



FLOOD HAZARD ASSESSMENT FOR GASA DZONGKHAG

**FLOOD ENGINEERING AND MANAGEMENT DIVISION,
DEPARTMENT OF ENGINEERING SERVICES
MINISTRY OF WORKS AND HUMAN SETTLEMENT**

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Flood Engineering and Management Division under Department of Engineering Services, Ministry of Works and Human Settlement have taken immense initiative and efforts in carrying out preliminary flood hazard assessment for Gasa Dzongkhag. All four gewogs under Gasa Dzongkhag are visited and rivers and streams posing flood hazard threat to the people, their farmland and public infrastructures are identified and assessed. The Division has successfully completed this project on time. However, it would not have been possible without the valuable support, guidance and help of many individuals and organizations. Therefore, we would like to extend our sincere thanks and appreciation to all of them:

Department of Hydro-met Services, Ministry of Economic Affairs, Bhutan

National Statistical Bureau, Bhutan

Dzongkhag Administration, Gasa Dzongkhag

The Flood Engineering and Management Division would also like to acknowledge and thank all those who have contributed and willingly helped us with their abilities towards carrying out the preliminary flood hazard assessment studies for Gasa Dzongkhag. We would like to extend our heartiest thanks to the Engineering Sector in Gasa Dzongkhag for accompanying the assessors to the site and rendering all the support required.

ACRONYMS:

FEMD	Flood Engineering and Management Division.
GLoF	Glacial Lake Outburst Flooding
Punatshangchu	One of the five major river system in Bhutan
MoChu	River flowing though Gasa Tshachu towards Punakha to form Punatshangchu
Pochu	River flowing though Lunana gewog towards Punatshangchu
GIS	Geographical Information System is a computer based method for analyzing geographical information and maps.
FHM	Flood Hazard Map.
PFHA	Preliminary Flood Hazard Assessment.
DHSM	Department of Hydro-Met Services.
MoWHS	Ministry of Works and Human Settlement.
DHS	Department of Human Settlement.
NSB	National Statistical Bureau.

EXECUTIVE SUMMARY

Flood hazard assessment of Gasa dzongkhag has been conducted as part of the activity under the overall objective of 11th five year plan to prepare similar report for all the 20 dzongkhags in the country. Gasa Dzongkhag flood hazard assessment is a study undertaken by the Flood Engineering and Management Division to ascertain the hazard posed by flooding in the dzongkhag. It covers the assessment conducted in all four gewogs in the district with emphasis on the settlement, agricultural land, public infrastructure which are exposed and vulnerable to different types of flooding.

The mochu river aslo flowing through the Gasa tshchu (hotspring) area and Phochu though Lunana gewog and are the major rivers in the dzongkhag. Mochu has caused flooding in the area where by the tshachu infrastructure had to be reconstructed. Phochu is mostly disastrous in case of glacial lake outburst at its source, thereby affecting the villages along its course. Other flooding issues are mostly due to summer monsoon flowing as surface runoff and eroding the agricultural yields, washing away the irrigation channel and blocking the roads. There are few rivers in laya which often wash away the bridges disconnecting the household and communities.

Although, one main objective of the study is also to prepare a flood hazard map for one critical river in the dzongkhag, National Center for Hydrology and Meteorology and Watershed Management Division with some other relevant stakeholders are performing the task. The flood hazard map with regard to GLoF and rainstorm flooding are also being prepared by NCHM along the punatshangchu basin. Hence, the report only comprise of the food hazard assessment in the dzongkhag.

INTRODUCTION

Background

Bhutan has a history of loss of life and damage to property due to flooding. Rivers are generally characterized by steep slopes in the upper catchment, which are subject to intense seasonal rainfall and high rates of erosion. As the rivers flow towards the southern foothills, the transition from mountainous areas to flat plains typically occurs and is accompanied by extensive flooding. On the other hand, owing to Climate Change, the rainfall pattern has become erratic with prolonged drought period followed by unusually high precipitation which causes flash floods all over the country. Climate change and variability has resulted in changing rainfall and temperature patterns, thereby aggravating these disaster risks, leading to higher risks, especially for the poor and vulnerable.

In the year 2011, the Government of Bhutan expressed concern for damages caused by floods and had instructed the MoWHS to establish an institution to oversee all the flood management works in the country. So in the following year 2012, a new Division named 'Flood Engineering and Management Division' (FEMD) under the Department of Engineering Services (DES) was created.

The mandates of Flood Engineering and Management Division are listed below, but are not limited to:

- Identification of flood prone areas
- Carry out Preliminary Flood Hazard Assessment Studies
- Design and Construction of Appropriate River Training Measures
- Fortification of towns and communities from flood
- Reclamation of land from flood plains
- Provide assistance to Local government in Implementation of Flood Alleviation Projects
- Planning and design of storm water drains.

One of the most important mandates for FEMD, DES, MoWHS is to conduct the preliminary flood hazard assessment for all the 20 Dzongkhags in Bhutan. The assessment is conducted through field trips to the villages and communities under the dzongkhag and carrying out necessary observation and remarks. Consultation with the locals who have seen flooding in their communities are asked about the history and behavior of the flooding. After the assessment, necessary mitigation works are planned and implemented in the flood prone areas.

Objective of the Study

Objective 1: Conduct preliminary flood hazard assessment in Gasa Dzongkhag and identify areas vulnerable to flood in the face of climate change and variability.

Objective 2: Prepare preliminary flood hazard map for the critical river in the Gasa Dzongkhag for preparedness and adaptation of local communities to climate change induced disasters.

Background of Study Area

Gasa Dzongkhag

Gasa Dzongkhag is one of the 20 dzongkhags (districts) comprising Bhutan. The northern part of Gasa District is a disputed zone under the control of the People's Republic of China. The capital of Gasa District is Gasa Dzong near Gasa. It is located in the far north of the county and spans the Middle and High regions of the Tibetan Himalayas. The dominant language of the district is Dzongkha, which is the national language. Related languages, Layakha and Lunanakha, are spoken by semi-nomadic communities in the north of the district.

Gasa has an area of 3,117.74 km² as of 2010, formerly 4,409.30 km² as of 2002. It had a population of 3,116 as of the 2005 census, making it the largest, least populated, and thus least densely populated of all the dzongkhags; it is also the least developed.

