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Glacial Lakes and Glacial Lake Outburst Floods in Nepal

GFDRR
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Note

This assessment of glacial lakes and glacial lake outburst flood (GLOF) risk in Nepal was conducted with the aim of developing recommendations for adaptation to, and mitigation of, GLOF hazards (potentially dangerous glacial lakes) in Nepal, and contributing to developing an overall strategy to address risks from GLOFs in the future. The assessment is also intended to provide information about GLOF risk assessment methodology for use in GLOF risk management in Nepal. The methodology that was developed and applied in the assessment can also be broadly applied throughout the Hindu Kush-Himalayan region. The assessment has been completed through activities carried out in collaboration with national partners, which include government and non-government institutions as well as academic institutions and universities.

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Dig Tsho on 24 April 2009; the GLOF event of 1985 caused more than 3 million dollars worth of damage and disrupted the downstream community for several months. The moraine dam was sufficiently destroyed that the reformed lake is no longer a threat.

Foreword

The Hindu Kush-Himalayan region contains the world's largest volume of glacier ice and perennial snow outside the polar regions. Its meltwater contributes to the major rivers that supply freshwater to almost a quarter of humanity residing in the downstream areas. Glaciers are sensitive indicators of increased air temperature. They have been studied extensively in many parts of the world as part of an international effort to improve understanding of the current pattern of global warming. Following the culmination of glacier advance during the Little Ice Age more than a hundred years ago, with short periods of reversal, glaciers have been thinning and retreating in many parts of the world. This process, in large part due to anthropogenic changes in the Earth's atmosphere, appears to have accelerated during the last few decades. The Hindu Kush-Himalayan region is no exception to the trend.

The Himalayan range extends for approximately 2,400 km within the 3,500 km length of the Hindu Kush-Himalayan ranges, and has about 33,000 sq.km of the estimated 110,000 sq.km of glaciated area. The Nepal Himalayas occupy 800 km of the central section of the Himalayan range.

Glacier thinning and retreat in the Himalayas has resulted in the formation of new glacial lakes and the enlargement of existing ones due to the accumulation of meltwater behind loosely consolidated end moraine dams that had formed when the glaciers attained their Little Ice Age maxima. Because such lakes are inherently unstable and subject to catastrophic drainage they are potential sources of danger to people and property in the valleys below them. The torrent of water and associated debris that sudden lake discharges produce is known as a glacial lake outburst flood (GLOF). Recent surveys have shown that many glacial lakes in Nepal are expanding at a considerable rate so that the danger they pose appears to be increasing. Nepal has experienced 24 GLOF events in the recent past, several of which have caused considerable damage and loss of life, for example, the Bhote Koshi Sun Koshi GLOFs of 1964 and 1981 and the Dig Tsho GLOF of 1985. The 1981 event damaged the only road link to China and disrupted transportation for several months, while the Dig Tsho GLOF destroyed the nearly completed Namche Small Hydroelectric Project, in addition to causing other damage farther downstream. The source of the former event was inside the Tibet Autonomous Region of China, indicating the necessity for international regional cooperation to address the dimension of the problem.

Glacial lakes, however, are not only sources of potential danger, they are also an important potential natural resource, which has yet to be effectively investigated. Monitoring glacier and water hazards, promoting community resilience and preparedness for disaster risk reduction, and ensuring the sharing of upstream-downstream benefits are priority areas in ICIMOD's programme. As glaciers and glacial lakes are related to both water resources and to water-related natural hazards, they need to be mapped and monitored to assess both their potential hazard and their resource value. ICIMOD has been involved in this type of endeavour since 1986.

The work reported here has received financial support from the World Bank. It is a systematic and comprehensive study of the status of glacial lakes in Nepal and an assessment of the hazard they pose and of the vulnerability of downstream people and property. It begins with the actual mapping of glacial lakes. This is followed by a hazard assessment. Next the problem of determining the most dangerous of the lakes is addressed, accompanied by analysis of the degree of downstream vulnerability. The report concludes by proposing some preliminary steps for development of a national strategy for response to the hazard, and emphasising the need for applying the experience obtained towards initiation of a region-wide international response. In this regard, on behalf of ICIMOD, I would like to thank the World Bank for its vital financial contribution. I would also like to thank the Swedish International Development Cooperation Agency (Sida) and the Norwegian Ministry of Foreign Affairs for additional financial support.

Andreas Schild
Director General, ICIMOD

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During the field investigation at Imja Tsho on 12 May 2009, one of the team members, Mr Suresh Maharjan, lost his life. The authors would like to pay a special tribute to him; his hard work and enthusiastic team spirit were substantial contributions to the field investigation and he is sadly missed. We hope that the addition of knowledge to this field will be a tribute to his commitment.

