local community is essential for the overall project's success and enhances ownership of outcomes and infrastructure generated under the program.

The National Programme on GLOF Risk Reduction and Mitigation attain and addresses all elements of prevention, preparedness and mitigation to avert or soften the GLOF risk. It covers institutional mechanisms, disaster prevention strategy, early warning system, disaster mitigation, preparedness, and human resource development for GLOF risk mitigation and management.

1.9. Causes of GLOF Occurrence in India

The presence of glacial lakes in the Himalayan region makes them a potential threat to the inhabitants of the Himalayas, particularly in the states and union territories of Jammu and Kashmir, Ladakh, Arunachal Pradesh, Sikkim, Himachal Pradesh, and Uttarakhand. The Indian Himalayan region has seen some of the worst events of disasters due to glacier and ice melt in the recent years,profoundly affecting the lives and livelihoods of people living in these regions.Despite these losses, disaster risk management related to GLOFs has not been mainstreamed into development policies and programmes.

Like other mountain ranges throughout the world, the Indian Himalayan Region (IHR) is currently facing the most serious risks from climate change and global warming, which are causing mountain glaciers to melt and resulting in the expansion of glacial lakes as well as the formation of new glacial lakes.Most of the Hindu Kush Himalaya is experiencing glacial retreat and melting as a result of global warming, which has resulted in the construction of numerous new glacial lakes with the potential to cause catastrophic glacial lake outburst floods.IHR is located in Seismic Zones IV and V, which makes the area extremely vulnerable to earthquakes. This leaves the glacial lakes vulnerable to breaches, releasing rapid, potentially deadly floods affecting the downstream communities. The most prevalent type of moraine Dam Lake in the Himalayan region is particularly susceptible to weakness and unexpected breaches, which might release millions of cubic metres of water and debris.This is accompanied by other disturbances like avalanches and falling boulders, making the glacial lakes vulnerable to breaches, unleashing sudden, potentially disastrous floods in the nearby communities. People who live downstream of unstable glacial lakes are at a serious risk of losing their lives and possessions.

The most common reasons for GLOF occurrences are rapid slope movement into the lake, heavy rainfall and snowmelt, cascading processes, earthquakes, melting of ice and forming the dam, obstruction of subsurface outflow tunnels, and long-term dam degradation. Other factors that exacerbate the dangers and risks associated with moraine-dammed glacial lakes include their enormous volume, narrow and high dams, stagnant glacier ice inside the dams, etc.

1.10. Occurrences of GLOF and their Impacts in India

Historically, GLOF has created much massive destruction in the Himalayan region. Since 1900, 150 GLOF events have been documented in the Himalayas. Incidents of flash

floods and cloudbursts have become quite frequent in all Himalayan states and UTs. In the past also, GLOF occurrences have occurred in these states and UTs, where they had a significant physical impact. However, their socio-economic impact was minimal because they occurred in sparsely populated terrain. There are quite a few reported events in Himachal Pradesh and Sikkim of GLOFs/flash floods/GLOF-induced river damming outbursts. Nevertheless, with increasing population and tourist destinations, the socio-economic impacts of GLOFs are increasing. Table 5 shows details of some of the GLOF occurrences and their impacts.

Table 5: Major GLOF disaster occurrence in the country

S. No.	Incident	Year	District	State	Loss & Damage
1	Shyok glacier GLOF	1926	Reasi district	Jammu & Kashmir	-
2.	Nyoma GLOF	1971	Leh	Ladakh	13 to 16 fatalities
3	Shaune Garang glacier GLOF	1981,1988	Kinnaur	Himachal Pradesh	-
4	Flash floods and cloud bursts	2000	Kinnaur	Himachal Pradesh	-
5	Domkhar GLOF	2003	Leh	Ladakh	Destroyed farmland and infrastructure
6	Parechu outburst flood	2005	Sutlej Valley, Kinnaur	Himachal Pradesh	Considerable damage to livelihoods, houses, roads, and bridges
7	Kedarnath Disaster	2013	Rudraprayag	Uttarakhand	5000 people killed & ~70,000 homeless
8	Gia	2014	Leh	Ladakh	damaged several agricultural terraces, a concrete bridge, & few houses

9	Chamoli flash floods	2021	Chamoli	Uttarakhand	-

In the past, GLOF occurrences have occurred in Ladakh as well, where they had a significant physical impact.However, their socio-economic impact was minimal because they occurred in sparsely populated terrain. There are quite a few reported events in Himachal Pradesh and Sikkim of GLOFs/flash floods/GLOF-induced river damming outbursts.

1.11. Objectives of the Programme

The primary objectives of the programme are:

- Prevent loss of life and reduce economic loss and damage to critical infrastructure due to GLOF and similar events.
- Strengthening the early warning and monitoring capacities based on last-mile connectivity.
- Strengthen scientific and technical capabilities in GLOF risk reduction and mitigation at local levels through strengthening local-level institutions and communities.
- Use of indigenous knowledge and scientific cutting-edge mitigation measures to reduce and mitigate GLOF risk.

1.12. Approach

This is essentially a National Programme, and it is the responsibility of the states identified to plan, execute and implement the programme successfully at the regional and ground level. This programme also meets the risk reduction goals of the Sendai Framework for Disaster Risk Reduction (2015-2030). The national programme will be implemented in phases as GLOFs are site-specific, and their vulnerability varies according to the geographical, geological and geodynamic conditions and vulnerability of people and assets (infrastructure, settlements, etc.) in the downstream areas. Six Himalayan states and one union territory have been identified for project implementation in phase-1.

1.13. Project Partners

The concerned ministries, institutes/ organisations, and stakeholders will provide technical and implementation support to the programme. NDMA will explore the possibility of a partnership with the following:

Ministries:

1. Ministry of Mines (MoM)
2. Ministry of Earth Science (MoES)
3. Ministry of Roads Transport & Highways (MoRTH)
4. Ministry of Panchayati Raj (MoPR)
5. Ministry of Rural Development (MoRD)

Government Organizations:

1. Central Water Commission (CWC), MoWR
2. Geological Survey of India (GSI)
3. India Meteorological Department (IMD)
4. National Remote Sensing Centre (NRSC)
5. Indian Institute of Remote Sensing (IIRS)
6. North-Eastern Space Application Centre (NESAC)

Academic, Research and Training Institutes

1. National Skill Development Cooperation (NSDC)
2. National Institute of Hydrology (NIH), MoWR
3. National Centre for Polar and Ocean Research (NCPOR), MoES
4. Centre for Development of Advance Computing (CDAC)
5. Defence Geoinformatics Research Establishment-Defence Research and Development Organisation (DGRE-DRDO)
6. National Institute of Disaster Management (NIDM)

This proposal envisages a programme-based approach. Proposals from the states, organizations, institutions, departments, etc. will be appraised technically and financially at the state and national level before being approved by the competent authority.

2. Components of the National Programme on GLOF Risk Reduction & Mitigation

Recognizing that GLOF hazard is relatively new and emerging, holistic risk reduction strategies have not been formulated. Only a limited set of activities to mitigate the risks posed by the hazard have been implemented. In order to address this emerging hazard, comprehensive mitigation strategies are needed. In the National Programme on GLOF Risk Reduction and Mitigation, four components are incorporated:

- GLOFRisk and Vulnerability Assessment.
- Development, Integration & Dissemination (DID) of GLOF Early Warning System (EWS)and Monitoring.

- Adopt site-specific mitigation measures with community involvement.
- Awareness Generation and Capacity Building.

2.1. Component –I: GLOF Hazard and Risk assessment

National Remote Sensing Centre (NRSC) had completed a project during 2011-15 on **"Inventory and Monitoring of Glacial Lakes / Water Bodies in the Himalayan Region of Indian River Basins"**, sponsored by Climate Change Directorate, Central Water Commission (CWC), New Delhi, Govt. of India. Under this project, glacial lakes and water bodies located in all three major river basins viz., Indus, Ganga, and Brahmaputra including trans-boundary region were mapped with a water spread area of size greater than 10 ha.Glacial lake extent change monitoring for lakes of size greater than 50 ha (477 glacial lakes and water bodies) has been carried out by NRSC from 2011 to 2015 during monsoon period of June to October on monthly basis. Since 2016, the CWC has continued the monitoring of 477 glacial lakes on a monthly basis.

A comprehensive risk and vulnerability assessment of glacial lakes is of utmost importance in managing the risk of GLOFs. Identifying potentially dangerous glacial lakes and recognizing their risks, including the ranking of the critical lakes, has become a priority task. The Geological Survey of India (GSI) and Defence Research & Development Organization (DRDO) carried out a risk assessment for South Lhonak Glacier Lake in Sikkim, incorporating various remote sensing techniques and field investigation. The NDMA Guideline on GLOF (https://ndma.gov.in/sites/default/files/PDF/Guidelines/Guidelines-on-Management-of-GLOFs.pdf) includes the mapping the current status of the glacial lakes, identification of new glacial lakes, identification of vulnerable and potentially dangerous glacial lakes, the nature of susceptibility of the lake and the modelling of the flood scenario, arrival time, inundation depth, discharge estimation etc.TheIndus, Ganga and Brahmaputra Rivers and Integrated Atlas of Indian Himalayan River Basins were brought out and were web published by NRSC-ISRO (https://www.nrsc.gov.in/Atlas_Glacial_Lake) (para 1.3). States may work upon this data. Further the report 'Synthesis Report on GLOF Hazard and Risk across the Indian Himalayan Region, prepared by NDMA and SDC may also be referred to (para 1.4).

A. Creation and updating glacial lake inventory and classification-

A1. Inventory:A glacial lake inventory is a comprehensive record of the location and characteristics of all the glaciated lakes. Preparing a comprehensive inventory of all glaciated lakes is a prerequisite for understanding the location and possibility of GLOF events. Due to many lakes' remote and inaccessible locations and their widespread geographical coverage, advanced spatial technologies can be used to generate the inventory. Based on the condition of the lakes, dams, associated parent glaciers, and topographic features surrounding the lakes and glaciers, various remote sensing technologies can be used to identify vulnerable and potentially dangerous glacial lakes.It is also possible to use advanced remote sensing techniques to identify glacier lakes, particularly for supraglacial lakes and small glacial lakes (less than 100 sq. m), which are typically found in distant locations and are challenging to monitor manually. The updated status (increased size, risk profile etc.) of the lakes, which are already included in the inventory, can be added. Furthermore, high-resolution satellite images can be used to classify glacial lakes and associated glaciers by combining manual, semi-automatic and automated classification methods. It is also possible to use methods for analysing remote sensing data using the Object-Based Image Analysis (OBIA) method. Identification of GLOF lake Outburst Flood (LLOF) potential sites along the river is also important and can be done during the project implementation.It will be necessary to incorporate and update the historical GLOF locations mentioned in earlier research reports and journal articles for identifying potential glacial lakes. This enables the early identification of potential hazards and can support risk management strategies and mitigation plans. Creating a GIS-based GLOF System and interactive, user-friendly glacial lake risk maps will be the primary outputs. Remote sensing techniques can be used to identify crucial glacial lakes and predict the possibility of future outbursts and glacial lake outburst floods by taking into account a variety of glacial lakes, glaciers, and local physical conditions and accordingly can be classified.

A2. Lake Classification: The glacial lakes should be classified according to different factors responsible for GLOFs, such as the lake area, lake growth, glacier and lake proximity, dam characteristics, the effect of mass movements and impact on the downstream locality. These factors play a significant role in identifying and evaluating the risk of potentially dangerous glacial lakes.The lake classification can be done based

on the size, stability and hazard proneness. Updated lake information and classification will help prioritize the preparedness or mitigation strategies.

States will build an inventory of glacial lakes in consultation with CWC, NRSC, and GSI. States may also appoint any Institute/University/Agency for this purpose. In this regard standard data set format, suggested by CWC may be followed, with local modification, as required. Required satellite images may be taken from NRSC. State may conduct field visit for necessary field validation of the satellite data.

Drawing upon these databases of States/UTs andalso on the existing database of NRSC/CWC, a national database may be built by CWC. This database may be improved further as a GIS-based Glacial Lake Information System with user-friendly features, interactive, and fieldvalidated data.

B. Hazard susceptibility assessment of vulnerable glacial lakes and risk evaluation:

Susceptibility ofvulnerable lakes includeselements such as the rapid expansion of glacial lakes, size of glacial lakes, strength of morainebarriers,seepages from the lakes, active slides in the morainic barriers and probability of rock and snow avalanches.The first level of hazard potential assessment can be done using remote sensing techniques; followed by detailed field investigation for high-risk glacial lakes. Various remote sensing techniques can be used to generate spatial information of glacier lakes, which has the potential to outburst floods. The Normalized Difference Water Index (NDWI) and Normalized Difference Snow Index (NDSI) are automated methods for detecting water bodies, including glacier lakes, using satellite imagery.Although the automatic classification approach can more quickly identify glacial lakes, it cannot be used throughout the entire region because of the uncertainties brought on by climatic and physical processes. In such circumstances, a manual delineation method based on visual image interpretation can be used to map alongside other physical features.Digital Elevation Model (DEM) can be used to extract topographic information about glacial lakes and their associated terrain and to understand the physical characteristics of glaciers, moraines, and surrounding places. High-resolution Digital Elevation Models can provideinformation like Lake Boundary delineation and other accurate surface information.The mapped glacial lakes should be checked, validated, and modified using reference imageries like Google Earth Imageries, aerial photographs and through field surveysfor better spatial accuracy. Field surveys,geotechnical andgeological investigations

and slope stability assessments can be done to understand the physical aspects. Attribution of the glacial lake inventory needs to be done based on physical and other characteristics of the glacier. The details like area, elevation,type of lake (moraine-dammed, ice-dammed, or bedrock-dammed) etc. can be updated in glacial Inventory. The stability survey of the lateral and terminal moraines would also help evaluate the risk of GLOFs.

Risk evaluation of GLOF can be done by bringing in vital information in areas downstream of the glacial lakes. The downstream flood path and maximum downstream travel distance for each GLOF path can be determined using empirical models. Risk evaluation can be done by combining sophisticated hazard modelling and mapping with the on-ground assessment of vulnerability and exposure of different asset types, mainly in the lakes' downstream areas. Large-scale data that can be used to characterize exposure to GLOFs with vulnerable elements includepopulation, village locations,forest areas, cultural heritage sites, tourism sites and hotels, agricultural land areas, wetland areas, transport infrastructure, and hydropower stations.The risk evaluation can be done using the satellite imageries like Sentinel imageries (10m spatial resolution) and LANDSAT imageries (30m spatial resolution). Categorization of the potentially dangerous lakes would be an additional benefit to strategize monitoring and EWS. Augmenting Information on extreme rainfall/snowfall events may help to the GLOF risk and vulnerability Assessment.

Risk identification is essential to plan mitigation. Considering emerging threat of GLOF hazard, risk assessment needs to be completed in a time bound manner. State may choose lake for risk evaluation. They may appoint any agency for such assessment in consultation with CWC, GSI. CWC may prepare an SOP for all the states for conducting such risk evaluation.

States may use data from sources like NRSC, CWC and SDC (as mentioned at Para 1.3, Para 1.4, 1.5). However,it is noteworthy that these data had beenacquired by remote sensing. Therefore, suitable field verification needs to be carried outbefore initiating any mitigation activity. States may appoint any agency for such assessment in consultation with CWC, GSI.

Table 6: Component 1 - Expected Output – Outcome, and Success Indicator

Sl. No.	Activity	Output	Outcome	National Budget (22-5) & Success Indicators
A.	Creation and updation of glacial lake inventory and classification	• Develop template/format of the database. • Classify Glacial Lakes based on the severity, size and volume of debris generated by a particular GLOF. • Compilation of Glacial Lake data. • Update existing data.	A standard glacial Lake database with risk classification.	Budget – 4.5 cr Each State/UT will prepare its database, which may be integrated by CWC for a pan India Database
B.	Hazard susceptibility assessment of vulnerable glacial lakes and risk evaluation	• Identify risky Glacial Lakes. • Study of an identified Glacial Lake, its moraine characters, geotechnical assessment. • Mapping all other causative factors for GLOF occurrence. • Conduct a detailed risk assessment of downstream elements at risk. • Prepare GLOF modeling of lakes. • Design model flood wave run-outs. • All critical infrastructures in high-risk areas are mapped. • Compile and evaluate data on risk scenarios. • Evaluate the geotechnical GLOF resilience of major infrastructures. Design model flood wave runouts • Conduct a detailed risk assessment of downstream elements at risk. • Identify various elements exposed to GLOF risk.	Multi-hazard risk maps of study area on the GIS platform and GLOF modelling of lakes.	Budget – 18 cr All Risky Lakes are identified

2.2. Component II: GLOFs Early Warning System (including remote sensing data, community involvement for monitoring, alerting/ dissemination)

Effective monitoring of hazard and early warning systems are an important part of disaster preparedness; they have the potential to greatly reduce loss of life and property. The four critical elements for a successful EWS for GLOF are Risk Knowledge, Site-specific risk assessment, Monitoring and Warning Services, Dissemination and communication, and Response capability(NDMA GLOF Guideline, 2020).The key challenges of establishing effective Early Warning for glacial lakes in the Indian Himalayan Region include remote

locations, unstable terrain, and limited information regarding the risk scenario.The system must be installed in the lake basin, which needs to be technically sound, simple to operate, easy to maintain or replace, and reliable to give accurate and timely warnings. This system includes sophisticated interconnected techniques such as remote sensing techniques, seismometers to detect tremors at an early stage, water sensors and a codified warning system using smartphones and siren towers placed at strategic locations of the lake downstream. Maximum efficacy is most likely achieved if local communities are involved in the various stages of the operation of the system.

The Component involves two sub-components:

A. Glacial Lake Monitoring:

Monitoring of glacial lakes involves remote sensing, aerial observations, and field study at particular intervals. Moreover, monitoring critical lakes may require direct periodic observation. This should be carried out with all stakeholders: communities, government departments, institutions, agencies, broadcasting media, and others. As many of these processes are more likely to occur during the monsoon months, cloud cover can prevent the use of optical remote sensing. In order to overcome this situation, microwave remote sensing techniques like RADAR and LIDAR can be employed, which work in all weather conditions.

Unmanned Aerial Vehicles (UAV), or drone-based images have gained attraction in recent years due to their advantages over traditional remote sensing platforms in glaciological studies to overcome the disadvantages associated with satellite remote sensing. UAVs can produce regular, low-cost aerial photographs of glacial zones in high resolution. Synthetic-Aperture Radar (SAR) imagery and LiDAR techniques are also used to monitor glacial lakes. Recent hardware and software developments have resulted in accurate 3D mapping and ortho-images with preferred spatial and temporal resolution in various glacial studies.

Field investigations, including topographical and bathymetric mapping, hydro-meteorological observations, and geological, geophysical and glaciological surveys, may be carried out for high-priority/vulnerable lakes. Drones and other unmanned aerial vehicles (UAVs) provide powerful tools for efficiently combining on-site fieldwork and remote sensing techniques.

B. Early Warning System:

There may be two kinds of early warning system:

(i) Community-based Early Warning System -

Citizen Science application for environmental monitoring can also be appropriately harnessed for GLOF monitoring. It is essential to design an application for smartphones allowing citizens to record critical environmental parameters, such as lake water levels, fragments of ice/debris from moraines in the river waters, unusual turbid nature of water, damming/ blockage of the river body by mass wasting, cracking sounds from the glaciers upstream, etc. Engaging communities in scientific monitoring makes them more likely to respond positively to any warnings or alerts. In addition, guides and porters employed by private/ semi-government agencies are regular visitors to the glacial lakes. Hence, human resource can be amalgamated into the monitoring after suitable training and registration for effective surveillance and reporting of the glacial lakes.

Community participation in early warning systems is crucial for preventing fatalities and minimizing injuries and ecological damage caused by disaster events. It is the process of including communities in collecting, assessing, monitoring, and disseminating hazard risk information. Community orientation and community-based systems need to be seamlessly integrated into the administrative information dissemination mechanisms. Guidelines should be developed to promote better understanding and response to warnings generated at the community level especially the population residing along the major rivers. The communities will be provided with technical assistance installing the early warning system's operation and integration. Mock drills can be conducted in consultation with line departments for various scenarios using the installed EWS to ensure its usability by involving relevant stakeholders. The warning dissemination protocols should ensure last-mile connectivity or community ownership as, more often than not; the people living in remote and hazard-prone areas have to withstand the worst of these disasters. Efforts must also be undertaken to document and build on traditional warning dissemination techniques within communities and include them in the proposed EWS. Furthermore, the EWS must address local communities' key concerns and needs.