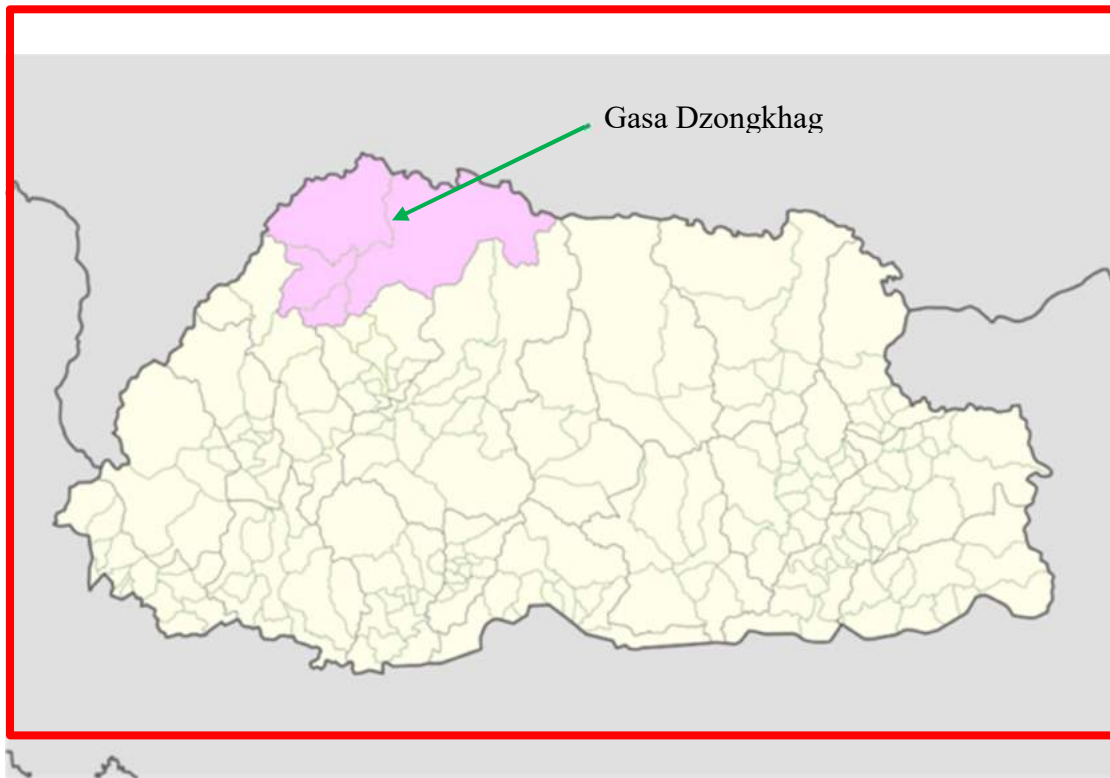


Figure 1 Bhutan map showing the Gasa Dzongkhag

Gasa Dzongkhag is a small dzongkhag with only four gewog (sub-district) –Khatoed and Khamoed gewogs area on the way to Gasa Dzong and Laya and Lunana are in the north towards the China- Bhutan border. There is a secondary national highway to Gasa which is not backtopped as of now. There is no road connecting Laya and Lunana and most of the other villages in the dzongkhag.

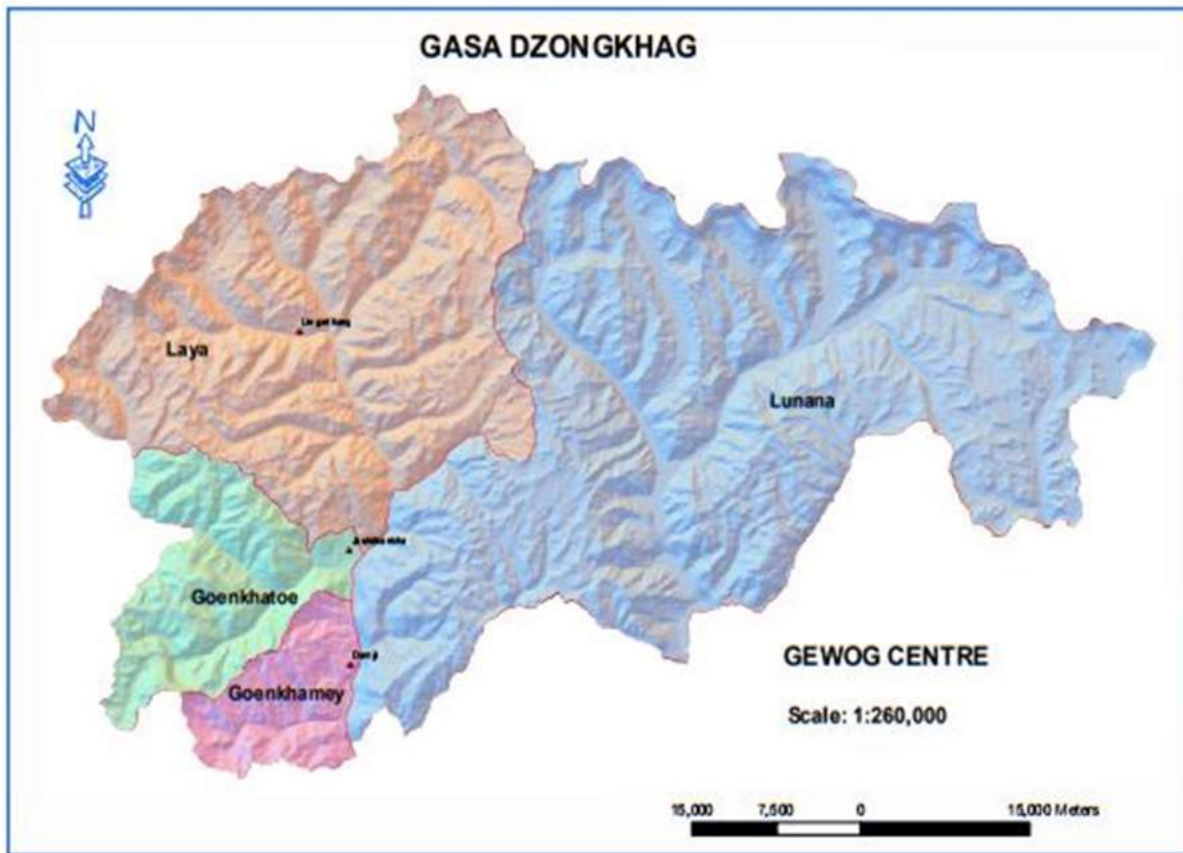


Figure 2. Gewogs under Gasa Dzongkhag.