Critical comments and suggestions received from Dr Golam Rasul, Head, Economic Analysis Division, ICIMOD, on the vulnerability assessment and GLOF risk management strategy sections of the report is much appreciated. Last but not least, the authors extend their sincere appreciation to Professor Jack D Ives of Carleton University, Canada for his detailed review and substantive input to the report at different stages, and Professor Dr Andreas Kääb, Department of Geosciences, University of Oslo, Norway for critically reviewing the report and sharing his insights and comments.

Executive Summary

The world's climate has been warming for more than a hundred years: there have been fluctuations, notably cooling phases in the 1960s and 1970s, although long-term records indicate an accelerating warming trend from about 1980. Although this has influenced ecosystems worldwide, its effects on glaciers and the duration of winter snow cover have been particularly noticeable, especially in the European Alps and Greenland, and on the reduction of sea ice cover in the Arctic Ocean. The Hindu Kush-Himalayan region has been no exception.

One of the more spectacular effects of recent atmospheric warming in the Himalayas has been the creation of meltwater lakes on the lower sections of many glaciers. In an increasing number of instances, especially well-documented in Nepal, several of these lakes have burst their natural retaining dams (usually old end moraines that were formed when the glaciers were thicker and more extensive than today). This has produced catastrophic flood surges (glacial lake outburst floods or GLOFs) that have destroyed infrastructure and taken human lives in the valleys below.

Fourteen GLOF events have been recorded in Nepal in recent decades; several others in Tibet Autonomous Region in China have crossed the international border to cause extensive damage in Nepal. Other GLOFs have been recorded across the Hindu Kush-Himalayan region.

Systematic application of remote sensing and air photo interpretation has shown that many hundreds of glacial lakes have formed in recent years, while others have enlarged, on occasion to lengths exceeding two kilometres with depths approaching a hundred metres. In this way, immense volumes of meltwater have accumulated behind potentially unstable moraine dams. There is no doubt that people and property for considerable distances downstream from the unstable lakes are facing a serious threat to their existence: the problem, however, is how to determine the degree of probability of such an event.

This situation, together with the realisation that the risk of damage and loss of life may continue to increase in the near future, has prompted the preparation of the present report. Its intent is to assess the current degree of risk, to determine the extent of vulnerability of people and property to the potential outburst of glacial lakes, and to provide a basis for strategy development to help ensure a timely response.

The report is based upon information and experience accumulated during collaboration with several partner institutions in Nepal. It outlines a stepwise approach to assessment of risk beginning with an extensive desk study of aerial photographs and satellite images that provided the first reconnaissance mapping of more than a thousand glacial lakes. There followed a provisional identification of six lakes that were considered to be potentially dangerous and that warranted special study. Three lakes, namely, Tsho Rolpa, Thulagi Lake, and Imja Tsho, were selected for detailed field investigation, application of computer dam-break modelling, and assessment of the vulnerability of human life and property for up to 100 kilometres downstream.

Analysis of the rapidly growing worldwide literature on the outburst of glacial lakes, and the project's field and theoretical experience, have led to the conclusion that it is not feasible to make a reliable prediction of a specific occurrence on the basis of our existing knowledge. The difficulty involved in any attempt to forecast danger is emphasised. Concomitantly, it is proposed that news media and other sources in recent years have perpetrated highly exaggerated claims of imminent large-scale catastrophe, and that this is in itself counter-productive and should be contested. Nevertheless, while the danger has been heavily distorted, GLOFs may occur in future, or even tomorrow (although spurious accuracy in assessment of probability is considered unhelpful). As direct predictions cannot be made, there is an urgent need to monitor a careful selection of prioritised lakes on a regular basis. This should be carried out in collaboration with other institutions, both nationally and internationally.

In view of the uncertainties facing the refinement of a 'probability index', Tsho Rolpa and Imja Tsho have been identified for continued and more intensive study. This will require both geophysical field investigation and more exacting downstream vulnerability assessments. The latter should involve generation of local awareness and incorporation of downstream populations and managers of large-scale infrastructure (such as hydroelectricity projects) into the observation of targeted lakes, and evaluation of early warning systems, and their possible installation: further refinement of dam-break modelling, as an essential part of vulnerability assessment, should be undertaken.

It is also recommended that ICIMOD develop an exhaustive archive for all relevant data: field data; satellite imagery; ground photographs; and all available scientific and technical reports and publications. A final and overriding recommendation is that the data and experience acquired during the formulation of this report be used as a basis for the development of a national strategy aimed at risk reduction. A draft outline of the elements for such a strategy is provided as part of this report.

Region-wide cooperation throughout the Hindu Kush-Himalayas should follow, and it is recommended that steps be taken to organise a region-wide planning session for experts and leaders of relevant national institutions to develop a more coordinated approach and begin laying the foundations for a glacial lake outburst risk reduction policy.