APPENDICES

Appendix - 1

Calculation Example of Standard Rainfall by Method A (Guideline Method)

Appendix - 2

Standard Rainfall for Warning and Evacuation against Sediment Disasters Established in Japan

Appendix - 1
Calculation Example of Standard Rainfall by Method A (Guideline Method)

1. Calculation of antecedent working rainfall (R_{WA}) and working rainfall (R_W)

Shown below are the calculation examples of the antecedent working rainfall (R_{WA}) and the working rainfall (R_W). It is the example in case that the half-life is one day and rainfall that does not give a significant effect on the working rainfall occurring during the period in which the deduction coefficient becomes less than 0.004. When actually setting a standard rainfall for the occurrence of sediment disasters, an adequate half-life must be determined by investigating the separability between the causing and non-causing rainfalls by the trial method changing the half-life to one day, two days, and three days.

(1) Causing rainfall

The antecedent working rainfall (R_{WA}) and the working rainfall (R_W) are calculated using sample data shown in Table 2 and Fig. 1 on the next page. From Table 2, it is known that the starting time of a series of rain is at 9:00 on September 10. Then, the antecedent working rainfall (R_{WA}) is calculated taking the 24-hour period from 9:00 to 8:00 as one day. As the half-life assumed here is one day, the antecedent working rainfall (R_{WA}) becomes 9.6 mm from the calculation result in Table 1.

Table 1 Calculation result of antecedent working rainfall (R_{WA})

Days before the start of a series of rain	24-hour rainfall	Deduction coefficient	Added value	Cumulative antecedent working rainfall
1	0.0	0.50000	0.000	0.000
2	38.0	0.25000	9.500	9.500
3	0.0	0.12500	0.000	9.500
4	2.0	0.03250	0.065	9.565
5	0.0	0.03125	0.000	9.565
6	0.0	0.01563	0.000	9.565
7	7.0	0.00781	0.055	9.620
8	-	0.00391	-	9.620
Total				9.620

Accordingly, the “working rainfall up to one hour before the occurrence of debris flow”, which is needed for the setting of standard rainfall by Method A (Guideline Method), is 269.6 mm. It is derived as the sum of the cumulative rainfall (260.0 mm) from the start of a series of rain to the occurrence of the debris flow and the antecedent working rainfall (9.6 mm).

(2) Non-causing rainfall

The rainfall indexes of non-causing rainfall in Method A (Guideline Method) are “the working rainfall before the maximum one-hour rainfall” and “the maximum one-hour rainfall during a series of rain”. The calculation method is the same as the causing rainfall above.

Table 2 Sample data of hourly rainfall

Time of debris flow occurrence: September 12, 17:00

Date \ Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily rainfall	24-hour rainfall before the start of a series of rain
9/3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	5.0	0.0	0.0	0.0	7.0	7.0
9/4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9/5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9/6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0
9/7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9/8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	9.0	8.0	6.0	8.0	6.0	38.0	38.0
9/9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9/10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	6.0	0.0	0.0	3.0	3.0	3.0	1.0	3.0	3.0	0.0	1.0	0.0	0.0	1.0	27.0	-
9/11	0.0	0.0	0.0	0.0	0.0	3.0	2.0	2.0	1.0	0.0	1.0	1.0	3.0	7.0	6.0	4.0	6.0	7.0	5.0	10.0	9.0	9.0	10.0	8.0	94.0	-
9/12	6.0	7.0	5.0	7.0	8.0	6.0	6.0	5.0	4.0	3.0	3.0	3.0	7.0	7.0	12.0	6.0	4.0	6.0	11.0	15.0	8.0	0.0	0.0	0.0	139.0	-
9/13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

