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Flood Modeling on a Reach of Hunza River to Identify Vulnerable Populated Areas

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ABSTRACT

The flood modeling is one of the engineering techniques which provide reliable information of the flood profile. The rainfall, runoff, catchment characteristics, and return period are the parameters which govern the flood. The purpose of flood modeling is to understand and manage the mechanisms at work in floodplains. The objective of this study is to perform one dimensional flood modeling by application of Hydrologic Engineering Centre River Analysis System (HEC-RAS) on a reach downstream of dam created due to natural land slide on Hunza river in Hunza valley of Pakistan. Due to existence of populated areas along the reach, this particular reach length was considered for the purpose of modeling in order to assess the possible risk of flooding. By using the available geometric data and flow data of this particular reach length (15797.71m), the 1-D flood routing was carried out with unsteady flow conditions by utilizing the available dam break outflow hydrograph at river location 16245.89m as upstream boundary condition. The simulated results were analyzed and the possible extent of flooding at specific downstream locations was taken into consideration. It has been found that the areas; Dainyor, Sakwar, Minawar, Hussainabad and Bagrot are vulnerable to flooding and severe disaster could occur in case of extreme flooding.

KEYWORDS

Hunza river, Landslide, One dimensional flood modeling, Flood vulnerability, HEC-RAS, Flood safety management

INTRODUCTION

Flood is a state of high water level along the river channel or on the coast that leads to inundation of land, which is not usually submerged. Floods are caused by many things, including rainstorms, earthquakes, dam failures, underwater volcanic eruptions and tsunamis, or hurricanes [9]. Floods are always considered to be one of the major hazards which could cause great disaster. The impact of high flooding on people and property could also be very significant.

Especially possible extreme flooding due to dam failure poses extra risks to people and property in river valleys downstream of the dams. Flood modeling is an important task for decision making in the field of flood risk management [2], [3], [4], [7], [8].The flood modeling is one of the engineering techniques which provide accurate information of the flood profile. The rainfall, runoff, catchment characteristics, and return period are the parameters which govern the flood. Flood inundation models enable us to make hazard predictions for floodplains, mitigating increasing flood fatalities and losses. The goal of such tools is to simulate probable inundation damage on a given area depending on several flood scenarios with different intensity, duration and return period. Model reliability is assessed by confronting simulation results and real data in a calibration process starting from a real inundation that occurred, with a given return period, difference between real data and output modeled data is minimized by adjusting some parameters of the model [7].

There are many tools available for flood modeling but in this case study a very versatile program i.e. Hydrologic Engineering Centre-River Analysis System (HEC-RAS) has been used. It is a free software that was developed by Hydrologic Engineering Centre which is division of the Institute for Water Resources (IWR) of the U.S. Army Corps of Engineers [5]. HEC-RAS is one dimensional software that allows the user to perform steady and unsteady flow river hydraulics calculation, sediment transport, mobile bed modeling, water quality and water temperature analysis [5], [6].

In this study flood modeling on a specific reach length (15797.71m) of Hunza river has been carried out where due to massive landslide natural lake/dam was created. This landslide occurred on January 04 2010 near Atabad village, which is located about 100 km upstream of the confluence of Hunza and Gilgit rivers. A part of Atabad village has been

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buried under the landslide. 19 people were killed due to this landslide [1].

The focus is on the 1-D flood routing on the project reach length of about 16km starting from downstream of Raheemabad to Bagrot using HEC-RAS in order to assess the possible risk of flooding for nearby populated area. Simulated results show that the areas of Dainyor, Sakwar, Minawar, Hussainabad and Bagrot are quite vulnerable to flooding.