The effectiveness of EWS can be gauged from the speed of community response. It must be imparted that greater community orientation and community-based systems need to be seamlessly integrated into the administrative information dissemination mechanisms. Guidelines to promote better understanding of and response to warnings generated at community level should be developed.

Involvement of local community in the EWS process could help in many ways like, the shepherds and others can inform rest of the people if any unusual things are noticed.

This kind of involvement will developa sense of ownership for the installed EWS infrastructure.

(ii) Sensor Based Early Warning System-

Early Warning systems consist of different instruments like water level gauges, cameras, trigger lines, integrated with sirensystems, and distributed hand mikes to the local task force and the downstream communities. Automatic Weather Station and GLOF sensors in the lake area, audio GLOF sirens, and siren nodes and services for upstream are part of the GLOF early warning system. Water level recorders for continuous or distinct measurements of water levels, automated devices such as pressure sensors and contact-less sensors can be used for water level measurements and recording and can be incorporated into an automated monitoring system. Water level sensors installed along the banks of the river channel immediately downstream of the lake outlet can be used to detect the onset of a breach of glaciated lakes. Integration of dual sensors (pressure based and radar-based) for water level may be more practically useful. The real-time data transmission is the backbone of EWS, however, real-time data transmission has some issues especially in bad weather conditions, therefore, a backup system may be kept. In addition to the traditional methods of water level sensors, the satellite altimeter and LIDAR can also be used for basin-level water level monitoring of glacier lakes and downstream rivers.

States will identify risky glacial lakes and its basin area on priority basis. In this regard they can refer to data on risky lakes as mentioned at para 1.3 as identified by Scientists of NRSC-ISRO, and as mentioned at para 1.4/Para 1.5, as identified by Scientists of University of Zurich and Scientists of CWC. Accordingly, after risk analysis, States may prioritize sites for early warning and/or site-specific intervention for mitigation. State may call for Expression of Interests (EoI) from universities/institutes/agencies and may engage them for preparing DPR and implementing EWS following due procedure. The EWS may be integrated with Common Alert Protocol (CAP) of NDMA for dissemination of alert message.

Further, it may be noted that early warning at any site is a continuous process until the lake bursts or vulnerable people and existing infrastructure is shifted to a safer place. Therefore, a long-term plan and budget support for maintenance is required. Hence, the implementation contract needs to have a long-term perspective for maintenance. The

implementing agency needs to have the capacity to support it for a longer period. The extant NDMF/SDMF guideline is applicable for repair and maintenance of the instruments.Always a cost-benefit analysis should be carried out before taking up any mitigation activity especially a EWS or other costly structural mitigation measures. Rehabilitation may be a simpler and cheaper solution sometimes.

Table 7: Component II-Expected Output, Outcome and Success Indicators

Sl. No.	Activity	Output	Outcome	Budget (52.5 cr.) and Success Indicators
A.	Glacial Lake Monitoring	• Ensure near real-time monitoring of lake • Site suitability analysis for installation of AWS & AWLR • Utilize InSAR for repeated monitoring • Prepare Alarm & Evacuation Protocol by involving existing Hydro-power project	A comprehensive monitoring system in the State	Budget – 10.5 cr. Each State/UTdevelops a comprehensive monitoring system
B.	Early Warning Systems	• A low-cost, and simple technology community based EWS is set up • A few sensor based EWS are set up • Ensure last-mile connectivity through SMS and sirens • Establish rainfall database locally	An EWS is set up in each State/UT Last mile connectivity is ensured	Budget – 42 cr. A community based EWS and at least one sensor based EWS is set up for each State/UT

2.3. Component III: Site Specific Intervention

Site Specific mitigation measures for can be divided broadly in two parts, such as A. Structural Measures and B. Non-Structural Measures.

A. Structural Measures:

Adopting appropriate structural measures is the most direct physical way to reduce the risk of glacial lake outburst floods. This typically involves building remediation structures on the lake itself and improving slope stability or lowering the water level to reduce potential peak discharge, and hydrostatic pressure on the dam is included in structural measures (Shrestha et al., 2012).

Most of the Risk Mitigation measures are not viable and feasible because of high cost and poor understanding of the local community about the measure. Risk mitigation measures need to be properly evaluated and assessed from the point of view of their efficacy to contribute towards risk mitigation in the identified areas/communities. Detailed assessment of the valley terrain, community settlements, width and topographical ingredient of the river/water channel should be made. Some simple mitigation measures which can be in the form of informal embankments or creation of natural barriers like plantations, boulders, spurs etc. for protection of precious assets. However, care must be taken to ensure that plantations do not begin to act as barriers obstructing the smooth flow of water and debris during a GLOF or flash flood event. Nevertheless, they should be planned to break the force, thrust and devastation potential of water body towards human habitations or other precious socioeconomic and development infrastructure as well as religious and cultural monuments of national heritage. This plantation activity should be through community participation to increase the sense of ownership among the communities.

Geo-Engineering measures such as reinforcing or strengthening dangerous moraines are the most effective in relieving or controlling the risk of GLOF disasters. ***Artificial dams*** can be built to strengthen the loose moraines and holdback the lake water. Further ***artificial drainage channels*** can be excavated to channelize the water to the nearby localities to solve their potable water issues or water need for other household or agricultural purposes through ***artificial exit tunnels, concrete steps and pipelines.***This is an artificial way of lowering the water level of from vulnerable glacial lakes through ***controlled breaching***. Installation of an **outlet control structure**, and tunnelling through the moraine barrier or beneath an ice dam. The impact of snow avalanche on glacial lakes can be protected through some engineering measures like **avalanche galleries, tunnels, Wedge like structures**. These lake waters can also be channelized and utilized for **hydroelectric power generation**. Pipes can be used to channelize the water to the required places. In case of open channels, concretization of both the sides of the channel is required. The concrete steps can help reduce the speed of the water flow on the steep terrains.

Artificial lowering of water level from vulnerable glacial lakes by controlled breaching, installation of an outlet control structure, pumping or siphoning out the water from the lake, and tunnelling through the moraine barrier or beneath an ice dam are some indicative measures.

Moreover, structural mitigation measures are also needed to be applied downstream to protect infrastructure and settlements from unexpected floods. In order to choose appropriate structural mitigation measures, a detailed investigation should be done. Thus, choosing an appropriate method for each lake will be based on detailed geological, geomorphological, glaciological, and geotechnical investigations.

B. Non-Structural Measures:

Some site-specific non-structural measures for GLOF risk Reduction can be as following. For Example -**First**is to reduce the melting rate of the ice sheets, **second is**to reduce the water level of the lake, and **third**is to strengthen the lake surrounding moraines.

The first objective of reducing the snow water-meltingrate can be achieved by ***growing Moss or Algae cover on the glaciers***. Normally it is seen that, if the ice or snow surface is covered with any dark material it enhances the melting. Normally the englacial or supra glacial debris and black carbon is known for inducing the glacial melt. However, the Moss colonies can reduce the temperature of the substrate up to 2 degree centigrade. Therefore, growing the moss colonies on the ice and the surrounding rocks can help reduce the ambient temperature and consequently melting rates of the ice sheets.

The second objective is to lower the lake water level can be done through siphoning. ***Pumping and siphoning out water*** from the lakes on regular basis especially during the summer months can help maintain the lake water level and reduce the spilling risk. This low cost adopted measure can lower the lake water level.

For millions of years, evolution has allowed life to develop a broad variety of slime, gooey substances that provide animals and plants with the ability to survive, adapt, and reproduce. Secretion of some of the plants and animals can work as the adhesives. Some of the ***ectotherms, barnacles, mussels and corals*** can act as the rock-binding agents. In addition, these have capabilities to thrive in the extreme temperatures at the mountain glacial lakes. If these are planted on moraines of the glacial lakes, they can create the cementing effect on loosemoraines. This will help to stabilize the end moraines naturally, which can ultimately create a natural dam for the glacial lakes.

Land Use Planning to Identify the Risks: It is essential to introduce concepts and practices related to land use planning and management at community and local administration level. This will help identify hazard-prone and vulnerable areas and prevent location of high value individual, community and development assets in these areas. Common people should be able to recognize the hazard zones easily and develop an understanding of the importance of land use planning concepts and practices in their day-to-day lives. The risks posed by GLOFs, for example, to what level the water could reach, what are the vulnerable structures in the path of a potential flash flood etc. need to be factored into the development planning process in vulnerable valleys. Promoting land use management is also critical in safeguarding socio-economic assets and development projects, which constitute the mainstays of economies of many of the mountain areas.

Mainstreaming DRR into Development Planning: Countries in the Himalayan region have been investing vast resources for developing socioeconomic and infrastructural assets like dams, hydel projects, bridges etc. With increasing hydro-meteorological hazards due to the impact of climate change, incorporating risk reduction elements into the development planning process will ensure their safety and sustainability. The development plans, national and/or local, formulated for mountain areas, must seek to mainstream risk reduction concerns to insulate the development process from recurrent GLOF hazards. For example, it is important to use the principles of land use planning while making plans on where exactly to lay the highways and bridges in the GLOF shadow areas and ensure incorporation of risk reduction elements to make them hazard resistant. Incorporating DRR into developmental planning forms an essential component of sustainable development and must also be communicated and established at community level.

Sustainable Natural Resource Management: Afforestation and Sustainable natural resource management including water/watershed management must be incorporated into risk mitigation strategies to protect the Himalayan ecosystem. It is well known that mountain communities are overwhelmingly dependent upon natural resources. Their lives and livelihoods are closely related to and intimately dependent upon the natural resources available in their vicinity. Connecting risk mitigation measures with natural resource management efforts will also help secure stronger buy-in and interest from the communities and make them more sustainable.

In order to choose appropriate mitigation measures, for each lake, detailed geological, geomorphological, glaciological, and geotechnical investigations are necessary.States will identify risky glacial lakes and its basin area for such investigation. In this regard they can refer to data on risky lakes as mentioned at para 1.3 as identified by Scientists of NRSC-ISRO, and as mentioned at para 1.4/Para 1.5, as identified by Scientists of University of Zurich and Scientists of CWC. Accordingly, after risk analysis, States may prioritize sites for early warning and/or site-specific intervention for mitigation.

States may appoint agencies for preparing DPR, implementing the mitigation measures etc. following due process. At the same time, States should ensure enactment of necessary land use regulations, building codes and compliance thereof.It is expected that in first phase of this programme States will take up at least ten risky glacial lakes for mitigation activity.

Table 8: Component III-Expected Output, Outcome and Success Indicators

Sl. No.	Activity	Output	Outcome	Budget (60 cr) and Success Indicators
A.	Adopt Site-specific Structural Mitigation Measures	• Slope stability of moraine dams • Controlled breaching • Construction of an outlet control structure (concrete steps & pipeline) • Construction of Artificial Drainage Channels • Artificial Exit Tunnel through the moraine barrier or under an ice dam. • Avalanche galleries & other avalanche preventing structures beside the lakes • Hydroelectric power stations	GLOF risk mitigated for the glacial lake.	At least 10 Critical Lakes are mitigated in each State/UT
B.	Adopt Site-specific Non-Structural Mitigation Measures	• Reduced ice melting • Controlled lake water level • Stable end moraines • Land Use Regulation • Compliance of Building Codes • Mainstreaming DRR in developmental activities		

1.4. Component IV: Capacity Building and Awareness Generation

The awareness and capacity building concept's fundamental goal is to provide a comprehensive education and training programme that is geared towards communities, stakeholders, scientists, and academic institutions. It deals with launching awareness of GLOF hazard and risk reduction and sensitizing all stakeholders on hazard mitigation. This involves raising awareness about glacial lakes, their characteristics, the level of hazards, and the required responses during and after GLOF events.Sensitization of GLOF risk information and early warnings to individuals and communities threatened by hazards will be essential to the awareness programme. The local community members in the catchment and downstream areas need to be sensitized to GLOF risk and early warning systems.

Experience has shown that hazards in one country have the potential to create a disaster in a downstream one. For example, a GLOF event in Bhutan or Nepal could have an impact in India and Bangladesh downstream. This is especially true in the context of the fact that disasters do not recognize boundaries as evidenced during the Kashmir earthquake in 2005 and Kosi floods in 2008 in the region. These incidents require greater cooperation between countries in the region in terms of monitoring, sharing data and disseminating timely warnings to countries/communities likely to be impacted. Satellite observations indicate that GLOF in one country have the potential to cause considerable devastation in neighbouring Himalayan countries, including the countries in riverine plains. Hence, it necessitates greater coordination between countries in the region in terms of joint monitoring, sharing of data, developing risk mitigation and preparedness strategies. Administrative integration among government departments, public sector agencies, NGOs and civil bodies should be given special attention to integrating activities related to creating awareness and preparedness.

A. Community Based GLOF Risk Awareness and Preparedness Programme- Community-level awareness programmes should be undertaken on a regular basis to sensitize people to the threat of GLOF.An awareness drive should be conducted to specific target groups, including communities in the downstream areas,and vulnerable groups, including women, children and senior citizens.Simple tools can be applied to encourage and make communities awareof GLOF hazard awareness. It includes awareness songs and movies on disaster risk reduction in the local language, painting and debate competitions on flash floods

in local schools, the use of traditional and folk mediums on hazards, etc.A culture of risk reduction and resilience can be significantly cultivated by making easy efforts to lower risks and improve preparedness for disasters during local fairs and festivals.This can also be done through extensive awareness creation and mock drills, including on the Early Warning System related to GLOF. This will help to enhance the confidence level of the communities in GLOF. Administrative integration among government departments, public sector agencies, NGOs and civil bodies should be given special attention to integrating activities related to creating awareness and preparedness. A holistic and collaborative approach towards trainingand awareness building should be adopted to develop action plans to spread awareness andpreparedness measures to the last mile.

NIDM will prepare detail scheme of such training/capacity building programme in consultation with stakeholders. States may conduct this sensitization and awareness generation programs with the support of identified SIDM/other agencies/institutes/NGOs at the regional and local levels. One such training programme has to be conducted in each identified GLOF risk prone village area annually. Also State may create a community village taskforce in those areas converging it with 'Aapda Mitra' Scheme of NDMA.

B. Preparation of Contingency Action Plan to Reduce GLOF Risk:

Preparing a contingency action plan for susceptible glacial lakes and collaborating with concerned local bodies/communities and other stakeholders can reduce and minimize GLOF risk. Communities must be sensitized, orientated, and trained to build participatory disaster management plans that define what needs to be done before, during, and after a disaster. Creating task forces to handle particular needs must also be a part of the contingency planning procedure. The identification of tasks for certain members, as well as their capacity building, to accomplish those activities must be considered in the plan. Emergency evacuation routes and shelters need to be identified and should be ingrained into the minds of the people. These could be done by simple tasks like painting the village map along the emergency evacuation routes and shelters onto the walls of community building where everyone can see it on a regular basis. States will prepare a contingency action plan involving community and stakeholders.

C. Research and Development (R&D) (Small grant window):

This programme also aims to invest for research and development activities to promote

in-house innovation.Research grant will be provided to Universities/Institutes to promote innovations in GLOF risk mitigation.

Activities should be related to the following:

a. GLOF Modelling and Prediction
b. Early warning system,
c. Network telemetry
d. Development/improvement of BIS codes,
e. Bio Restoration
f. Bio-engineering
g. Engineering Solution
h. Risk assessment
i. Application of remote sensing in DRR,
j. Capacity building in DRR
k. Application of Information Technology in DRR
l. Non-Structural Measures
m. Recent Progress in glacial lakes and GLOF patterns due to climate change
n. GLOF triggers and GLOF susceptibility indicators
o. GLOFs and human dimension context

NDMA will prepare detailed terms of reference in this regard. After circulation of the said terms of reference, Universities/Institutes may send proposal to NDMA for appraisal. NDMA may request the state, where the University/Institute is situated to release the fund as per extant NDMF guidelines. In case the fund is insufficient from the State, NDMA may ask any other State, having highest amount of balance fund for this sub-component, to release the fund from NDMF as per extant NDMF guidelines.

Table 9: Component IV-Expected Output, Outcome and Success Indicators

Sl.No.	Activity	Output	Outcome	Budget (15 cr) and Success Indicators
1.	Community-Based GLOF Risk Awareness & Preparedness Programme	• Training modules/manuals for different target groups • Capacity building and local community awareness for local-level interventions to reduce GLOF risk. • Community participation is ensured. • Identified target participants among the elected members from Panchayat Raj Institutions (Local bodies)	• Enhanced adaptive capacity and create awareness in GLOF risk management	Budget: 3.75 cr One such training programme is conducted in each identified village/muni

		• Regular training sessions for specific skill development • NGOs/institutes for facilitation of training programme are identified • Recognized role and responsibilities of different stakeholders • A village task force in each village • Villagers are sensitised about the hazard, vulnerability and elements at risk in their respective villages and surroundings. • Ensured effective and prompt action to rescue and respond in the event of a disaster. • Skill development of the community through Indigenous knowledge and methods • Prepare contingency action plan • Training of stakeholders as per this plan		cipality annually.
2	Preparation of contingency action plan to reduce GLOF risk	• Prepare contingency action plan • Training of stakeholders as per this plan	A contingency Action plan prepared	Budget – 3.75 cr A contingency Action plan prepared by each State/UT
3.	Research and Development	• Supported individual scientific studies on GLOF or related subject • Facilitated the creation of knowledge sharing, networking and publication on GLOF risk reduction	Some indigenous measures developed	Budget – 7.5 cr Some indigenous and measures are developed

3. Coverage of States & UTs

The program will be focused on Himalayan States and Union Territories (UTs) in a phase-wise manner. Four states and two Union Territories are the country's vulnerable areas prone to GLOF. Two states, Uttarakhand, Himachal Pradesh,and two Union Territory, i.e. Jammu Kashmir and Ladakh, have been selected from the Western Himalaya. From

easternHimalaya, two states, Sikkim and Arunachal Pradesh, have been selected. Each of these vulnerable states mayhave prioritized districts for the project implementation-based vulnerability of the districts.

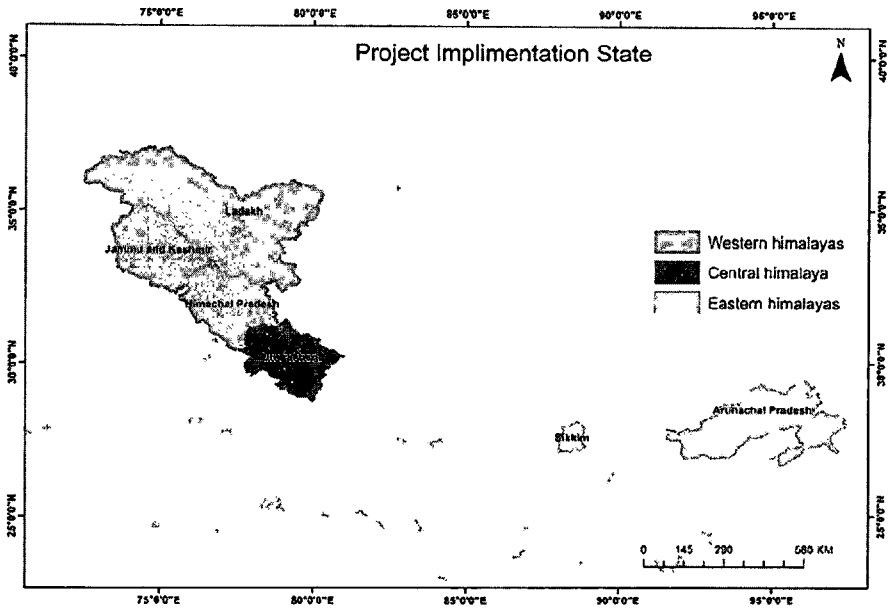

Figure 3: Project Implementation States

4. Budget

4.1. The Government of India has a policy commitment to reducing disaster risk by mitigation strategy. The 15th Finance Commission has recommended setting up Mitigation Funds at the national and state levels as the National Disaster Mitigation Fund and State Disaster Mitigation Fund consisting of 20% of the National Disaster Risk Management Fund (NDRMF) and State Disaster Risk Management Fund (SDRMF), respectively. The Finance Commission has allocated resources for the National Disaster Mitigation Fund and State Disaster Mitigation Fund. In addition,the 15th Finance Commission (XV-FC) has recommended Rs. 32,031 crore (20 % of the State Disaster Risk Management Fund (SDRMF) of Rs. 1,60,153 crore) for SDMF of States.

