Chapter 10
Mitigation of Natural Hazards in Mountain Watersheds of Japan

Hideaki Marui

1 Introduction

In Japan, the disasters associated with seismic and volcanic activities occur frequently (Ministry of Land, Infrastructure and Transport 2002). In recent decades, more intensive rainfalls (associated with the global climate change) caused serious sediment disasters. Inhabitants living in the orogenic zone had to live with such disasters and endeavoured to develop technologies to mitigate their impacts (Hokuriku Regional Development Bureau 2007). Nowadays, standardized techniques for torrent control and for landslide stabilization are available. As a result, sediment discharge is strongly reduced in many torrents and a lot of landslide slopes are stabilized at least concerning smaller scale or middle scale landslides. However, a completely different solution is needed for the mitigation of catastrophic disasters caused by large scale landslides, because structural measures are not able to sufficiently resist against large scale landslides (National Institute for Land and Infrastructure Management 2012).

In the last 20 years, researchers and engineers have made significant efforts to clarify necessary targeting items concerning large scale landslides. Although certain progress is recognized, some essential uncertain items are still remaining. It is urgently needed to clarify such uncertain items in order to arrange more sophisticated and effective way to mitigate future disasters caused by large scale landslides. In this article, background conditions and actual state of large scale landslide occurrences are introduced and specific items to be clarified are pointed out.

H. Marui (✉)
Reseach Center for Natural Hazards and Disaster Recovery, Niigata University,
Ikarashi-Ninocho 8050, Nishi-Ku, Niigata 950-2181, Japan
e-mail: maruihi@cc.niigata-u.ac.jp

J. Křeček et al. (eds.), *Ecosystem Services of Headwater Catchments*,
DOI 10.1007/978-3-319-57946-7_10

2 Large Scale Landslides

The Ministry of Land, Infrastructure and Transport, which is responsible for mitigation of sediment disasters, carried out nationwide evaluation of danger degree of large scale landslides. At first, “Estimated frequency map of large scale landslides” was formulated in 2010, as shown in Fig. 10.1a. In order to estimate frequency of large scale landslides, 120 examples since last 150 years were collected. The frequency was estimated based on analysis of the 120 examples with consideration of quaternary uplift value and geological formation. The frequency is classified into four categories from extremely high to extremely low. The areas of very high frequency are concentrated in the central part of the main island, namely in the Japanese Alpine Region. Areas of very low frequency are distributed, for example, in the Kanto Plain including Tokyo metropolitan area.

As a next step, more detailed “Density map of scars of large scale landslides” was formulated in 2012, as shown in Fig. 10.1b. In this map, the whole territory of Japan was divided into grids of 5 km meshes. The relative density of scars of large scale landslides was indicated concerning individual grids of 5 km meshes and is classified into four categories from extremely high to no landslide. The areas of very high density of scars of large scale landslides are remarkably concentrated in the Japanese Alpine Region.

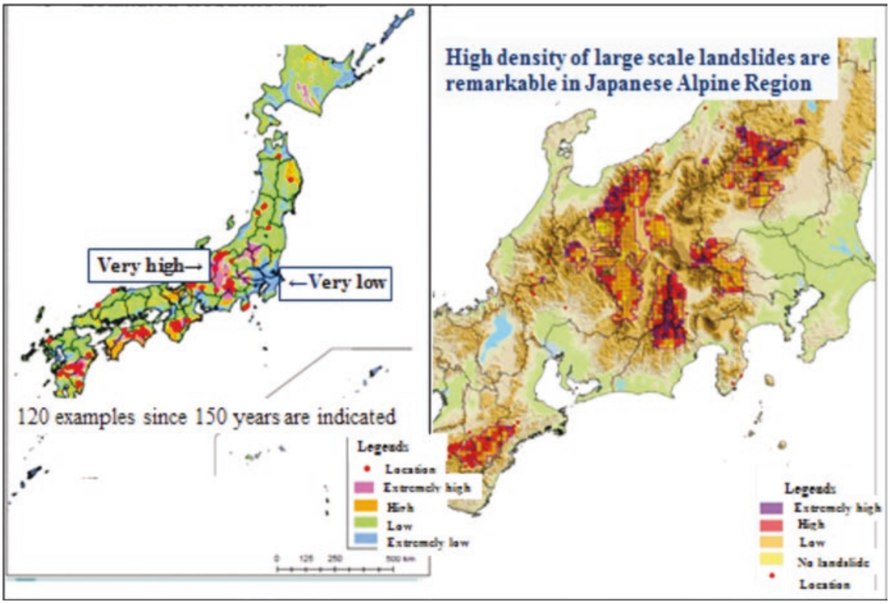


Fig. 10.1 (**a**) (*left*) Frequency map of large scale landslides. (**b**) (*right*) Density map of scars of large scale landslides (*Source:* Ministry of Land Infrastructure and Transport)

