Republic of Indonesia

Master Plan for Land Erosion and Volcanic Debris Control in the Area of Mt. Merapi

SUPPORTING I

A. GEOMORPHOLOGY
B. GEOLOGY AND LAHAR DEPOSITS
C. HYDRAULICS AND HYDROLOGY
D. RIVER SURVEY
E. RECORD OF DISASTER AND HAZARD AREAS
F. SOCIO-ECONOMY

March 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

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SUPPORTING REPORT A

GEOMORPHOLOGY

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1. INTRODUCTION

1.1 Topography

G. Merapi is located on 30km north from Yogyakarta in central Java and is 2,968m high above the sea level. The studied area spread approximately 850km^2 on the south and west slopes of G. Merapi.

G. Merapi, one of the most active volcano in Indonesia, is a volcanologically very young Quarternary strato volcano with a beautiful conical shape. It erupted many times on a large scale even in recent times. The south-western part of mountain body, or the so-called older Merapi, was almost totally destroyed in 1,006 A.D. The present active younger Merapi was formed on the old Merapi. The younger Merapi is surrounded by the older Merapi except the south-western slope.

Nine main tributaries flowing down radially dissect the mountain slope. Five of them are tributaries of K. Progo: K. Pabelan, K. Blongkeng, K. Putih, K. Batang and K. Krasak. Three of them are tributaries of K. Opak: K. Boyong, K. Kuning and K. Gendol. K. Opak and K. Progo pour into the Indonesian Sea 30km south from Yogyakarta. K. Woro is a branch of K. Dengkeng, which is one of the tributaries of Bengawan Solo.

G. Merapi can be divided to three areas vertically as shown in Figs. 1 and 2 in accordance with its geomorphological characteristics: namely, the upper slope area above 2,000m the middle slope area between 2,000 - 500m and the foothill area below 500m. All slopes are described in detail below.

(1) The upper slope area is situated on the older Merapi body and is always affected directly by the present volcanic activity. This area is composed of pyroclastic materials, lava and ash, and has an incline of more than 30 degrees. Owing to the regular supply of the new volcanic products, this area has become almost bare. Sometimes thin gullies develop on the slope composed of pyroclastic materials.

As a great drop occurs between the crater in the south-west side of this area, a large part of the eruptive products flow down along this drop and cause damage in the south-western foothill area.

(2) The middle slope area has somewhat complex topography because it is composed of the remaining of the older Merapi and of the slope composing of the eruptive products of the younger Merapi.

The older Merapi forms a horseshoe shape which is higher in north-east side and opened and lower on the south-east side. The older Merapi is very steep due to severe erosion. Especially in the north-eastern side, valleys are deep with steep walls because the eruptive products of the younger Merapi were not distributed around this area.

In the south and north area, the products of the younger Merapi flow down along the valleys dissecting the mountain body of the older Merapi so that the area can be divided into visibly separate topographic units: upper, middle and lower slopes.

Products of the younger Merapi, flowing down along the older valleys, expanded and were deposited in a fan shape along the outlets of the valleys.

In the upper slope area, a valley formation is not pronounced; however for some small gullies in the middle slope area, below 2,000m where, water has easily concentrated to cause the rill erosion to develop into radial deep valleys. In the middle slope area, mainly consisting of deposits of nuée ardente, deep valleys are formed at the present time. During a large scale eruption, nuée ardente flows down into this area, fills up valleys and even changes the direction of the valleys. When the eruption becomes weak, valley formation immediately starts because the gradient deposition of nuée ardente is steeper than the gradient of streams below it.

The slope surface of this area is relatively more undulated than that of the footslope area. This may mean that the deposited materials in this area are more viscous than the materials in the lower part. Gentle and step slopes are numerous in this area and their gradient becomes more gentle in the lower area. These steep parts can be visualized as many small circles steps surrounding G. Merapi.

(3) The foothill area stretches from the place where the deep valleys of the middle slope disappear. This area stretches from a location of 500 - 600m in height with gradient of 3 degrees for K. Progo. The slope of the south side of Yogyakarta is approximately 1 degree. This area is poorly undulating and forms a very gently inclined smooth surface. The radially developed valleys from G. Merapi have become shallow by the time they reach this area. However, they form deep valleys before they flow into K. Progo and K. Opak because the channels of K. Progo and K. Opak are deep in this flat area.

K. Woro, flowing into K. Dengkeng, forms a raised riverbed in the lower reach area where the riverbed is 5 ∿ 6m higher than the general surface. K. Dengkeng generally forms a marsh area on the right bank side.

However, the foothill area is also considered to be composed of volcanic materials, and shows only small undulation due to its more fluid origin.

Along K. Boyong, K. Kuning and K. Woro, alluvial fans are formed in this area. These fans are composed of old volcanic deposits and fan gravels.

1.2 Objectives and Scope of This Study

The purpose of this study is to determine the geomorphological land conditions in order to forecast the endangered area to Lahar and Banjir flooding and to design the masterplan for sediment and erosion control.

The main work of the geomorphological survey is to prepare a land condition map in order to locate the endangered points and areas.

The scope of work of geomorphological study was limited to the Type-I area since the greatest amount of recent damage from volcanic eruption has taken place there and since Type-II and Type-III areas have similar features. (for definition of terminology see Section 2.1)

1.3 Validity of Methodology

In the study area, the relationship between landforms and Lahar/Banjir occurances was studied. The probable endangered areas were analysed by using the landform classification map. For a more accurate and quantative estimation, other maps and data (isoclinal slope distribution, relative height of the banks/cliffs of valleys, stream system map, etc.) were also prepared and analysed.

In order to determine the accuracy of the estimation, two methods were employed: One was to study the data of Lahar/Banjir occurances in 1975 and 1976. The other was to simulate a model of the endangered area in the K. Krasak and K. Putih.

According to the results of this investigation, the accuracy and the forecast of endangered area are valid for use a basis for the masterplan for the following reasons

1) The area covered by Lahar/Banjir in 1975 and 1976 correspond to the probable endangered area estimated by geomorphological method.

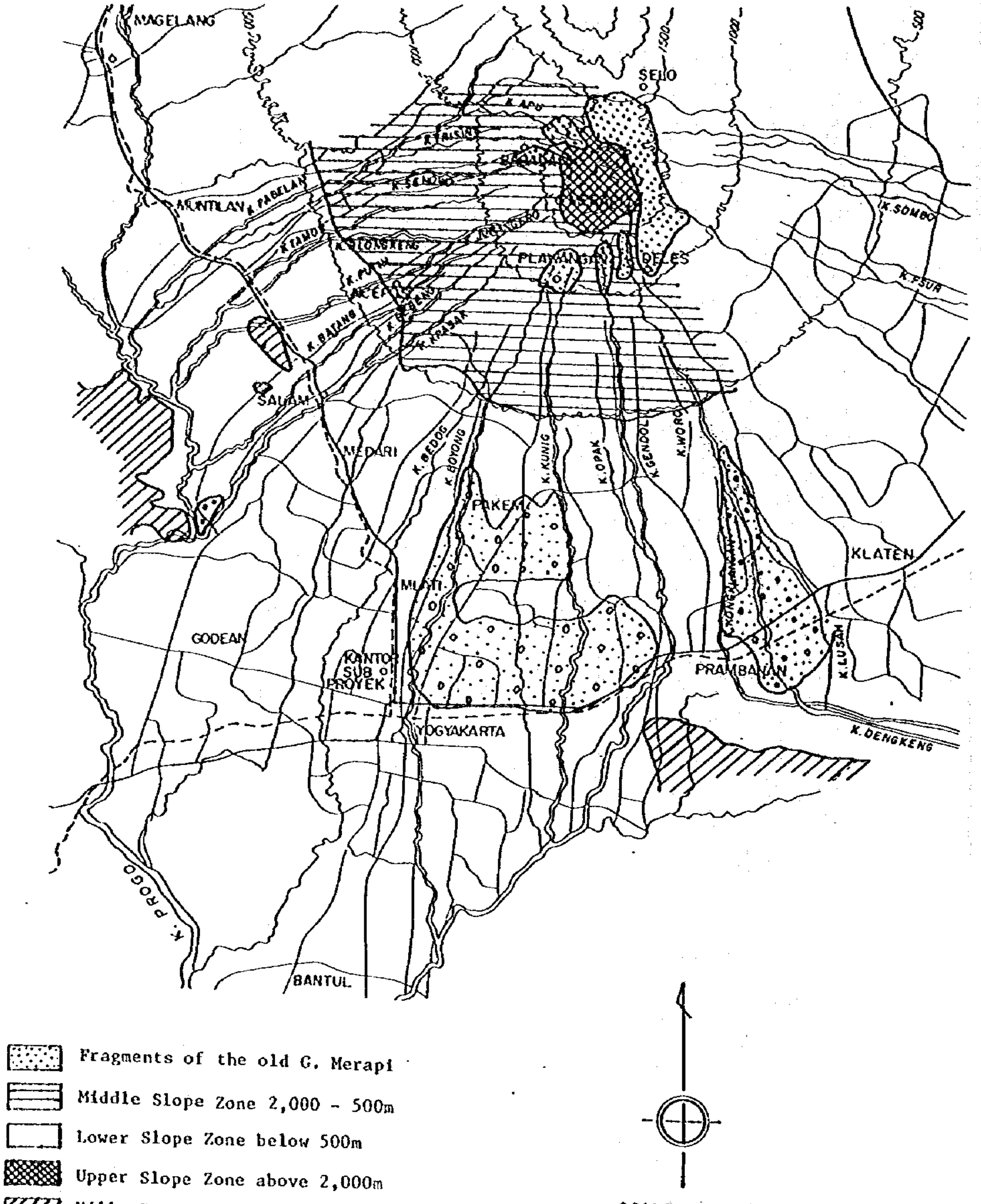
2) The cross-sections estimated as endangered points by the simulation study are located in the geomorphologically probable endangered area.

3) The area estimated by the geomorphological survey and the simulation are very similar with each other.

Although the investigation of the probable endangered area was undertaken only in Type I areas along the tributaries of K. Krasak and K. Putih, the characteristics of flood, geomorphology and volcanic materials are more or less the same in Type II and Type III areas.

Consequently, the masterplan can be developed for the whole project area based on the assumptions verified by this study.

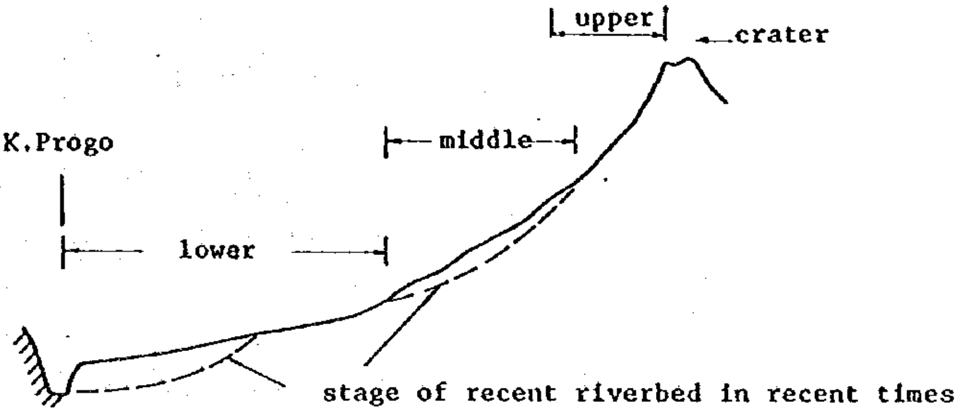
Fig. 1 Map of Main Morphological Areas



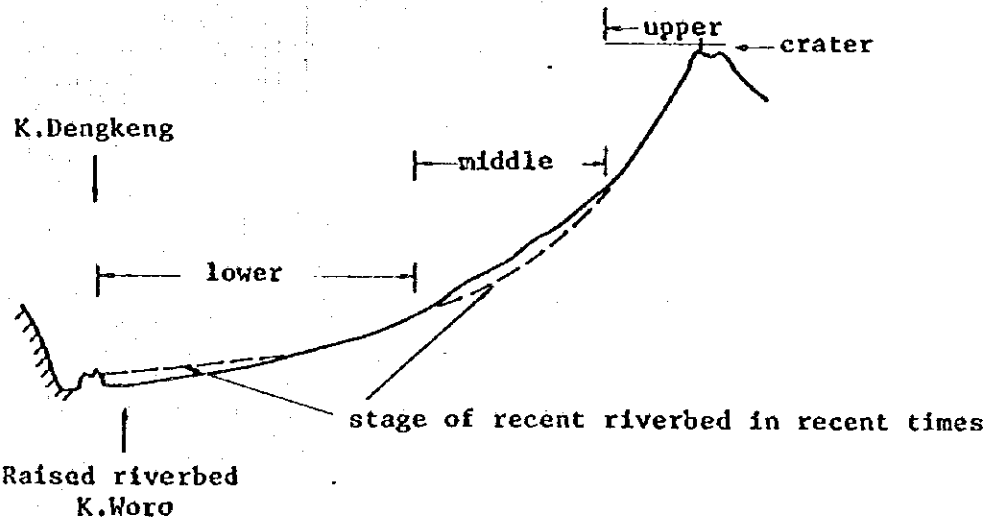
(Note: Main cities along the national road are shown in capital letters)

Fig. 2 Idealized Profile of the River and Slope

K. Krasak Profile



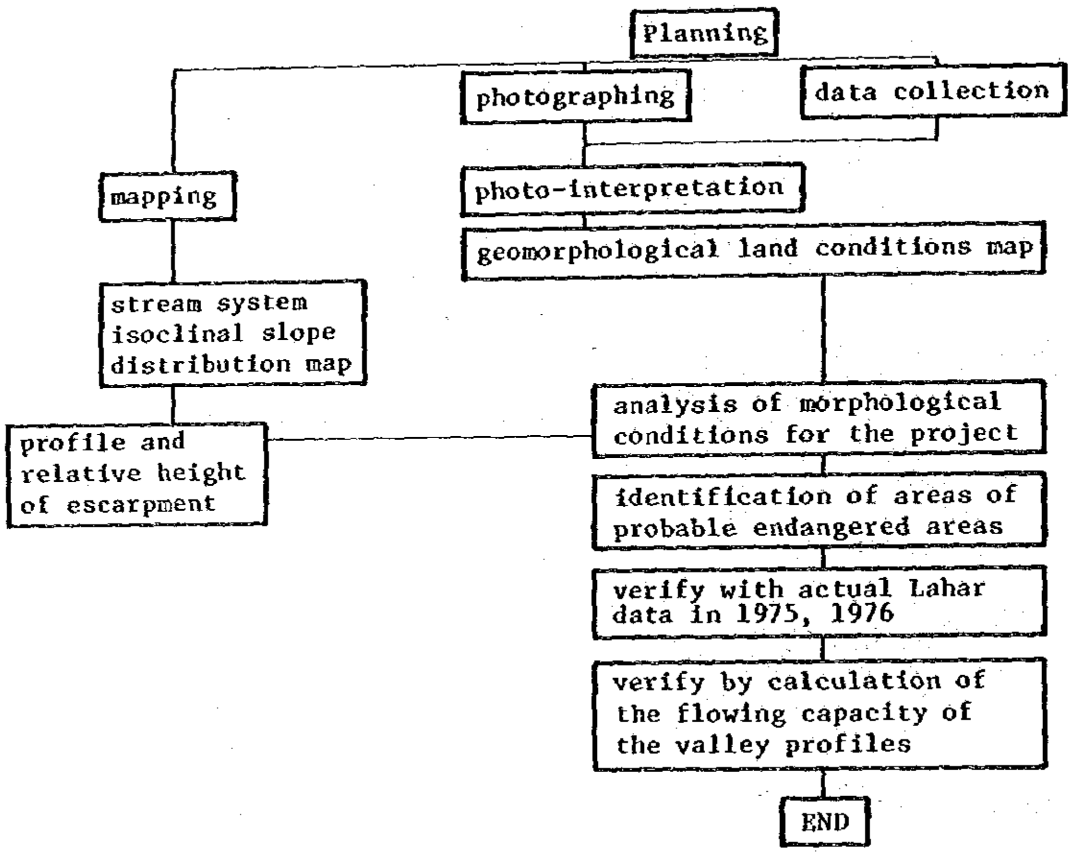
K. Woro Profile



1.4 Geomorphological Study Work Flow

An outline of the flow of work is shown in Fig. 3.

Fig. 3 Work Flow



2. GEOMORPHOLOGICAL STUDY

2.1 Land Condition Map

The land condition map was prepared using a scale of 1/25,000. Photo-interpretation techniques and field survey were employed for this work. Geomorphological features and their explanations used in this map are as follows(See Appendix-1; photo Interpretation Cards):

2.1.1 Items of geomorphological classification

(1) Volcanic morphology

1) Recent lava flow deposits (Young valcanic deposits of G. Merapi)
2) Former lava flow deposits (Young valcanic deposits of G. Merapi)
3) Old valcanic deposits of G. Merapi.
4) Volcanic debris: around the crater
5) Deposits of nuée ardante d'avalanche (1954, 1969)
6) Deposits of nuée ardante d'avalanche (Uncertain dates)
7) Mountain side composed of valcanic debris (Upper Zone)
8) Mountain side composed of valcanic debris (Lower Zone)
9) Breaking zone of slope caused by valcanic debris flow
10) Flowing units of valcanic debris
11) Former valley buried by nuée ardante d'avalanche
12) Poorly defined shallow valley

(2) River morphology

1) Riverbed
2) Point-bar deposits
3) Flood terrace
4) Accumulation terrace
5) Erosion terrace
6) Escarpment
7) Deposits of recent Lahar
8) Sand bars, Natural levees
9) Alluvial fan
10) Alluvial fan (dissected)
11) Raised riverbed
12) Local sediment by flood
13) Altered valley caused by nuée ardante

14) Former riverbed
15) Small valley (⊔ - shape)
16) Small valley (⌴- shape)
17) Small valley (V - shape)
18) Alluvial plain
19) Swamp
20) Limit of sediment transportation
21) Knick point

(3) Others

1) Slopes of hill
2) Slump block
3) Landslide
4) Talus
5) Piedmont plain
6) Gully, Rill
7) Spring

2.1.2 Explanation of Geomorphological items above

(1) Volcanic morphology

Recent lava flow deposits are divided into two parts. One is distributed on the upper part of G. Merapi. The other is developing on the middle and lower slope.

Old valcanic deposits of G. Merapi consist of the older G. Merapi which is surrounding the young Merapi crater.

Deposits of nuée ardente from the eruptions in 1954 and 1969 were deposited mainly around K. Blongkeng, K. Putih, K. Batang, K. Bebeng and K. Krasak. These materials filled up old river valleys and changed the river course in some cases for example, between K. Putih and K. Blongkeng.

