Sediment-Related Disaster Forecasting Warning System Project

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Typhoon Committee
Sediment-Related Disaster Forecasting / Warning System Project

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TABLE OF CONTENTS

FOREWORD

The Typhoon Committee (TC) area is the region with the most severe natural disasters in the world, and floods are probably the most recurring, widespread, disastrous and frequent natural hazards in the region. According to the ADRC's Natural Disasters Data Book (2006), out of all natural disasters worldwide, the amount of deaths caused by sediment-related disasters comes to 1.1%. However, in Asia, the numbers come to 9.2%.

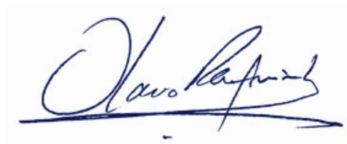
The aim of this Project on Sediment-Related Disaster Forecasting/Warning System is to build the framework for non-structural measures, especially the necessity of a sediment-related disaster forecasting/warning system, which helps in judgment during public evacuations.
This project, led by Japan, is one of the most successful projects of TC Working Group on Hydrology (WGH). It is in line with 2 of the 7 TC Key Results Areas (KRAs) of Strategy plan, namely: 1) to reduce the number of deaths by typhoon-related disasters by half (using the decade 1990-1999) in Typhoon Committee Region; and 2) to reduce the socio-economic impacts of typhoon-related disasters per GDP per capita by 20 per cent (using decade 1990-1999) as the base line to compare with the decade 2006-2015) in Typhoon Committee Region.

This project was kicked off in 2001. By that time, the TC had directed its assiduous efforts toward reducing disasters due to meteorological phenomena, notably typhoons. The Hydrological Component of the Committee, in cooperation with the Meteorological and Disaster Prevention and Preparedness Components, had pursued the upgrading of flood forecasting and warning systems, improvement of the statistics compilation system for natural disaster damage, etc. In the meantime, the socioeconomic conditions of most of the Committee Members had developed rapidly with the rapid growth of their populations, industries, and assets in urban areas. These socio-economic changes had led to important changes in the disaster patterns and its socioeconomic impacts. With the foregoing circumstances taken into account, the Typhoon Committee at its 33rd session in 2000 decided to undertake a comprehensive review of its activities in the Hydrological and Disaster Prevention and Preparedness Components, including a regional survey and an expert review mission to the Members to discuss the framework for these related activities. Based on the results of the regional survey compiled responses to the questionnaires and subsequent discussion at the Hydrology Workshop held in Bangkok in August 2001, a plan for priority action including 11 cooperation projects was submitted to TC at its 34th Session and approved by the Committee. The Government of Japan committed to take the lead of two of them: "Pilot project on the preparation of Inundation and Water-related Hazard Maps" and "Pilot project on the establishment on flash-flood warning system including debris flow and landslides".

During its implementation in the past 8 years, the project on Sediment-Related Disaster Forecasting / Warning System has been spreading the technique of establishing Sediment-Related Disaster Forecasting/ Warning among TC Members. There are 6 of 14 TC Members taking part in this project, namely: China, Malaysia, Vietnam, Thailand, United States of America and Japan.

Following a decision made at the forty-first session of the Typhoon Committee held in Chiang Mai, Thailand, from 19 to 24 January 2009, this project is going to be finalized in 2009. This final report aims to review and summarize the progress and the achievement of the project in the past years.

I am confident that the project has achieved the expected goals and its success will have a great impact in relation to the flood-related disaster prevention, preparedness and mitigation not only for the Typhoon Committee but also for the Members of the Panel on Tropical Cyclones, Hurricane Committee and other WMO Members. Also I believe that this final report does not mean the end of the cooperation related to sediment disaster prediction and warning in TC area. We are appreciated that a new project named "Hazard Mapping for Sediment-related Disaster Management" has been launched in 2009. I would like to express my appreciation to TC Members for their kind cooperation and great contribution to this project during the past 8 years.



Olavo Rasquinho
(Secretary of Typhoon Committee)

1. INTRODUCTION

1.1. Public Demand for Sediment-Related Disaster Measures

According to the ADRC's Natural Disasters Data Book (2006), out of all natural disasters worldwide, the amount of deaths caused by sediment-related disasters comes to 1.1%. However, in Asia, the numbers come to 9.2%. It is clear that Asia has a much higher amount of deaths compared to other regions.

The CREED EM-DAT Database, compiled by the ADRC, is filled with reports in categories such as "Over 10 deaths", "Over 100 people affected", "State of Emergency Announced", "International Aid Requested". Take Japan for example; although it is rare to reach a state of emergency, there are multiple reports of sediment-related disasters and deaths yearly. With this in mind, we can assume that there are yearly occurrences of sediment-related disasters in other countries as well.

There are various natural causes of sediment-related disasters, such as rainfall and earthquakes, but if you look at the overall frequency of occurrences, the vast majorities are caused by rainfall. Due to the natural setting of Southeast Asia, it is prone to typhoon damage as well, so there is a growing demand to reduce the potential risk.

1.2. Aims of the Establish a Flash Flood and Sediment-Related Disaster Forecasting / Warning Information System

To reduce the potential risk of sediment-related disasters, there are both structural and non-structural measures. The most common example of a structural measure is a check-dam or a run-off channel. Non-structural measures have limits when it comes to shelter and land use. Measures using structural methods have proved to control debris flow, but on the other hand they carry a large price tag. On one side non-structural measures, such as sediment-related disaster forecasting systems, or the maintenance of information hazard map creation systems don't require much money, but on the other side they can't actually contribute to the control of debris flow. Based on these features, to truly reduce the risk of sediment-related disasters, we need a combination of structural and non-structural measures.

The aim of this project is to build the framework for non-structural measures, especially the necessity of a sediment-related disaster forecasting / warning system, which helps in judgment during public evacuations. This project was started in 2002 as a part of the RCPIP. The content of the RCPIP was reconstructed at the 39th session in 2006 where 7 subjects to tackle and 14 objectives were brought together to form a strategic plan. From that point on, we used the same strategic plan as a base for the reconstruction of all of our projects.

The first point of this new strategy is in a position to contribute to reducing the loss of lives in typhoon related disasters.

1.3. Operation of the Establish a Flash Flood and Sediment-Related Disaster Forecasting / Warning System Project

This project was originally carried out between 2002 and 2007. The original plan was to have the participating members carry out tests on pilot areas and the applications for sediment-related disaster forecasting technology and make modifications between 2002 and 2005. After that the participating members planned to begin investing in the spread of technology to all areas within their boundaries.

At the time that this program began its development, sediment-related disaster forecasting systems were found to be underdeveloped on a worldwide scale. Because of that, this project was created to set precedence and were entrusted with Japan's early warning rainfall reference prediction technology to use as a base for implementation. Two years after beginning the project and creating the guidelines based on Japan's early warning rainfall reference prediction technology, some of the participating countries were delayed in arranging their model areas, others showed no occurrences of sediment-related disaster. Due to factors like these, the original goals remained unachieved. As a result, the deadline was extended 2 years, to 2009.

1.4. Details of the Final Report

In the final report we will outline how the technology was adapted to the sediment-related disaster forecast / warning information measure project and give details of the accomplishments of the 6 participating members, China, Malaysia, Vietnam, Thailand, The United States of America and Japan.

2. HOW TO FORECAST THE OCCURRENCE OF SEDIMENT-RELATED DISASTERS

2.1. Outline

At the present moment, the technique of properly and theoretical analyzing occurrences of sediment-related disasters is still in the experimental stage, so this project has been based on previous records of sediment-related disasters, and employed experience based techniques. The largest base influences on the occurrence of sediment-related disasters are topography and geology, and heavy rain acts as the catalyst. This project paid extra attention to rainfall to base the forecast system on.
With this in mind, Japan is making the criterion for the forecasting and warning system. We are not only using past rainfall observation data, but also holding on to the data of past occurrences of sediment-related disasters as well. With these tools, we have been able to make informed judgments to make a time based scale of occurrence and non-occurrence. To display the difference between occurrence and non-occurrence, we have created a simulation called “The Critical Line”. Utilizing this, we can predict the likelihood of occurrences by looking at a scale of the time and amount of rainfall. In an effort to save more human lives, when rainfall comes near the Critical Line (CL), it is necessary to begin preparation for evacuation. To that end, we have simulated not only the CL, but also an Evacuation Preparation Line. But, within the confines of this particular project, we will only express the CL.

2.2. Procedure for Determining the Critical

Figure 2.1 is a conceptual map of which the X and Y axis were calculated from the rainfall indexes. These indexes were compiled using past rainfall records and plotted on this graph. The black circles show occurrences of sediment-related disaster, and the white circles show cases of non-occurrence. It is possible to draw a direct line between these circles, this is the CL.

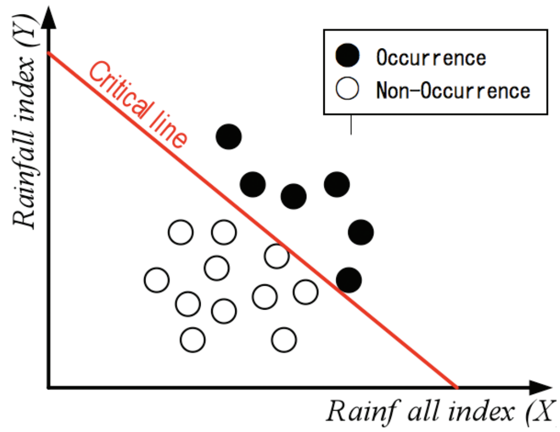


Figure 2.1 Critical Line Display

On Table 2.1, the X and Y axis give us a quick glance at the rainfall index information adapted from Japan’s 2004 records all together. We would like to introduce the following case in Japan: In the case of Guideline Method A, the X axis is the half-life of the day’s working rainfall and the Y axis displays hourly rainfall volume. In the case of Guideline Method B, the X axis is the effective rainfall volume, and Y axis displays the effective rainfall intensity. In the case of the Committee Method, the X axis is the half-life of 72hours of working rainfall, and the Y axis displays the half-life of 1.5 hours of working rainfall volume.

Table 2.1 Rainfall indexes of the Critical Line

	X axis	Y axis
Guideline Method A	Half-life of one day working rainfall	Hourly rainfall
Guideline Method B	Half-life of one day working rainfall	Effective rainfall strength
Committee Method	Half-life of working rainfall for 72hrs	Half-life of working rainfall for 1.5hours

Figure 2.2 shows a series of rainfall and is intended to calculate the rainfall volume index of Guideline Method A, Guideline Method B, and the Committee Method.

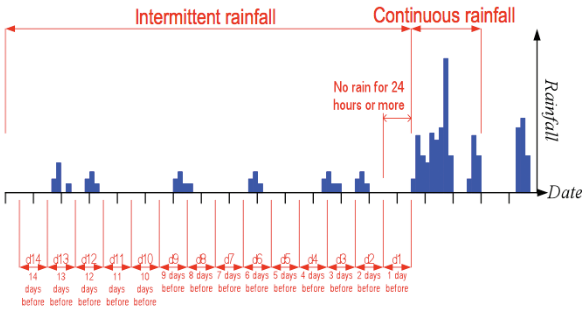


Figure 2.2 Continuous Rainfall Display

The various methods of working rainfall volume can be calculated with the formula:

$$R_W = \alpha_1 \cdot d_1 + \alpha_2 \cdot d_2 + \cdots + \alpha_{14} \cdot d_{14} = \sum_{t=1}^{14} (\alpha_t \cdot d_t) \quad \cdot \cdot \ (2.1)$$

In Formula 2.1, R_w is the working rainfall volume (mm), *t* is the reduction coefficient of *t* days earlier. *dt* is the rainfall volume within 24 hours *t* days earlier. The reduction coefficient can be calculated with the formula:

$$\alpha_t = 0.5^{t/T} \quad \cdot \cdot \cdot \ (2.2)$$

In Formula 2.2, *T* is the half-life of days. In Guideline Method A and Guideline Method B *T* = 1 In the Committee Method the X axis is *T* = 72/24=3, and the Y axis is *T* = 1.5/24 = 0.0625. The effective rainfall intensity can be calculated with the formula:

$$I_E = \frac{R_E}{T_E} \quad \cdot \cdot \cdot \ (2.3)$$

In Formula 2.3 I_E is the effective rainfall intensity (mm/h), *RE* is the effective rainfall (mm), and T_E is the effective time (hours). The effective rainfall is the total sum of rainfall volume beginning with the observation of a continuous rainfall at least 4mm/h which continues at this level or higher for the total duration of at least 3 hours. The effective time is the total time beginning with the observation of rainfall at least 4mm/h and continues at this level until rainfall below 4mm/h has been observed for over 3 hours.

In general, Guideline Method A is the standard system, but as stated above, when it is not easy to separate whether continuous rainfall will result in sediment-related disasters or if will result in non-occurrence, Guideline Method B is employed. Guideline Method A and Guideline Method B have the advantage of being easy to understand, but they have the disadvantage of not being able to predict time changes when it rains for extended periods of time or when rainfall is intermittent. In order to improve on the shortcomings of Guideline Method A and Guideline Method B, a new system was created. In 2004 the Committee Method gradually became mainstreamed. We must choose which system to employ based on the understanding of each technique's specialization, their compatibility with the CL of the region, and the intersection.

2.3. The Process of Setting the Critical Line

2.3.1. When there is Rainfall Volume Data

The Setting of the Critical Line can be broken down into 4 stages.

1. Choosing a observatory for rainfall data collection.
2. Collecting and compiling data on continuous rainfall resulting in occurrence and non-occurrence of sediment-related disaster.
3. Calculate the rainfall indexes from the data collected in stage 2 and plot it on the proper figure.
4. Find the general line between occurrence and non-occurrence.

Table 2.2 demonstrates how to calculate the rainfall indexes when sediment-related disaster occurs due to continuous rainfall. Similarly, Table 2.3 demonstrates how to calculate the rainfall indexes when sediment-related disaster didn't occur due to continuous rainfall. The working rainfall volume and the effective rainfall intensity are as stated above. Table 2.4 has been adapted to fill the gap of information related to continuous rainfall not resulting in the occurrence of sediment-related disaster.

Table 2.2 Calculation for rainfall indexes causing sediment-related disasters

	X axis	Y axis
Guideline Method A	The working rainfall (half-life of one day) one hour prior to the occurrence of sediment-related disaster	The hourly rainfall at the occurrence of sediment-related disaster
Guideline Method B	The working rainfall (half-life of one day) at the occurrence of sediment-related disaster	The effective rainfall strength at the occurrence of sediment-related disaster
Committee Method	The half-life of 72hrs of working rainfall at the occurrence of sediment-related disaster	The half-life of 1.5hrs of working rainfall at the occurrence of sediment-related disaster

Table 2.3 Calculation for rainfall indexes resulting in non-occurrence of sediment-related disaster

	X axis	Y axis
Guideline Method A	The working rainfall (half-life of one day) until one hour previous to the maximum one hour volume of rainfall	The maximum one-hour volume of rain within continuous rainfall
Guideline Method B	The working rainfall (half-life of one day) prior to continuous rainfall at 4mm/h for over 3hours	The effective rainfall strength from when rainfall above 4mm/h was first observed until rainfall of less than 4mm/h continued for over 3hours
Committee Method	The value half-life of the greatest 72hours of working rainfall at the time of the of the value of the half-life of greatest 1.5hours of working rainfall	The greatest 1.5hours of working rainfall (half-life of one day) within continuous rainfall

Table 2.4 Conditions for data on continuous rainfall not resulting in sediment-related disaster

Type of sediment-related disaster	Conditions
Debris flow	Continuous rainfall over 80mm, or hourly rain over 20mm
Slope failure	Continuous rainfall over 40mm, or hourly rain over 10mm

Table 2.5 List of natural conditions

Factors	Categories
Region	1. Volcanic regions
	2. Non-volcanic regions
Rainfall	1. Low rainfall region
	2. Average rainfall region
	3. Heavy rainfall region
Geology	1. Granite zone
	2. Volcanic ejection zone (active)
	3. Volcanic ejection zone (inactive)
	4. Tertiary sedimentary

The CL can be expressed in Guideline Method A, Guideline Method B, and in the Committee Method with this formula:

$$Y = aX + b \qquad \cdot\cdot\cdot (2.4)$$

Here, X and Y are the values of the rainfall indexes in compliance with the Method. The slope is represented by *a*, and *b* is the intersection. In the case of Guideline Method A, the value of *a* is required to be within the limits of $-1<a<0$.

2.3.2.When there is no Rainfall Volume Data

In the event that no rainfall data is available, it is not possible to follow the stages to set the CL in 2.3.1. So, values for the CL slope and intersection from Japan's 2004 records were gathered and looked into to find what range the values should fall into from the standpoint of the main cause and catalyst. The results are shown in Figures 2.3 to 2.5. On the basis of these results, we have the following process to set the CL. Also, in this situation we use Guideline Method A and the Committee Method techniques on Table 2.1.

1. When choosing a region to apply the CL to, an applicable index must be chosen for any natural conditions of note in the target region. (see Table 2.5)
2. Determine the average slope the CL, in other words choose the rainfall indexes from Table 2.1.
3. Use Formula 2.4 slope *a* value. For Guideline Method A *a*=-0.45, and for the Committee Method *a*=-0.9.
4. Choose a combination of the 100-year return period hourly rainfall/3 (mean value) and the working rainfall (mean value) equivalent to the conditions of the chosen target region (from stage 1) and the chosen CL determining technique (from stage 2).
5. Base the slope on the value determined in stage 3, the value of *X* on the working rainfall (mean value), and the value of *Y* on the 100-year return period hourly rainfall/3 (mean value) and calculate the intersection *b* using Formula 2.4.
6. Using the above method, finalize the value of slope *a* and the intersection *b*.

As shown on Table 2.5, a region whose 100-year return period daily rainfall is less than 250mm/day is categorized as a Low Rainfall Region, a region whose 100-year return period daily rainfall is between 250mm/day and 350mm/day is categorized as an Average Rainfall Region, and a region whose 100-year return period daily rainfall is over 350mm/day is categorized as a Heavy Rainfall Region.
Stages (1) through (6) for the procedure of determining the CL were created in reference to the specific case of Japan. They may not be suitable to the circumstances other countries. Therefore, to see if the CL is in accordance with the compiled data on whether or not there is a change in time or occurrence of sediment-related disaster needs to be verified regularly. In the event that adjustments need to be made, please refer to the applications in 2.3.1.

