TWO LARGE LANDSLIDE DAMS AND OUTBURST DISASTERS - IN THE SHINANO RIVER, CENTRAL JAPAN

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ABSTRACT

Large landslides or debris flows caused by heavy rainfall or earthquakes often block mountain rivers to form landslide dams. The area upstream of the dam is submerged under water and the downstream area is flooded when the landslide dam breaks. As many as 19 landslide dams have formed in the last 500 years in the northern region of Nagano Prefecture in central Japan, and all except two have broken. Seven were formed when the Zenkoji Earthquake occurred in 1847. This abundance of landslide dams is probably caused by the geotectonic background of this area, which is located at the western end of a major tectonic line called "Fossa Magna."

A large landslide dam formed in the upstream area of the Shinano River about 250 years ago, while another large landslide dam in the midstream area 160 years ago. The Tobata landslide occurred on June 24, 1757 because of heavy rain. And the Mt. Iwakura landslide occurred on May 8, 1847 because of the Zenkoji Earthquake. Detailed information on the formation and subsequent bursting of these landslide dams remains in historical records such as old documents and picture maps.

Keywords: Shinano River, Landslide Dam, Tobata Landslide, Zenkoji Earthquake, Mt. Iwakura Landslide, Old Documents, Picture Maps

INTRODUCTION

Major flooding damage may occur to the downstream area of a river, if a large landslide dam bursts becased of the build-up of water behind it. Researchers such as Schuster (1986) and Tabata et al. (2002) have collected data on landslide dams and performed related analyses. As a recent example in Japan, large landslide dams were formed in the Imo River, a tributary of the Shinano River, when the Niigata Prefecture Chuetsu (Mid-Niigata) Earthquake

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occurred on October 23, 2004. Various measures were taken to prevent the bursting of these dams.

In a survey of past sediment floods in the downstream areas of rivers and alluvial fans caused by a major collapse or by other sediment yielding in the upstream area, it was found that many of those floods were triggered by the bursting of the landslide dams. However, to date, sediment control plans have focused only on collapse and landslides in the upstream area, ignoring the formation and bursting of landslide dams. To property elucidate on sediment-related disasters, it is impossible to ignore the formation and bursting phenomena of landslide dams. Intending to make sediment control engineers aware of this fact, the authors are investing past landslide dams based on a variety of literature, picture maps and historical documents. We expect future sediment control plans will consider these phenomena and we believe it will be possible to predict potential locations and scales of landslide dams based on an accumulation of these case studies.

DISRIBUTION OF LANDSLIDE DAMS IN NAGANO PREFECTURE

Table 1 shows a list of landslide dams in this area and Figure 1 shows the distribution of landslide dams in the northern region of Nagano Prefecture, in central Japan. As many as 19 landslide dams have been formed in the last 500 years in this area, and all except two landslide dams have broken. Of this number, seven were formed when the Zenkoji Earthquake occurred in 1847.

Table 1 List of Landslide Dams in Northern Nagano Prefecture (Mori, et al, 2007)

No.	Landslide Dam	Date Formed	Cause	Failure Timing
(1)	Aoki Lake	30,000 years ago	Unknown	Continuing today
(2)	Kashima River	1441	Heavy Rain	3 days later
(3)	Mt. Manaita	1502?	Essa Earthquake	Unknown
(4)	Mt. Shimizu	1502?	Essa Earthquake	Unknown
(5)	Tobata Landslide	1757	Heavy Rain	54 hours later
(6)	Mt. Iwakura	1847	Zenkoji Earthquake	19 days later
(7)	Kiriake	1847	Zenkoji Earthquake	Gradually failed
(8)	Mt. Amamizu	1847	Zenkoji Earthquake	A few days later
(9)	Yanakubo Lake	1847	Zenkoji Earthquake	Continuing today
(10)	Ikari	1847	Zenkoji Earthquake	16 days later
(11)	Somuro	1847	Zenkoji Earthquake	Gradually failed
(12)	Oyasawa	1847	Zenkoji Earthquake	Unknown
(13)	Garagara Sawa	1891	Heavy Rain	Gradually failed
(14)	Mt. Hieda	1911	Heavy Rain	3 days later
(15)	Lake Taisho	1915	Eruption	Continuing today
(16)	Mt. Kazahari	1939	Snowmelting Flood	Gradually failed
(17)	Mt. Akahage	1967	Snowmelting Flood	101 days later
(18)	Mt. Kozuchi	1971	Heavy Rain	Gradually failed
(19)	Susobana River	1997	Snowmelting Flood	Did not fail due to countermeasures

