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ADAPTIVE HUMAN SETTLEMENT PLANNING FOR GLACIER LAKE OUTBURST FLOODS IN BHUTAN

Kinzang Dorji [1,*]

Abstract

Some of Bhutan's earliest civilizations occurred along the valleys of major river systems due to their fertile deposits favourable for agriculture and settlement. Since then, the river systems and tributaries have not only shaped Bhutan's physical landscape and guided human settlement patterns but also have progressively become the very source of livelihood. Even to this day, Bhutan is highly dependent on its fast-flowing rivers used for generating hydropower, which contributes to 14 percent of GDP and 26 percent of the annual revenue, becoming the largest contributor to the Bhutanese economy. Most of these rivers originate in the frigid alpine regions in the north fed by Glacier Lake, melting snow, and rain. However, with the erratic rainfall pattern and change in temperature induced by the growing impact of climate change, the country's fragile alpine topography has been subjected to increasing risk from its river system, particularly the risks associated with the Glacier Lake Outburst Floods (GLOFs). While there are a significant number of studies conducted on the mitigation measures of the threat from GLOFs in Bhutan, there are none that focus on adaptive planning in the event of such threats. Therefore, this article shares the experience of Bhutan's unique challenges in its adaptation efforts and attempts to provide alternate adaptive solutions from the perspective of urban and spatial planning.

Keywords: Human Settlement, Planning, Glacier Lake Outburst Flood, Bhutan

1. INTRODUCTION

Bhutan is a small country of little more than 38,000 sq.km located in the Himalayan region. Being situated in the fragile mountain ecosystem, Bhutan faces different types of natural hazard such as earthquakes, floods including flash floods and Glacial Lake Outbursts Floods (GLOFs), landslides and forest fires. The United Nations report on Disaster Management Analysis in Bhutan, 2005, shows that the GLOFs are one of the greatest hazards the country will continue to face given its numerous rivers which are glacially fed. According to the Reassessment of Potentially Dangerous Glacial Lakes in Bhutan, 2019 report, there are 17 potentially dangerous glacial lakes in Bhutan.

Glacial lake outburst floods are a catastrophic and devastating discharge of large quantities of water from glacial lakes. As the glaciers retreat, they leave behind reservoirs of water which grow in size over time increasing the risk of a breach of the walls holding the lakes. This phenomenon is further exacerbated by the impact of climate change. Due to the rising mean temperature, the glaciers in Bhutan are receding at a rate of 30-60 meters per decade (UNDP 2011). The melting ice from these receding glaciers is increasing the volume of water in the glacial lakes. The melting of ice-core dams is destabilizing them, increasing the risk of GLOFs to critical levels. Climate change is a global concern but the hardest hit are people living in developing countries like Bhutan where their vulnerability is compounded by poverty.

[1] Kinzang Dorji, Regional and Rural Planning Division of Department of Human Settlement in Ministry of Works and Human Settlement in Bhutan. Email: kinzangd@mowhs.gov.bt

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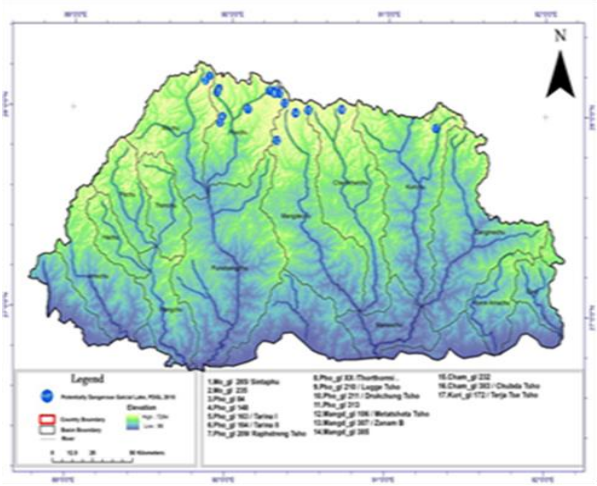

Figure 1: The map of the major rivers system are overlaid to understand the river course (Source: Base map from NCHM).

Locations of the updated list of 17 Potentially Dangerous Lakes in Bhutan as of 2019. The earlier inventory of dangerous glacial lakes was initially published by Department of Geology and Mines (DGM) and International Center for Integrated Mountain Development (ICIMOD) in 2001 wherein they identified 25 potentially dangerous lakes. However, the inventory then was based on remote sensing technique and consequently, it was updated in 2019 by National Center of Hydrology and Meteorology (NCHM).