As per the PHCB 2005, Gasa has 727 households and a total population of 3,196 out of which, 2,651 live in the rural areas.¹ The estimated population for the Gasa Dzongkhag as of February 2017, based on PHCB 2005 population and the population growth rate used for the Population projection report is 3,716.² People are mostly depended on agriculture and livestock. Paddy, maize and millet, wheat, buckwheat are the major cereal crops grown while orange, plum and vegetables are the principal cash crops. Mushroom constitutes an important source of cash

¹Annual Dzongkhag Statistics 2011, Tsirang Dzongkhag, National Statistics Bureau.

²www.nsb.gov.bt

income for most of the farmers. Livestock rearing is also an important economic activity with poultry, piggery, horses and yak contributing to income generation.

Economy

Gasa has become a tourist destination because of its pristine forests and the exceptionally scenic location of its Dzong. In 2008 a massive flood on the Mo Chhu (Female River) destroyed a popular hot spring complex, which is under restoration and was to re-open in late 2011. The high altitude makes farming difficult, although government programs seek to establish mustard and summer vegetable planting programs. Residents herd yaks and dzos, and a small number benefit from the nascent tourism industry. A narrow road from Punakha, which is mostly unpaved, reaches up to the Dzong and is now being extended up to Laya. The majority of the known herds of wild Takin occur in Gasa. Electricity is also being supplied to some of the gewogs and all electrification programmes are expected to be complete by 2012.

Gasa is most famous for its Layap people, and for the Snowman Trek, one of the most challenging treks in the Himalayas.

Environment

All of Gasa is an environmentally protected area of Bhutan. Most of the dzongkhag lies within Jigme Dorji National Park(Khamaed, Khatoed, Laya, Lunana Gewogs), although the northeast reaches of Gasa are part of Wangchuck Centennial Park(Lunana Gewog).[4][5] Several of Bhutan's glaciers are located in Gasa, namely in Lunana Gewog, which borders Tibet.

Climate and Hydrology

Gasa has warm summer with cold winter. The elevation across the district ranges from 1500 - 4500meters above the mean sea level. The two gewogs namely Laya and Lunana are covered with snow during most part of the year. There is only about 40 millimetres (1.6 in) of annual precipitation—primarily snow.

The average temperature of Gasa Dzongkhag is about 10° C with a minimum of 3°C and maximum of 17°C. The temperatures, rainfall and snowfall graphs for the 12 months in 2016 are provided the following representation. The maximum and the minimum rainfall in a year are 150mm and 3mm respectively. Subsequently, the maximum and minimum snowfall are +10cm and +1.5cm respectively.

