The Landslide Dam Breach Impact Assessment - A Case Study of the Hokkaido Earthquake in Japan

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1. INTRODUCTION

A large-scale landslide near Atsuma Town, Hokkaido, Japan was induced by 6th September 2018 Hokkaido Iburi-Tobu Earthquake, causing natural dam and barrier lake formed. On September 6, 2018, in the early morning and JMA magnitude of 6.7 earthquake struck Hokkaido, Japan. The Iburi-Tobu Earthquake event resulted in 36 deaths (Yamagishi and Yamazaki, 2018). The large-scale landslide formed a natural dam of 40 ~ 50 m height, 400 ~ 500 m width, and dammed the river about 1100 m length in the flow direction and resulted in a backwater length of 2 km long (**Fig. 1**). To study and understand the overall impact area of potential sediment disaster, the numerical model was used to simulate Hidaka Horobon Inukawa natural dam breach. The potential natural dam break was modeled and analyzed using HEC-RAS 2D model based on available geometry data. Physiographic parameters are determined from Geospatial Information Authority of Japan Website and Hokkaido Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism Website. The results indicate that natural dam break increases the downstream flooding risk as breach formation time decrease.

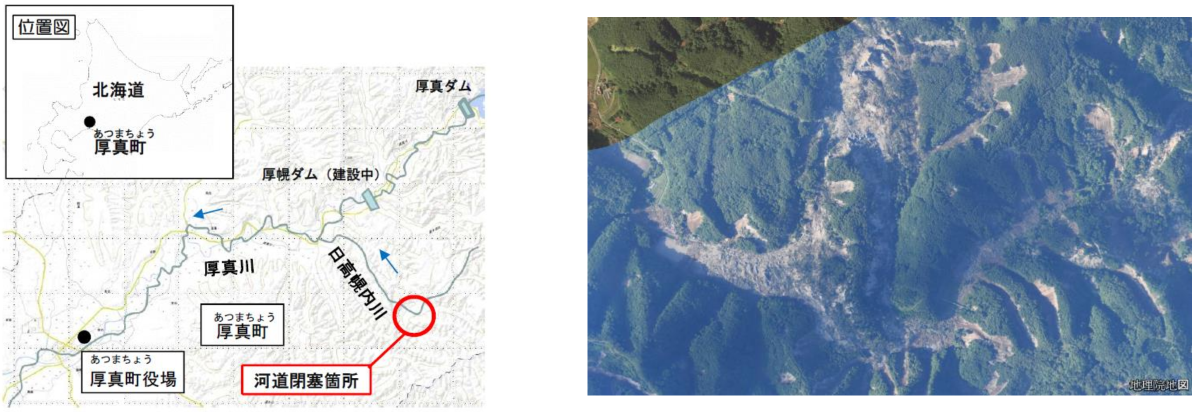

Fig. 1 Location of large-scale landslide at Atsuma Town, Hokkaido, Japan (Geospatial Information Authority of Japan Website).

2. MATERIALS AND METHOD

(1) Site condition

The earthquake occurred just after typhoon Jebi (No. 21 in Japan) and the precipitation was accumulated up to 100 mm over 3 days from September 3 to 5, 2018 (Yamagishi and Yamazaki, 2018). To analyze the sediment disaster condition, this study uses the digital elevation model (DEM) data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDEM V2) and orthophoto from the Maps of Geospatial Information Authority of Japan. The resolution of GDEM V2 is 30 x 30 m. The large-scale landslide formed natural dam of 400 width in right bank side, 50 m height, and sediment blocked the river about 1100 m long. The barrier lake water surface is 92 (m) on October 1, 2018, and 97.8 (m) on March 18, 2019 (Hokkaido, MLIT website, 2019).

(2) Scenario of natural dam breach simulation

This study used the Hydrology Engineering Center River Analysis System 2D model to simulate the flood propagation and dam breach analysis. The HEC-RAS 2D can be divided into three modules. The geometry data was developing from the terrain model and convert it into a gridded data format. The detailed and accurate hydraulics model relies on the quality of the terrain model the user can import. The boundary condition types are flow hydrograph at upstream and normal depth at the outlet. Once the simulation was complete, the results can be viewed within RAS Mapper for inundation areas, velocity, water depth, and other types of output.

The simulation has been made for unsteady flow routing for 2 days duration. Based on the GEDM V2 terrain model data, the simulation domain could be identified as **Fig. 2**. The parameters used in the model were listed in **Table 1**, and the mesh size is 50 x 50 m, dam height is 50m, and with different breach formation time (0.5 to 6 hours). The hydrograph of the discharge could be estimated by the rational formula and imposed as the upstream boundary condition for overtopping failure breach analysis. The estimated elevation-volume curve of the barrier lake (**Fig. 3**) is also imposed at the upstream boundary of the computational domain for this dam breach simulation.

3. RESULTS AND DISCUSSIONS

The results of the flood map indicate that flooding and rapidly flow is observed in the downstream area. The flood wave arrival time result showed the short breach formation time was earlier than that of the long breach formation time. The simulation using short breach formation time showed that flow depth, velocity, and inundated area much larger, and a flood wave arrival time earlier 2 to 8 times, than that modeled by the longer breach formation time cases (**Table 2**).