The total budget for all activities for the National GLOF Risk Mitigation Programme (NGRMP) in Phase-I is proposed to be ₹150 crores (comprising Rs. 135 crores from NDMF and 15 cr as States' share, excluding UTs budget) for three years from April 2023 to March

2026 (Table-10). The programme will be funded by NDMF for States whereas it will be funded by regular UT grants for UTs. States' share will be applicable as per extant NDMF guidelines.

This programme is also proposed to be implemented for UTs of Jammu & Kashmir and Ladakh as well. All components may be extended to them. An amount of Rs. 15 cr may be allocated to each of them.

Table 10: Component and Activity-wise budget allocation for Phase-1 (FY 2023-24 to 2025-26):

	Component	Activities	Ratio in %	Budget (Ratio in %)
1	GLOF Hazard and Risk Assessment	A.Creation and Updation of glacial lake inventory and Classification	20	15
		B. Hazard, Vulnerability and Risk Assessment of Glacial Lakes	80	
2	Glacial Lake Monitoring & GLOF Early Warning System	A.Glacial Lake Monitoring	20	35
		B. Early Warning System	80	
3	Site Specific Intervention	A.Structural measures	70	40
		B.Non-Structural Measures	30	
4	Awareness Generation and Capacity Building	A.Community Based GLOF Risk Awareness and Preparedness Programme	25	10
		B. Preparation of Contingency Action Plan to Reduce GLOF Risk	25	
		C. Research & Development (R&D) (Small Grant Window)	50	
	Total			100

Allocation of funds among components/sub-components have been mentioned in terms of percentage of gross allocation. State-wise distribution of funds is indicated in Table-11. States will divide allocated fund among components and sub-components as per ratio shown in Table-10.There could be flexibility for re-allocation of fund across sub-components of a component by States as per respective requirement; however, the fund allocation across

components may be inter-changeable only with approval of NDMA on reasonable ground shown by the State.

NRSC has identified total 7570 glacial lakes within Indian territory under National Hydrology Project funded by MoJS in 2017 (Table-1). Out of these lakes, though some risky glacial lakes have been identified NRSC, CWC, SDC (as mentioned at Para 1.3, 1.4, 1.5), this activity was done based on remote sensing.Also, this data does not cover all of 7570 glacial lakes. Hence, this data needs ground validation before taking up any mitigation activity for these risky lakes. Hence, total number of glacial lakes has been considered for budget allocation under this programme rather than number of risky glacial lakes in each State/UT (Table-11).

Accordingly, The state wise details of allocations for the period from FY 2023-24 to 2025-26 (Phase - 1) is given in Table-11:

Table-11: State-wise Distribution of Budget

Sl. No	State/UT	Number of Glacial Lakes*	Centre share (Rs. in crore)	State share (Rs. in crore)	Total Budget
1	Himachal Pradesh	537	31.5	3.5	35
2	Uttarakhand	347	27	3	30
3	Sikkim	733	36	4	40
4	Arunachal Pradesh	2,188	40.5	4.5	45
	Total	**7570**	**135**	**15**	**150**
5	Jammu & Kashmir (UT)	546			15
6	Ladakh (UT)	3,219			15

[* Source of data – NRSC-ISRO (Table-1)]

In addition, there will remain scope for further allocation of funds from NDMF based on States' performance. States are encouraged to utilize resources from SDMF also to enhance the scope of GLOF risk mitigation in line with this national programme.

Allocation from NDMF will be made at a proportion of 20%, 40%, and 40% of the total allocation in three FY 2023-24 to 2025-26. This allocation has been shown at Table 12. In addition to the budget, the fund flow for the project activities will be linked to outputs and

released in tranches as agreed by implementing partners. Subsequent installments may be released on utilization of 75% of funds released earlier. NDMA will have the authority to take all the financial decisions concerning unspent allocation or extension of projects with the approval of the Ministry of Home Affairs (MHA).

Table 12:State-wise details of the annual allocation

					FY 23-24			FY 24-25			FY 25-26		
S. No.	States/UTs	NDMF (Cr)	State Share (Cr)	Total Budget (Cr)	NDMF (Cr)	State Share (Cr)	Total Budget (Cr)	NDMF (Cr)	State Share (Cr)	Total Budget (Cr)	NDMF (Cr)	State Share (Cr)	Total Budget (Cr)
1	Uttarakhand	27	3	30	5.4	0.6	6	10.8	1.2	12	10.8	1.2	12
2	Himachal Pradesh	31.5	3.5	35	6.3	0.7	7	12.6	1.4	14	12.6	1.4	14
6	Arunachal Pradesh	40.5	4.5	45	8.1	0.9	9	16.2	1.8	18	16.2	1.8	18
	Sikkim	36	4	40	7.2	0.8	8	14.4	1.6	16	14.4	1.6	16
	Total	**135**	**15**	**150**									
16	Jammu & Kashmir	-	-	15	3			6			6		
17	Ladakh	-	-	15	3			6			6		

The release of the funds shall be subject to the submission of the following documents:

- Utilization Certificate for the funds released earlier, quarter-wise in the form prescribed.
- A Certificate regarding the requisite physical completion of works.
- A certificate that the grant released to the Scheme will be used for non-relief works only.
- A certificate that the state has a necessary budget provision in its plan to incur 25% of the expenses for the Scheme. The State share shall not be met out of funds available under SDMF

4.2. Account and Audit

a. The state NDMF account should distinctly show the source of receipt in the fund's name
   - Central share of NDMF
   - The state share of NDMF
   - Returns on investment
   - Redemption of investment
   - Contribution from reconstruction bond/CSR/implementing partners/community, etc., if any
   - Panel Interest (at bank rate or overdraft rate as the case may be)

b. The actual expenditure out of NDMF should be booked under respective Minor Heads within Major Head 2245

c. The detailed accounts of funds and investment thereof shall be maintained by the Account General in charge of Accounts of the State
d. The account of NDMF shall be audited annually by Comptroller & Auditor General. The State Government shall furnish a copy of the audit report of CAG to the Ministry of Finance and Ministry of Home Affairs

The States/institutes will ensure that the accounts are audited by a CAG / Chartered Accountant selected from a panel approved by the CAG. This account will be supported by a statement of reconciliation from the competent authority.

Based on the scale and nature of the projects, all the projects are taken up for financial and social audits as decided by the Disaster Management Authority

- **Financial Audits** – A financial audit of the funds received and expenditures made will be carried out by the Comptroller and Auditor-General (CAG) of India
- **Technical Audit-** National Disaster Management Authorities identify technical experts to conduct technical audits of all mitigation projects. The authority will decide the number of required audits as per the size and complexity of the projects. The mid-term reviews and projects-end evaluation should be undertaken by experts included in the roster for this purpose
- **Social Audit-** Since most of the mitigation measures require community participation during its process, the social audit will be conducted during the project cycle to review how the project has sought to involve the people at risk and deliver the results to communities, as prescribed by the authority.

5. Project Appraisal, Approval, Implementation, and Monitoring

5.1. Project Preparation

The implementing SDMA will be responsible for identification and conducting a pre-feasibility study for the project, which includes both structural and non-structural aspects.

For project proposals submitted by Central Government Ministries/Departments/Agencies, they need to follow the guidelines outlined in the NDMF guidelines issued by MHA on February 28, 2022. This involves using a specific template for the pre-feasibility check as provided in the NDMA Guidelines. Additionally, they will be responsible for preparing the project proposal and identifying the type of intervention needed for the project.

The NDMA or SDMA (as prescribed above) will review the project's financial viability and technical feasibility within 30 days of getting the proposal. If a project has a budget under Rs 1 crore, it only needs to submit a basic concept note and does not require a detailed feasibility study. NDMA/SDMA will assess the proposal and inform the organization responsible for implementing the project about any necessary changes or recommendations.

A mitigation project may be local community-based interventions that reduce the risk and promote environment-friendly settlement and livelihood practices. The three procedures that mitigation initiatives pass through during the project preparation phases include Project identification, a project feasibility check, and preparation of a detailed project proposal:-

a. **Project identification:** A GLOF mitigation project may be identified based on GLOF risk and their impacts. It should cover the characteristics of the area's GLOF proneness, evaluate the risk magnitude, analyze the GLOF impacts, and recommend mitigation solutions. A mitigation project can be proposed based on a rationale for mitigation investment based on expected impacts and a cost-benefit analysis. Project proposal needs to be prepared in the template prescribed for the pre-feasibility check (as prescribed in Guideline for NDMF)
b. **Pre-feasibility check:** The pre-feasibility check would be conducted to understand the relevance of the project, its financial viability and technical feasibility. The pre-feasibility check would be conducted to understand the relevance of the project, its financial viability and technical feasibility.

c. **Preparation & Appraisal of Detailed Project Report (DPR):**

Once the project passes the initial feasibility check, the organization responsible for implementing it needs to provide a Detailed Project Report (DPR). This report should include in-depth technical and financial details, as well as information about the project's social aspects. The format for this report is specified in the NDMF Guideline issued by NDMA.

The DPR for a State's disaster mitigation project will be reviewed by the Technical Appraisal Committee (TAC) at SDMA. This committee looks at projects from both technical and social angles. They also review and suggest improvements for projects that are funded through the NDMF/SDMF.

Once the State TAC reviews the DPR, the State's Executive Committee (SEC) approves it. The SEC examines the proposal from all angles, including administrative aspects. This review process by the TAC and SEC should be completed within 30 days of receiving the DPR. After the SEC's approval, the landslide project is submitted to NDMA for final approval.

The DPR for disaster mitigation projects proposed by Central Government Ministries, Departments, or Agencies from the NDMF will be reviewed by the TAC at NDMA. The TAC evaluates mitigation projects from both technical and social perspectives.

The DPR lays the project goals, activities, cost estimates, and intended impacts in adequate detail.

The formulation of DPR would require several steps

- A risk assessment of the GLOF, risk exposure and accompanying vulnerabilities
- Analysis of the context- socio-economic, governance/regulatory and environmental
- Analysis of the stakeholder's capacities- technical, organizational, and financial

- Activities planned under the project and the outputs
- Cost-benefit analyses
- Budget for the project activities
- Implementation plan and the timeline for the completion of the project
- Reporting and monitoring arrangement

5.2. Appraisal/Advisory Committees

Technical Advisory Committee (TAC): The TAC for SDMA and NDMA are formed by technical experts. It includes specialists like Geologists, Soil Conservation Officers, Geographers, Civil Engineers etc.

Appraisal at NDMA by Project Appraisal Committee (PAC): After receiving the DPRs from both the State and any Central Government Department or agency, the Project Appraisal Committee (PAC) at the NDMA will review them. The PAC, which includes Members and officials of NDMA, officials from the relevant Ministers/Departments, and disaster management experts, will assess the projects in terms of administration and finances. The PAC at NDMA may refer the DPR for a further technical review through the NDMA's TAC. This review process, carried out by PAC, will be finished within 30 days of receiving the DPR.

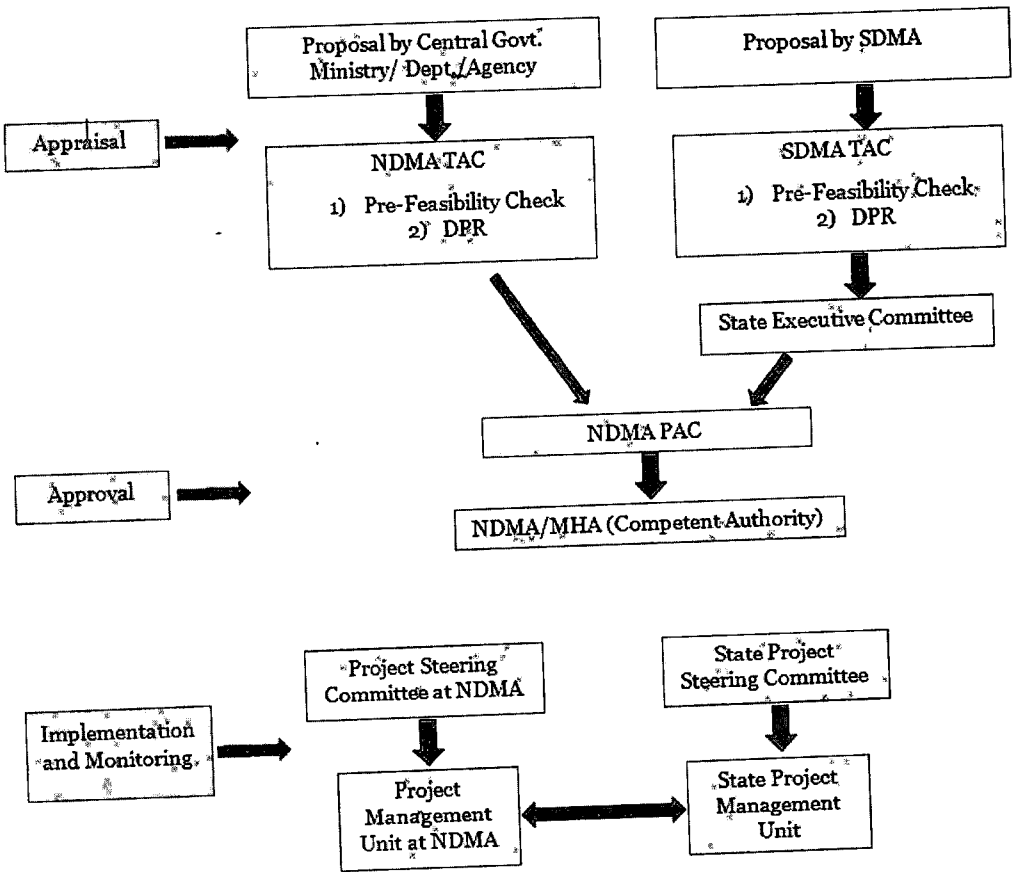

Figure 4: Project Appraisal, Approval, Implementation and Monitoring Mechanism

5.3. Project Approval

After approval by HLC on the programme as a whole, States will prepare proposal and submit each of them to NDMA for appraisal. If the Pac at NDMA approves a proposal and it falls within the financial power of the NDMA, the proposal gets the final sanction, and the funds are released by the NDMA. However, if the proposal exceeds NDMA's budget authority, it will be sent to the MHA with NDMA's recommendation for approval and funding by the appropriate authority.

After approval States will implement it and States will be Approval Authority for various stages of implementation.

5.4. Implementation and Monitoring

NDMA will manage the project and have the overall responsibility for the implementation. Since the project will be carried out in different states, NDMA will take on this role at the national level, while state-level agencies will do so in their respective jurisdictions. The main

groups responsible for carrying out and keeping an eye on the project are the PMU (Project Monitoring Unit) at the national level and the SPIUs (State project Implementation Unit) at the state level.

Two-Tier Project Management Structure:

a. Project Steering Committee:

Both the PMU and SPIUs will set up a Project Steering Committee (PSC) to guide and monitor the project as a whole. The PSC at the national level will be led by the Member (Mitigation) of NDMA, while at the state level, it will be led by the respective Chief Secretaries. The State Project Steering Committees (SPSCs) will approve project investments and play an active role in expediting the implementation process.

During implementation, the National Project Steering Committee (NPSC) will provide strategic oversight. This will happen through yearly or half-yearly review meetings, where the NPSC will:

- Review and approve the annual or revised budgets,
- Assess progress based on set milestones,
- Examine important findings from audit and evaluation reports, and
- Offer necessary guidance for the project.

Likewise, at the state level, the SPSC will oversee the project strategically during implementation. Their key responsibilities will include:

- Creating and submitting annual work plans, procurement plans, and financial estimates,
- Managing and supervising overall project implementation,
- Reviewing significant findings from semi-annual and annual project progress reports, as well as audit and evaluation reports,
- Supervising, guiding, and approving proposals from different Line Departments, and
- Monitoring project progress and providing guidance to achieve project objectives and goals.

b. Project Management Unit (PMU):

A PMU (known as the Mountain Hazard Cell), will be set up at NDMA and led by an Advisor (Mitigation). This unit will oversee the project's implementation, monitoring, and evaluation. The PMU will coordinate, report, and offer technical support to State Disaster Management Authorities (SDMAs). It is headed by an Advisor (Mitigation), and supported by relevant experts.

In each state a Project Implementation Unit (SPIUs), will function (also to be known as State Mountain Hazard Cell, SMHC)). It will manage project implementation within the state. The State MHC, led by the Secretary, SDMA, will have experts from different sectors, including line departments responsible for project investments, as well as other subject specialists. State MHC will also handle tasks like submitting

completion certificates and reports and maintaining an updated database of project information.

Line departments in the states will implement the project tasks and maintain the infrastructure that has been set up. They will assign nodal officers and carry out the project through field offices.

The project activities will undergo periodic reviews: mid-term, annual, and project-end evaluations, conducted by external experts to provide an unbiased assessment of project performance. The mid-term review happens halfway through the program's implementation, considering all targets and outcomes. The annual review focuses on indicators specified in annual plans. The project-end evaluation comprehensively analyses progress and performance throughout the program's duration.

Regular progress and performance will be tracked through defined milestones, outputs, and outcomes. A manual for project implementation and monitoring will also be developed.

A **Time Frame of the programme (Phase-I) has been given at ANNEXURE – E.**

5.5. Implementation Set-up

Responsibility of NDMA: NDMA will assist the approved projects under NDMF/SDMF with technical guidance and share their findings on the mitigation portal. NDMA's technical assistance will involve specialized experts for different tasks, including consulting with project proponents and beneficiaries, evaluating and approving projects, overseeing implementation and progress, making mid-term corrections if needed, evaluating outcomes, and closing projects related to landslides.

NDMA will also assist States in effectively carrying out these projects, addressing technical questions from project proponents, maintaining a database of project progress alongside SDMAs and DDMAs, and conducting research to improve assessment, approval, and other procedures.

NDMA will support states in dealing with landslides and other mountain hazards, facilitate the implementation of various mitigation projects, develop location-specific mitigation solutions, and prepare technical reports onlandslides and other mountain hazards, and manage the national-level monitoring and coordination of projects and programs.

Responsibility of NIDM: NIDM will undertake research/training/capacity-building activities for the programme in partnership with the SDMAs, DDMAs,and the Panchayati Raj Institutions for adequate training and learning along with a sensitization programme for the Village-level task force at the Panchayat level.

Role of Central Water Commission (CWC):

Being the nodal agency (subject to notification) for GLOF disaster and a premier organization in the country under Ministry of Jal Shakti, CWC will have a major role of

providing technical assistance for GLOF risk mitigation. CWC is already monitoring glacial lakes, as mentioned earlier; they have also done first order GLOF impact analysis of eight critical lakes in some States. They have engineers, who are capable to provide guidance for mitigation. They have already been proposed for being nodal agency for GLOF hazard.
States will carry out hazard risk mapping, geotechnical analysis, mitigation planning in consultation with CWC, whenever required. At the same time, it is necessary to build capacity of other agencies/institutes/universities, who are working in this area, for similar kind of activities and it is necessary to utilize their knowledge base for disaster risk reduction. Engaging them will also expedite the programme. Hence, States may decide and appoint implementing agencies, for relevant activities. However, CWC may mentor all such other agencies, for their relevant activities. Therefore, CWC and Ministry of Jal Shakti are expected to extend all sorts of cooperation in this regard in a time bound manner.

Mountain Hazard Cell (MHC) at NDMA

Some of the important functions of the Mountain Hazard Cell (MHC) are:

- Undertake techno-scientific consent/ consultation of project proponents and beneficiaries, project appraisal, approval, implementation/execution, monitoring, mid-term evaluation/ correction, evaluation, project closure etc., of the projects on GLOFs.
- Provide necessary technical assistance to States for successful implementation of the projects. Respond to the technical and scientific queries from various project proponents.
- Maintains a database of all projects and their progress in coordination with SDMA/DDMA and conducts research studies to enhance the assessment, approval, and other procedures.
- Support states concerning GLOFs and other mountain hazards and facilitate for implementation of various mitigation strategies.
- Ensure the sustainability of various strategies that will be taken under the GLOF mitigation programme
- Assist NDMA in the preparation of scientific and technical reports on various mountain hazards
- Overall monitoring and coordination of projects / programmes at the national level.

Knowledge Management network:

NDMA will create an extra-vertical for inter-agency coordination and collaboration for knowledge sharing amongst stakeholders through a common platform.

MHC at NDMA, with assistance of States, will work to bring together indigenous knowledge, innovations made within the country for use in GLOF and GLOF Risk mitigation. It will strive for international collaboration and create awareness among states about global best practices. Under this activity, resource persons/organizations available in the domain will be identified for specified services. NDMA also may create a GIS platform for DRR related applications for States.