Mountain sides are composed of valcanic debris rather than deposits from rivers. Distribution is on the upper, middle and lower slope. (Please refer Figs. 1 and 2). The breaking zone of a slope is caused by volcanic debris flow. When the flow stops on a slope, it makes a gap on the slope. Because the volcanic material have a high visconsity. This gap or breaking zone is quite significant for detecting the endangered points to nuée ardente and Lahar.

Former valleys can be filled up and buried by nuée ardante.

(2) River morphology

Flood terrace. Very low terraces which are submerged by big floods.

Sand bars, natural levees. A little higher place, composed of sand, which is distributing in the fan and riverbed.

Alluvial fan. Mainly sandy deposition. K. Krasak, K. Kuning and K. Boyong have big fans and fan-like areas. Only K. Krasak's fan is active nowadays. The other two rivers have dissected fans in the lower foothills.

Raised riverbed. A lot of sand deposited between the embankment has caused the riverbed to rise: This condition makes flooding over the levee very easy. Sandy sedimentation which was transported during the inundation can be seen along the embankment, and is identified as local sediment by flooding.

Altered valley caused by nuée ardente. After a valley has been filled by nuée ardente, the old valley capacity to hold water becomes very small. This area is located just downstream from dammed point on the old river.

Former riverbed. This area can become quite dangerous during nuée ardente flow, lahar and banjir.

Small valleys. They do not have big catchment areas, and ground water is usually the main water source. However, small valleys have possibility to become flowing courses for nuée ardente and so on. They are identified according to the shape of valley.

2.2 Relative Depth of Valley

The overflow point of Lahar/Banjir is related to the height difference of the mountain slope and valley bottom. The relative height of the side cliff was measured and plotted to obtain a longitudinal profile of each river.

2.3 Isoclinal Slope Distribution Map

By measurement of the contour interval, the gradient of the slope was estimated. Slopes in a uniform gradient zone where grouped to make the Isoclinal Slope Map. The zone where gradient clearly changes has the highest probability of occurance of Lahar/Banjir.

2.4 Stream System

The purpose of this map is to estimate the flow direction of Lahar and Banjir. When Lahar and Banjir overflow the riverbank, they spread over the foot of the mountain or flow down along the valleys which then fill up with volcanic materials.

3. RESEARCH OF ENDANGERED AREAS

3.1 Endangered Area Map Preparation

3.1.1 The purposes of this Survey

The purposes of this survey are to study the relationships between geomorphological conditions and Lahar and Banjir in order to estimate the endangered area to Lahar and Banjir.

There is no clear dividing line between Lahar and Banjir; however it is generally understood that Lahar includes more sand and gravel than Banjir.

The endangered area is mainly on the slope of the active volcano, G. Merapi. K. Krasak (K. Bebeng) and K. Putih were the most endangered tributaries in recent years. People in villages along these rivers experienced the heavy damage from G. Merapi's explosion in 1969 which plugged the upper reach of K. Blongkeng with volcanic deposits and changed its channel to K. Putih. A similar alternation of river course happened to K. Batang with the plugging of K. Bebeng. When Lahar and Banjir are regarded as a geomorphic stage, geomorphological analysis can be used to determine the probable endangered areas to Lahar or Banjir in the near future.

The geomorphological land condition map in this report was prepared with using aerial photo-interpretation (scales: map 1/25,000 and photos 1/40,000). According to the geomorphological study, there has been quite a close relationship between landforms and Lahar/Banjir occurences. Figs. 4 and 5 show that the rivers generally overflow at the places where their channels turn sharply or where riverbed gradients change and become more gentle. These topographical changes correspond to the geological and lithological differences in the slope of the volcano. The landforms of the volcano's slope are the result of volcanic activity: lava flow, nuée ardente d'avalanche, pumice-flow, Lahar, Banjir, etc. Usually Lahar/Banjir flow along former river cources, small valleys, shallow valleys and so on. Today's landforms suggest the area which will probably be covered by the next Lahar/Bajir occurances. The isoclinal slope map, drainage system map and flow direction map are prepared as supplemental information.

3.1.2 The relationship between landform and Lahar/Banjir

According to the survey of the Lahar and Banjir in 1975 and 1976, the relationships are found between them as follows:

Points of overflow (breaking point)

1) The point where the stream gradient becomes more gentle.
2) Crossing points with former river courses.
3) A riverbed zone which is raised up.
4) River terraces.

5) Zones where the capacity of the valley is decreasing as compared with its upper reach.

6) At a sharp river bend course of the river.

The flooding areas

1) The boundary of a flood area is ill-defined except by small landforms such as small undulations, stream, roads, etc.

2) The flood spread into small rivers or former river courses.

3) If the small river or the former river course does not have enough capacity to pass all the volcanic material, the flood will overflow again.

4) A lot of the sand transported by the flood remains: along small channels, in former river courses or on roads over which the main flood current has passed.

5) The damage to houses and loss of life are mainly distributed in the sand deposit areas.

Location of previous Lahar damaged areas and the breaking zones are shown in Fig. 5.

3.1.3 Estimation of the endangered area

Using the relationships between the landform and Lahar/Banjir, the endangered area is estimated.

The degree of probable flooding is divided into five categories based on the height of the bank.

Degree of probable flooding

Height of bank	Degree of probable flooding
0 - 5m	very high
5 - 10m	high
10 - 20m	middle
20 - 30m	low
30 - m	very low

The area was determined by using the geomorphological landcondition map and other information. In the cases where areas overlapped, the higher degree of probable flooding was adopted. The most endangered areas such as the point of overflowing, and former river courses and terraces are shown in the map.

Flood types are also categorized depending on the volume of sand contained as follows:

Types of floods

1) Flood contains a lot of sand and gravel
2) Flood contains less sand
3) Flood contains little sand and the inundation period is rather long

3.2 Damage by Lahar and Banjir in Recent Years

By means of a questionnaire the areas damaged and flowded in 1975 and 1976 were surveyed. The survey was conducted along the K. Putih and K. Bebeng. The items questioned were as follows:

Table 1 Question Card

(1)	Did you experience Lahar or Banjir?	yes, no
(2)	When did it happen?	19__
(3)	At what time did it attack here?	
(4)	The time of the highest flooding?	
(5)	How deep was the flood?	______ m
	Sand deposited?	______ m
(6)	What was the main direction of Lahar flow? (Show on the map)	
(7)	Where was the boundary of the sand deposition? (Show on the map)	
(8)	Where was the end or boundary of the water flow? (Show on the map)	
(9)	How many houses were damaged?	______________
	How many people were injured or killed?	

Data of Lahar/Banjir in 1975, 1976

The results of the questionnaire and field survey are summarized in Table 2 and shown in the map, Fig. 7. In the map, areas of sand deposit have a thickness of more than 30cm.

Table 2 Questionaire Survey Results

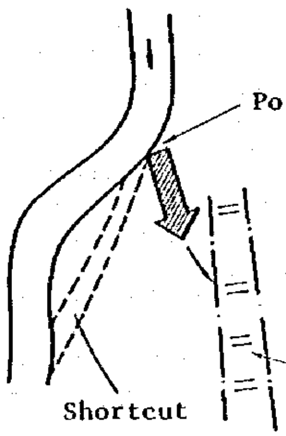
Item No.**	River	Year of Flooding	Places Flooded	Area Flooded (m^2)	Area of Sand Deposition (m^2)	Approx. Volume of (m^2)	Buildings Damaged	Deaths
1	K. Putih	1976	Salamsari Ngablak	132,000	34,000	26,000	2	--
2		1975	Gemblongan	135,000	90,000	68,000	2	–
3	K. Bebeng	1976	Brojonalan Pakel	596,000	227,000	86,000	5	–
4		1975	Gembokan	184,000	46,000	28,000	40	--
5	K. Krasak	1976	Tempel	3,000	3,000	2,000	2	1
6		1976	Kricakan*	2,501,000	1,500,000	1,180,000	67	26

*Also including Sumokaton, Madesan, Mriyan, Guling, Pokok, Kerisan, Banjarejo

**Further details explaining the conditions at each site of flooding are given in subsequent paragraphs by item no.

Item 1: This area is located on the junction of present and former river courses. At first the food went into the old river course and then overflowed its banks. The flood water rejoined K. Gremeng and K. Putih again at the end.
On the left bank at Ngablak (near the bridge) was attacked by sandy flood waters and a house and a school were damaged. Sand deposited only along K. Putih and the smaller river, K. Gremeng. Other places were covered only by water.

Item 2: This point is at a sharp bend in the river course. A shortcut has now been constructed to avoid the same overflowing again. Near the present river the flood spread a lot of sand over the area and went into the former river course.



Item 3: K. Bebeng overflowed near its confluence with K. Krasak. This point is located at the upper side of the sand pocket which was not completed at that time.
The level of the riverbed had been raised by sand pocket construction. The relative height between the volcanic slope and the riverbed is presently less than 2 meters.

Item 4: This point is just at the bend in the river course. The flood split into two courses: one along the small valley and the other along the road. The flood along the road went back to the K. Krasak 600m lower downstream. The 40 houses damaged at that time were along this road.

Item 5: At a bridge crossing the national road. K. Krasak narrows and changed the direction of flow suddenly to the right at an angle wider than 90 degree. The flood attacked the left bank. A man in a car was killed by the flood. The flooded area was very small.

Item 6: The overflow occured at four points in this area.

(1) The biggest flood attacked the right bank at the Kricakan village. Most of the flood waters flowed into a small channel passing through villages such as Sumokaton,

Madesan, Mriyan and Guling. Along this small channel most of the damage resulted from the flow of sandy water.

The heaviest damage was seen in this area as shown below.

village name	houses damaged	deaths
Madesan	48	9
Mriyan	8	1
Guling	4	16
Total	60	26

(2) On the right bank 1.3km below the first point. The flood spread from the channel to the fields, and then poured into K. Petel. The sand deposition in this area was small.

(3) On the right bank 3.5km below the first point. The flood attacked the channel of K. Petel near Banaran. K. Petel has the very big channel as compared with its present discharge. It might be old river course of K. Krasak. As main current of the flood passed through the K. Petel channel, the channel was filled by a lot of sand. Along the channel, 7 houses were destroyed by the secondary overflow from K. Petel channel.

(4) On the left bank just opposite the third point. The flood poured into the small valley and was contained; it did not overflow again.

3.3 Simulation Study of the Endangered Area

Using the changes of the capacity for each section along the river course, the endangered area can be computed. Data such as a morpho-meteorological, hydrological and experiences of flooding were collected in order to compare the capacity of each section along the river valley. The following is a summary of the factors considered and computational formulas used in the computer simulated model.

(1) Cross-Section

1) The cross-section was measured using photogrametry techniques and aerial photographs taken in 1976.

2) The cross-section was taken each 100 meters as a rule.

3) Plotting scale: 1/1,000 horizontal and 1/400 vertical.

(2) The River Valleys Studied

1) K. Putih

measuring line number 202300 -- 500800

2) K. Krasak and K. Bebeng

measuring line number 402150 -- 500800

(3) Formulas for Valley Flood Capacity Calculation

The capacity of each valley section to pass the flood discharge was calculated one by one. Average velocity without sand was calculated using Manning's equation, and velocity with sand was calculated with Wang's formula respectively as follows:

		Capacity for water only Manning's equation	Capacity for water and sand Wang's equation
Flood velocity	:	$V = 1/n \cdot R^{2/3} \cdot I^{1/2}$	$V_1 = \frac{\gamma W}{\gamma W + \alpha (d - \gamma W)}$
Quantity of runoff	:	$Q = Av$	$Q_1 = Av_1$

where

V : average velocity of pure water
V_1 : velocity of flow with sand
n : Manning's roughness coefficient (see below)
R : hydraulic mean radius ($R = A/P$)
I : slope of riverbed
Q : quantity of runoff of only water
Q_1 : quantity of runoff including sand
A : cross-sectional area
γW : specific weight of water
d : specific weight of bed load
α : ratio of sediment to water
P : wetted perimeter

Roughness coefficient (n)

The manning's roughness coefficient should be based on data from each cross-section. However, since data about roughness could not be obtained from the gauged run-off, the Manning Strickler equation was used to estimate it as an expendient as follows:

$$n = 0.0417\ dm^{1/6}$$

where n : roughness coefficient
dm : mean diameter of grain

(4) Parameters for the above equations

- Area of cross-section, hydraulic mean radius and slope of the riverbed were obtained from the photogrametrical measurement data.

- Roughness "n"

  The relationship of the mean diameter of the riverbed material to the slope of the riverbed was estimated using the data shown in Table 3 and the formula below.

  The angle of slope was decided for each section from its longitudinal profile.

  Relationship of the slope and mean diameter (D)

$$D = 95.52\ e^{I} - 92.77$$

where
D : mean diameter
I : slope of riverbed
e : base of natural logarithms with a value of 2.71828

Correlation coefficient of D and I is 0.96. (r=0.96)

Table 3 The Mean Diameter of the Riverbed Material and the Slope of the Riverbed

Location No.	Measurement line No.	Slope (I)	Riverbed mean diameter (D) in mm
1	401090		
2	401150	0.045	7.43
3	401270	0.042	6.92
4	401370	0.037	
5	401740	0.033	5.31
6	402610	0.018	4.78

(5) Calculation of the Capacity

K. Putih and K. Krasak river courses were each divided into four longitudinal zones according to slope gradient. The slope, diameter and roughness coefficient are given for each section as shown in Table 4 below.

Table 4 Topographical Parameters per Zone

River	Zone	Slope (I)	Riverbed diameter (D)mm	Roughness (n)
K. Putih	No. 202300 -- 201830	0.024	5.07	0.055
	No. 201820 -- 201500	0.033	5.95	0.056
	No. 201490 -- 201160	0.042	6.85	0.057
	No. 201150 -- 500800	0.057	8.35	0.059
K. Krasak	No. 402150 -- 401920	0.020	4.68	0.054
	No. 401910 -- 401310	0.038	6.45	0.057
	No. 401300 -- 500980	0.047	7.35	0.058
	No. 500970 -- 500800	0.063	8.96	0.060

Wang's equation is used to obtain the velocity when the flood contain a lot of sand. Each parameter was defined as follows:

(K. Putih)

γw = 1.0 t/m^3

d = 2.8 t/m^3

α = 0.41 (Data from Salam Jan. 9, '78, on K. Krasak used here)

(K. Krasak)

γw = 1.0 t/m^3

d = 2.8 t/m^3

α = 0.11 (Zones 402150 - 401920 gaged on Jan. 9, '78: Blanburan)

α = 0.41 (Zones 401910 - 500800 gaged on Jan. 9, '78: Salam)

(6) The Estimation of Probable Endangered Area

The capacity of each river section to pass the flood volume through its banks was studied by computer to determine the following characteristics of probable following:

(1) The runnoff volume

(2) Location of the river section with insufficient capacity to pass the total flood volume received from the section just prior to it.

The method used for calculation is based on three major assumptions as follows:

(1) That the starting point of the runoff would be zone 500800 for both K. Putih and K. Krasak.

(2) That four volumes for the runoff would be considered:

Case a:	runoff equal to	1/4	the height of the	riverbank
Case b:	"	1/2	"	"
Case c:	"	3/4	"	"
Case d:	"	the full height		"

A summary of the data resulting from the first two assumptions is shown table below.

Name of river	Flooding start point of assumed runoff	Height of bank (m)	Starting Volume of Assumed runoff m3/sec.) (a) 1/4 height of bank	(b) 1/2 height of bank	(c) 3/4 height of bank	(d) full height of bank
K. Putih	No.500860	12	393	1,598	4,750	8,577
K. Krasak	No.500800	20	634	4,968	12,535	27,616

(3) That the maximum volume of a river section would be passed on to the next section regardless of whether overflow occurred or not. If overflow did occur, the volume of the overflow (i.e., the difference between the received runoff and the capacity of the section) would be assumed to be permanently deducted from the river system (i.e., from all the subsequent river sections).

For example, assume that 393 m3/sec is the starting runoff, and that the lower 20 sections of K. Putih have enough capacity to pass through this volume, but that the 21st section (No. 201060) has only 365 m^3/sec as capacity. This means an overflow of 28 m3/sec will probablly occur in the 21st section. On the lower reach, the new runoff amount of 365 m^3/sec will be discharged. If a subsequent section has less capacity than 365 m3/sec, it will be labelled as an overflow point in a similar fashion, and so on.

The results of a computer simulation based on the above assumptions are shown in Tables 5 and 6 for each section of K. Putih and K. Krasak respectively. A summary of the probable endangered flooding areas are shown on the maps in Figs. 9 and 10 for the K. Putih and K. Krasak respectively.

