HYDRAULIC MODELING OF FLOOD OF POCHU RIVER

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ABSTRACT

This paper focuses on the upper watershed of Pochu River in Bhutan which comes under Punakha District. Pochu has been a main tributaries of PunatshangChu which receives a enormous amount of discharge throughout year either by rainfall as well as by melting the glaciers at the sources of the river Pochu.On October 7, 1994 a glacial lake outburst flood (GLOF) occurred on the Glacial Lake of Luggye in the Kingdom of Bhutan, sending a flood wave down the Phochhu and Punatsangchhu Rivers, claiming 22 lives and causing massive property and livestock damage. Although major flooding had occurred in the past, the 1994 GLOF was the catalyst for the government of Bhutan to establish an Early Warning System giving downstream inhabitants sufficient time for evacuation. Similarly another Raptreng lake is located which is to be outbursted at point of time.The study is carried out over a stretch 20 km of Pochu river modeling taking the discharge from Rapstreng lake to see the water profile if this Raptreng lake would outburst. River analysis and steady flow water surface profiles were calculated using HEC-RAS.

Keywords: *GLOF, Pochu, Satellite images, HEC-RAS, HECGeoRAS.*

1. INTRODUCTION

Glaciers in the Himalayas are shrinking more rapidly than glaciers in other regions of the world (Fujita *et al.*, 1997). Glacier lakes are the most visible and probably the most dramatic consequence of climate change in the mountains. The possible outburst of such lakes is a direct threat to downstream populations and infrastructure. This paper gives an overview of the present situation and the potential danger. The dynamic development of glacial lakes and the dramatic consequences in case of outburst has to be seen in wider context: glacial lakes are the tip of the iceberg of climate change. It can mean the gradual receding of the storage capacity of water in glaciers for the dry season, a quicker runoff of water during monsoon season, and extended days with little water. The long term consequences affect the availability of water downstream for food production and have direct implications on food security.

The lakes of Bhutan comprise its glacial lakes and its natural mountain lakes. Bhutanese territory contains some 2,674 high altitude glacial lakes and subsidiary lakes, out of which 25 pose a risk ofGLOFs(Tirwa, Badan (2008-01-19),Pelden, Sonam (2010-09-03). There are also more than 59 natural non-glacial lakes in Bhutan, covering about 4,250 hectares (16.4 sq mi). Most are located above an altitude of 3,500 metres (11,500 ft), and most have no permanent human settlements nearby, though many are used for grazing yaks and may have scattered temporary settlements.*(Bisht, Ramesh Chandra,Survey of the Waters of Bhutan)*.Glacial outburst floods can be produced by water reservoirs existing in front, or at the surface, base, or margins of glaciers (Haèberli 1983). During the strong glacier shrinkage of the 20th century, dangerous lakes developed in particular behind moraines which had been deposited by former glacier advances (predominantly from the Little Ice Age or earlier Holocene cold periods). Such moraine-dammed lakes show different characteristics in comparison to icedammed lakes, which often have seasonal cycles of filling and emptying (Blown and Church 1985). Moraine-dammed lakes usually do not form again after a complete catastrophic drainage

The flood destroyed bridges, homes, agricultural land and the nearly completed Namche Small Hydropower Plant, two weeks before its inauguration, which resulted in an estimated loss of US$ 1.5 million. Remarkably, only 4-5 people lost their lives in the flood itself because a Sherpa festival was in progress and few people were walking the trails at the time (ICIMOD/ UNEP 2002; Kattelmann 2003).

2. DATA AND METHODOLOGY

Satellite images of different years of 2009 are taken for present study. For the watershed delineation ASTER DEM and SRTM DEM 90 m are used.

It has been analyzed on the basis of only water surface profile as the river does not have the cross-sections measurements. The cross sections were being extracted from the HEC-GeoRAS and it is one of the extension tools for the GIS. With the help of Digital Elevation Model, converting it into Triangulated Network System (TIN), cross section can be drawn on it and were exported to the HEC-RAS. The Table 1.0 shows the every five years of interval of volumes and discharges of Rapstreng glacial lakes considering the increment of lake per year would be 450923.67 m^3. These are the input data for the steady flow analysis.