This abundance of landslide dams is probably caused by the geotectonic background of the area which is located at the western end of the Fossa Magna, Japan's central graben belt (Geological Survey of Japan, 1995). The Shinano River, which is the longest river in Japan,

runs through the mountainous region of central Japan and flows into the Sea of Japan.

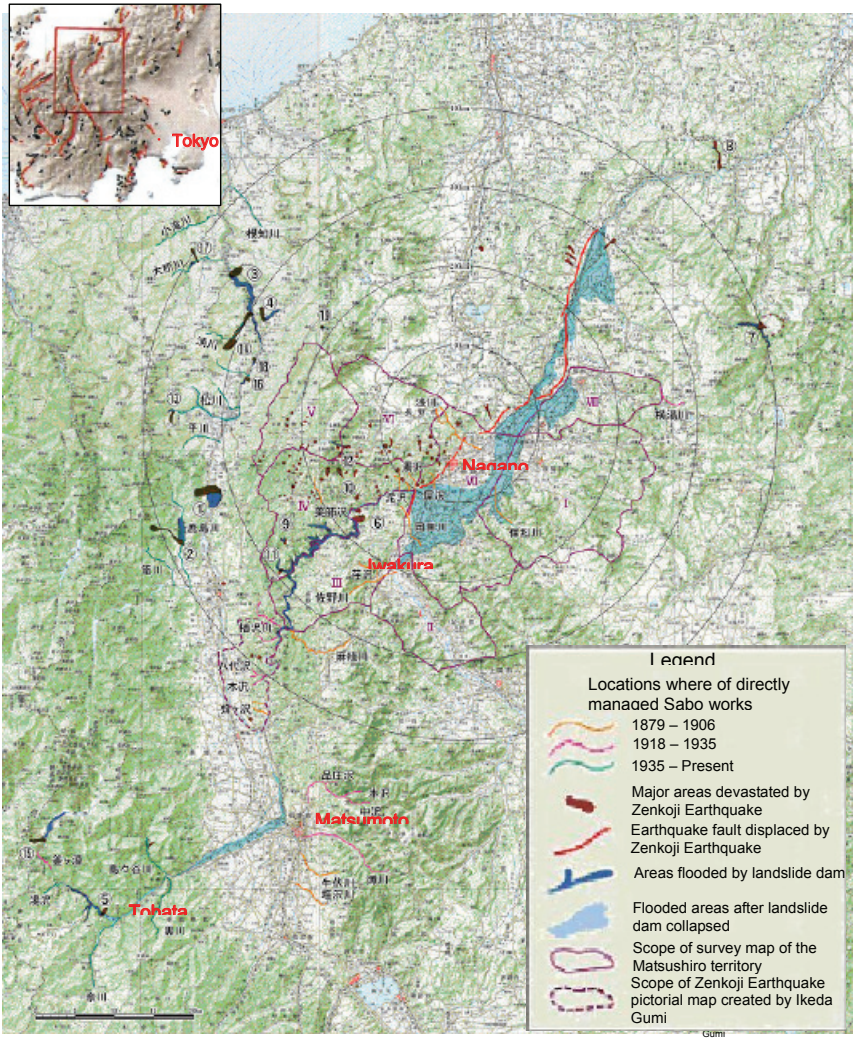

Fig1: Distribution of landslide dams in the northern region of Nagano Prefecture in central Japan (Mori et al, 2007)

A landslide dam was formed in the upstream area of the river about 250 years ago, with another one forming in the midstream area about 160 years ago. Detailed information on the formation and bursting of these landslide dams remains in historical records such as old documents and picture maps.

