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ESTIMATION OF DEBRIS VOLUME TRANSPORTED FROM LANDSLIDE POINTS IN MOUNTAIN DISTRICTS

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INTRODUCTION

Many reports and papers are published up to present on researches for the yeild of debris and for the phenomena of transportation of debris that caused by landslides to river courses. The outline of these reports and papers are summarized in the reference 1). On the other hand, the most of these researches are not instructive for the plan of the adjustment of debris along river courses to control flood, because they are described qualitatively on the special river basin not covering the whole. In recent years, most of the river beds in Japan have gone down rapidly by the reasons that the river bed materials have been excavated for concretes aggregates and dams have restricted new supplies for river bed materials. Consequently, the projects of river course treatment are being generally reexamined. Under the present circumstances, it is necessary to research quantitatively on the phenomena such as yielding, transproting and depositing of debris along the river courses for the maintenances of all rivers.

The authors have studied to estimate the debris volumes and those carry down amount to river courses and the special attentions were paid to the upper basin of the Tenryu River. The results of research have been reported in references 1) to 7). The authors have concluded from the above studies that the debris volumes yielded from landslides may be estimated according to the rainfall and also to the volumes which were carried down from landslide points on the upper Tenryu River basin. However, on the other basins, it seems to be unfavorable to apply the results of the authors' researches because the other basins have the different lie of the land and unlike geological structures. Accordingly, the authors have originated a new methodology which can be applied to any other river basins, which have some similar geological conditions, based on the facts studied on the upper Tenryu River

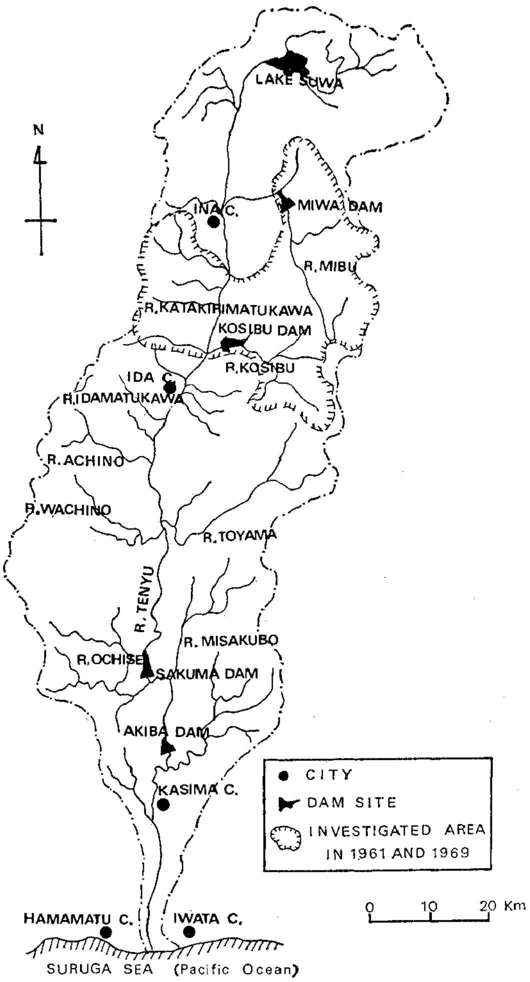

Fig. 1 Map of Tenryu River Basin

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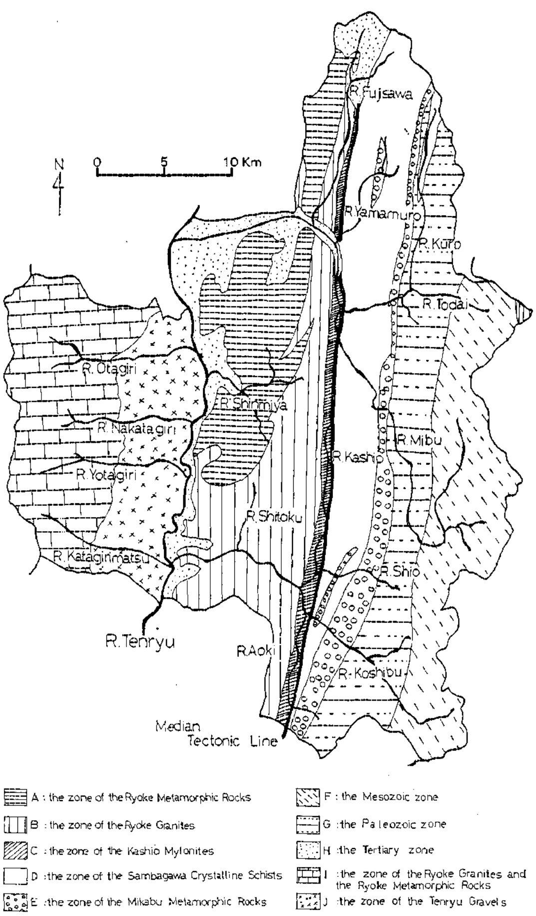


Fig. 2 Geologic Map

basin. This report shows the new method and some examples as the results of its applications.