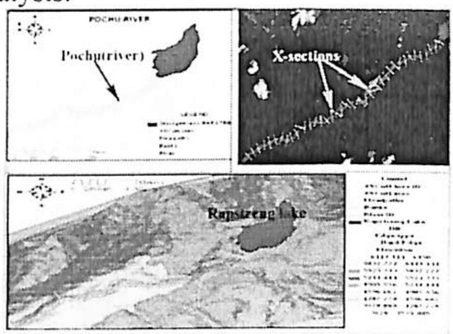


Fig.1 Cross-section created in GIS by HEC-GeoRAS

2.1 VOLUME OF GLACIAL LAKES

There is no estimate available for volume of glacial lakes in Bhutan from their water spread areas. However, some estimates are available for glacial lakes in Swiss Alps, as given by Huggel et al. , (2002). In the absence of information on the volume of potentially dangerous glacial lakes in Bhutan, it is considered appropriate to use the same relationships developed for the lakes in Swiss Alps for estimating the water volume for the lakes on Pho Chu and Mo Chu sub-basins.

The empirical relationships as available in the study by Huggel et al. (2002) are:
The lake volume is given by:

(V)= 0.104 A1.42(1)

where V is the lake volume in m^3 A is the lake area in m^2.

The volume of potentially dangerous lakes on Pho Chu sub basin were accordingly estimated by equation and its rate of growing per year are shown in Table 1. It has been observed that volume of glacial lakes are keep on increasing and among that these lakes, Rapstreng lake is one of the biggest volume at present as in Figure 1. Thus this lake can be outburst at any time creating a catastrophic flow at the downstream valley and for calculating the maximum discharge, formula used as below.

$$Q_{max}=179(V_O*10^{-6})^{0.64}(2)$$

Table 1 Input data for HEC-RRAS

Name of Glacial Lakes	Rate of increment year =450923.67 m3	2009	2014	2019
Rapstreng	Volume,Vo (m^3)	47519129.9	49773748.2	52028366.6
Rapstreng	Peak Discharge (m^3s^{-1}),	2118.6	2182.39	2245.16
	ft cubic/second	74786.56	77038.52	79254.05

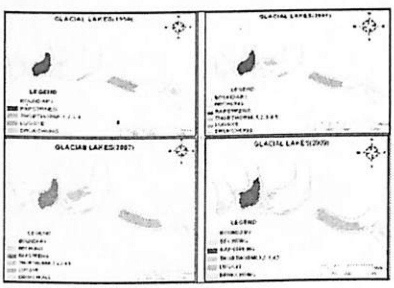
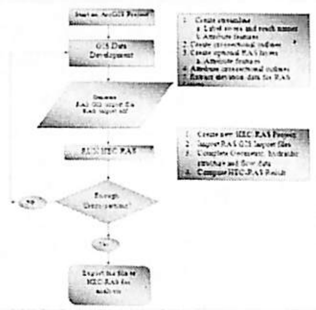


Fig. 2 Figure showing the different glacial lakes located at the Source of Pochu (river)

Fig. 3 Methodology Chart



2.2 DEVELOPMENT OF HEC-RAS MODEL FOR STEADY FLOW, WATER SURFACE PROFILE CALCULATION

HEC-RAS gives one-dimensional, steady and unsteady flow water surface profile calculations. In this contest only steady flow water surface profiles are generated with the model and compared with observed river discharge at the same river locations.

The steady flow system is designed for application in flood plain management and flood insurance studies to evaluate flood way encroachment. It also support for assessing the change in water surface profile due to channel improvement which gives flow optimization at stream junction.

3. STUDY AREA

The princely Kingdom of Bhutan is a landlocked country, about 300 km long and 150 km wide encompassing an area of 46,500 square kilometers. Located between longitude 88°45' and 92°10' East and latitudes 26°15' and 28°40' North in the Eastern Himalayas, it is bounded by India in South and South-West and Tibetan autonomous region of China in the North and North-West respectively.

Virtually the entire country is mountainous, and ranges in elevation from 100m along the Indian border to the 7,554m KulhaGangri peak on the Tibetan border. These two extremes frame a landscape which stretches from sub-tropical to arctic like conditions. The maximum East-West stretch of the country is approximately 300 km and north-South about 150 km.

Lunana region is situated at the latitude of 28°05'30.20" and longitude of 90°11'33.56" in the northern part of country at the 4352 m a.m.s.l. Mostly the northern part of Bhutan is covered with snow throughout the year and also have glacier coverage. And there are few glaciers in which it has been noticed that rate of retreating is faster forming.