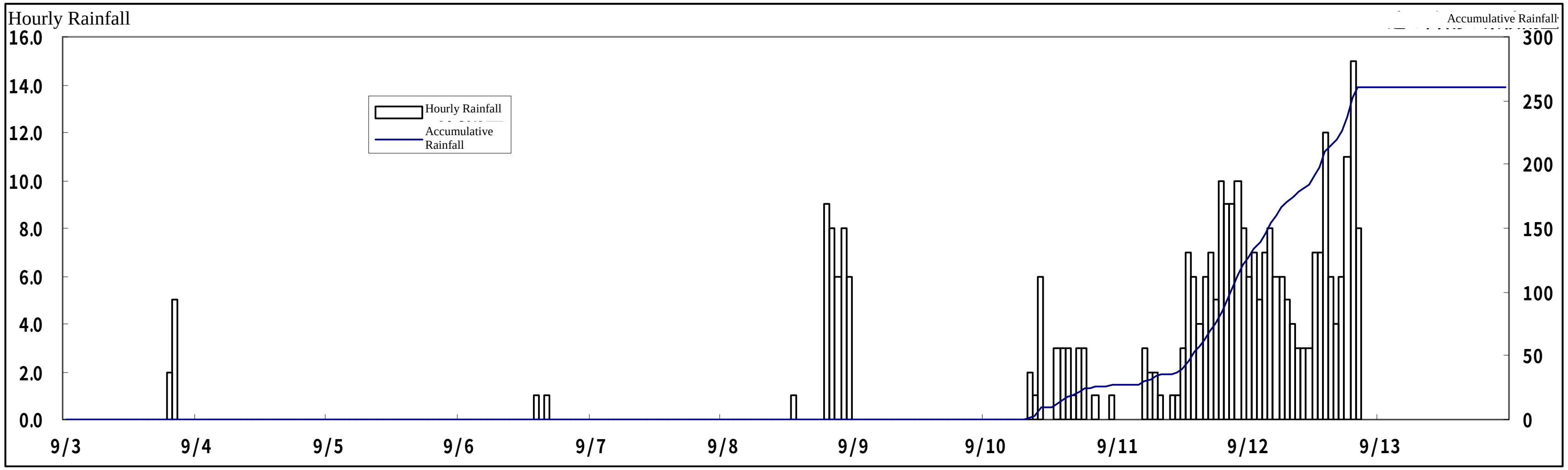

Fig. 1 Hyetograph of sample data

2. Setting of the critical line (CL), warning line (WL), and evacuation line (EL)

Here, the X-Y graph is prepared. The critical line (CL), warning line (WL), and evacuation line (EL) are determined using Method A (Guideline Method) from the rainfall data shown below.

Table 3 Sample rainfall data

	Year	Mon.	Day	Hour	Hourly rainfall	Maximum two-hour rainfall	Working rainfall up to one hour before	Total working rainfall
Causing rainfall	1980	9	12	17	26.0	29.0	162.3	188.3
	1982	8	2	2	14.0	18.0	112.3	126.3
	1982	8	1	16	28.0	38.0	74.3	102.3
Non-causing rainfall	Date/time of maximum hourly rainfall				Maximum hourly rainfall	Maximum two-hour rainfall	Working rainfall up to one hour before	Total working rainfall
	1983	5	16	19	14.0	22.0	52.1	66.1
	1983	8	16	17	32.0	38.0	20.0	52.0
	1983	9	28	18	16.0	20.0	126.0	142.0
	1985	6	24	8	8.0	12.0	39.2	47.2
	1985	7	1	2	17.0	33.0	177.9	194.9
	1986	8	4	19	12.0	38.0	67.4	79.4
	1986	9	3	4	14.0	26.0	55.6	69.6
	1988	9	25	15	11.0	19.0	68.5	79.5
	1989	7	17	18	17.0	33.0	24.4	40.4
	1989	8	27	13	19.0	28.0	51.1	70.1

The rainfall indexes depicted in the graph by Method A (Guideline Method) are shown in Table 4. The X-Y graph prepared from these data is presented in Fig. 2.