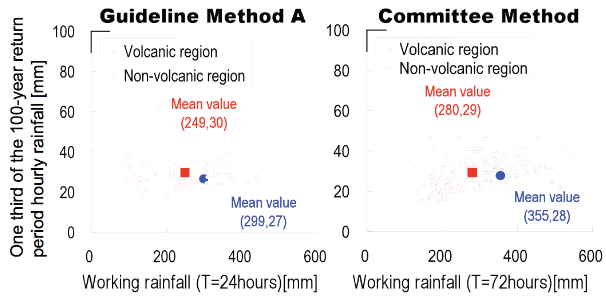


Figure 2.3 The relationship between one third of the 100-year return period hourly rainfall and the working rainfall Regional factors

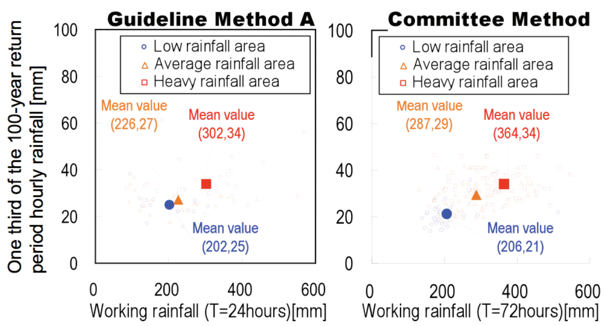


Figure 2.4 The relationship between one third of the 100-year return period hourly rainfall and the working rainfall Regional factors

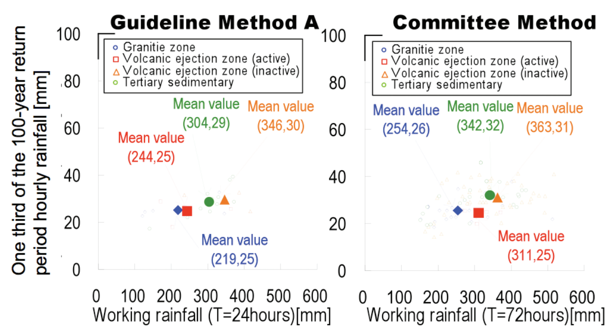


Figure 2.5 The relationship between one third of the 100-year return period hourly rainfall and the working rainfall Geological factors

2.4. An Example of the Critical Line

2.4.1. When there is Rainfall Data

Table 2.6 uses sample data. The data is based on Guideline Method A and the CL has been set. On Figure 2.6 occurrences of sediment-related disasters (in relation to continuous rainfall) are categorized with an “”, and non-occurrences with an “×”. On this graph the CL was drawn with the following points in mind:
All of the occurrences of sediment-related disaster have been plotted to the right of the CL.
Using Guideline Method A the value of slope of the CL must be between -1 and 0.

Table 2.6 Continuous Rainfall sample Data

Occurrence of sediment-related disaster	Rainfall at the occurrence of sedimentt-related disaster [mm/h]	Working rainfall until one hour prior to sedimentt-related disaster [mm]
	26	162.3
	14	112.3
	28	74.3
Non-occurrence of sedimentt-related disaster	Greatest hourly rainfall [mm/h]	Working rainfall until one hour prior to greatest hourly rainfall [mm]
	14	52.1
	32	20
	16	126
	8	39.2
	17	177.9
	12	67.4
	14	55.6
	11	68.5
	17	24.4
	19	51.1

2.4.2. When there is no Rainfall Data

Table 2.7 is based on the method described in 2.3.2 to determine the CL. Also, in Figures 2.7 to 2.12 the same CL is as in Figure 2.7. A straight line was created in accordance with the conditions of the region, so it is possible to determine the CL.

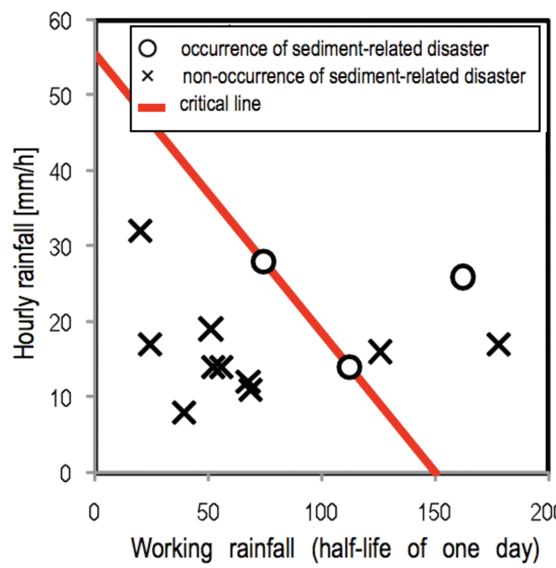


Figure 2.6 Working rainfall (half-life of one day) critical line display

Table 2.7 CL chart

Conditions	Cases	Guideline Method A	Committee Method
Region	Volcanic regions	y=-0.45x+161.6	y=-0.90x+347.5
	Non-volcanic regions	y=-0.45x+142.1	y=-0.90x+281.0
Rainfall	Low rainfall region	y=-0.45x+115.9	y=-0.90x+206.4
	Average rainfall region	y=-0.45x+128.7	y=-0.90x+287.3
	Heavy rainfall region	y=-0.45x+169.9	y=-0.90x+361.6
Geology	Granite zone	y=-0.45x+123.6	y=-0.90x+254.6
	Volcanic ejection zone (active)	y=-0.45x+134.8	y=-0.90x+304.9
	Volcanic ejection zone (inactive)	y=-0.45x+185.7	y=-0.90x+357.7
	Tertiary sedimentary	y=-0.45x+165.8	y=-0.90x+339.8

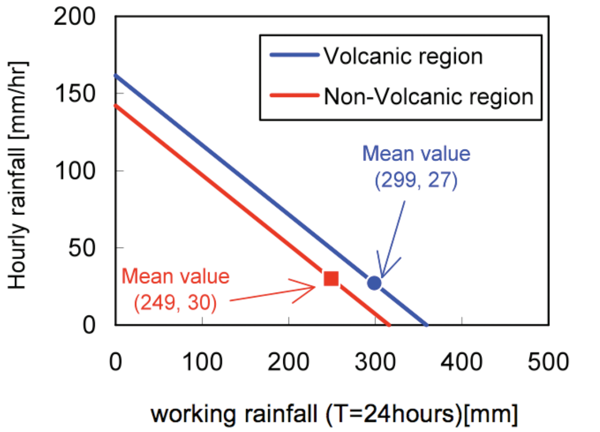


Figure 2.7 Standard CL using Guideline Method A Regional factors

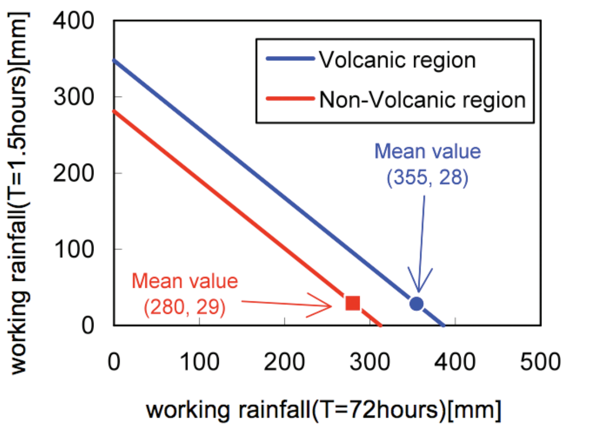


Figure 2.8 Standard CL using the Committee Method Regional factors

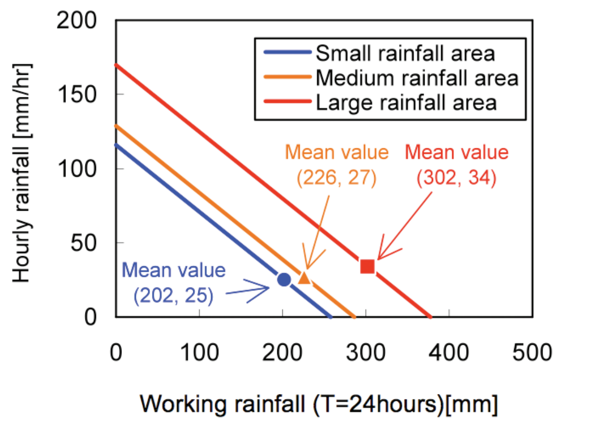


Figure 2.9 Standard CL using Guideline Method A Rainfall conditions

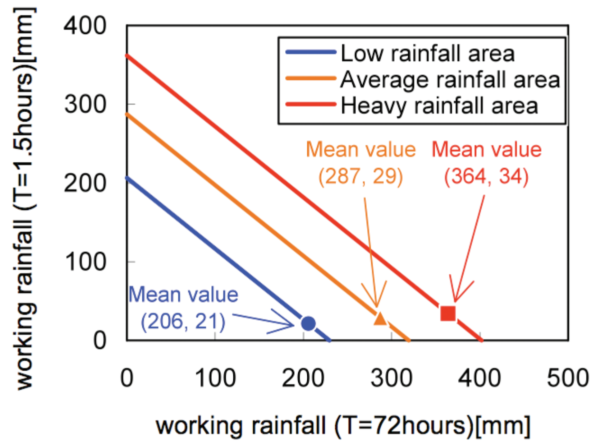


Figure 2.10 Standard CL using the Committee Method Rainfall conditions

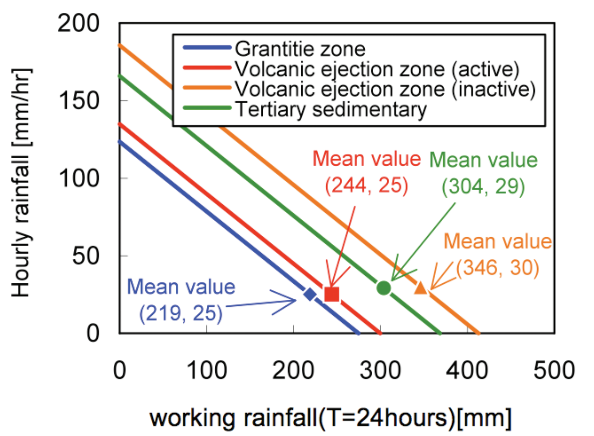


Figure 2.11 Standard CL using Guideline Method A Geological factors

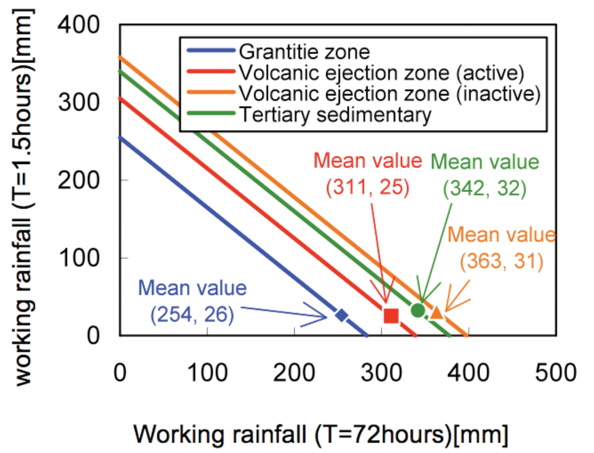


Figure 2.12 Standard CL using the Committee Method Geological factors

Let's check the accuracy of the CL on Table 2.7. The cases in subject are the main occurrences of sediment-related disasters in 2004. Table 2.8 shows the locations, times, and the regional conditions of occurrences of sediment-related disasters. The CL and Snakeline of each disaster is shown on Figures 2.14 to 2.25. As the geological conditions for the following regions were outside of the CL target, they have been excluded: Kamikatsu-cho (Tokushima Prefecture), Niihama-shi (Aichi Prefecture), Miyagawa-mura (Mie Prefecture). From the figures the CL, using both Guideline Method A and the Committee Method, we could acquire verification of all of the target disasters based on the rainfall conditions, and the effectiveness of the system. However, we have to take into consideration that due to regional and geological conditions, there are various points where disasters occur before crossing the CL. The actual application in these situations will necessarily cause the data to vary widely.

From the above, when there is not enough rainfall or disaster data, using the CL requirements as a base is the most effective means.

Figure-2.13 Location of sediment-related disasters

Table 2.8 Places where sediment-related disaster occurred and their natural conditions

Place of occurrence	Date of occurrence	Region	Rainfall	Geology
Tochio (Niigata pref.)	13-Jul-04	Volcanic	Low rainfall	Volcanic ejection zone (active)
Miyama (Fukui pref.)	18-Jul-04	Non-volcanic	Low rainfall	Tertiary sedimentary
Kamikatsu (Tokushima pref.)	1-Aug-05	Non-volcanic	Heavy rainfall	Other zone
Niihama (Ehime pref.)	17-Aug-05	Non-volcanic	Average rainfall	Fracture zone
Miyagawa (Mie pref.)	29-Sep-04	Non-volcanic	Heavy rainfall	Other zone

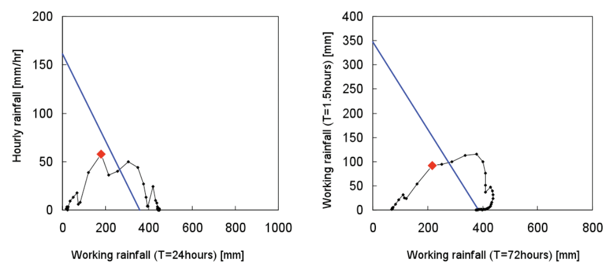


Figure 2.14 Case study in Tochio, Niigata pref. Regional factor volcanic

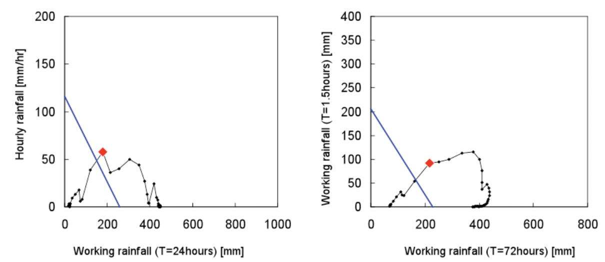
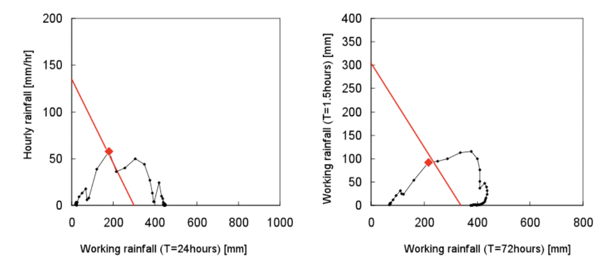
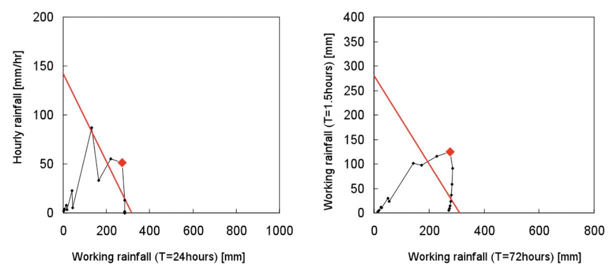


Figure 2.15 Case study in Tochio, Niigata pref. Rainfall condition Low



cal condition Volcanic ejection zone (active)



factor:non-volcanic)

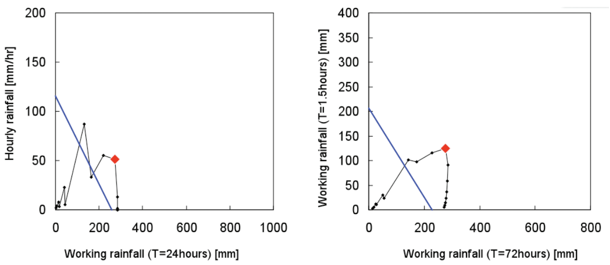


Figure 2.18 Case study in Miyama, Fukui pref.(Rainfall condition:Low)

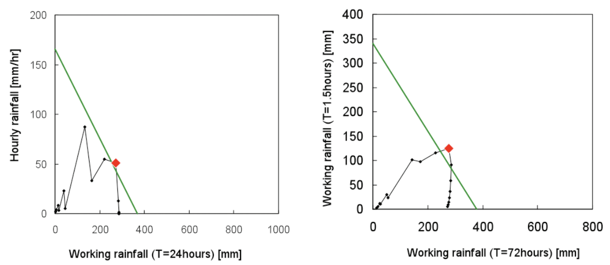


Figure 2.19 Case study in Miyama, Fukui pref. Geological condition Tertiary sedimentary

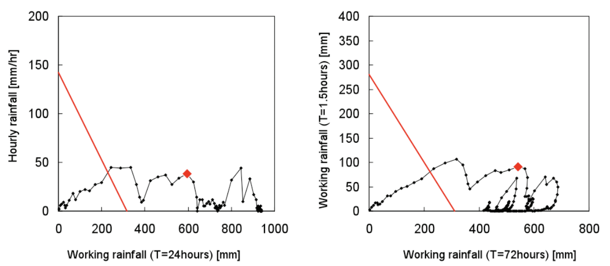
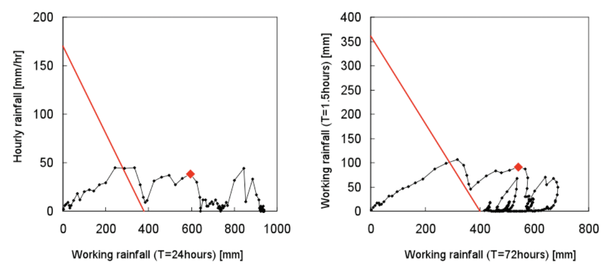


Figure 2.20 Case study in Kamikatsu, Tokushima pref. (Regional factor:non-volcanic)

Figure 2.21 Case study in Kamikatsu, Tokushima pref.



(Rainfall condition:Heavy)

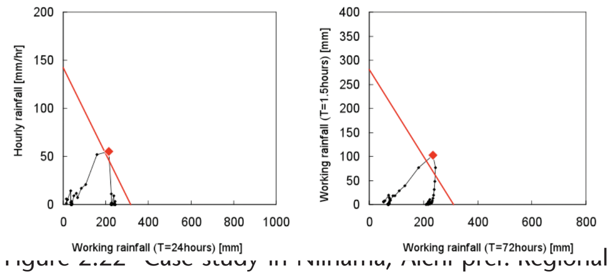


Figure 2.22 Case study in Niihama, Aichi pref. Regional factor non-volcanic

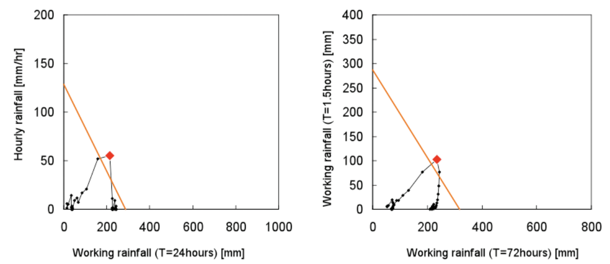


Figure 2.23 Case study in Niihama, Aichi pref. Rainfall condition average

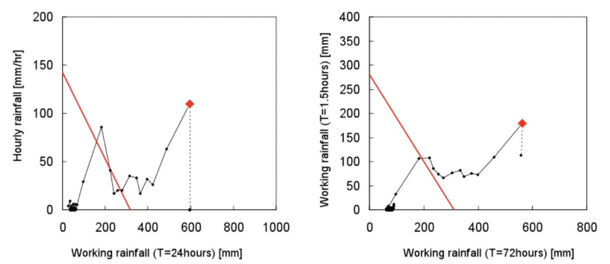


Figure 2.24 Case study in Miyagawa, Mie pref. Regional factor non-volcanic

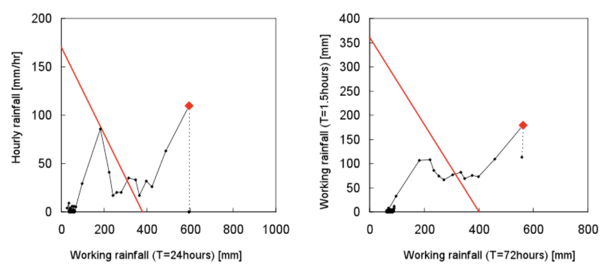


Figure 2.25 Case study in Miyagawa, Mie pref Rainfall condition Heavy

3. ACCOMPLISHMENTS OF THE PARTICIPATING COUNTRIES

3.1. China

3.1.1. Outline

Figure 3.1.1 shows the topography of China. 2/3 of China is occupied by mountainous regions, and has complicated topography including areas of fragile geology where heavy rainfall causes sediment-related disasters with a terrible effect.