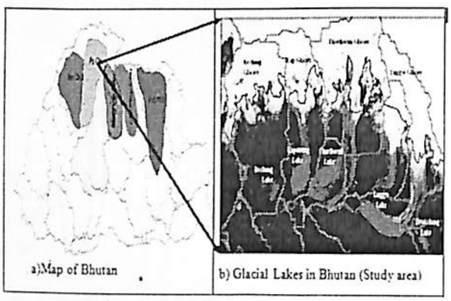


Fig. 4 Study area

4. RESULT AND DISCUSSION

4.1 WATER SURFACE PROFILE IN HEC-RAS AND CROSS-SECTION OF RIVER

The following figure 5 is water surface profile of river at the first stage of out bursting mechanism whereas the last water surface profile of river at the last stage of outburst is shown in Figure 6. It indicates the water surface level rises abruptly at the first cross section at A of the river and then keeps on lowering the water surface. When it reaches to middle cross-section, the water tends to flood over the channel as the slope of the river becomes lower and flatter. As it is seen that cross-sections at B and C are flooding over the channels and also it is seen in Figure 7 at cross-section C, the cross-section is mount up at the middle, it is because of deposition of sediments at that place.

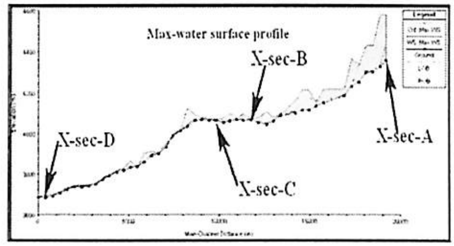


Fig. 5 River profile at the first stage of Outburst.

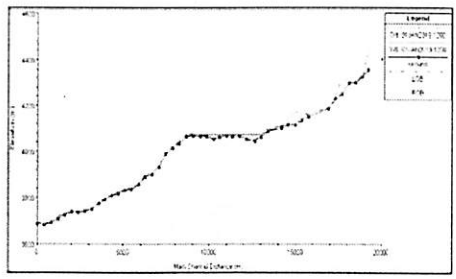


Fig. 6 River profile at the last stage of Outburst.

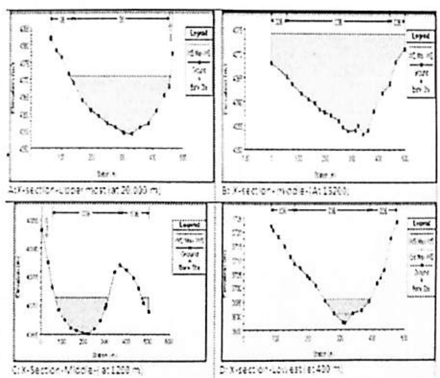
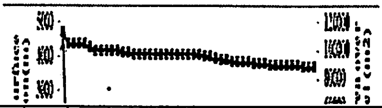


Fig. 7 Four Cross-sections of river at different places.

The Table 2 shows the general characteristics of River (Pochu). It shows the variations of discharges at different locations, flow area variation at different locations and water surface elevation at different locations. Figure 8 indicates the comparison of water surface elevation (m) and flow area in m^3/sec throughout the length of river.