LANDSLIDE IN HUNZA RIVER VALLEY

The Hunza is a mountainous valley in the Gilgit–Baltistan region of Pakistan. The Hunza is situated north/west of the Hunza River, at an elevation of around 2,500 metres (8,200 ft). The territory of Hunza is about 7,900 square kilometres (3,100 sq mi). Aliabad is the main town while Baltit is a popular tourist destination because of the spectacular scenery of the surrounding mountains like Ultar Sar, Rakaposhi, Bojahagur Duanasir II, Ghenta Peak, Hunza Peak, Passu Peak, Diran Peak and Bublimotin (Ladyfinger Peak), all 6,000 metres (19,685 ft) or higher. Hunza River is the principal river of Hunza, in the Northern Areas of Pakistan. It is formed by the confluence of the Kilik and Khunjerab nalas (gorges) which are fed by glaciers. It is joined by the Gilgit River and the Naltar River before it flows into the Indus River. The river cuts through the Karakoram range, flowing from north to south. The Karakoram Highway crosses the Hunza River near Hunza and Nagar valleys. [1]

A massive landslide occurred in Hunza river basin on January 04 2010 near Atabad village as shown in Fig.1, which is located about 100 km upstream of the confluence of Hunza and Gilgit rivers. Atabad in situated on right bank of Hunza river about 30 km upstream of Aliabad, and about 10 km downstream of Gulmit. A part of Atabad village has been buried under the landslide. [8]

Fig. 1: Occurrence of Landsliding at Atabad- Hunza [8]

The Hunza River was completely blocked for five months, creating a massive lake now called Lake Gojal as shown in Fig. 2 [8]. The landslide created a natural dam of about 126 m to 210 m height across Hunza river. The volume of the water that would be stored in the bank up to the top of the landslide has been estimated as 305 MCM. [1], [8]

Fig. 2: View of the growing lake formed behind the landslide, seen from the ruins of Atabad village on February 1, 2010 [8]

Due to blockage created by the landslide the water of the Hunza river flowing to the location started accumulating and a lake started to form upstream of the dam resulting from the landslide. The rising waters inundated several villages and eventually submerged 22 kilometers of the Karakoram Highway. Some 25,000 people were displaced. Two years later, these communities remained cut off from the rest of the country. [8]

As there is no spillway in the landslide mass, it would overtop after filling with water .The overtopping of the landslide mass would cause erosion of the soil which is expected to progress rapidly as the downstream slope of the landslide dam is quite steep; 1(horizontal) to 0.7 (vertical). This rapid erosion of the soil can progress so fast that it may washout most of the landslide mass within a few hours which is the situation of the dam break event. So in order to drain the water from the lake, 24 m deep and 45 m wide channel was excavated by Frontier Works Organization (FWO). [1], [8]

TOPOGRAPHY OF THE LANDSLIDE

The topographic survey of landslide mass was carried out by Frontier Works Organization (FWO). The topographic data indicates that the length of the landslide mass along the river is about 2000 m while its width across the river is about 400 m. The plan of the landslide mass as developed from topographic survey is shown in Fig. 3. The longitudinal section of the landslide mass along the possible flow path is shown in Fig. 4. The maximum depth of the landslide mass along possible flow path is about 126 m, whereas the maximum height of the landslide mass above the river bed is 210 m. [1]

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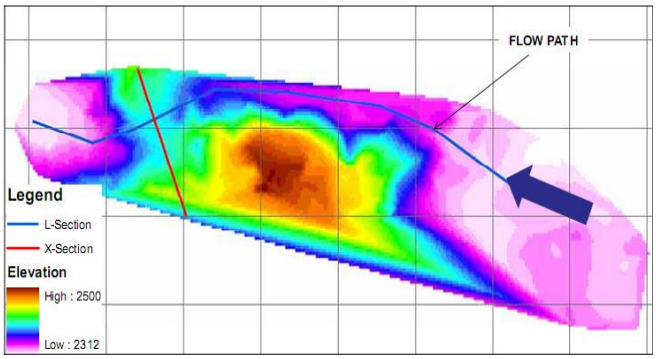

Fig. 3: The layout of landslide mass (Developed from Topo survey) [1]