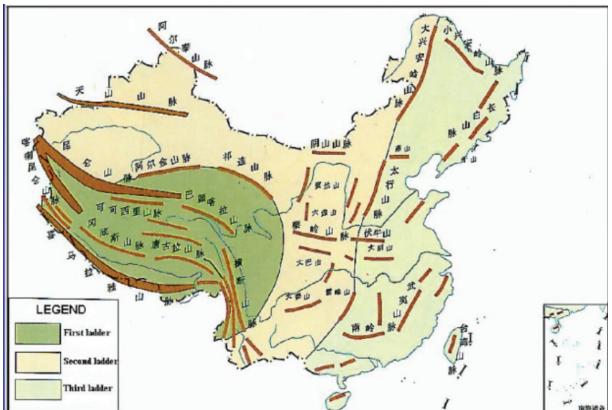


Figure 3.1.1 China's Topographical Features

3.1.2. Sediment-Related Disaster Status and Introduction of Measures

3.1.2.1. Sediment-Related Disaster Status

Figure 3.1.2 shows the distribution of sediment-related disaster occurrence in 2004. Looking back to the 10 years between 1992 and 2002, especially in the Yunnan, Guizhou, Sichuan, and Shanxi Provinces, over 400 areas experienced the occurrence of sediment-related disasters. We found over 60 areas with a high risk for sediment-related disasters. A majority of them occurred in repetition between June and September. In this manner a great about of lives and property were lost to sediment-related disasters. Photo 3.1.1 shows an example of this.

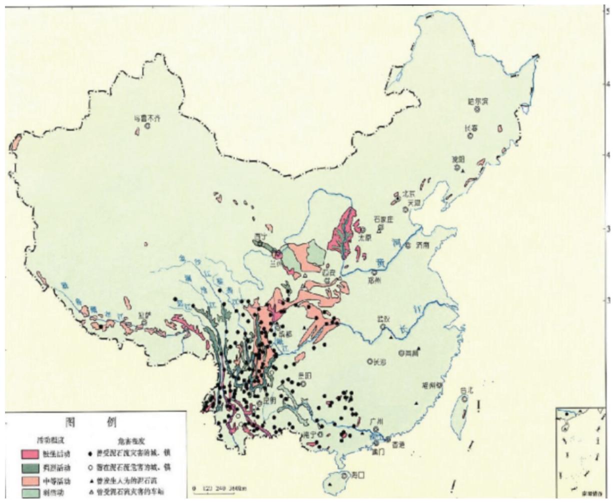


Figure 3.1.2 2004 Occurrences of Sediment -Related Disasters

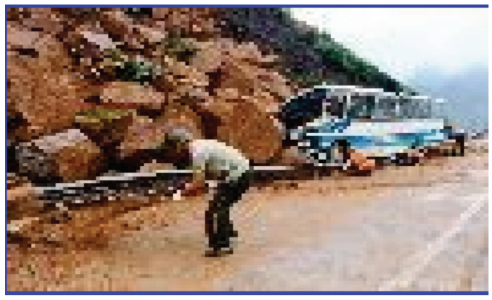


Photo 3.1.1 Example of Sediment-Related Disaster

Figure 3.1.3 is the progression rate of deaths caused by sediment-related disaster and floods and deaths caused by sediment-related disasters alone, based on statistical data from the Office of State Flood Control and Drought Relief Headquarter of China. The following 2 points can be read from Figure 3.1.3:

1. Although the amount of deaths have fallen in the 10 years between 1992 and 2002, the fact that sediment-related disasters are clearly accompanied by economic, social, population and property centered disasters is becoming more and more obvious.
2. In 2003, the number of deaths dropped by 597, and (the sediment-related disaster) ration dropped below 50%, making it a year of historical importance. However, the amount of deaths due to flooding and sediment-related disasters increased.

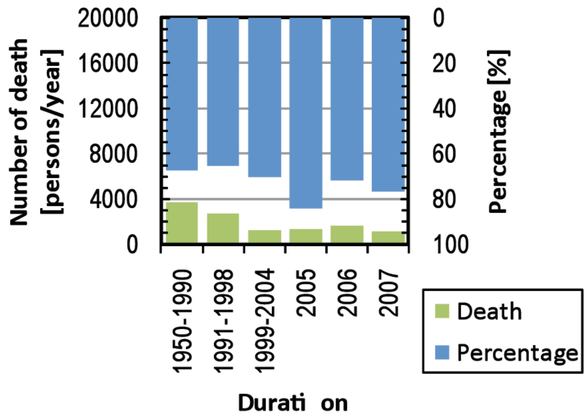


Figure 3.1.3 Number of Deaths Related to Sediment Disaster, and Percentage of deaths from Sediment-Related Disasters and Flooding

3.1.2.2. Sediment-Related Disaster Prevention Law

Since the Ministry of Water Resources, China Meteorology Administration, and Ministry of Land Resources introduced sediment-related disaster prevention laws in 2003, a lot of money has been spent on prevention methods, especially in the area of warnings. The sediment-related disaster prevention laws give attention to the following 3 points:

1. Clarify sediment-related disaster hazard regions
2. Create a warning/evacuation system
3. Encourage relocation of homes in the hazard regions

This project will report in more detail on (1) and (2).

3.1.2.2.1. Produce of Sediment Disaster Hazard Area

Based on the sediment-related disaster prevention laws, each province has examined the following categories and has drawn out the sediment-related disaster hazard areas:

1. Rainfall requirements
2. Topography requirements
3. Economics requirements

These regions show a risk for sediment-related disasters and high chance of flooding.

Figure 3.1.4 shows the Shanxi Province's sediment-related disaster procedural flow-chart as an example.

Figure 3.1.5 shows the location of Shanxi, which is in central China.

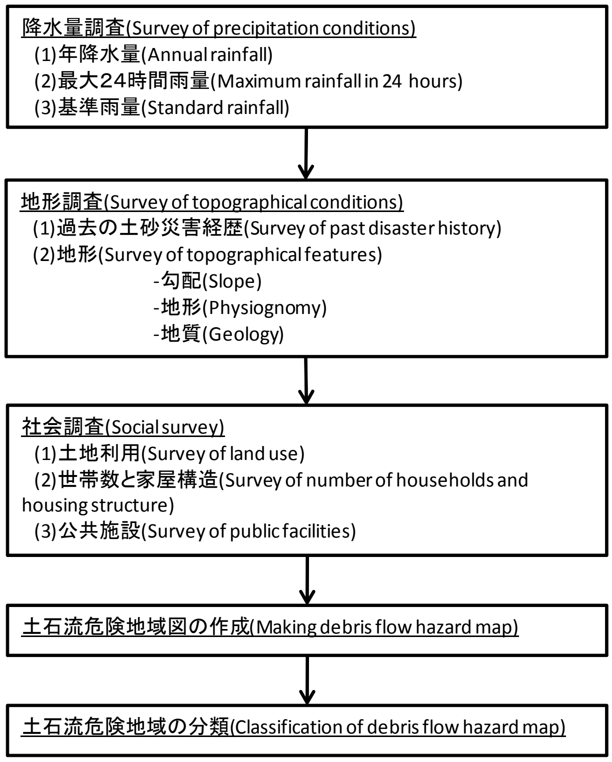


Figure 3.1.4 Investigation Process

Figure 3.1.5 Map of Shanxi Province

3.1.2.2.1.1. Investigation of Precipitation Conditions

Table 3.1.1 shows the average rainfall ranking and the volume distribution for the regions. The regions with high values are denoted as Region , moderate values are denoted as Region, and low values are designated as Region. The Shanxi Province was divided following this criterion.

Table 3.1.1 Ranking of Yearly Mean Rainfall

	Requisites	Region
Region (high)	750 R_m	Southern
Region (medium)	550 $R_m < 750$	Central
Region (low)	$R_m < 550$	Northern

Rm: Yearly Mean Rainfall [mm]

Table 3.1.2 shows the distribution of the years maximum rainfall in a 24hr period. The regions with high values are denoted as Region 1, moderate values are denoted as Region 2, and low values are designated as Region 3. In Shanxi there is a strong relationship between the maximum rainfall in a 24hr period and the occurrence of sediment-related disasters. Following this table, the average yearly rainfall has been again divided into the areas with the most and least yearly rainfall within a 24hr period.

Table 3.1.2 Ranking of Maximum Yearly Rainfall in a 24hr Period

	Requisites
Region 1 (high)	90 H_{24}
Region 2 (medium)	70 $H_{24} < 90$
Region 3 (low)	$H_{24} < 70$

H24:Maximum Yearly Rainfall in a 24hr Period [mm]

Table 3.1.3 shows the division of regions according to the critical rainfall. The regions with high values are denoted as Region (1), moderate values are denoted as Region (2), and low values are designated as Region (3). The critical rainfall is a division of the {average value of a period of rainfall} by {the critical rainfall of the same period}. The critical rainfall is defined as follows:

Table 3.1.3 Ranking of Critical Rainfall Coefficient

	Requisites
Region (1) (high)	1 K
Region (2) (medium)	0.84 $K < 1$
Region (3) (low)	$K < 0.84$

K: critical rainfall coefficient

A region is assumed to have S amount of rainfall observation stations and have N occurrences of sediment-related disasters. Out of that coming to the j^{th} sediment-related disaster at the i^{th} observatory's maximum rainfall for t-period of time is labeled as R_{tij}. R_{tij} is the calculation for all N occurrences of sediment-related disaster. Out of those, the R_{tij} with the least value becomes i^{th} observatory's t-period critical rainfall. In other words the t-period critical rainfall can be calculated from this formula:

$$R_{tiCritical} = \mathrm{Min}(R_{tij}) \quad (j=1,2,\cdots,N) \cdots (3.1)$$

Here, $R_{tiCritical}$ is the i^{th} observatory's critical rainfall coefficient. One region's t-period critical rainfall is the average of all the observatory's t-period critical rainfall in that region.

$$\overline{R_t} = \frac{\sum_{i=1}^{S} (R_{tiCritical})}{S} \quad \cdots\cdots (3.2)$$

Here $\overline{R_t}$ is the critical rainfall coefficient, and S is the amount of rainfall observatories in a region. The area of a region is around 20×20km². In addition, on the basis of past records, the t-period is 6hr. The t-period is the previously mentioned time period. Figure 3.1.6 was derived from the above mentioned classifications.

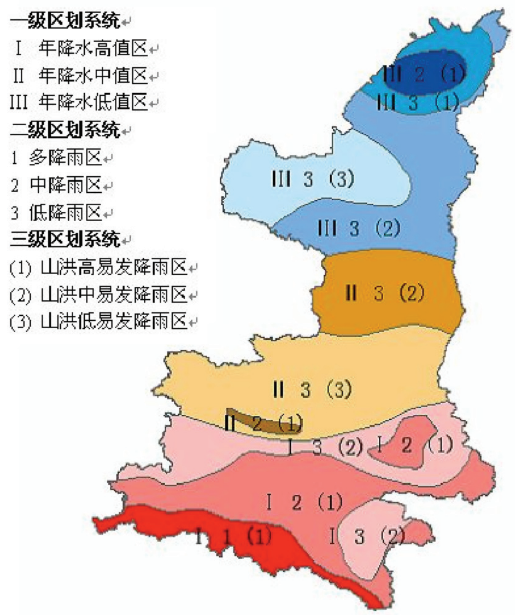


Figure 3.1.6 Rainfall Index Distribution

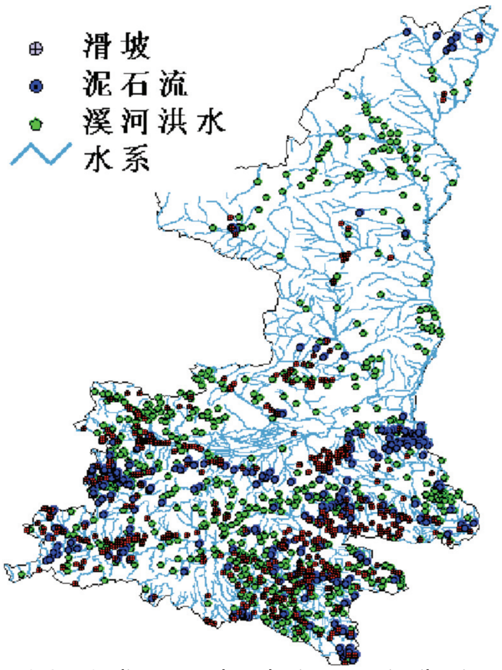


Figure 3.1.7 Sediment-Related Disaster Distribution

3.1.2.2.1.2. Investigation of Topographical Conditions

Next, an investigation to the topography was undertaken. Figure 3.1.7 is a distribution of occurrences of sediment-related disasters in Shanxi based on the last 7 years records. Figure 3.1.8 shows the distribution of slope angles by area. Figure 3.1.9 shows the distribution of topography by area. Figure 3.1.10 shows the distribution of geology by area. Figure 3.1.11 is a sediment-related disaster occurrence forecast map, made from a compilation of Figures 3.1.7 to 3.1.9.

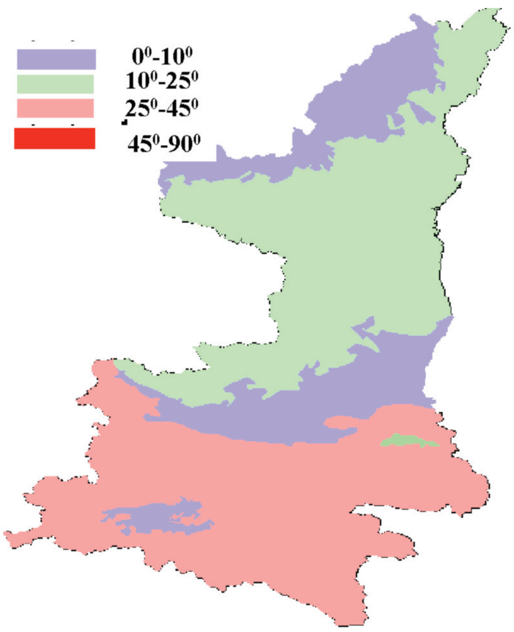


Figure 3.1.8 Slope Distribution

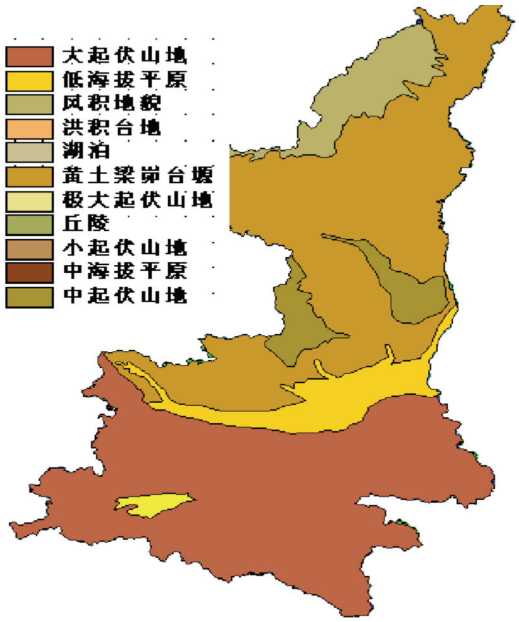


Figure 3.1.9 Topographical Distribution

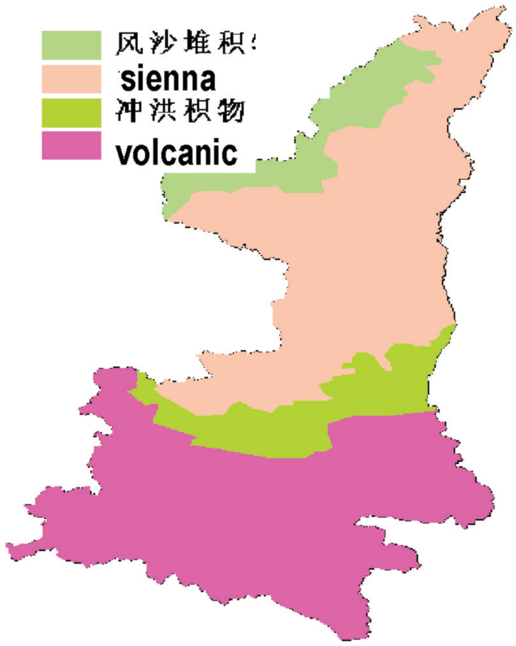


Figure 3.1.10 Geographical Distribution

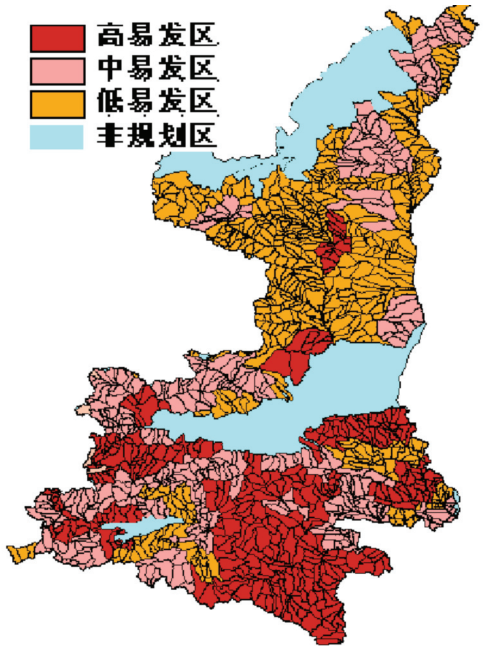


Figure 3.1.11 Sediment-Related Disaster Forecast

3.1.2.2.1.3. Social Investigation

The next step was conducting an investigation of social economics. Figure 3.1.12 is a social economic map based on the number of families and homes, public facilities, and businesses.

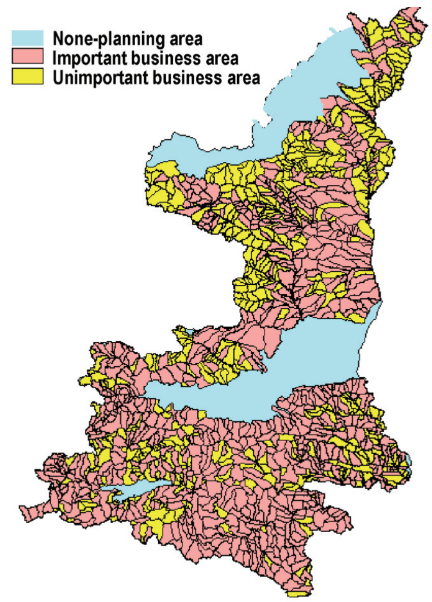


Figure 3.1.12 Economic and Social Distribution

3.1.2.2.1.4. Produce of Sediment Hazard Map

Next, based on the above analysis a sediment-related disaster hazard map was formed. Figure 3.1.13 was created based on a combination of rainfall requirements (Figure 3.1.6), topographical requirements (Figure 3.1.11), and social economic requirements (Figure 3.1.12). This map was divided into: areas requiring sediment-related disaster prevention: Class 1 and Class 2; areas requiring moderate protection; and areas not requiring protection.