1. THE OUTLINE OF THE AUTHOR'S RESEARCHES ON THE UPPER TENRYU RIVER BASIN

Generally speaking, the yield of debris in mountain districts is mainly originated by landslides, and the quantities and scales of landslides depend on rainfall amounts. On June 27th 1961, a heavy storm accompanied by rainy front attacked the upper Tenryu River basin and caused many landslides of large scales as well as much yields of debris around this area. It was the severest disaster since 1710 by floods and the carried down debris filled around this area. The case study on the states of these landslides is shown in Tables 1 and 2, and in which, other cases of landslides are seen corresponding to geological conditions. The authors, by these facts, adopted four geological conditions in this area as (1) the Terrace and the Pliocene Gravel zone, (2) the Granites zone on the east side of the Tenryu River, (3) the Sambagawa Crystalline Schists and the Mikabu Metamorphic Rocks zone and (4) the Mesozoic and the Paleozoic zone. The authors proposed a formulae which estimate the debris volume carried down from landslide points as relation to the whole rainfall during one storm considering each geological condition. The formulae will be seen in the reference 2).

In 1969, the Ministry of Construction reinvestigated the actual states of landslides appeared after 1961 by means of aerial photographs and field surveys. Using above results, the authors compared them closely with authors' investigations in 1968, and found varying states of landslides, moreover, new landslides as well as decreased volume of remained debris in landslide points. The authors rearranged these data and reported on the special characteristics of landslide states concerning to each geological condition in the reference 1). In this study of varying states of landslides, the authors have found no standards to judge the appropriateness of the time period; 8 years. In this paper, the authors have tried making use of the chances and data reinvestigated by the Ministry of Construction. It seems, however, that the period to restore to original state is about 10 years in cases of the central part of Japan.

As a result of these works, the following facts

Table 1 The Number of Landslides/(km^2)

Geological Conditions / Rainfall amount	Granite Rocks (on the West Side of T. River)	Terrace and Pliocene Gravels	Granite Rocks (on the East Side of T. River)	Mylonites	Sambagawa and Mikabu zones	Mesozoic and Paleozoic zones
200 - 300 mm					0.7	4.5
300 - 400		0.4	20.0	19.6	10.9	5.5
400 - 500	24.3	2.9	59.2	17.0	13.2	5.4
500 - 600	15.7	34.2	65.7		20.2	13.3

Table 2 Debris Volume/(a Landslide) (m^3)

Geological Conditions \ Rainfall amount (mm)	~ 300	300 ~ 400	400 ~ 500	500 ~ 600
Granite Rocks (on the West side of the T. River)			1,095	m^3 2,368
Terrace and Pliocene Gravels			1,817	1,327
Granite Rocks (on the East Side of the T. River)		1,212	1,394	1,295
Myronites			2,917	
Sambagawa and Mikabu zone		250	3,951	5,795
Mesozoic and Paleozoic zone	861	3,457	1,717	

are confirmed. The whole debris volume which yielded from landslides is $1350\times10^4 M^3$ and $1870\times10^4 M^3$, respectively, in the tributary Mibu river basin and in the Koshibu river basins. The volume of debris carried down to the main Tenryu stream, simultaneously with the outbreak of landslides, was about 80% of total amount and the remained debris volume decreased to nearly 10% of total volume from 1961 to 1969. The carried down debris which simultaneously accompanied by outbreak of landslides on heavy storm, causes severe disasters along the river. Moreover, the debris which is running successively is harmful both to the damaged districts and to the maintenace of river courses.

By these reasons, the authors intended to clarify the actual states of debris movements from landslide points. On the upper Tenryu River basin, landslides are classified by the scales of those area and by their modified types according to the geological conditions. Then, the distribution of landslides are clarified after each category. Secondly, it is assumed that the number of landslides yielded by heavy storms depends on the distribution rules on each geological condition. Then, the authors detected several unit values per each transformation type of landslides, such as an area ratio (total areas that varied during 8 years by total original areas of landslides per each geological condition), mean depth of carried down debris (under the assumption that they remained on the original slope), and so on. In thie work, the modified types of landsledes are classiffed into four types; enlarging, invariable, reducing and disappeared. The authors then determined a method to estimate debris volume that was carried down continuously from landslide points during 8 years by an application of the above stated unit values. Details of this work are included in the reference 1).