Over the past decades, Bhutan experienced several instances of GLOF events. The most devastating was the bursting of the Lugge Tsho lake in 1994 causing chaos downstream and taking the lives of 20 people and damaging and destroying valuable infrastructure and property (Watanabe, 1996). The most recent GLOF event occurred in 2015 where there was damage to property but people were evacuated to safety and no one was killed (CNDP, 2019). Ever since then, the government has recognized the increasing threat from the GLOFs, and initiated various projects such as artificially lowering the water level of Thorthormi Lake which has been assessed as posing the most imminent threat of flooding in Bhutan, installation of a GLOF Early Warning System (EWS) in Punakha-Wangdue Valley, and strengthening Disaster Management and Community Awareness.

With the majority of Bhutan's population and infrastructural development concentrated along the large river valleys, the consequences of GLOFs would be severe and could impact on the nation as a whole, unless preventative measures are put in place. While a significant number of hydro-meteorological studies have been conducted on this subject, there isn't one that specifically focuses on land use planning and the interventions required to adapt to a GLOF disaster. This is particularly important when considering the role of land use in planning the distribution of settlements and infrastructure. A well-planned settlement would not only respond well to a disaster but also have the inherent capacities to adapt to it. Human settlement encompasses many sectors such as land, environment, climate change, disaster, etc., and it is important that the spatial planning of human settlement addresses the threat from the GLOFs and incorporates adaptive measures in the planning process. This paper examines and compares the various existing national policies, strategies, legislation and relevant factors and sets out the findings, conclusions and recommendations for the preparation of development plans to adapt to and mitigate threats posed by GLOFs. The threats from the GLOFs have been an important consideration in all planning processes and a study on this subject will go a long way in ensuring that our settlements are resilient and sustainable.

Figure 2: Flows of debris caused by GLOF in 1994 (Source: Department of Geology and Mines, Ministry of Economic Affairs).

2. METHODOLOGY

Both primary and secondary data were collected. National policies, strategies and legislation relating to human settlement planning were compiled and compared in the analysis of the provision of measures to adapt to the threat posed by GLOFs. Information about past GLOF events in the Himalayan region were studied through the review of published documents and articles. Data on glacial lakes and glaciers were collected from the National Centre for Hydrology and Meteorology (NCHM), Royal Government of Bhutan. Various settlement study reports published by the Department of Human Settlement under the Ministry of Works and Human Settlement, were compiled and compared to derive prominent settlement patterns in Bhutan.

3. EMPERICAL: Lessons from Traditional Settlement Hierarchy and Pattern

The Department of Human Settlement has conducted numerous settlement studies across the country and one of the most common features observed was that traditional Bhutanese settlements are spatially organised and arranged in hierarchical manner.

The village temple normally occupies the highest location followed by the clusters of houses on the gentler slopes and finally the agricultural fields in low lying areas. From the perspective of GLOF disaster this is a perfect adaptive response to the threat posed by GLOFs, flooding and erosion. The accounts of catastrophic outburst of Lugge Tsho Glacial Lake in 1994 reported that the river mostly devastated the flat and low-lying valleys of the settlements (Watanabe, Teiji & Rothacher, Daniel, 1996). This distinct settlement hierarchy and pattern ensures that the agricultural fields are located in the low-lying areas that are most affected and the houses which are located on the relatively higher grounds are spared from disaster. Such hierarchical arrangement restricts the damage to only the agricultural fields and lives of the people can be saved. It is not clear whether this comes from the local wisdom gained by living with the rivers, but the settlement study reports from the Department of Human Settlement suggests that these patterns have gradually evolved over time in response to social and cultural changes.