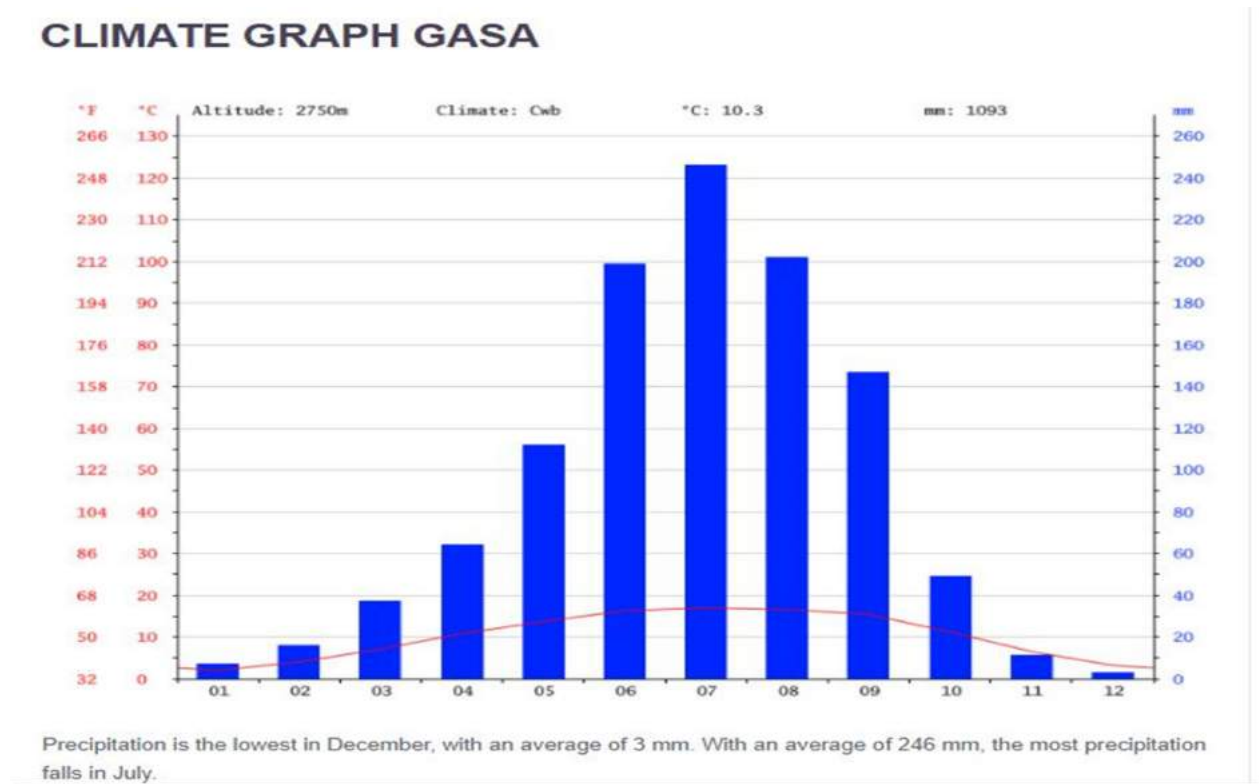


Figure 3. Climate graph for Gasa

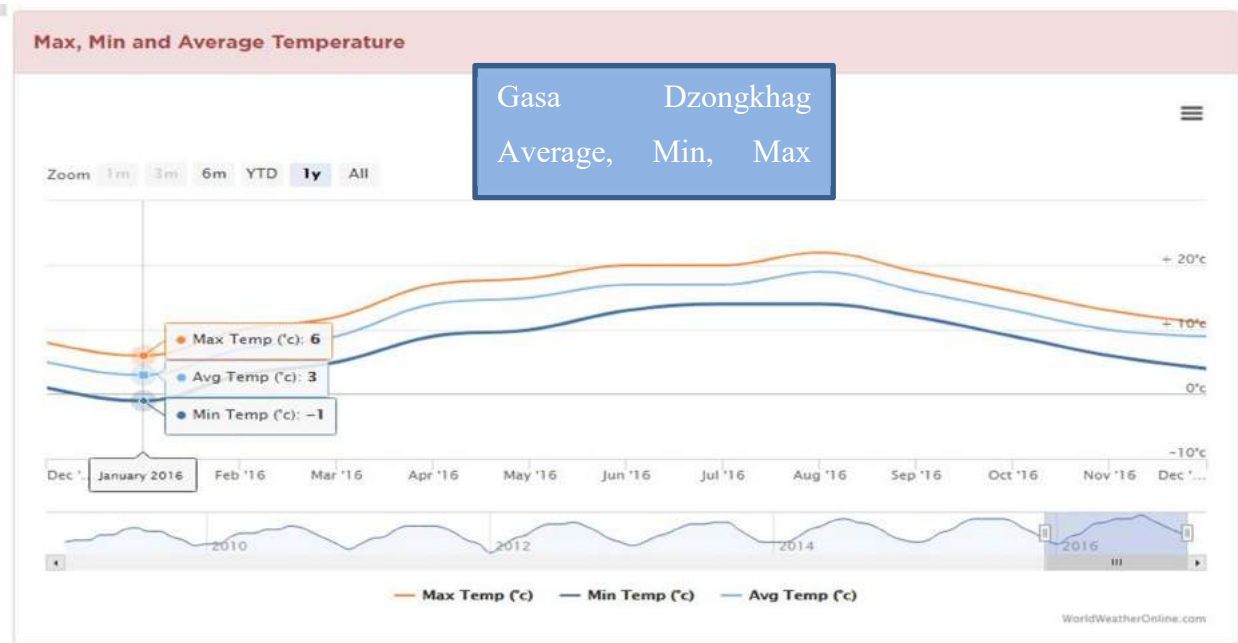


Figure 4. Temperature graph for Gasa Dzongkhag in 2016

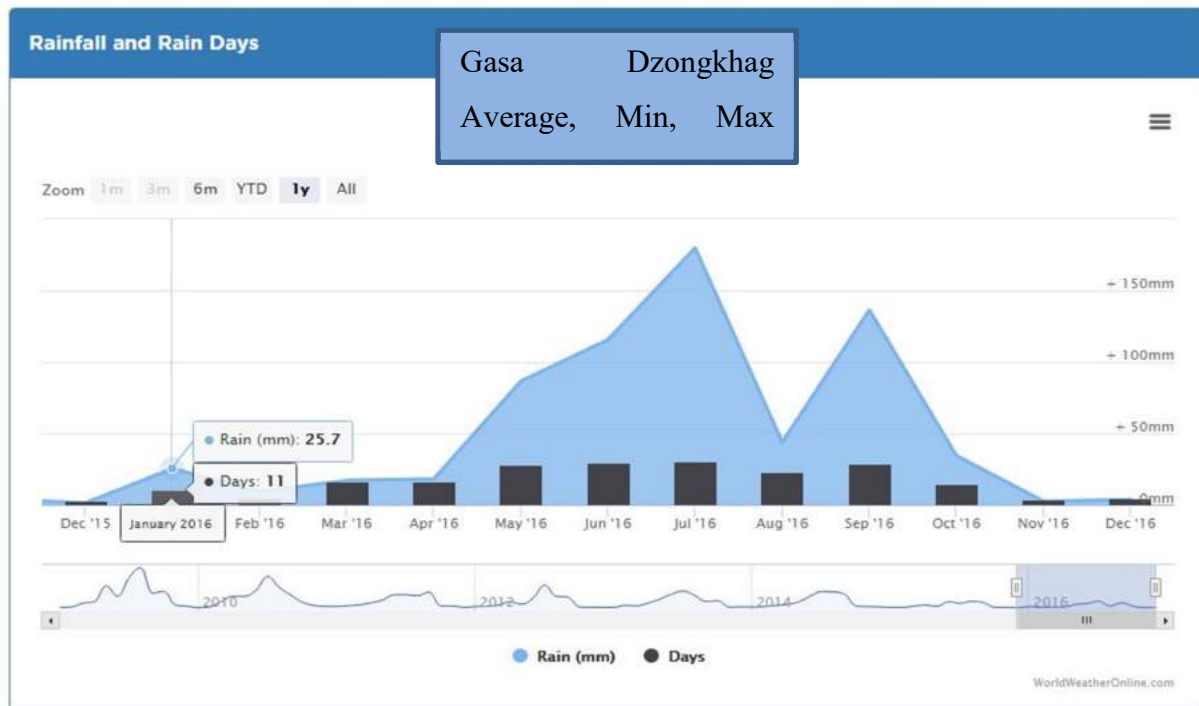


Figure 5 Rainfall graph for Gasa Dzongkhag in 2016



Figure 6 Snowfall graph for Gasa Dzongkhag in 2016

Problem Statement

Bhutan is prone to multiple natural hazards that pose varying degrees of risk to the lives and livelihoods of its population. Flash floods and landslides pose an annual threat to human lives, properties and livelihoods. Although, floods are common and more dangerous in the south, whereby the geology are weak and falls under siwalik zone and very much susceptible to the erosion and land degradation. Also the people and settlements are crowded and busier with more economic opportunities. The yearly monsoon rain is quite heavy and brings along huge discharge and debris flow. Hence, the flash floods in the south usually affects huge number of people and public infrastructure.

However, the northern part of the country are equally risky and vulnerable to the flood – flash flood during the monsoon season. The geographical topography of the area are steep and is susceptible to huge runoff water every time there is a continuous rain for several hours. Houses, agricultural land and public infrastructures are located on the slopes of the mountains. Gasa dzongkhag is one of them and flash flood are quite prevalent in the area with farmland and

houses being affected during the monsoon season. The farm roads gets washed away or blocked by landslides, numerous irrigation channels whereby people depend so much for feeding their paddy fields are washed away. Sometimes the disastrous runoff water washes away the agricultural yields and leave the farmers in pain and sorrow. Glacier lake outburst is the primary and the most worrying fear for the people of Lunana under the Gasa dzongkhag. There are four potential lakes at the source of the pochu which flows through Lunana gewog.