Table 3 Classification of geological conditions

Zone	Geological Condition
A	Ryoke Metamorphic Rocks on East Side of the T. River
B	Ryoke Granites on the East Side of the T. River
C	Kashio Myronites
D	Samba Crystalline Schists
E	Mikabu Metamorphic Rocks
F	Mesozoic Rocks
G	Paleozoic Rocks
H	Tertiary Rocks on the East Side of the T. River
I	Ryoke Granites and Ryoke Metamorphic Rocks on the West Side of the T. River
J	Tenryu Gravels on the West Side of the T. River

Table 4 Class of the Landslide Area

Class	Area (m^2)
I	~ 500
II	500 ~ 2,000
III	2,000 ~ 4,000
IV	4,000 ~ 8,000
V	8,000 ~ 16,000
VI	16,000 ~

Table 5 Area ratio of landslides against the type of the transformation ($\%\times10^4/km^2$)

Tape of Modification	Geological condition									
	A	B	C	D	E	F	G	H	I	J
New landslides	290	298	891	370	159	825	820	355	4,860	43
Enlarging	0	7	19	72	219	228	849	7	1,262	—
Invariable	258	1,135	593	693	1,508	4,385	1,153	8	5,945	245
Reducing	581	3,394	1,163	591	3,696	1,222	1,135	30	1,630	6
Disappeared	1,097	993	2,548	4,943	10,390	687	1,567	237	3,766	640

Table 6 Mean Depth of Transported Debris (m)

Geological Zone / Type of Modification	A	B	C	D	E	F	G	H	I	J
New Landslide	2.32	1.78	4.49	3.75	4.35	4.28	2.98	2.57	1.84	1.82
Enlarged L.	0.00	1.50	8.10	3.27	5.15	4.85	1.47	1.28	1.43	0.00
Invariable L.	0.10	0.08	0.51	0.50	0.13	0.08	0.55	0.22	0.22	0.37
Reduced L.	0.20	0.37	2.20	1.17	1.60	3.26	2.06	0.83	2.44	0.79
Disappeared L.	0.18	2.00	0.86	0.32	0.50	0.70	0.60	0.31	0.35	0.35

In this paper, the authors divided this area into ten zones after the geological conditions as shown in Table 3 and classified landslides by the scales of areas in as Table 4. In addition, the unit values or the area ratios and the mean depths of carried down debris, are shown in Table 5 and Table 6, respectively.

2. GENERALIZATION OF METHODS TO ESTIMATE DEBRIS VOLUME WHICH IS CARRIED DOWN FROM LANDSLIDE POINTS

(1) The formula to estimate debris volume which was carried down from landslide points on the upper Tenryu River basin

The carried down volumes from the landslide points will be estimated by the formula (1) based on the investigations on the landslides on the Upper Tenryu River basin, using the unit values shown in Tables 5 and 6 per each geological condition;

$$V_i = A_i \sum_{j=1}^{5} (\text{Area ratio})_{i,j} \cdot (\text{Mean depth})_{i,j} \qquad \cdots\cdots(1)$$

where,

V_i: Volume of debris that carried down during 8 years from landslide points on each i-th geological condition, (M^3).

A_i: Total area of the proposed geological zone, (M^2).

j: Ordered number on the types of landslide transformation.

The formulae (1) can not, however, be extended to apply to the other river basin, and also to the areas where investigations of landslides are not operated on even in the Tenryu River basin.

(2) Selection of main elements related to the yield of landslides

There are many elements to be considered in relation to the occurence of landslides such as the topographical and geological conditions of land and the hydrological conditions. Provided, however, the amount of rainfall is equally distributed, the authors assume that the distribution of landslides depend merely on the mean tangent of landslopes on each geological condition. The reasons are deduced from the following articles;

(a): The elevation concerned to the distribution of landslides can be replaced by the rainfall amount which depends on the elevation.

(b): The influence of the slope orientation against the landslide distribution can be ignored, because it is considered that the distribution of the slope orientations must be equal in all directions if the total area of a geological condition is large enough.

(c): The influence of vegetative conditions covering on slope surfaces can be neglected, because it seems to decrease the effects gradually as rainfall amount increases.

(d): The mean tangent of land slope is the most important factor for the distribution of landslides and it can not be replaced by any others.

However, it is very difficult to find out the tangent of slope at individual point of landslide put out from maps with $1/5 \times 10^4$ scales or from aerial photographs.

Even if the tangent of slopes was known previously by the sample investigations of object landslides, they can not be available for the planning of river improvement works from the above reasons. Therefore the authors originated a mean tangent value of every 2 Km square mesh to use on the proposed geological zones. The mean tangent of one mesh I_i is calculated by the formula (2).

$$I_i = (h \sum l_n)/A \qquad \cdots\cdots(2)$$

where,

I_i = mean tangent on one mesh.

h = difference of height between neighbouring contour lines (m).

l_n = the length of a contour line included by a mesh.

A = the area of a mesh ($=4 \times 10^6\ M^2$).