Fig. 4 Relationship Between Lahar and Breaking Zone

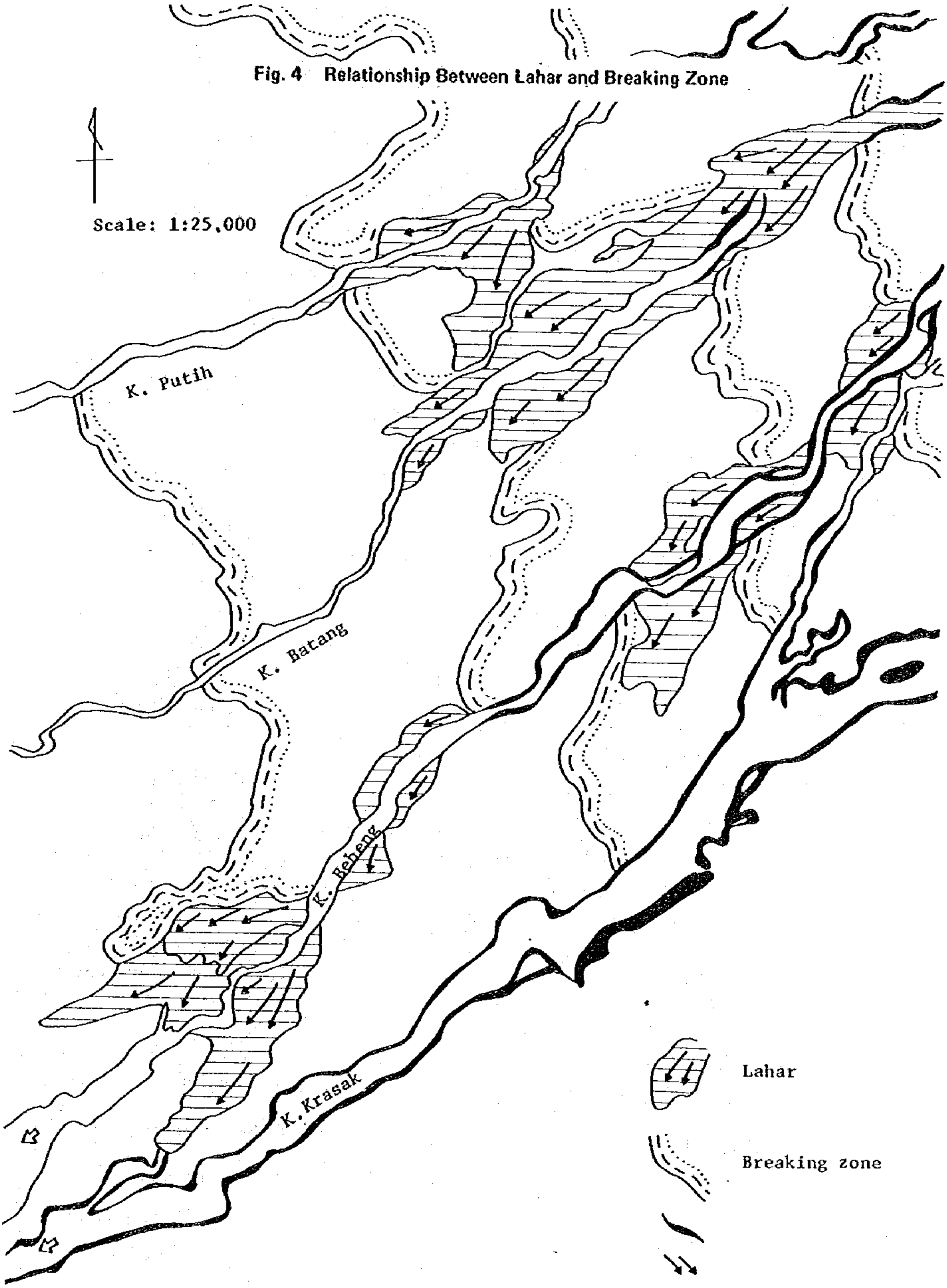
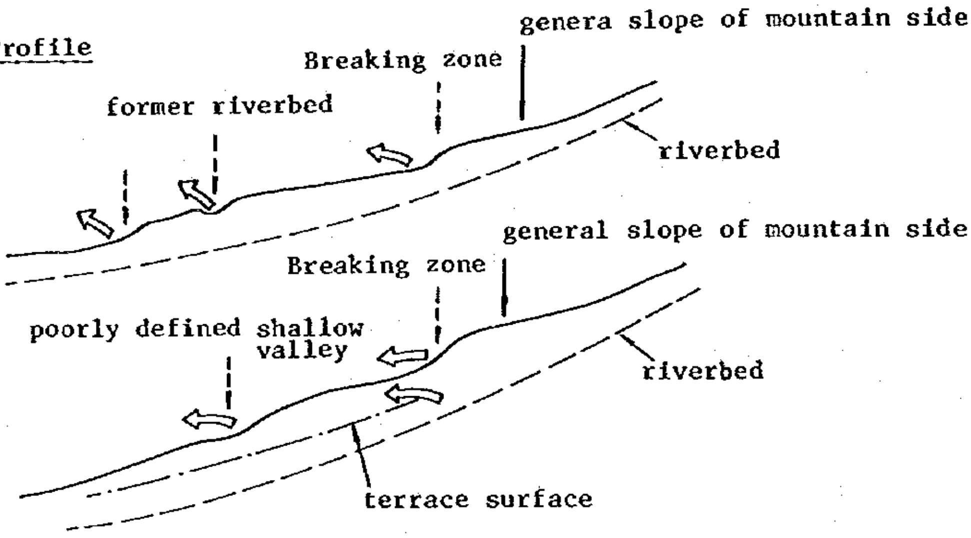


Fig. 5 Idealized Pattern of Lahar Occurrence

A. Profile



B. Morphological aspect

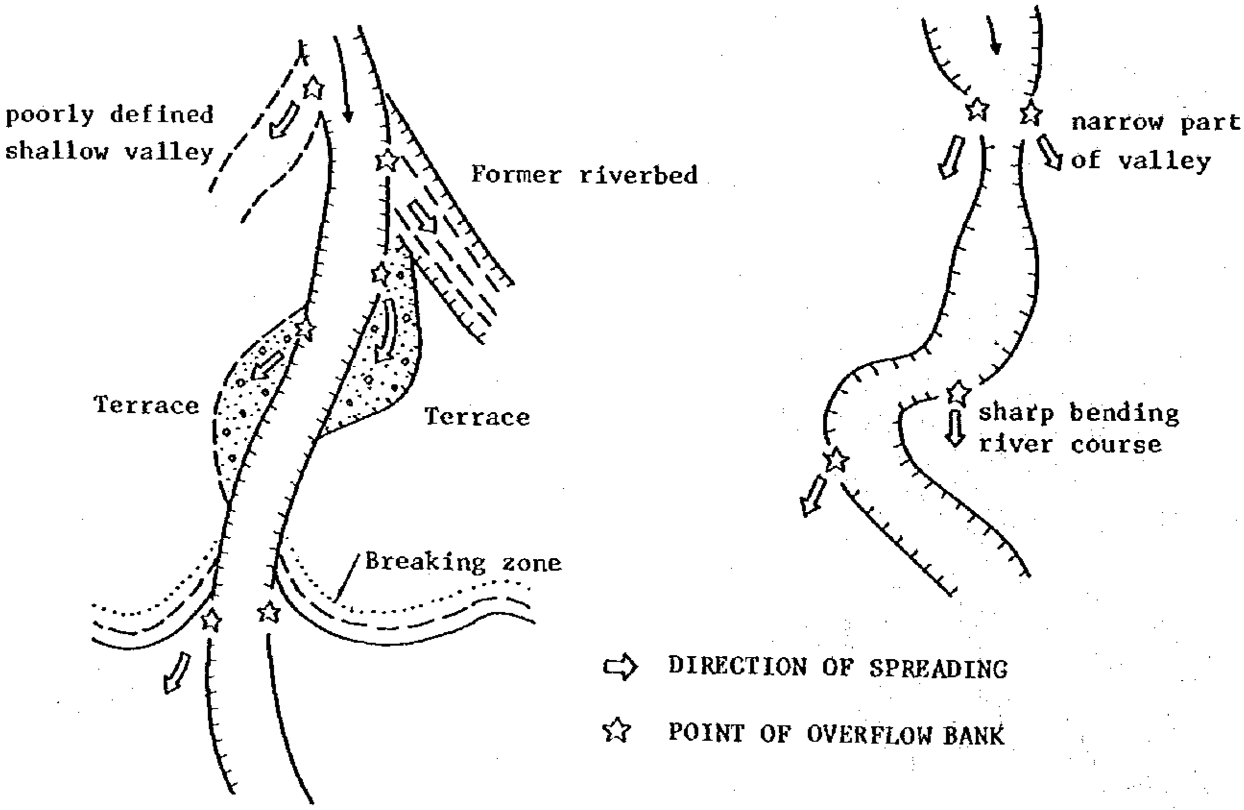
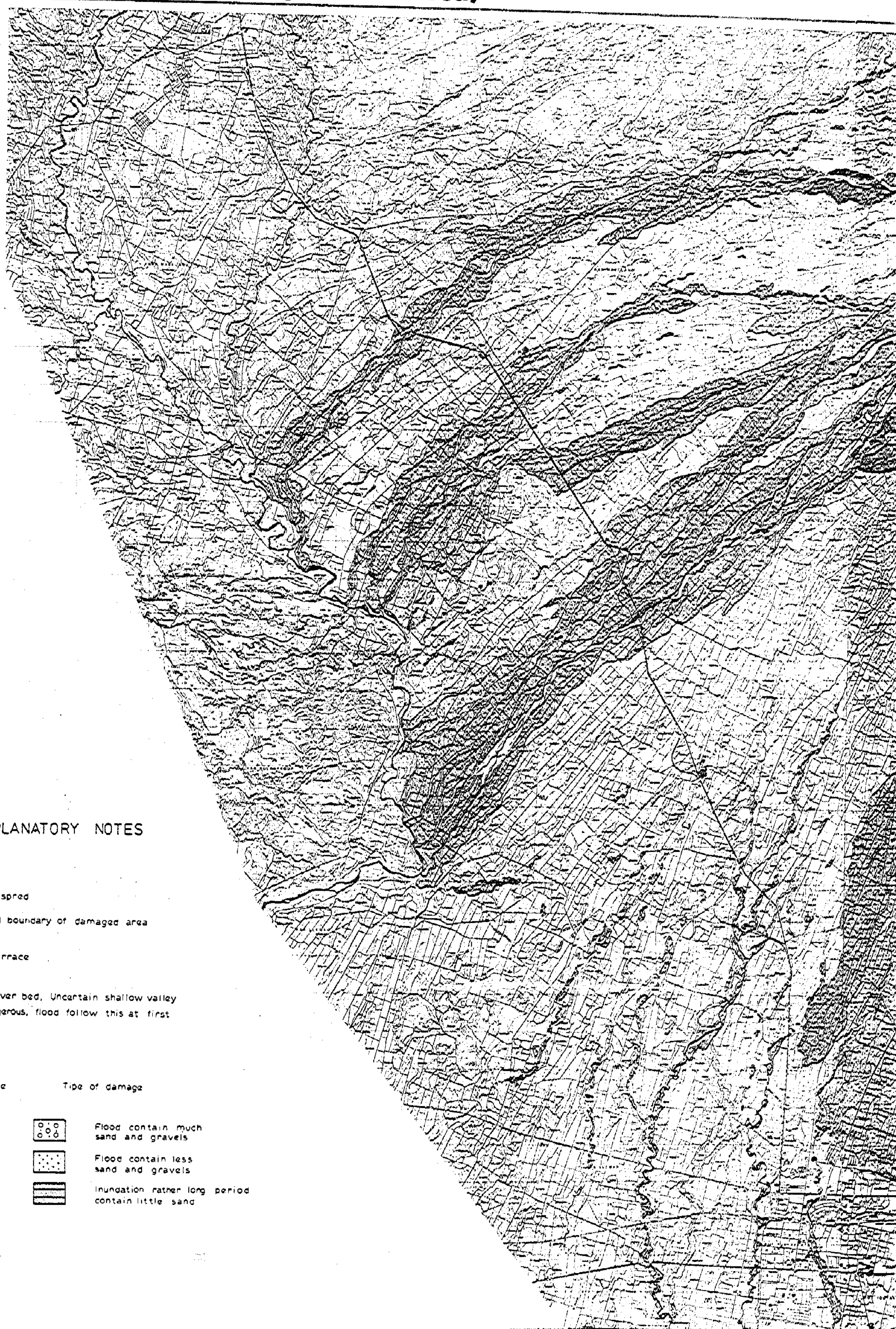


Fig 6 PROBABLE ENDANGERED AREA MAP
(Lahar/Banjir Hazard Area)



EXPLANATORY NOTES

Lahar, Banjir

Point of spred

Estimated boundary of damaged area

River terrace

Former river bed, Uncertain shallow valley
very dangerous, flood follow this at first

Dangerous degree	Tipe of damage
Very high	Flood contain much sand and gravels
High	Flood contain less sand and gravels
Middle	Inundation rather long period contain little sand
Low	
Very low	

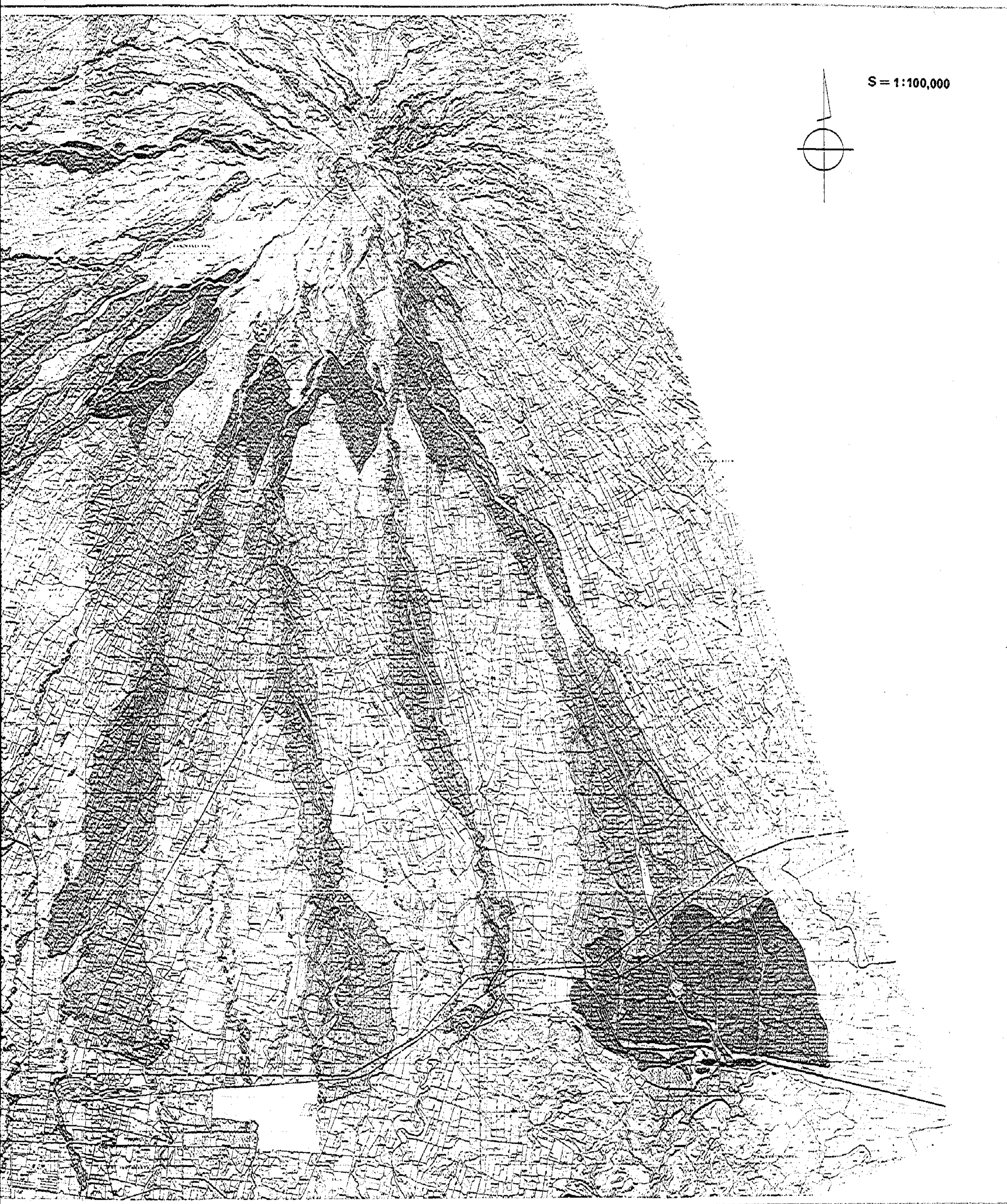

S = 1:100,000

Fig. 7 Map of The Area Damaged by The Floods (RAHAR/BANJIR) in 1975, 1976

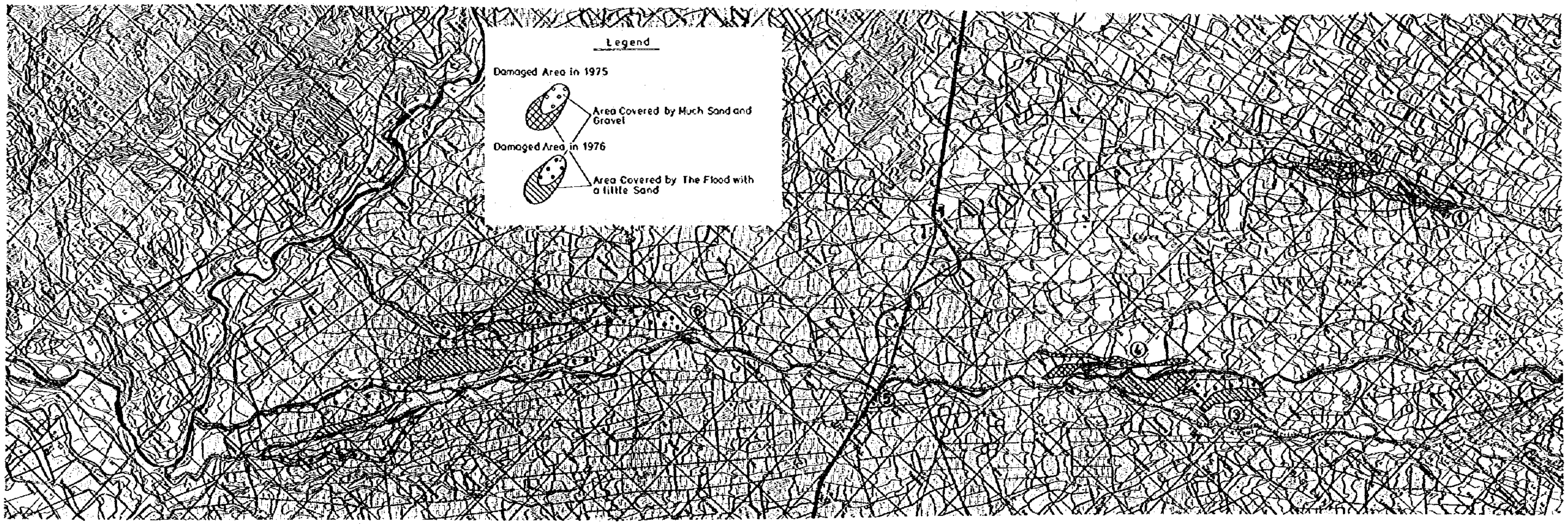


Fig. 8 Sampling Points Of Riverbed Material In The K·Krasak

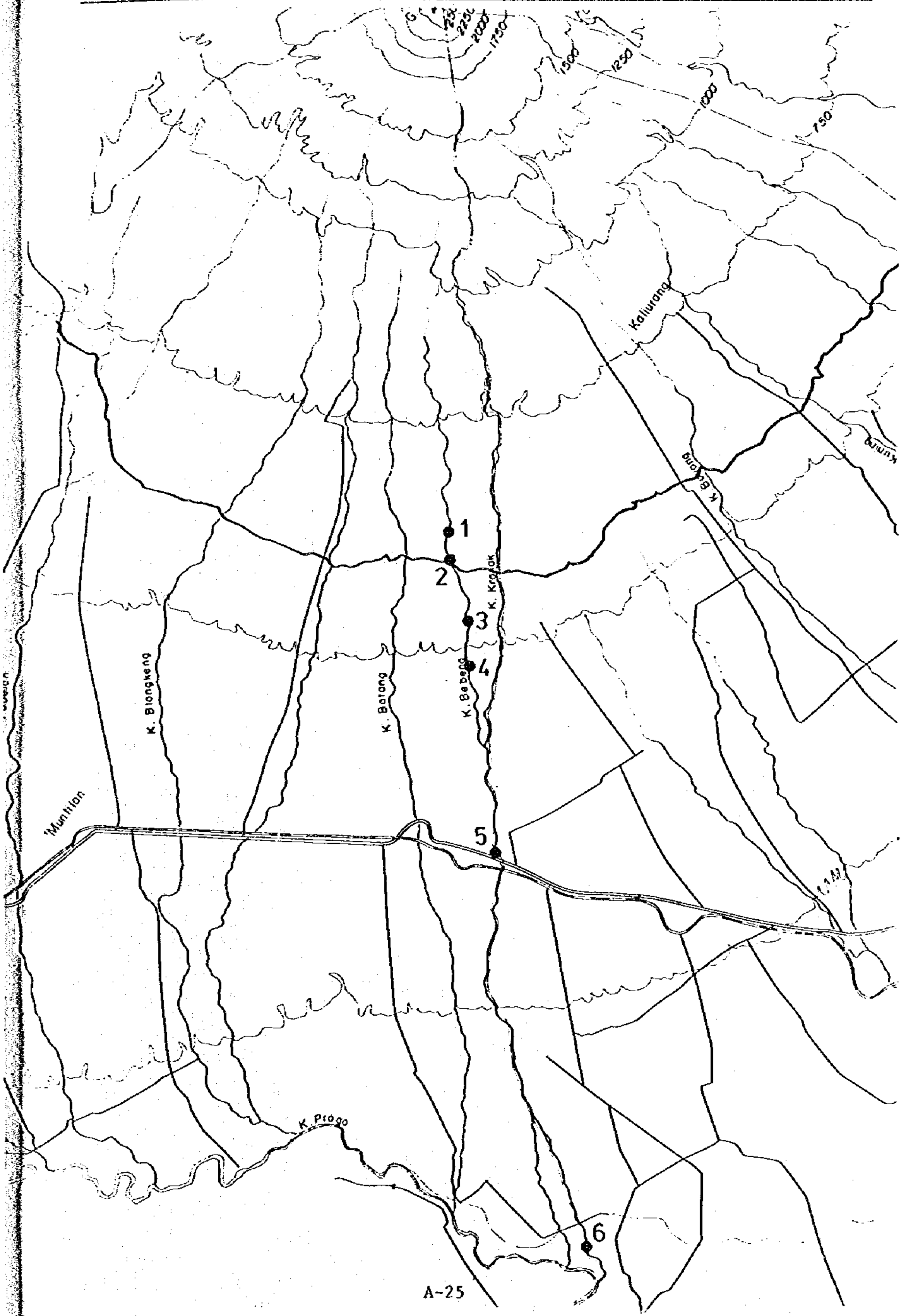


Fig. 9 Probable Endangered Areas (K. KRASAK)