LANDSLIDE DAM FORMED IN 1757

In the Azusa River, three dams – the Nagawado, Midono, and Inekoki Dams – were completed in 1969 by a power generation company and have since been producing hydropower. The Nagawado Dam is an arch dam, 155 meters high, and Lake Azusa with a total storage capacity of 123 millions cubic meters is the dam lake. Figure 2 shows the location of the Nagawado Dam and Tobata Landslide in the upstream section of the Azusa River. This area belongs to the Mino Terrane of the Jurassic Period. The geology in this area consists of an alternation of chert and sandsone/mudstone, and has a strike roughly in the noutheast-southwest direction (Otsuka & Nemoto, 2003). Also, a few faults lie in the same direction, together with fractured zones with a width ranging from several tens of centimeters to several meters.

Photo 1 shows the Tobata Landslide before the impounding of Lake Azusa. Figure 3 shows the longitudinal section of the Azusa River in the upstream area of the Shinano River and the location of the Tobata Landslide and the hydropower dam reservoirs.

In the early morning of June 24, 1757, a landslide occurred on the left bank of the Azusa River because of torrential downpours in the rainy season (the estimated sediment movement was 10 million cubic meters). A large landslide dam formed in the river. From historical records, old topographical maps and aerial photos, it is estimated that the water height reached 150 meters and the water volume reached 98 million cubic meters.