Table 4 Definitions of rainfall indexes depicted in the graph

	X-axis (abscissa)	Y-axis (ordinate)
Causing rainfall	(j)：Working rainfall up to one hour before the occurrence of debris flow	(k)：One-hour rainfall immediately before the occurrence of debris flow
Non-causing rainfall	(g)：Working rainfall up to the time of maximum one-hour rainfall	(e)：Maximum one-hour rainfall during a series of rain

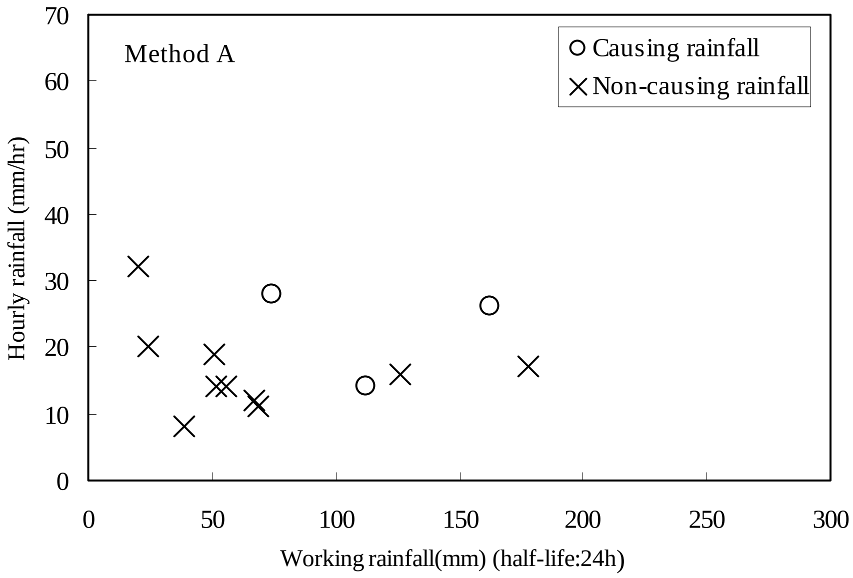

Fig. 2 X-Y graph by Method A (Guideline Method)

In Fig. 2, the line drawn between causing rainfalls and non-causing rainfalls is the critical line (CL). The critical line (CL) shall be set with the following conditions: a) all causing rainfalls must come in the unsafe zone; b) the gradient of the CL, a, must be within - 1< a <0.

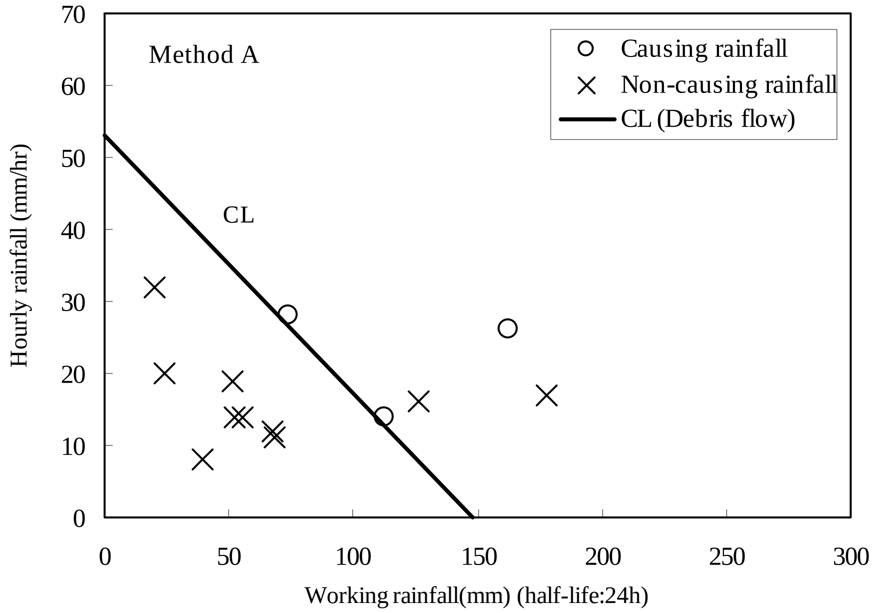

Fig. 3 Setting of the critical line (CL)

According to the rainfall data in Table 3, the past maximum one-hour rainfall, R_{H1M}, is 32.0 mm and the past maximum two-hour rainfall, R_{H2M}, is 48.0 mm. Then, the evacuation line (EL) and the warning line (WL) become as shown in Fig. 4. As a result, the standard rainfall for warning, R_1, becomes 42 mm and the standard rainfall for evacuation, R_2, becomes 58 mm.