River Buffer as a Precautionary Measure for GLOF

For any land use planning, the Water Regulation of Bhutan 2014 mandates a compulsory transitional buffer of 100 feet long on both sides of a river where none of developments and building constructions is permitted. It is very likely that this figure of

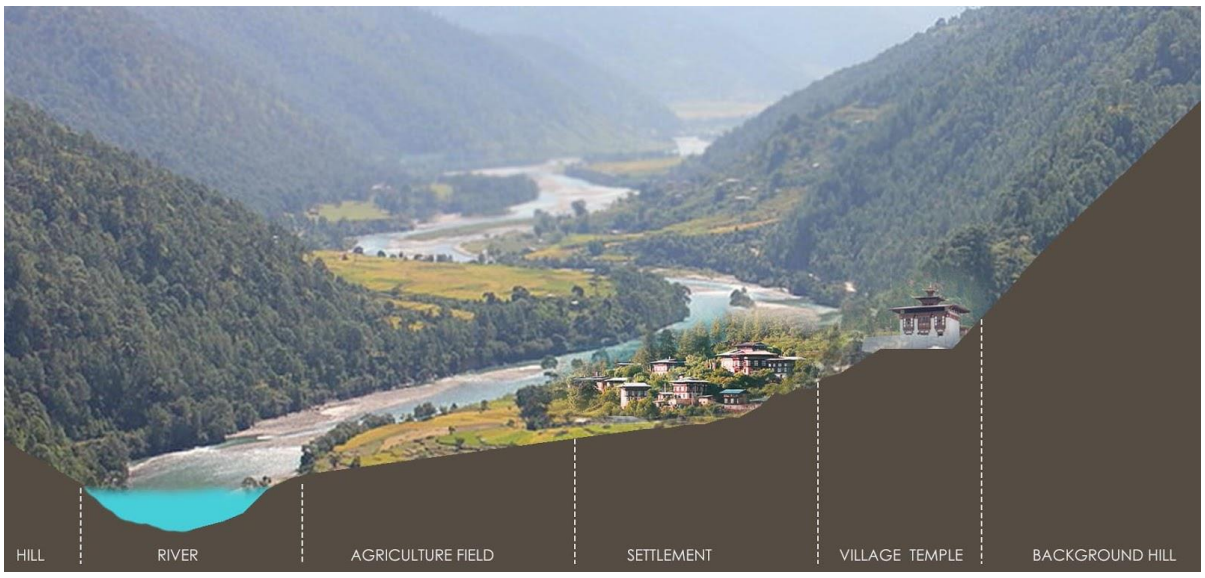

Figure 3: Hierarchy of Traditional Bhutanese Settlements (Illustrated by Authour)

100 feet buffer requirement is directly adopted from the then Forest and Nature Conservation Rules 2006. However, it is unclear as to why 100 feet is prescribed, nor does it refer to any international standards.

On the other hand, the *Guideline for Planning and Development of Human Settlements to reduce the environmental impact 2013* recommends that all rivers and streams across the country should have a compulsory buffer of at least 200 feet on either side. This recommendation is inconsistent with the provisions in *water regulation of Bhutan 2014*.

It is understood that the requirement mandated by the water regulation is in view of the increasing pollution of rivers and streams by human settlements and not necessarily to mitigate flooding including GLOFs. However, the *Guidelines for Planning and Development of Human Settlements in Bhutan* to minimize environmental impacts makes specific reference to Bhutan's vulnerability to the GLOFs and the need for special precautionary measures for any construction within the river buffer zones.

The study also observed that there is ambiguity in the measurement of buffers along the river. The rules state that the measurement of buffer distance starts from its determinable highest flood level. However, despite the country's small size, the physical landscape and topographical features of Bhutan ranges from steep terrain in the north to relatively flat areas in the south. The rivers in the north have a definite watercourse and it is therefore, easy to determine the highest flood level but as it flows towards relatively flatter areas in the south, the watercourse keeps changing because of which the measurement of the buffer in flat topography is difficult.

As far as GLOF is concerned, it is uncertain as to how effective the buffer requirement of 100 feet will have. According to the reports from NCHM, the moraine dam breaches at Thorthormi lake will discharge 53 million cubic metres of water rushing downstream. This sort of volume of water will inundate the areas far beyond the buffer zone. Therefore, the prescription of river buffer requirement of 100 feet may be adequate to address the regular flash floods, but will not have significant impact in risk reduction from GLOF disaster.

Hazard Mapping and Zonation

While the requirement of river buffer is a blanket nationwide prescription, GLOF hazard zonation is a site specific and need more accurate measurement. The map divides the areas into different zones and each zone will represent the varying degree of susceptibility of the respective areas to GLOF impact.