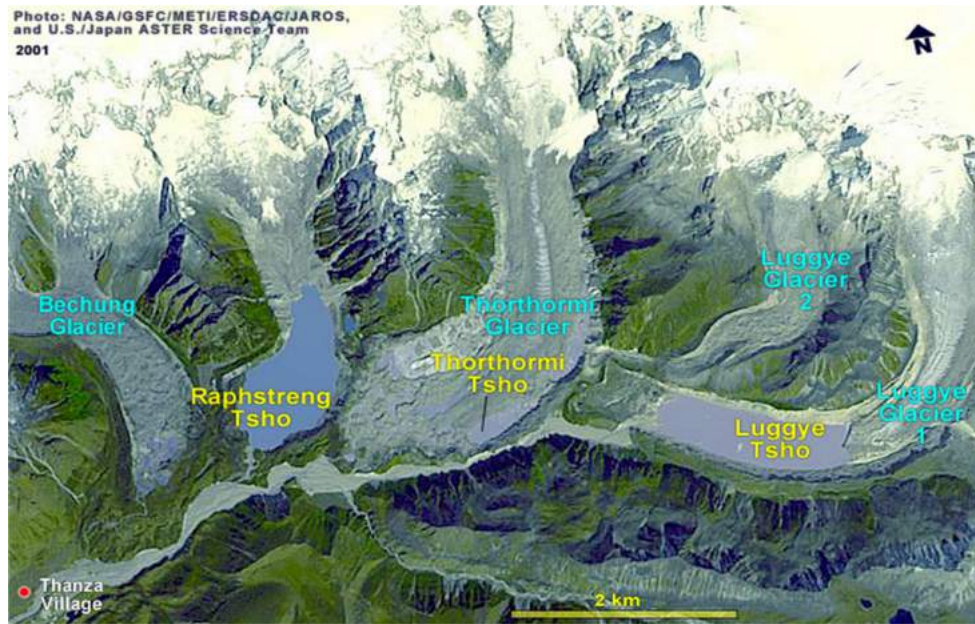


Figure 7 Potential Glacial lakes at the source of Pochu



Figure 8 NAPA project for reducing GLOF threat. Figure 9 Early warning system at Lunana

In 1994, the glacier lake outburst of Lugge Tsho at the source of the pochu created one of the worst catastrophic disaster event in the country where by human lives were lost, animal and houses were washed away, acres of forest and agricultural lands were washed away downstream of Pochu. Punakha Dzong was also affected by the flooding event. Villages located below the potential lakes in the north of Lunana had to be always in fear and mindful of the danger of the lake outburst upstream. The government has then invested huge amount in addressing the glacial lakes. Through various internationally supported projects, the lake levels were brought down. National Centre for Hydrology and Metreology (NCHM) through JICA assistance has installed early warning systems at the sources and the settlements downstream. Awareness programs organized timely by the Department of Disaster Management on the GLOF and the contingency plans as part of the preparatory phase for the hazard.



Figure 10 Debris being brought by surface runoff water.

Hence, Gasa Dzongkhag main fear is with the glacier lake outburst at the source of Phochu. But as mentioned above, the monsoon rainfall has been bringing along huge discharge damaging especially the crops and irrigation channels.

GASA DZONGKHAG FLOOD HAZARD ASSESSMENT

Overall Objective

Floods are natural processes occurring throughout the world, difficult to prevent but can be managed in a proper way to reduce its impacts. Flooding is a threat to life, properties and the environment in the face of climate change. It is therefore, very important that flooding hazards be assessed to identify any flood risk to the area and accordingly plan mitigation measures to reduce its impacts on the most vulnerable.

The Preliminary Flood Hazard Assessment is intended to identify communities (i.e. village settlements, educational and health facilities, commercial buildings) around the country where the risk due to flooding might potentially be significant and thus, need further study and interventions. Different techniques, methods and their combinations can be used to do the assessment. The factors that will determine the adoption of suitable methods are as follows:

1. The nature of the Flood Hazard.
2. Availability of data like the hydro-met data and topographic data.
3. Feasibility of collecting additional data.
4. Resources available for analysis.
5. Technical capacity of the engineers.

The main objective of the preliminary flood hazard assessment is to identify the area which is more prone to flood by site investigations, interactions with the people living in the locality, modeling using different river analysis system etc. The localities are asked on the past flooding events, areas affected, inundation areas, infrastructure constructed in the past for flood protections, etc. The assessment will also include pictographic evidences of the affected areas, the existing infrastructures in the flood prone areas, the gauging stations for rainfall and discharge etc.

Based on the field observations and the past damage reports, the high risk flood prone area is identified. After identifying the high risk area, cross-sectional survey of the critical river is

conducted for modeling purposes. Subsequently, hydrological and meteorological data such as discharge, rainfall etc. are also collected from the relevant agency for the most critical flood prone area. Then a preliminary Flood Hazard Map is prepared based on the availability of data. The Flood Hazard Map showing the inundated area is validated by comparing the inundated area with the recorded past flood event.

Thus, with the limited knowledge and resources, FEMD has been carrying out the assessment studies to develop the in-house capacity of the engineers and develop database for the flood prone rivers in the country. The preliminary flood hazard assessment carried out will be used as a baseline for carrying out the flood risk assessment in the future after identifying the critical flood prone areas.

The preliminary flood hazard assignment under Gasa Dzongkhag is to locate specific areas based on history data collected from respective Dzongkhag. To know how critical in present situation and future, it also give information/inventory for proposing flood protection structure, existing structure and lose of agriculture land and human settlement due to bank erosion, flooding etc. It's also giving little information on reclaim the eroded lands for sustainable land use.

The specific objective is to prepare a Preliminary Flood Hazard Assessment Report (PFHAR) including Flood Hazard map & Feasibility Study for River Protection works along with specific river with observation and recordation, further in future threats by erosion of the banks and reclamation of land damaged by the specific river for sustainable land use under Gasa Dzongkhag.