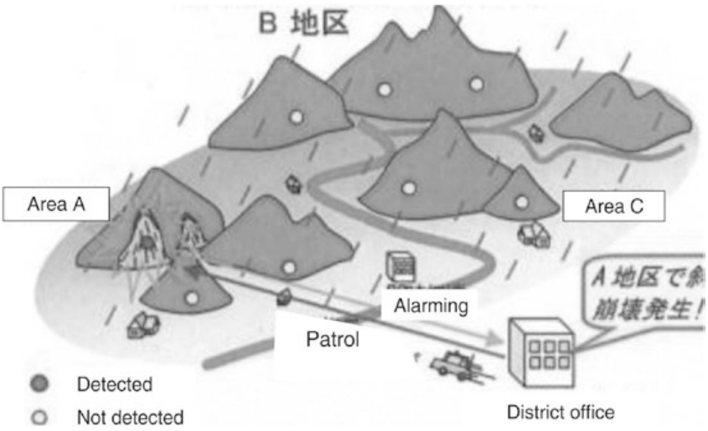


Fig. 10.2 Network system of detecting sensors

Further detailed investigations were carried out concerning the areas of very high density of the scars. As a result of the detailed investigations, the danger degree of large scale land-slides was evaluated concerning individual torrent watersheds with approximately 1 km^2 in the target areas.

Practical management for mitigation of disasters caused by large scale landslides is to be planned and operated by the responsible agency, namely by Regional Development Bureau under the Ministry of Land, Infrastructure and Transport. The agency is responsible for the emergency operation in case of occurrence of large scale landslides. Dissemination of necessary information like danger degree of the concerned torrent watershed to local inhabitants should be also arranged beforehand. For this purpose network systems of detecting sensors using seimograph are installed to catch occurrence of large scale landslides (Fig. 10.2). Furthermore, aerial laser profilings are carried out before and after the landslide occurrence. Surface displacement after disaster can be analysed in detail by comparison between both profiles before and after.

3 Recent Research Results on Large-Scale Landslides

There are certain difficult items on “definition and classification”, “accuracy of prediction” and “feasibility of counter measures” in order to plan sophisticated and effective mitigation measures against large scale landslides. At first, various scales and types are included in the categories of “large scale landslides”. It is basic prerequisite for practical mitigation measure to clearly identify scale, type and characteristics of each individual large scale landslide. At the next point, it is considered that the evaluation of “relative danger degree” is possible and therefore areas with

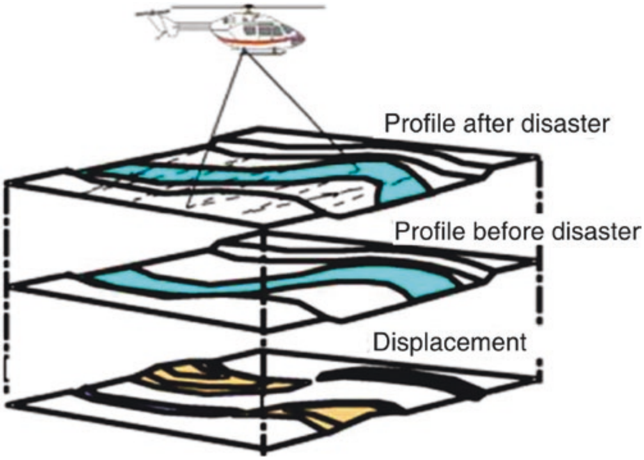


Fig. 10.3 Aerial laser profiling before and after disaster

"high danger degree" can be predicted with certain accuracy. However, the prediction of an individual large scale landslide event and especially its occurrence time is considered to be very difficult to assess. Further, applicability and limitation of each individual countermeasure should be clearly evaluated. It is to be recognized that structural measures are effective only for possible scale of landslides (Fig. 10.3).

The principal triggering factors of large scale landslides are increase of groundwater level or increase of pore water pressure caused by intensive rainfalls and/or snowmelts, and strong shaking of the ground surface caused by earthquakes. An example of a large scale landslide caused by snowmelt accompanied by intensive rainfall is shown in Fig. 10.4. Another example of a large scale landslide caused by earthquake is shown in Fig. 10.5. It is to be pointed out that such a scale of landslide with volume of several millions m^3 can be caused only by strong earthquake and not by rainfall.