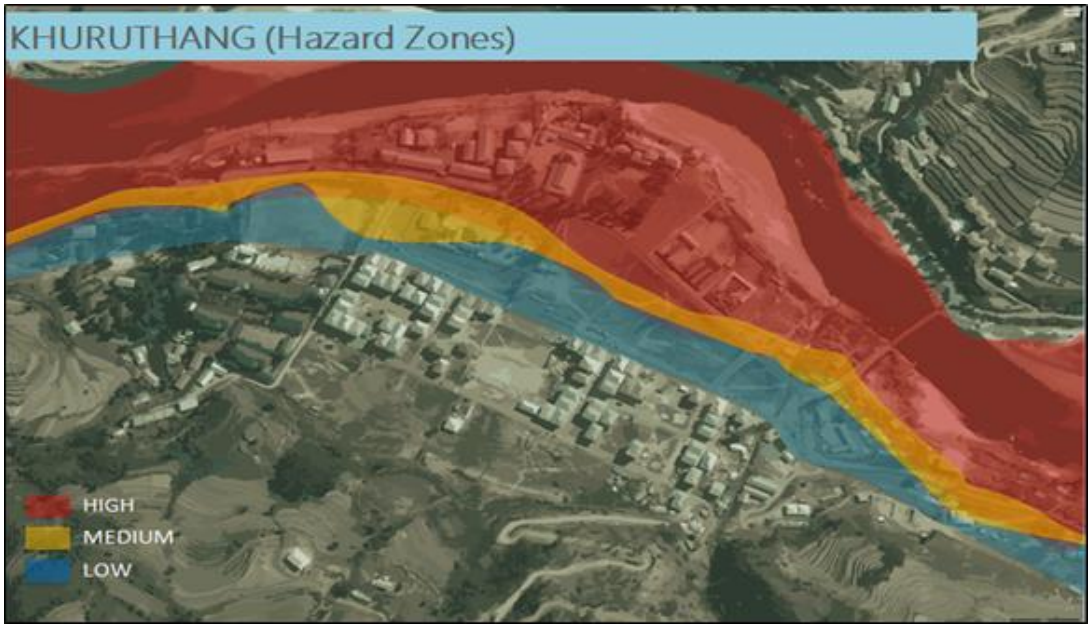

Figure 4: Hazard Zonation Map of Khuruthang. The areas in the immediate elevation range to the rivers are classified as high risk (Source: Punakha Structure Plan)

Table 1: Different Levels of Hazard and Recommended Planning Intervention

Hazard Level	Map Colour	Recommended Land Use	Planning Recommendations
High	Red	Conservation area, recreations, parks and green open spaces	*Prohibition Zone:* Construction and settlements are to be prohibited
Medium	Yellow	Low density development and commercial centres	*Regulation Zone:* Construction to be permitted with regulatory and precautionary measures.
Low	Blue	High density development	Inhabitants to be informed of the threat from the GLOFs

(Source: Punakha Structure Plan)

The GLOF hazard classifies the area into high, medium and low risks which guides planners in assigning appropriate land use

According to the Comprehensive National Development Plan for Bhutan, the development of GLOF hazard maps is still in its preliminary phase. The National Centre for Hydrology and Meteorology has prepared GLOF hazard maps for Mangde Chhu and Chamkhar Chhu basins, generated by a hydraulic simulation model (CNDP, 2019). However, except for the areas falling in the planned areas, it is yet to see as to how the hazard zonation is used by the local governments in their decision- making process.

Evacuation Centres

Evacuation Centres are important to any disaster event and it is particularly important for GLOFs disasters where most of the residents will be displaced from their homes. Inefficient operation and management of evacuation centre were the major drawbacks of the 1985 GLOFs in Khumbu area of eastern Nepal (Posch, 2019).

Development of a full-time operational evacuation centre may not be feasible in view of the limited available land; but land use planning should allocate adequate open space to be identified as evacuation centres in the event of a GLOF disaster. The open space can be proposed in the form of green spaces, recreational areas, parks, etc. However, the current practise of allocating the parks and open spaces along the river course, makes these become high hazard areas which means that they cannot serve the functional purpose as evacuation centres; since these areas will be inundated by flood water during a disaster. Therefore, it will be important to identify and allocate some open spaces in the form of parks at relatively high ground to function as evacuation centres during GLOFs. The urban facilities in parks can be designed to be able to function and support evacuation centres which can be equipped with emergency facilities during disasters.