Table 7 Distribution Number of Landslide/Km^2

Geological Condition / Mean Tangent of Mesh	A		B		C		D		E		F		G		H		I		J	
	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old
0 - 0.05															0.00	0.00			0.00	0.00
0.05 - 0.10													1.54	2.20	0.10	0.80			0.00	1.40
0.10 - 0.15			0.00	3.20			0.00	0.00					—	—	0.00	0.00			0.50	2.00
0.15 - 0.20	0.00	3.80	—	—			—	—					—	—	0.00	0.80			0.00	0.00
0.20 - 0.25	0.53	1.10	0.00	0.00			—	—					—	—	0.00	0.00			0.29	2.00
0.25 - 0.30	0.00	0.98	0.55	4.40			0.00	0.50					—	—	0.30	0.40			—	—
0.30 - 0.35	0.70	4.00	0.00	14.30			0.25	2.40					—	—	0.49	1.20	0.93	0.93	0.56	8.30
0.35 - 0.40	0.56	4.80	0.23	29.20			0.62	4.50	0.95	5.60			—	—	—	—	—	—		
0.40 - 0.45	0.59	8.00	0.90	26.90	0.78	6.30	0.48	5.60	0.00	0.00			0.37	1.30	0.00	1.90	1.59	11.30		
0.45 - 0.50	0.80	1.73	0.37	20.00	1.82	7.20	1.06	8.60	0.30	5.60			0.00	3.40	0.00	1.60	3.15	14.40		
0.50 - 0.55	1.30	—	0.94	35.90	0.98	4.40	1.01	13.60	1.10	4.40	0.00	5.40	0.71	4.60			5.50	44.00		
0.55 - 0.60	0.00	11.60	1.07	33.50	0.87	10.10	1.69	12.20	0.61	5.20	0.00	5.30	1.64	7.10			12.00	33.70		
0.60 - 0.65			0.55	35.50	3.14	15.90	1.13	4.30	0.00	3.10	0.79	6.00	1.02	5.50			9.10	19.00		
0.65 - 0.70			1.90	24.50	1.65	6.40			0.63	4.40	1.04	7.50	2.01	7.20			9.84	22.20		
0.70 - 0.75			0.69	25.30							1.57	9.90	1.80	5.10			4.55	17.20		
0.75 - 0.80			1.12	6.00							1.38	13.10	1.73	11.20			2.80	12.50		
0.80 - 0.85			—	—							1.46	12.30	1.25	7.80			0.70	25.70		
0.85 - 0.90			0.00	28.30							2.57	12.30					4.35	8.70		
0.90 - 0.95			0.55	1.60							—	—								
0.95 - 1.00			0.00	1.90							1.38	6.20								

Note: (1) New: The Landslides occured from 1962 to 1969
(2) Old: The Landslides occured in 1961

In this study, the authors adopted each 2 Km square mesh to calculate the mean tangent. The reasons are as follows;

(a) The largest area scale of one landslide was 128×10^3 M^2 in the actual data in 1961 in this upper Tenryu River area.

(b) The difference between a mesh mean tangent and a partial point tangent of slope grows larger as length of mesh is choosen longer.

(c) As a standard mesh, it is desirable the distance of mesh being small, if the necessary data could be obtained.

(3) The relation of the mean tangent of a mesh against distribution of landslides

The authors counted the number of landslides included in every mesh on each geological zone from the investigations of the upper Tenryu River basin in 1961 and 1969, being shown in Table 7 as results.

It has generally been recognized that the distribution pattern of those numbers of landslides, which subjected to slope angles of given positions, are nearly equal to a shape of a triangle, the peak of which lies about 30 to 40 degrees. The same properties are found on the investigations carried out in 1961 on the upper Tenryu River basin, being shown in the reference 2). Figs 3 to 12 show the distribution diagrams of landslides per unit area of 1 square kilometer against mean tangents of slope in each mesh against each geological zone of the upper Tenryu River basin. These diagrams have the mean tangents divided into 0.5. Every two side lines that terminate the distribution triangles are drawn by means of the least square calculus. The amount of rainfall shown in the figures is the integrated one through one storm. In 1961, the total rainfall of the proposed storm reached more than 300 mm in the investigated area, and it was less than 300 mm through the year from 1961 to 1969. The authors, therefore, classified these figures into two cases. These diagrams are named by the authors as the basic distribution diagrams of landslides relating with mean tangent of 2 Km square mesh.

It seems that the distribution number and the scale of landslides have some relation to the total rainfall on the same geological condition. In the central part of Japan, referring to the actual data of disasters, there are a border upon the total rainfall of 300 mm. The authors, then, adopted 300 mm rainfall as the total rainfall in order to separate the data of landslides.

(4) The whole mean gradient of surface slopes

The geological zones in the mountain district either concentrates in an area or disperse into several areas on the object basin. The former cases, when the zone concentrated in one area, the whole mean tangent agrees with the simple mean value calculated by that in every mesh. On the latter cases, whole mean gradients of slopes are defined as;

Whole mean tangent of slope,

$$I=\frac{\sum I_i \cdot A_i}{\sum A_i} \quad \cdots\cdots(3)$$

where

I_i: mean tangent of the i-th separated area,

A_i: area (M²) of the i-th separated area.