Recently researches on large scale landslides are intensively carried out from various interdisciplinary viewpoints. Geological and geomorphological approach to detect dangerous slopes on large scale landslides was developed by various researchers (Chigira 2014). National Institute for Land and Infrastructure Management has pointed out several specific topographic features which are directly related with occurrence of large scale landslides, such as "double ridge", "linear depression" and "arc-shaped crack" (Fig. 10.6).

Prediction method of occurrence of large scale landslides by monitoring of electric conductivity of torrent water is currently being developed (Jitozono 2014). Longitudinal distribution of electric conductivity of torrent water is measured to detect areas with high concentration of groundwater, which indicates high possibility of large scale landslide occurrence. An example of such measurement of electric conductivity of torrent water is shown in Fig. 10.7. Measured values of the longitudinal distribution of electric conductivity along the torrent channel in

Fig. 10.4 Hachimantai landslide caused by snowmelt (Length: 700 m, Width: 400 m, Volume: 70 million m^3)

Fig. 10.5 Aratosawa landslide caused by earthquake (Length: 1.3 km, Width: 1 km, Volume: 6 million m^3)

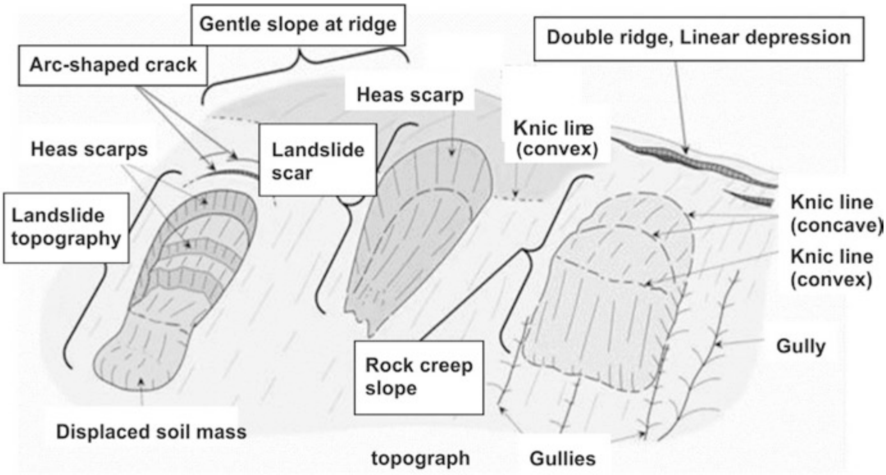


Fig. 10.6 Specific topographic features related with large scale landslides (*Source:* National Institute for Land and Infrastructure Management)

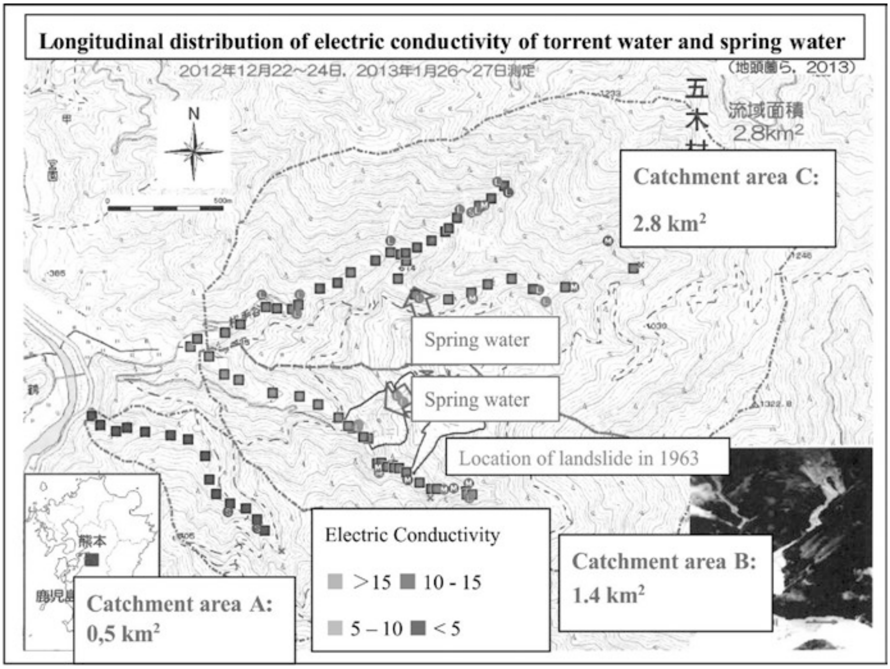


Fig. 10.7 Prediction of large scale landslides by monitoring of electric conductivity of torrent water

three catchment areas are indicated in the figure. In the catchment area A, measured values at all points show very low electric conductivity. In the catchment area B, in the middle part of which a landslide occurred in 1963, measured values show high and very high electric conductivity. In the catchment area C, measured values show different intensity of electric conductivity from medium to high according to the location of torrent channel.

