

Country Name	<b>Study on GLOFs (Glacial Lake Outburst Floods) in the Bhutan Himalayas</b>
Kingdom of Bhutan	

**I. Project Outline**

Background	<p>A glacial lake outburst flood (GLOF) occurs when a body of water that is contained by a glacier or terminal moraine is released. In Bhutan, hazard from GLOF was an urgent environmental and economic issue. Since 1960s, a number of GLOFs had been recorded concurrently with shrink of glaciers and expansion of glacial lakes over the region. The most recent flood at the time of ex-ante evaluation occurred in October 1994 from the partial burst of the Luge Tsho in eastern Lunana. This flood caused loss of life and extensive damage to property along the Punakha- Wangdi valley. These observations led to a notion that recent global warming might have resulted in an increasing amount of GLOF risk. Therefore, mitigation of GLOF risk was one of the top priorities for climate change adaptation in Bhutan. Under those situations, the project was approved as a SATREPS project.</p>				
Objectives of the Project <sup>2</sup>	<p>Through the Outputs namely 1) identification of potential risk lakes in the Himalayas, 2) clarification of the history and process of glacial lake development as reviewable inventory, 3) comprehensive assessment of outburst risks of glacial lakes in Mangde Chhu basin, 4) development of hazard map in Mangde Chhu, and 5) development of a plan for the early warning system for pilot site and its catchment area, the project aimed at assessing the risk of GLOF in Bhutan through a joint research, strengthening capacity to conduct investigation and research on the GLOF phenomenon, and building capacity to propose effective disaster management in the Bhutan Himalayas, thereby contributing to improvement of safety against GLOF.</p> <ol style="list-style-type: none"> <li>1. Overall Goal: Safety against GLOF is improved in the Bhutan Himalayas.</li> <li>2. Project Purpose: To assess the risk of GLOF in Bhutan through a joint research, to strengthen capacity to conduct investigation and research on the GLOF phenomenon, and to build capacity to propose effective disaster management.</li> </ol>				
Activities of the Project	<ol style="list-style-type: none"> <li>1. Project site: The Bhutan Himalayas and Mangde Chhu basin (as model site)</li> <li>2. Main activities: 1) connection of a common network system of satellite data for the joint research, development of a database of dangerous glacial lake in the Himalaya region, based on potential assessment using satellite data (ASTER-DEM), establishment of an assessment criteria based on verification of former condition in topography and water level of once broken lakes; 2) development of an inventory of historical glacial lake expansions based on the analysis of satellite data; climatologically analysis on historical expansions of glacial lakes using the inventory, clarification of the expanding mechanism of glacial lake through the consideration of ice/water interaction, based on field survey and observation; 3) detailed analysis on the hazardous lakes selected using satellite data (ALOS-DEM), assessment of risk factors and triggers of GLOF in/around glacial lakes based on ALOS-DEM analyses, selection of the high-priority places as the pilot sites according to the results of field survey and the satellite data analyses; 4) evaluation of a vulnerability to dam collapse based on field survey and geophysical profiling at the moraine, repeated analyses based on records of GLOFs in Himalaya region, simulation of break and flood at the glacial lakes of pilot site(s), drawing of the hazard map including unstable river bank under the flood based on geological and topographical field survey in the lower stream of Mangde Chhu; 5) an inventory survey on social and infrastructure facilities in the downstream area of Mangde Chhu, development of proposal on an effective early warning system</li> <li>3. Inputs (to carry out above activities) <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top;"> <b>Japanese Side</b> <ol style="list-style-type: none"> <li>1) Experts from Japan: (long-term) 2 persons; (short-term) 24 persons</li> <li>2) Training in Japan: 9 persons</li> <li>3) Equipment: Surveying instruments, Automatic weather instrument, Satellite data processing machine, Satellite data, Geophysical equipment, GIS software, etc.</li> <li>4) Local cost: cost for research equipment, etc.</li> </ol> </td> <td style="width: 50%; vertical-align: top;"> <b>Bhutanese Side</b> <ol style="list-style-type: none"> <li>1) Staff allocated: 18 persons</li> <li>2) Land and facilities: office space at Department and Geology and Mining (DGM), etc.</li> <li>3) Local cost.</li> </ol> </td> </tr> </table> </li> </ol>			<b>Japanese Side</b> <ol style="list-style-type: none"> <li>1) Experts from Japan: (long-term) 2 persons; (short-term) 24 persons</li> <li>2) Training in Japan: 9 persons</li> <li>3) Equipment: Surveying instruments, Automatic weather instrument, Satellite data processing machine, Satellite data, Geophysical equipment, GIS software, etc.</li> <li>4) Local cost: cost for research equipment, etc.</li> </ol>	<b>Bhutanese Side</b> <ol style="list-style-type: none"> <li>1) Staff allocated: 18 persons</li> <li>2) Land and facilities: office space at Department and Geology and Mining (DGM), etc.</li> <li>3) Local cost.</li> </ol>
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Project Period	May 2009 to April 2012 (Extension: April 2012)	Project Cost	(ex-ante) 220 million yen, (actual) 219 million yen		
Implementing Agency	Department of Geology and Mines (DGM) <sup>3</sup> , Ministry of Economic Affairs (MEA)				