(5) A generalized method to estimate debris volume which is carrying down from landslide points

Extending the analysis to any other river basin, the authors assume that the distribution of landslides on a geological zone may correspond to the ratio, that is, the whole mean tangent of the geological zone to that of the same geological zone on the upper Tenryu River basin. The debris volume which is carrying down continuously from landslides will be consequently calculated by the following formula (4),

$$V_i=(C_a)_i \cdot N_i \cdot A_i \sum_{j=1}^{5} (r_a)_{i,j} \cdot (d_m)_{i,j} \quad \cdots\cdots(4)$$

where,

V_i = Volume of debris which is carrying down continuously from landslide points during eight years for i-th geological condition under consideration, (M³).

N_i = Number of landslides distribution corresponding to whole mean tangent for i-th geological condition, on a river basin under consideration.

(The values will be found in Figs. 3

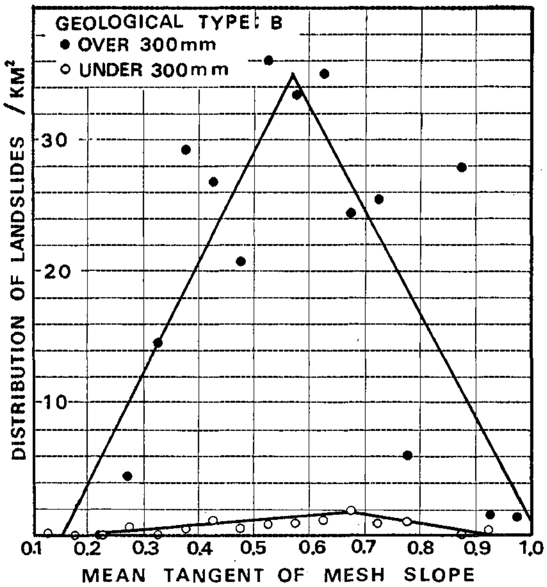


Fig. 4

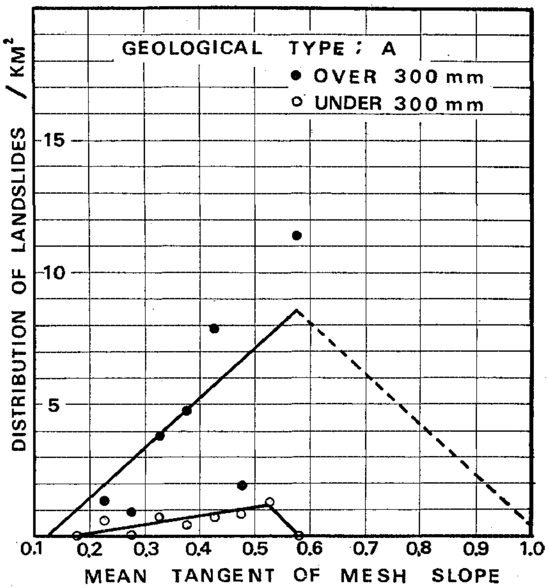
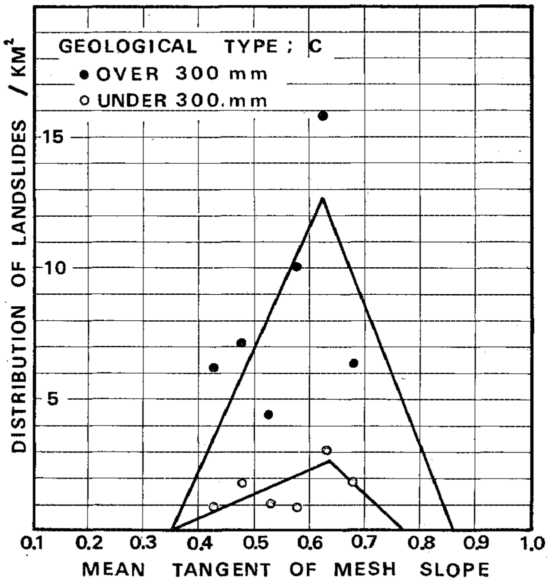


Fig. 3



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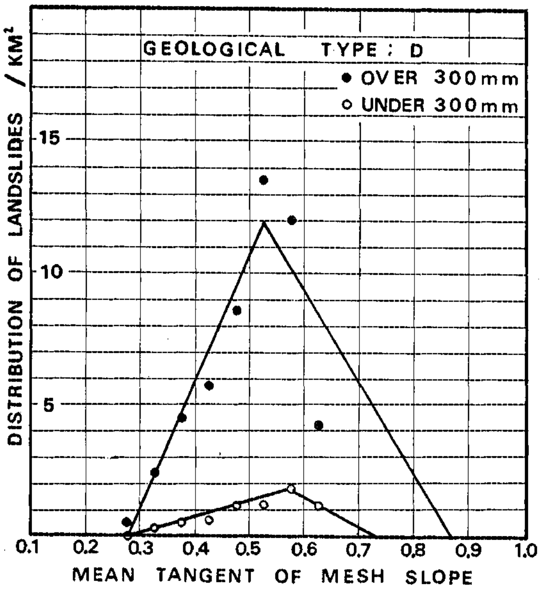