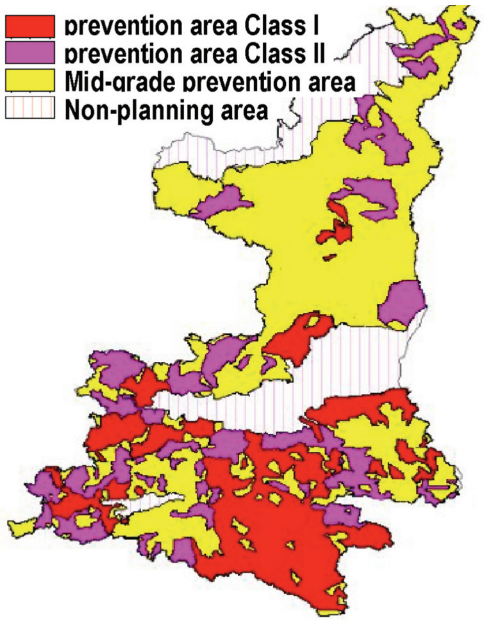


Figure 3.1.13 Sediment Related Hazard Distribution

Development of the Warning and Evacuation System (The Project Results)

Methodology

Analysis methods for real time forecasting were deliberated. To be more specific, the rainfall settings were based on past streams of observation data. On a graph, the prediction line or the territory used is divided into 2 rainfall groups. If rainfall volume exceeds the prediction line is crossed or enters the territory, debris flow occurs.

3.1.2.2.2. Outline of the Model Watershed

3.1.2.2.2.2.1. Shi Jia Gao

Figure 3.1.14 is a map of the Shijiagau River, which is one of the headwaters of the Yangtze River watershed, which flows through Shichuan Province. Due to the geographical and topographical features of the Shijiagou river watershed, the watershed is often met with sediment-related disasters. According to past data, there is an occurrence of sediment-related disaster once every 3 years on average.

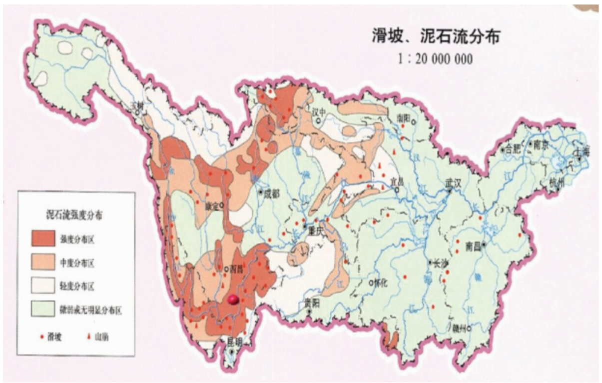


Figure 3.1.14 Shijiagou River watershed

Table 3.1.4 shows the magnitude of the sediment-related disasters, which occurred in the past in the Shijiagou river watershed.

Table 3.1.4 Magnitude of Sediment-Related Disasters

No	Date	Discharged sediment	
		Area [m²]	Volume[m³]
1	1991/10/07	1,500	1,800
2	1991/10/08	3,500	5,250
3	1991/10/14	1,620	1,782
4	1991/10/18	1,650	1,980
5	1991/10/21	1,830	2,379
6	1993/09/12	2,010	3,015
7	1995/07/23	1,350	1,620

Table 3.1.5 shows the continuous antecedent rainfall (in the case of occurrence and non-occurrence) and highest 24hr period of rainfall (in the case of occurrence and non-occurrence) between 1959 and 1996. Each year was divided into one of 2 categories: rainfall leading to sediment-related disaster and rainfall

leading to non-occurrence.

Figure 3.1.15 is a division of Table 3.1.5's data of occurrence and non-occurrence of sediment-related disasters. From this graph we can say the following points:

1. It is possible that there will be debris flow when the continuous antecedent rainfall exceeds 66mm and the rainfall within a 24hr period exceeds 28mm.
2. Even if the continuous antecedent rainfall does not exceed 66mm, when the rainfall in a 24hr period exceeds 62mm, there might also be the possibility of debris flow.

Table 3.1.5 Division of Occurrence and Non-occurrence

	Date	Continuous antecedent rainfall [mm]	Daily rainfall [mm]	Total [mm]
Causeing rainfall	Jul. 1959	2.1	84.8	86.9
	Sep. 1965	91.7	28.9	120.6
	Sep. 1968	14.7	63.2	77.9
	Aug. 1971	44.6	72.4	117.0
	Sep. 1978	91.4	106.3	197.7
	Jul. 1974	100.6	33.1	133.7
	Sep. 1976	97.9	42.9	140.8
	Sep. 1980	27.3	71.8	99.1
	28 Jun. 1981	16.7	66.9	83.6
	23 Jun. 1983	16.3	92.7	109.0
	7 Oct. 1991	66.3	3.2	69.5
	12 Sep. 1993	99.6	54.2	153.8
	23 Jul. 1995	80.4	2.0	82.4
Non-causing rainfall	1960	27.7	56.9	84.6
	1961	30.6	44.8	75.4
	1962	19.2	47.2	66.4
	1963	43.6	43.9	87.5
	1964	16.9	57.1	74.0
	1966	63.7	52.8	116.5
	1967	10.1	63.0	73.1
	1969	47.1	57.7	104.8
	1970	57.4	58.1	115.5
	1972	10.5	51.1	61.6
	1975	27.0	33.4	60.4
	1977	41.5	66.6	108.1
	1978	46.5	76.2	122.7
	1979	107.2	64.1	171.3
	1992	22.9	83.8	106.7
	1994	56.0	42.8	98.8
	1996	35.2	66.6	101.8

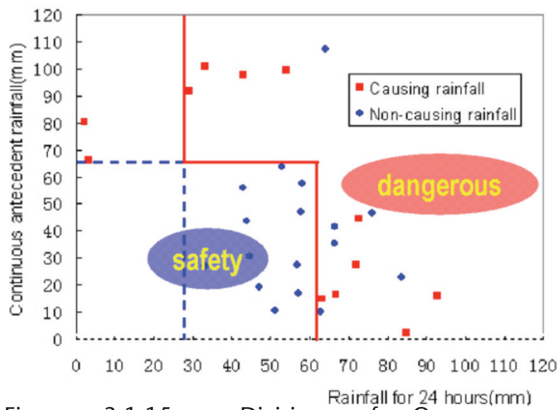


Figure 3.1.15 Division of Occurrence and Non-occurrence

3.1.2.2.2.2.2. Huangjin

Dazhou city in Sichuan Province has also proposed to pilot a sediment-related disaster warning system project. Dazhou is famous for it's regular occurrences of sediment-related disasters. There was a disaster in Huangjin in 2005.

Figure 3.1.16 shows the CL from the Maoba observatory, a city near Huangjin. The CL was applied to the Huangjin observatory. Figure 3.1.17 is an example of a real-time forecast. From this example, you can see that there was debris flow, and the snake-line crossed the CL.

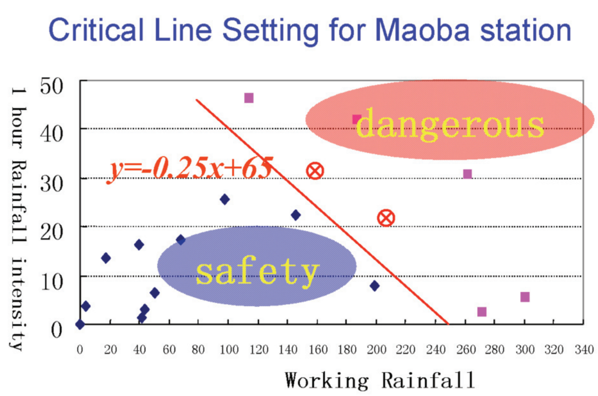


Figure 3.1.16 CL for Maoba Observatory

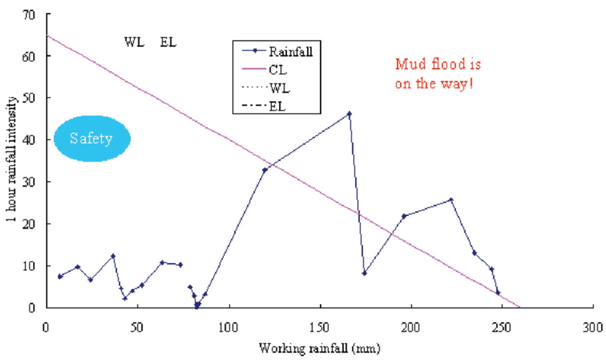


Figure 3.1.17 Real-time Forecast CL

3.1.2.3. Development of Areas Outside the Model watershed

In October of 2006, the National Council approved and began enforcement of the National Mountain Flood Protection Plan. To protect mountain streams from disasters, this plan calls for giving attention to 29 provinces targeting small watersheds under 200km^2 (32,753 watersheds). This project cost an investment of 25,000,000,000 USD. The first goal of the National Mountain Flood Protection Plan was to reduce the amount of injuries and lives lost with a combination of protection and relief measures, where the protection measures take precedence. In addition, they plan to use a combination of structural and non-structural measures, where the non-structural measures take precedence. This includes reinforcing the management of hills, mountains, and the relocation of citizens. The base of this project is the implementation of a weather monitoring system including the development of an automatic monitoring network, a weather radar observatory, and so on. In the debris and mud-flow of 1926, disasters were observed in 2,676 landslide hazard areas.

Figure 3.1.18 shows how the methods described in 3.1.2.2.1 were applied to areas outside the model watershed. Here, the values shown in Table 3.1.5 were altered, where in Region (1) k is a value over 1.2, in Region (2) k is a value over 1, and in region (3) k is a value below 1.

Figure 3.1.19 is a screenshot of the rainfall observation system with the Flash Flood Forecast and Warning System in the case of the critical rainfall method. A change in rainfall can be observed from 3 indexes: the critical rainfall, the maximum rainfall volume, and the return period.

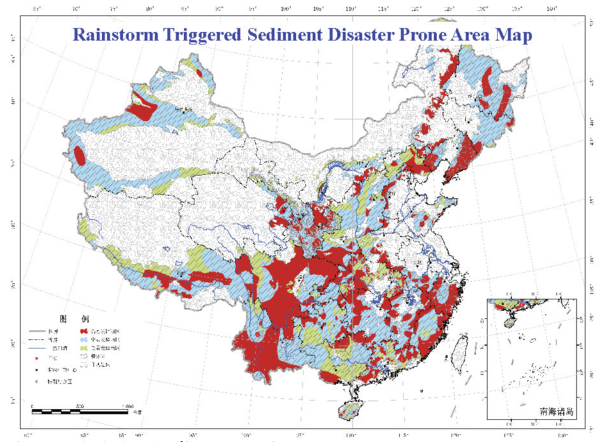


Figure 3.1.8 Sediment Disaster Prone Area Map

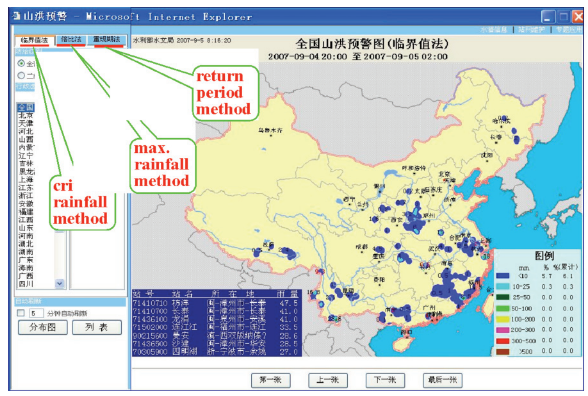


Figure 3.1.19 Screenshot of Flash Flood Warning Information System

3.1.3. Conclusion

Out of all natural disasters in China's mountainous regions, mountain floods have the largest loss of human life.

The National Mountain Flood Protection Plan has been accepted in China. First, a plan must be made to control mountain floods, and attention must be given to protection. Then, focus must be given to non-structural measures, protection, and relief measures. This plan is made up of, observation, information gathering, a warning platform, information referencing, forecasting, decision-making, and warning announcements.

To improve this system in the future, the following points need to be given attention:

1. Quantitative Precipitation Forecast (QPF)
2. Forecasting from a radar rain gauge
3. Forecasting from a radar rain gauge
4. A physical distribution model
5. A landslide and debris flow forecasting model

3.2. Japan

3.2.1. Outline

The area of Japan is covered 70% in mountains, and only 30% in plains. As sediment-related disasters occur on mountains and at the feet of mountains, Japan has few areas that can be considered safe.

Figure 3.2.1 shows the distribution of yearly rainfall in 1987. Most areas along the sea-line have a high yearly rainfall volume. From the observations between 1971 and 2000, the average yearly rainfall varied between 802mm and 3,922mm. As a general rule, the rainy season is between June and July. Between 1971 and 2000, only 2.6 typhoons per year landed in Japan on average. Most typhoon landings are concentrated in August and September. The rainfall in the rainy season and the typhoon season is very heavy.

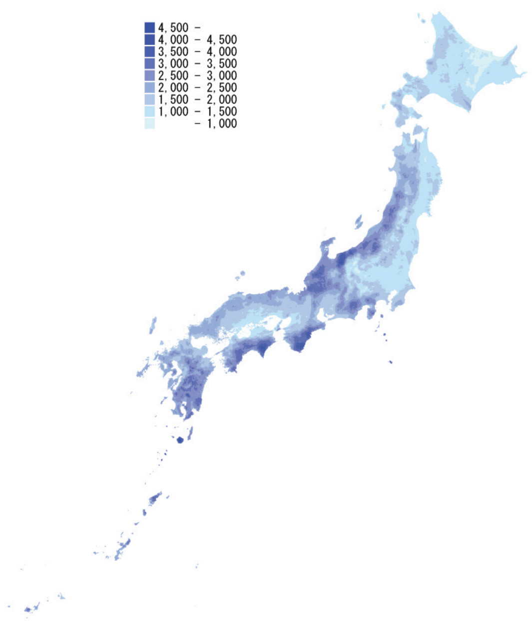


Figure 3.2.1 Distribution of Annual Rainfall (At the FY 1987)

In Japan, to prevent against sediment-related disasters, structural and non-structural measures have been undertaken. Photo 3.2.1 is an example of a structural measure consisting of a check-dam connected to channel works to catch and control debris flow. Photo 3.2.2 is an example of a non-structural measure, consisting of a rain-gauge for monitoring rainfall activity and a speaker system to inform locals of warnings.

Photo 3.2.1 Example of structural measures

Photo 3.2.2 Example of non-structural measures

The Japanese government is divided into 3 levels: national, prefectural, and local. Structural measures are mainly controlled by government on the prefectural and national levels. The national branch responsible is the Ministry of Land, Infrastructure, Transport and Tourism (MLITT). Non-structural measures are mainly controlled by government on the local and prefectural levels. This project, in relation to warning and information of sediment-related disasters, is mainly controlled by MLITT's Erosion Control Division, the Japanese Meteorological Agency, and the prefectural government.

3.2.2. Sediment-Related Disaster Status

Figure 3.2.2 shows number of sediment-related disaster occurrences in the last 5 years between 2003 and 2007. In Japan sediment-related disasters are divided into 3 categories: debris flow, landslides, and slope failure. Within these categories, the disaster with the highest rate of occurrence is slope failure, where debris flow and landslides are tied for 2nd place. Of all the sediment-related disasters in this period (6,655 cases), 16% are attributed to debris flow (1,078 cases), 17% are attributed to landslides (1,139 cases), and 67% are attributed to slope failure (4,438 cases).

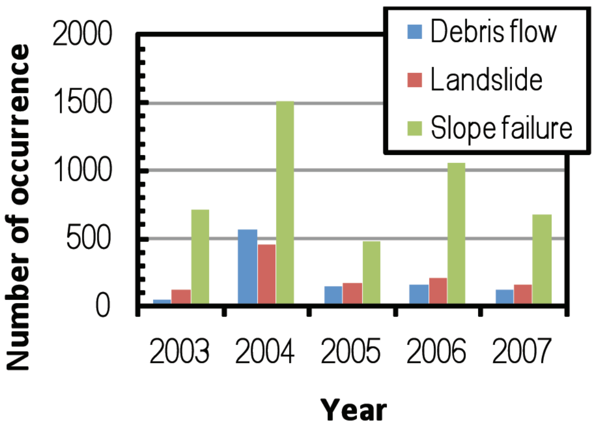


Figure 3.2.2 Sediment-Related Disasters Occurrence Frequency

Figure 3.2.3 shows the number of fatalities due to sediment-related disaster occurrences in the last 5 years between 2003 and 2007. Fatalities are ranked from highest to lowest, with debris flow at the top, and landslides at the bottom. Of the total number of deaths (140 fatalities), 57% were due to debris disaster (79), 11% due to landslides (16), and 32% due to slope failure (45). The ratio of fatalities is as follows:

- Debris flow: 0.073/case
- Landslides: 0.014/case
- Slope failure: 0.010/case

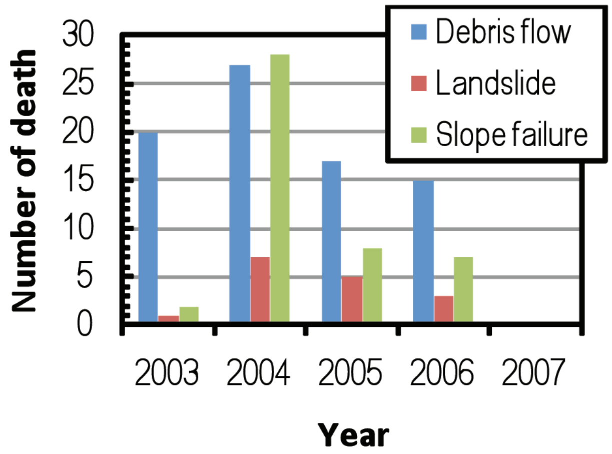


Figure 3.2.3 Number of Deaths Caused by Sediment-Related Disasters

As you can see, the effect of debris flow has the tendency to cause great loss of human life. Figure 3.2.4 shows the locations of areas in which debris flow disasters occurred between 2001 and 2005. It is clear that sediment-related disasters occur all over the country.

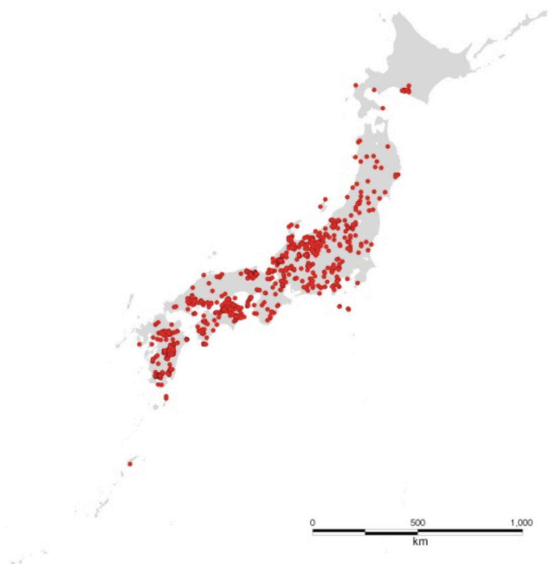


Figure 3.2.4 Location of Debris flow

3.2.3. Development of the Warning and Evacuation System (The Project Results)

As the leader of this project, Japan offers solution techniques to technological problems and issues as well the management of progress. The following are some of the fruits of this effort:

3.2.3.1. Creation of Guidelines

At the 2004 Seoul workshop, the guidelines that Japan created were given out to the participating countries. These guidelines are a detailed explanation of chapter 2 of this report, put together from the methodology in operation in the country at that time. The guidelines given out in the 2004 Seoul workshop are printed at the end of this report.