<sup>1</sup> Science and Technology Research Partnership for Sustainable Development.

<sup>2</sup> Source: The logical framework which officially added the overall goal approved by the Minutes of the Meeting (M/M) 1 (9/3/2010) and confirmed by the M/M (1/4/2011) of the Joint Coordinating Committee.

<sup>3</sup> Under DGM, Glaciology Division was in charge of survey and research on GLOF. In 2013, the function of Glaciology Division was transferred to newly established Snow and Glacier Division of Department of Hydromet Service (DHMS) under MEA. In 2016, DHMS was reorganized into an autonomous agency called National Center for Hydrology & Meteorology (NCHM), and Snow and Glacier Division was renamed as Cryosphere Service Division (CSD).

Cooperation Agency in Japan	Nagoya University, Japan Aerospace Exploration Agency, Earth System Science, Co., Ltd.
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## II. Result of the Evaluation

### < Special Perspectives Considered in the Ex-Post Evaluation >

- In the terminal evaluation, achievement status of the Outputs of the project and improvement status of skills and knowledge of counterparts (C/Ps) were used to assess achievement level of the Project Purpose. Respecting the judgement made by the terminal evaluation, they shall be used as supplementary information to confirm the achievement status of the Project Purpose.
- Since Indicators for the Overall Goal were not set for the project, achievement level of the Overall Goal shall be judged based on the progress of the expected goals shared by the concerned parties through the terminal evaluation, that is utilization of the following research outputs by the project i.e. assessment of the dangerous lakes is implemented in Mangde Chhu basin and in wider area in Bhutan, utilizing the methods developed by the project including satellite data-based monitoring and field observation (Item 1) and the plans on early warning system proposed by the project are implemented in Mangde Chhu basin and wider area in Bhutan (Item 2). In addition, utilization status of other major research outputs<sup>4</sup> for improvement of safety against GLOF shall be confirmed (Item 3).

### 1 Relevance

#### <Consistency with the Development Policy of Bhutan at the Time of Ex-Ante Evaluation and Project Completion>

The project was consistent with the development policy of the Bhutanese government, which put GLOF as a priority issue, as stated in the draft of the 10th Five Year Plan (FYP) (2008-2013) at the time of ex-ante evaluation and the 10th FYP at the time of project completion.

#### <Consistency with the Development Needs of Bhutan at the Time of Ex-Ante Evaluation and Project Completion >

As stated in “Background”, the project was consistent with the development needs of Bhutan of mitigation of GLOF risk at the time of ex-ante evaluation. Change in the development needs was not observed at the time of project completion.