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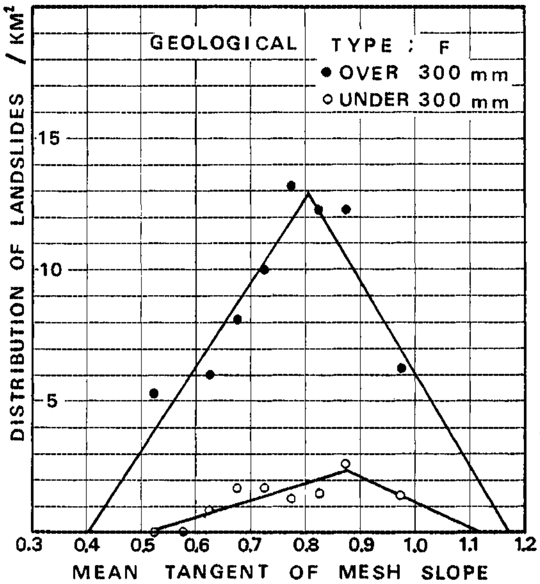

Fig. 8

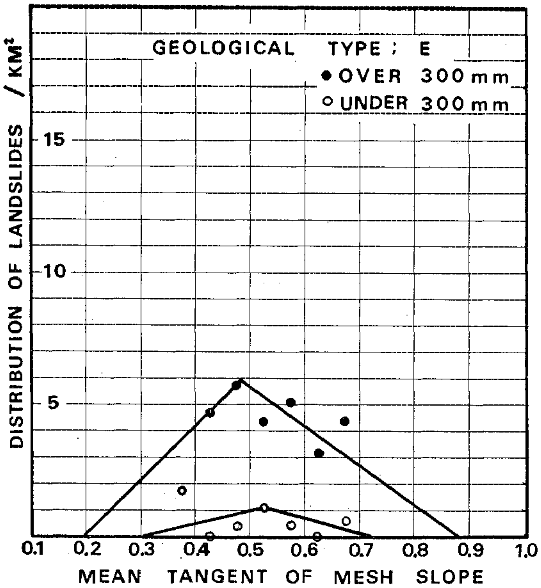

Fig. 7

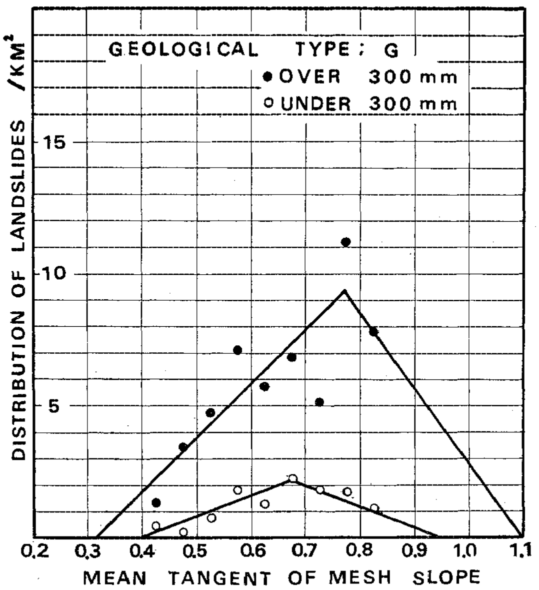

Fig. 9

to 12 against each geological condition).

A_i=Total areas of i-th geological condition, (M^2).

$(r_a)_{i,j}$=Area ratio of i-th geological condition against j-th type of landslide modification, (Table 5).

$(d_m)_{i,j}$=Mean depth of the debris which carried down from landslides point in the i-th geological condition against j-th type of landslide modification, (M), (Table 6).

$(C_a)_i$=Adjustment value, or the reciprocal number of landslide distribution agaist the whole mean tangent of the geological zone found in the Tenryu River basin, being found on Figs. 3 to 12.