At the state level, an institution with expertise in dealing with GLOFs and mountain hazards should be identified to facilitate the technical and scientific inputs for implementing the programme. This state-level technical institute can interact with expert institutions such as

GSI on various GLOF research and knowledge-sharing activities. Strengthening the institutional capacity of higher education institutions located in mountainous areas of GLOF risk reduction is vital for facilitating GLOF knowledge management at the regional level. Establishing a GLOF risk reduction centre or similar set-up in those identified institutions can be an ideal platform for facilitating knowledge creation and research and development activities. MHC may play an important role in creating a national-level centre and its integration with other technical institutions at the State level. This centre may focus on strengthening qualitative capacities in GLOF mitigation by developing a database of local GLOF events, disaster information, experience sharing, and knowledge transfer to the local community. This can also act as liaison support between various research and development institutions.

Mountain Hazard Cell (MHC) at State Level

State may form a Mountain Hazard Cell (MHC) under SDMA in same line as described it for NDMA above. It will comprise of manpower engaged for mitigation projects funded by mitigation fund as mentioned in the guideline issued by MHA. State MHC will be responsible for the overall state-level planning and monitoring of this programme. It should have sufficient human resources with adequate technical capacity to manage the components of this programme.

The State MHC also co-ordinate site visit / inspection, monitoring, periodic-term evaluation and mid-term course correction. The site visits / inception may be conducted to assess physical progress and quality of work implemented at the respective.

State MHC will supervise and monitor the approved projects during implementation and will be responsible for submitting completion certificates as well as required reports, including maintaining an updated database containing information about all projects implemented with the assistance from NDMF. Mitigation activity may be done only after proper risk identification. Otherwise, all four components may be implemented simultaneously.

5.6. Convergence among Projects

This programme may also be integrated with the ongoing skill and livelihood initiatives of the Government of India like the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), National Rural Livelihood Mission (NRLM), and National Urban Livelihood Mission (NULM), Compensatory Afforestation Fund Management and Planning Authority (CAMPA), to reduce GLOF risk and its mitigation. States may converge mitigation activities under this programme with other Central Government sponsored programme or State run programme. For example:

a. Community based mitigation activities for slope stabilization, bio restoration may be converged with MGNREGA, CAMPA activities.
b. Structural mitigation activities may be converged with road development programs like PMGSY, NHAI/State highway project.
c. Creation of volunteers may be converged with Aapda Mitra Scheme.

5.7. Sustainability of the Programme

The basic purpose of NDMF is to promote investment for mitigation rather than recovery and reconstruction. Alike NDMF this is first such mitigation programme, which will address the issue of threat from GLOF. The programme will involve all aspects of GLOF mitigation comprehensively. Nevertheless, it will also encourage mainstreaming GLOF mitigation in developmental activities. Though it is proposed to be implemented with a corpus of 150 Cr. in first phase, this amount is insufficient to mitigate all GLOF prone glacial lakes within the country. At the same time there are a large number of lakes (~20000, as per NRSC data 2017 under NHP), which are trans-boundary but area under GLOF threat lies also within Indian territory. This is a critical issue, which requires special attention and multilateral cooperation as well. Hence, this programmehas to be continued until GLOF resilience is achieved fully.

Based on learning and outcomes of first phase,the Phase-II of the programme will be planned. Subsequent phases after phase-I may be funded from NDMF, granted by subsequent Finance Commissions or otherwise, having similar arrangements of funding. Thus, its financial sustainability may be ensured.

During implementation of first phase of the programme States/UTs will set up a Mountain Hazard Cell comprising subject experts. SDMAs/DDMAs also will develop institutional arrangements for planning, implementation, and monitoring of mitigation activities, as mentioned earlier. These arrangements will build institutional capacities and may be continued during subsequent phases as well. Thus, the institutional sustainability of this programme may be ensured.

There will be sufficient scope to build capacity among work force engaged during implementation of first phase of the programme. Various organizations/institutes at national/state level will get exposure to mitigation activities; they may also get technical assistance from international collaboration. Accordingly, trained work force will get ready for more intensive subsequent phases. Thus, the technical sustainability of this programme will be ensured.

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Annexure A

District Wise Distribution of Glacial Lakes in India
(Source: NRSC-ISRO, 2017)

District-wise list of Glacial Lakes in Arunachal Pradesh State

S.No	District	Number of Glacial Lakes
1	Anjaw	449
2	Changlang	9
3	Dibang Valley	669
4	East Kameng	63
5	KraDaadi	4
6	KurungKumey	75
7	Lohit	3
8	Lower Dibang Valley	6
9	Siang	13
10	Tawang	443
11	Upper Siang	87
12	Upper Subansiri	154
13	West Kameng	173
14	West Siang	40
	TOTAL	2,188

District-wise list of Glacial Lakes in Sikkim State

S.No	District	Number of Glacial Lakes
1	North Sikkim	589
2	South Sikkim	1
3	West Sikkim	59
4	East Sikkim	84
	TOTAL	733

District-wise list of Glacial Lakes in Himachal Pradesh State

S.No	District	Number of Glacial Lakes
1	Chamba	66
2	Kangra	39
3	Kinnaur	128
4	Kullu	93
5	Lahul&Spiti	185
6	Shimla	26
	TOTAL	537

District-wise list of Glacial Lakes in Uttarkhand State

S.No	District	Number of Glacial Lakes
1	Bageshwar	8
2	Chamoli	192
3	Pithoragarh	43
4	Rudraprayag	11

5	TehriGarhwal	10
6	Uttarkashi	83
	TOTAL	347

District-wise list of Glacial Lakes in Ladakh UT

S.No	District	Number of Glacial Lakes
1	Kargil	307
2	Leh	2,912
	TOTAL	3,219

District-wise list of Glacial Lakes in Jammu & Kashmir UT

S.No	District	Number of Glacial Lakes
1	Anantnag	52
2	Badgam	25
3	Bandipore	64
4	Baramula	8
5	Doda	13
6	Ganderbal	45
7	Kishtwar	197
8	Kulgam	28
9	Kupwara	1
10	Muzaffarabad	74
11	Punch	22
12	Rajauri	10
13	Reasi	4
14	Srinagar	2
15	Udhampur	1
	TOTAL	546

ANNEXURE - B

[Data Source – NRSC, NHP, 2017]

1. List of 614 ranked Glacial Lakes in Indus River Basin

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
1	32.499	77.547	128.690	Himachal Pradesh	Lahul&Spiti

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
2	34.316	80.858	232.340	Transboundary	
3	34.432	74.925	161.038	Jammu & Kashmir	Ganderbal
4	32.526	77.220	77.594	Himachal Pradesh	Lahul&Spiti
5	34.920	74.521	60.600	Jammu & Kashmir	Muzaffarabad
6	34.829	74.062	93.895	Jammu & Kashmir	Muzaffarabad
7	33.159	76.984	59.780	Ladakh	Kargil
8	34.457	78.136	95.677	Ladakh	Leh
9	30.385	81.930	59.794	Transboundary	
10	35.315	74.937	20.130	Ladakh	Leh
11	33.945	76.230	49.656	Ladakh	Kargil
12	31.523	78.383	3.834	Himachal Pradesh	Kinnaur
13	30.390	81.819	14.508	Transboundary	
14	31.459	78.369	1.067	Himachal Pradesh	Kinnaur
15	34.184	75.373	16.801	Jammu & Kashmir	Anantnag
16	35.092	76.252	24.012	Ladakh	Leh
17	32.930	76.672	4.826	Himachal Pradesh	Chamba
18	34.136	75.314	7.280	Jammu & Kashmir	Anantnag
19	31.914	78.840	18.034	Transboundary	
20	31.993	78.845	20.899	Transboundary	
21	32.736	78.726	34.789	Ladakh	Leh
22	36.025	73.933	3.647	Ladakh	Leh
23	36.348	73.524	2.479	Ladakh	Leh
24	34.005	76.722	18.322	Ladakh	Leh
25	35.239	73.742	2.406	Ladakh	Leh
26	31.661	78.168	23.202	Himachal Pradesh	Kinnaur
27	34.422	75.058	40.118	Jammu & Kashmir	Bandipore
28	34.495	75.639	7.648	Ladakh	Kargil
29	32.888	76.734	1.156	Himachal Pradesh	Lahul&Spiti
30	32.269	76.488	1.499	Himachal Pradesh	Chamba
31	31.917	77.422	2.988	Himachal Pradesh	Kullu
32	32.934	78.212	2.450	Ladakh	Leh
33	31.984	79.958	15.730	Transboundary	
34	32.505	79.476	1.633	Transboundary	
35	33.184	76.125	6.975	Jammu & Kashmir	Kishtwar
36	32.157	77.299	6.613	Himachal Pradesh	Kullu
37	35.379	76.186	2.244	Ladakh	Leh
38	31.585	78.186	4.721	Himachal Pradesh	Kinnaur
39	32.492	78.852	11.122	Ladakh	Leh
40	31.709	78.741	1.888	Himachal Pradesh	Kinnaur
41	33.027	78.481	3.630	Ladakh	Leh
42	34.158	76.009	1.772	Ladakh	Kargil
43	33.165	78.177	6.857	Ladakh	Leh
44	32.385	79.669	6.460	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
45	32.059	78.807	9.302	Transboundary	
46	33.868	76.121	39.440	Jammu & Kashmir	Kishtwar
47	32.101	79.908	1.239	Transboundary	
48	33.456	76.393	1.430	Jammu & Kashmir	Kishtwar
49	31.672	77.662	1.700	Himachal Pradesh	Shimla
50	33.174	76.056	3.993	Jammu & Kashmir	Kishtwar
51	34.398	77.983	28.024	Ladakh	Leh
52	32.577	79.487	2.297	Transboundary	
53	32.234	76.754	9.704	Himachal Pradesh	Chamba
54	33.182	76.113	2.617	Jammu & Kashmir	Kishtwar
55	35.739	73.256	18.920	Ladakh	Leh
56	36.306	73.250	9.450	Ladakh	Leh
57	33.713	76.674	1.473	Ladakh	Kargil
58	35.825	73.211	26.435	Ladakh	Leh
59	35.028	77.626	1.607	Ladakh	Leh
60	32.705	78.698	3.528	Ladakh	Leh
61	34.351	76.075	10.632	Ladakh	Kargil
62	34.381	77.243	2.113	Ladakh	Leh
63	34.040	75.844	25.262	Ladakh	Kargil
64	36.300	73.252	1.910	Ladakh	Leh
65	33.753	78.274	1.063	Ladakh	Leh
66	35.006	76.372	1.199	Ladakh	Leh
67	33.303	78.233	1.510	Ladakh	Leh
68	33.618	77.614	8.642	Ladakh	Leh
69	36.023	72.877	1.208	Ladakh	Leh
70	34.721	76.840	1.458	Ladakh	Leh
71	35.053	77.425	1.115	Ladakh	Leh
72	33.498	77.702	1.514	Ladakh	Leh
73	32.300	78.985	9.658	Transboundary	
74	34.980	75.039	9.086	Ladakh	Leh
75	34.051	76.718	15.805	Ladakh	Leh
76	34.532	75.879	1.300	Ladakh	Kargil
77	35.090	76.230	2.732	Ladakh	Leh
78	35.096	74.902	6.952	Ladakh	Leh
79	35.073	74.177	11.970	Ladakh	Leh
80	31.419	78.069	1.234	Himachal Pradesh	Kinnaur
81	32.762	77.196	5.376	Himachal Pradesh	Lahul&Spiti
82	35.343	76.302	2.968	Ladakh	Leh
83	31.035	81.513	2.868	Transboundary	
84	34.693	77.023	1.838	Ladakh	Leh
85	36.352	73.522	1.065	Ladakh	Leh
86	30.477	80.592	12.626	Uttarakhand	Pithoragarh
87	35.105	74.219	2.521	Ladakh	Leh

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
88	32.943	78.197	2.199	Ladakh	Leh
89	36.069	72.924	1.319	Ladakh	Leh
90	32.029	78.845	15.618	Transboundary	
91	33.115	78.009	9.378	Ladakh	Leh
92	31.919	78.784	13.437	Transboundary	
93	33.558	78.506	25.325	Ladakh	Leh
94	32.149	78.488	5.473	Himachal Pradesh	Lahul&Spiti
95	35.032	77.700	18.020	Ladakh	Leh
96	36.353	73.520	1.540	Ladakh	Leh
97	33.548	78.494	4.089	Ladakh	Leh
98	32.996	79.981	3.613	Transboundary	
99	32.872	80.126	1.318	Transboundary	
100	34.674	77.071	2.010	Ladakh	Leh
101	31.967	79.890	2.209	Transboundary	
102	34.606	76.725	2.349	Ladakh	Leh
103	31.915	77.526	9.711	Himachal Pradesh	Kullu
104	32.142	78.919	2.537	Transboundary	
105	31.406	78.012	4.414	Himachal Pradesh	Kinnaur
106	34.915	74.788	3.558	Ladakh	Leh
107	32.389	79.659	12.305	Transboundary	
108	34.957	76.913	1.404	Ladakh	Leh
109	32.376	79.647	1.908	Transboundary	
110	31.937	79.994	14.455	Transboundary	
111	35.076	76.358	1.408	Ladakh	Leh
112	34.398	77.257	2.639	Ladakh	Leh
113	32.965	80.202	1.747	Transboundary	
114	32.098	77.454	1.258	Himachal Pradesh	Kullu
115	35.899	73.070	6.962	Ladakh	Leh
116	33.134	76.602	4.130	Himachal Pradesh	Chamba
117	34.920	75.143	5.403	Ladakh	Leh
118	35.002	76.376	1.724	Ladakh	Leh
119	31.234	81.138	10.921	Transboundary	
120	35.880	73.577	30.858	Ladakh	Leh
121	34.476	77.046	1.994	Ladakh	Leh
122	34.450	77.060	2.520	Ladakh	Leh
123	34.156	76.063	3.833	Ladakh	Kargil
124	32.362	79.589	1.090	Transboundary	
125	35.032	77.691	7.093	Ladakh	Leh
126	34.624	76.725	1.040	Ladakh	Leh
127	33.702	78.227	3.436	Ladakh	Leh
128	32.867	76.932	2.327	Himachal Pradesh	Lahul&Spiti
129	34.006	76.788	14.145	Ladakh	Leh
130	32.576	79.447	1.621	Ladakh	Leh

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
131	31.965	78.416	4.731	Himachal Pradesh	Lahul&Spiti
132	33.671	77.606	7.626	Ladakh	Leh
133	34.560	75.707	3.219	Ladakh	Kargil
134	34.752	76.436	4.988	Ladakh	Kargil
135	32.393	77.309	1.224	Himachal Pradesh	Lahul&Spiti
136	35.086	76.733	2.709	Ladakh	Leh
137	35.030	76.323	2.731	Ladakh	Leh
138	33.024	79.955	2.042	Transboundary	
139	35.366	75.131	2.443	Ladakh	Leh
140	32.844	77.280	3.132	Himachal Pradesh	Lahul&Spiti
141	32.945	78.198	1.530	Ladakh	Leh
142	31.950	79.986	10.435	Transboundary	
143	32.363	78.272	13.590	Himachal Pradesh	Lahul&Spiti
144	32.557	79.447	4.291	Ladakh	Leh
145	33.922	75.632	4.080	Jammu & Kashmir	Kishtwar
146	31.898	78.714	1.024	Himachal Pradesh	Kinnaur
147	32.555	79.297	4.794	Ladakh	Leh
148	35.067	76.691	1.386	Ladakh	Leh
149	33.918	75.614	1.799	Jammu & Kashmir	Kishtwar
150	35.089	76.180	1.214	Ladakh	Leh
151	34.998	76.918	1.362	Ladakh	Leh
152	34.477	76.972	9.341	Ladakh	Leh
153	34.423	77.087	3.381	Ladakh	Leh
154	34.871	74.602	3.068	Ladakh	Leh
155	33.162	76.134	1.245	Jammu & Kashmir	Doda
156	34.572	76.815	1.343	Ladakh	Leh
157	31.554	78.751	10.667	Himachal Pradesh	Kinnaur
158	32.966	78.423	2.772	Ladakh	Leh
159	33.332	78.206	2.381	Ladakh	Leh
160	36.447	73.106	1.307	Ladakh	Leh
161	32.099	79.871	4.660	Transboundary	
162	36.642	73.407	14.061	Ladakh	Leh
163	34.855	76.351	2.495	Ladakh	Kargil
164	35.071	74.225	2.059	Ladakh	Leh
165	32.728	78.779	1.712	Ladakh	Leh
166	31.972	79.973	6.668	Transboundary	
167	34.905	77.616	14.509	Ladakh	Leh
168	31.898	77.526	1.948	Himachal Pradesh	Kullu
169	33.844	76.375	18.492	Ladakh	Kargil
170	32.963	78.422	2.799	Ladakh	Leh
171	32.307	77.089	2.162	Himachal Pradesh	Kullu
172	32.017	78.875	6.580	Transboundary	
173	31.960	79.936	4.101	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
174	32.356	79.704	4.077	Transboundary	
175	31.408	78.027	3.196	Himachal Pradesh	Kinnaur
176	31.102	81.417	2.167	Transboundary	
177	34.717	77.725	3.569	Ladakh	Leh
178	33.312	76.363	6.583	Jammu & Kashmir	Kishtwar
179	31.140	81.259	1.256	Transboundary	
180	35.055	76.759	1.007	Ladakh	Leh
181	32.537	79.421	5.362	Ladakh	Leh
182	32.972	79.957	1.266	Transboundary	
183	32.135	77.433	1.159	Himachal Pradesh	Kullu
184	32.409	78.900	30.440	Ladakh	Leh
185	35.962	73.761	1.017	Ladakh	Leh
186	33.942	76.019	24.045	Jammu & Kashmir	Kishtwar
187	36.630	73.751	2.941	Ladakh	Leh
188	34.527	77.157	1.363	Ladakh	Leh
189	34.674	77.754	1.574	Ladakh	Leh
190	34.559	76.925	1.094	Ladakh	Leh
191	32.410	79.604	5.922	Transboundary	
192	34.394	77.337	3.242	Ladakh	Leh
193	34.000	77.422	3.655	Ladakh	Leh
194	35.343	75.185	2.791	Ladakh	Leh
195	36.608	73.883	2.864	Ladakh	Leh
196	32.576	79.429	1.790	Ladakh	Leh
197	35.364	74.682	1.868	Ladakh	Leh
198	32.338	79.002	4.247	Transboundary	
199	34.567	76.817	4.440	Ladakh	Leh
200	34.657	77.736	3.381	Ladakh	Leh
201	35.321	75.188	4.744	Ladakh	Leh
202	36.676	73.730	1.942	Ladakh	Leh
203	31.673	77.663	2.216	Himachal Pradesh	Shimla
204	32.510	79.445	1.094	Transboundary	
205	32.180	77.493	4.688	Himachal Pradesh	Kullu
206	33.144	76.672	1.654	Himachal Pradesh	Chamba
207	31.908	78.802	1.189	Transboundary	
208	33.714	76.669	1.124	Ladakh	Kargil
209	32.855	80.134	1.272	Transboundary	
210	35.893	73.267	1.738	Ladakh	Leh
211	32.474	78.848	7.263	Ladakh	Leh
212	34.410	77.089	2.676	Ladakh	Leh
213	31.898	77.533	1.272	Himachal Pradesh	Kullu
214	33.460	76.474	6.235	Jammu & Kashmir	Kishtwar
215	32.193	79.792	2.245	Transboundary	
216	34.110	76.425	1.333	Ladakh	Kargil