#### <Consistency with Japan’s ODA Policy at the Time of Ex-Ante Evaluation>

The project was consistent with the draft of Rolling Plan for the Kingdom of Bhutan being examined at the time of ex-ante evaluation, in which measures against GLOFs were regarded to contribute to Development Issue which focuses on South Asia Regional Assistance.

#### <Evaluation Result>

In light of the above, the relevance of the project is high.

### 2 Effectiveness/Impact

#### <Status of Achievement of the Project Purpose at the time of Project Completion>

The Project Purpose was achieved at the time of project completion. A joint research report between Japan and Bhutan on inventory on glacial lakes was produced by DGM and three joint research papers were published in an international journal, and a proposal on rainstorm and GLOF early warning systems in Mangde Chhu basin and Chamkar Chhu basin, developed by the project, was submitted to DGM (Indicator). All of the Outputs of the project were achieved (Supplementary Information 1). It is judged that, through such collaborative research with Japanese experts, capacity of C/P researchers for survey and research on GLOF was strengthened (Supplementary Information 2).

#### <Continuation Status of Project Effects at the time of Ex-post Evaluation>

The project effects have mostly continued. When Glaciology Division of DGM was reorganized into Snow and Glacier Division of DHMS (presently CSD of NCHM) in 2013, DHMS (presently NCHM) took over research on GLOFs, while DGM was mandated to provide geological and geophysical data for the research to DHMS (presently NCHM) whenever requested. Since the reorganization, DHMS/NCHM has continued survey and research on GLOF based on the research outputs produced by the project. At the time of ex-post evaluation, 4 research activities are conducted by NCHM (i.e. time-series monitoring of glacial lakes, revision of inventory of glacial lakes developed by the project, study on glacial mass balance, and a collaborative research with Royal University of Bhutan on run off waters from the glacier lakes). In addition, a new organization, Department of Disaster Management (DDM) under the Ministry of Home and Cultural Affairs, has developed a GLOF hazard map for Thimphu Chhu river basin in collaboration with local governments. Further, the major research outputs by the project, including the joint research report on inventory on glacial lakes and the proposal on rainstorm and GLOF early warning systems, have been utilized for improvement of safety against GLOF. (See “Status of Achievement for Overall Goal at the time of Ex-Post Evaluation”).

Meanwhile, not all of the research equipment provided by the project has been fully utilized along the intended purpose continuously. At the time of reorganization mentioned above, automatic weather instrument was handed over to DHMS (presently NCHM) and the other critical items were retained at DGM. Automatic weather instrument has been continuously utilized for research on GLOF. As for the research equipment retained at DGM, satellite data has been shared with DHMS/NCHM for research on GLOF. However, satellite data processing machine has been used to process geophysical data using other software<sup>5</sup> and GIS software has not been in use due to high price for renewal of the respective software licenses. It is noted that, this has not affected the research on GLOF because NCHM is able to acquire the up-to-date high resolution satellite data of glaciers from Sentinel 2 for free of charge due to advancement of technology and DGM has been using an alternative GIS software obtained by the government at a subsidized rate. The other critical research equipment has been utilized as intended and the collected data required for research on GLOF has been shared with DHMS/NCHM<sup>7</sup>.

#### <Status of Achievement for Overall Goal at the time of Ex-post Evaluation>

The Overall Goal has been achieved. As a follow-up to this SATREPS project, a technical cooperation project (TCP) of JICA “The Project For Capacity Development of GLOF and Rainstorm Flood Forecasting and Early Warning in the Kingdom of Bhutan” was implemented by DHMS/NCHM from 2013 to 2016. With the support of the TCP, assessment of dangerous lakes was implemented in Mangde Chhu basin and in Chamkhar Chhu basin, utilizing the methods developed by the project, including satellite data-based monitoring

<sup>4</sup> Other major research outputs are 1) inventory of potentially high-risk glacial lakes based on the common network system of satellite data and the database of dangerous glacial lakes; 2) research report on the history and process of glacial lake development; 3) the methods for detailed assessment of risk factors of glacial lakes outburst in Mangde Chhu basin, including list of dangerous glacial lakes; and 4) hazard map in Mangde Chhu basin.