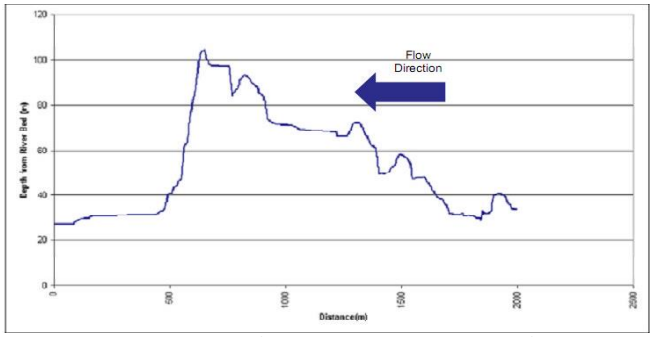

Fig. 4: Longitudinal section of landslide mass along possible flow path [1]

The longitudinal section of the landslide plotted in Fig. 4 shows that there is a sharp drop of about 70 m in a stretch of 100 m length just downstream of overtopping location. Thus once the water starts to overtop the landslide mass, it would flow very rapidly over the sharp drop, leading to very fast erosion. This could be a precursor of rapid breach of landslide mass. [1]

ID FLOOD ROUTING IN HEC-RAS

For flood routing of project reach of 15797.71m on Hunza river, the available geometrical data and flow data was utilized to setup the model in HEC-RAS. The step by step description of flood modeling has been given below.

Available 19 cross sections were inserted in HEC-RAS. As there was no exact information available regarding the roughness in cross sections so a value of 0.05 for Manning's 'n' was initially considered for each cross section.

The dam break outflow hydrograph at 24m cut (peak Q=25882.15 m^3/s) was taken from the Dam break study of

Hunza river by NESPAK [1] at 16245.89m as shown in Fig. 5.

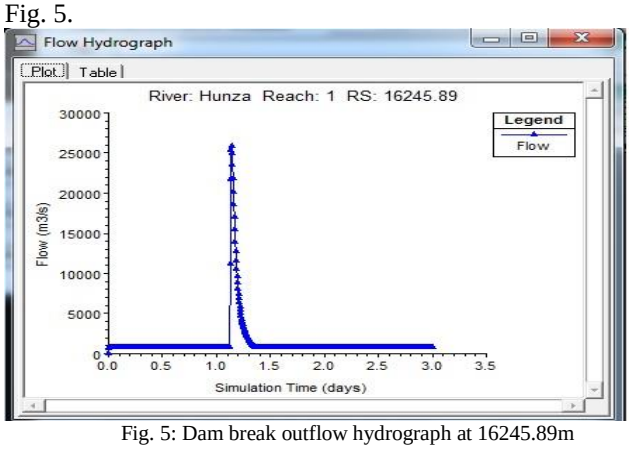

Fig. 5: Dam break outflow hydrograph at 16245.89m

At downstream reach location at 448.176m the available option of normal depth (in terms of channel slope) in HEC-RAS was considered.

After overcoming the numerical instability through several simulations, an initial run was made. In order to calibrate the model, different scenarios of flood routing were carried out by inserting different values of manning's 'n' and finally the model was found completely stable with manning's value 'n' 0.075.

RESULTS OF FLOOD ROUTING

After attaining the numerical stability of the model, the model was run with unsteady flow conditions. The results of dam break flood routing were compared with the results of the reference dam break study (NESPAK). In Figs. 6 and 7, the comparison of maximum water levels and maximum discharge has been shown.