Table 2 General Characteristics of River Pochu by HEC-RAS

Fig. 8: Water surface elevation and flow area throughout the length of River



Reach length (m)	Q(m3/sec)	Min.cha elevation (m)	Water surface elevation (m)	Flow area (m2)	Top with (m)	Reach length (m)	Q(m3/sec)	Min.cha elevation (m)	Water surface elevation (m)	Flow area (m2)	Top with (m)
20000	2500	4956.9	[illegible]	[illegible]	311.9	9200	41	4265.4	[illegible]	554	[illegible]
19600	1556.4	4926.4	4361.3	[illegible]	345.5	8800	184	4234.9	4239.7	224.9	105.2
19200	2667.1	4300.1	4361.4	[illegible]	337.6	8400	234	4216.8	4231.3	23669	222.4
18800	1565.5	4296.7	4361.4	[illegible]	[illegible]	8000	1380	3587	3988	23.1	[illegible]
18400	492.4	4253.3	4361.4	[illegible]	[illegible]	7600	450	3831.5	[illegible]	[illegible]	88.1
18000	13366	4230.4	4246.1	[illegible]	299.1	7200	1350	3500.7	3936	457.4	146.5
17600	215.9	4154.5	4159.7	[illegible]	[illegible]	6800	[illegible]	3592.4	[illegible]	86.5	99.9
16400	2424.9	4149.7	4173.3	7465.7	390.1	6400	29.8	3159.2	3866.6	13132	[illegible]
16000	780.1	4136.7	4173.5	12248.3	400	6000	234	3836.1	3837.5	115.1	114.5
15600	561.3	4116.1	4165	9229.5	195.3	5600	1600	3852.2	3834.4	73.2	54.3
15200	283.9	4114.5	4169	8597.4	178.8	5200	264.8	3815.4	3825	1187	216.2
14800	51.1	4101.1	4117.8	2463.5	254.7	4800	27.4	3805.8	3809.9	47.4	70.1
14500	1500	4088.5	4093.1	172.8	153.2	4400	13.2	3792	3797.6	810.1	[illegible]
13600	550.3	4062.2	4073.3	2416.5	316.2	4000	53	[illegible]	[illegible]	492	175
13200	23.8	4044.5	4073.3	9342.2	385.2	3600	169.1	3749.4	3791.7	208.1	132.9
12800	12.5	4354	4074	4271.4	276.4	3200	209.8	3742.3	3743.2	90	169.5
12400	257.1	4068	4073.4	921.5	284.5	2800	7.4	3739.3	3716.3	51.5	81.5
12000	298.4	4365	4073.5	2291.5	409.9	2400	84.2	3738	3740.6	221.7	135
11600	316.3	4566.8	4073.5	1356.5	281.4	2000	119.4	3724.9	[illegible]	134.7	95.4
11200	392.9	4062.8	4073.6	1225.5	201.6	1600	9.2	3704.8	3721.1	21909	182.3
10800	278.5	4054.0	4071.7	5631.9	400	1200	118	3692.1	3696.7	255.5	[illegible]
10400	219	4064.7	4073.7	4895.1	552.6	800	1144	3681.8	3688.1	10729	[illegible]
10000	675.5	4564.7	4582.5	4863.6	396	400	1451	3656	3694.3	[illegible]	159
9600	54.4	4567	4573.8	945.5	200.2						

5. CONCLUSION

The mountain glaciers are highly sensitive to climate change and any change in temperature highly affects glaciers on mountains. It has been noticed that GLOF phenomena in October, 1994 and glacier retreat are one of the main concern for the government of Bhutan in very recent years. To mitigate and adapt to the adverse impacts of climate change, Bhutan, Bangladesh, India and Nepal must set a long-term shared vision and cooperative actions to manage GBM basins(which is now taking shape) develop more practical collaborative structural and nonstructural projects of flood preventive measures resulting from GLOF and erratic monsoons.

GIS. based analysis and HEC-RAS model helps for analysis of water surface profiles for different river discharge. It also helps to identify and design flood frequency analysis for various return periods which helps for engineering design of hydraulic structures like bridges, culverts. There is a flooding at the cross-section at B of 13200 m.

REFERENCES

Bisht, Ramesh Chandra. *International EncycopaediaOf Himalayas*. Mittal Publications. pp. 34–5. ISBN 81-8324-265-0.

Blown, I., and Church, M. 1985.Catastrophic lake drainage within the Homathko River basin, British Columbia. Canadian Geotechnical Journal, 22: 551–563.

Fujita,K,Nakawo,M,Fujii.Y.&paudyyaj,P(1997) changes in glaciers in Hidden valley, MkutHimal, Nepal Himalayas, from 1974 to 1994, j Glaciol, 43 583-58

Haeberli, W. 1983. Frequency and characteristics of glacier floods in the Swiss Alps. Annals of Glaciology, 4: 85–90.

Huggel et al.: The *2002* rock/ice avalanche at Kolka/Karmadon, Russian Caucasus.

ICIMOD, UNEP (2002): Glaciers, glacial lakes and glacial lake outburst floods in

Nepal. Poster presentation, www.rrcap.unep.org/issues/glof/allpostersfor2002april15& 16.pdf

Kattelmann, Richard (2003): Glacial lake outburst floods in the Nepal Himalaya: A manageable hazard? In: Natural hazards, Vol. 28, 145 – 154.

Pelden, Sonam (2010-09-03). "Thorthormi water level brought down 43 cm". Bhutan Observer online. Retrieved 2011-03-27.

Tirwa, Badan (2008-01-19). "Managing health disaster". Thimphu: Bhutan Observer online. Retrieved 2011-03-27.