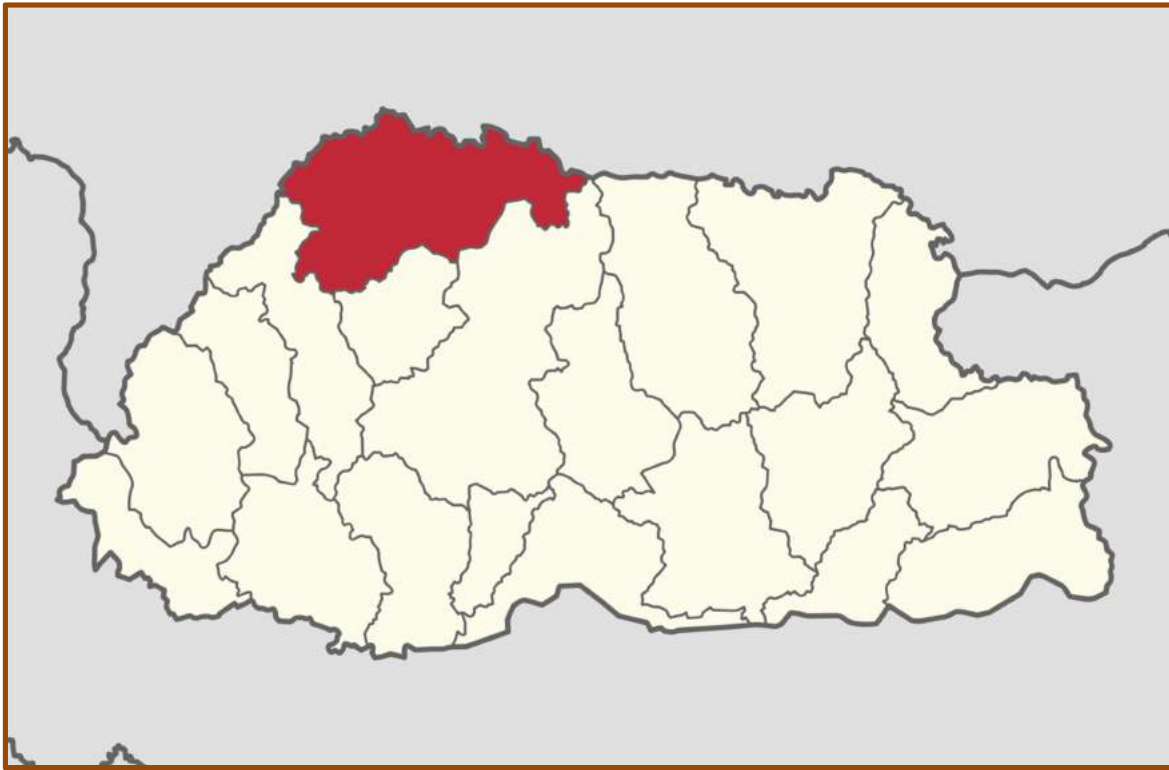


Figure 11 Gasa Dzongkhag on Bhutan Map.

Source: From Wikipedia, the free encyclopedia, Gasa District(Google)

Gasa Dzongkhag is located on a mountain with a plateau some flat area. The dzong is located on the mountain and the Gasa town are established behind and beside the mountain in the calculated flat area available. There is no big river flowing through the town like most of the towns do. The mochu flows through the bottom of the Gasa Dzongkhag where the famous Gasa Tshachu (hot spring) is located. The hot spring considered to be a medicine/cure to a number of health issues. Bhutanese people also come to soak into hot spring as part of their holiday in winter as in summer it is quite warm at Gasa and people cannot stay long in the hot spring. Hence, the only risk of flooding by a river is the Gasa hot spring and the few hotels/guesthouses at the bank.

However, more than the river (mochu), it is the summer monsoon rain threatening to the people in Gasa which brings along huge surface runoff water aggravated by the sloppy topography of the place wherein all settlements are also located. The surface runoff water has history of washing away the paddy yields, irrigation channels and triggering landslide.

Gasa Dzongkhag being the least populated dzongkhag has also one of the least number of Gewogs – it has four gewogs: 1). Khadmoed 2). Khatoed 3). Laya and 4). Lunana.



Figure 12 Gasa Dzong and settlement.

Source: From Wikipedia, the free encyclopedia, Gasa District(Google)

Floods are naturally occurring phenomena that can and do happen almost anywhere. In its most basic form, a flood is an accumulation of water over normally dry areas. Floods become hazardous to people and property when they inundate an area where development has occurred, causing losses. Mild flood losses may have little impact on people or property, such as damage to

landscaping or the generation of unwanted debris. Severe flood losses can destroy buildings, crops, and cause severe injuries or death.

FEMD, DES, MoWHS is mandated to conduct a flood hazard assessment report and prepare flood hazard map for twenty Dzongkhag. Therefore, the Division visited the flood prone areas in Gasa Dzongkhag to carry out the preliminary Flood Hazard Assessment. The team from FEMD met with the relevant personnel in the dzongkhag looking after the disaster and preparing for it. The engineering cell in the dzongkhag was responsible for the duty and thus the District engineer narrated the story of disaster in the dzongkhag and then introduced to the engineers of the concerned gewogs. While on visit to the gewogs, the tea were firstly met with the gewog head – Gup and Gewog administrative officer.

The team briefed the Dzongkhag and gewog officials on the importance of carrying out flood hazard assessment and subsequently identification of most critical river for preparation of flood hazard mapping in Gasa. The team also conveyed that flood prone areas were identified by the Dzongkhag initially and the list given to FEMD for record and therefore, the validation of the flood prone areas will also be carried out during the site visit.

Assessment of flood hazard in the Khatoed and khamoed gewogs in caused primarily by the surface runoff water during the monsoon season were in line with the data collected from the field in December 2016. Primary data, basically on past hazards, socioeconomic conditions and efforts made by local people to mitigate floods and other water induced disasters in the recent past, were collected during field work. Information on the magnitude, recurrence intervals, and damage from different types of disaster was collected through group discussions with the help of structured checklists. Local elders and knowledgeable people were consulted to collect data from the past. The individual households, information on the perception of local people about flood hazards and efforts made to mitigate hazards at household level was collected through household surveys.

The flood hazard assessment is carried out to find out the area which is at the risk of flooding and prioritize the area needing immediate attention. Based on the priority as per the flood hazard assessment, the appropriate flood protection structures to reduce the impacts of floods on the vulnerable to population, infrastructure etc. is recommended. During the assessment, the team

also try to identify the most flood risk river to the settlement and cross section survey of the river is conducted to prepare flood hazard map. The team visited Khatoed gewog, Khamoed gewog, and halfway to Laya gewog as per the inventory of flood prone available with FEMD and interactions with Gewog officials.