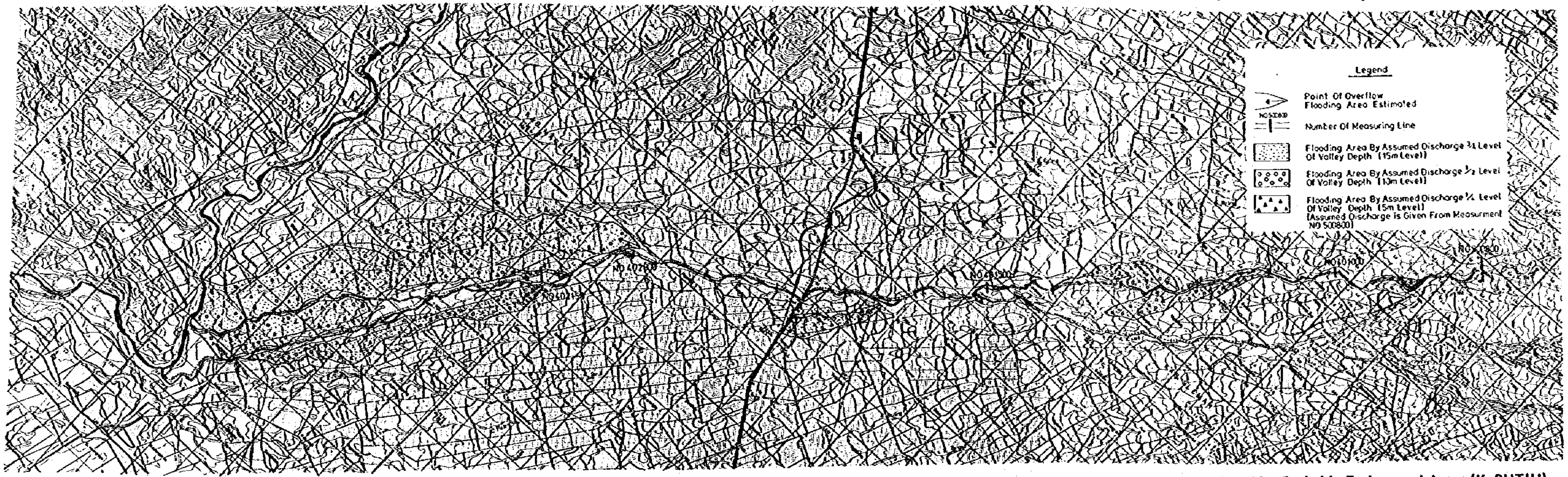


Fig. 10 Probable Endangered Areas (K. PUTIH)

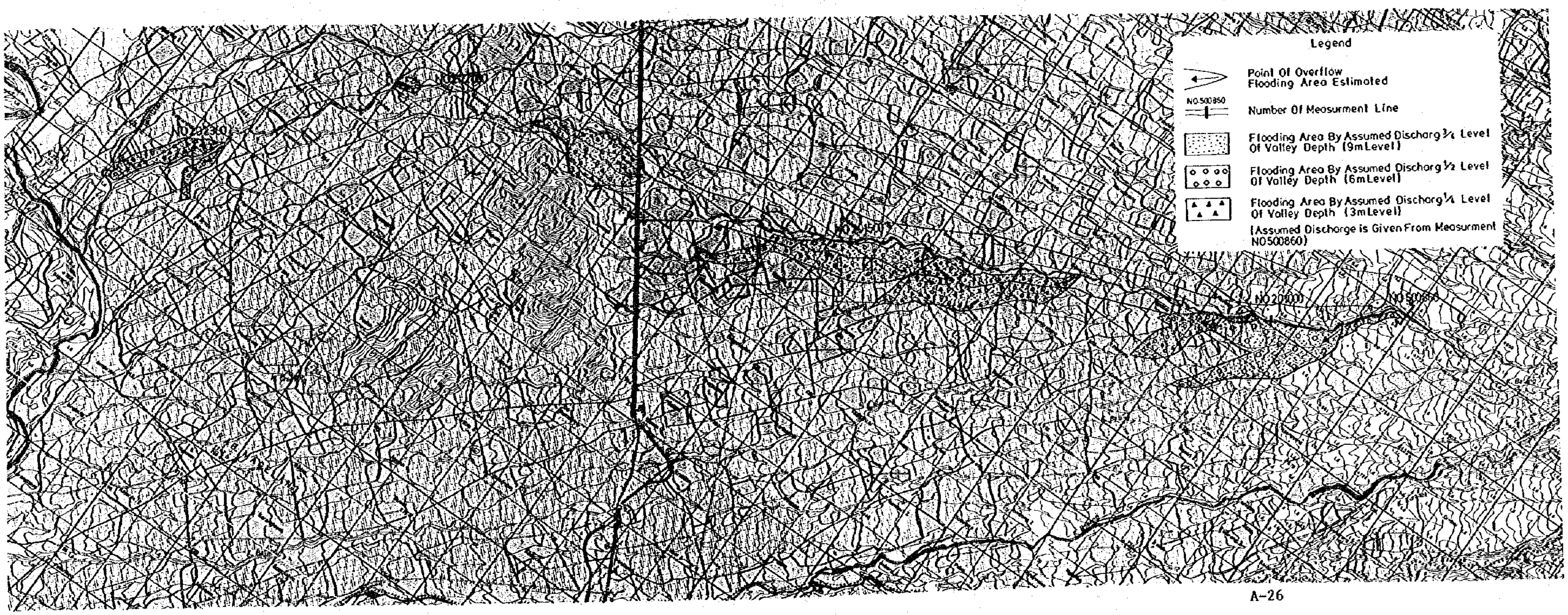


Table 5 The Capacity of The Valley for The Flood (K. Putih)

Point No.	Altitude	Elevation of Riverbed	Height of Riverbed	Width of Riverbed	River Course Area (A)	Slope of River Course (1)	Wetted Perimeter (P)	Hydraulic Radius (R)	Velocity (V)	Runoff (Q)	Velocity with sediment (VI)	Runoff (Q1)	
202300	229.6	219.4	10.2	67.2	257.	30.	85.	3.02353	6.6	1691.0	3.8	973.0	
202290	233.2	224.1	8.9	53.8	182.	30.	67.	2.71642	6.1	1115.1	3.5	641.6	
202280	232.8	225.3	7.5	36.6	133.	24.	48.	2.77083	5.6	738.5	3.2	424.9	
202270	235.7	228.8	6.9	66.6	133.	28.	68.	1.95588	4.8	632.6	2.7	364.0	
202260	239.3	230.9	8.4	53.4	141.	5.	59.	2.38983	2.3	323.8	1.3	186.3	++++
202250	241.7	229.7	12.0	69.2	223.	9.	79.	2.82278	3.4	767.7	2.0	441.7	
202240	242.9	232.6	10.3	90.6	424.	30.	104.	4.07692	8.0	3404.4	4.6	1958.8	
202230	245.3	235.6	9.7	77.0	290.	53.	92.	3.15217	9.0	2607.6	5.2	1500.4	
202220	248.8	243.2	5.6	73.8	176.	42.	85.	2.07059	6.1	1064.9	3.5	612.7	
202210	252.8	244.0	8.8	69.8	184.	10.	85.	2.16471	3.0	559.5	1.7	321.9	
202200	252.4	245.2	7.2	30.4	153.	18.	39.	3.92308	6.1	927.5	3.5	533.7	
202190	254.8	247.6	7.2	69.0	203.	26.	76.	2.67105	5.6	1145.0	3.2	658.8	
202180	257.6	250.4	7.2	66.8	248.	19.	79.	3.13924	5.4	1331.5	3.1	766.1	
202170	259.0	251.4	7.6	60.4	262.	20.	74.	3.54054	6.0	1563.6	3.4	899.7	
202160	261.0	254.4	6.6	61.2	215.	19.	65.	3.30769	5.6	1195.2	3.2	687.7	
202150	262.8	255.1	7.7	63.0	261.	16.	77.	3.38961	5.2	1353.4	3.0	778.7	
202140	265.8	257.5	8.3	63.8	306.	25.	74.	4.13513	7.4	2264.2	4.3	1302.7	
202130	268.6	260.0	8.6	121.8	464.	28.	135.	3.43704	6.9	3212.4	4.0	1848.3	
202120	269.8	263.1	6.7	98.8	261.	26.	76.	3.43421	6.7	1740.3	3.8	1001.3	
202110	272.3	265.2	7.1	67.6	268.	27.	78.	3.43590	6.8	1821.6	3.9	1048.1	
202100	274.2	268.4	5.8	108.6	264.	21.	93.	2.83871	5.3	1893.6	3.0	801.3	
202090	276.7	269.3	7.4	63.4	225.	19.	63.	3.57143	5.9	1316.4	3.4	757.4	
202080	278.6	272.2	6.4	83.0	259.	31.	96.	2.69792	6.2	1605.8	3.6	923.9	
202070	279.3	275.4	3.9	72.8	206.	27.	78.	2.64103	5.7	1175.1	3.3	676.1	
202060	282.5	277.5	5.0	94.6	280.	25.	103.	2.71845	5.6	1566.8	3.2	901.5	
202050	285.8	280.3	5.5	89.6	239.	31.	99.	2.41414	5.8	1376.1	3.3	791.7	
202040	285.9	283.6	2.3	62.0	87.	31.	66.	1.31818	3.8	334.8	2.2	192.6	++++
202030	292.0	286.4	5.6	127.8	457.	21.	140.	3.26429	5.8	2647.6	3.3	1523.3	
202020	294.0	287.8	7.0	111.8	606.	18.	180.	5.05000	7.2	4346.5	4.1	2500.9	
202010	296.0	290.0	6.0	64.8	218.	21.	62.	3.51613	6.1	1327.0	3.5	763.5	
202000	298.7	292.0	6.7	42.4	182.	18.	54.	3.37037	5.5	997.2	3.2	573.8	
201991	299.3	293.3	6.8	50.0	127.	20.	61.	2.08197	4.2	532.2	2.4	306.2	
201990	300.4	294.0	6.4	63.6	180.	44.	80.	2.25000	6.5	1178.1	3.8	677.9	
201980	302.4	298.4	4.0	112.2	338.	34.	119.	2.84034	6.7	2271.1	3.9	1306.7	
201970	305.8	300.7	5.1	61.2	221.	24.	71.	3.11268	6.0	1326.1	3.5	763.0	
201960	309.0	303.2	5.8	74.8	297.	23.	85.	3.49412	6.3	1884.2	3.7	1084.1	
201950	310.2	305.2	5.0	64.8	193.	22.	58.	3.32759	6.0	1159.2	3.5	667.0	
201940	313.2	307.5	5.7	64.0	273.	22.	75.	3.64000	6.4	1740.6	3.7	1001.5	
201930	314.8	309.6	5.2	82.6	357.	21.	89.	4.01124	6.6	2372.5	3.8	1365.0	
201920	319.6	311.7	7.9	61.8	308.	26.	72.	4.27778	7.7	2377.2	4.4	1367.8	
201910	322.5	314.7	7.8	42.8	232.	26.	54.	4.29630	7.7	1795.8	4.5	1033.2	
201900	325.0	316.8	8.2	49.2	189.	24.	69.	4.18841	7.3	2113.1	4.2	1245.8	
201890	326.3	319.5	6.8	34.0	194.	25.	46.	4.21739	7.5	1454.4	4.3	836.8	
201880	330.8	321.7	9.1	65.4	342.	19.	83.	4.12048	6.4	2200.9	3.7	1266.3	
201870	332.8	323.2	9.6	93.8	284.	25.	108.	2.62963	5.5	1554.4	3.1	894.4	
201860	335.2	326.6	8.6	154.2	692.	25.	168.	4.11905	7.4	5107.0	4.2	2938.4	
201850	334.6	328.1	6.5	128.4	335.	25.	137.	2.44526	5.2	1746.9	3.0	1005.1	
201840	337.3	331.5	5.8	95.8	284.	29.	105.	1.70476	6.0	1705.9	3.5	981.5	
201830	343.0	333.8	9.2	146.2	776.	27.	162.	4.79012	8.5	6581.0	4.9	3786.5	

Overflow point

+ Flooding by assumed runoff equal to full of valley depth (depth of water more than 12 meter) Q : 8,577 m^3/sec

++ Flooding by assumed runoff equal to 3/4 of valley depth (depth of water more than 9 meter) Q : 4,750 m^3/sec

+++ Flooding by assumed runoff equal to 1/2 of valley depth (depth of water more than 6 meter) Q : 1,598 m^3/sec

++++ Flooding by assumed runoff equal to 1/4 of valley depth (depth of water more than 3 meter) Q : 393 m^3/sec

Point No.	Altitude	Elevation of Riverbed	Height of Riverbed	Width of Riverbed	River Course Area (A)	Slope of River Course (1)	Wetted Perimeter (P)	Hydraulic Radius (R)	Velocity (V)	Runoff (Q)	Velocity with sediment (V1)	Runoff (Q1)	Overflow point
201820	346.5	336.8	9.7	205.0	1165.	30.	222.	5.24775	9.3	10869.3	5.4	6253.9	
201810	348.8	339.8	9.0	194.8	1023.	33.	198.	5.16667	9.7	9907.0	5.6	5700.2	
201800	350.4	343.4	7.0	99.0	421.	37.	114.	3.69298	8.2	3452.0	4.7	1986.2	
201790	352.5	347.2	5.3	120.6	405.	32.	130.	3.11538	6.8	2757.5	3.9	1586.6	
201780	355.8	349.7	6.1	61.2	427.	21.	70.	6.10000	8.6	3684.5	5.0	2120.0	
201770	359.5	351.3	8.2	84.8	456.	22.	96.	4.75000	7.5	3409.3	4.3	1961.6	
201767	359.0	352.6	6.4	84.2	196.	33.	94.	2.08511	5.5	1037.2	3.0	596.8	
201762	359.3	353.8	5.5	68.0	298.	33.	67.	4.44776	8.8	2611.8	5.0	1502.8	
201760	360.0	354.6	5.4	16.4	63.	38.	22.	2.86364	7.0	441.9	4.0	254.3	
201750	363.0	358.3	4.7	47.0	59.	34.	23.	2.56522	6.2	363.8	3.5	209.3	++++
201740	365.2	361.3	3.9	65.2	88.	32.	44.	2.00000	5.1	446.0	2.9	256.6	
201730	368.0	364.6	3.4	99.6	94.	29.	52.	1.80769	4.5	424.0	2.6	244.0	
201720	372.0	367.0	5.0	66.2	166.	23.	56.	2.96428	5.6	927.0	3.2	533.4	
200710	375.8	369.2	6.6	104.8	301.	30.	115.	2.61739	5.9	1767.0	3.4	10016.7	
201700	378.2	373.0	5.2	78.8	182.	40.	86.	2.11628	5.9	1070.9	3.4	616.2	
201690	383.3	377.2	6.1	162.2	596.	37.	175.	3.40571	7.8	4630.3	4.5	2664.2	
201680	386.8	380.4	6.4	74.0	422.	38.	86.	4.90698	10.0	4237.4	5.8	2438.1	
201670	390.2	384.8	5.4	91.8	390.	42.	96.	4.06250	9.3	3630.4	5.4	2088.9	
201660	394.0	388.8	5.2	78.0	332.	34.	84.	3.95238	8.2	2730.2	4.7	1570.9	
201650	396.2	391.6	4.6	63.0	200.	27.	69.	2.89855	6.0	1192.2	3.4	685.9	
201640	398.9	394.1	4.8	64.8	225.	30.	72.	3.12500	6.6	1486.4	3.8	855.2	
201630	402.6	397.5	5.1	65.8	240.	36.	73.	3.28767	7.5	1976.5	4.3	1033.6	
201620	405.3	401.3	4.0	75.8	216.	33.	72.	3.00000	6.7	1456.4	3.9	838.0	
201610	408.3	404.0	4.3	114.8	245.	26.	122.	2.00820	4.6	1122.4	2.6	645.8	
201600	411.2	406.5	4.7	100.4	347.	34.	105.	3.30476	7.3	23533.0	4.2	1457.4	
201590	416.0	410.8	5.2	106.8	232.	37.	116.	2.00000	5.5	1264.4	3.1	727.5	
201580	420.0	413.8	6.2	106.6	277.	34.	117.	2.36752	5.8	1619.2	3.4	931.7	
201570	420.7	417.6	3.1	94.0	212.	35.	98.	2.16327	5.6	1184.0	3.2	681.3	
201560	424.0	420.8	3.2	63.8	135.	31.	65.	2.07692	5.1	690.6	2.9	397.4	
201550	429.7	423.7	6.0	51.2	195.	33.	62.	3.14516	7.0	1356.9	4.0	780.7	
201540	433.0	427.4	5.6	37.8	162.	37.	57.	2.84210	6.9	1115.7	4.0	642.0	
201530	436.0	431.1	4.9	40.0	138.	35.	58.	2.37931	6.0	821.2	3.4	472.5	
201520	440.3	434.4	5.9	57.2	211.	31.	63.	3.34921	7.0	1483.8	4.0	853.8	
201510	443.3	437.2	6.1	75.6	199.	34.	77.	2.48052	6.0	1151.7	3.5	662.7	
201500	446.5	441.2	5.3	59.8	209.	35.	64.	3.26563	7.3	1535.7	4.2	383.6	
201490	448.0	444.2	3.8	58.2	125.	36.	66.	1.89394	5.1	636.7	2.9	366.3	
201480	450.9	448.4	2.5	48.2	116.	34.	55.	2.10909	5.3	616.8	3.1	354.9	
201470	456.8	451.0	5.8	66.0	262.	43.	73.	3.58904	8.5	2232.4	4.9	1284.5	
201460	463.0	457.0	6.0	106.0	492.	51.	118.	4.16949	10.3	5044.9	5.9	2902.7	
201450	466.3	461.2	5.1	146.4	388.	38.	155.	2.500323	6.3	2444.8	3.6	1406.7	
201440	469.3	464.6	4.7	78.6	205.	43.	88.	2.32955	6.4	1309.8	3.7	753.6	
201430	473.8	469.8	4.0	76.8	183.	44.	84.	2.17857	6.2	1131.2	3.6	650.8	
201420	477.3	473.4	3.9	80.4	188.	36.	89.	2.11236	5.5	1029.7	3.2	592.5	
201410	481.0	477.0	4.0	107.6	260.	47.	113.	2.30088	6.6	1722.5	3.8	991.1	
201400	484.7	482.8	1.9	89.8	82.	49.	94.	0.87234	3.5	290.8	2.0	167.3	++++
201390	490.0	486.8	3.2	78.6	163.	39.	83.	1.96385	5.4	885.2	3.1	509.3	
201380	493.7	490.5	3.2	72.4	146.	40.	79.	1.84810	5.3	771.2	3.0	443.7	
201370	498.8	494.7	4.1	96.6	267.	46.	101.	2.64356	7.2	1919.5	4.1	1104.4	
201360	503.5	499.6	3.9	125.8	391.	40.	142.	2.75352	6.9	2693.4	4.0	1549.7	
201350	507.4	502.7	4.7	101.2	223.	37.	110.	2.02727	5.4	1204.9	3.1	693.2	
201340	512.2	507.0	5.2	100.4	263.	43.	111.	2.36937	6.5	1699.5	3.7	977.8	
201330	515.8	511.2	4.6	108.0	194.	44.	117.	1.65812	5.2	999.8	3.0	575.3	
201320	521.2	515.7	5.5	100.8	269.	43.	110.	2.44545	6.6	1775.2	3.8	1021.4	
201310	524.5	519.7	4.8	137.2	364.	39.	146.	2.49315	6.4	2317.4	3.7	1333.3	