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
217	34.312	77.448	2.076	Ladakh	Leh
218	35.219	75.226	1.541	Ladakh	Leh
219	34.947	74.726	4.480	Ladakh	Leh
220	35.025	77.660	4.723	Ladakh	Leh
221	31.401	78.489	2.043	Himachal Pradesh	Kinnaur
222	34.341	76.084	1.271	Ladakh	Kargil
223	35.001	74.987	1.492	Ladakh	Leh
224	35.204	75.230	1.359	Ladakh	Leh
225	34.453	76.924	3.442	Ladakh	Leh
226	32.240	77.449	2.339	Himachal Pradesh	Lahul&Spiti
227	35.062	74.223	1.743	Ladakh	Leh
228	36.294	73.116	1.547	Ladakh	Leh
229	31.964	79.899	4.754	Transboundary	
230	34.619	76.813	2.606	Ladakh	Leh
231	34.593	76.787	1.285	Ladakh	Leh
232	34.781	76.529	1.085	Ladakh	Leh
233	31.095	81.504	4.441	Transboundary	
234	34.506	77.298	1.485	Ladakh	Leh
235	34.108	76.418	1.694	Ladakh	Kargil
236	34.335	77.457	2.407	Ladakh	Leh
237	33.846	76.015	1.171	Jammu & Kashmir	Kishtwar
238	32.135	77.435	1.621	Himachal Pradesh	Kullu
239	33.088	76.701	1.648	Himachal Pradesh	Chamba
240	34.543	76.835	2.469	Ladakh	Leh
241	32.769	76.970	1.200	Himachal Pradesh	Lahul&Spiti
242	32.284	79.676	4.256	Transboundary	
243	33.009	76.757	1.470	Himachal Pradesh	Chamba
244	35.853	73.149	2.192	Ladakh	Leh
245	32.044	78.832	2.092	Transboundary	
246	32.978	76.259	2.084	Himachal Pradesh	Chamba
247	31.899	77.538	2.034	Himachal Pradesh	Kullu
248	34.532	76.951	2.304	Ladakh	Leh
249	32.842	76.538	4.590	Himachal Pradesh	Chamba
250	34.374	77.328	1.636	Ladakh	Leh
251	36.240	73.954	1.850	Ladakh	Leh
252	34.446	78.143	20.526	Ladakh	Leh
253	33.019	78.488	1.986	Ladakh	Leh
254	34.831	76.358	2.523	Ladakh	Kargil
255	36.022	73.722	1.046	Ladakh	Leh
256	34.513	77.911	3.793	Ladakh	Leh
257	34.543	77.049	2.763	Ladakh	Leh
258	32.296	79.679	2.100	Transboundary	
259	30.427	81.476	1.182	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
260	34.805	73.879	1.491	Jammu & Kashmir	Muzaffarabad
261	33.527	76.283	2.306	Jammu & Kashmir	Kishtwar
262	32.039	79.918	3.593	Transboundary	
263	34.360	75.140	9.593	Jammu & Kashmir	Bandipore
264	32.591	79.432	1.337	Ladakh	Leh
265	30.416	81.468	10.021	Transboundary	
266	31.666	77.619	4.025	Himachal Pradesh	Kullu
267	32.775	76.951	1.389	Himachal Pradesh	Lahul&Spiti
268	33.308	78.642	1.150	Ladakh	Leh
269	31.956	79.924	1.804	Transboundary	
270	34.621	76.968	1.877	Ladakh	Leh
271	32.584	79.338	1.574	Transboundary	
272	31.179	81.152	19.911	Transboundary	
273	31.845	80.480	1.117	Transboundary	
274	34.149	76.057	2.373	Ladakh	Kargil
275	31.148	81.222	7.341	Transboundary	
276	34.454	77.275	4.348	Ladakh	Leh
277	32.095	79.773	2.076	Transboundary	
278	31.916	80.449	1.189	Transboundary	
279	32.410	79.585	3.305	Transboundary	
280	34.401	78.079	20.392	Ladakh	Leh
281	32.886	76.647	2.435	Himachal Pradesh	Chamba
282	32.283	79.694	5.064	Transboundary	
283	34.530	76.833	2.562	Ladakh	Leh
284	35.193	74.616	8.040	Ladakh	Leh
285	32.367	79.652	1.265	Transboundary	
286	31.970	78.869	6.030	Transboundary	
287	32.967	80.201	1.852	Transboundary	
288	32.305	77.086	1.597	Himachal Pradesh	Kullu
289	34.907	77.609	1.185	Ladakh	Leh
290	34.510	76.971	2.196	Ladakh	Leh
291	32.258	78.978	2.287	Transboundary	
292	34.882	75.907	4.100	Ladakh	Leh
293	34.503	77.985	8.453	Ladakh	Leh
294	32.722	77.413	10.000	Himachal Pradesh	Lahul&Spiti
295	33.144	77.053	6.053	Ladakh	Kargil
296	33.033	79.937	3.319	Transboundary	
297	32.249	77.416	1.092	Himachal Pradesh	Lahul&Spiti
298	34.470	77.315	1.049	Ladakh	Leh
299	31.264	81.445	3.278	Transboundary	
300	31.886	77.537	1.473	Himachal Pradesh	Kullu
301	34.560	77.061	1.917	Ladakh	Leh
302	33.128	77.065	7.452	Ladakh	Kargil

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
303	31.694	80.664	14.112	Transboundary	
304	31.919	80.467	1.205	Transboundary	
305	32.047	79.832	3.900	Transboundary	
306	32.441	78.925	10.651	Ladakh	Leh
307	35.954	76.030	10.615	Ladakh	Leh
308	32.708	78.688	3.949	Ladakh	Leh
309	33.708	78.220	1.370	Ladakh	Leh
310	34.561	76.849	3.413	Ladakh	Leh
311	31.981	78.838	3.532	Transboundary	
312	33.503	74.833	4.033	Jammu & Kashmir	Kulgam
313	36.458	74.882	3.121	Ladakh	Leh
314	32.631	77.307	5.317	Himachal Pradesh	Lahul&Spiti
315	34.937	75.828	2.019	Ladakh	Leh
316	34.145	75.293	1.132	Jammu & Kashmir	Anantnag
317	32.246	77.448	1.858	Himachal Pradesh	Lahul&Spiti
318	34.495	77.177	2.309	Ladakh	Leh
319	34.437	77.256	9.718	Ladakh	Leh
320	32.388	78.892	1.322	Transboundary	
321	32.256	76.778	2.686	Himachal Pradesh	Kangra
322	31.964	78.812	3.936	Transboundary	
323	32.718	78.751	8.331	Ladakh	Leh
324	34.015	75.819	4.187	Jammu & Kashmir	Kishtwar
325	32.353	79.634	1.132	Transboundary	
326	32.050	79.825	1.459	Transboundary	
327	32.422	76.849	1.560	Himachal Pradesh	Kangra
328	32.317	79.638	5.072	Transboundary	
329	32.690	78.757	5.556	Ladakh	Leh
330	35.150	74.515	1.338	Ladakh	Leh
331	32.439	79.121	1.360	Ladakh	Leh
332	35.339	76.520	1.344	Ladakh	Leh
333	30.428	81.480	1.999	Transboundary	
334	32.694	78.749	1.584	Ladakh	Leh
335	32.028	78.790	1.447	Transboundary	
336	35.272	75.163	6.136	Ladakh	Leh
337	35.337	75.192	1.890	Ladakh	Leh
338	32.711	78.708	2.939	Ladakh	Leh
339	36.601	73.862	2.259	Ladakh	Leh
340	31.961	79.937	1.036	Transboundary	
341	32.228	76.776	1.464	Himachal Pradesh	Kangra
342	32.754	77.442	1.091	Himachal Pradesh	Lahul&Spiti
343	35.213	75.226	5.775	Ladakh	Leh
344	30.545	80.599	5.762	Transboundary	
345	34.282	80.090	25.662	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
346	32.137	77.915	1.440	Himachal Pradesh	Lahul&Spiti
347	32.977	79.972	2.386	Transboundary	
348	32.313	79.657	4.454	Transboundary	
349	34.613	75.400	7.387	Ladakh	Kargil
350	31.729	77.662	1.724	Himachal Pradesh	Kullu
351	32.232	76.778	2.133	Himachal Pradesh	Kangra
352	33.723	77.612	5.203	Ladakh	Leh
353	32.537	79.424	4.647	Ladakh	Leh
354	32.961	79.952	2.065	Transboundary	
355	35.829	75.740	5.997	Ladakh	Leh
356	30.400	81.853	13.909	Transboundary	
357	34.544	75.682	1.062	Ladakh	Kargil
358	32.922	77.010	1.176	Himachal Pradesh	Lahul&Spiti
359	32.043	79.901	4.577	Transboundary	
360	32.352	78.899	2.085	Transboundary	
361	32.469	78.840	1.373	Ladakh	Leh
362	31.736	80.678	3.690	Transboundary	
363	32.339	79.674	1.839	Transboundary	
364	32.721	77.384	8.519	Himachal Pradesh	Lahul&Spiti
365	36.671	73.208	4.578	Ladakh	Leh
366	32.723	77.330	4.527	Himachal Pradesh	Lahul&Spiti
367	35.239	75.475	1.409	Ladakh	Leh
368	32.722	77.377	1.586	Himachal Pradesh	Lahul&Spiti
369	32.273	76.986	1.500	Himachal Pradesh	Kangra
370	32.704	77.348	1.482	Himachal Pradesh	Lahul&Spiti
371	33.690	78.535	6.089	Ladakh	Leh
372	32.411	79.589	1.072	Transboundary	
373	34.825	75.383	22.941	Ladakh	Leh
374	34.145	75.723	2.929	Ladakh	Kargil
375	31.979	78.837	1.210	Transboundary	
376	32.871	80.072	1.534	Transboundary	
377	34.464	77.083	2.967	Ladakh	Leh
378	32.872	77.174	2.361	Himachal Pradesh	Lahul&Spiti
379	35.213	77.167	1.295	Ladakh	Leh
380	33.164	78.151	1.980	Ladakh	Leh
381	30.552	80.400	26.564	Transboundary	
382	32.283	79.680	2.730	Transboundary	
383	35.314	75.154	1.973	Ladakh	Leh
384	34.391	77.982	9.921	Ladakh	Leh
385	35.964	73.434	1.281	Ladakh	Leh
386	32.964	77.300	3.711	Ladakh	Kargil
387	30.392	81.964	20.831	Transboundary	
388	31.977	78.838	1.237	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
389	32.986	76.968	1.350	Himachal Pradesh	Lahul&Spiti
390	33.124	76.714	2.191	Himachal Pradesh	Chamba
391	31.266	81.089	5.458	Transboundary	
392	34.780	73.831	1.958	Jammu & Kashmir	Muzaffarabad
393	32.044	79.835	2.379	Transboundary	
394	31.564	78.610	1.815	Himachal Pradesh	Kinnaur
395	35.036	77.721	4.255	Ladakh	Leh
396	34.020	75.827	3.271	Ladakh	Kargil
397	36.412	72.901	11.226	Ladakh	Leh
398	33.124	76.711	1.320	Himachal Pradesh	Chamba
399	33.704	78.284	1.732	Ladakh	Leh
400	33.066	76.824	1.849	Himachal Pradesh	Lahul&Spiti
401	32.226	76.809	2.093	Himachal Pradesh	Kangra
402	34.066	75.750	3.967	Ladakh	Kargil
403	33.020	76.357	1.562	Himachal Pradesh	Chamba
404	31.277	81.029	1.100	Transboundary	
405	31.131	79.491	1.371	Transboundary	
406	31.104	81.413	1.227	Transboundary	
407	33.710	78.252	1.268	Ladakh	Leh
408	30.379	81.843	2.893	Transboundary	
409	35.265	77.176	1.044	Ladakh	Leh
410	32.935	77.165	1.245	Ladakh	Kargil
411	32.698	78.734	1.989	Ladakh	Leh
412	31.542	78.736	1.063	Himachal Pradesh	Kinnaur
413	33.183	76.530	1.004	Himachal Pradesh	Chamba
414	32.122	79.794	3.698	Transboundary	
415	32.020	78.876	1.770	Transboundary	
416	31.322	78.760	1.018	Himachal Pradesh	Kinnaur
417	35.220	75.223	2.901	Ladakh	Leh
418	34.904	77.170	2.286	Ladakh	Leh
419	34.459	78.015	5.176	Ladakh	Leh
420	30.427	81.466	2.021	Transboundary	
421	34.445	78.026	1.548	Ladakh	Leh
422	34.768	76.586	1.352	Ladakh	Leh
423	35.296	77.175	2.616	Ladakh	Leh
424	32.724	77.378	1.425	Himachal Pradesh	Lahul&Spiti
425	37.014	75.139	1.632	Transboundary	
426	34.006	76.705	1.327	Ladakh	Leh
427	31.514	80.794	4.057	Transboundary	
428	34.457	78.013	5.515	Ladakh	Leh
429	36.661	73.622	1.221	Ladakh	Leh
430	32.380	78.121	1.766	Himachal Pradesh	Lahul&Spiti
431	34.508	77.033	6.367	Ladakh	Leh

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
432	31.099	81.513	3.032	Transboundary	
433	33.738	76.636	1.015	Ladakh	Kargil
434	36.513	74.867	3.271	Ladakh	Leh
435	30.385	81.841	12.418	Transboundary	
436	31.218	81.160	6.420	Transboundary	
437	31.285	81.032	13.535	Transboundary	
438	32.718	77.376	1.246	Himachal Pradesh	Lahul&Spiti
439	32.204	78.418	3.212	Himachal Pradesh	Lahul&Spiti
440	34.315	80.794	6.434	Transboundary	
441	35.300	77.174	2.455	Ladakh	Leh
442	32.860	80.106	2.155	Transboundary	
443	33.332	78.662	1.737	Ladakh	Leh
444	32.316	78.994	1.466	Transboundary	
445	32.245	76.787	2.704	Himachal Pradesh	Kangra
446	30.376	82.020	11.617	Transboundary	
447	34.309	77.530	1.143	Ladakh	Leh
448	31.959	79.895	2.990	Transboundary	
449	31.114	81.435	3.854	Transboundary	
450	31.195	81.138	4.754	Transboundary	
451	35.721	76.375	12.139	Ladakh	Leh
452	35.876	72.874	1.640	Transboundary	
453	30.546	81.991	1.304	Transboundary	
454	35.876	73.075	1.921	Transboundary	
455	32.604	77.618	5.279	Himachal Pradesh	Lahul&Spiti
456	35.866	75.282	3.473	Ladakh	Leh
457	31.040	79.753	3.850	Transboundary	
458	31.564	80.860	4.818	Transboundary	
459	30.478	80.569	1.904	Transboundary	
460	36.561	73.596	1.804	Ladakh	Leh
461	31.593	80.780	2.093	Transboundary	
462	35.930	72.930	7.101	Ladakh	Leh
463	35.871	75.323	1.216	Ladakh	Leh
464	34.223	78.380	2.087	Ladakh	Leh
465	32.107	79.801	1.213	Transboundary	
466	35.869	75.326	1.105	Ladakh	Leh
467	33.510	76.596	2.185	Ladakh	Kargil
468	34.292	80.824	1.005	Transboundary	
469	31.103	81.546	2.389	Transboundary	
470	35.687	75.908	2.210	Ladakh	Leh
471	32.259	79.680	2.240	Transboundary	
472	34.113	76.427	1.071	Ladakh	Kargil
473	31.618	80.732	2.973	Transboundary	
474	34.204	78.473	2.352	Ladakh	Leh

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
475	34.429	77.136	1.775	Ladakh	Leh
476	34.457	78.009	1.385	Ladakh	Leh
477	33.972	76.118	2.663	Ladakh	Kargil
478	35.937	76.026	7.287	Ladakh	Leh
479	32.560	79.332	2.556	Transboundary	
480	34.460	78.011	1.051	Ladakh	Leh
481	33.368	78.662	1.939	Ladakh	Leh
482	35.907	72.810	1.870	Ladakh	Leh
483	33.935	76.004	6.996	Jammu & Kashmir	Kishtwar
484	36.400	75.390	2.169	Ladakh	Leh
485	32.972	77.297	2.317	Ladakh	Leh
486	35.861	75.260	2.889	Ladakh	Leh
487	31.051	81.515	1.477	Transboundary	
488	36.413	74.487	1.246	Ladakh	Leh
489	34.278	78.222	6.364	Ladakh	Leh
490	35.828	72.903	1.151	Transboundary	
491	31.264	81.431	3.303	Transboundary	
492	34.024	76.310	1.354	Ladakh	Kargil
493	30.387	81.848	3.443	Transboundary	
494	30.556	80.618	1.224	Transboundary	
495	31.546	80.817	1.232	Transboundary	
496	33.163	78.145	1.047	Ladakh	Leh
497	33.642	76.007	1.570	Jammu & Kashmir	Kishtwar
498	31.774	80.537	1.711	Transboundary	
499	32.434	78.922	5.161	Ladakh	Leh
500	31.517	80.791	5.113	Transboundary	
501	32.554	79.332	1.341	Transboundary	
502	34.044	78.664	3.937	Ladakh	Leh
503	30.409	81.476	11.761	Transboundary	
504	31.207	81.019	2.173	Transboundary	
505	31.322	81.336	4.662	Transboundary	
506	35.894	73.246	2.760	Ladakh	Leh
507	32.512	79.298	1.115	Transboundary	
508	34.974	77.190	1.086	Ladakh	Leh
509	35.833	72.910	4.357	Transboundary	
510	30.390	81.895	10.273	Transboundary	
511	33.658	76.091	1.430	Jammu & Kashmir	Kishtwar
512	36.989	74.657	1.960	Ladakh	Leh
513	31.450	78.793	7.614	Himachal Pradesh	Kinnaur
514	35.856	72.927	1.556	Ladakh	Leh
515	30.399	81.866	8.536	Transboundary	
516	32.525	77.942	1.987	Himachal Pradesh	Lahul&Spiti
517	35.934	73.385	1.331	Ladakh	Leh

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
518	32.941	77.326	2.150	Ladakh	Leh
519	31.111	81.222	1.166	Transboundary	
520	31.240	81.083	4.216	Transboundary	
521	34.410	77.979	1.486	Ladakh	Leh
522	32.780	77.912	1.787	Ladakh	Leh
523	31.029	79.730	4.884	Transboundary	
524	34.350	79.542	6.603	Ladakh	Leh
525	32.435	78.866	1.384	Ladakh	Leh
526	36.841	73.920	4.440	Ladakh	Leh
527	32.445	78.903	3.635	Ladakh	Leh
528	30.381	81.830	3.022	Transboundary	
529	34.426	80.796	3.913	Transboundary	
530	35.245	77.110	2.821	Ladakh	Leh
531	33.846	76.369	1.040	Ladakh	Kargil
532	34.520	78.101	10.275	Ladakh	Leh
533	31.270	81.109	3.115	Transboundary	
534	34.779	75.492	3.845	Ladakh	Kargil
535	32.121	78.940	4.100	Transboundary	
536	31.160	81.112	1.148	Transboundary	
537	30.374	82.016	3.797	Transboundary	
538	32.457	78.473	5.249	Transboundary	
539	30.553	80.473	1.219	Transboundary	
540	31.695	80.615	1.729	Transboundary	
541	30.551	80.471	1.564	Transboundary	
542	34.415	78.069	6.526	Ladakh	Leh
543	35.723	76.389	1.954	Ladakh	Leh
544	31.129	81.228	4.301	Transboundary	
545	31.295	80.822	2.964	Transboundary	
546	32.610	77.912	2.936	Himachal Pradesh	Lahul&Spiti
547	32.408	78.976	5.270	Ladakh	Leh
548	34.281	78.156	1.052	Ladakh	Leh
549	30.606	80.293	2.783	Transboundary	
550	30.352	81.978	7.228	Transboundary	
551	34.324	80.840	13.219	Transboundary	
552	31.849	77.789	3.100	Himachal Pradesh	Kullu
553	34.457	78.148	3.061	Ladakh	Leh
554	32.607	77.989	4.210	Ladakh	Leh
555	32.377	78.923	5.543	Transboundary	
556	30.344	81.977	8.380	Transboundary	
557	33.672	76.151	1.053	Jammu & Kashmir	Kishtwar
558	31.273	81.085	1.625	Transboundary	
559	34.457	78.152	2.005	Ladakh	Leh
560	34.328	80.810	1.891	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
561	30.367	81.995	2.060	Transboundary	
562	32.476	78.303	3.251	Himachal Pradesh	Lahul&Spiti
563	34.321	80.815	1.507	Transboundary	
564	32.405	78.928	4.102	Ladakh	Leh
565	33.698	76.187	1.040	Jammu & Kashmir	Kishtwar
566	32.122	78.943	2.399	Transboundary	
567	30.376	81.878	1.391	Transboundary	
568	35.723	76.365	1.117	Ladakh	Leh
569	31.089	79.513	1.800	Transboundary	
570	34.325	80.829	1.823	Transboundary	
571	34.407	80.801	1.289	Transboundary	
572	34.325	80.833	2.353	Transboundary	
573	34.521	78.090	10.617	Ladakh	Leh
574	34.039	79.469	1.250	Transboundary	
575	32.122	78.948	1.170	Transboundary	
576	30.998	79.767	1.646	Transboundary	
577	35.495	76.618	1.135	Ladakh	Leh
578	34.311	80.884	8.391	Transboundary	
579	30.380	82.021	1.081	Transboundary	
580	32.588	79.459	2.269	Ladakh	Leh
581	35.661	76.617	1.495	Ladakh	Leh
582	34.233	79.561	2.189	Ladakh	Leh
583	35.337	77.623	2.907	Ladakh	Leh
584	35.334	77.608	1.088	Ladakh	Leh
585	31.519	78.735	3.003	Transboundary	
586	35.338	77.627	1.098	Ladakh	Leh
587	35.352	77.603	1.080	Ladakh	Leh
588	35.364	77.140	2.437	Ladakh	Leh
589	30.553	80.407	1.509	Transboundary	
590	35.728	76.281	1.578	Ladakh	Leh
591	30.598	80.404	2.323	Transboundary	
592	34.522	78.096	1.437	Ladakh	Leh
593	34.523	78.099	1.724	Ladakh	Leh
594	31.153	79.341	3.427	Transboundary	
595	35.857	75.766	1.016	Ladakh	Leh
596	35.730	76.410	13.276	Ladakh	Leh
597	35.588	76.698	2.604	Ladakh	Leh
598	35.476	77.514	21.929	Ladakh	Leh
599	31.144	79.366	3.382	Transboundary	
600	35.879	75.730	1.731	Ladakh	Leh
601	35.880	75.728	1.089	Ladakh	Leh
602	31.150	79.357	1.101	Transboundary	
603	35.431	77.066	1.374	Ladakh	Leh