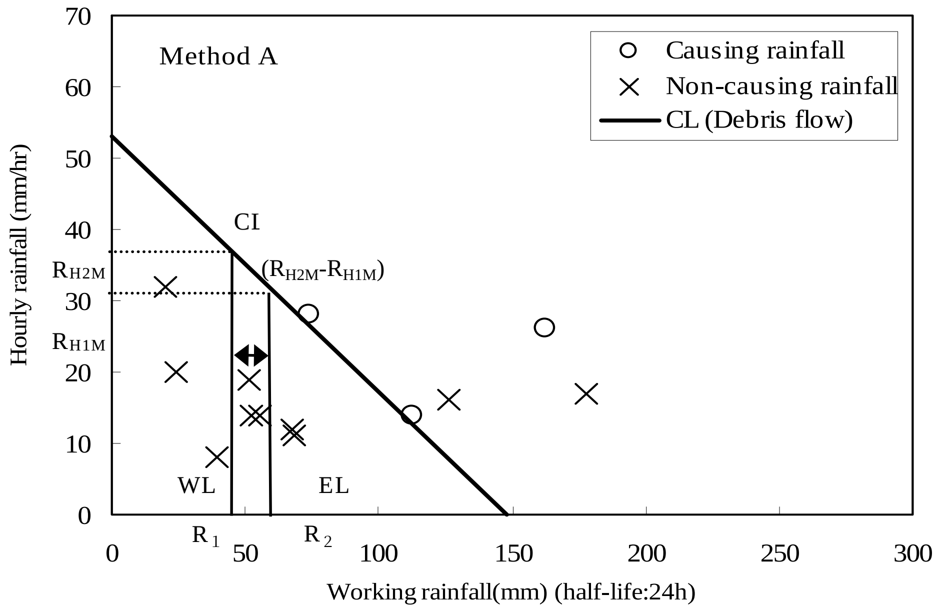

Fig. 4 Setting of the warning line (WL) and the evacuation line (EL)

3. Verification of the critical line (CL), warning line (WL), and evacuation line (EL)

Here, verification on the critical line (CL), warning line (WL), and evacuation line (EL) that are set in Chapter 2 is made based on the rainfall data and the setting method.

(1) Verification of separability

Among 10 non-causing rainfalls depicted in the graph, 8 rainfalls exist on the lower left side of the CL which is the safe zone. It is denoted as $S_c = 8/10 = 0.8$, which shows a high separability.

(2) Investigation of the frequency of warning issuance and evacuation instruction

The standard rainfall for warning, R_1, is 42 mm and the standard rainfall for evacuation, R_2, is 58 mm. The number of rainfalls of which total working rainfall exceeds R_1 and R_2 is as shown in Table 5.

Table 5 Comparison between total working rainfall, standard rainfall for warning, and standard rainfall for evacuation

Causing/non-causing	Rainfall exceeding R_1 (42 mm)	Rainfall exceeding R_2 (58 mm)
Causing rainfall	3	3
Non-causing rainfall	9	8

The data collection years are 10 years as is known from Table 3. Then, the frequency of warning issuance and the frequency of evacuation instruction are calculated as follows.

Frequency of warning issuance: $F_w = \dfrac{k_{yw} + k_{nw}}{n} = \dfrac{3+9}{10} = 1.2$ (time/year)

Frequency of evacuation instruction: $F_w = \dfrac{k_{ye} + k_{ne}}{n} = \dfrac{3+8}{10} = 1.1$ (time/year)

(3) Investigation of the non-hit rate of warning issuance and evacuation instruction

The non-hit rates of warning issuance and evacuation instruction are calculated as follows from Table 5.

