THE REPUBLIC OF INDONESIA

THE FEASIBILITY STUDY ON THE VOLCANIC DEBRIS CONTROL AND WATER CONSERVATION PROJECT IN THE SOUTHEASTERN SLOPE OF MT. SEMERU

MAIN REPORT

DECEMBER, 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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P R E F A C E

In response to the request of the Government of the Republic of Indonesia, the Japanese Government decided to conduct a feasibility study on the Volcanic Deblis Control and Water Conservation Project on the Southeastern Slope of Mt. SEMERU and entrusted the study to the Japan International Cooperation Agency (JICA).

The JICA sent to Indonesia a survey team headed by Mr. K. HIRAO, comprising experts of Yachiyo Engineering Co., Ltd., in March, 1982.

The team had discussions on the Project with the officials concerned of the Government of Indonesia and conducted a field survey on the south eastern slope of Mr. SEMERU. After the team returned to Japan, further studies were made and the present report has been prepared after studies extending for nearly three years.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Indonesia for their close cooperation extended to the team.

December, 1984

Keisuke Arita
President
Japan International Cooperation Agency

A Distant View of Mt. Semeru

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GLOSSARY

Debris flow : Mass movement of mixture of some 40% sediment and some 60% water. It flows down with stepped flow concentrated by boulders at the front.

Bed load flow : Individual movement of river bed materials by tractive force of running water

Mud flow : Intermediate flow between debris flow and bed load flow. It has not stepped flow and boulder concentration.

Lahar : Traditional alias for flow of mixture of sediment and water. It is corresponded to Debris flow and Mud flow.

Yield suppression sediment volume:
Effect of facilities to reduce the sediment production at the source.

Run-off regulation sediment volume:
Effect of facilities to deposit temporarily at big flood and then to flow them down gradually by force of the subsequent flood.

Run-off storage sediment volume:
Effect of facilities to catch the run-off sediment in its reservoir.

Sediment transport adjustment volume:
Effect of facilities to improve sediment discharge capacity.

Control sediment volume:
Combined concept of yield suppression sediment volume, run-off regulation sediment volume, run-off storage sediment volume and sediment transport adjustment volume.

Sediment discharge: Run-off sediment volume per second

Check dam : Sediment control facility which is constructed crossing the river and has height of over 5m.

Consolidation dam : Sediment control facility which is constructed crossing the river and has height of under 5m.

Sand pocket : Sediment control facility composed of the consolidation dams and dikes at the both banks.

Sabo plan : Synthetic scheme to prevent the sediment disaster.

Design reference point, Design supplementary reference point: Points to decide design run-off sediment volume, design excess sediment volume and design allowable sediment volume

K., BS., Curah : River or channel in Java Language

Desa : Samllest rural administrative subdivision

Kecamatan : Administrative division controlling several Desas

Kabpaten : Administrative division controlling several Desas, Prefecture

SUMMARY

1. REVIEW OF THE MASTER PLAN

The Existing Master Plans prepared by the Government of Indonesia were reviewed by the Study Team on the basis of new survey data including the disaster in May, 1981 for the main purpose of the selection of priority projects.

As a result of review, problems in the Existing Master Plans were identified, modification in the sediment control plan and the warning system plan was proposed as shown in Table-1. The principal revisions are as follows:

- Disaster prevention areas are newly established;

- Scale of plan is changed to 100 years, from 50 years (K. Mujur), 70 years (K. Rejali) and 2 years (K. Glidik);

- Design sediment volume on each river is settled on the basis of the result from the sediment runoff-control simulation instead of that in the existing master plan;

- As sediment control system, sediment yield suppression, sediment runoff regulation and sediment transport adjustment system are employed in addition to a sediment storage system which is only employed in the existing master plan;

- Some of locations and specifications of sediment control facilities in the existing master plan are changed, and some additional sediment control works are planned.

- Proposals for the reinforcement of warning system comprised of: i) information collection system, ii) information processing system and iii) public information system are offered.