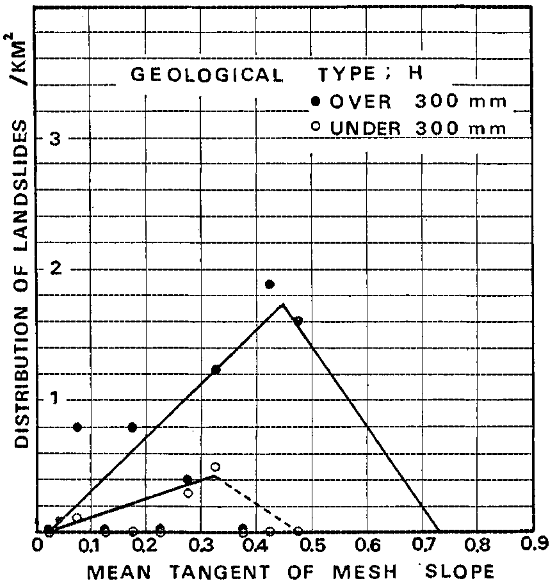

Fig. 10

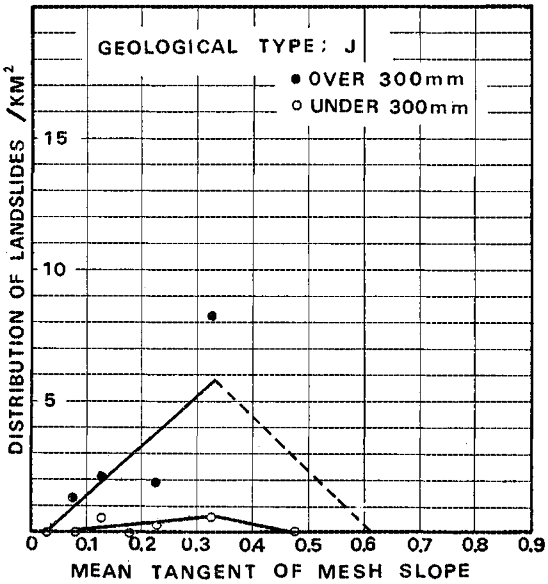

Fig. 12

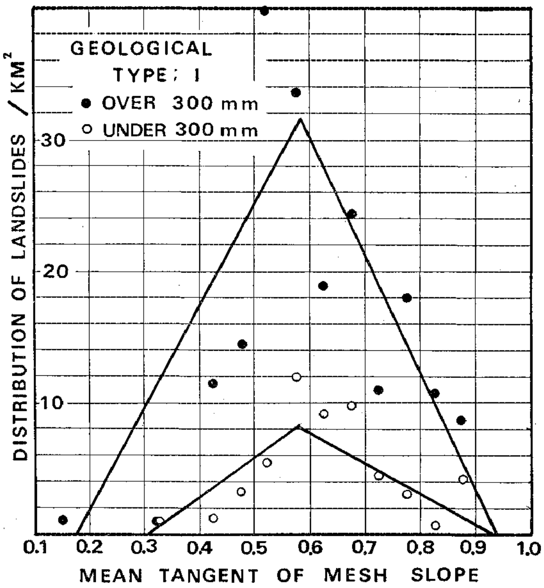

Fig. 11

The values (C_a) are evaluated on Table 8 corresponding to each geological zone of the upper Tenryu River basin. The process of the above calculation is then explained in the following articles;

(a) An adopted area of a river basin is divided and classified into several geological conditions tracing on a topographical map with scales of $1/5 \times 10^4$.

(b) The area is drawn by 2 Km square meshes covering it. Mean gradient of slopes is calculated in each mesh, then whole mean values of tangent are calculated in each geological zone, respectively.

(c) Number of landslide distribution is counted against the whole mean tangent calculated by article (b), on Figs. 3 to 12 showing them per each geological condition of the upper Tenryu River basin. The numbers must be selected against the total rainfall amount in the proposed area either more or less than 300 mm.

(d) (C_a) is choosen from Table 8 on every geological condition.

Table 8 Adjustment Value C_A

Geological Condition		A	B	C	D	E	F	G	H	I	J
Rainfall amount (mm)	300 ≦	0.172	0.031	0.124	0.127	0.182	0.092	0.172	1.000	0.039	0.556
	< 300	1.250	0.833	0.667	1.000	0.952	0.667	0.645	2.857	0.156	5.263

(e) The formula (3) is applicable to any other river basins, if the geological condition is similar to that of the upper Tenryu River area, and debris volume through eight years can be estimated per each geological zone.

Strictly speaking, the formula (3) does not include the element of debris which is carried down on the mountain slope. There are, however, no investigated data on the debris volume which was carried down on the mountain slope in this area. The authors, then, took no account of this debris volume in this study.

3. BRIEF SUMMARIES ON EXAMPLE EVALUATIONS

(1) Estimation of debris volume for the Sakuma Dam catchment area

The dam is one of the largest in Japan, completed in May, 1956, the site being shown in Fig. 1, has the catchment area 3827 Km^2 in which the investigated area 1180 Km^2 are included. The debris volume that was carried down from the landslide points during 8 years from 1961 to 1969 is estimated as $2573\times10^4\,M^3$ by the method mentioned above. The results are as follows. The geological area components and the whole mean tangents of each geological area were calculated and shown in Table 9. Then, debris volume in this area can be estimated by the Figs. 3 to 12, and formula (1) or (4). The formula (1) is, however applied to the investigated area of 1180 Km^2. On the other hand, the volume of debris that is actually surveyed at the site on the reservoir of the Sakuma Dam and also in the upper reaches of river is calculated and shown in Table 10.

Table 9 Ths elements of the Sakuma Dam catchment area

		Area (km^2)	Whole mean values of tangent	Debris volume ($\times10^4\,m^3$)
Geological condition	A	169.8	0.433	12.7
	B	535.9	0.537	423.6
	C	48.0	0.605	46.4
	D	211.6	0.445	101.6
	E	22.9	0.515	17.2
	F	316.2	0.722	305.4
	G	460.8	0.584	312.8
	H	140.5	0.225	34.3
	I	868.3	0.523	1294.1
	J	484.6	0.168	24.5
Total		3258.6		2572.6

Total rainfall amount	≧ 300 mm	< 300 mm
Area (km^2)	2880.6	378.0

Note: The catchment area in this table does not include the catchment area of the Lake Suwa.