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
604	35.471	77.079	5.810	Ladakh	Leh
605	35.490	77.505	2.319	Transboundary	
606	35.480	77.166	1.354	Ladakh	Leh
607	35.480	77.170	1.335	Ladakh	Leh
608	35.750	76.473	3.050	Ladakh	Leh
609	35.496	77.223	1.623	Ladakh	Leh
610	35.475	76.905	7.554	Ladakh	Leh
611	35.521	76.940	1.378	Ladakh	Leh
612	35.783	76.548	1.090	Ladakh	Leh
613	35.552	76.924	4.679	Ladakh	Leh
614	35.557	76.920	1.704	Ladakh	Leh

2. List of 864 ranked Glacial Lakes in Ganga River Basin

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
1	28.322	85.838	540.353	Transboundary	
2	28.360	85.871	463.780	Transboundary	
3	28.374	86.305	391.497	Transboundary	
4	28.691	83.852	340.210	Transboundary	
5	28.128	87.404	6.732	Transboundary	
6	27.861	86.476	158.403	Transboundary	
7	27.798	87.092	182.157	Transboundary	
8	28.638	84.016	2.392	Transboundary	
9	27.947	86.446	156.761	Transboundary	
10	27.898	86.925	139.771	Transboundary	
11	27.696	86.792	12.949	Transboundary	
12	28.358	85.538	10.825	Transboundary	
13	28.118	87.615	35.670	Transboundary	
14	27.687	86.858	31.797	Transboundary	
15	28.329	85.869	213.518	Transboundary	
16	28.488	84.486	89.444	Transboundary	
17	28.494	84.733	1.957	Transboundary	
18	27.795	86.877	1.671	Transboundary	
19	31.225	79.155	1.269	Uttarakhand	Uttarkashi
20	28.095	86.193	6.829	Transboundary	
21	28.096	86.195	1.618	Transboundary	
22	27.897	86.797	1.284	Transboundary	
23	28.798	83.186	6.304	Transboundary	
24	27.946	88.075	148.586	Transboundary	
25	28.585	85.022	11.988	Transboundary	
26	28.397	85.569	6.859	Transboundary	
27	28.799	83.978	1.163	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
28	31.191	79.150	7.893	Uttarakhand	Uttarkashi
29	27.887	86.844	4.443	Transboundary	
30	28.404	85.496	5.611	Transboundary	
31	30.267	80.591	1.774	Uttarakhand	Pithoragarh
32	27.928	88.002	113.216	Transboundary	
33	27.926	87.771	97.658	Transboundary	
34	28.230	87.591	78.900	Transboundary	
35	27.995	86.339	1.673	Transboundary	
36	28.497	84.256	11.381	Transboundary	
37	28.136	86.096	2.589	Transboundary	
38	28.135	86.531	97.854	Transboundary	
39	28.199	86.582	134.640	Transboundary	
40	28.137	87.428	25.854	Transboundary	
41	27.755	86.958	86.498	Transboundary	
42	27.894	86.913	11.276	Transboundary	
43	28.178	87.563	104.192	Transboundary	
44	27.836	86.585	1.614	Transboundary	
45	27.845	86.433	7.807	Transboundary	
46	28.482	85.302	8.496	Transboundary	
47	27.793	87.974	22.318	Transboundary	
48	28.372	85.568	3.890	Transboundary	
49	27.845	86.463	9.653	Transboundary	
50	28.393	86.379	100.112	Transboundary	
51	27.869	87.866	68.121	Transboundary	
52	28.067	86.066	32.497	Transboundary	
53	28.500	85.430	3.746	Transboundary	
54	28.148	87.469	39.585	Transboundary	
55	28.676	85.410	21.041	Transboundary	
56	27.728	86.569	2.946	Transboundary	
57	30.003	81.554	1.105	Transboundary	
58	28.303	86.157	59.046	Transboundary	
59	30.233	81.350	26.790	Transboundary	
60	28.185	86.805	2.644	Transboundary	
61	28.335	86.192	55.000	Transboundary	
62	30.211	81.361	1.842	Transboundary	
63	28.118	86.119	5.812	Transboundary	
64	28.444	85.495	1.533	Transboundary	
65	28.170	86.060	4.433	Transboundary	
66	27.779	86.612	117.309	Transboundary	
67	28.596	84.629	22.255	Transboundary	
68	28.794	83.983	2.761	Transboundary	
69	27.816	87.749	17.165	Transboundary	
70	29.822	82.712	19.684	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
71	28.009	88.259	59.695	Transboundary	
72	27.901	86.576	2.757	Transboundary	
73	28.185	86.532	67.677	Transboundary	
74	29.205	83.848	1.887	Transboundary	
75	28.744	83.997	1.584	Transboundary	
76	28.468	85.519	43.674	Transboundary	
77	28.183	86.226	12.341	Transboundary	
78	28.313	85.948	25.055	Transboundary	
79	28.092	86.257	7.144	Transboundary	
80	27.797	88.007	1.166	Transboundary	
81	28.068	87.047	78.934	Transboundary	
82	28.195	87.641	47.425	Transboundary	
83	27.909	86.580	1.730	Transboundary	
84	30.911	78.771	3.150	Uttarakhand	Uttarkashi
85	28.136	87.416	2.852	Transboundary	
86	27.844	87.081	41.151	Transboundary	
87	27.864	87.737	13.982	Transboundary	
88	28.193	86.361	3.224	Transboundary	
89	28.033	86.500	60.855	Transboundary	
90	28.417	85.522	8.907	Transboundary	
91	28.787	83.180	1.701	Transboundary	
92	28.509	85.446	9.005	Transboundary	
93	28.973	83.743	1.225	Transboundary	
94	28.152	86.330	6.715	Transboundary	
95	28.621	84.792	2.320	Transboundary	
96	28.321	86.158	22.436	Transboundary	
97	28.553	85.424	4.339	Transboundary	
98	27.857	86.500	2.466	Transboundary	
99	27.929	86.433	31.991	Transboundary	
100	28.752	83.929	1.151	Transboundary	
101	28.420	85.532	3.002	Transboundary	
102	28.129	85.837	1.849	Transboundary	
103	28.233	85.611	2.930	Transboundary	
104	28.150	86.313	1.062	Transboundary	
105	29.354	82.739	2.488	Transboundary	
106	27.832	87.661	1.258	Transboundary	
107	28.671	83.859	1.379	Transboundary	
108	28.093	87.637	72.469	Transboundary	
109	28.377	85.167	2.284	Transboundary	
110	28.137	85.788	2.537	Transboundary	
111	28.672	83.864	2.582	Transboundary	
112	27.778	86.643	29.275	Transboundary	
113	27.874	86.586	40.185	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
114	29.798	82.671	13.701	Transboundary	
115	27.790	87.934	14.103	Transboundary	
116	30.219	81.336	3.516	Transboundary	
117	28.432	85.532	5.720	Transboundary	
118	28.833	83.471	1.050	Transboundary	
119	29.994	82.045	2.575	Transboundary	
120	30.085	81.829	1.113	Transboundary	
121	28.168	85.866	3.902	Transboundary	
122	28.044	86.514	57.941	Transboundary	
123	28.508	85.494	26.419	Transboundary	
124	28.236	87.501	20.478	Transboundary	
125	27.838	86.875	3.632	Transboundary	
126	28.114	87.655	146.343	Transboundary	
127	27.770	87.658	3.028	Transboundary	
128	28.726	83.890	14.991	Transboundary	
129	28.321	85.930	11.184	Transboundary	
130	28.974	83.740	2.009	Transboundary	
131	27.747	87.649	4.724	Transboundary	
132	28.835	84.797	1.907	Transboundary	
133	28.023	86.099	1.471	Transboundary	
134	29.109	83.070	4.274	Transboundary	
135	27.905	86.581	2.140	Transboundary	
136	29.741	81.570	5.909	Transboundary	
137	28.186	86.343	2.566	Transboundary	
138	28.140	87.417	5.717	Transboundary	
139	27.950	87.930	83.659	Transboundary	
140	28.645	84.272	1.080	Transboundary	
141	28.167	87.623	20.869	Transboundary	
142	27.757	86.888	7.009	Transboundary	
143	28.160	86.076	1.308	Transboundary	
144	30.129	81.781	75.649	Transboundary	
145	28.190	86.134	1.096	Transboundary	
146	27.743	86.844	25.727	Transboundary	
147	28.211	85.847	61.339	Transboundary	
148	28.621	84.787	1.327	Transboundary	
149	27.996	86.820	1.153	Transboundary	
150	27.725	87.619	7.536	Transboundary	
151	28.673	85.126	1.128	Transboundary	
152	27.813	87.139	9.270	Transboundary	
153	27.921	86.675	2.724	Transboundary	
154	28.193	86.351	19.871	Transboundary	
155	28.426	85.564	29.388	Transboundary	
156	28.240	86.365	24.721	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
157	30.456	80.516	3.049	Uttarakhand	Pithoragarh
158	28.310	85.633	6.071	Transboundary	
159	27.801	88.107	6.384	Transboundary	
160	27.933	86.746	7.562	Transboundary	
161	28.558	85.396	1.577	Transboundary	
162	28.520	85.436	3.944	Transboundary	
163	27.781	87.945	3.817	Transboundary	
164	28.255	87.648	1.530	Transboundary	
165	28.627	84.291	4.485	Transboundary	
166	28.172	87.479	23.907	Transboundary	
167	28.523	85.435	1.046	Transboundary	
168	27.760	86.863	6.747	Transboundary	
169	30.830	79.894	4.833	Uttarakhand	Chamoli
170	29.773	81.527	49.988	Transboundary	
171	28.996	83.755	2.432	Transboundary	
172	28.566	85.464	16.346	Transboundary	
173	27.722	87.928	3.826	Transboundary	
174	29.919	81.739	1.778	Transboundary	
175	30.964	79.386	1.283	Uttarakhand	Chamoli
176	28.830	84.223	1.179	Transboundary	
177	27.758	87.650	1.387	Transboundary	
178	27.672	87.620	1.452	Transboundary	
179	28.253	86.103	14.978	Transboundary	
180	28.011	86.412	1.030	Transboundary	
181	28.613	84.317	1.202	Transboundary	
182	28.023	86.391	1.346	Transboundary	
183	30.811	79.921	2.936	Uttarakhand	Chamoli
184	27.887	86.897	5.352	Transboundary	
185	28.347	86.225	55.904	Transboundary	
186	30.119	81.873	1.272	Transboundary	
187	28.616	84.320	2.748	Transboundary	
188	27.989	86.649	5.101	Transboundary	
189	27.958	86.661	4.835	Transboundary	
190	29.980	81.113	2.012	Transboundary	
191	30.909	79.539	5.113	Uttarakhand	Chamoli
192	27.846	87.962	8.189	Transboundary	
193	28.448	85.557	1.776	Transboundary	
194	27.933	88.066	83.349	Transboundary	
195	28.163	85.630	13.052	Transboundary	
196	28.226	87.053	17.187	Transboundary	
197	28.181	86.343	2.476	Transboundary	
198	27.997	86.835	11.547	Transboundary	
199	27.545	88.050	25.723	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
200	28.320	85.631	6.068	Transboundary	
201	29.147	83.803	2.167	Transboundary	
202	30.213	81.383	4.392	Transboundary	
203	29.113	82.716	1.072	Transboundary	
204	27.939	86.815	2.888	Transboundary	
205	27.920	86.745	2.479	Transboundary	
206	29.815	82.448	1.171	Transboundary	
207	28.166	86.807	5.214	Transboundary	
208	28.201	86.163	2.615	Transboundary	
209	28.270	86.127	1.746	Transboundary	
210	29.118	83.779	1.980	Transboundary	
211	28.278	87.661	3.763	Transboundary	
212	28.397	85.631	2.733	Transboundary	
213	28.176	86.357	1.246	Transboundary	
214	27.680	87.603	2.541	Transboundary	
215	28.398	86.487	1.144	Transboundary	
216	28.803	83.068	2.431	Transboundary	
217	28.518	85.440	4.852	Transboundary	
218	29.743	81.544	5.634	Transboundary	
219	28.817	84.333	3.988	Transboundary	
220	29.139	82.785	1.613	Transboundary	
221	27.835	86.482	2.315	Transboundary	
222	27.831	87.659	2.369	Transboundary	
223	27.956	86.806	1.261	Transboundary	
224	28.433	85.535	1.646	Transboundary	
225	28.495	85.549	1.591	Transboundary	
226	29.115	83.786	6.002	Transboundary	
227	27.783	86.957	87.280	Transboundary	
228	27.900	87.699	11.272	Transboundary	
229	27.950	86.782	3.648	Transboundary	
230	28.211	86.213	5.964	Transboundary	
231	29.790	82.460	1.951	Transboundary	
232	30.565	80.179	17.807	Uttarakhand	Pithoragarh
233	28.279	87.670	2.490	Transboundary	
234	28.236	87.659	3.588	Transboundary	
235	28.007	86.641	3.808	Transboundary	
236	30.241	81.332	8.106	Transboundary	
237	28.217	86.302	1.323	Transboundary	
238	28.194	85.871	7.377	Transboundary	
239	28.462	84.262	1.757	Transboundary	
240	28.295	86.151	16.510	Transboundary	
241	30.948	79.341	2.201	Uttarakhand	Chamoli
242	28.073	86.520	23.115	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
243	27.853	87.790	6.118	Transboundary	
244	28.022	88.355	56.288	Transboundary	
245	28.194	86.314	27.790	Transboundary	
246	28.645	84.263	1.430	Transboundary	
247	28.323	85.924	8.798	Transboundary	
248	29.693	82.240	2.824	Transboundary	
249	27.946	87.981	5.963	Transboundary	
250	30.901	79.754	22.035	Uttarakhand	Chamoli
251	28.545	85.448	1.256	Transboundary	
252	28.568	85.335	1.337	Transboundary	
253	28.013	87.611	2.194	Transboundary	
254	30.067	82.127	62.325	Transboundary	
255	28.287	85.602	2.411	Transboundary	
256	30.266	81.349	20.368	Transboundary	
257	27.833	86.565	2.688	Transboundary	
258	28.787	83.330	43.573	Transboundary	
259	27.844	87.664	3.358	Transboundary	
260	29.800	81.525	1.401	Transboundary	
261	28.273	86.103	1.251	Transboundary	
262	28.041	86.706	2.755	Transboundary	
263	27.916	86.477	14.075	Transboundary	
264	28.954	83.737	2.981	Transboundary	
265	28.063	86.520	2.789	Transboundary	
266	28.017	88.288	50.431	Transboundary	
267	28.014	86.475	1.186	Transboundary	
268	28.959	83.187	27.617	Transboundary	
269	30.991	79.359	3.292	Uttarakhand	Chamoli
270	27.736	86.876	1.159	Transboundary	
271	28.221	86.086	8.581	Transboundary	
272	30.639	79.695	1.378	Uttarakhand	Chamoli
273	27.781	87.661	3.968	Transboundary	
274	31.005	79.406	1.977	Uttarakhand	Chamoli
275	28.459	84.259	6.363	Transboundary	
276	29.085	83.748	1.789	Transboundary	
277	28.252	87.655	2.143	Transboundary	
278	27.729	87.632	3.139	Transboundary	
279	30.112	81.814	2.119	Transboundary	
280	27.823	86.571	3.789	Transboundary	
281	28.268	87.634	10.039	Transboundary	
282	28.392	86.415	20.173	Transboundary	
283	28.052	87.627	18.395	Transboundary	
284	28.294	86.131	23.993	Transboundary	
285	30.916	79.541	2.713	Uttarakhand	Chamoli