Prediction method of occurrence time of large scale landslides using effective rainfall amount is also currently being developed (Kosugi 2013). If the rainfall amount of the selected target catchment area is continuously measured, effective rainfall amount at any time can be calculated. Key issues for arrangement of practical alarming and evacuation are to select appropriate indicator of rainfall amount and to formulate appropriate critical line as threshold line. Generally, accumulated rainfall amount is used as a long-term indicator to evaluate effects of antecedent rainfall and 1 h rainfall is used as short-term indicator to evaluate effects of rainfall intensity. A prediction method of dangerous situation using snake curve is shown in Fig. 10.8. In the diagram, horizontal axis shows long-term rainfall indicator and

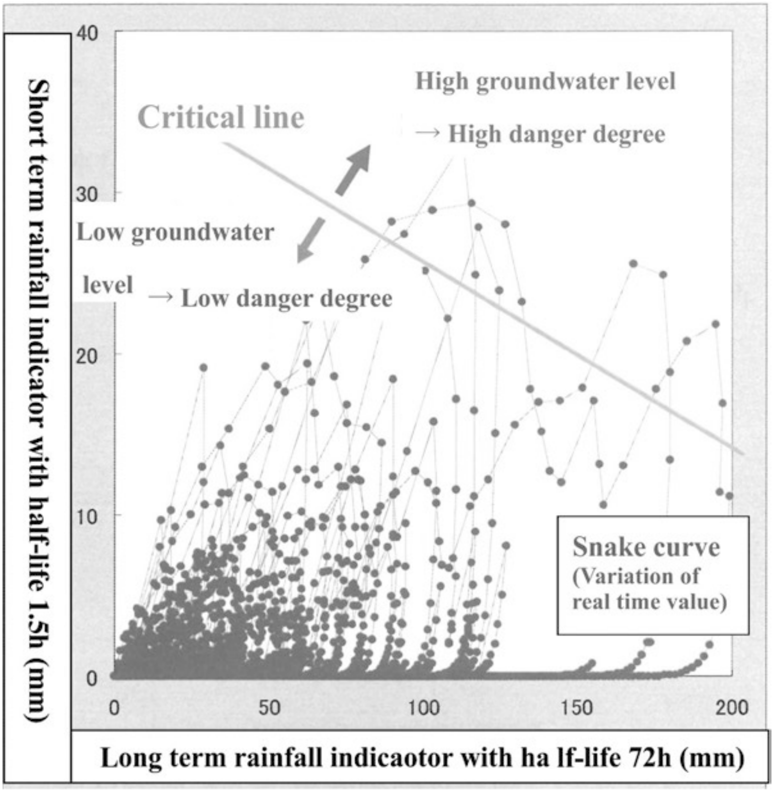


Fig. 10.8 Prediction method of occrrence time of large scale landslide using effective ranfall (Kosugi 2013)

vertical axis shows short-term rainfall indicator. On the basis of past occurrence of large scale landslides in the neighbouring area, a critical line as threshold line can be introduced. Lower area of the critical line should be safe area and upper area should be dangerous area. Snake line shows variation of real time value of both long-term and short-term indicators. If the snake line exceeds the critical line, it means dangerous situation.

Although a certain progess as mentioned above are recognized as a result of recent intensive research activities, some essential uncertain items are still remainig. It is urgently needed to improve accuracy of prediction concerning the occurrence of individual event of large scale landslides, especially on occurrence time.

4 Comprehensive Watershed Management

Landslide mitigation measures should be conducted in order to prevent or reduce the movement of the sliding soil mass so that the resulting damages can be minimized. However, in general effectivity of structural countermeasures both in the source area and downstream area is limited against large scale landslides. Non-structural measures focussing on arrangement of evacuation and appropriate land-use are mostly recommended. Two representive examples of comprehensive watershed management are described.