Overflow point
- \+ Flooding by assumed runoff equal to full of valley depth (depth of water more than 12 meter) Q : 8,577 m^3/sec
- ++ Flooding by assumed runoff equal to 3/4 of valley depth (depth of water more than 9 meter) Q : 4,750 m^3/sec
- +++ Flooding by assumed runoff equal to 1/2 of valley depth (depth of water more than 6 meter) Q : 1,598 m^3/sec
- ++++ Flooding by assumed runoff equal to 1/4 of valley depth (depth of water more than 3 meter) Q : 393 m^3/sec

Point No.	Altitude	Elevation of Riverbed	Height of Riverbed	Width of Riverbed	River Course Area (A)	Slope of River Course (1)	Wetted Perimeter (P)	Hydraulic Radius (R)	Velocity (V)	Runoff (Q)	Velocity with sediment (VI)	Runoff (Q1)	
201300	529.2	523.4	5.8	120.0	273.	38.	140.	1.95000	5.3	1456.6	3.1	838.1	
201290	532.0	527.2	4.8	101.2	265.	42.	108.	2.45370	6.5	1732.3	3.8	996.7	
201280	535.0	531.7	3.3	142.4	305.	41.	147.	2.07483	5.8	1761.7	3.3	1013.6	
201270	539.7	535.4	4.3	133.8	293.	39.	142.	2.06338	5.6	1644.5	3.2	946.2	
201260	544.2	539.4	4.8	148.6	280.	43.	156.	1.79487	5.4	1503.8	3.1	865.3	
201250	547.0	544.0.	3.0	125.4	239.	44.	131.	1.82443	5.5	1312.7	3.2	755.3	
201240	552.3	548.2	4.1	129.8	392.	43.	137.	2.86131	7.3	2872.2	4.2	1652.6	
201230	554.8	552.6	2.2	128.4	123.	41.	134.	0.91791	3.4	412.7	1.9	237.5	++++
201220	561.0	556.3	4.7	142.0	329.	39.	150.	2.19333	5.8	1923.2	3.4	1106.6	
201210	564.0	560.3	3.7	108.8	278.	42.	139.	2.00000	5.7	1585.9	3.3	912.5	
201200	570.0	564.7	5.3	113.0	499.	40.	123.	4.05691	8.9	4449.5	5.1	2560.1	
201190	573.7	568.2	5.5	98.6	330.	42.	88.	3.75000	8.7	2861.3	5.0	1646.3	
201180	578.0	573.0	5.0	113.8	431.	42.	124.	3.47581	8.2	3552.8	4.7	2044.2	
201170	581.6	576.5	3.2	69.2	186.	41.	137.	2.08759	5.8	1658.7	3.3	954.4	
201160	585.8	581.2	4.6	64.2	235.	46.	75.	3.13333	8.1	1892.0	4.6	1088.6	
201150	588.4	585.7	2.7	86.4	170.	73.	93.	1.82796	6.8	1163.4	3.9	669.4	
201140	600.0	595.8	4.2	80.6	286.	72.	83.	3.44578	10.4	2964.9	6.0	1705.9	
201130	605.8	600.0	5.8	88.6	399.	20.	99.	4.03030	6.1	2419.9	3.5	1392.3	
201120	604.5	599.8	4.7	77.0	219.	5.	87.	2.51724	2.2	485.4	1.3	279.3	++++
201117	604.2	600.6	3.6	48.8	118.	46.	56.	2.10714	6.0	704.7	3.4	405.5	
201115	605.0	601.6	3.4	74.8	131.	46.	81.	1.61728	5.0	655.9	2.9	377.4	++++
201110	608.0	604.4	3.6	76.4	231.	51.	84.	2.75000	7.5	1734.4	4.3	997.9	
201100	614.3	609.2	5.1	117.0	454.	50.	127.	3.57480	8.9	4019.3	5.1	2312.6	
201090	619.8	614.4	5.4	103.2	413.	53.	115.	3.59130	9.1	3776.0	5.3	2172.6	
201080	625.0	619.8	5.2	96.0	264.	50.	104.	2.53846	7.0	1860.7	4.1	1070.6	
201070	629.7	624.3	5.4	86.4	265.	63.	100.	2.65000	8.1	2157.5	4.7	1241.4	
201060	635.0	632.4	2.6	77.2	122.	61.	88.	1.38636	5.2	634.8	3.0	365.3	++++
201050	641.7	636.4	5.3	97.8	189.	45.	113.	1.67257	5.1	957.2	2.9	550.7	+++
201040	646.8	641.4	5.4	98.4	244.	55.	116.	2.10345	6.5	1591.4	3.8	915.7	
201030	652.3	647.4	4.9	49.2	158.	61.	60.	2.63333	8.0	1260.5	4.6	725.2	+++
201020	658.8	653.6	5.2	48.2	175.	56.	55.	3.18182	8.7	1517.3	5.0	873.0	+++
201010	665.2	658.6	6.6	60.6	666.	54.	74.	9.00000	17.0	11333.0	9.8	6520.7	
201000	671.0	664.4	6.6	43.8	263.	53.	56.	4.69643	10.9	2875.0	6.3	1654.2	
500990	676.3	669.1	7.2	63.2	392	49.	77.	5.09091	11.1	4347.7	6.4	2501.5	
500980	681.8	674.2	7.6	53.0	370.	56.	68.	5.44118	12.4	4585.8	7.1	2638.5	
500970	687.6	680.2	7.4	74.2	298.	59.	85.	5.50588	9.5	2828.9	5.5	1627.7	
500960	691.8	686.0	5.8	67.4	334.	58.	80.	4.17500	10.6	3531.6	6.1	2032.0	
500950	697.6	691.8	5.8	67.8	206.	60.	59.	3.49152	9.5	1966.7	5.5	1131.6	
500940	706.0	698.0	8.0	59.2	305.	69.	75.	4.06667	11.3	3456.6	6.5	1988.7	
500930	711.3	705.5	5.8	33.4	167.	62.	46.	3.63043	10.0	1663.4	5.7	957.1	+++
500920	717.1	710.4	6.7	65.6	359.	54.	74.	4.85135	11.3	4047.8	6.5	2329.0	
500910	722.3	716.2	6.1	58.2	318.	54.	67.	4.74627	11.1	3533.6	6.4	2033.2	
500900	728.1	721.2	6.9	35.2	211.	50.	49.	4.30612	10.0	2114.5	5.8	1216.7	+++
500890	733.2	726.2	7.0	45.2	260.	55.	59.	4.40678	10.7	2775.2	6.1	1596.8	+++
500800	738.8	732.2	6.6	54.2	298.	60.	68.	4.38235	11.1	3309.9	6.4	1904.4	++
500870	746.2	738.1	8.1	70.4	428.	60.	86.	4.97674	12.1	5174.1	7.0	2977.0	++
500860	756.0	744.2	11.8	132.2	996.	66.	156.	6.38461	15.0	14907.3	8.6	8577.3	
500850	764.3	751.2	13.1	202.0	1573.	68.	243.	6.47325	15.3	24117.8	8.8	13876.8	
500840	772.4	757.8	14.6	188.0	1498.	72.	218.	6.87156	16.4	24592.6	9.4	14149.9	
500830	784.8	765.5	19.3	144.8	1696.	94.	178.	9.52809	23.3	39550.8	13.4	22756.5	
500820	792.0	776.5	15.5	107.6	1386.	84.	141.	9.82979	22.5	31195.0	13.0	17948.8	
500810	797.6	782.3	15.3	134.2	1152.	66.	140.	8.22857	17.7	20416.3	10.2	11747.0	
500800	808.4	789.6	18.8	229.8	1290.	66.	161.	8.01242	17.4	22460.3	10.0	12923.1	

Overflow point
+ Flooding by assumed runoff equal to full of valley depth (depth of water more than 12 meter) Q : 8,577 m^3/sec
++ Flooding by assumed runoff equal to 3/4 of valley depth (depth of water more than 9 meter) Q : 4,750 m^3/sec
+++ Flooding by assumed runoff equal to 1/2 of valley depth (depth of water more than 6 meter) Q : 1,598 m^3/sec
++++ Flooding by assumed runoff equal to 1/4 of valley depth (depth of water more than 3 meter) Q : 393 m^3/sec

Table 6 The Capacity of the Valley for the Flood (K. Krasak)

Point No.	Altitude	Elevation of Riverbed	Height of Riverbed	Width of Riverbed	River Course Area (A)	Slope of River Course (I)	Wetted Perimeter (P)	Hydraulic Radius (R)	Velocity (V)	Runoff (Q)	Velocity with sediment (VI)	Runoff (Q1)	
402150	235.9	234.6	1.3	161.8	82.	20.	122.	0.67213	2.0	164.8	1.7	137.6	++++
402140	238.5	236.6	1.9	166.0	183.	20.	168.	1.08928	2.8	507.4	2.3	423.5	
402130	240.7	238.6	2.1	200.0	226.	18.	196.	1.15306	2.7	617.4	2.3	515.3	
402120	242.2	240.2	2.0	203.6	191.	16.	208.	0.91827	2.2	422.7	1.8	352.8	
402110	243.8	241.8	2.0	31.2	95.	22.	126.	0.75397	2.3	216.2	1.9	180.5	++++
402100	246.8	244.6	2.2	77.8	121.	22.	82.	1.47561	3.6	430.7	3.0	359.5	
402090	249.0	246.2	2.8	92.2	174.	19.	101.	1.72277	3.7	638.1	3.1	532.6	
402080	250.8	248.3	2.5	103.6	135.	24.	108.	1.25000	3.3	449.4	2.8	375.1	
402070	254.5	251.0	3.5	150.8	375.	23.	158.	2.37342	5.0	1872.8	4.2	1563.3	
402060	255.8	252.8	3.0	178.2	334.	20.	183.	1.82514	3.9	1305.8	3.3	1090.0	
402050	256.9	255.0	1.9	162.2	232.	21.	211.	1.09953	2.9	663.2	2.4	553.6	
402040	260.0	257.0	3.0	133.4	279.	19.	137.	2.03650	4.1	1143.7	3.4	954.7	
402030	263.3	258.8	4.5	130.0	409.	23.	140.	2.92143	5.7	2345.7	4.8	1958.0	
402020	265.4	261.6	3.8	135.0	370.	23.	142.	2.60563	5.3	1966.4	4.4	1641.4	
402010	266.8	263.4	3.4	160.0	306.	24.	147.	2.08163	4.7	1430.5	3.9	1194.1	
402000	267.6	266.4	1.2	140.0	101.	22.	148.	0.68243	2.1	215.1	1.8	179.5	++++
401990	271.0	167.8	3.2	170.4	236.	20.	136.	1.73529	3.8	892.2	3.2	744.7	
401980	273.8	270.4	3.4	181.2	288.	22.	128.	2.25000	4.7	1357.6	3.9	1133.2	
401970	276.8	272.2	4.6	116.8	354.	15.	127.	2.78740	4.5	1589.1	3.7	1326.5	
401960	277.1	273.3	3.8	132.6	250.	20.	140.	1.78571	3.9	963.3	3.2	804.1	
401950	282.0	276.2	5.8	102.8	531.	25.	172.	3.08721	6.2	3294.0	5.2	2749.6	
401940	281.1	278.2	2.9	70.2	136.	19.	74.	1.83784	3.8	520.7	3.2	434.6	
401930	284.0	280.0	4.0	83.2	204.	14.	90.	2.26667	3.8	770.9	3.2	643.5	
401920	286.4	281.0	5.4	100.8	298.	23.	110.	2.70909	5.5	1625.3	4.6	1356.7	
401910	291.0	284.6	5.4	159.4	815.	29.	173.	4.71098	8.4	6835.6	4.8	3933.0	
401900	293.8	286.7	7.1	125.6	638.	15.	139.	4.58993	5.9	3782.3	3.4	2176.2	
401890	295.2	287.6	7.6	159.0	696.	28.	160.	4.35000	7.8	5439.4	4.5	3129.7	
401880	297.4	292.2	5.2	125.8	481.	37.	136.	3.53676	7.8	3764.8	4.5	2166.2	
401870	301.0	295.0	6.0	131.0	539.	25.	140.	3.85000	6.8	3669.4	3.9	2111.3	
401860	305.8	297.2	8.6	109.4	664.	24.	128.	5.18750	8.1	5402.1	4.7	3108.2	
401850	307.0	299.8	7.2	115.4	629.	19.	127.	4.95275	7.0	4414.9	4.0	2540.2	
401840	311.0	301.0	10.0	143.0	1002.	24.	160.	6.26250	9.2	9241.3	5.3	5317.2	
401830	314.5	304.6	9.9	166.0	1162.	36.	186.	6.24731	11.3	13104.3	6.5	7539.9	
401820	318.4	308.2	10.2	189.2	1330.	30.	209.	6.36364	10.4	13861.3	6.0	7975.4	
401810	320.3	310.6	9.7	216.2	1264.	28.	234.	5.40171	9.0	11410.8	5.2	6565.5	
401800	323.7	313.8	9.9	182.4	1414.	31.	202.	7.00000	11.3	15962.1	6.5	9184.2	
401790	326.3	316.8	9.5	169.9	1183.	29.	190.	6.22632	10.1	11947.2	5.8	6874.1	
401780	328.6	319.5	9.1	124.4	826.	33.	143.	5.77622	10.2	8464.8	5.9	4870.4	
401775	327.8	321.8	6.0	146.4	641.	39.	159.	4.03145	8.8	5620.2	5.0	3233.7	
401770	329.2	323.4	5.8	46.8	716.	22.	161.	4.44720	7.0	5033.6	4.0	2896.2	
401764	332.0	324.2	7.8	196.6	865.	35.	217.	3.98617	8.2	7130.9	4.7	4102.9	
401758	334.0	327.6	6.4	201.2	496.	40.	212.	2.33962	6.2	3065.4	3.6	1763.8	
401750	338.0	329.8	8.2	154.6	970.	29.	166.	5.84337	9.7	9390.6	5.6	5403.1	
401740	343.0	332.8	10.2	156.2	953.	33.	204.	4.67157	8.9	8478.9	5.1	4847.5	
401730	346.0	336.4	9.6	139.8	908.	48.	178.	5.10112	11.4	10330.9	6.5	5944.1	
401720	348.0	324.4	5.6	108.6	269.	32.	120.	2.24167	5.4	1445.2	3.1	831.5	
401710	349.0	342.8	6.2	120.8	436.	15.	132.	3.30303	4.8	2076.1	2.7	1194.5	
401708	353.3	344.2	9.1	104.0	583.	54.	123.	4.73984	11.5	6699.6	6.6	3854.8	
401706	354.2	346.0	346.0	8.2	101.4	483.	54.	116.	4.16379	10.5	6.1	2929.5	
401700	355.2	348.2	7.0	132.8	664.	36.	144.	4.61111	9.2	6117.0	5.3	3519.6	
401695	358.0	350.0	8.0	135.6	580.	32.	152.	3.81579	7.7	4440.8	4.4	2555.1	
401690	359.0	351.4	7.6	144.8	716.	26.	163.	4.39264	7.6	5427.3	4.4	3122.7	

Overflow point
- \+ Flooding by assumed runoff equal to full of valley depth (depth of water more than 20 meter) Q : 27,616 m^3/sec
- ++ Flooding by assumed runoff equal to 3/4 of valley depth (depth of water more than 15 meter) Q : 12,535 m^3/sec
- +++ Flooding by assumed runoff equal to 1/2 of valley depth (depth of water more than 10 meter) Q : 4,968 m^3/sec
- ++++ Flooding by assumed runoff equal to 1/4 of valley depth (depth of water more than 5 meter) Q : 634 m^3/sec