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
286	30.908	79.825	8.112	Uttarakhand	Chamoli
287	27.793	86.838	22.894	Transboundary	
288	28.701	84.124	1.120	Transboundary	
289	28.182	86.347	2.254	Transboundary	
290	30.892	78.819	3.263	Uttarakhand	Uttarkashi
291	30.746	78.987	25.560	Uttarakhand	TehriGarhwal
292	30.814	79.926	5.017	Uttarakhand	Chamoli
293	29.216	82.563	2.448	Transboundary	
294	28.666	84.528	1.001	Transboundary	
295	27.794	86.424	1.984	Transboundary	
296	30.049	80.887	2.008	Transboundary	
297	28.053	86.491	1.852	Transboundary	
298	28.228	86.204	5.145	Transboundary	
299	29.117	83.738	11.608	Transboundary	
300	28.561	85.396	4.669	Transboundary	
301	28.445	85.560	1.778	Transboundary	
302	27.759	86.875	4.836	Transboundary	
303	28.378	86.488	1.992	Transboundary	
304	28.352	85.618	4.845	Transboundary	
305	27.783	87.662	1.237	Transboundary	
306	30.967	79.362	3.084	Uttarakhand	Chamoli
307	30.041	80.878	5.961	Transboundary	
308	28.048	86.504	9.003	Transboundary	
309	29.674	82.409	3.563	Transboundary	
310	28.139	85.919	10.149	Transboundary	
311	27.911	87.816	2.443	Transboundary	
312	27.674	87.621	2.040	Transboundary	
313	28.206	86.239	1.515	Transboundary	
314	28.722	83.891	1.544	Transboundary	
315	28.057	87.622	1.088	Transboundary	
316	30.892	79.528	2.050	Uttarakhand	Chamoli
317	28.069	87.134	25.494	Transboundary	
318	28.269	86.127	1.910	Transboundary	
319	27.951	86.690	42.112	Transboundary	
320	28.292	85.170	20.328	Transboundary	
321	28.156	86.338	7.567	Transboundary	
322	28.206	87.560	15.947	Transboundary	
323	28.249	86.150	13.157	Transboundary	
324	28.172	86.518	4.127	Transboundary	
325	30.890	79.304	2.306	Uttarakhand	Chamoli
326	28.843	83.941	1.616	Transboundary	
327	28.328	85.685	3.190	Transboundary	
328	29.270	82.590	10.043	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
329	29.993	82.197	24.672	Transboundary	
330	28.064	86.456	1.774	Transboundary	
331	27.927	86.420	15.721	Transboundary	
332	28.044	87.626	3.170	Transboundary	
333	30.994	79.354	1.814	Uttarakhand	Chamoli
334	28.446	85.562	2.095	Transboundary	
335	29.195	83.735	1.657	Transboundary	
336	27.964	87.814	40.609	Transboundary	
337	28.044	86.519	1.096	Transboundary	
338	29.844	81.553	1.410	Transboundary	
339	27.884	86.891	1.380	Transboundary	
340	28.457	84.252	1.300	Transboundary	
341	30.098	81.826	3.270	Transboundary	
342	27.798	86.478	4.510	Transboundary	
343	27.847	87.970	2.390	Transboundary	
344	27.766	86.871	13.684	Transboundary	
345	29.687	82.419	2.414	Transboundary	
346	27.731	87.623	1.834	Transboundary	
347	30.976	79.460	17.016	Uttarakhand	Chamoli
348	28.065	87.193	10.783	Transboundary	
349	27.952	87.908	64.786	Transboundary	
350	28.236	86.356	8.556	Transboundary	
351	28.155	85.911	7.952	Transboundary	
352	31.060	79.414	3.168	Uttarakhand	Chamoli
353	28.163	86.067	1.637	Transboundary	
354	30.278	81.880	1.010	Transboundary	
355	27.709	86.563	2.570	Transboundary	
356	27.987	86.492	1.125	Transboundary	
357	27.942	86.816	1.391	Transboundary	
358	27.791	86.621	46.732	Transboundary	
359	28.826	84.851	3.607	Transboundary	
360	27.831	87.611	1.961	Transboundary	
361	30.297	81.388	26.147	Transboundary	
362	28.106	86.531	4.568	Transboundary	
363	28.563	85.468	8.943	Transboundary	
364	28.267	86.130	1.237	Transboundary	
365	28.194	86.220	4.689	Transboundary	
366	27.853	87.602	3.916	Transboundary	
367	27.850	87.729	1.365	Transboundary	
368	28.006	86.481	1.533	Transboundary	
369	28.871	83.493	2.102	Transboundary	
370	28.617	85.416	1.981	Transboundary	
371	28.426	85.539	1.129	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
372	28.641	83.788	8.326	Transboundary	
373	28.615	85.420	2.348	Transboundary	
374	28.179	87.478	1.010	Transboundary	
375	28.393	86.451	5.237	Transboundary	
376	27.881	87.805	34.317	Transboundary	
377	30.228	81.415	1.246	Transboundary	
378	30.294	81.375	8.724	Transboundary	
379	27.771	88.019	1.035	Transboundary	
380	30.105	81.805	1.184	Transboundary	
381	28.231	86.148	1.805	Transboundary	
382	31.025	79.363	1.537	Uttarakhand	Chamoli
383	28.970	83.640	3.051	Transboundary	
384	27.795	86.617	1.746	Transboundary	
385	30.172	81.879	1.914	Transboundary	
386	28.003	86.445	2.165	Transboundary	
387	28.583	84.084	1.654	Transboundary	
388	30.324	80.590	1.130	Uttarakhand	Pithoragarh
389	27.979	86.733	1.575	Transboundary	
390	28.547	85.445	5.876	Transboundary	
391	28.867	83.490	5.274	Transboundary	
392	27.732	87.624	1.271	Transboundary	
393	28.701	83.837	1.297	Transboundary	
394	28.004	88.241	41.798	Transboundary	
395	28.374	85.173	2.329	Transboundary	
396	28.143	87.102	2.009	Transboundary	
397	30.322	81.376	13.962	Transboundary	
398	27.860	88.054	5.793	Transboundary	
399	28.219	85.562	4.478	Transboundary	
400	28.854	84.375	2.452	Transboundary	
401	28.260	86.213	1.927	Transboundary	
402	27.918	87.725	4.391	Transboundary	
403	28.032	86.073	2.316	Transboundary	
404	31.152	79.267	4.590	Uttarakhand	Uttarkashi
405	28.404	85.605	12.012	Transboundary	
406	28.860	84.783	1.829	Transboundary	
407	27.992	86.652	2.042	Transboundary	
408	28.038	86.710	15.440	Transboundary	
409	28.010	88.373	3.132	Transboundary	
410	29.201	83.684	22.463	Transboundary	
411	28.316	85.951	6.028	Transboundary	
412	28.179	85.698	5.743	Transboundary	
413	27.929	86.446	6.528	Transboundary	
414	28.392	85.614	1.165	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
415	28.217	86.305	1.863	Transboundary	
416	28.301	85.178	5.559	Transboundary	
417	30.053	80.883	3.112	Transboundary	
418	28.173	87.562	2.332	Transboundary	
419	27.836	87.605	8.765	Transboundary	
420	28.042	86.518	2.925	Transboundary	
421	28.050	86.493	2.725	Transboundary	
422	30.214	81.758	12.120	Transboundary	
423	28.603	85.321	1.511	Transboundary	
424	30.903	79.674	1.145	Uttarakhand	Chamoli
425	27.806	87.819	1.115	Transboundary	
426	28.192	86.326	1.993	Transboundary	
427	27.838	87.936	1.194	Transboundary	
428	30.264	80.713	2.266	Uttarakhand	Pithoragarh
429	27.835	88.078	16.475	Transboundary	
430	27.796	88.105	2.460	Transboundary	
431	27.828	86.573	3.971	Transboundary	
432	28.824	84.418	1.138	Transboundary	
433	28.151	86.535	18.482	Transboundary	
434	27.951	86.777	3.672	Transboundary	
435	28.634	84.752	1.835	Transboundary	
436	28.202	86.309	6.573	Transboundary	
437	31.054	79.407	2.097	Uttarakhand	Chamoli
438	28.243	86.196	17.695	Transboundary	
439	28.769	83.036	2.776	Transboundary	
440	30.981	79.488	5.599	Uttarakhand	Chamoli
441	28.747	84.600	8.455	Transboundary	
442	28.886	83.527	30.918	Transboundary	
443	31.053	79.412	1.585	Uttarakhand	Chamoli
444	28.538	85.488	2.350	Transboundary	
445	28.821	84.875	1.034	Transboundary	
446	28.141	86.553	1.271	Transboundary	
447	27.809	87.701	2.907	Transboundary	
448	31.024	79.361	3.336	Uttarakhand	Chamoli
449	27.944	86.549	5.501	Transboundary	
450	27.982	86.782	1.155	Transboundary	
451	27.945	87.789	2.073	Transboundary	
452	27.888	87.722	2.338	Transboundary	
453	27.975	86.737	2.813	Transboundary	
454	28.664	84.558	1.096	Transboundary	
455	27.834	88.067	2.940	Transboundary	
456	30.315	81.360	4.155	Transboundary	
457	28.374	86.259	27.538	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
458	28.412	85.600	1.039	Transboundary	
459	31.024	79.356	1.045	Uttarakhand	Chamoli
460	28.015	86.503	1.921	Transboundary	
461	27.945	86.818	1.543	Transboundary	
462	30.079	82.119	1.376	Transboundary	
463	30.222	81.777	9.093	Transboundary	
464	28.405	85.588	10.508	Transboundary	
465	29.169	83.765	1.750	Transboundary	
466	28.232	86.412	8.598	Transboundary	
467	28.136	86.264	3.384	Transboundary	
468	28.019	86.733	3.449	Transboundary	
469	28.275	85.798	1.921	Transboundary	
470	28.826	84.150	10.737	Transboundary	
471	28.083	86.503	1.161	Transboundary	
472	30.353	81.351	1.768	Transboundary	
473	28.142	87.105	16.525	Transboundary	
474	31.061	79.410	3.280	Uttarakhand	Chamoli
475	30.904	79.747	11.055	Uttarakhand	Chamoli
476	28.230	86.146	1.718	Transboundary	
477	29.961	82.084	2.522	Transboundary	
478	27.781	86.589	1.106	Transboundary	
479	28.211	86.743	1.286	Transboundary	
480	27.711	86.599	7.730	Transboundary	
481	27.805	87.749	1.161	Transboundary	
482	29.297	82.705	10.034	Transboundary	
483	27.936	86.713	1.359	Transboundary	
484	27.788	86.632	4.679	Transboundary	
485	30.290	81.364	7.574	Transboundary	
486	28.858	83.473	1.269	Transboundary	
487	28.776	85.122	5.676	Transboundary	
488	27.820	87.672	2.406	Transboundary	
489	28.252	86.218	9.075	Transboundary	
490	29.051	83.605	3.064	Transboundary	
491	27.674	87.625	4.203	Transboundary	
492	28.552	85.414	1.396	Transboundary	
493	27.719	86.910	14.932	Transboundary	
494	30.139	81.789	1.795	Transboundary	
495	30.402	80.784	43.347	Transboundary	
496	28.738	85.146	1.238	Transboundary	
497	31.142	79.260	1.706	Uttarakhand	Uttarkashi
498	27.994	88.402	18.970	Transboundary	
499	28.065	88.543	7.307	Transboundary	
500	28.151	85.905	12.596	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
501	28.210	86.654	1.131	Transboundary	
502	28.968	83.208	8.336	Transboundary	
503	31.138	79.309	1.078	Uttarakhand	Uttarkashi
504	28.239	86.158	1.053	Transboundary	
505	29.039	83.669	7.883	Transboundary	
506	30.312	81.409	13.272	Transboundary	
507	28.277	87.588	5.349	Transboundary	
508	28.389	85.856	3.746	Transboundary	
509	29.007	83.503	1.011	Transboundary	
510	28.363	86.487	4.974	Transboundary	
511	28.224	85.804	4.640	Transboundary	
512	28.035	87.858	2.103	Transboundary	
513	29.072	83.645	3.907	Transboundary	
514	28.202	86.549	6.188	Transboundary	
515	30.021	81.367	1.215	Transboundary	
516	27.993	86.838	1.675	Transboundary	
517	27.855	87.753	4.858	Transboundary	
518	27.829	87.095	12.058	Transboundary	
519	28.617	84.912	10.082	Transboundary	
520	28.348	86.493	34.510	Transboundary	
521	27.943	86.554	1.387	Transboundary	
522	30.392	80.532	11.212	Uttarakhand	Pithoragarh
523	27.814	87.632	1.374	Transboundary	
524	30.057	81.941	13.872	Transboundary	
525	31.379	79.014	4.004	Uttarakhand	Uttarkashi
526	28.778	83.046	5.964	Transboundary	
527	27.938	86.711	9.829	Transboundary	
528	29.459	82.394	7.419	Transboundary	
529	28.229	86.320	8.202	Transboundary	
530	30.901	79.746	11.407	Uttarakhand	Chamoli
531	28.265	86.413	1.137	Transboundary	
532	27.647	87.981	2.215	Transboundary	
533	30.898	79.754	1.691	Uttarakhand	Chamoli
534	28.640	84.789	3.538	Transboundary	
535	28.178	86.322	3.803	Transboundary	
536	30.302	81.399	11.680	Transboundary	
537	30.277	81.877	5.456	Transboundary	
538	28.133	86.548	3.669	Transboundary	
539	30.314	81.399	9.474	Transboundary	
540	28.771	83.032	1.098	Transboundary	
541	28.962	83.633	2.151	Transboundary	
542	28.237	86.227	1.218	Transboundary	
543	28.780	83.042	1.393	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
544	28.005	86.632	2.486	Transboundary	
545	28.171	87.068	7.840	Transboundary	
546	30.920	79.314	1.970	Uttarakhand	Chamoli
547	28.000	86.435	1.315	Transboundary	
548	27.974	87.280	9.085	Transboundary	
549	28.273	86.676	1.710	Transboundary	
550	28.188	86.249	1.544	Transboundary	
551	30.157	81.773	1.390	Transboundary	
552	28.024	86.671	2.571	Transboundary	
553	30.147	81.099	1.916	Transboundary	
554	27.771	86.871	1.018	Transboundary	
555	29.809	82.664	4.106	Transboundary	
556	28.100	87.076	9.970	Transboundary	
557	28.993	83.173	15.983	Transboundary	
558	28.123	87.058	2.917	Transboundary	
559	28.144	86.834	1.887	Transboundary	
560	27.988	86.644	1.191	Transboundary	
561	28.229	87.558	6.801	Transboundary	
562	29.931	81.035	9.218	Transboundary	
563	28.164	87.578	20.216	Transboundary	
564	30.287	81.822	1.883	Transboundary	
565	29.812	82.701	1.046	Transboundary	
566	28.029	86.670	2.860	Transboundary	
567	28.519	85.322	1.588	Transboundary	
568	28.967	83.210	1.540	Transboundary	
569	28.270	86.187	12.642	Transboundary	
570	27.838	87.929	1.475	Transboundary	
571	28.381	86.384	13.918	Transboundary	
572	29.183	83.705	2.332	Transboundary	
573	27.804	87.131	1.109	Transboundary	
574	28.105	87.058	1.346	Transboundary	
575	28.228	87.578	21.942	Transboundary	
576	27.693	86.921	1.153	Transboundary	
577	28.820	84.871	1.058	Transboundary	
578	27.886	87.702	8.371	Transboundary	
579	30.446	80.388	10.004	Uttarakhand	Pithoragarh
580	29.836	81.552	2.815	Transboundary	
581	29.862	81.585	2.053	Transboundary	
582	29.714	82.250	11.542	Transboundary	
583	28.189	86.323	1.060	Transboundary	
584	28.083	86.470	7.429	Transboundary	
585	28.142	87.112	25.059	Transboundary	
586	28.273	86.156	2.859	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
587	28.287	85.784	6.181	Transboundary	
588	29.935	82.208	12.006	Transboundary	
589	29.898	81.578	28.514	Transboundary	
590	28.005	88.320	38.575	Transboundary	
591	30.216	81.802	19.306	Transboundary	
592	27.648	86.854	5.082	Transboundary	
593	28.133	87.479	3.679	Transboundary	
594	28.356	86.260	2.616	Transboundary	
595	28.418	85.559	1.020	Transboundary	
596	28.794	85.037	3.300	Transboundary	
597	28.413	85.856	3.632	Transboundary	
598	28.323	85.908	14.556	Transboundary	
599	29.921	81.031	18.608	Transboundary	
600	31.174	78.628	5.635	Uttarakhand	Uttarkashi
601	28.320	85.903	5.196	Transboundary	
602	29.106	83.672	1.191	Transboundary	
603	28.243	86.157	2.840	Transboundary	
604	28.073	87.031	3.777	Transboundary	
605	28.204	86.748	5.619	Transboundary	
606	28.016	86.724	1.085	Transboundary	
607	29.765	81.537	1.018	Transboundary	
608	28.638	84.730	2.070	Transboundary	
609	29.046	83.674	12.138	Transboundary	
610	27.932	86.422	1.576	Transboundary	
611	28.040	86.673	2.382	Transboundary	
612	29.249	82.564	29.004	Transboundary	
613	27.940	86.708	2.463	Transboundary	
614	28.392	86.440	4.915	Transboundary	
615	29.075	83.654	1.546	Transboundary	
616	28.201	86.240	1.675	Transboundary	
617	30.213	82.095	1.075	Transboundary	
618	28.262	86.217	1.981	Transboundary	
619	27.808	87.147	4.985	Transboundary	
620	28.120	87.486	8.524	Transboundary	
621	27.943	86.710	8.256	Transboundary	
622	30.190	81.786	1.153	Transboundary	
623	28.830	84.843	2.307	Transboundary	
624	27.941	86.714	1.885	Transboundary	
625	31.064	79.287	1.036	Uttarakhand	Uttarkashi
626	28.131	87.599	14.176	Transboundary	
627	29.854	82.339	4.969	Transboundary	
628	27.943	88.041	10.316	Transboundary	
629	28.272	86.180	6.714	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
630	27.997	88.382	1.836	Transboundary	
631	28.228	86.220	4.194	Transboundary	
632	28.001	88.327	6.511	Transboundary	
633	27.832	87.103	3.250	Transboundary	
634	27.786	86.632	2.474	Transboundary	
635	28.663	85.029	1.963	Transboundary	
636	29.853	81.515	1.298	Transboundary	
637	30.399	81.293	3.067	Transboundary	
638	28.031	86.647	1.969	Transboundary	
639	28.254	86.141	5.357	Transboundary	
640	30.021	81.315	1.488	Transboundary	
641	28.984	83.730	1.740	Transboundary	
642	28.270	85.806	1.455	Transboundary	
643	28.707	83.163	1.332	Transboundary	
644	27.834	87.100	2.809	Transboundary	
645	27.975	86.681	57.834	Transboundary	
646	28.681	83.208	2.133	Transboundary	
647	27.714	86.916	6.457	Transboundary	
648	29.803	82.674	2.657	Transboundary	
649	29.798	82.416	2.991	Transboundary	
650	28.282	85.702	6.144	Transboundary	
651	28.245	86.321	21.559	Transboundary	
652	28.790	85.050	5.479	Transboundary	
653	28.130	87.082	19.293	Transboundary	
654	28.942	83.598	2.745	Transboundary	
655	28.982	83.727	1.591	Transboundary	
656	28.017	86.721	19.805	Transboundary	
657	28.181	86.249	4.422	Transboundary	
658	27.725	86.900	3.023	Transboundary	
659	28.030	87.869	1.203	Transboundary	
660	27.721	86.907	1.512	Transboundary	
661	27.951	87.985	4.305	Transboundary	
662	28.967	83.605	2.905	Transboundary	
663	27.828	87.068	2.004	Transboundary	
664	28.141	86.831	6.110	Transboundary	
665	28.992	83.201	1.985	Transboundary	
666	28.233	86.331	3.069	Transboundary	
667	27.988	88.221	11.941	Transboundary	
668	30.204	81.878	12.662	Transboundary	
669	28.015	87.233	9.401	Transboundary	
670	30.408	80.511	2.176	Uttarakhand	Pithoragarh
671	27.975	87.851	2.618	Transboundary	
672	28.133	87.078	4.971	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
673	28.830	84.145	2.311	Transboundary	
674	27.972	87.845	6.264	Transboundary	
675	28.262	86.262	8.719	Transboundary	
676	27.928	88.019	13.254	Transboundary	
677	28.247	86.317	3.315	Transboundary	
678	29.832	82.697	1.098	Transboundary	
679	28.161	87.487	10.286	Transboundary	
680	28.255	86.216	1.357	Transboundary	
681	28.906	83.463	1.089	Transboundary	
682	28.048	87.581	7.254	Transboundary	
683	30.481	79.874	3.352	Uttarakhand	Chamoli
684	28.266	86.217	2.968	Transboundary	
685	29.022	83.639	1.058	Transboundary	
686	29.850	81.511	1.685	Transboundary	
687	30.268	81.872	8.026	Transboundary	
688	30.131	81.793	2.225	Transboundary	
689	28.238	86.371	3.042	Transboundary	
690	28.781	85.083	1.154	Transboundary	
691	28.057	88.517	7.029	Transboundary	
692	30.032	82.127	1.587	Transboundary	
693	27.857	86.937	21.449	Transboundary	
694	29.912	82.215	5.794	Transboundary	
695	28.279	85.751	3.521	Transboundary	
696	29.731	82.637	6.048	Transboundary	
697	28.980	83.300	1.165	Transboundary	
698	30.336	80.644	2.185	Uttarakhand	Pithoragarh
699	28.005	87.142	43.700	Transboundary	
700	30.023	82.122	1.301	Transboundary	
701	29.929	82.207	32.968	Transboundary	
702	28.278	86.236	1.943	Transboundary	
703	29.022	83.620	1.025	Transboundary	
704	28.072	87.578	3.206	Transboundary	
705	28.854	83.550	1.137	Transboundary	
706	28.118	86.862	6.092	Transboundary	
707	29.076	83.652	2.627	Transboundary	
708	28.145	86.968	1.965	Transboundary	
709	28.032	87.870	1.503	Transboundary	
710	27.996	88.316	2.442	Transboundary	
711	30.992	79.303	1.941	Uttarakhand	Uttarkashi
712	28.559	85.333	12.603	Transboundary	
713	27.783	86.628	1.620	Transboundary	
714	28.255	86.147	3.412	Transboundary	
715	28.207	86.629	27.780	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
716	28.244	86.227	2.905	Transboundary	
717	28.183	87.080	1.222	Transboundary	
718	28.787	85.047	1.864	Transboundary	
719	28.969	83.606	1.176	Transboundary	
720	28.224	87.582	2.088	Transboundary	
721	27.969	87.868	4.000	Transboundary	
722	27.750	86.523	2.466	Transboundary	
723	28.274	86.688	5.996	Transboundary	
724	27.888	87.693	3.368	Transboundary	
725	30.046	82.167	2.599	Transboundary	
726	28.155	87.612	13.823	Transboundary	
727	28.021	87.895	7.539	Transboundary	
728	27.988	86.609	3.060	Transboundary	
729	28.132	86.851	3.450	Transboundary	
730	28.026	86.682	18.710	Transboundary	
731	28.128	87.480	2.655	Transboundary	
732	27.994	88.211	5.075	Transboundary	
733	27.980	87.833	2.189	Transboundary	
734	28.277	86.676	1.576	Transboundary	
735	28.854	83.530	1.728	Transboundary	
736	31.269	78.339	1.264	Uttarakhand	Uttarkashi
737	27.988	87.869	6.998	Transboundary	
738	28.314	85.771	1.948	Transboundary	
739	27.837	86.935	29.393	Transboundary	
740	29.977	82.209	1.545	Transboundary	
741	28.613	84.922	3.570	Transboundary	
742	28.833	83.627	2.631	Transboundary	
743	28.124	87.486	1.533	Transboundary	
744	28.265	86.222	1.452	Transboundary	
745	27.926	87.991	5.596	Transboundary	
746	28.218	86.280	5.438	Transboundary	
747	28.112	86.863	39.399	Transboundary	
748	27.840	87.201	7.414	Transboundary	
749	28.397	86.440	1.688	Transboundary	
750	28.999	83.287	4.752	Transboundary	
751	27.965	87.871	2.665	Transboundary	
752	28.820	84.125	3.764	Transboundary	
753	28.036	88.381	1.012	Transboundary	
754	29.862	82.383	3.249	Transboundary	
755	28.234	86.667	9.873	Transboundary	
756	27.711	86.977	6.296	Transboundary	
757	27.805	86.974	16.767	Transboundary	
758	27.992	88.317	1.608	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
759	30.905	79.736	1.718	Uttarakhand	Chamoli
760	30.189	81.792	1.030	Transboundary	
761	28.107	87.584	15.909	Transboundary	
762	28.931	85.001	1.795	Transboundary	
763	27.799	86.966	21.362	Transboundary	
764	27.794	86.911	18.874	Transboundary	
765	28.222	87.574	6.128	Transboundary	
766	28.111	87.065	31.034	Transboundary	
767	28.761	84.069	4.978	Transboundary	
768	28.116	87.586	12.429	Transboundary	
769	27.821	86.960	4.219	Transboundary	
770	30.491	80.375	5.283	Uttarakhand	Pithoragarh
771	30.057	82.143	3.303	Transboundary	
772	30.201	81.918	1.580	Transboundary	
773	28.039	87.167	24.072	Transboundary	
774	28.255	86.530	1.063	Transboundary	
775	28.568	85.457	23.604	Transboundary	
776	27.832	86.917	33.073	Transboundary	
777	27.943	87.897	2.663	Transboundary	
778	29.218	83.702	42.486	Transboundary	
779	30.388	80.525	1.156	Uttarakhand	Pithoragarh
780	30.412	80.763	4.173	Transboundary	
781	28.234	87.607	3.015	Transboundary	
782	29.675	82.193	15.166	Transboundary	
783	30.405	80.762	3.247	Transboundary	
784	28.170	86.624	3.746	Transboundary	
785	27.924	86.786	54.853	Transboundary	
786	30.001	81.065	3.292	Transboundary	
787	27.821	86.910	2.150	Transboundary	
788	27.710	86.590	3.262	Transboundary	
789	27.981	86.609	3.071	Transboundary	
790	28.036	86.481	3.620	Transboundary	
791	30.285	81.475	1.193	Transboundary	
792	28.237	87.619	1.062	Transboundary	
793	30.032	82.284	1.594	Transboundary	
794	28.310	85.771	1.750	Transboundary	
795	28.242	86.658	1.336	Transboundary	
796	28.257	86.151	2.223	Transboundary	
797	27.900	86.909	3.283	Transboundary	
798	29.751	82.687	1.614	Transboundary	
799	30.807	79.123	3.494	Uttarakhand	Uttarkashi
800	30.373	80.603	1.194	Uttarakhand	Pithoragarh
801	28.007	87.028	14.227	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
802	28.271	85.783	7.456	Transboundary	
803	30.910	79.746	6.077	Uttarakhand	Chamoli
804	29.750	82.683	1.169	Transboundary	
805	29.632	82.787	3.888	Transboundary	
806	28.028	86.685	2.086	Transboundary	
807	28.349	86.182	1.629	Transboundary	
808	30.303	81.391	4.799	Transboundary	
809	28.009	87.062	3.161	Transboundary	
810	30.320	81.450	3.147	Transboundary	
811	28.351	86.179	1.944	Transboundary	
812	28.016	86.643	3.423	Transboundary	
813	30.342	81.458	1.958	Transboundary	
814	27.850	86.928	48.860	Transboundary	
815	28.028	86.687	1.456	Transboundary	
816	30.317	81.448	5.131	Transboundary	
817	27.834	86.909	1.320	Transboundary	
818	29.878	82.383	12.592	Transboundary	
819	28.154	87.617	5.475	Transboundary	
820	30.350	81.948	1.157	Transboundary	
821	27.977	86.607	2.028	Transboundary	
822	28.008	87.033	5.978	Transboundary	
823	27.969	87.884	17.898	Transboundary	
824	27.938	86.432	4.190	Transboundary	
825	29.723	82.644	18.860	Transboundary	
826	29.743	82.647	7.557	Transboundary	
827	27.803	86.984	1.088	Transboundary	
828	28.305	85.767	1.946	Transboundary	
829	27.818	86.955	7.159	Transboundary	
830	27.836	86.958	4.006	Transboundary	
831	30.324	81.406	1.024	Transboundary	
832	28.286	86.514	4.712	Transboundary	
833	27.828	86.914	5.547	Transboundary	
834	27.824	86.927	7.094	Transboundary	
835	30.340	81.465	1.804	Transboundary	
836	27.840	86.951	6.944	Transboundary	
837	30.188	81.824	1.132	Transboundary	
838	28.284	86.510	2.018	Transboundary	
839	28.020	87.584	2.556	Transboundary	
840	28.663	84.017	5.304	Transboundary	
841	27.857	86.918	7.379	Transboundary	
842	29.255	83.493	2.184	Transboundary	
843	28.212	86.626	1.036	Transboundary	
844	29.355	82.813	2.918	Transboundary	