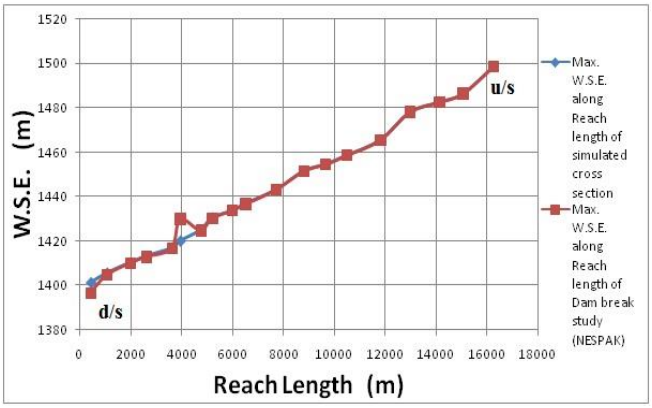

Fig. 6: Comparison of maximum water levels along project reach

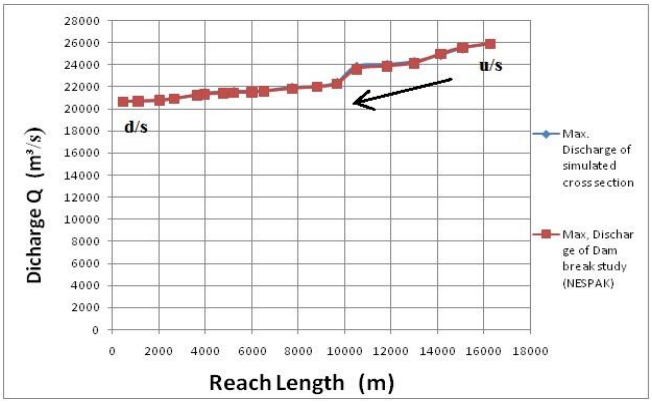

Fig. 7: Comparison of maximum discharge along project reach

The overall results of maximum water level and maximum discharge are quite comparable along the project reach. The maximum water level differs at few downstream locations. The discharge decreases along the reach due to retention of hydrograph with respect to the shape of cross-sections.The simulated results were analyzed to estimate the risk of flooding for populated areas existing along the project reach. It was revealed from simulation that up to first 10km the maximum water level does not exceed the banks and is within

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the limits. But after first 10km cross sections, significant rise in water level was observed as shown in Fig. 8.

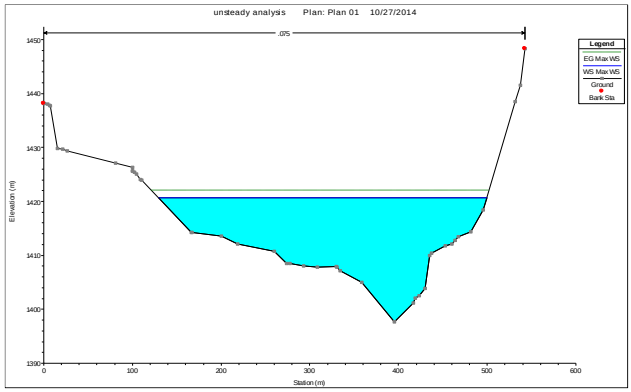

Fig.8: Flow profile in cross-section at 4136.15m

Further downstream of reach, the water level was continuously increasing at some cross-sections which shows danger of flooding for the areas lying along this portion of the project reach as shown in Fig. 9.

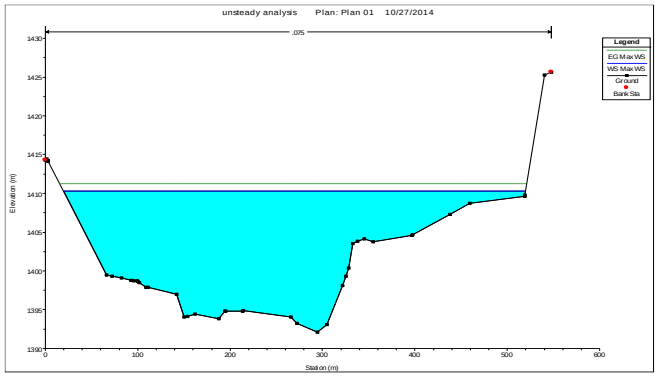

Fig.9: Flow profile in cross-section at 2003.191M**t**

his cross section at 2003.191m indicates that population on left side is under threat because maximum elevation of left bank is 1414.26 m while water surface elevation on this side is 1410.28 m. So there are great chances of overtopping on left side in case of further increase in dam breach flooding. In the following cross- section risk to population on right side of river is shown in Fig. 10.