3.2.3.2. Creation of Example Critical Line Settings

In Japan, rainfall observation systems have been set up all over the country, from which we have gathered our rainfall data. As described in 3.2.2, an outline of information on yearly sediment-related disaster occurrences has been preserved. The guidelines given out at the 2004 Seoul workshop were easy to apply to countries/regions who had gathered sufficient sediment-related disaster data. However, they were troublesome to apply to countries that did not supply sufficient data.

Gathering examples of CLs from within Japan, the angle of the CL and the value of they Y-intercept have been divided on regional, rainfall and geographical viewpoints. From this, we were able to set the CL for countries and regions even if they had insufficient rainfall and sediment-related disaster data. Once countries that have implemented this method gather sufficient rainfall and sediment-related disaster data, it is necessary to update the CL values.

The above analysis simple example settings were made into a report and handed out at the 2005 Kuala Lumpur workshop. That document has also been added to the end of this report.

3.2.3.3. Establishing a Technical Help-Desk

With the sharing of technical information in mind, the guidelines and settings were converted into electrical data for easy downloading, and the International Sabo Network homepage (http://www.sabo-int.org/index.html) and a help-desk within were established.

3.2.3.4. Example Applications

Figure 3.2.5 shows the flow of communication for warning information for sediment-related disasters. In 2009, the prefectural government in co-operation with local meteorological observatories decide if to send sediment-related disaster warnings or not. In the event of a sediment-related disaster warning announcement, the prefectural government informs the local government of the warning, who in turn inform citizens. Another alternative is to have the local meteorological observatories inform the prefectural government at the same time as television, radio, and the Internet to inform citizens. Figure 3.2.6 shows how the prefectural government can offer additional real-time information on rainfall variation with 4 warning levels.

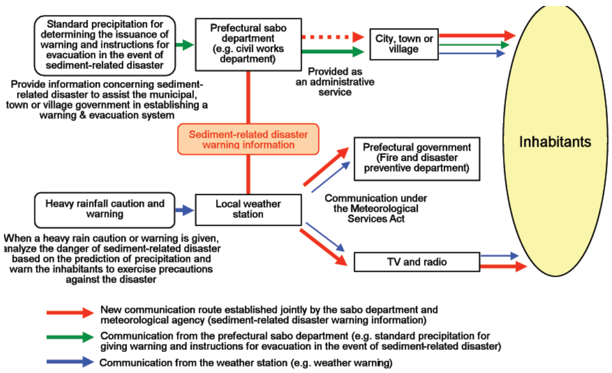
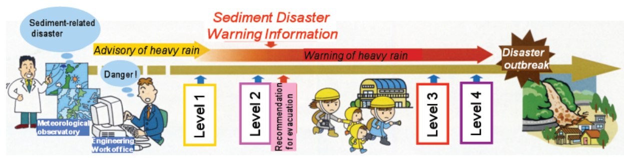


Figure 3.2.5 Procedure for Issuing Sediment Disaster Warning Information



Level 1: The condition of rain is likely to exceed the standard value of sediment-related disaster occurrence within three hours. It is under the situation to inform for the resident.

Level 2: The condition of rain is likely to exceed the standard value of sediment-related disaster occurrence within two hours. It is under the condition to announce a refuge advice. Sediment disaster warning information is issued.

Level 3: The condition of rain is likely to exceed the standard value of sediment-related disaster occurrence within one hour. It is necessary to confirm the resident in dangerous areas finishing to refuge.

Level 4: The condition of rain has already exceeded the standard value of sediment-related disaster. It is under the very dangerous condition.

Figure 3.2.6 Example of Additional Information and the Criteria for Evacuation

An example of this report was given in Shimane Prefecture when slope failure occurred on July

15th 2006. Photo 3.2.3 shows the site.

Photo 3.2.3 Sediment-Related Disaster in Shimane Prefecture

Figure 3.2.7 shows hourly rainfall and Figure 3.2.6 shows the decided upon risk level's real-time variation. Figure 3.2.8 shows the CL and snake-line. The disaster occurred at 3:30am on July 19th 2006. The sediment-related disaster warning information system sent out a warning at 6:55 on July 17th, and the city hall informed representatives to warn citizens. Based on the real-time rainfall levels, the risk level was raised from 2 to 4 on July 18th at 9:30pm until 11pm. On July 18th at 11:54pm, the city hall issued another disaster warning on the radio. The next day at 3:30am sediment-related disaster occurred. The same day at 10:35pm the sediment-related disaster warning information system lifted the warning. In this example, fortunately the warning was given before the disaster occurred, and the citizens were duly informed.

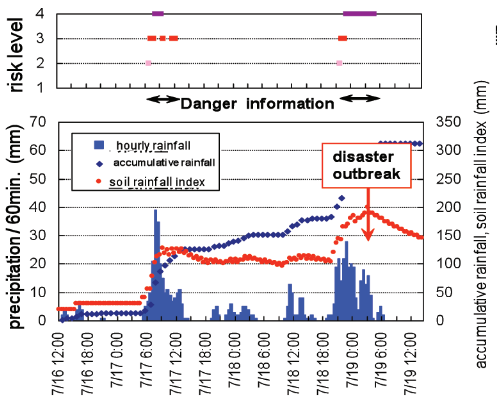


Figure 3.2.7 Rainfall and Risk Level Variation

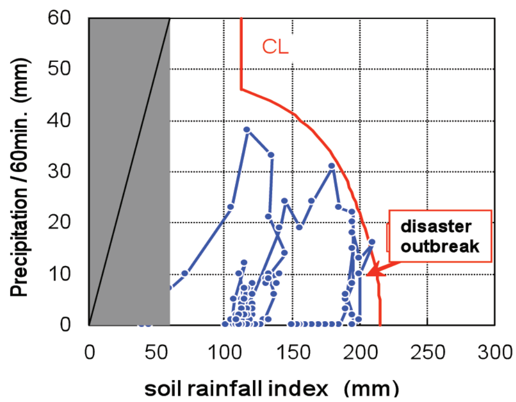


Figure 3.2.8 CL and Snake-Line for Shimane Prefecture

3.2.3.4. Future Issues

Not only in Japan, but also in each of the participating countries, sediment-related disasters are natural disasters, which cause great damage. Because of that, measures to reduce damage are necessary. Out of those, non-structural measures are the most financially viable. Therefore, using the technical help-desk that this project has established, we would like to continue offering technical support in the event that one of the participating countries sets up it's own warning information system.

3.3. Malaysia

3.3.1. Outline

Malaysia lies between the 100 and 119 degree longitude lines, and between 1 and 7 degrees latitude. It has a land area of 330,000 km^2. 68% of all the land is covered in forests. The population is 23,000,000. Between November and January there are seasonal winds from the northeast. Between April and May the winds come from the southwest on the peninsula, and from May to July in the eastern areas. The temperature varies between 21 and 32 degrees and the humidity is around 80%. The yearly rainfall is between 2,420 and 3,830mm.

3.3.2. Sediment-Related Disaster Status

Malaysia is apprehensive about human casualties in relation to landslides. Recently there have been occurrences of landslides on May 31st, 2006 in Kg Pasir (see Photo 3.3.1), in 2004 in Gua Tempurung (see Photo 3.3.2), in 2002 in Sumunjang Sarawak (see Photo 3.3.2).

Photo 3.3.1 Landslide in Kg. Pasir

3.3.3. Development of the Warning and Evacuation System (The Project Results)

3.3.3.1. Methodology

As mentioned in 2.3, Malaysia uses the CL as a base. When the snake-line crosses the CL, a warning is sent out.

Photo 3.3.2 Landslide in Gua Tempurung

Photo 3.3.3 Landslide in Gua Tempurung

The CL was set using the following steps:

1. Determine rainfall resulting in occurrence and non-occurrence of sediment-related disaster
2. Note the day and time of sediment-related disasters
3. Calculate the working rainfall
4. Calculate the maximum hourly rainfall
5. Set the CL
6. Set the Warning Line (WL)
7. Set the Evacuation Line (EL)

8. Graph the snake-line

3.3.3.2. Outline of the Model Watershed

Figure 3.3.1 shows the location of the model watershed. The watershed is located north of Kuala Lumpur in the Cameron Highlands.
Table 3.3.1 shows 10 examples of sediment-related disasters in recent years. There were examples where 250 people lost their lives in a disaster, and 15,000 were negatively affected by another. As you can see, this area has occurrences of large disasters.
Figure 3.3.2 shows the location of the rainfall observatory. In the Cameron Highlands, there are 8 observatories (: automatic : manual).

Figure 3.3.1 Location of Cameron Highland

Date	Incident	Number of death
24 Oct., 1993	Kandslide in Km58, Kuala Lips-Gua Musang road	1
11 Dec., 1993	Highland Towers collapse after landslide	48
30 Jun., 1995	Genting slip road debris flow	20 (22 injured)
29 Aug., 1996	Pos Dipang debris flow	44
26 Dec., 1996	Pampang River, Keningau, west coast of Sabah (storm GREG) debris flow	241 (102 people missing, 6308 homes damaged)
4 Feb., 1999	Kg. Gelam landslide	17
15 May, 1999	Landslide at Bukit Antarabangsa Hulu Kelang, Selangor	(100 people trapped on the peak of Wangan Height)
6 Jan., 2000	Mudflow in Ca,eron Highland	6 (15000 affected)
27 Dec., 2001	Kg. Sri Gunung Pulai, Pontian, Johor	5 (4 houses carried away by strong mud-flow)
20 Nov., 2002	Taman Hilview landslide	8

Table 3.3.1 Cameroon Highland Disaster List

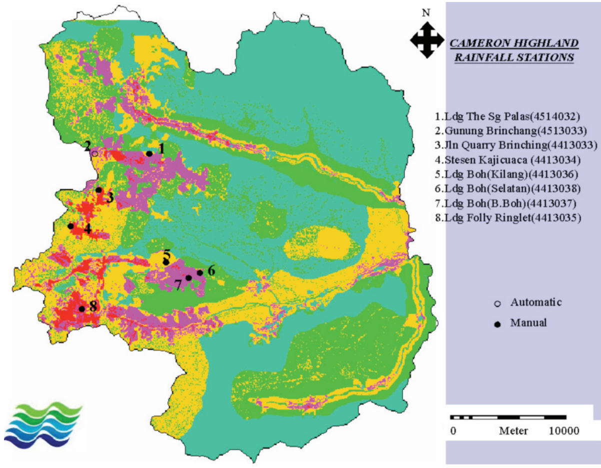


Figure 3.3.2 Location of the Rainfall Observatories

3.3.3.3. Setting the Critical Line

Table 3.3.2 is a list of rainfall data used to set the CL. 3 examples of occurrence of rainfall and 75 examples of non-occurrence of rainfall were collected. We believe that 2 of the non-occurrences of rainfall resulted in a landslide, but that data was not recorded.

Table 3.3.2 Data List for the CL

Cameron Highlands

		summary	
Date	Working rainfall	Occurance mm/hr	Non-occurance mm/hr
		Occurrence	Non-occurrence
06-12-94	63.8	31.4	
06-12-99	75.9	22.9	
06-01-00	66.4	21.3	
25-01-99	32	(3 Events)	12.9
22-04-94	19		13.1
08-02-94	36		20.4
18-03-94	35		30.3
22-08-94	24.9		18.1
22-06-96	28.5		11.5
			(75 Events) 26

Figures 3.3.3 and 3.3.4 show the plotted figures of rainfall collected until 2003 and 2004. On these graphs a line was drawn between the plots of occurrence and non-occurrence. This line was used as the CL. If you look at the 2004 CL and the 2003 CL, you will notice that the y intercept has decreased by 10mm, and the x intercept has increased by 20mm. As a result, the 2004 safe area was larger than the 2003 safe area. This is due to the addition of the non-occurrence data. Figure 3.3.5 shows the location of landslide

occurrence. The location of the Gunung Brinchang observatory is also shown in the same figure. In this case, the online warning system was unable to send a warning before the occurrence. This is because the rainfall did not cross the lines of 40mm of daily rainfall nor 30mm of rainfall in a 2 hour period (see Figure 3.3.6). One of the reasons that the online system didn't give a warning is that the rainfall observatory is 10km away from the landfall site, and it is believed that the actual rainfall in that area was not observed. In response to this, a new rainfall observatory was set up in Tanah Rata, which is closer to the landslide.

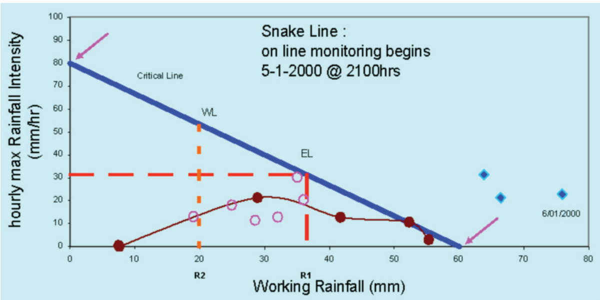


Figure 3.3.3 CL, EL, WL (2003)

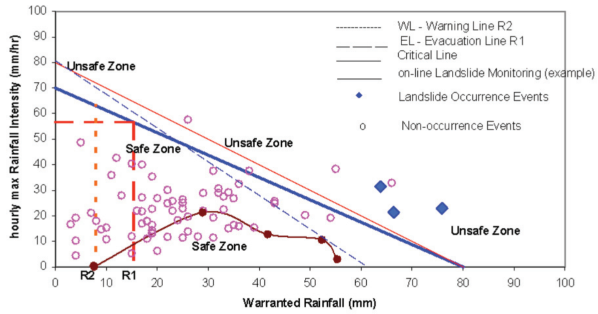


Figure 3.3.4 CL, EL, WL (2004)

3.3.3.4. Application in the Model Watershed

In Malaysia, an online warning system was developed to give warnings on the Internet in real-time.

Figure 3.3.7 is a screen-shot from the online system.

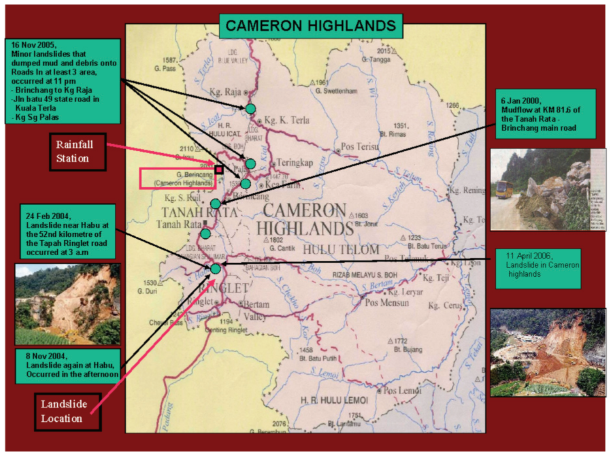


Figure 3.3.5 Location of Landslide and Rainfall Observatory

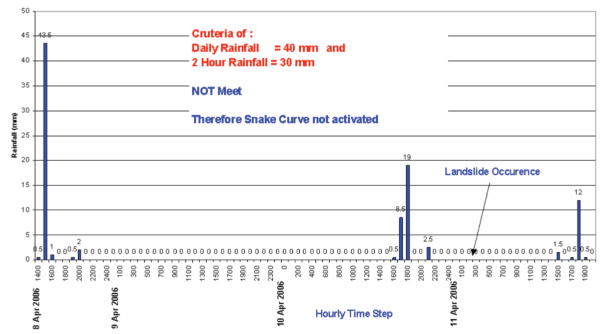


Figure 3.3.6 Rainfall Around Time of the Landslide

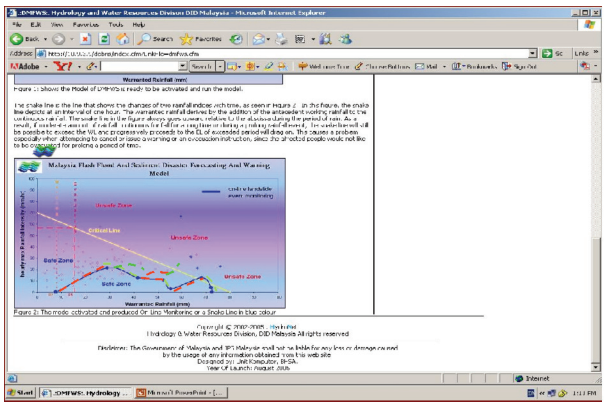


Figure 3.3.7 Online Warning System Screenshot

3.3.4. Future Issues

We need to analyze past disasters (occurrence and non-occurrence rainfall) to increase the precision of the CL.

3.4. Thailand

3.4.1. Outline

Mr. Disaster Warning is not only made up of government administration, but also of local volunteers participating in a warning and evacuation system. Within that flash flood and landslide decision-making is based mainly on rainfall information.

3.4.2. Sediment-Related Disaster Status

Figure 3.4.1 shows the locations of the main recent occurrences of sediment-related disasters. Table 3.4.1 shows the number of fatalities from flash floods and landslides. Photo 3.4.1 shows the occurrence of sediment-related disaster in Pipoon on November 2nd, 1988. 230 people died in this disaster. Thailand has many disasters of this nature.

More recently, the typhoon Chanthu caused sediment-related disasters between June 6th and 23rd of 2004. Figure 3.4.2 shows the course of Chanthu. Due to Chanthu, Mae Sod city in Tak Province received 262mm of rainfall in the 3 days between June 21st and 23rd.

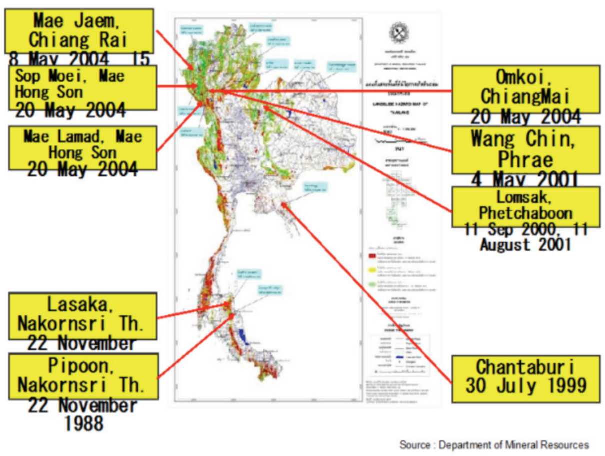


Figure 3.4.1 Main Sediment-Related Disasters in Thailand

Table 3.4.1 Number of Deaths Caused by Main Sediment-Related Disasters

Thailand's Landslide/Flashflood History

Region	Year	Fatalities
South	Nov 1988	230
South	Nov 1988	12
East	Jul 1999	-
North	Sep 2000	12
North	May 2001	43
North	Aug 2001	136
North	Sep 2002	-
North	May 2004	-
North	May 2004	1
North	May 2004	5
South	May 2004	3
North	May 2006	88

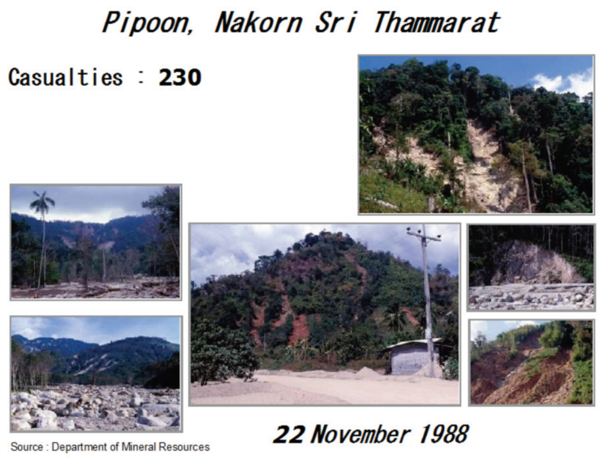


Photo 3.4.1 Sediment-Related Disaster in Pipoon on November 22nd, 1988

Figure 3.4.2 Course of typhoon Chanthu

3.4.3. Development of the Warning and Evacuation System (The Project Results)

3.4.3.1. Warning Information System (The Project Results)

In 2005 the Thai Cabinet signed for the implementation of an early warning system. The system covers 2,730 villages specified as risk areas by setting up the priority according to the level of risk.