Non-hit rate of warning issuance: $M_w = \dfrac{k_{nw}}{n} = 0.9$ (time/year)

Non-hit rate of evacuation instruction: $M_e = \dfrac{k_{ne}}{n} = 0.8$ (time/year)

Appendix - 2
Standard Rainfall for Warning and Evacuation against Sediment-Related Disasters Established in Japan

1. Setting examples of standard rainfall for warning and evacuation against sediment-related disasters

Standard rainfalls for warning and evacuation against debris flow disasters that are established in prefectures in Japan were surveyed as of February 2004. Some of those standard rainfalls, warning lines (WL), and evacuation lines (EL) that are set against debris flows are presented in the table shown below.

2. Relationship between probability rainfall and critical line (CL) for the occurrence of debris flows

Fig.1 shows two kinds of relationships: a) the relationship between the probable daily rainfall of 100 years and the X-intercept (continuous rainfall taking the antecedent rainfall into account) of the critical line (CL) for the occurrence of debris flows, and b) the relationship between the probable hourly rainfall of 100 years and the Y-intercept (short-term rainfall intensity) of the critical line (CL) for the occurrence of debris flows. Those relationships are described in the figure by separating into the volcanic region and the non-volcanic region. Those relationships are characterized as follows.

- No clear distinctions are found between the volcanic and non-volcanic regions.
- Concerning the Committee Method,
  - As to the relationship between the probable daily rainfall of 100 years and the X-intercept, the relationship is roughly 1:1 when the probable daily rainfall is less than 600 mm, and the relationship becomes less proportional when the probable daily rainfall is 600 mm or more.
  - As to the relationship between the probable hourly rainfall of 100 years and the Y-intercept, a positive correlation is seen slightly.
- Concerning Method A (Guideline Method),
  - A positive correlation is seen slightly, though a scatter is larger compared with that of the Committee Method.