<sup>5</sup> The processed data has been provided to NCHM as needed.

<sup>7</sup> It is noted that the provided survey instruments have been used as back up since 2017 because DGM procured new ones.

and field observation (Item 1). Rainstorm and GLOF early warning systems in the two basins, proposed by the project, were established (Item 2). Other major research outputs were utilized to improve safety against GLOF. Inventory of potentially high-risk glacial lakes and the methods for detailed assessment of risk factors of glacial lakes outburst in Mangde Chhu basin were utilized to assess the dangerous lakes, and the other major research outputs (i.e. research report on the history and process of glacial lake development and hazard map in Mangde Chhu basin) were utilized in the activities of the TCP. At the time of ex-post evaluation, assessment of dangerous lakes is continued by NCHM under the research activities on time-series monitoring of glacial lakes and revision of inventory of glacial lakes (Item 1) and rainstorm and GLOF early warning systems in the two basins are functional (Item 2).

<Other Impacts at the time of Ex-post Evaluation>

Various positive impacts have been observed. The scientific literacy and awareness of the related government organizations and policy makers about the potential risks of GLOF has been improved through extensive media coverage and scientific seminars about the research outputs of the project. According to NCHM, recommendations from the research outputs of the project such as the list of the dangerous glacial lakes in Bhutan, has contributed to the formation of some of the activities for the 11th FYP (2013-2018) and the draft 12th FYP (2018-2023). The research outputs by the project have been applied to mitigation of disaster other than GLOF: NCHM and DGM have developed flood and landslide hazard maps in Mangde Chhu basin and Chamkar Chhu basin under the TCP. In addition, DGM has conducted geological and geophysical survey and research, utilizing the research method introduced by the project as well as the provided equipment retained at DGM. Meanwhile, no negative impacts have been observed.

<Evaluation Result>

Therefore, the effectiveness/impact of the project is high.

#### Achievement of Project Purpose and Overall Goal

Aim	Indicators	Results
(Project Purpose) To assess the risk of GLOF in Bhutan through a joint research, to strengthen capacity to conduct investigation and research on the GLOF phenomenon, and to build capacity to propose effective disaster management.	Joint research report between Japan and Bhutan on GLOF 1) Database of quantitatively-assessed dangerous glacial lakes 2) Draft/Proposal on GLOF countermeasure	Status of the Achievement: achieved (continued) (Project Completion) - A joint research report between Japan and Bhutan on inventory on glacial lakes was produced by DGM and three joint research papers were published in an international journal. - Proposal on rainstorm and GLOF early warning systems in Mangde Chhu basin and Chamkar Chhu basin was developed and submitted to DGM. (Ex-post evaluation) *See the results of the Overall Goal.
(Overall Goal) Safety against GLOF is improved in the Bhutan Himalayas.	Item 1: Assessment of the dangerous lakes is implemented in Mangde Chhu basin and in wider area in Bhutan, utilizing the methods developed by the project including satellite data-based monitoring and field observation.	(Ex-post Evaluation) achieved - Assessment of the dangerous lakes was implemented in Mangde Chhu basin (twice) and Chamkar Chhu basin (once) in the TCP (2013-2016), and it is continued by NCHM.
	Item 2: The plans on early warning system proposed by the project are implemented in Mangde Chhu basin and wider area in Bhutan.	(Ex-post Evaluation) achieved - Rainstorm and GLOF early warning systems in Mangde Chhu basin and Chamkar Chhu basin, proposed by the project, have been established with support of the TCP.
	Item 3: Other major research outputs by the project are utilized for improvement of safety against GLOF in Mangre Chhu basin and wider area in Bhutan.	(Ex-post Evaluation) achieved - Other major research outputs by the project have been utilized for assessment of the dangerous lakes and the TCP for improvement safety against GLOF.