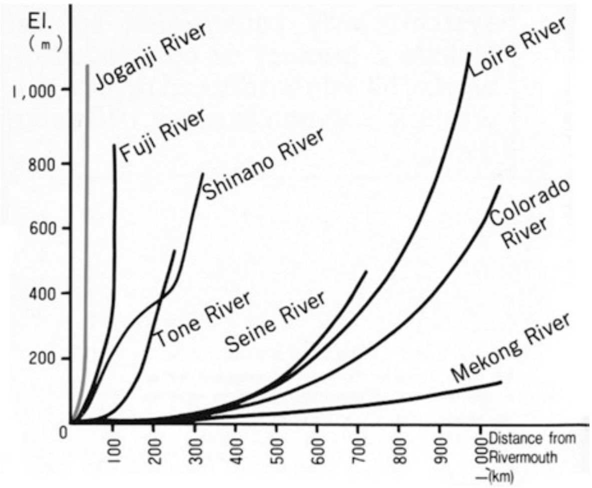
4.1 Holistic System of Torrent Control Works in Tateyama

The Tateyama Caldera is located in the most northern part of the Japanese Alpine Region and is headwater catchment area of the Joganji River (Fig. 10.9). The length and the total catchment area of the Joganji River are 56 km and 386 km^2 respectively. Joganji River has extremely steep longitudinal profile comparing with large rivers in Europe (Fig. 10.10). Overview of Tateyama Caldera is shown in Fig. 10.11. The combination of weathered materials on slopes and intensive rainfall amount can bring high landslide frequencies and also removal of sediment materials. In 1858, a large scale landslide with displaced soil volume of 1.27×10^8 m^3 triggered by the Hietsu Earthquake with M 7.1 occurred and formed a landslide dam. After 14 days and 59 days from the earthquake, two debris flows caused by the collapse of the landslide dam subsequently brought serious damage to the downstream. These destructive debris flows destroyed 163 villages and killed 1800 people. Until now several sizes of landslides and debris flows triggered by intensive rainfall have frequently occurred in the calderea area. Due to landslides and debris flows in the caldera, many people living in the downstream area of the Joganji River suffered from sediment related disasters.

Holistic countermeasures were intensively implemented in the upstream and also in the midstream area by state government since 1926 (Fig. 10.12). A fundamental

Fig. 10.9 Location of the Joganji river basin

Fig. 10.10 Longitudinal profile of Joganji River



high check dam (Shiraiwa dam) was constructed at the exit of the calderea area in order to keep the basic level against erosion and to deposit sediment materials as much as possible in the caldera area (Fig. 10.13). Further more in several torrential gullies in caldera a series of steps-like check dams were constructed for consolidation of torrent gully bed (Fig. 10.14). After 70 years this gully is completely covered by vegetation. A large scale check dam was constructed at the exit of the middle stream. This dam with very large sediment trap capacity of 5 millions m^3 aimed to retain sediment materials to protect Toyama Plain in downstream area.

This holistic system of torrent control works was conducted by Dr. Akagi with utilization of modern torrent control technology developed in European Alpine Region in early stage of the twentieth century in combination with Japanese traditional technology of hillside works. After that, since 80 years, a lot of control works are added and also maintenamce works are continuously carried out to keep the expected functions of the old facilities.

Fig. 10.11 Overview of Tateyama Caldera

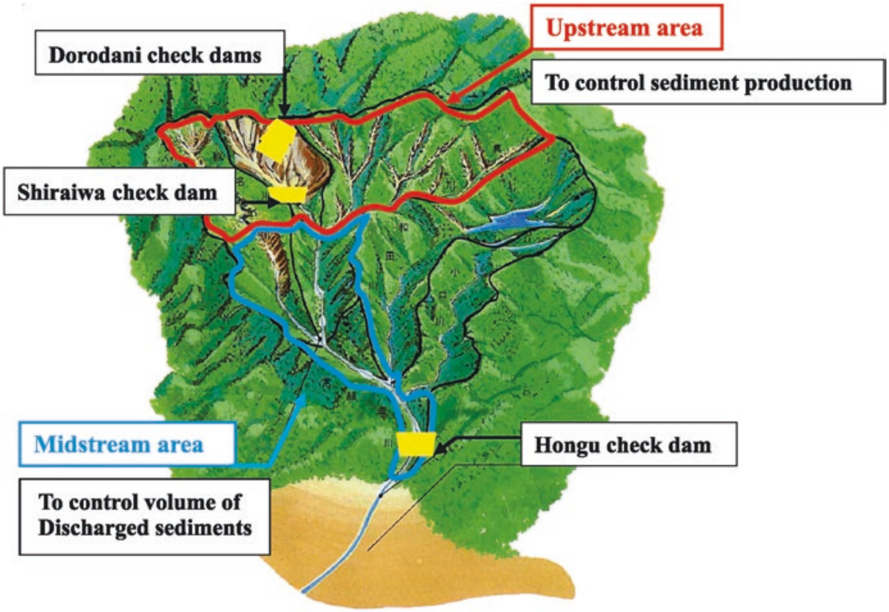


Fig. 10.12 Schematic diagram of holistic system of torrent control works in Tateyamara Caldera