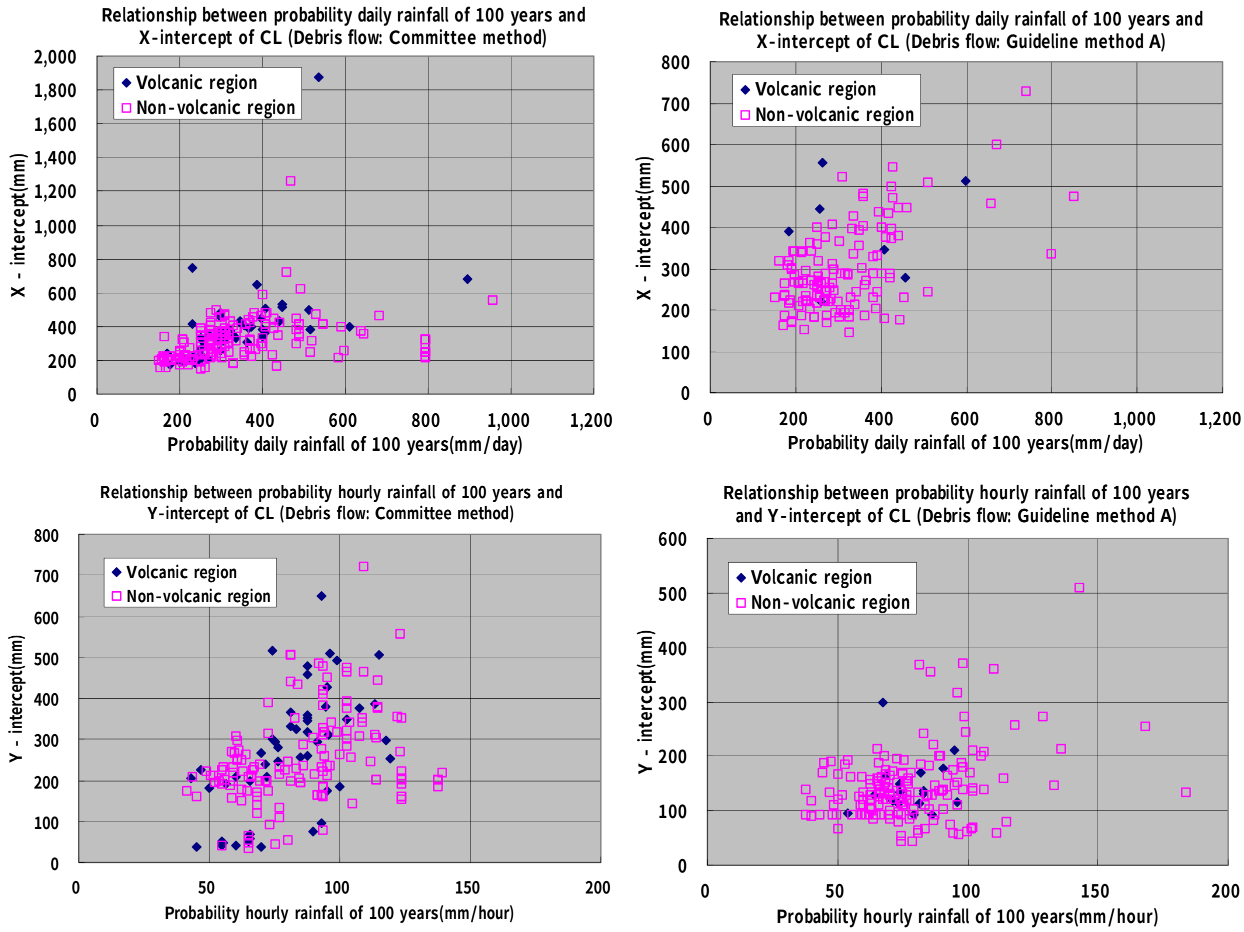

Fig. 1 Relationship between the probable rainfall and the critical line (CL) for the occurrence of debris flows

3. Critical line (CL) for the occurrence of debris flows

(1) Tendency of critical lines (CL)

The critical lines (CL) set by the Committee Method and Method A (Guideline Method) (half-life:24 hours) which are being used for the establishment of standard rainfall for warning and evacuation against debris flows in various regions in Japan are evaluated here, with a focus on the geological conditions and the rainfall amount.

Geological conditions are grouped as shown below by referring to the "Technical Standard for River Works (Tentative) - Design, Chapter 4 - Basis of Sabo Plan".

1: Granite zone
2: Volcanic ejection zone (active zone)
3: Volcanic ejection zone (inactive zone)
4: Tertiary sedimentary rock zone
5: Fracture zone
6: Other zones

Rainfalls are grouped as shown below by the amount of rainfall, taking the probable daily rainfall of 100 years as the representative rainfall.

1: Small rainfall area: less than 250 mm/day
2: Medium rainfall area: 250 mm～350mm/day
3: Large rainfall area: more than 350 mm/day

To find a tendency of critical lines (CL) that differ by the geological conditions and rainfall amount classified above, values at the X-intercept and the Y-intercept of the critical lines (CL) derived by Committee Method and Method A (Guideline Method) are plotted as Point (X, Y) in the graph by each type of geological zone (See Figs. 2 and 3). In these figures, critical lines (CL) for the occurrence of debris flows that correspond to each point are also shown. However, not all critical lines are shown. Shown in the figure are only those around the boundaries between the small rainfall area, the medium rainfall area, and the large rainfall area, which is useful for grasping the range of the critical lines (CL).

(2) Use of the critical lines (CL) prepared by Committee Method and Method A (Half-life: 24 hours)

It is not easy to find a relationship between the critical lines (CL) and the geological conditions from Figs. 2 and 3. However, a tendency is roughly found that the X and Y intercepts of the critical line (CL) are small in areas having a small probable daily rainfall of 100 years, and that the X and Y intercepts are large in areas having a large daily probable rainfall of 100 years, although a scatter is seen.

It is difficult to establish a critical line (CL) by referring to only Figs. 2 and 3, and examples of standard rainfalls for warning and evacuation against sediment disasters currently employed in Japan. But, they can be utilized as the reference when installing a tentative standard rainfall for warning and evacuation against sediment disasters in regions where rainfall data are not available, or when attempting to verify the analysis results on standard rainfall.

It must be kept in mind that these critical lines (CL) are just a reference material, and what is important is to accumulate rainfall data in each region and to establish a critical line (CL) based on the actual rainfall data as quickly as possible.