Source : Terminal Evaluation Report, Project Completion Report, questionnaire and interview survey to DGM and NCHM.

### 3 Efficiency

While the project cost was within the plan (ratio against the plan: 100%), the project period slightly exceeded the plan (ratio against the plan: 103%). Although the project activities in Bhutan were completed by March 2012, the end of the planned project period, it was in April 2012 that the project was officially completed (reasons for the extension is unknown). The Outputs of the project were produced as planned. Therefore, the efficiency of the project is fair.

### 4 Sustainability

<Policy Aspect>

Improvement of safety against GLOF is consistent with the 11th FYP (2013-2018) and the draft 12<sup>th</sup> FYP (2018-2023) because they recognize the importance to continuously monitor and validate glacier lakes under the program for reducing and preventing Risk associated with Geo-hazards.

<Institutional Aspect>

CSD of NCHM, the succeeding organization of Glaciology Division of DGM, is mandated to study and monitor cryosphere (snow, glaciers, glacier lakes) and its associated risks to implement appropriate mitigation and adaptation measures, and its functions include time-series monitoring of glacial lakes and assessment of risks associated GLOF. Total of 8 researchers have been assigned for research activities based on the research outputs by the project. The necessary number of staff has been allocated because the research activities have been carried out as planned. Also, NCHM has been slowly developing linkage with other relevant organizations for continuation of the related research and utilization of the research outputs. For example, NCHM has received the geological and geophysical data required for research on GLOF from DGM and has started a collaborative research with Royal University of Bhutan. It has shared the results of

assessment of glacial lakes with the relevant stakeholders such as Department of Hydropower Systems, Druk Green Power Corporation, Ministry of Agriculture and Forests and other relevant authorities. It has also shared the observation data of the water level from the early warning systems to DDM. As for the maintenance of the provided equipment, both NCHM and DGM have assigned persons in charge of management for each item.

NCHM feels that, in order to provide all the services required by the mandates of NCHM, it will need to further expand their research capacity and focus; in addition, it will also need to create linkages with other relevant institutions within the country and the region. In the 12th FYP period (2018-2023), NCHM plans to increase the number of researchers and collaborative research with other national and international institutions and develop a platform or linkage with organizations with similar mandates.

<Technical Aspect>

Researchers of NCHM (former C/Ps of the project) have sustained and improved their capacity to continue the related survey and research by participating in the TCP mentioned in “Effectiveness/Impact” and other short-term training and seminars organized in Bhutan and other countries. They have also kept in close touch with the Japanese researchers involved in the project for carrying out the research activities. In addition, in order to enhance its research capacity, NCHM has recently created Research Publication Division to produce small research articles for internal distribution and review. In the future, it plans to expand this division so that the research results could be shared externally. Besides, as stated in “Institutional Aspect”, NCHM plans to further enhance its research capacity by increasing collaborative research and by developing a platform or linkage with the relevant organizations in the 12th FYP period. NCHM and DGM has maintained skills and knowledge for O&M of the critical research equipment provided under the project by continuous utilization. Further, the related organizations are assumed to maintain the scientific literacy for utilization of the research outputs/outcome by the project for improvement of safety against GLOF because they have used the research outputs by the project and information provided by NCHM to analyze, assess, and propose policy matters in their respective fields.

<Financial Aspect>

Budget for the research activities on GLOF using the research outputs by the project has been financed by the government. According to NCHM, the necessary budget has been secured to carry out the research activities. For example, in Bhutanese fiscal year (BFY) 2018, it received Bhutanese Ngultrum (BTN) 1.15 million for time series monitoring of glacial lakes and BTN 0.65 million for research on glacial mass balance. NCHM has also secured the budget for O&M of the automatic weather instrument as part of its annual budget. DGM has secured the budget for O&M of the provided equipment under general maintenance budget. The budget amount for the O&M of the provided equipment was not available because it was impossible to segregate it from the overall budget.