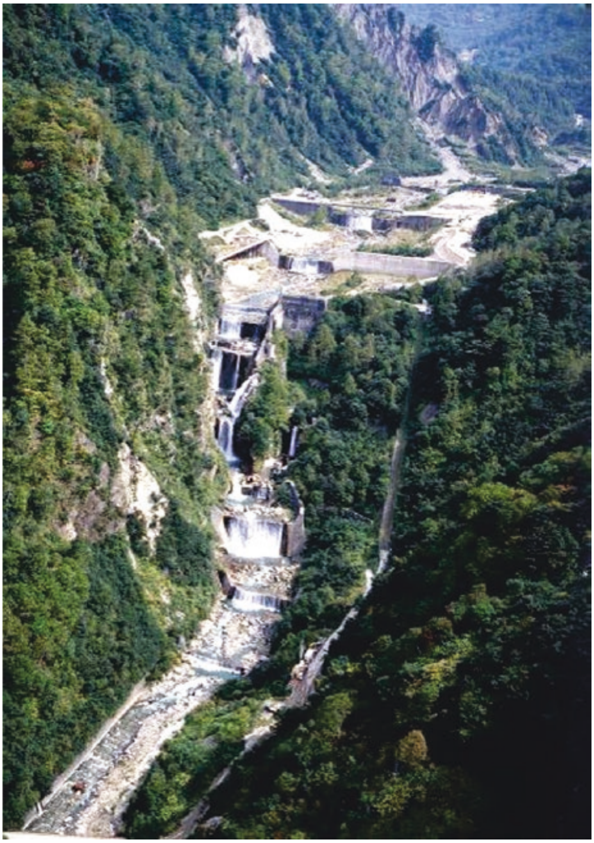


Fig. 10.13 Shiraiwa check dam

4.2 Comprehensive Watershed Management Against Jinnosukedani Landslide

Jinnosukedani landslide, which is located in the headwater catchment area of the Tedori River, is one of the most representative landslides in Japan. The length and the total catchment area of the Tedori River are 72 km and 809 km^2 respectively (Fig. 10.15). Tedori River has very dangerous torrential characteristics and repeatedly flooded. Especially the downstream area of the Tedori River has experienced disastrous flood after the landslide occurrence triggered by heavy rainfall and snowmelt in the headwater catchment in 1934. More than 100 people were killed by this flood. Abundant water amount in the watershed has been utilized for electric power generation, industrial use and irrigation for agriculture.

Tedorigawa dam was constructed between 1969 and 1979 as a multipurpose dam, which is utilized for flood control, industrial use and hydroelectric power generation. It is a rockfill type dam (Fig. 10.16) with the height of 153 m, the length of