Point No.	Altitude	Elevation of Riverbed	Height of Riverbed	Width of Riverbed	River Course Area (A)	Slope of River Course (I)	Wetted Perimeter (P)	Hydraulic Radius (R)	Velocity (V)	Runoff (Q)	Velocity with sediment (VI)	Runoff (Q1)	
401685	359.3	352.6	6.7	120.0	474.	22.	132.	3.59091	6.1	2889.9	3.5	1662.8	
401680	362.5	353.6	8.9	127.0	640.	16.	154.	4.15584	5.7	3667.7	3.3	2110.3	
401675	364.4	354.2	10.2	125.8	749.	34.	145.	5.16552	9.7	7232.4	5.6	4161.3	
401670	365.3	357.0	8.3	119.2	560.	34.	136.	4.11765	8.3	4649.5	4.8	2675.2	
401665	366.0	357.6	8.4	114.8	585.	34.	135.	4.33333	8.6	5025.1	4.9	2891.3	
401660	367.3	360.4	6.9	107.4	455.	53.	122.	3.72951	9.7	4415.6	5.6	2540.6	
401659	368.7	362.9	5.8	99.6	400.	53.	112.	3.57143	9.4	3771.5	5.4	2170.0	
401658	369.2	362.4	6.8	101.8	506.	53.	116.	4.36207	10.8	5450.7	6.2	3136.2	
401657	369.2	365.6	3.6	100.2	263.	53.	102.	2.57843	7.6	1996.1	4.4	1148.5	
401655	369.9	366.5	3.4	123.6	137.	53.	133.	1.03008	4.1	564.4	2.4	324.7	++++
401650	373.6	368.2	5.4	192.0	556.	53.	207.	2.68599	7.8	4336.3	4.5	2495.0	
401645	376.7	371.8	4.9	221.8	750.	48.	231.	3.24675	8.4	6315.9	4.8	3634.0	
401640	378.4	373.0	5.4	246.0	674.	28.	255.	2.64314	5.6	3780.0	3.2	2174.9	
401635	380.7	374.6	6.1	243.2	924.	32.	268.	3.44776	7.2	6612.6	4.1	3804.7	
401630	381.8	376.2	5.6	236.6	907.	34.	245.	3.70204	7.7	7015.4	4.5	4036.5	
401625	383.4	378.0	5.4	237.8	770.	38.	250.	3.08000	7.2	5570.3	4.2	3205.0	
401620	385.3	380.0	5.3	103.4	768.	46.	205.	3.74634	9.1	6964.5	5.2	4007.2	
401615	386.2	382.6	3.6	172.2	315.	46.	180.	1.75000	5.5	1720.6	3.1	990.0	
401610	389.0	384.6	4.4	140.0	619.	41.	169.	3.66272	8.4	5220.4	4.9	3003.7	
401605	491.7	387.6	5.0	124.6	575.	28.	152.	3.78289	7.1	4094.5	4.1	2395.9	
401600	393.4	387.4	6.0	152.0	654.	37.	169.	3.86982	8.3	5435.1	4.8	3127.2	
401595	394.5	390.4	4.1	140.8	395.	30.	171.	2.30994	5.3	2096.2	3.1	1206.1	
401590	395.3	390.4	4.9	166.0	411.	28.	166.	2.47590	5.4	2206.8	3.1	1269.8	
401585	396.0	393.2	2.8	148.2	272.	40.	154.	1.76623	5.1	1394.0	2.9	802.1	
401580	399.6	394.4	5.2	144.2	550.	50.	154.	3.57143	7.1	3901.6	4.1	2244.9	
401575	401.8	396.2	5.6	133.6	448.	44.	145.	3.08965	7.8	3494.7	4.5	2010.8	
401570	402.8	398.8	4.0	147.6	450.	48.	156.	2.88461	7.8	5502.5	4.5	2015.2	
401565	403.8	401.0	2.8	164.8	272.	26.	170.	1.60000	3.9	1052.3	2.2	605.4	
401560	406.9	401.4	5.5	159.6	540.	24.	170.	3.17647	5.9	3169.0	3.4	1823.3	
401555	408.3	403.4	4.9	179.8	536.	31.	195.	2.74872	6.1	3246.6	3.5	1868.0	
401550	411.2	404.5	6.7	158.4	627.	34.	168.	3.73214	7.8	4875.9	4.5	2805.5	
401545	413.5	406.8	6.7	172.0	728.	33.	186.	3.91398	7.9	5757.0	4.6	3312.4	
401540	413.6	407.8	5.8	163.6	642.	30.	178.	3.60674	7.1	4584.2	4.1	2637.6	
401535	417.0	409.8	7.2	176.0	743.	24.	190.	3.91053	6.7	5007.8	3.9	2881.4	
401530	419.1	410.2	8.9	187.6	738.	27.	204.	3.61765	6.8	5009.3	3.9	2882.2	
401524	419.8	412.8	7.0	171.2	795.	46.	190.	4.18421	9.8	7760.1	5.6	4464.9	
401520	424.5	414.8	9.7	233.0	1256.	37.	263.	5.80228	10.9	16608.8	6.3	9556.2	
401515	426.6	415.8	10.8	275.8	2080.	21.	302.	6.88742	9.2	19118.0	5.3	11000.0	
401510	428.0	416.9	11.1	306.4	2170.	56.	333.	6.51652	14.5	31391.6	8.3	18061.9	
401505	430.4	421.4	9.0	152.0	2161.	59.	341.	6.33724	14.6	31497.2	8.4	18122.6	
401500	431.4	422.8	8.6	145.4	1956.	36.	328.	5.96341	10.9	21385.8	6.3	12304.8	
401495	433.8	425.0	8.8	144.2	1864.	36.	320.	5.82500	10.8	20063.6	6.2	11544.1	
401490	436.0	426.4	9.6	170.6	2118.	35.	337.	6.28487	11.2	23645.6	6.4	13605.1	
401485	437.0	428.5	8.5	158.8	1761.	36.	295.	5.96949	10.9	19266.8	6.3	11085.6	
401480	438.3	430.0	8.3	176.8	2093.	35.	376.	5.56649	10.3	21551.9	5.9	12400.4	
401475	441.5	432.0	9.5	162.6	2077.	30.	349.	5.95129	10.0	20702.0	5.7	11911.4	
401470	443.3	433.0	10.3	152.2	1687.	36.	354.	4.76554	9.4	15886.0	5.4	9140.4	
401465	444.2	435.6	8.6	128.0	2136.	24.	403.	5.30025	8.3	17628.4	4.7	10142.9	
401460	445.0	435.4	9.6	149.8	2653.	36.	434.	6.11290	11.1	29488.6	6.4	16967.0	
401455	447.4	439.2	8.2	149.4	2262.	50.	439.	5.15262	11.7	26443.2	6.7	15214.7	
401450	450.3	440.4	9.9	124.0	1641.	49.	466.	5.66738	12.3	32564.5	7.1	18736.8	
401440	453.7	446.6	7.1	100.6	2400.	47.	468.	5.12820	11.3	27115.8	6.5	15601.7	
401430	455.7	449.8	5.9	120.8	1942.	39.	500.	3.88400	8.6	16609.9	4.9	9556.9	

Overflow point
- + Flooding by assumed runoff equal to full of valley depth (depth of water more than 20 meter) Q : 27,616 m^3/sec
- ++ Flooding by assumed runoff equal to 3/4 of valley depth (depth of water more than 15 meter) Q : 12,535 m^3/sec
- +++ Flooding by assumed runoff equal to 1/2 of valley depth (depth of water more than 10 meter) Q : 4,968 m^3/sec
- ++++ Flooding by assumed runoff equal to 1/4 of valley depth (depth of water more than 5 meter) Q : 634 m^3/sec

Point No.	Altitude	Elevation of Riverbed	Height of Riverbed	Width of Riverbed	River Course Area (A)	Slope of River Course (1)	Wetted Perimeter (P)	Hydraulic Radius (R)	Velocity (V)	Runoff (Q)	Velocity with sediment (VI)	Runoff (Q1)	Overflow point
401420	458.5	454.4	4.1	158.6	1651.	43.	548.	3.01277	7.6	12519.8	4.4	7203.6	
401410	462.5	458.3	4.2	173.4	1695.	41.	469.	3.61407	8.4	14168.1	4.8	8152.0	
401400	466.6	462.6	4.0	201.0	2186.	42.	552.	3.96014	9.0	19655.1	5.2	11309.0	
401390	471.0	466.6	4.4	580.0	3043.	39.	672.	4.52827	9.5	28827.7	5.5	16586.7	
401380	476.0	470.4	5.6	675.0	4142.	39.	718.	5.76880	11.1	46105.3	6.4	26527.8	
401370	480.0	474.4	5.6	721.0	4297.	37.	808.	5.31807	10.3	44131.0	5.9	25391.8	
401360	484.2	477.8	6.4	800.0	6266.	32.	882.	7.10431	11.6	72577.8	6.7	41759.4	
401350	484.8	480.8	4.0	105.0	209.	35.	114.	1.83333	4.9	1027.1	2.8	591.0	
401340	488.4	484.8	3.6	105.0	205.	41.	113.	1.81416	5.3	1082.8	3.0	623.0	
401330	493.8	489.0	4.8	66.0	206.	41.	79.	2.60759	6.7	1385.5	3.9	797.2	
401320	498.6	492.9	5.7	68.0	264.	41.	81.	3.25926	7.8	2060.0	4.5	1185.2	
401310	502.0	497.2	4.8	103.5	363.	42.	124.	2.92742	7.4	2668.9	4.2	1535.6	
401300	506.2	501.2	5.0	83.0	344.	38.	108.	3.18518	7.3	2501.0	4.2	1439.0	
401290	510.0	504.8	5.2	53.5	219.	49.	77.	2.84416	7.7	1676.7	4.4	964.7	
401280	518.0	511.0	7.0	69.0	319.	46.	93.	3.43011	8.4	2680.8	4.8	1542.4	
401270	519.6	513.9	5.7	148.0	534.	42.	180.	2.96667	7.3	3892.9	4.2	2239.8	
401260	525.2	519.4	5.8	110.0	369.	56.	135.	2.73333	8.0	2941.2	4.6	1692.3	
401250	529.2	525.0	4.2	50.0	103.	52.	64.	1.60938	5.4	556.0	3.1	319.9	++++
401240	534.6	529.8	4.8	95.0	249.	47.	106.	2.34906	6.6	1643.7	3.8	945.8	
401230	539.5	534.4	5.1	66.0	202.	31.	79.	2.55696	5.7	1145.9	3.3	659.3	+++
401220	543.8	536.0	7.8	86.0	407.	47.	105.	3.87619	9.2	3750.5	5.3	2158.0	
401210	547.0	543.8	3.2	80.5	189.	66.	92.	2.05435	7.2	1352.2	4.1	778.0	
401200	553.0	549.2	3.8	119.0	345.	55.	132.	2.61364	7.7	2645.2	4.4	1522.0	
401190	559.0	554.8	4.2	79.0	226.	52.	89.	2.53933	7.3	1652.8	4.2	951.0	
401180	663.6	559.6	4.0	91.0	230.	44.	119.	1.93277	5.6	1290.1	3.2	742.3	
401170	568.4	563.6	4.8	71.5	185.	46.	77.	2.40260	6.6	1226.5	3.8	705.7	+++
401160	573.4	568.8	4.6	67.0	215.	52.	76.	2.82895	7.9	1690.6	4.5	972.2	
401150	578.2	573.9	4.3	97.5	249.	45.	110.	2.26364	6.3	1569.2	3.6	902.9	+++
401140	585.6	577.8	7.8	101.5	515.	42.	120.	4.29167	9.3	4801.0	5.4	2762.4	
401130	589.0	582.2	6.8	91.0	312.	43.	107.	2.91589	7.3	2275.1	4.2	1309.0	+++
401120	595.6	586.4	9.2	107.5	642.	45.	136.	4.72059	10.3	6600.8	5.9	3797.9	
401110	601.0	591.2	9.8	95.5	665.	45.	116.	5.73276	11.7	7781.6	6.7	4477.3	
401100	605.6	595.4	10.2	84.0	673.	39.	110.	6.11818	11.4	7656.1	6.5	4405.1	
401090	611.0	599.0	12.0	61.5	518.	46.	83.	6.24096	12.5	6485.1	7.2	3731.4	+++
401080	618.4	604.6	13.8	60.0	747.	50.	117.	6.38461	13.3	9899.1	7.6	5695.7	
401070	623.0	609.0	14.0	90.0	839.	43.	125.	6.71200	12.7	10659.9	7.3	6133.4	
401060	629.4	613.2	16.2	86.0	1037.	53.	120.	8.64167	16.7	17308.6	9.6	9958.9	
401050	635.8	619.5	16.3	140.0	1622.	58.	177.	9.16384	18.2	19449.7	10.4	16944.6	
401040	635.2	624.7	10.5	170.0	629.	57.	135.	4.65926	11.5	7215.4	6.6	4151.5	+++
401030	646.0	630.9	16.1	136.0	1567.	59.	146.	10.73288	20.3	31880.4	11.7	18343.2	
401020	651.8	636.5	15.3	204.0	2375.	41.	227.	10.46255	16.7	39601.0	9.6	22785.4	
401010	659.0	639.0	20.0	173.0	2698.	39.	254.	11.52991	17.3	46808.2	10.0	26932.2	
401000	664.4	644.3	20.1	158.0	2508.	64.	242.	10.36364	20.7	51918.2	11.9	29872.4	
500990	663.6	651.7	11.9	84.0	700.	52.	109.	6.42202	13.6	9496.9	7.8	5464.3	++
500980	670.2	654.7	15.5	105.0	1190.	40.	150.	7.93333	13.7	16300.0	7.9	9378.6	
500970	676.0	659.7	16.3	124.0	1410.	56.	160.	8.1250	16.8	23691.8	9.7	13631.6	
500960	688.0	665.8	22.2	138.0	2558.	67.	189.	13.53439	24.5	62564.0	14.1	35997.7	
500950	692.8	673.1	19.7	192.0	3176.	66.	243.	13.06996	23.7	75325.1	13.6	43340.1	
500940	698.2	679.0	19.2	107.5	1741.	57.	151.	11.52980	20.3	35298.6	11.7	20309.9	
500930	703.2	684.5	18.7	120.0	1749.	57.	165.	10.60000	19.2	33529.7	11.0	19292.1	

Overflow point

- \+ Flooding by assumed runoff equal to full of valley depth (depth of water more than 20 meter) Q : 27,616 m^3/sec
- ++ Flooding by assumed runoff equal to 3/4 of valley depth (depth of water more than 15 meter) Q : 12,535 m^3/sec
- +++ Flooding by assumed runoff equal to 1/2 of valley depth (depth of water more than 10 meter) Q : 4,968 m^3/sec
- ++++ Flooding by assumed runoff equal to 1/4 of valley depth (depth of water more than 5 meter) Q : 634 m^3/sec

Point No.	Altitude	Elevation of Riverbed	Height of Riverbed	Width of Riverbed	River Course Area (A)	Slope of River Course (1)	Wetted Perimeter (P)	Hydraulic Radius (R)	Velocity (V)	Runoff (Q)	Velocity with sediment (VI)	Runoff (Q1)	
500920	709.0	690.4	18.6	126.0	2098.	67.	168.	12.48809	23.2	48636.0	13.3	27983.9	
500910	714.0	697.8	16.2	162.5	2332.	63.	203.	11.48768	21.3	49586.3	12.2	28530.7	
500900	723.0	703.0	20.0	177.5	2059.	62.	231.	8.91342	17.8	36680.1	10.2	21104.7	
500890	730.0	710.1	19.9	113.0	1674.	86.	162.	10.33333	23.2	38755.8	13.3	22299.1	
500880	737.5	720.2	17.3	162.5	1897.	81.	224.	8.46875	19.7	37332.4	11.3	21480.1	
500870	743.2	726.2	17.0	81.5	1068.	52.	139.	7.68345	14.8	15783.5	8.5	9081.4	++
500860	748.8	730.5	18.3	82.0	1038.	56.	125.	8.30400	16.2	16764.3	9.3	9645.7	++
500850	759.2	737.4	21.8	92.0	1718.	64.	143.	12.01399	22.1	37934.4	12.7	21826.5	
500840	765.0	743.2	21.8	110.0	1983.	53.	152.	13.04605	21.2	42093.8	12.2	24219.7	
500830	770.0	748.0	22.0	92.0	1581.	57.	148.	10.68243	19.3	304065.8	11.1	17529.2	++
500820	778.0	754.6	23.4	123.5	2142.	81.	166.	12.90361	26.1	55801.3	15.0	32106.6	
500810	788.2	764.2	24.0	176.0	3313.	84.	261.	12.69349	26.2	86934.9	15.1	50020.1	
500800	792.4	771.4	21.0	115.5	1688.	84.	155.	10.89032	23.7	39997.2	13.6	23013.4	

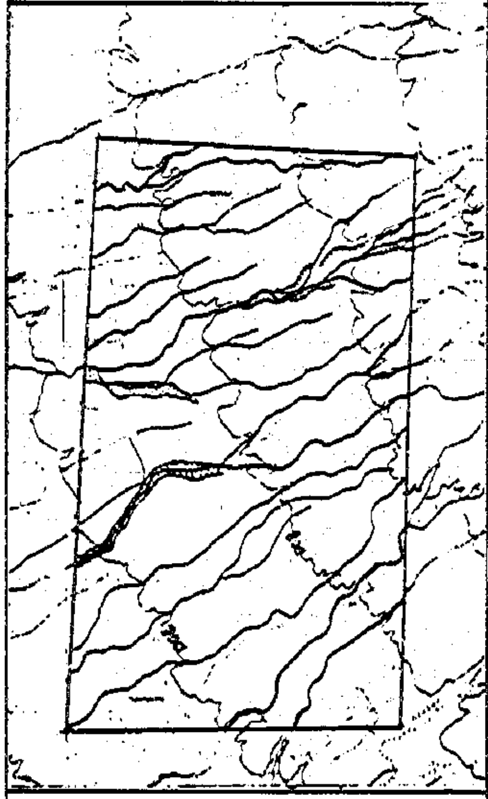
Overflow point
+ Flooding by assumed runoff equal to full of valley depth (depth of water more than 20 meter) Q : 27,616 m^3/sec
++ Flooding by assumed runoff equal to 3/4 of valley depth (depth of water more than 15 meter) Q : 12,535 m^3/sec
+++ Flooding by assumed runoff equal to 1/2 of valley depth (depth of water more than 10 meter) Q : 4,968 m^3/sec
++++ Flooding by assumed runoff equal to 1/4 of valley depth (depth of water more than 5 meter) Q : 634 m^3/sec