The villages we divided into high-risk, medium-risk, and low-risk with 398, 576, and 1,396 villages respectively. The following equipment was installed in each village:

1. Automatic rain gauge
2. Soil moisture gauge
3. Early warning system
4. A communication linkage system

Photo 3.4.2 shows an example of the equipment.

Photo 3.4.2 Observation Equipment

Figure 3.4.3 shows a conceptual model and the thinking process of system development. The flood warning system is aimed to be installed in upstream watersheds where flash floods frequently occur, and to facilitate downstream communities as decision making tools to decide whether to evacuate based on heavy rainfall upstream.

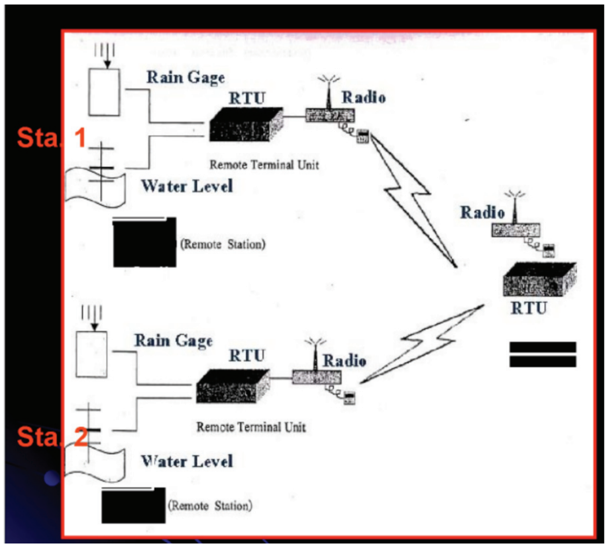


Figure 3.4.3 Conceptual Model and Thinking Process of System Development

Figure 3.4.4 shows the early-warning steps. A system receives a rainfall information signal from stations located upstream, and sends out a warning signal to other stations. The signal is distributed to all communities immediately in the case of a heavy storm caused by heavy rainfall.

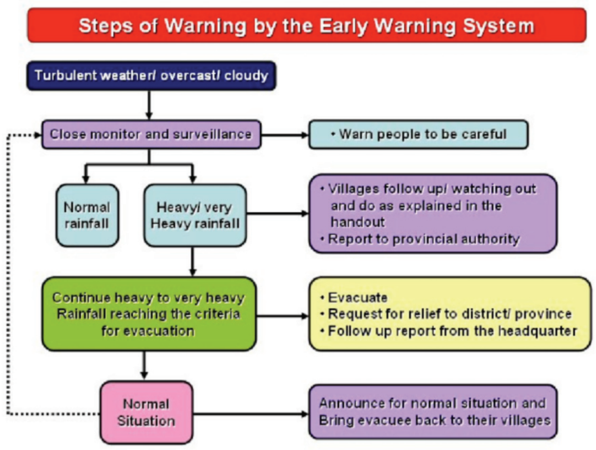


Figure 3.4.4 Early Warning System Steps

Figure 3.4.5 shows the antecedent precipitation index (API) used for evacuation decision-making. The API has become the base point for announcing a warning.

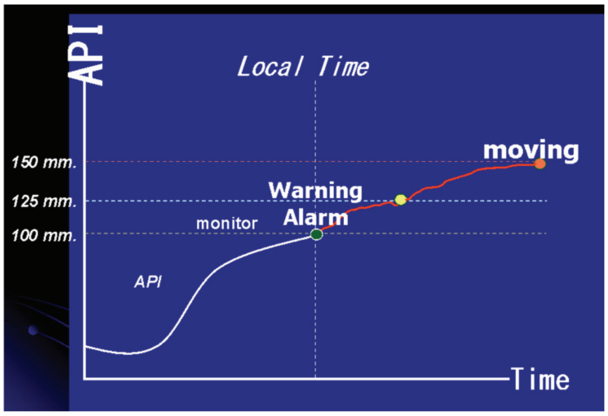


Figure 3.4.5 Antecedent Precipitation Index for Evacuation Decision-Making

Figure 3.4.6 shows the flow of warning information. This information includes: flood warnings, landslide warnings, drought warnings, and rainfall/runoff warnings. When each observatory sends out its own warning signal, that information is received by the local government. After that, each system informs the Coordination Center Bureau of Research, Development and Hydrology.

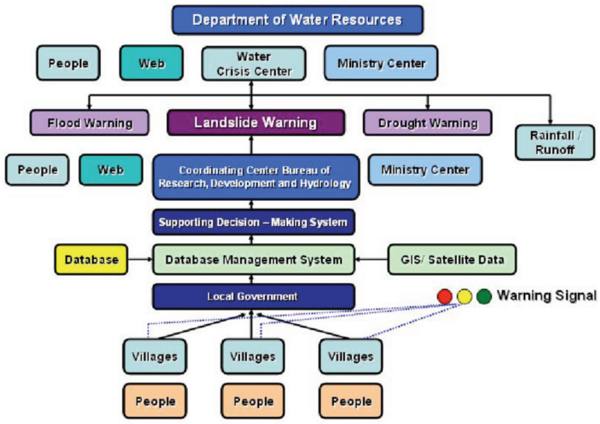


Figure 3.4.6 Information Flow

3.4.3.2. Introduction of the Mr. Disaster Warning Project

The roles of the volunteer villagers are as follows:

1. Weather watching
2. Rain gauge confirmation/recording
3. Following the warning steps where there is heavy rainfall
4. Observing falling debris/soaked soil
5. Observing water color, the sound of falling debris, and water current
6. Disseminating information on landslides and flash floods to the community
7. Formulation of an evacuation plan
8. Warning the villagers and starting the evacuation
9. Completing evacuation to designated areas
10. Locating missing persons
11. Rechecking the evacuees and making a list of missing persons
12. Reporting to central evacuation headquarters
13. Leading evacuees to the evacuation sites
14. Reporting to the persons in charge
15. Coordinating with those involved to seek information on requirements and making a situational report
16. Reporting to the person in charge and any temporary emergency centers
17. Assisting in bringing people back to their places of origin

Villagers are selected on a voluntary basis and trained to play roles in disaster prevention in relation to monitoring, warning, and evacuation. Volunteers learn monitoring in relation to: landslide information, weather, landslide prevention, water levels, slopes, and equipment operating procedures.

Volunteers learn information in relation to: warning for readiness, warning for evacuation. And in relation to evacuation, they learn: how to warn people to move to a safe area, how to move people to a safe area, and how to coordinate with other evacuating activities.

This project is being undertaken by the Department of Disaster and Mitigation, the Department of Provincial Administration, the Thai Meteorological Department, the Department of Mineral Resources, the Department of National Parks, the Department of Wildlife and Plant Conversation, and the National Disaster Warning Center. As of August 31st, 2006, about 5,00 villagers had been trained.

3.5. USA

3.5.1. Outline

The area around Guam (Figure 3.5.1), which is under the jurisdiction of The National Weather Service (NWS) was the target of this project. This section is responsible for giving warnings for public, marine, fire, air, and tropical cyclones in an area including Marianas, Palau, from west of the international dateline to 130 degrees East longitude, from the equator to the Marshal Islands at 25 degrees N Latitude.

Figure 3.5.1 NWS WFO

Figure 3.5.2 shows the location of the Micronesian Commonwealth. Micronesia is located just above the equator in the center of the Pacific Ocean covering an area of 2,500km. It is divided into 4 regions named Yap, Chuuk, Pohnpei, and Kosrae. Of the 607 islands, only 65 are inhabited. Pohnpei is the largest and supports a large crowded population. Although typhoons don't usually pass through this area, in November of 1997, July and December of 2002, Nina, Chata'an, and Pongsona passed through, respectively.

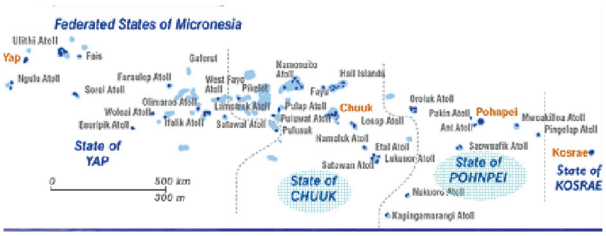


Figure 3.5.2 Location of the Malaysian commonwealth

3.5.2. Sediment-Related Disaster Status

In the Chuuk region, a landslide hazard map was created as a test. In addition to the large population, more and more typhoons pass through the area causing a higher possibility of landslides due to sediment-related disaster.

The 1st and 2nd of July 2002 felt the effects of Chata'an (Figure 3.5.3). In that period 500mm of rainfall fell. During the rainfall and for several days later, over 200 landslides occurred. Most of the landslides occurred between 7am and 2pm on the 2nd where 47 people lost their lives. From this disaster, we found the need to step ahead on following points:

1. Using the landslide map as a base, define the landslide hazard zone and create safe living areas in the region in the future
2. Create awareness of unstable cracks on the local level
3. Create a system to illuminate land use and create support using the highest level of technology from the government and the international community
4. Enlighten the locals in relation to re-foresting
5. Create a communication system to inform citizens of disasters and establish safe areas for evacuation
6. Continually renewing the landslide hazard map

Figure 3.5.3 Islands with occurrence of landslides

3.5.3. Development of the Warning and Evacuation System (The Project Results)

The Federal Government and the NWS have prescribed forecast guidelines for the Micronesian commonwealth. These guidelines give consideration to topography, geology and land use conditions, set the base requirements for rainfall volume, time, and length. For example, the following are the base settings for Palau:

1. Warning Criteria: 36hrs of rainfall at 5-6inch, allowing for a variation of 0.5inch in a 1hr period.
2. Critical Criteria: 36hrs of rainfall at 8inch, allowing for a variation of 0.5inch in a 1hr period.

As an example for other areas in the region, a landslide hazard map was created using Chata'an as a base and integrating the concept of the CL. The NWS is making calculations for rainfall power and cumulative rainfall volume based on radar and land observations for the Flash Flood Monitoring Program (FFMP). This program also targets small watersheds between 2-15km^2. Yet, the requirements "Flash Flood Guidance" for each small watershed have been laid down. Figure 3.5.4 is a screenshot of the FFMP.

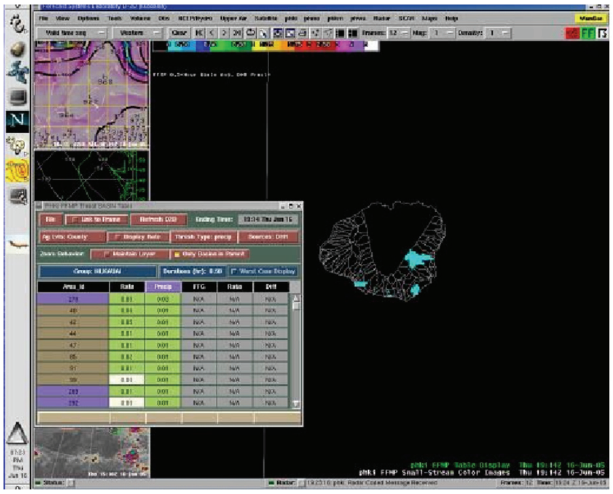


Figure 3.5.4 FFMP screenshot

3.6. Viet Nam

3.6.1. Outline

Flash floods are predicted by the National Hydro-Meteorological Services (NHMS) and include debris flow and landslides.
Figure 3.6.1 shows the location of the NHMS. The NHMS is split into 3 levels: National, Prefectural, and Local. There are 93 Surface Synoptic (SYNOP) observatories, 323 Meteorological Stations, 157 rainfall observatories, 138 water-level observatories.

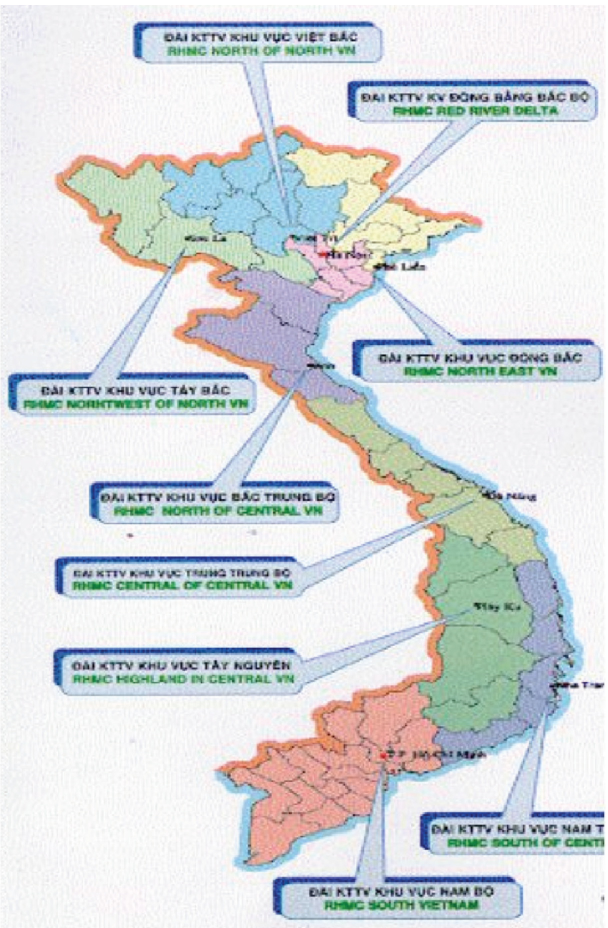


Figure 3.6.1 Location of the NHMS

3.6.2. Sediment-Related Disaster Status

In the 15 years between 1990 and 2004, there were nearly 170 flash floods in the mountainous regions, especially in Kai Chau, Son La, and Ha Giang. They experienced flash floods in 11 out of the 15 years. From scenes like this a flash flood hazard maw was created along with a warning system for the Nam Pan and Nam La rivers.

3.6.3. Development of the Warning and Evacuation System (The Project Results)

3.6.3.1. Outline of the Model Watershed

Son La, in which the Nam Pan, Nam La, Ngoi Pha (see Photo 3.6.1), and Ngai Lao river watersheds flow through was chosen as the model watershed. The Nam Pan river watershed is $418km^2$ in area, the Nam La river watershed is $445km^2$, the Ngoi Pha is $54.5km^2$, and the Ngoi Lao is $541.5km^2$.

Photo 3.6.1 Ngoi Pha River Watershed Area

In the Nam Pan watershed and the Nam La watershed experienced heavy rainfall and flooding in a $2430km^2$ area due to a typhoon on June 27th, 1990 where 76 people died or went missing. Also 1157 private residences were flooded costing 20,000,000,000 VND (2,000,000 USD). On September 27th 2005, Ngoi Pa experienced a flash flood in which 30 people died or went missing, and hundreds of houses were destroyed. Hundreds of hectares of rice fields were submerged in water and hundreds of sheep were washed away.
Figure 3.6.2 shows the locations of the rainfall observatories and water level observatories and their communication centers. In this figure, combined automatic rainfall/water level observatories are marked with a, and automatic rainfall observatories are marked with a. At each observatory rainfall intensity and water levels are represented by different colors. Also, "P" represents 10 minutes of rainfall, and "H" represents the water level. At the current time,

the online system cannot provide flash flood warnings. If the 10 rainfall volume exceeds 10mm or the water level exceeds 2m, the data is sent automatically to the communication center. At the same time, that area's color changes to red and a report must be made. Due to this it is necessary to create a warning system for each mountain stream and flash flood forecast model.

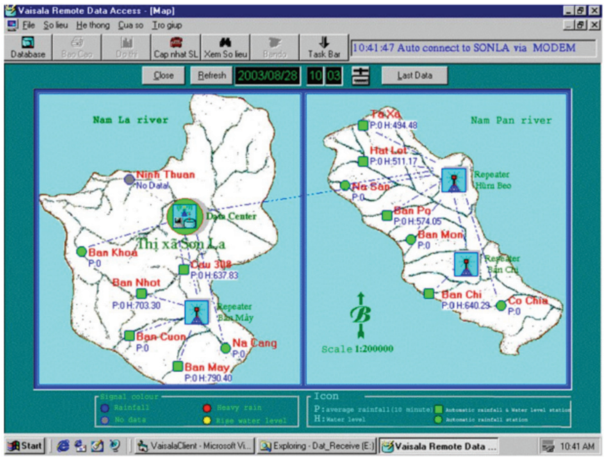


Figure 3.6.2 Rainfall Observatory Network

Different from the method that will be expressed later (in 3.6.3.2), a real-time flood warning prediction system was developed. Figure 3.6.3 is a numerical simulation of that concept. The simulation system is a combination of Marine and LELEMAC2. Figure 3.6.4 is a 20m×20m mesh digital elevation map made using this simulation system.

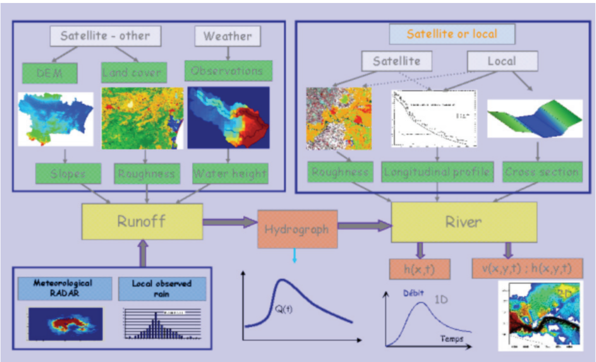


Figure 3.6.3 Concept of the Numerical Simulation

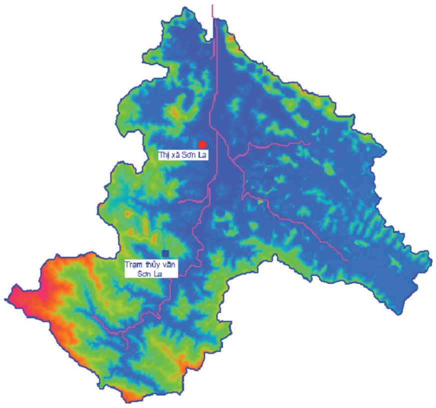


Figure 3.6.4 Mesh Digital Elevation Map

3.6.3.2. Methodology

In Vietnam they used the base system previously described (chapter 2) where occurrence and non-occurrence was not divided by a line, but by a square.