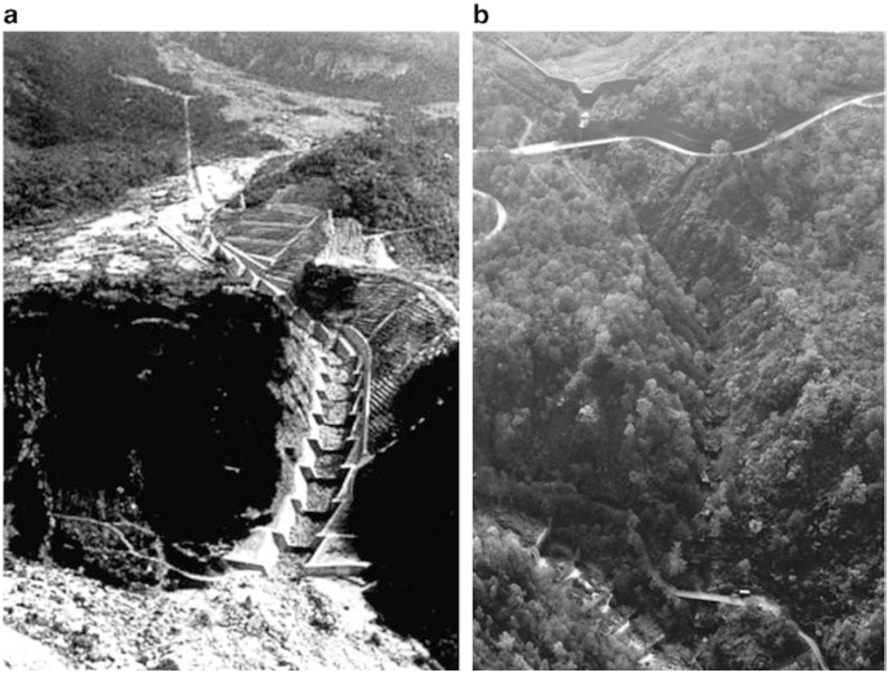
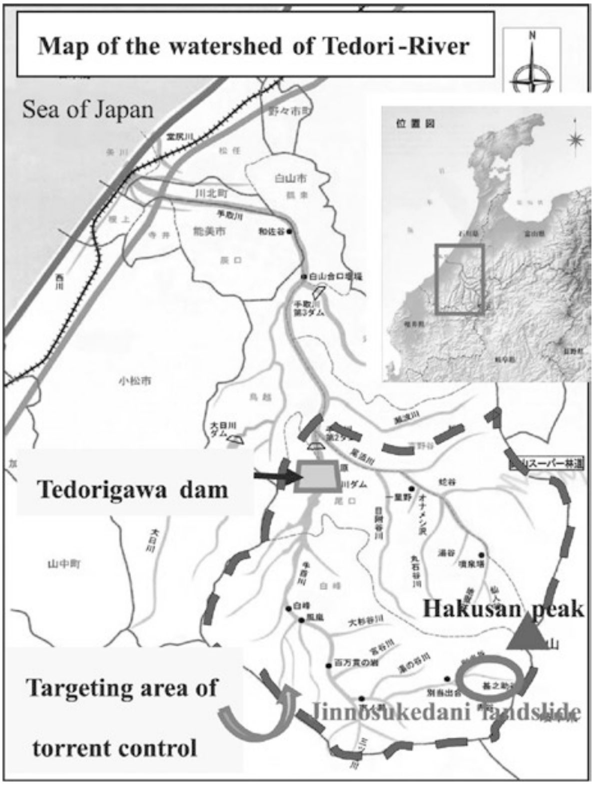


Fig. 10.14 Steps-like check dams in a steep gully (Dorodani). (**a**) Construction of dams in 1933. (**b**) Recent situation in 2007

420 m and the maximum volume of stored water about 10 million m^3. The total volume of the stored water amount is 231 million m^3 and 190 million m^3.

Concerning the countermeasures against Jinnosuke landslide, structural measures have been carried out only in the active sliding blocks (1.7 million m^3). However, very large potential sliding block (34 million m^3) is showing certain continuous movement. It is not feasible to stabilize such dimesion of potential block by installation of structural measures. Furthermore, extremely large area (500 ha) is designated as operational area for mitigation of landslide disaster as shown in Fig. 10.17. In this case, practically structural measures are only applicable for the active sliding blocks. Continuous monitoring should be carried out to detect the movement of the potential sliding block. If some dangerous movement over threshold value will be detected, appropriate alarming and evacuation should be operated. Concerning the unpredictable critical event of a extremely large scale landslide, displaced soil mass should be eventually retained in the reservoir area of the Tedorigawa dam. For this case of Jinnnosukedani landslide, comprehensive watershed management including torrent control works should be only possible way of disaster mitigation.