<Evaluation Result>

Therefore, the sustainability of the effects through the project is high.

5 Summary of the Evaluation

The project achieved the Project Purpose (i.e. To assess the risk of GLOF in Bhutan through a joint research, to strengthen capacity to conduct investigation and research on the GLOF phenomenon and to build capacity to propose effective disaster management). The effect of the project has been mostly continued, and the Overall Goal (i.e. Safety against GLOF is improved in the Bhutan Himalayas.) has been achieved. Regarding the sustainability, the policy support for improvement of safety against GLOF is ensured. The establishment of NCHM and its future plans have also helped to sustain the effects of the project in terms of institutional and technical aspects. Budget for the research on GLOF and O&M of the provided equipment has been secured by both DGM and NCHM. As for the Efficiency, the project period slightly exceeded the plan due to unknown reasons. Considering all of the above points, this project is evaluated to be highly satisfactory.

### III. Recommendations & Lessons Learned

Recommendations for Implementing Agency:

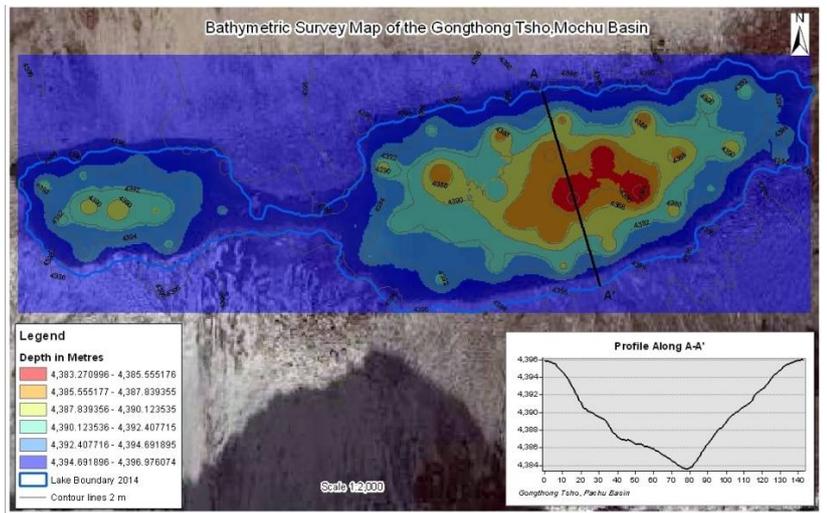
- By the end of 12th FYP (i.e. June 2023), NCHM should further strengthen their linkages with other national and international research institutes as planned so that the former C/Ps have the opportunity to enhance their ability to analyze, interpret and prepare reports related to glacial lakes and their impacts.
- By the end of 12th FYP, NCHM should take forward the recently formed Research Publication Division as planned, which is in its nascent stage and can be highly beneficial to organizations within Bhutan and the region.
- By the end of 12th FYP, NCHM should foster a platform where researchers from other organization can collaborate with researchers of NCHM as planned.

Lessons Learned for JICA:

The TCP, which was proposed and successfully implemented as one of the outcomes of this SATREPS project, provides a good example of the synergy in between two projects. If a successive TCP follows a SATREPS in a timely manner even with the political will of a host country, it will allow bringing in the social implementation component which is usually insufficient in a SATREPS project. Also, sometimes there may arise some difficulty to evaluate the effectiveness/impact of the research outputs during the ex-post evaluation due to less enhanced social implementation component of SATREPS. Such complementarity of projects should be recommended where a TCP immediately follows a SATREPS, which would allow a holistic achievement of the project purpose with better prospects.



Researchers from NCHM/DGM perform a bathymetric survey at Chamkhar Chhu



Bathymetric Analysis of Gongthong Lake