Rank	Latitude	Longitude	Area (ha)	State/Transboundary	District
845	28.213	86.624	1.014	Transboundary	
846	29.253	83.492	1.019	Transboundary	
847	27.961	87.928	2.169	Transboundary	
848	28.283	86.502	22.625	Transboundary	
849	27.968	87.891	1.180	Transboundary	
850	28.317	86.502	1.282	Transboundary	
851	27.795	87.114	1.194	Transboundary	
852	29.755	82.664	1.362	Transboundary	
853	28.319	86.505	1.337	Transboundary	
854	28.317	86.505	1.346	Transboundary	
855	31.270	78.940	5.231	Uttarakhand	Uttarkashi
856	28.321	86.511	10.753	Transboundary	
857	27.825	86.933	1.907	Transboundary	
858	27.822	86.934	2.945	Transboundary	
859	28.212	86.585	2.157	Transboundary	
860	30.354	80.655	5.479	Uttarakhand	Pithoragarh
861	27.817	86.937	2.633	Transboundary	
862	28.285	85.839	6.498	Transboundary	
863	28.360	85.902	1.242	Transboundary	
864	28.397	86.321	2.067	Transboundary	

Note:

The distribution of glacial lakes is carried out using the Indian Administrative boundary available with NRSC.

Annexure C

State Wise Distribution of High-risk Glaciers in India

Report - 'Synthesis Report on GLOF Hazard And Risk Across the Indian Himalayan Region', University of Zurich, Switzerland.

(Source: Allen et al. 2020)

S/N	ID	Lat	Long	State	Area (ha)
1	27	34.381	74.876	Jammu & Kashmir	12.3
2	98	34.392	75.085	Jammu & Kashmir	3.2
3	173	34.765	76.71	Jammu & Kashmir	9.5
4	180	34.353	76.077	Jammu & Kashmir	8.8
5	182	34.234	75.325	Jammu & Kashmir	7.9
6	931	33.929	75.389	Jammu & Kashmir	22
7	932	34.051	76.717	Jammu & Kashmir	19.6
8	938	33.953	75.378	Jammu & Kashmir	18.8
9	951	34.067	75.475	Jammu & Kashmir	9
10	958	34.138	75.416	Jammu & Kashmir	33.2
11	963	34.139	75.376	Jammu & Kashmir	17.7
12	976	34.185	75.372	Jammu & Kashmir	5.3
13	993	34.227	75.222	Jammu & Kashmir	3.2
14	1014	34.299	75.06	Jammu & Kashmir	1.5
15	1032	34.386	75.064	Jammu & Kashmir	39.5
16	1037	34.422	75.058	Jammu & Kashmir	11.4
17	1352	35.074	76.293	Jammu & Kashmir	10.8
18	1360	35.027	75.725	Jammu & Kashmir	20.3
19	1774	32.221	76.788	Himachal Pradesh	10.4
20	1805	32.762	77.195	Himachal Pradesh	5.3

21	1847	31.915	77.527	Himachal Pradesh	246.2
22	1936	32.256	76.777	Himachal Pradesh	6.5
23	1948	32.526	77.219	Himachal Pradesh	1.2
24	1998	32.32	76.908	Himachal Pradesh	4.6
25	2031	31.339	78.253	Himachal Pradesh	102.4
26	2041	31.661	78.168	Himachal Pradesh	24.7
27	2108	30.976	79.459	Uttarakhand	17.9
28	2147	30.98	79.487	Uttarakhand	5.6
29	2207	30.912	78.958	Uttarakhand	12.1
30	2299	30.184	79.88	Uttarakhand	0.4
31	192	27.993	88.547	Sikkim	60.2
32	195	27.993	88.801	Sikkim	9.6
33	224	27.816	88.657	Sikkim	14.4
34	225	27.894	88.761	Sikkim	48.1
35	227	28.006	88.655	Sikkim	4.5
36	228	27.951	88.705	Sikkim	2.5
37	236	27.92	88.672	Sikkim	8.5
38	237	27.873	88.638	Sikkim	4.1
39	238	27.701	88.514	Sikkim	6.4
40	239	27.864	88.747	Sikkim	18.5
41	256	27.854	88.806	Sikkim	21.9
42	258	28.002	88.64	Sikkim	30.3
43	260	27.695	88.716	Sikkim	13.1
44	261	88.1986	27.9119	Sikkim	153.5
45	264	88.7128	28.0071	Sikkim	138.6
46	288	88.6979	28.0091	Sikkim	112.8
47	292	88.8155	27.9917	Sikkim	311.2
48	293	88.6164	27.9753	Sikkim	61.6
49	295	88.5616	28.0144	Sikkim	28.5
50	298	88.5718	28.0073	Sikkim	27.4
51	312	88.5078	27.9823	Sikkim	40.6
52	345	88.6493	27.9608	Sikkim	20.7
53	515	88.0857	27.5335	Sikkim	35.8
54	569	88.7895	27.8733	Sikkim	13.6
55	599	88.8629	27.8645	Sikkim	15.3
56	39	27.775	92.314	Arunachal Pradesh	13.2
				Total	**56**

Annexure D

Assessment of 8 Glacial Lakes by CWC

(2022)

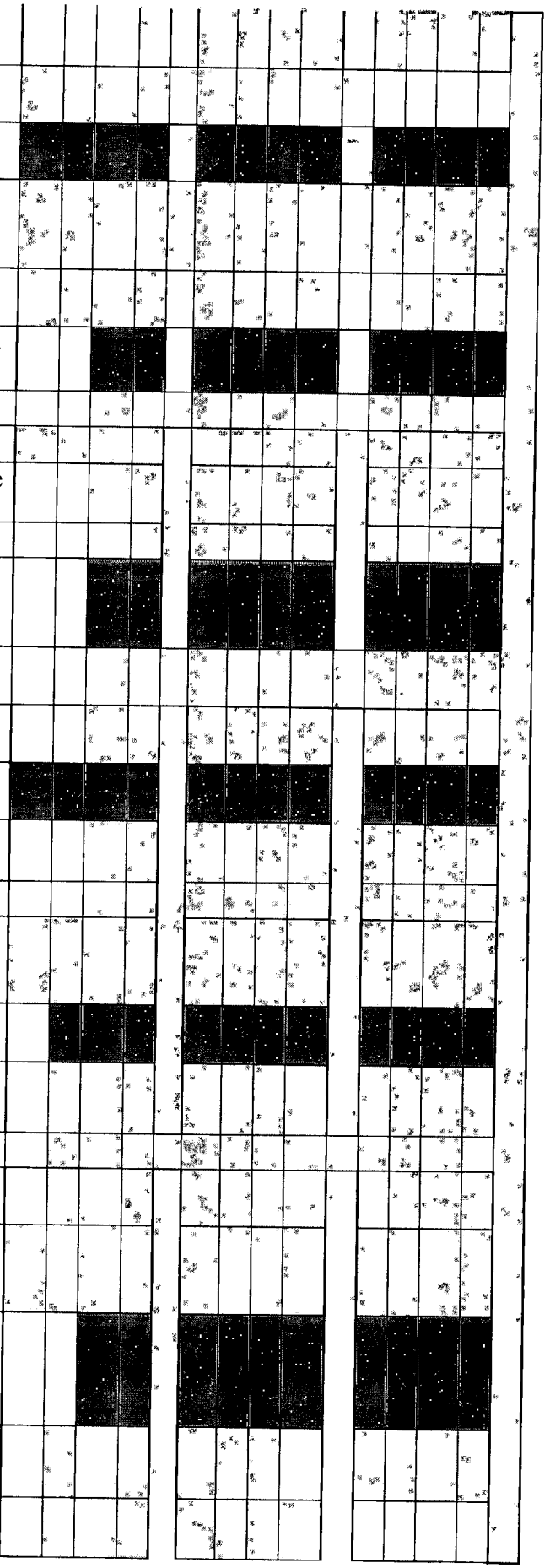
State		HP				J&K		UK	Ladakh
Salient Features of Lake	*Lake_ID*	01_52H_02	01_53J_02	01_52H_01	01_52D_15	01_43N_08	01_43N_03	02_53N_05	01_52B_010
	SDC_ID/Map_ID	1948	2041	1805	1936	976	1037	2108	932
	Basin	Indus	Indus	Indus	Indus	Indus	Indus	Ganga	Indus
	Sub-basin	Chandra	Sutlej Lower	Bhaga	Ravi	Jhelum	Kishanganga	Alaknanda	Indus Upper
	River	Chenab	Sutlej	Dudha Khol	Thamsar Nala	Daphkimpar Nar	Gadsar Nala	-	Spang
	Lat	32.526	31.661	32.763	32.256	34.185	34.422	30.976	34.051
	Long	77.219	78.168	77.195	76.777	75.372	75.058	79.459	78.717
	Orthometric Elevation (m)	4069	4256	4775	4606	4314	3603	5587	5122
	District	Lahul & Spiti	Kinnaur	Lahul & Spiti	Kangra	Anantnag	Bandipora	Chamoli	Leh
Water Spread Area Based on Remote Sensing in ha	*Monitored Since*	2011	2022	2022	2022	2022	2022	2022	2022
	June-2022	99	-	1	-	-	40	17	-
	Jul-22	90	30	1	3	17	40	17	15
	Aug-22	97	30	3	3	16	37	20	16
	Sep-22	110	25	3	3	15	37	19	16
	Last 5 yr avg	97	-	-	-	-	-	-	-
	Last 10 yr avg	83	-	-	-	-	-	-	-
Parameters used by NRSC for ranking of lakes	*Distance from Glacial Snout to Lake inlet (m)*	2830	380	350	200	250	250	640	210
	Slope between Glacial Snout to Lake inlet	0.091	0.116	0.477	0.25	0.288	0.576	0.244	0.329
	Distance from Lake outlet to nearest Settlement (m)	10800	11000	13500	5860	9000	29500	29000	20000
	Slope between lake outlet and nearest settlement	0.095	0.093	0.096	0.237	0.156	0.036	0.084	0.092
	Type	End moraine Dammed Lake	End moraine Dammed Lake	End-moraine Dammed Lake	Other moraine Dammed Lake	Cirque Erosion Lake	Cirque Erosion Lake	End-moraine Dammed Lake	End moraine Dammed Lake
	Lake Area (2022)	99	28.3	2	3	15.5	37	19.5	16.00
Degree of Hazard of Lake	*By SDC*	Very High Risk	Very High Risk	Very High Risk	Very High Risk	High Risk	Medium Risk	Very High Risk	Medium Risk
	By NRSC	Indus_4	Indus_26	Indus_81	Indus_321	Indus_15	Indus_27	Ganga_347	Indus_75

ANNEXURE -E

Component-wise Activities Time Frame

S/N	Activities	First Year				Second Year				Third Year			
		Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
1.	Creation of Glacial Lake Inventory database												
2.	Template/format to record GLOF catalogue												
3.	Classify GLOFs based on severity, size, volume of debris generated												
4.	Compilation of GLOF Database												
5.	Mapping Causative factors of GLOFs												
6.	Detailed investigation and mapping of dangerous/high-risk glacial lakes												
7.	Detailed risk assessment of downstream elements at risk												
8.	GLOF modelling of lakes												
9.	Evaluate the geotechnical GLOF resilience of major infrastructures												
10.	Design model flood wave runouts												
11.	Cadastral level mapping using High-resolution satellite data, Digital Elevation Model and LiDAR data												
12.	Map all critical infrastructures in the high-risk areas												
13.	Retrofitting all the sub-standard construction												
14.	Compile and evaluated data on risk scenarios												
15.	Develop mesoscale maps in high-risk areas												
16.	Mapping the causative factors for the occurrence of landslide												
17.	Identify various elements exposed to GLOF risk												
18.	Creation of GLOF Hazard Zonation maps with low, medium, and high hazard zonation												
19.	Creation of web-based and app-based dissemination tools for the preparation of mesoscale maps												
20.	Develop sensor based monitoring and Early Warning Systems with last-mile connectivity and outreach												
21.	Design a low cost, and simple technology community-centric early warning system												
22.	Install instrumentation-based GLOF early warning system for societal use.												
23.	Real-time monitoring of lake. Utilize InSAR for repeated monitoring												
24.	Site suitability analysis for installation of AWS & AWLR												
25.	Prepare Alarm & Evacuation Protocol by involving existing Hydro-power project												

26.	Construction of diversion waterways, designing drainage systems to run along natural drainage lines
27.	Enhance adaptive capacity and create awareness in GLOF risk management
28.	Research and Development (R&D) & carry out scientific study on GLOF risk management
29.	Conduct seminar/workshops/symposium. collaboration of national and international organizations / Institutions in the workshops
30.	Identification of appropriate structural measures and implementing site-specific structural measures
31.	Bio restoration initiative for slope stability of moraine dams
32.	Develop bio-restoration protocol
33.	Establish local rainfall database
34.	Construction of an outlet control structure (concrete steps & pipeline)
35.	Controlled breaching
36.	Construction of Artificial Drainage Channels and artificial exit tunnel through the moraine barrier or under an ice dam
37.	Construction of Avalanche galleries & other avalanche preventing structures beside the lakes
38.	Maintenance of Hydroelectric power stations in the GLOF prone areas
39.	Identification and adoption of site-specific structural measures
40.	Feasibility study of social and environmental acceptability of mitigation project
41.	Publication of research articles and scientific reports
42.	Preparing Training modules/manuals for different target groups
43.	Capacity Building Programmes for state and district level officers
44.	Sensitize the government officials about the landslide risk under their jurisdiction
45.	Strengthening the training institutes on GLOF risk
46.	Improve organizational capability and skills to deal with GLOF risk situations
47.	Recognize the role and responsibilities of different stakeholders. Identification of NGOs/institutes for facilitation of training programmes
48.	Impart training to the targeted participants among the elected members of Panchayat Raj Institutions (Local bodies) and Institution members in the in the GLOF-prone areas
49.	Capacity building and local community awareness for local-level interventions to reduce GLOF risk
50.	Creation of a village task force in each village



51.	Villagers are sensitized about the hazard, vulnerability and elements at risk in their respective villages and surroundings
52.	Skill development of the community through Indigenous knowledge and methods
53.	Conduct site visits in the past GLOF locations
54.	Recognize the role and responsibilities of local self-government members in GLOF risk reduction
55.	Enhancing adaptive capacity and creating awareness in GLOF risk management
56.	Prepare Contingency Action Plan
57.	Preparation of illustrated booklet with information on GLOF awareness in local languages.
58.	Creation of Knowledge Management centre. Knowledge sharing, networking and publications on GLOF risk reduction
59.	Capacitate communities to prevent, mitigate and cope with disasters effectively
60	Involvement of local communities, inhabited individuals, youth clubs, NGOs in awareness programmes
61.	Identification of GLOF safe locations in the proximity of the village for the construction of temporary or permanent community centres
62.	Constitute a Mountain Hazard Team at the NDMA level
63.	Enhance the network among various expert institutions in GLOF management
64.	Facilitate research and documentation in GLOF risk management
65.	Creation of GLOF research centres in different institutions
66.	Mainstreaming awareness activities
67.	Regular training sessions for specific skill development.
68.	Rescue and response to ensure effective and prompt action in the event of a landslide