Flood Hazard Assessment

There are four gewogs under Gasa Dzongkhag. Khatoed and Khamoed gewogs are exposed/vulnerable basically to surface runoff water from the monsoon triggered by the steep terrain. The impacts area mostly on the paddy fields on the slope and houses located there. Irrigation channels were washed away most of the time. The streams swells up and blocks the road and farmland. Enroute to Laya, there is a river which swells during the monsoon season and at times washes away the bridge cutting the connectivity of the settlements on the two sides. And there are smaller streams posing threat to the agricultural land. Although, Lunana couldn't be reached during the assessment, it is known that the main threat of flooding are the glacial lakes at the source of Pochu which flows through the villages. History has shown that the outburst of the glacial lakes has had catastrophic impact to the villages by flooding away the people, animals and the houses alongside the river way. However, the concerned agencies has had early warning systems installed at the glacial lake as well as at the places deemed vulnerable to the threat. Sirens are installed at these places. The 1994 Lugge tsho (glacial lake) outburst was the most catastrophic disaster happened in this era.

The team had visited above geog and assess flood prone in both present, future and furnish as below:

Khamoed Gewog

Flood Hazard Assessment of Gasa Dzongkhag									
sl.no	Gewog	Village/Chiwog	Flood risk River/stream name	Land type/infrastructur e and area (acre)	No. of people at risk	No. of House at risk	Past flooding history	Investment on rehabilitation works	Most recent flooding
1	Khamoed	Damji	Surface runoff flooding	Wetland (paddy field), cowshed, cows, horse			every year but a disastrous one in 2012	.3million investment every year	June'2016
		Damji	Sibjana	irrigation channel					
		Sisibara		irrigation channel					
		Thablumaad		irrigation channel					
		Silikha	Sibjana	irrigation channel					
		Yemina, Barsa	Sumchulum	irrigation channel					
		Gatana	Sibjana	irrigation channel					
		Khailo	Surface runoff flooding	landslide		1 house			may - june/2017

Table 1: Khamoed Gewog flooding report

Khamoed gewog is threatened and impacted by monsoon rain every year. Although not through a major river in the gewog, it is affected by a stream and mostly by the surface runoff water. As the topography/profile of the most places in Gasa are steep slope in nature, a continuous rain for hours leads to a flash flood.



Figure 13 Khamoed gewog susceptible to monsoon surface runoff water.

The surface runoff water has affected mostly Damji and Khailo villages frequently washing away the wetland, cowshed and animals. Also there were landslide caused by the surface runoff water at the road point or in the paddy field area. The stream of Sibjana and sumchulum have every year washed away the irrigation channel in Thablumaad, Silikha, Yemina, Barsa, Gatana on which the Dzongkhag administration spends 3 million every year. The most disastrous flooding/surface runoff water happened in June 2016 cutting even Gasa town from rest of the country (the road has been washed away). A heavy discharge of surface runoff water has affected the road, paddy fields, animals and bridges at various location in the gewog.

Khatoed Gewog

Flood Hazard Assessment of Gasa Dzongkhag									
sl.no	Gewog	Village/Chiwog	Flood risk River/stream name	Land type/infrastructure and area (acre) at risk	No. of people at risk	No. of House at risk	Past flooding history with year	past affected datas (people , houses, animal,land)	Most recent flooding
2	Khatoed								
		Mani chewog	Surface runoff water	landslides affecting the pady field, roadblocks. A house at risk of flooding requires retaining wall			2009 may - june		may - june/2017
		Tshachu area	Surface runoff water and Mochu	Tshachu and residences	household = 15nos.			Jun-09	

Table 2: Khatoed Gewog flooding report

Khatoed Gewog does not have any major streams in the gewog. The Gasa Dzongkhag administration and Gasa town falls under this gewog. Like Khamoed gewog, Khatoed is also affected mostly by the surface runoff water considering the steep slope in terms of the topography. Mani Chewog is affected by the surface runoff water which has triggered landslides and risk of flooding to the houses. The landslides has affected the paddy fields and private lands. The risk of flooding is high on a house which could be addressed upon placing a retaining wall.



Figure 14 Khatoed gewog susceptible to monsoon surface runoff water.

Tshachu area is the most vulnerable place in the gewog. The Tshachu is located at the base of the Gasa Dzongkhag and visited by people all over the country to soak in it which is considered as a medication for any health issues. People usually visit the hot spring during the winter but summer still see few coming to soak in it. The **Mochu river** flowing from base of Laya gewog passes by the Tshachu area (*Coordinate : 27°53'17.15"N and 89°44'16.02"E with elevation of 7175 ft*). Presently a huge gabion wall retaining walls are being built at the a turnaround point of the river, risks are still high for the Tshachu area. The guesthouse are on a higher elevation and not so at the risk high area. The Tshachu area being at the base also is susceptible to the high flowing surface runoff water during the times of continuous rain. In June 2009, the surface runoff water and partly Mochu happen to wash away the four Tshachu ponds. No casualties were there but the Tshachu infrastructures were damaged by the flooding. There were minor flooding in may and june 2017 but there were no major impacts apart from some erosion at the river banks.

Laya Gewog

Flood Hazard Assessment of Gasa Dzongkhag									
sl.no	Gewog	Village/Chiwog/ location	Flood risk River/stream name	Land type/infrastructure and area (acre) at	No. of people at risk	No. of House at risk	Past flooding history with year	past affected datas (people , houses, animal,land)	Most recent flooding
3	Laya	Lungu	Lunguchu	Risk of waging away the Chumdonazam (could disconnect Lungu and Laya (household in Lungu= 52, peple= 310 Laya household= 205, people = 918)				10.07.2016	
		Baro Zam	Barochu	Risk of waging away the Barozam (bridge) connecting Gensa and Sumchana to Laya				26.07.2016	
		Baji Zam	Baji chu	Risk of waging away the Bajizam(bridge) connecting Laya and Tsari Jatha				26.07.2016	
		Rodhiphu	Rodhichu	1 storied Transit camp washed away				26.07.2016	
		Lamthang Zam	Lamthangchu	Wahed away the bridge connecting Laya to Lingzhi				26.07.2016	
		Menchu Zam	Menchu chu	bridge washed away				26.07.2016	
		Zamdo Zam	Zamdochu	washed away the bridge connecting Laya and Dung Goenpa				26.07.2016	

Table 3: Laya Gewog flooding report

Laya Gewog unlike the villages in Khamoed and Khatoed gewogs donot encounter surface runoff water as it is located on slightly a flatter land. However, there are number of streams and

smaller rivers which pose threat during the times of summer monsoon rainfall.