3.6.3.3. Setting the Critical Line

Figure 3.6.5 shows the CL. The conditions for flash floods are thus:

1. Continuous antecedent rainfall of 198mm or more, or over 125mm of rainfall in a 24 hour period.
2. When continuous antecedent rainfall is less that 198mm, but there is more than 150mm of rainfall in 24 hours.

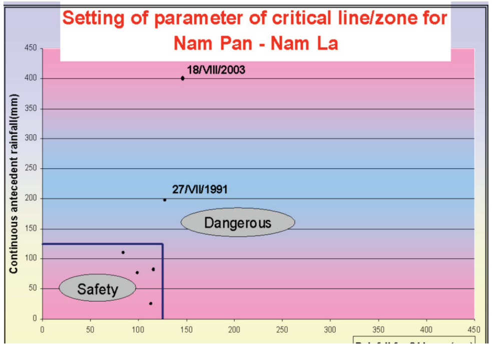


Figure 3.6.5 CL for Nam Pam, Nam La

3.6.4. Future Issues

There is a need for verification of the conditions shown in 3.6.3.3 along with the creation a forecasting model.
Also, I would like to set the CL for each watershed as well as plan a flash flood warning system.

4. CONCLUSION

In the end, this project was undertaken in the 7 years between 2002 and 2008. We must properly forecast both the natural phenomenon of sediment shifting and strategize the human operation of home construction and evacuation, or we cannot properly reduce the risks of damage from occurrences of sediment-related disasters. Especially the when's, where's, and how much's of sediment shifting are the main subjects of research. We can say that a system to accurately forecast the amount of movement of phenomenon such as debris flow, landslides, and slope failure. From this point, the Sediment-Related Disaster/Warning System Project gives attention to the strong relationship between sediment shifting and rainfall. We aim to create an warning and public evacuation system based on past occurrences of sediment related disasters.

At the time this project began, there were various technologies to create hazard maps for debris disaster, landslides, and slope failure, but there was no technology to connect forecast/warning systems to evacuation procedures.

Initially many of the participating countries failed to take hold of this project's technological recommendations in addition to the delays in schedule can be assumed to be rooted in this background. However 3 years into this project we recommended a swift movement towards using the CL. Determining the CL for test watersheds and applying the CL system to other places in the country began, especially in active countries like China and Malaysia. In addition, when applying the CL to other areas, it evolved in new ways to meet the needs of those areas. Moreover, an Internet based warning system was created based on the original forecast/warning information system.

We can say that by the last year of this project, the six participating countries, as mentioned in chapter 3, each created their own model watersheds and forecast/warning systems based on the CL. From this standpoint, we can consider this project a success. If some of six participating countries have evaluated the CL as a reliable system, the other countries can begin to base their evaluation on that as well. We hope that the countries that have not yet finalized their evaluation will undergo this evaluation along with the development of a warning system for their country. The Internet warning system developed in Malaysia and China was an accomplishment above and beyond our initial expectations. In the future, we would like to improve the reliability of the forecast warning/information system by gathering data on sediment related disasters from the participating countries, and if possible we would be happy to create new methods as well as update the CL system.

Finally, I would like to express my thanks to all those involved with this project, especially those governments and individuals who were asked to carry out difficult duties.

APPENDIX

PROCEDURE AND EXAMPLES OF SETTING STANDARD FOR CRITICAL RAINFALL FOR WARNING AND EVACUATION FROM SEDIMENT-RELATED DISASTERS

AUGUST 2005

NATIONAL INSTITUTE FOR LAND AND INFRASTRUCTURE MANAGEMENT

MINISTRY OF LAND, INFRASTRUCTURE AND TRANSPORT, JAPAN

CONTENTS

1. Procedures of setting standard for critical rainfall for warning and evacuation from sediment-related disasters

To set critical line (Critical Line:Hereafter, CL)for the occurrence of sediment-related disaster, you need to obtain enough data in regards to rainfall and disasters. However, if you cannot obtain enough information, you can set average CL based on the characteristics of the concerned area. Following are procedures of setting standard CL.

1. For the area concerning CL setting, select natural conditions to focus. Among the conditions choose applicable items for the concerned area. Refer to Table-1.1:

Table-1.1 List of natural conditions

Conditions	Cases
Regional	1. Volcanic regions
	2. Non-volcanic regions
Rainfall	1. Small rainfall area
	2. Medium rainfall area
	3. Large rainfall area
Geological	1. Granite zone
	2. Volcanic ejection zone (active zone)
	3. Volcanic ejection zone(inactive zone)
	4. Tertiary sedimentary

Where

Small rainfall area	:	Probabilistic rainfall of 100 years less than 250mm/day
Medium rainfall area	:	Probabilistic rainfall of 100 years from 250 to 350mm/day
Large rainfall area	:	Probabilistic rainfall of 100 years more than 350mm/day

2. Select the method of setting CL（Guideline Method A or Committee Method）.
3. Determine average slope of CL with the CL setting method selected.

Where the slope of CL for Guideline Method A：-0.45， for Committee Method：-0.9.

4. Calculate one third of probabilistic rainfall of 100 years per hour (mean value) and working rainfall (mean value), which corresponds to selected CL setting method, condition and item. (Refer to Figure 1.1~1.3).
5. Decide the linear line, that will pass one third of probabilistic rainfall of 100 years per hour (mean value) and working rainfall (mean value)(x, y axis) calculated in (4) with the slope of CL determined in paragraph (3). This linear line is standard CL, which corresponds to the natural characteristic of the concerned area.

(1) Regional condition

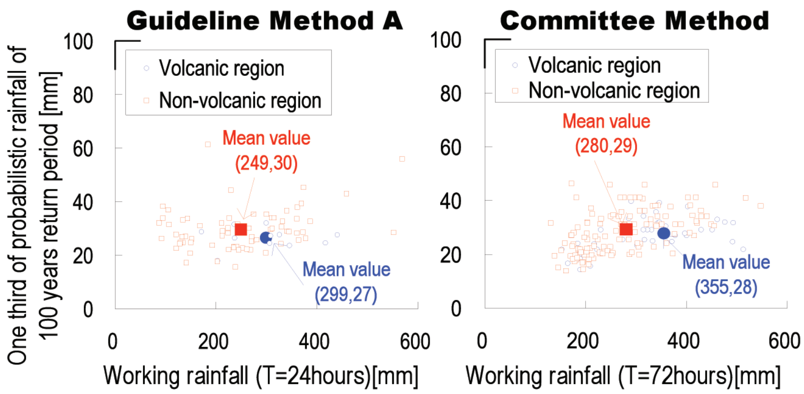


Figure-1.1 Relationship between one third of probabilistic rainfall of 100 years per hour and working rainfall (Regional condition)

(2) Rainfall condition

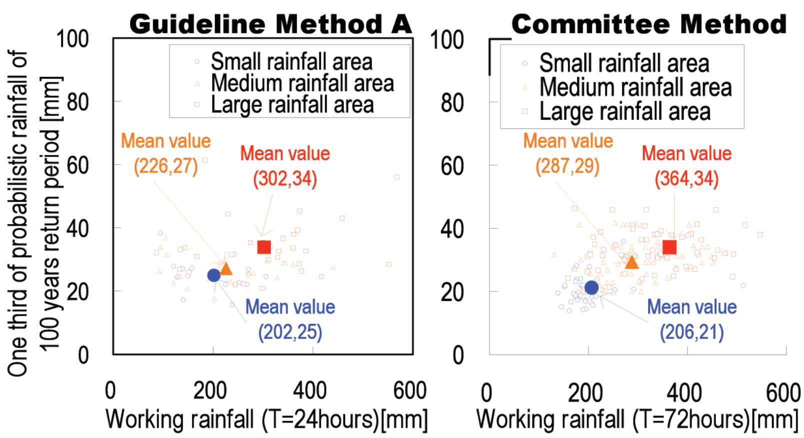


Figure-1.2 Relationship between one third of probabilistic rainfall of 100 years per hour and working rainfall (Rainfall condition)

(3) Geological condition

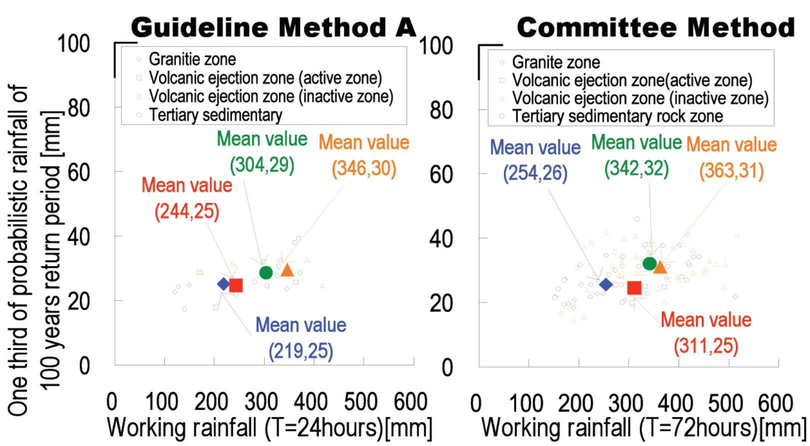


Figure-1.3 Relationship between one third of probabilistic rainfall of 100 years per hour and working rainfall (Geological condition)

2. Examples of setting standard for critical rainfall for warning and evacuation from sediment-related disasters

2.1. Setting CL

For the three conditions mentioned in section 1, we have set CL for both Guideline Method A and Committee Method. Tabel-2.1 as well as Figure-2.1～Figure-2.6 show the CL set.

Table-2.1 CL chart

Conditions	Cases	Guideline Method A	Committee Method
Regional	Volcanic regions	y=-0.45x+161.6	y=-0.90x+347.5
	Non-volcanic regions	y=-0.45x+142.1	y=-0.90x+281.0
Rainfall	Small rainfall area	y=-0.45x+115.9	y=-0.90x+206.4
	Medium rainfall area	y=-0.45x+128.7	y=-0.90x+287.3
	Large rainfall area	y=-0.45x+169.9	y=-0.90x+361.6
Geological	Granite zone	y=-0.45x+123.6	y=-0.90x+254.6
	Volcanic ejection zone (active zone)	y=-0.45x+134.8	y=-0.90x+304.9
	Volcanic ejection zone (inactive zone)	y=-0.45x+185.7	y=-0.90x+357.7
	Tertiary sedimentary	y=-0.45x+165.8	y=-0.90x+339.8

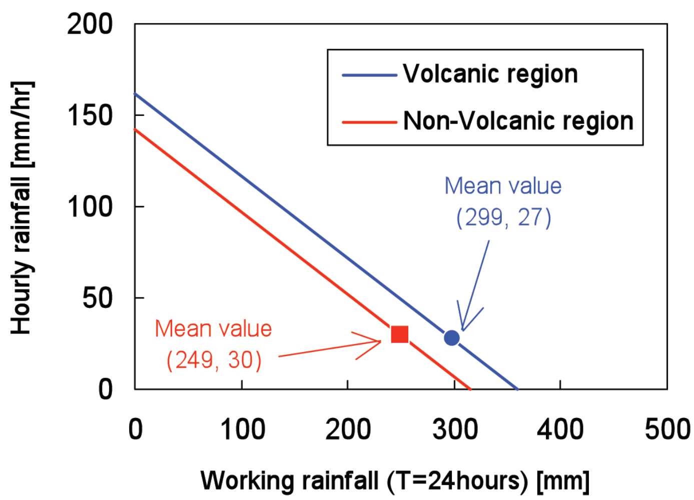


Figure-2.1 Standard CL with Guideline Method A Regional condition

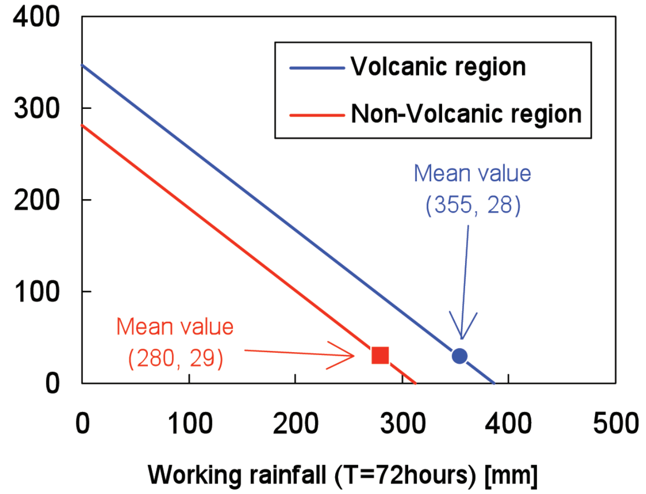


Figure-2.2 Standard CL with Committee method Regional condition

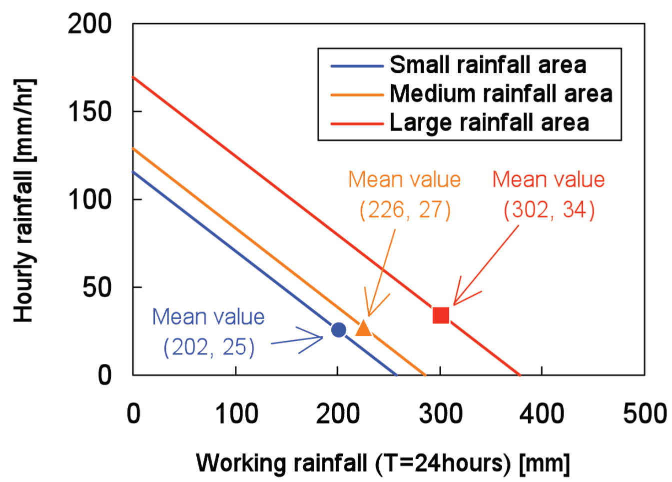


Figure-2.3 Standard CL with Guideline Method A Rainfall condition

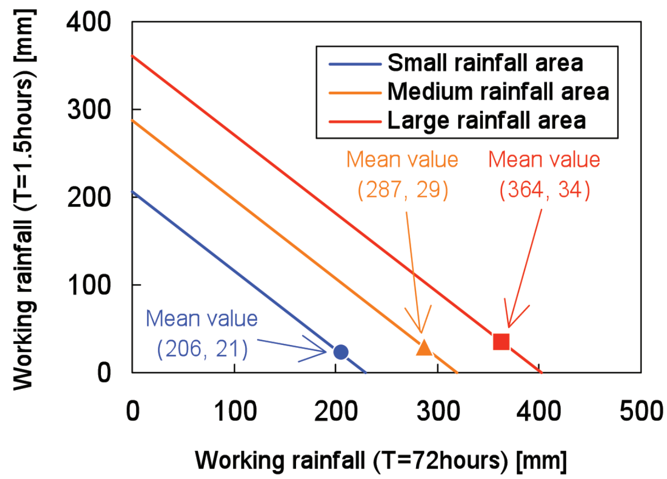


Figure-2.4 Standard CL with Committee method Rainfall condition

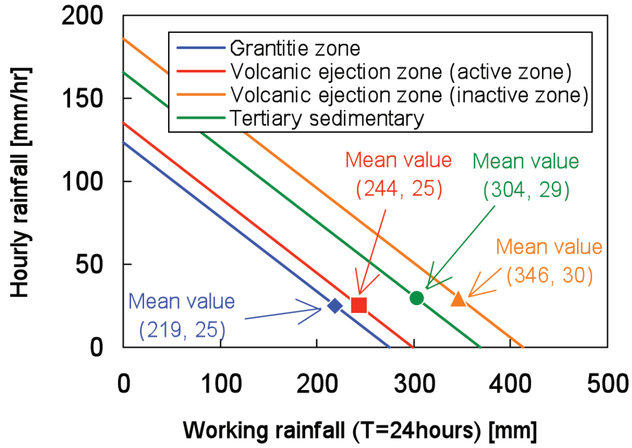


Figure-2.5 Standard CL with Guideline Method A Geological condition

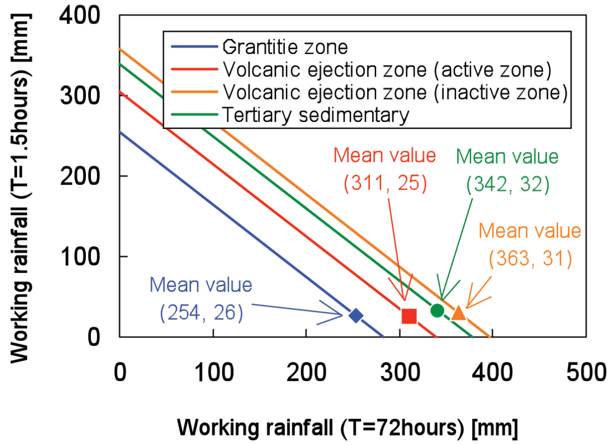


Figure-2.6 Standard CL with Committee method Geological condition

2.2. Verification of CL precision

We verified the concerned CL precision with the rainfall (snake line), which caused major sediment-related disasters in Japan during the year 2004 against CL set in the paragraph 2.1.

Place, date, and natural conditions of each region, where major sediment-related disaster occurred during the year 2004 are shown in the Table-2.2. CL and snake line set for each area are shown on Figure-2.7 ~Figure-2.18. Regarding geological condition of Kamikatsu (Tokushima pref.), Niihama (Ehime pref.) and Miyakawa (Mie pref.), it was out of setting conditions, therefore, it is excluded here.

From the figures, regarding the CL based on the rainfall condition, both Guideline Method A and Committee Method have predicted sediment-related disasters which are object for verification, which means its validity has been confirmed. However, regarding the regional and geological conditions, sediment-related disasters occurred before the snake line reached CL in some areas. Therefore, when you actually apply those methods, you need to consider standard deviation in data.

Considering above-mentioned facts, in case there is not enough data for rainfall and sediment-related disaster, selecting the CL based on rainfall condition among the three conditions mentioned is most effective.