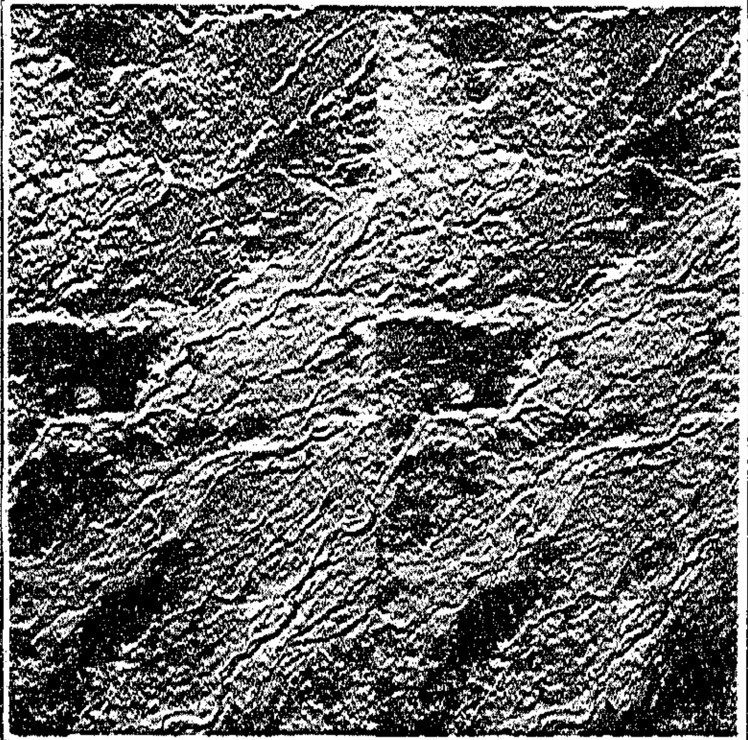
Appendix - 1

Photo Interpretation Cards

Photo Interpretation Card

Name of Place	Location	Topographic Map	Classification
Julang Jero, KAB. MAGELANG	Southwestern foot of Mt. MERAPI	Gn. MERAPI	Deposits of nuée ardante d'avalanche





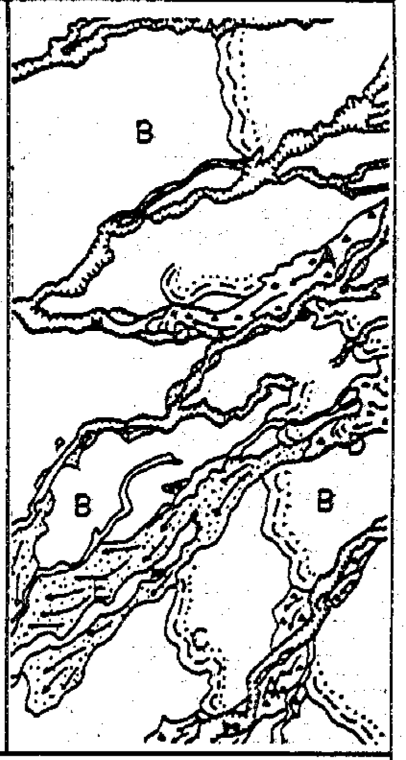


PHOTO DATA:

Strip Number:	VIII-14,15
Photo Scale:	1:40,000
Flying Height:	3160 meters
Camera:	RC-10
Focal Length:	88.78 mm
Film:	Kodak
Date:	27 October 1976
Photography:	PENAS

Interpretation:

bl: K. Blongkeng p: K. Putih ba: K. Batang

be: K. Bebeng

A. Deposits of Nuée Ardante d'avalanche: The deposits of Nuee Ardante d'avalanche appear in the area where the tone is relatively light and an irregularly-shaped net-like pattern is seen.

B. Mountainside Composed of Volcanic Debris (Upper Zone): This morphology can be seen in almost all of the photo. This is a gently sloping area.

C. Breaking Zone: The Breaking Zone of the slope can be observed in area B extending from the upper to the lower part of the photo in the center.

D. Former Valley Buried by Nuée Ardante d'avalanche: This morphology can be seen at K. Batang and K. Blongkeng. Nuee Ardante d'avalanche flowed down along the valley and stopped here. The deposits buried the valley.

E. Deposits of Lahars: Deposits of lahars appear as a whitish tone and are seen mainly along K. Putih.

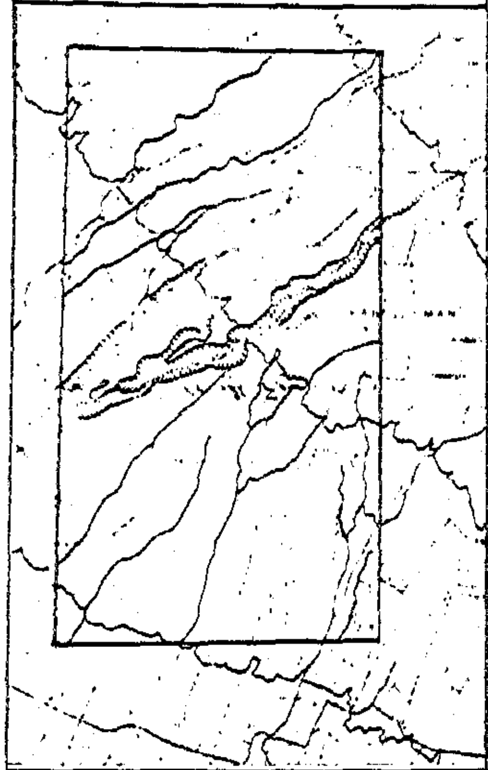
Explanation:

This area is located at the foot of Mt. Merapi on its southwestern slope. The geographical features in this area change with each new volcanic eruption and the resulting erosion.

During the eruption in 1969, Nuee Ardante d'avalanche occurred. It flowed down the southwestern slope and covered the upper reaches of the valleys and slopes in Type I area. Nuee Ardante d'avalanche flowed down K. Blongkeng and buried its valley. After that, the upper reach of K. Blongkeng changed its course to that of K. Putih by flowing through the K. Juranjero. The same case can be observed on the K. Batang. In this case, K. Batang was buried and its upper reach changed course and flowed into K. Bebeng. Generally, lahar starts spreading just at the point of the Breaking Zone on the mountainside. This phenomenon is similar to that of an alluvial fan which is formed at the mouth of the valley. However, lahar spread takes place at two, three or more points along the same river.

Photo Interpretation Card

Name of Place	Location	Topographic Map	Classification
Lombong 2, KAB. MAGELANG	Lower reach of K. Bebeng	MUNTILAN	Deposits of recent lahar



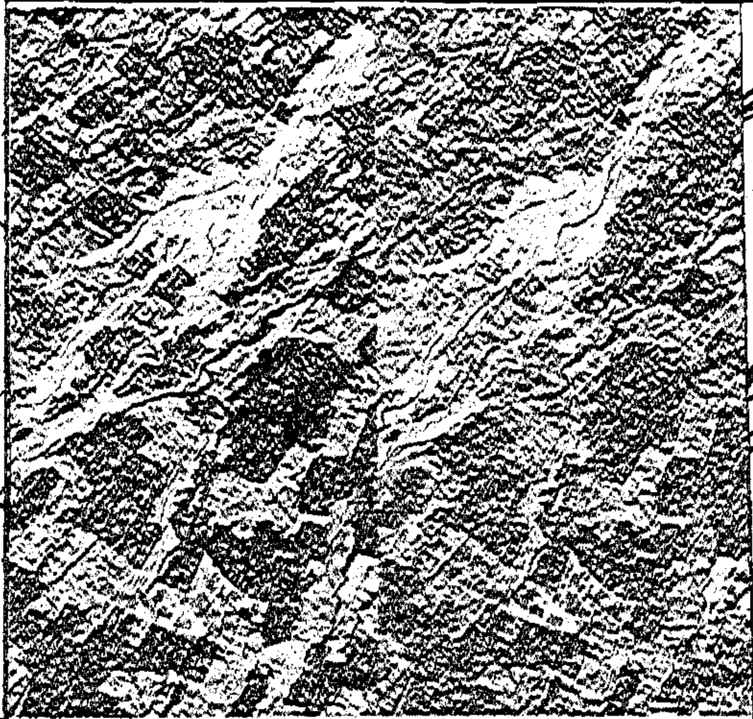


PHOTO DATA:

Strip Number:	VII-12.14
Photo Scale:	1:40,000
Flying Height:	3960 meters
Camera:	RC-10
Focal Length:	88.78 mm
Film:	Kodak
Date:	21 October 1976
Photography:	PENAS

Interpretation:

ba: K. Batang be: K. Bebeng k: K. Kurasak

A. Deposits of Lahar: The area in the central part of the photo is white in tone. This area contains deposits of a lahar which occurred in 1969. The irregular lines observed on the deposits were caused by the flow direction of the lahar.

B. Deposits of Nuée Ardante d'avalanche: The area in the upper part of the photo where the tone is light is covered by deposits of Nuée Ardante d'avalanche.

C. Mountainside Composed of Volcanic Debris (Upper Zone): This morphology can be seen in the right-hand part of the photo as a gently undulating slope.

D. Mountainside Composed of Volcanic Debris (Lower Zone): This morphology can be seen in the left-hand part of the photo. In this area, the slope inclination is rather gentle and the surface of the ground is smooth.

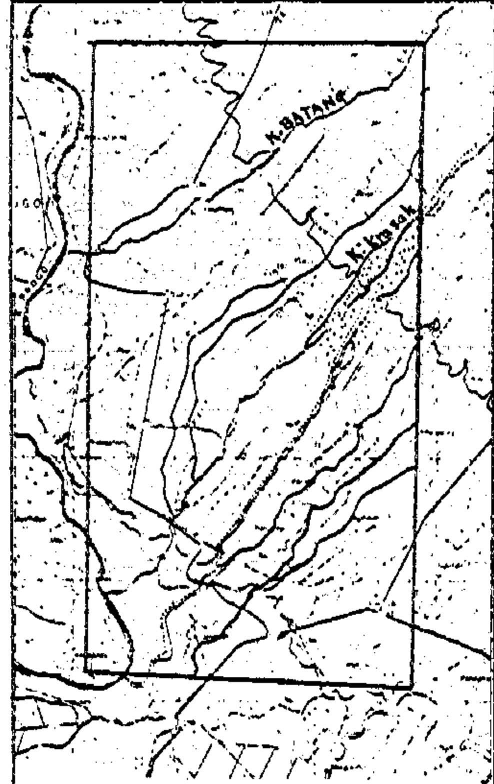
Explanation:

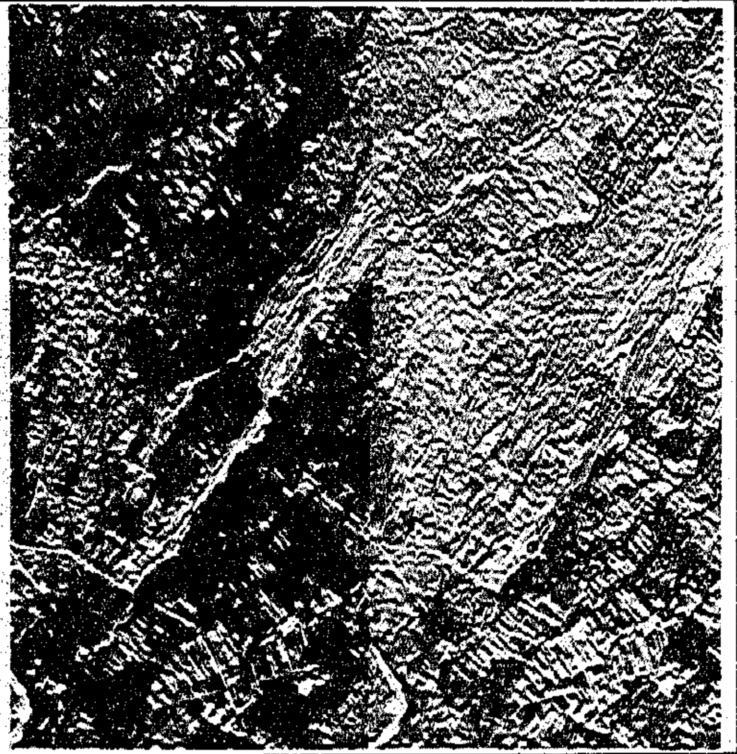
This areas is located in lower reach of K. Bebeng. K. Bebeng continuously changes and these changes cause disasters. When Mt. Merapi erupted in 1969, Nuee Ardante d'avalanche occurred and flowed down the mountainside. On the lower parts of the slope, it flowed along the rivers. Afterwards, lahar flowed down along K. Bebeng and destroyed villages. The lahar overflowed the valley just at the Breaking Zone and at the bend in the river course.

E. Former River Bed: The former river bed can be seen in the upper part of the photo, on the left side of K. Kurasak. Although it looks like an Uncertain Shallow Valley, it is a former river bed of K.Kurasak.

Photo Interpretation Card

Name of Place	Location	Topographic Map	Classification
Banjarejo, KAB.SLEMAN	Lower Reach of K. Kurasak	SALAM	Mountainside composed of volcanic debris, alluvial fan





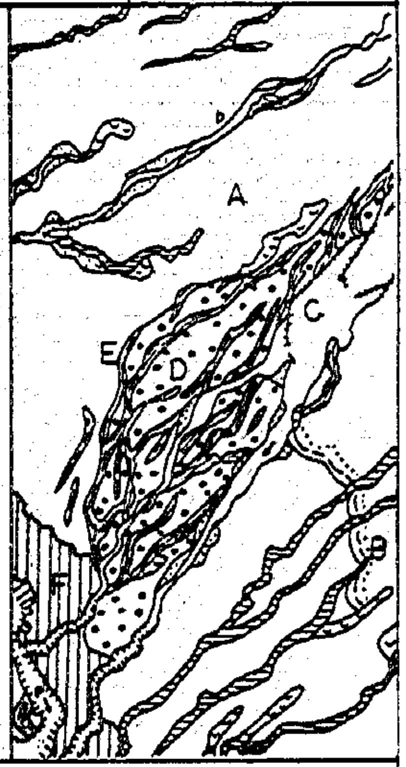


PHOTO DATA:

Strip Number:	CVI-13,14
Photo Scale:	1:40,000
Flying Height:	2880 meters
Camera:	RC-10
Focal Length:	88.78 mm
Film:	Kodak
Date:	18 October 1976
Photography:	PENAS

Interpretation:

k: K. Kurasak b: K. Batang p: K. Progo

A. Mountainside Composed of Volcanic Debris (Lower Zone): This morphology which is smooth and gentle can be observed in almost all parts of the photo.

B. Breaking Zone of Slope Caused by Volcanic Debris Flow: This morphology can be observed faintly to the left of K. Kurasak.

C. River-Bed: The area where the tone is rather light and an irregularly-shaped net-like pattern appears, is the river-bed of the K. Kurasak.

D. Alluvial Fan: This morphology can be observed in the central part of the photo. The shapes of the fields are irregular in this area. Former river-beds appear as net-like patterns.

E. Former River-Bed: This morphology, which appears as a net-like pattern, can be observed in the central part of the photo. The tone of this area is rather dark.

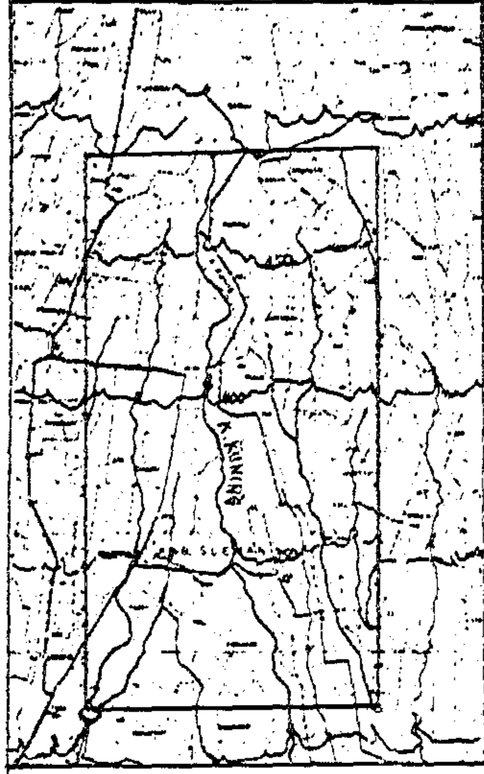
F. Eroded Terrace: This morphology can be observed in the lower left part of the photo. The surface of the terrace is smooth. The terrace is a little lower than the general surface of the ground.

Explanataion:

This area is located in the lower reach of the K. Kurasak. In this area, the K. Kurasak does not dissect the valley except at the lowest reach near K. Progo. Flood waters overflowed the banks and spread over this area causing materials to accumulate. Thus, a fan was formed in this area. Longitudinal dykes have been constructed to protect the villages. However, in 1976, a lahar destroyed the dykes and caused a lot of damage to the villages.

Photo Interpretation Card

Name of Place	Location	Topographic Map	Classification
Cilikan, KAB.SLEMAN	Middle Reach of K. Kuning	BUTUH	Alluvial Fan



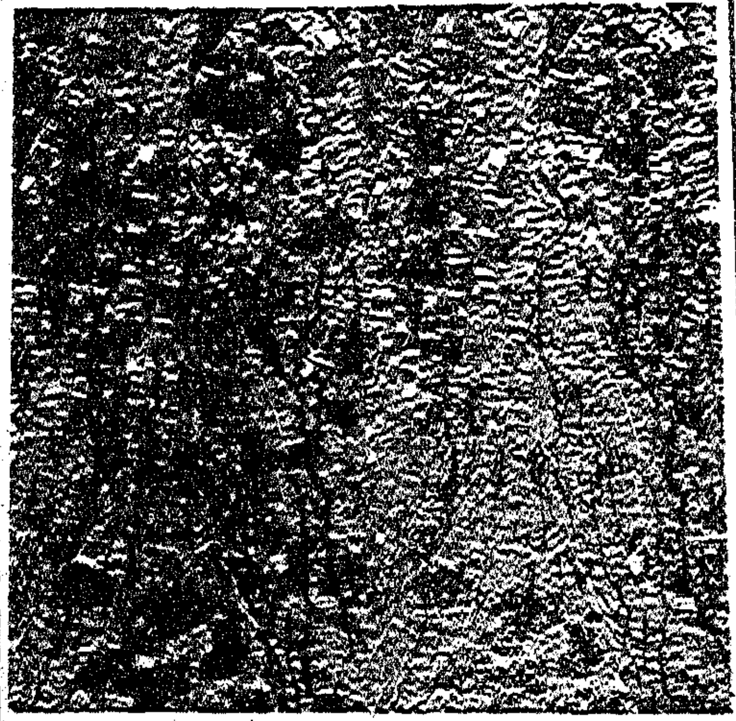


PHOTO DATA:

Strip Number:	CVI-R.9
Photo Scale:	1:40,000
Flying Height:	2880 meters
Camera:	RC-10
Focal Length:	88.78 mm
Film:	KODAK
Date:	18 October 1976
Photography:	PENAS

Interpretation:

kr K. Kuning

A. Mountainside Composed of Volcanic Debris (Upper Zone): This morphology can be observed in the upper part of the photo. The slope in this area is undulated.