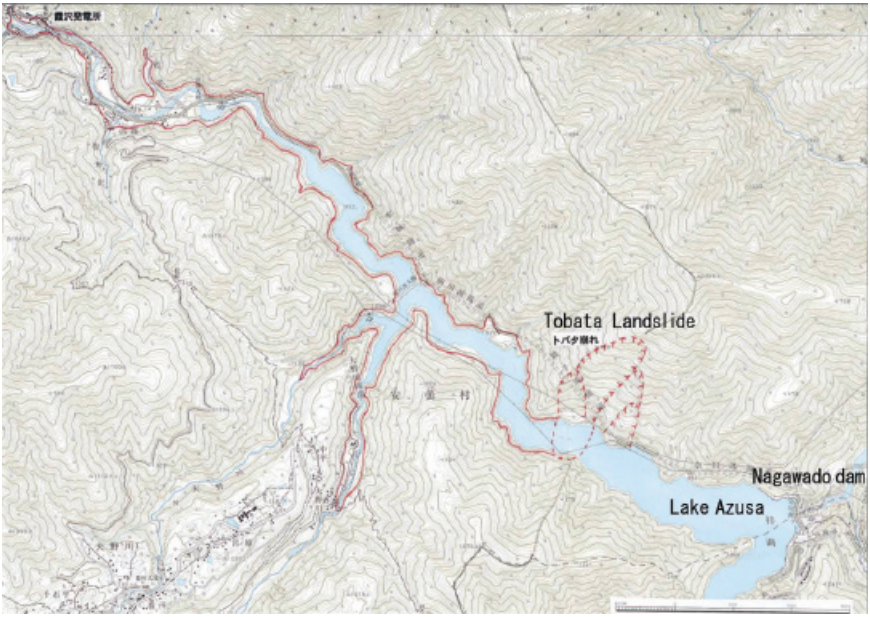

Fig2: Nagawado Dam and Tobata Landslide upstream in the Azusa River

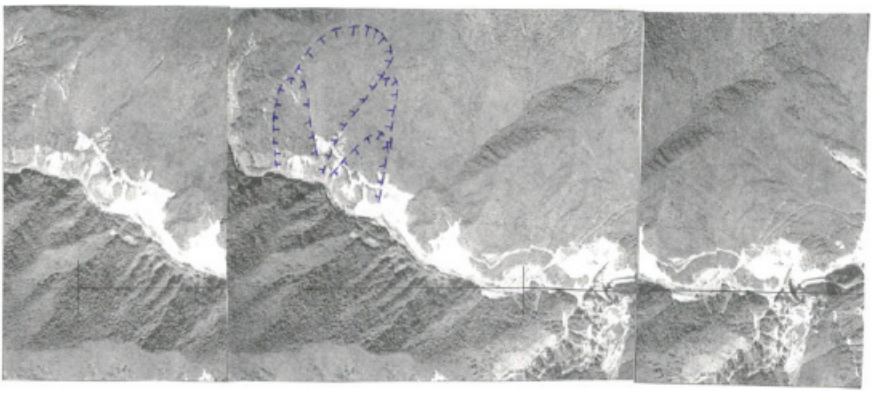

Photo 1: Tobata Landslide before impounding of Lake Azusa (Photographed on Sept. 20, 1968)

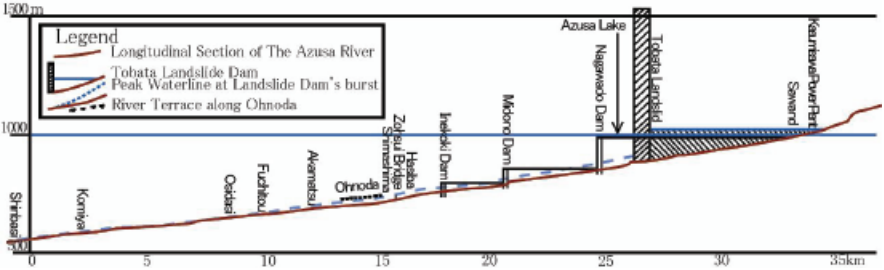

Fig3: Longitudinal section of the Azusa River and Location of Tobata Landslide and the hydropower dam reservoirs

Around 10 a.m. on the third day (54 hours after the landslide), the landslide dam burst and its water flooded the Matsumoto-Daira, an alluvial fan, up to the confluence with the Narai River in the upstream area of the Shinano River. The Zousui Bridge (which was 14.4 meters above the water and had a length of 34.2 meters), was located 12 kilometers downstream. Since it was washed away by the flood, it is estimated that the flood height of the peak flow was 20 meters. According to calculations using Manning's formula, it is estimated that the flood water ran down the river in a concentrated path with a velocity of 12 m/s and a peak flow of 27,000 m^3/s. When the dam burst, local people were quickly ordered to evacuate and no casualties occurred during this flood. The lords ruling the areas (the Matsumoto feudal clans) at the time and local people collaborated together to watch, report on and quickly evacuate the site. Although houses and arable land were washed away, casualties were few because people quickly evacuated to a safe place.

LANDSLIDE DAM FORMED IN 1847

The Zenkoji Earthquake occurred on May 8, 1847 and had a magnitude of 7.4 on the Richter scale. As shown in Figure 1 and 4, large landslides and collapses occurred in various locations in the area, forming several landslide dams.