Table 10 Surveied debris volumes

	Settled volumes	Remarks
Miwa Dam Reservoir	$251\times10^4\,M^3$	1961 - 1969
Sakuma Dam Reservoir	$2{,}120\times10^4\,M^3$	1961 - 1969
Tenryu River Course	$618\times10^4\,M^3$	1961 - 1969 Scouring
Debris Barrier Reservoirs in the investigated area	$507\times10^4\,M^3$	1961 - 1969
Total	$2{,}260\times10^4\,M^3$	

(2) Debris volume at the Akiba Dam site

The dam located near the Sakuma Dam downstream has the catchment area of 4401 Km^2. The sediment put into the Akiba Dam reservoir is mainly supplied by two triburaries Ochise River and Misakubo River. The authors' estimation on the debris volume evaluated as $450\times10^4\,M^3$ in this area during eight yeas. As the results, the geological components and the whole mean tangents of this geological areas were calculated and shown in Table 11. Then, the debris volumes which were carried down can be estimated by the Figs. 3 to 12, and the authors' formula (4). Deposited debris volumes are found to be $440\times10^4\,M^3$ against the above volumes in the reservoir of the Akiba Dam during 8 years through 1961 to 1969.

Table 11 The elements of the Akiba Dam catchment area

		Area (km^2)	Whole mean values of tangent	Debris volume ($\times10^4\,m^3$)
Geological condition	B	24.2	0.678	9.0
	C	20.8	0.507	17.0
	D	69.2	0.555	44.5
	F	99.6	0.647	64.5
	G	65.0	0.648	58.7
	H	139.7	0.489	3.0
	I	147.7	0.495	231.9
	J	7.6	0.341	1.0
Total		573.8		429.6

Total rainfall amount	≧ 300 mm	< 300 mm
Area (km^2)	573.8	0

Note: The catchment area in this table does not include the catchment area of the Sakuma Dam.

(3) Debris volumes at the Yokoyama Dam site

This dam is constructed as a multiple purpose dam in the Ibi River system. Granites and Paleozoic rocks are found as geological conditions in this catchment area. A heavy storm attacked this area in August, 1965, and rainfall reached about 400 mm. In this case, the authors applied only Granites and Paleozoic rocks data of the upper Tenryu River basin to this area. The each geological area and whole mean tangents of this area was calculated and shown in the Table 12. Debris volumes are estimated by the authors as $370 \times 10^4 M^3$ during eight years from 1966 to 1973. Corresponding to the above volumes, actual surveys carried out in the reservoir of the Yokoyama Dam got $398 \times 10^4 M^3$ during the same period.

Table 12 The elements of the Yokoyama Dam catchment area

		Area (km^2)	Whole mean values of tangent	Debris volume ($\times 10^4$ m^3)
Geological condition	B	64.6	0.437	28.2
	G	385.0	0.503	343.1
Total		449.6		371.3
Total rainfall amount			≧ 300 mm	< 300 mm
Area (km^2)			160.7	288.9

4. CONCLUSION

The landslides, occurred by the storm in June, 1961, brought severe disasters on the Upper Tenryu River basin. According to the investigation of the landslides, the authors proposed several formulae to estimate debris volumes yielded from the first landslides under the assumptions that the debris volumes are related to a function of rainfall. On the other hand, after the first landslides occurred, considerable volume of debris was carried down from these landslide points. The authors found the changing states of landslides from 1961 to 1698 through investigations on landslides. Moreover, the authors knew that the ratio of debris volume which was carried down simultaneously with first landslides to the whole one which yielded from first landslides was about 4 to 5, and the debris volume which was carried down during eight years was about a half of the remained debris volume at the positions of first landslides. The authors then classified the states of landslides into severalt ypes of landslide variations after each geological condition and found the unit values related to the carried down volume amount of the remained debris. The authors also proposed the estimation methods of the carried down debris volumes in the upper Tenryu River basin on the investigated data in 1961. Conclusively, the authors proposed generalized estimation methods of debris volumes that was carried down continuously to be applied to any river basin which has a similar geological condition of the upper Tenryu River basin, after the first landslide. Several results are obtained by the application of the methods on some river basins and it seems that this estimation method is useful one for the planning of river maintenances as well as to the river course treatments.

Up to the present time, the estimating method of the carried down debris volume from landslide points, is the ordinary one in order to investigate the yielded landslides and the debris volume which was carried down to river courses, after heavy rainfalls. As mentioned above, however, that the upper Tenryu River basin has many investigated data of landslides and debris movements to be refferred, it is found very useful on the authors' method for estimating the yielded debris volume and the carried down volume of debris from landslide points on any other river basin which has some similar geological conditions. The authors have testified that the new method can be generally applied to any other river cases considering the strength of the upper Tenryu River basin data.

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