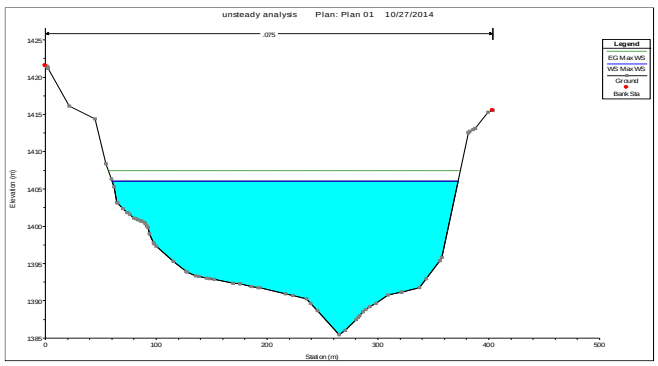

Fig.10: Flow profile in cross-section at 1176.93m

This cross section indicates that population on right side is under threat because maximum elevation of right bank is 1415.54 m while water surface elevation on this side is 1406.07 m. So there are great chances that the areas lying on right side of bank are vulnerable to flooding in case of dam breaking. The areas which are under threat of flood inundation in project reach are Dainyor, Sakwar, Minawar, Hussainabad and Bagrot as shown in Fig. 11. There could be severe disaster in these areas in case of extreme flooding due to possible increase in dam breach depth. The areas under threat are shown by red arrows. Black arrow shows the direction of North.

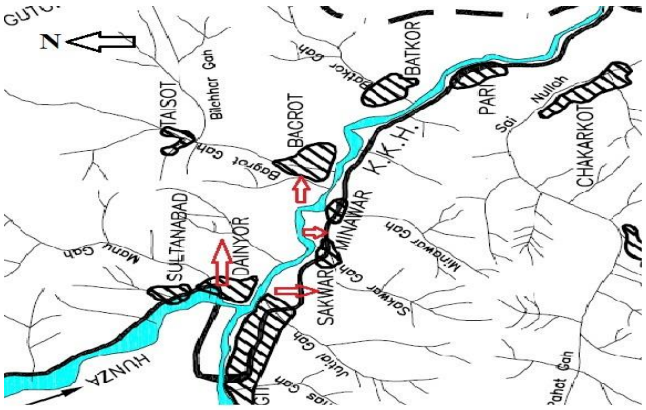

Fig. 11: Populated areas under threat of flooding

CONCLUSIONS AND RECOMMENDATIONS

Flood modeling is an important task for decision making in the field of flood risk management. Due to existence of populated area along the project reach of Hunza River, this particular reach length of about 16km was considered for the purpose of modeling in order to assess the possible risk of flooding. 1-D flood routing in HEC-RAS was carried out with unsteady flow conditions by utilizing the available dam break outflow hydrograph at location 16425.89 as upstream boundary condition. After analyzing the results it was found that banks on cross sections of river station 5988.128m to 2003.191m are susceptible to flooding. The areas lying along the lower part of the project reach; Dainyor, Sakwar, Minawar, Hussainabad and Bagrot are seriously under threat in case of severe flooding.

The people of vulnerable areas should be aware of possible flood risks and flood damages. It is the responsibility of local government to relocate the people of these areas, to some other locations which are safe and also there should be enhancement in flood safety measures both structural and non-structural. There should be improvement in emergency preparedness and evacuation techniques in order to minimize the possible risks of flooding in that particular study area. The relocation of people at risk should be done as quickly as possible before occurrence of any unexpected flood

disaster. This study would be useful for flood safety management in Pakistan as well as in other parts of the world.

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