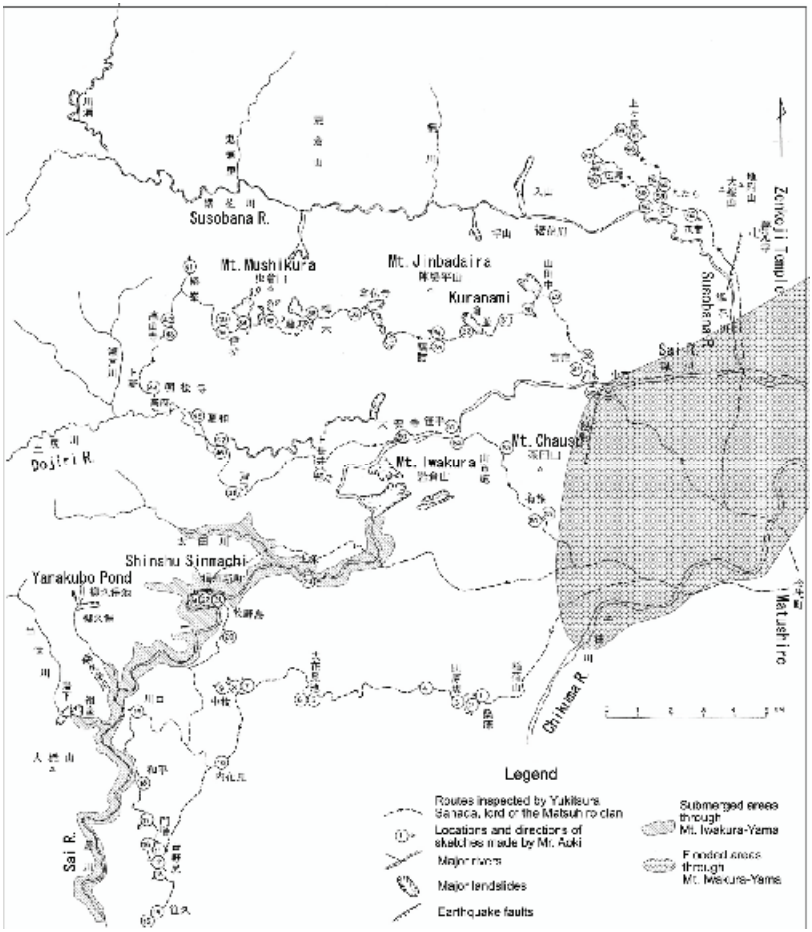

Fig4: Mt. Iwakura landslide dam, outburst flood area and sketch points of painter Sekkei Aoki (Zenkoji Earthquake Disaster Study Group, 1994)

This area consists of the Neogene formation, which is prone to landslides and collapses, and landslide dams form easily there, just like the area hit by the Niigata Prefecture Chuetsu (Mid-Niigata) Earthquake on October 24, 2004. Table 1 and Figure 1show the locations of

seven landslide dams that were formed by this earthquake.

Because of the Zenkoji Earthquake, the largest landslide (with an estimated sediment movement of 20 million cubic meters) occurred at Mt. Iwakura in the midstream section of the Shinano River (the Sai River), and a large landslide dam was formed when the river was blocked. Although the river blockage height was 70 meters, the water volume built up to as much as 300 million cubic meters, making it the largest landslide dam ever recorded in Japan. Figure 4 shows the Mt. Iwakura landslide dam and the outburst flood area.

The water level reached its maximum 16 days after the landslide because of an abundant water supply from melted snow (the average flow rate was 254 m^3/s). The water gradually began to overflow from the top of the dam, eroding the 1,000 meter-long debris masses. The landslide dam finally collapsed on the 19-th day. The resulting flood flow, reaching a height of 21 meters and a peak flow of 34,000 m^3/s, caused serious damage to areas in the downstream section which are presently the sites of Nagano City (Zenkoji-Daira) and Iiyama City in Nagano Prefecture.

Fig5: Large Earthquake Disaster Map three months after the earthquake
(Sanada Museum in Nagano City)

Fig6: Mt. Iwakura landslide dam sketched by Sekkei Aoki two years after the earthquake (Sanada Museum in Nagano City)

Fig7: Mt. Iwakura landslide dam mapped by the Matsushiro Clan five years after the earthquake (Kyoto University Museum in Kyoto City)

CONCLUSION

Our report introduced the formation and bursting of two landslide dams and the resulting flooding using vivid depictions in the aforementioned maps and drawings. Historical records on landslide dams and their associated floods will be further studied and documented. The authors are currently simulating the bursting phenomena of landslide dams. We are also Proceeding to study risk management in relation to these phenomena. This information is taken into account when disaster prevention plans or warning and evacuation systems are made in each area.

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