Table-2.2 Places where sediment-related disaster occurred and their natural conditions

Place of occurrence	Date of occurrence	Regional	Rainfall	Geological
Tochio (Niigata pref.)	July 13, 2004	Volcanic	Small rainfall	Volcanic ejection zone (active zone)
Miyama (Fukui pref.)	July 18, 2004	Non-volcanic	Small rainfall	Tertiary sedimentary
Kamikatsu (Tokushima pref.)	August 1, 2005	Non-volcanic	Large rainfall	Other zone
Niihama (Ehime pref.)	August 17, 2005	Non-volcanic	Medium rainfall	Fracture zone
Miyagawa (Mie pref.)	September 29,2004	Non-volcanic	Large rainfall	Other zone

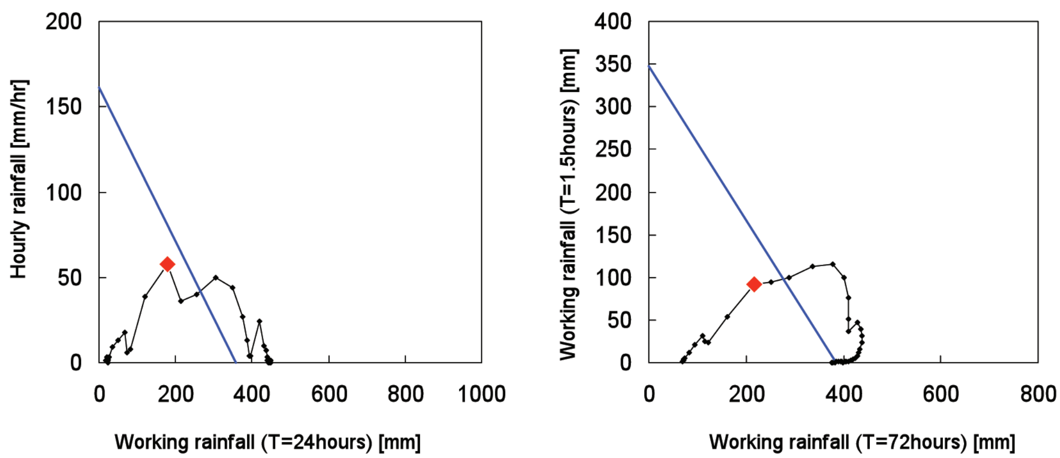


Figure-2.7 Case study in Tochio, Niigata pref. Regional condition volcanic

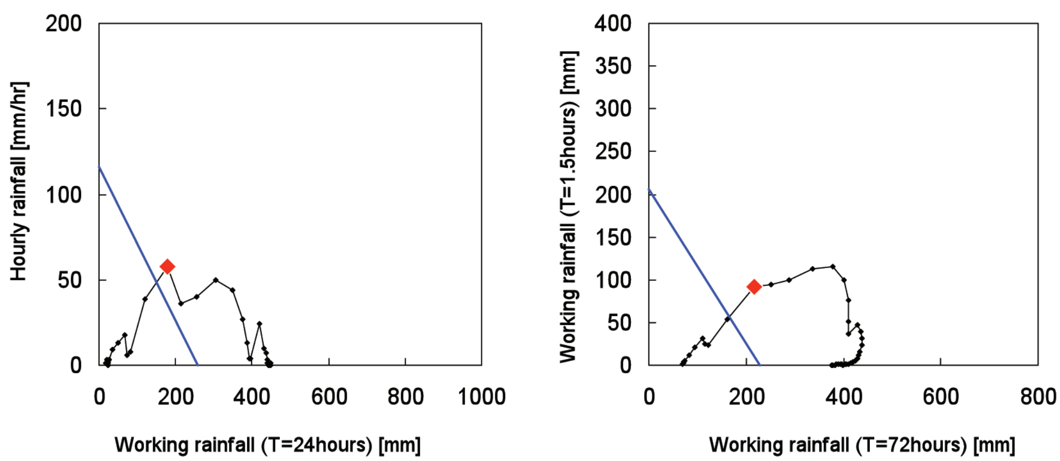


Figure-2.8 Case study in Tochio, Niigata pref. Rainfall condition small

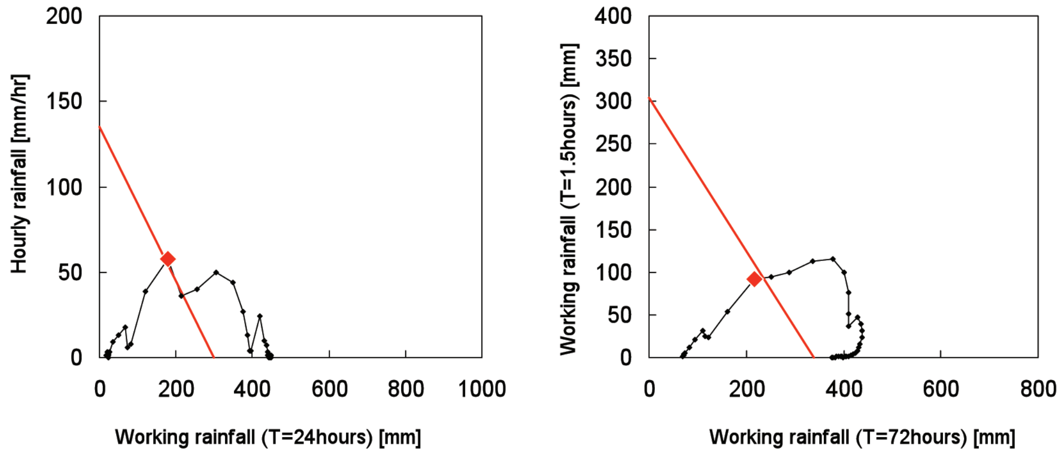


Figure-2.9 Case study in Tochio, Niigata pref. Geological condition Volcanic ejection zone (active zone)

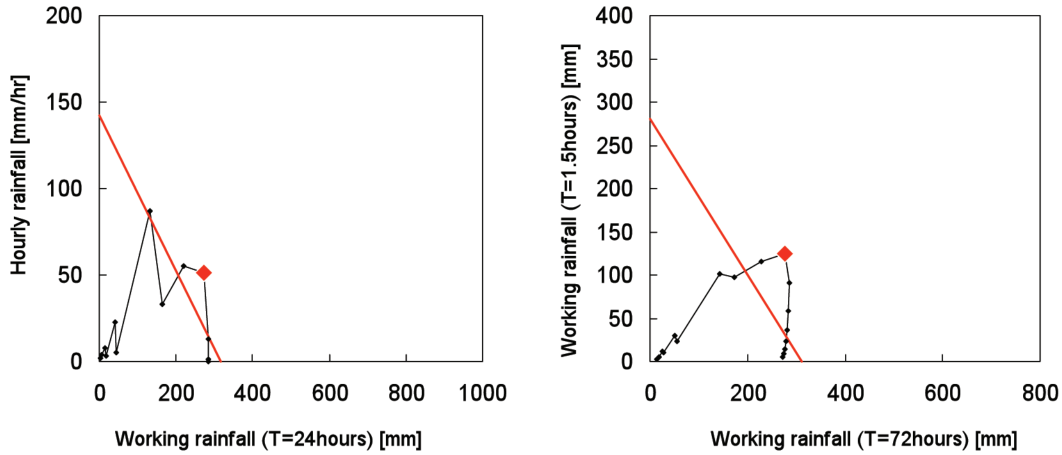


Figure-2.10 Case study in Miyama, Fukui pref. Regional condition non-volcanic region

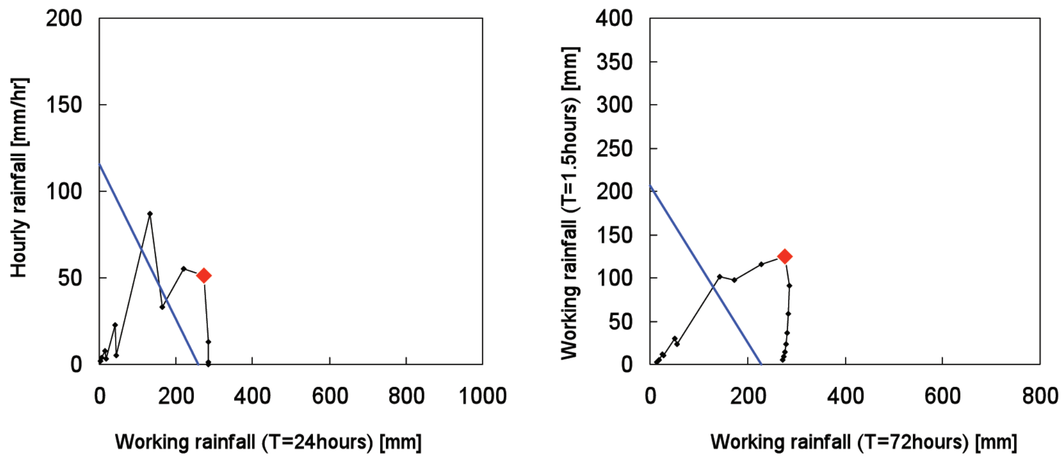


Figure-2.11 Case study in Miyama, Fukui pref. Rainfall condition small

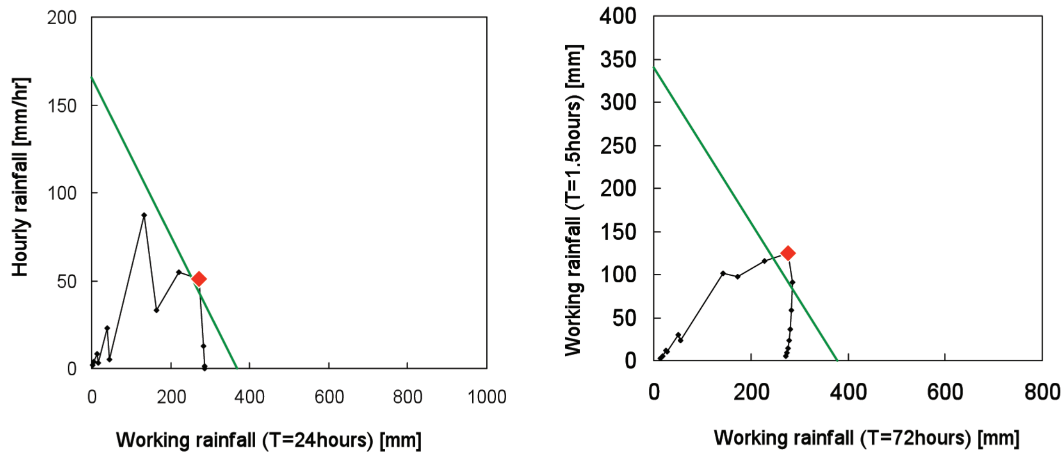


Figure-2.12 Case study in Miyama, Fukui pref. Geological condition Tertiary sedimentary

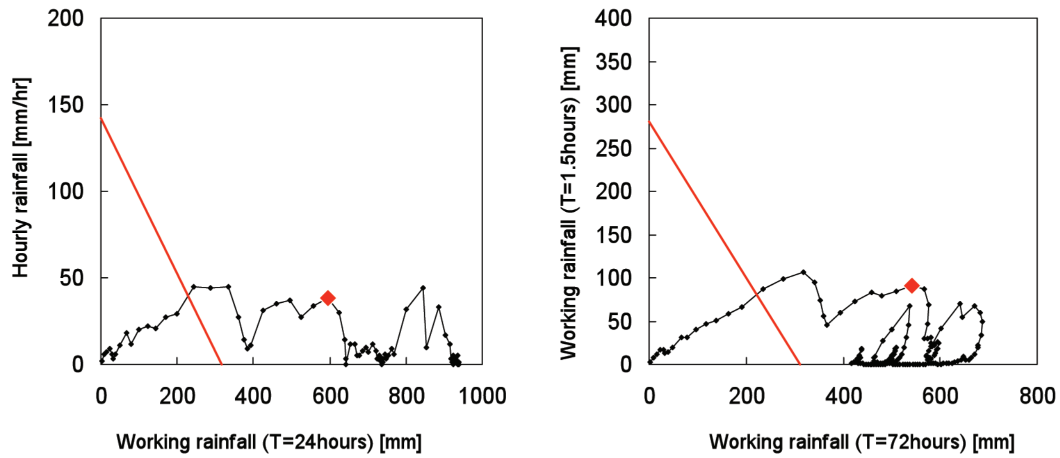


Figure-2.13 Case study in Kamikatsu, Tokushima pref. Regional condition non-volcanic

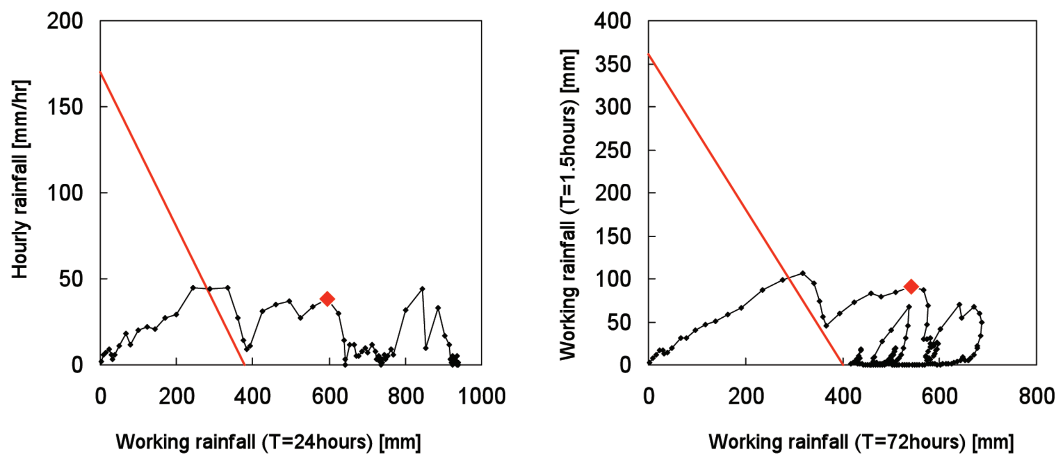


Figure-2.14 Case study in Kamikatsu, Tokushima pref. Rainfall condition large

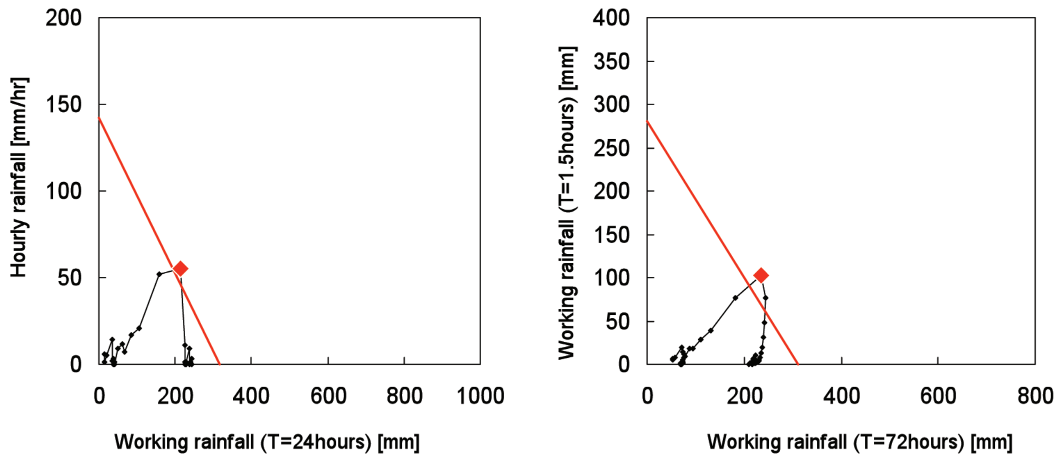


Figure-2.15 Case study in Niihama, Aichi pref. Regional condition non-volcanic

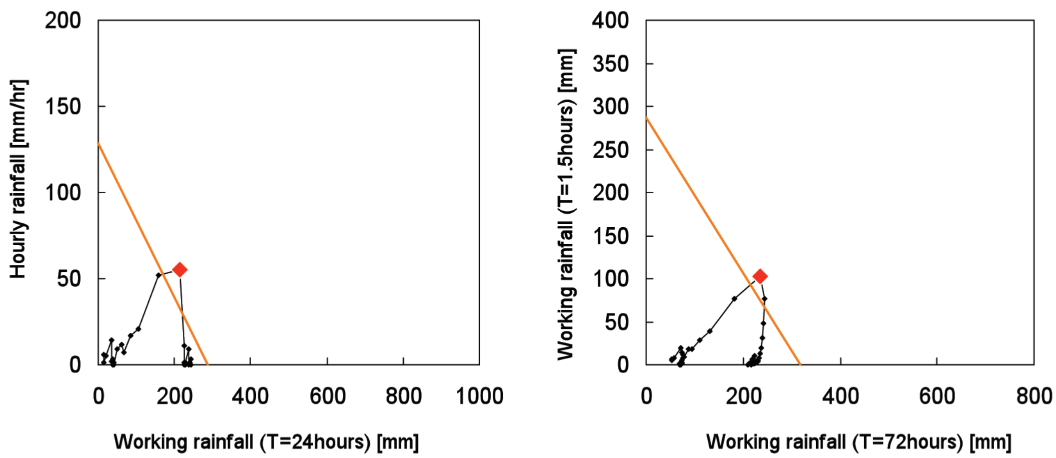


Figure-2.16 Case study in Niihama, Aichi pref. Rainfall condition medium

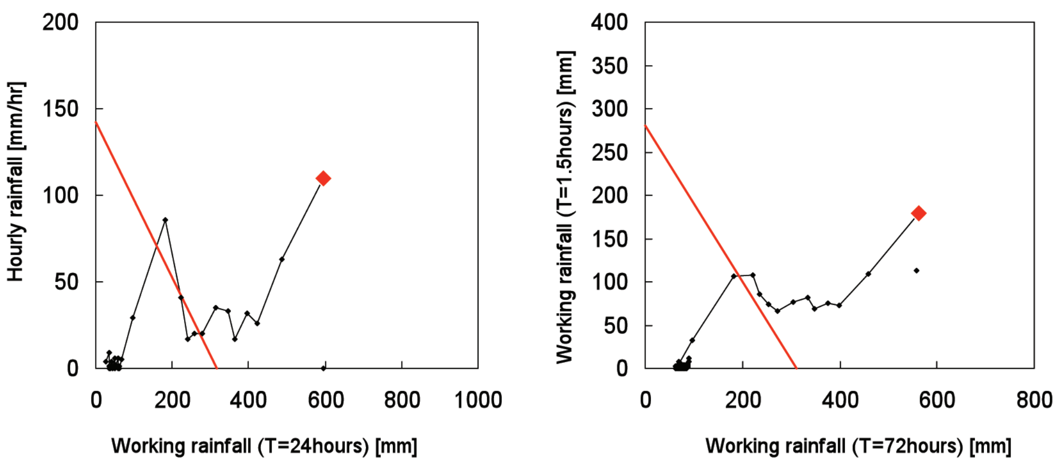


Figure-2.17 Case study in Miyakawa, Mie pref. Regional condition non-volcanic

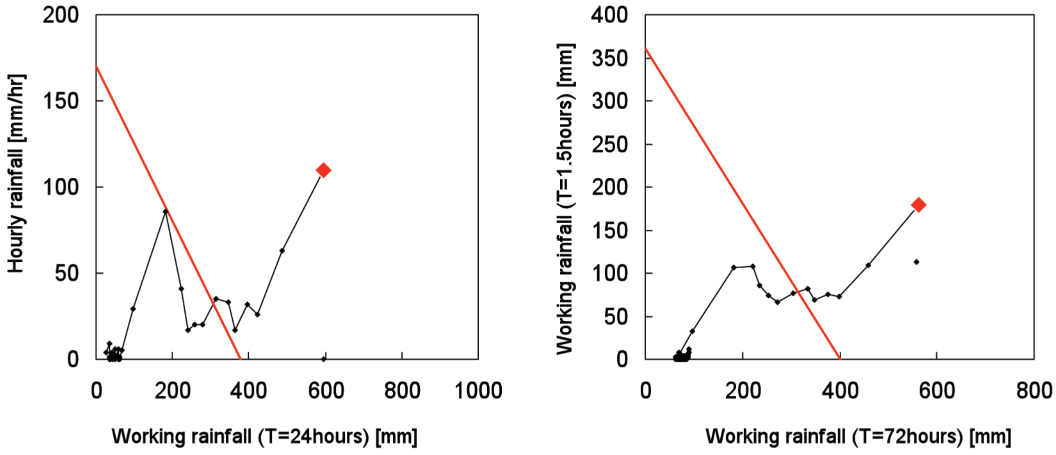


Figure-2.18 Case study in Miyakawa, Mie pref Rainfall condition large

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