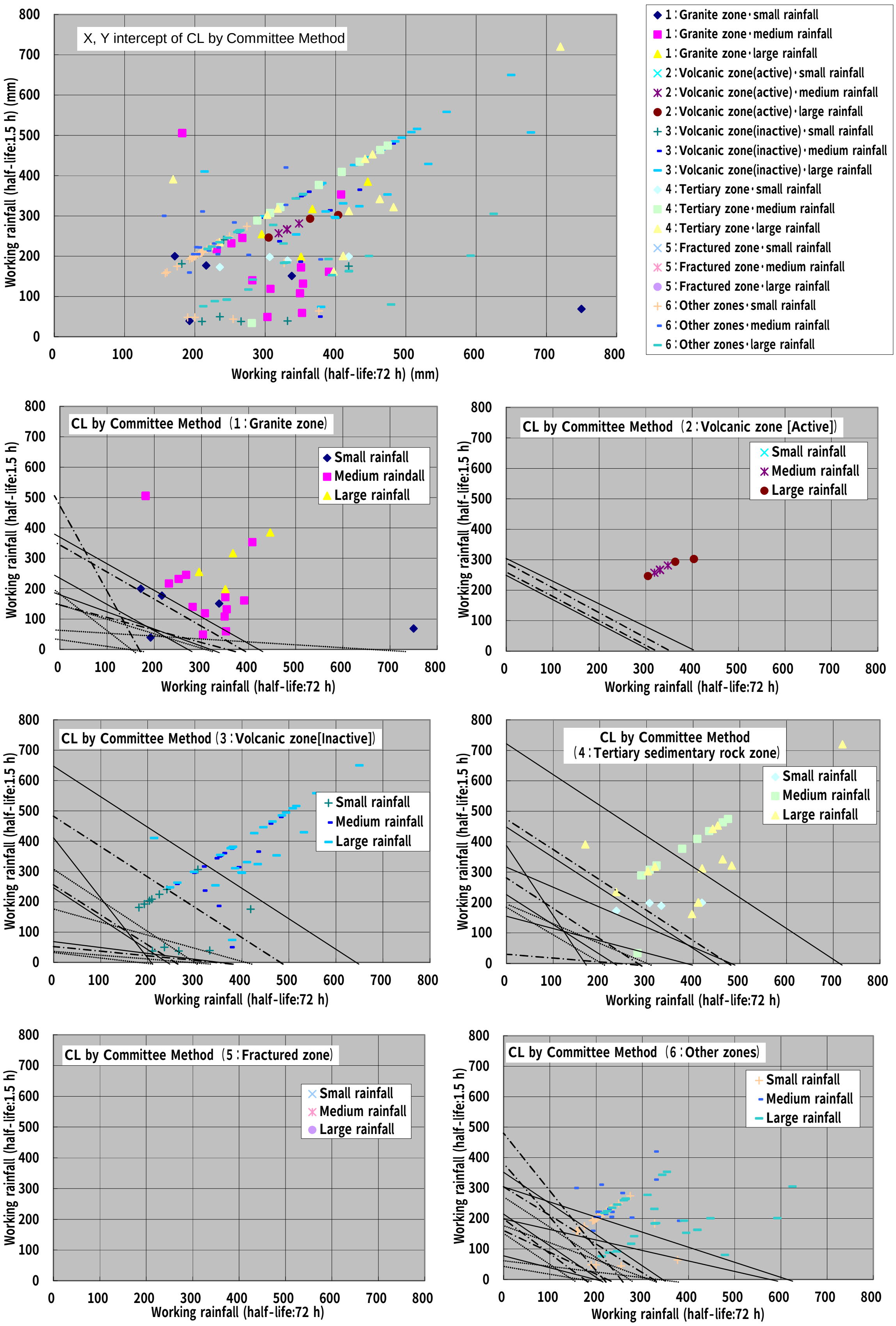

Fig. 2. Standard rainfalls CL by the Committee Method (Debris Flows)

Critical Line (CL)