B. Mountainside Composed of Volcanic Debris (Lower Zone): This morphology can be observed in the right-hand part of the photo. The inclination of the slope is quite gentle and the surface is smooth.

C. Alluvial Fan: This morphology can be seen in the central and lower parts of the photo. It is difficult to distinguish the alluvial fan and mountainside composed of volcanic debris (Lower Zone) by photo interpretation.

D. Uncertain Shallow Valley: A typical example of this morphology can be observed in the upper part of the photo. These valleys are U-shaped and do not have clear escarpments.

Explanation:

This area is located in the middle reach of K. Kuning. This photo shows the Breaking Zone which divides the upper and lower zones. The alluvial fan is formed in the lower zone where the valley of K. Kuning becomes shallower. Lahar and flood waters flowed over the banks and materials accumulated. Original volcanic debris also flowed down into this area thereby making the composition of this area an alternation of alluvial materials and volcanic debris.

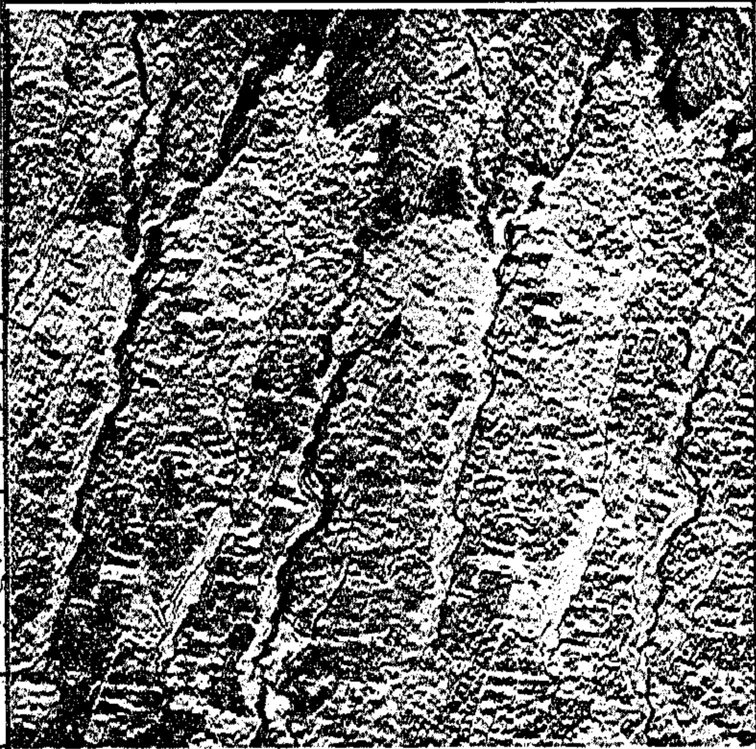
E. Former River Bed: This can be seen in the alluvial fan. It forms a shallow and unclear valley.

F. Accumulation Terrace: Accumulation terraces developed along K. Kuning. They are very low compared with general mountain slopes.

G. Small Valley: These valleys have clear escarpments but their depths, widths and lengths are minimal. They developed on the general flood slopes.

Photo Interpretation Card

Name of Place	Location	Topographic Map	Classification
Kaliurang, KAB. SLEMAN	Upper Reach of K. Boyong	Gn. MERAPI	Mountainside composed of volcanic debris (Upper Zone)



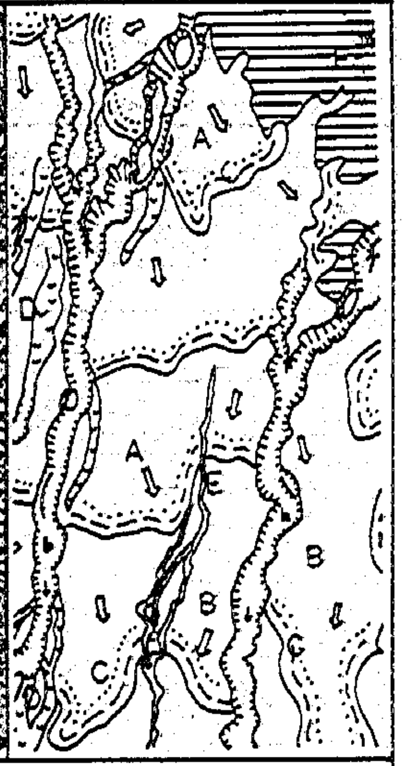


PHOTO DATA:

Strip Number: VII-15,17
Photo Scale: 1:40,000
Flying Height: 3960 meters
Camera: RC-10
Focal Length: 88.78 mm
Film: Kodak
Date: 21 October 1976
Photography: PENAS

Interpretation:

b: K. Boyong k: K. Kuning

A. Mountainside Composed of Volcanic Debris (Upper Zone): This morphology is distributed extensively in the area covered by this photo. Area A was formed by volcanic debris flowing down along the K. Boyong.

B. Mountainside Composed of Volcanic Debris (Upper Zone): This morphology, which can be seen in the right-hand part of the photo, is the same morphology as that of area A. But, the deposits of area B are from the K. Kuning; this makes them a different "unit".

C. Breaking Zone: In areas A and B, several gaps or steps have formed on the slope. In the upper part of the photo, the Breaking Zones are rather clear, but in the lower part of the photo, these Zones are not very clear.

D. Uncertain Shallow Valley: These valleys are observed along the K. Boyong. They do not have clear escarpments surrounding them.

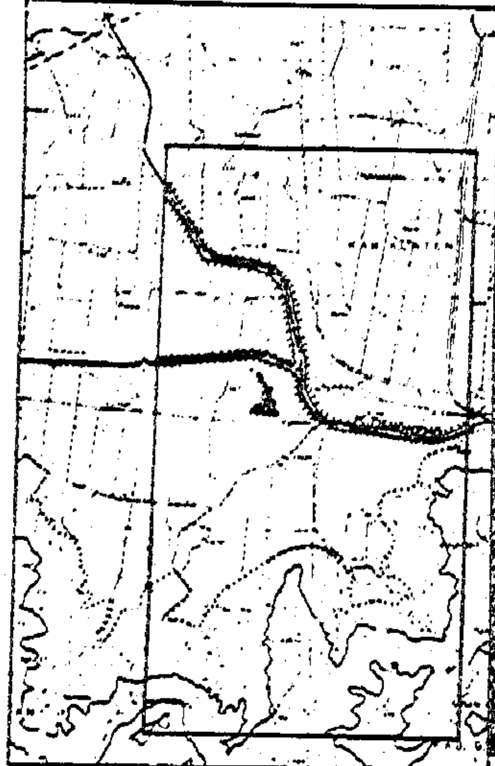
Explanation:

This area is located on the southern slope of Mt. Merapi. Kaliurang can be seen in the upper part of the photo. Volcanic debris flowed down along K. Boyong and K. Kuning and spread out to form fan-like topography.
In this area, volcanic debris spread out from the valley. As a result, the areas on either side of the valley were built up and the rivers flowed in the higher part of the debris flow. The boundary which divides the debris flow from K. Boyong and K. Kuning can be seen faintly in the photo.
In the lower left-hand part of the photo, an Uncertain Shallow Valley can be seen extending from the bend in the K. Boyong. A lava disaster can easily occur under such topographical circumstances.

E. Small Valley: These valleys have developed on the side of the mountain. They have clear escarpments which have been eroded by streams. The transversal valley is basically U-shaped.

Photo Interpretation Card

Name of Place	Location	Topographic Map	Classification
Somopuro, KAB.SLEMAN	Lower Reach of K. Woro	KRANGHONGO	Rised Up River-Bed



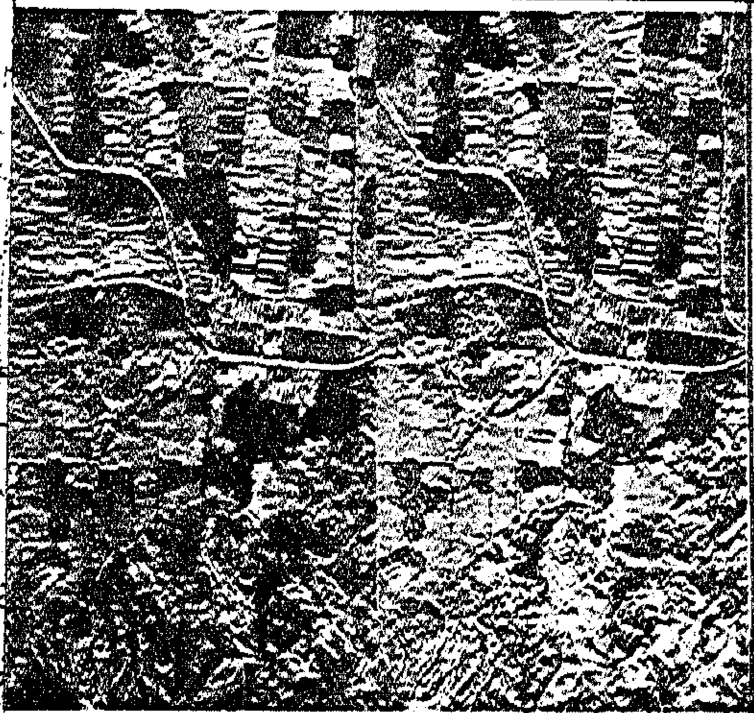


PHOTO DATA:

Strip Number:	IV-4.5
Photo Scale:	1:40,000
Flying Height:	2880 meters
Camera:	RC-10
Focal Length:	88.78 mm
Film:	Kodak
Date:	27 October 1976
Photography:	PENAS

Interpretation:

w: K. Woro   d: K. Dengkeng

A. Rised Up River Bed: In the central part of the photo, some linear land forms can be seen whose level is higher than the general level of the ground. This is a rised up river-bed.

B. Alluvial Plain: This morphology has a smooth surface. It is distributed along the upper part of the photo.

C. Sand-Bar, Natural Levee: There are sand-bars or natural levees along the rivers. This area is a little higher than surrounding areas.

D. Former River Bed: This morphology appears as a dark tone belt in the Alluvial Plain.

E. Swamp: This area can be observed in the central part of the photo. This generally is dark in tone.

F. Alluvial Fan: This can be observed from the central to the lower parts of the photo. It has a gentle inclination.

G. Piedmont Plain: This can be observed in the right-hand part of the photo.

H. Hills: This morphology can be seen in the lower part of the photo. The general slope is rather steep.

I. Slump: This can be observed in the Hill area.

J. Local Sediment Deposited by Flood: This morphology can be observed in the left-hand part of the photo. It is a little higher than the natural levee and sand-bar.

Explanation:

This area is located in the lower reach of the K. Woro. The area which appears in the upper part of the photo has the characteristics of an alluvial plain. Alluvial fan and piedmont plain can be seen in the middle part of the photo. In this area, the river cannot transport river-bed materials, and so, they are deposited. This is one reason why the river-bed in this area is rised up.

Photo Interpretation Card

Name of Place	Location	Topographic Map	Classification
Kaliurang, KAB.SLEMAN	Middle Slope of Mt. MERAPI	Gn. MERAPI	Volcanic morphology

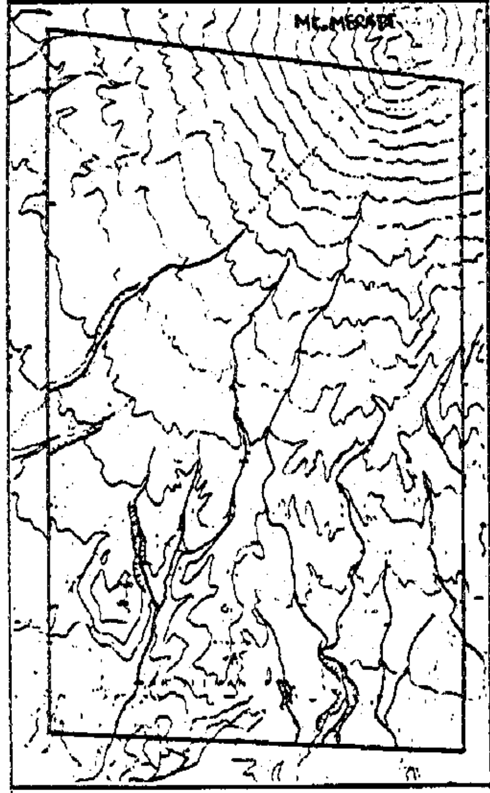


PHOTO DATA:

Strip Number: CXI - 8.9
Photo Scale: 1:40,000
Flying Height: 5130 meters
Camera: RC-10
Focal Length: 88.78
Film: Kodak
Date: October, 1976
Photography: PENAS

Interpretation:
k: Kaliurang b: K. Boyong ku: K. Kuning
g: K. Gendol be: K. Bebeng

A. Volcanic Deposits of Old Merapi: This morphology which is eroded, can be observed from the upper right-hand to the lower left-hand sides of the photo.

B. Former Lava Flow Deposits: This morphology can be seen in the central part of the photo. Flowing units of lava can also be observed. Some of them have ridges which follow the direction of the flow. This phenomenon indicates that the deposits are highly viscous.

C. Mountainside Composed of Volcanic Debris (Upper Zone): This morphology can be seen in the lower part of the photo. This area is flatter than areas A and B and is fan-shaped.

D. Deposits of Nuee Ardante d'avalanche: This morphology can be observed in the upper left-hand part of the photo. The tone of the area is rather light. This area has often been covered by volcanic deposits. Vegetation is sparse.

Explanation:

This area is located on the southern slope of Mt. Merapi. The distinction between the old and new Mt. Merapi areas is quite clear in the photo. Old Mt. Merapi, composed of lava and volcanic debris, is quite eroded now. Step-like formations caused by different layers are seen on the steep slopes.
Highly viscous materials from new Mt. Merapi have caused levee-like ridges to form along the edges of the lava flow. This morphology can be observed in the area covered by lava.
The upper mountainside has highly undulating topography compared with the lower part of the mountain. This might be caused by the viscosity of materials. The materials on the upper slope have a rather high viscosity. Materials on the lower slope may have very low viscosity because they are not undulating but rather alluvial fan-shaped.

SUPPORTING REPORT B

GEOLOGY AND LAHAR DEPOSITS

CONTENTS

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List of Figures

1. GEOLOGICAL BACKGROUND OF G. MERAPI

1.1 Stratigraphy

The geology in the area of G. Merapi can be classified into the following five groups which are also presented in Table 1.

(1) Recent Volcanic Products from Eruptions of G. Merapi

This group consists mainly of lava flows and pyroclastic fragments from eruptions since 1888, the exact dates of which are known, and lahar that has occurred since 1930.

(2) Terrace and Other Unconsolidated Deposits

This group consists mainly of present riverbed deposits, terrace deposits, alluvial fan deposits in the lower stream area, and other alluvial deposits.

(3) Young Merapi Volcanic Products

This group includes lahar deposits and lava-flows before 1930 (exact dates are not known).

(4) Old Merapi Volcanic Products

This group consists of Old Merapi lava flow, intrusive and pyroclastic rocks.

(5) Base Rocks

This group includes volcanic rocks and deposits of the tertiary period which form the foundation of G. Merapi.

1.2 History of Volcanic Activity of G. Merapi

G. Merapi has had a long recorded history of eruptions. There is a record of damage caused by a major lahar flow in 1006 on a stone monument with Sanskrit inscriptions of old Javan stories. There is also a record of some three thousand deaths caused by a major eruption in 1672 which produced glowing clouds and volcanic mud flows. A record of the mountain's volcanic activity after 1800 was kept by R.W. Bemmelen. This record is summarized in Table 2 along with the records for recent years.

The summary suggests a cycle of 1-7 years of activity followed by a dormant period of 1-6 years. Except for recent years, the exact scale of damage caused by such activity is unknown.

Records indicating the direction of lava flows in recent years is summarized in Fig. 1. This summary shows that there has been a shift in the direction from NW-W-SW-N-NW-W-SW. Since the old Merapi volcanic wall in the southeast remains, it can be expected to control lava over-flows in that direction. The principal nuée ardente danger zone should continue to be in the direction of SW-W-NW.

1.3 Terminology of Volcanic Products

In this "Study for Making Master Plan" the terminology of volcanic products used by the Japanese Study Team is based on R.W. van Bemmelen, I. Suryo and field surveys by the team as shown Fig. 2.

(1) Nuée Ardente: Avalanche Type

During an active stage of G. Merapi, viscous lava may flow-over the crater rim and form a lava tongue. Parts of the unstable lava mass may callapse and red hot lava blocks will roll down the slope, breaking into numerous lava fragments. Some of the fragments will turn into glowing sand and ash, and form a suspension of glowing particles in hot air, which will descend as a dense cloud.

R.W. Van Bemmelen is of the opinion that lava blocks measuring about $100m^3$ do not cause nuée ardente, but only common avalanches, and that the development of smoke and dust from such avalanches is small. If thousands of cubic meters of lava break off, the development of heat and pulverized lava is so great, that the avalanche appears to expand rapidly. This incandescent flow of volcanic debris is called "ladu" in Indonesian.

Such nuée ardente of the avalanche type at G. Merapi usually move 1 - 3km from the crater, but big avalanches may reach a distance of 7km.

(2) Nuée Ardente: Explosion Type

During volcanic explosions, lava masses may be emitted from the eruption vent. The lava is thrown upwards and a part of it flows over the crater rim and rushes down the slope. This flow of incandescent debris is accompanied by the nuée ardente.

The difference between nuée ardente of type 1 and 2 is that the explosion type is always accompanyed by a rising califlower cloud of volcanic ash.

(3) "Lahar" Mud Flows

The Indonesian term "lahar" is used to describe the volcanic mud flows on the Merapi and Kelut volcanoes. Lahar of Merapi are classified as rain lahar.

During or after eruption, a huge amount of volcanic material is deposited on the slope of the volcano. Rain water mixed with this unconsolidated hot volcanic material turns it into a high density mass, which descends with increasing velocity and forms lahars in the middle and lower reaches. Such lahar is called hot rain lahar until they cool.

The concept of lahar is very similar to the Japanese "Dosekiryu", in respect to massive straight movement and the inclusion of big blocks and thick and poorly sorted sediments. The characteristics of sediment products and discharges in Indonesia are very similar to those in Japan. (See Appendix-1; B-48)