Figure 15 villages in Laya gewog susceptible to surface runoff water.



Figure 16 wooden bridges washed away by the rivers during monsoon rain.

The streams and rivers have been the bypass or were flowing between two villages and its increase in discharge always had a problem form the people located on either sides of the river. The streams and rivers namely Lunguchu, Barochu, Bajichu, Rodhichu, Lamthangchu, menchu Chu and Zamdochu all have a bridge connecting villages in Laya. The bridges are not any steel engineered bridges but made up of wooden deck and bamboos nevertheless they always

served the people in the villages. There were many a times whereby these streams and rivers have washed away the bridges disconnecting the people on either side of the villages. The villages under Laya gewog has one of the highest number of houses and people in Gasa Dzongkhag. Hence, the disconnection causes a massive problem for all these people.

The most recent flooding along these streams/rivers occurred on 26th July 2016 – washing away the bridges. The Rodhichu on the occasion washed away a single storied transit camp.

Lunana Gewog

Flood Hazard Assessment of Gasa Dzongkhag									
sl.no	Gewog	Village/Chiwog	Flood risk River/stream name	Land type and area (acre) at risk	No. of people at risk	No. of House at risk	Past flooding history with year	past affected datas (people , houses, animal,land)	Most recent flooding
1	Lunana	Lhadi	Lhadichu	Bridge connecting Lhadi village to other side of the hill washed away.					21.07.2016
	Lunana	Lunana	Throthormi lake	villages of Tanza, Thenza, Denji, Tshojo, Lhedi, Shangsa are all under risk if the glacial lake outburst.					

Table 4: Lunana Gewog flooding report

The village of Lunana located at an altitude of 4000 meters from sea level is extremely cold throughout the year. This place is covered with snow during most part of the year. The precipitation is mostly in the form of snow. But the danger of flooding still exists in this highland. In terms of river, Lhadichu has often washed away the bridge connecting Lhadi village to the other side of the hill during the summer monsoon rain.

However, the most worrying fear for the people of Lunana is the potential Glacial lakes at the north. The Rapstrang Tsho, Thorthormi Tsho and Lugge Tsho at the north of Lunana are potential lakes and could burst at any time due to any type of causes like snowmelt and

earthquake. In 1994, glacial lake at Lugge Tsho outburst has caused devastating damage downstream. Human lives were lost, animals and homes were washed away. The damage was done from Lunana till the base of the then wangdue Town. The outburst flowed through Pochu.



Figure 17 Glacial lakes at the source of the phochu.



Figure 18 Tenza village vulnerable to glacial lake outburst.

Similarly, the Thorthormi tsho is a very vulnerable glacial lake which could have a damaging affect to villages in Lunana and downstream. Tanza village will be the first to be affected/washed away by the enormous glacial lake discharge. This will be followed by the schools, houses and agricultural land in Tenze, Lhedi, Tshojo, Denji and Shangsa villages. This could lead to loss of at least 70 percent of the lives of people and animal in Lunana village. However, Government has taken enough initiative from its part though flood warning system, early warning systems, sirens and alarm at every point and risk zone downstream. Measures to control the glacial lake outburst at the source are undertaken.

OBSERVATION

The assessment team from the Department has undertaken detailed study of the flooding in the Gasu Dzongkhag. Carrying the past flooding prone areas submitted by the dzongkhag, the team conducted its own assessment visiting every gewogs and in particular the places susceptible to the flooding hazard. The streams and rivers were also being studied for their nature and other characteristics causing the hazard. Past flooding history were dug upon consultation with the

people who have seen or lived it in the past. Other details were asked to the gewog engineer and the local representatives. The following Observations were made upon visiting the gewogs and the streams and rivers which causes flooding:

- ✓ Gasa Dzongkhag being in north and being located at the top of mountain donot have any major river flowing through the Dzongkhag administration/town. There are no flood Plaines as such.
- ✓ Most of the flash flood in Khamoed and Khatoed gewog are caused by the surface runoff water owing to the steep slope/nature of the villages in terms of its topography.And the impacts are mostly on the irrigation channel and agricultural lands. Few landslide at the roadside. The Mochu flowing via tshachu has affects on the four tshachu ponds.
- ✓ Laya has mostly streams and smaller rivers which increases its volume in summer and washes away the bridges but there are no impact on the settlement and properties.
- ✓ In Lunana, the main threat as feared by all living in the downstream settlemnts (Lunana, Khuruthang, Bajo) are the potential glacial lakes outburst (GLOF).
- ✓ There are risk of four potential glacial lake outburst at the source of the phochu and mochu.
- ✓ Hence, there are no critical rivers as such in Gasa Dzongkhag which poses devastating threat to the people and settlement apart from the surface runoff water and smaller rivers washing away the wooden bridges.
- ✓ Hazard maps could be drawn for the glacial lake outburst case considering the Lunana village. This however is being undertaken as a major project by the National Centre for Hydrology and Meteorology (NCHM). Hence, to avoid the duplication and further complication, the hazard map for the Gasa Dzongkhag considering the glacial lake outburst scenario will be referred from the NCHM's project.

LIMITATIONS

- ✓ There are no proper detail of rainfall datas at Gasa Dzongkhag.
- ✓ History of surface runoff water are hard to find and people are not cleared themselves on the nature and behavior of flooding.
- ✓ It is hard to visit Lunana village considering the distance from Gasa Dzong and the disruptive whether.
- ✓ Road point only upto Gasa dzong.
- ✓ Wild animals are also a barrier while conducting the study in the northern and high altitude places like Gasa.

RECOMMENDATIONS

- ✓ The study recommends installation of permanent rainfall stations providing hourly data to represent the spatial rainfall pattern over the entire catchment. Further, a proper study is to be done to select the best method for rainfall interpolation and estimation.
- ✓ The study strongly recommends that necessary equipment for acquisition of discharge data be installed along the river at suitable location for updating the flood hazard map in future.

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