: Small rainfall
: Medium rainfall
: Large rainfall

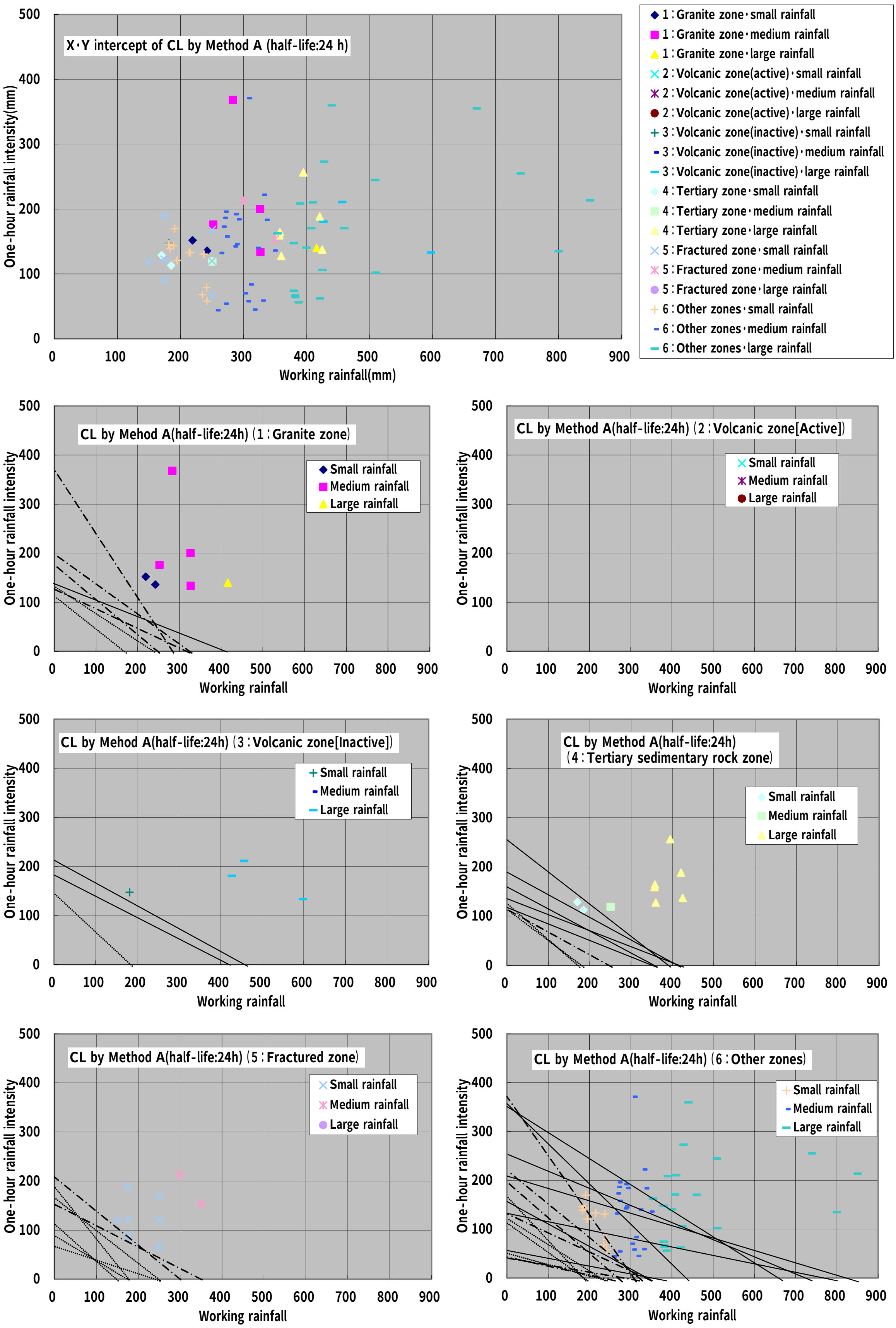

Fig. 3. Standard rainfalls CL by Guideline Method A: Half - life 24 hours（Debris Flows）

Critical Line (CL)

: Small rainfall
: Medium rainfall
: Large rainfall