4. CONCLUSIONS

HEC-RAS 2D has a graphic-user-interface for unsteady flow hydrodynamics analysis and it can easily setup the model to estimate potential impact risk of a dam break. In this preliminary study, the simulating of inundated areas, velocity, water depth, and outflow of dam break were estimated. The result indicates that the outburst of the dam breach increase the impact of downstream reach depends on the breach development time. The inundated areas, flow depth, velocity, and arrival time are very important for officials to make a decision and early warning response to the emergency plan.

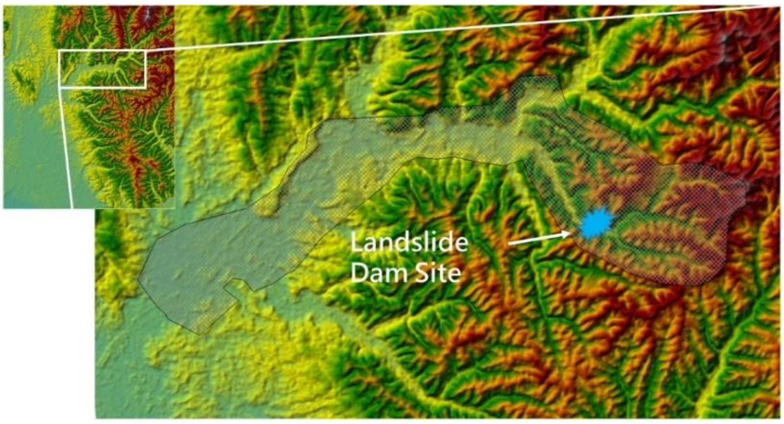

Fig. 2 Study map of the natural dam location and simulation domain

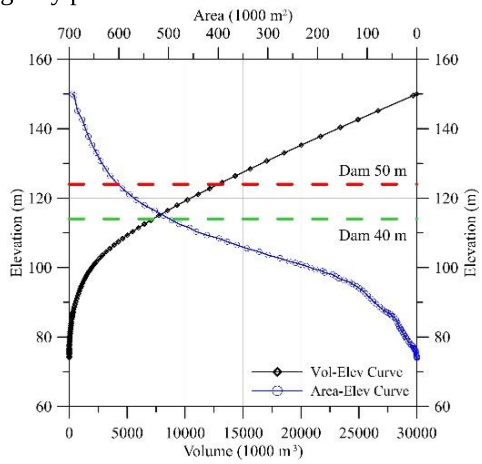

Fig. 3 The estimated elevation-area-volume curve of impounded lake

Table 1 Parameters of the simulation

Case Number	Failure mode	Water supply discharge	Model parameter				Empirical methods and their breach formation time	
							Method	C_{bw}
		Q_p (m³/s)	n	h_b	C_{bw}	T_f	MacDonald et al (1984)	0.96
Run 1	Overtopping	40	0.04	50	2.6	0.5	Forehlich (1995)	0.33
Run 2		40	0.04	50	2.6	1	Forehlich (2008)	0.3
Run 3		40	0.04	50	2.6	3	Von Thun & Gillete	1.05
Run 4		40	0.04	50	2.6	6	Xu & Zhang (2009)	1.14
Note	h_b : Dam height (m); C_{bw} : Breach Weir Coefficient (-); T_f : Breach formation time (hour); n: Manning's n (s/m$^{1/3}$)							

Table 2 Summary of dam breach analysis

Case Number	Village 1			Village 2			Village 3			Inundated area (km²)
	Arrival time (min)	Depth (m)	Velocity (m/s)	Arrival time (min)	Depth (m)	Velocity (m/s)	Arrival time (min)	Depth (m)	Velocity (m/s)	
Run 1	11	15.2	13.9	19	6.8	18.6	39	0.92	0.17	5.9
Run 2	20	11.9	11.2	31	5.6	16.2	57	0.89	0.17	5.7
Run 3	47	7.8	7.4	69	3.8	12.2	121	0.87	0.16	5.4
Run 4	80	6.0	5.4	116	2.9	9.8	206	0.86	0.16	5.1

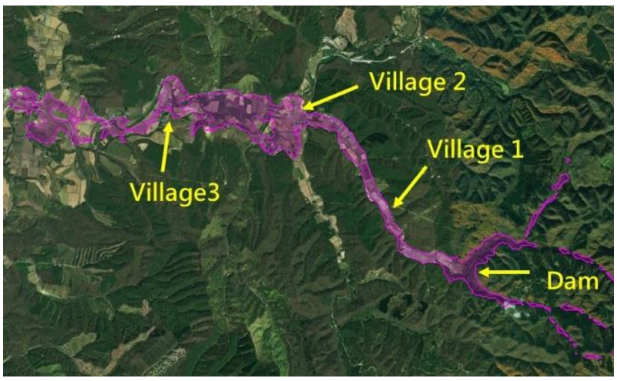

Fig. 4 Inundated area of dam break in Atsuma river

References

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Keywords: Flood routing, Natural dam, Two-dimensional simulation, Dam breach analysis.