A well-planned evacuation centre, supported by a systematic early warning system will be the most efficient measure in preventing loss of life. According to the historical accounts of the Luggae Tsho GLOF outbreak, the highest estimation of velocity was 12km/hr and the flood took around seven hours to reach Punakha where flooding occurred (Watanabe, Teiji & Rothacher, Daniel, 1996). Therefore, the time it takes for the outbreak to reach settlement areas should provide sufficient time to plan and execute the evacuation actions.

4. DISCUSSION & RECOMMENDATIONS

While GLOF is identified as one of the most serious phenomena among potential natural hazards in the country, the probability and frequency of occurrence is much lower compared to other natural disasters such as landslides, floods, etc. On an average GLOF events occur in the Himalayan region every 3-10 years with varying degrees of socio-economic impact (UNDP PIMS, 2015).

Bhutan witnessed a total of 4 major GLOFs since 1957 (DDM ADRC, 2014). Therefore, the investments in the implementation of high cost structural measures may not be preferable from the economical point of view. For instance, the artificial lowering of Thorthormi Lake project in Bhutan and the Tsho Rolpa Lake project in Nepal—range from $1 million to $3.2 million per lake (ADB, 2014). According to the National Centres for Hydrology and Meteorology, there are 17 potentially dangerous glacial lakes in Bhutan and to implement similar measures for all of these would entail significant costs. It is also important to conduct cost-benefit analyses prior to the execution of such high cost measures. If the costs of the investments far outweigh the cost of the losses and damage the GLOF may inflict, the high cost investment is not recommended. For example, there are 3 potentially dangerous Glacial Lakes along Mangdechhu Basin (NCHM, 2019). However, there aren't a significant number of settlements residing along the Mangde Chhu Basin as compared to Mo Chhu and Pho Chhu sub basin which lies downstream of the Thorthormi Lake.

Likewise, the enforcement of a strict land use policy may not be desirable considering the very limited available land for development in Bhutan. Records with the Ministry of Agriculture and Forests show that about 8% of the total land is used for cultivation; whereas only 1% of the land is occupied by human settlements (NHSP, 2019). Most of the settlements in Bhutan are situated along the fertile valleys of major river systems. These rivers are fed by glaciers from the Himalayan ranges. When a GLOF occurs along the rivers, most of these settlements along the rivers are displaced posing huge risks to the lives and properties of the people living downstream. However, if the developments along these valleys are restricted, the remaining land available will be inadequate to accommodate the human settlements. Therefore, it is necessary to adopt different measures to make optimal use of the valley without compromising the safety of people from the threats of GLOFs.

The following recommendations are some of the planning interventions that can be adopted without incurring huge costs of the enforcement of a strict land use policy. There are a number of measures for GLOF risk reduction. Awareness and preparations could be in place for prompt evacuation if necessary. The instalment of early warning systems would be key to the effectiveness of other measures. This paper provides some recommendations based on measures that are relevant to urban and land use planning for Bhutan which are;

- The existing land use pattern and hierarchy of our traditional settlements should be preserved and promoted. A similar hierarchical arrangement can be replicated as proposals for future land use planning in the areas vulnerable to GLOFs.
- GLOF Hazard Zonation mapping should be made a compulsory prerequisite for land use planning in all the areas along the river basins of potentially dangerous glacial lakes.
- No construction of habitable structures should be allowed in the areas falling in the red zone of hazard zonation mapping. Instead, open areas such as riverfront development, parks and recreational areas should be proposed. Likewise, in the areas falling in yellow zones, good structural and precautionary measures should be put in place.
- The preparation of any future settlement planning should be based on a detailed risk and vulnerability assessment of the planning area and its context.
- A nationwide mandatory river buffer requirement of 100 feet may not be an applicable mitigation measure in the context of GLOFs. It is recommended that a site-specific study should be undertaken to assess the vulnerability along the water courses.

- Land use planning should be provided for ample space to be used as evacuation centres at relatively higher ground.

Learning from natural disasters in term of the GLOF in the past reminds Bhutanese to live coexist with water and its nature in better future. However, increasing impact of climate change is one of the global challenges which require more adaptative planning and practices to cope with. Importantly, collaboration across multi-disciplines is imperative in order to achieve comprehensive strategies and to push planning into more practice for achieving sustainable future.

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