Fig. 10.15 Overview of watershed of Tedori River



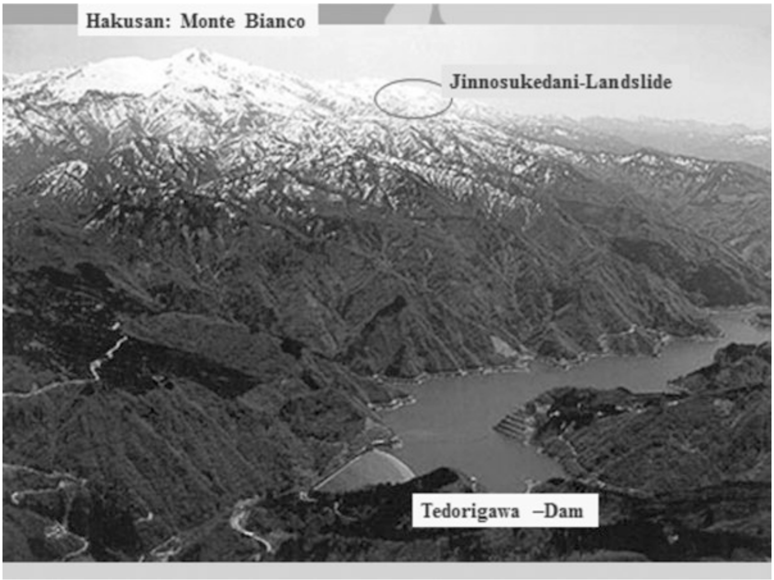


Fig. 10.16 Overview of Tedorigawa dam

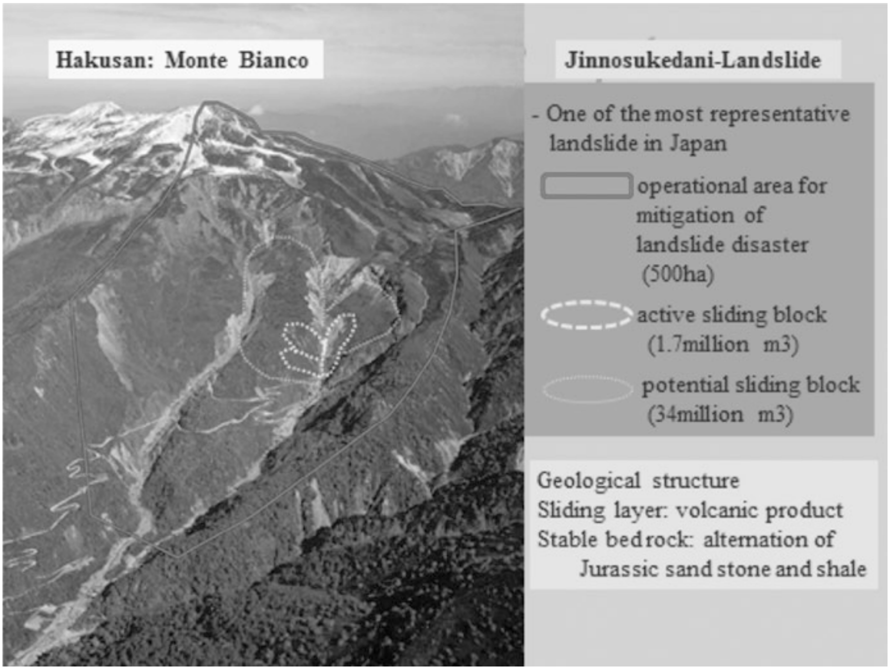


Fig. 10.17 Overview of Jinnosuke landslide

5 Conclusions

Mitigation of large scale landslide disasters is still very difficult task, although a certain basic knowledge is available. Main difficulties are lying on the complexity of the targeting phenomena, which have wide range of scales and types, and on the insufficient accuracy of prediction method and also on the unclear feasibility of countermeasures.

Practical disaster management should be planned on the basis of the clear identification of the target phenomena. It is urgently needed to develop appropriate prediction method with sufficiently higher accuracy in selection of endangered areas and also in occurrence time using hydrological approach.

Due consideration should be paid on the limitation of effectivity of structural measures against large scale landslides. With recognition of such limitation, practical non-structural measures like “arrangement of early warning and evacuation system” and “management of appropriate land-use” should be operated.

Concerning the unpredictable large scale landslide, most probably comprehensive watershed management should be only possible solution. For this purpose preparedness with “formulation of emergency disaster management plan” should be an essential item.

References

Chigira, M. (2014). Geological and topographic detection of dangerous slopes on large scale landslides. Abstract for the 63th annual meeting of SABO Society (in Japanese).

Hokuriku Regional Development Bureau. (2007). *Report on Jinnosukedani landslide*. www.hrr.mlit.go.jp/kanazawa/hakusansabo/H18_4-7_jinnosukepdf

Jitozono, T. (2014). Site prediction of potential deep-seated landslides by using electric conductivity of mountain stream water. *Journal of the Japan Society of Erosion Control Engineering, 66*(6), 56–59. (in Japanese with English abstract).

Kosugi, K. (2013). Prediction of occurrence time of large scale landslides using effective rainfall. Report for the seminar on deep-seated landslides, 2 (in Japanese).

Ministry of Land, Infrastructure and Transport. (2002). *Density map of scars of large scale landslides*. www.mlit.go.jo/common/000223656.pdf.

National Institute for Land and Infrastructure Management. (2012). *Actual state and management of deep-seated landslides*. www.nilim.go.jp/lab/bbg/kouenkai/kouenkai2012/pdf