Table-1 Proposed Revisions for the Existing Master Plans

Item		Existing Master Plans			Proposed Revisions		
Objective		To protect the disaster area from Lahar disaster and to improve the socio-economic condition.			No revision		
Sediment control plan	Disaster prevention area	Areas along the river channel.			Identify possible disaster areas. Areas are classified into 5 groups.		
	Magnitude of plan	K. Mujur 50 years K. Rejali 70 years K. Glidik 2 years			100 years		
	Design reference point	Not established			One sabo reference point and supplementary reference points are established.		
	Sediment volume dealt with by the plan	K. Mujur 10,144,000 m^3 K. Rejali 8,500,000 m^3 K. Glidik 4,400,000 m^3			K. Mujur 5,040,000 m^3 5,220,000 m^3 4,500,000 m^3		
	Sediment control function F1: Sediment Yield Suppression F2: Sediment Runoff Regulation F3: Sediment Runoff Storage F4: Sediment Transport Adjustment	K. Mujur F3 by check dam and sand pockets.			K. Mujur F1 and F2 by check dam F3 by sand pocket F4 by dike and etc.		
		K. Rejali F3 by check dam F4 by channel work			K. Rejali F1 and F2 by check dam F3 by sand pocket F4 by diversion channel and etc.		
		K. Glidik F4 by embankment			K. Glidik F1 and F2 by check dam F4 by dike		
	Facility	K. Mujur	K. Rejali	K. Glidik	K. Mujur	K. Rejali	K. Glidik
	Check dam	24 units	5 units	0	11 units	9 units	9 units
	Sand pocket	1 unit	0	0	3 unit	1 unit	0
	Consolidation dam	4 units	0	20 units	12 units	22 units	0
	Dike	5.0 km	0.6 km	4 km	8.8 km	9.5 km	9.6 km
	Spur dike	0	12 units	0	0	0	0
	Channel work	0	9.5 km	6 km	0	0	0
	River excavation	0.6 km	0	0	6.8 km	0	0
	Diversion channel	-	-	-	-	1 unit	-
	Construction cost (Maintenance cost/year)	K. Mujur	K. Rejali	K. Glidik	K. Mujur	K. Rejali	K. Glidik
		Rp10.9x10^9 (0)	Rp10.9x10^9 (Rp0.05x10^9)	Rp8.9x10^9 (Rp0.1x10^9)	Rp32x10^9 (Rp0.06x10^9)	Rp33x10^9 (Rp0.04x10^9)	Rp23x10^9 (0)
	Construction term	K. Mujur	K. Rejali	K. Glidik	K. Mujur	K. Rejali	K. Glidik
		10 years	10 years	10 years	15 years	20 years	13 years
Warning system		Necessity for reinforcement of information collection system and telephone communication system is indicated.			Reinforcement of the following warning systems was proposed Information collection system Information processing system Public information system		
Water conservation		Not mentioned.			Preliminary water conservation plan in K. Rejali including the K. Lengkong fan is proposed.		

2. SELECTION OF PRIORITY PROJECTS

The urgent rehabilitation project loaned by OECF has recently started and will bring about substantial effect to the K. Mujur basin in the near future. The K. Mujur basin will become more safety than the other basin. Some 180,000 people and the properties in the area of 178km^2 would be secured soon, though the following countermeasures should be executed successively. Moreover, the recent sediment disaster is frequently being occurred in the K. Rejali basin than in the K. Mujur basin. Considering above situations, the first priority should be given to the sediment control facility project in K. Rejali and the second priority to that in K. Mujur.

The debris flow warning system project around Mt. Semeru southeastern slope should be also recommended as the first priority project in combination with the sediment control facility project. Because, the sediment disaster in the Study area tends to cause a great loss of lives and it will take a long period to complete fully the sediment control facility project, however the warning system with main purpose of human lives conservation will soon take effect on the entire area.

3. THE FIRST PRIORITY PROJECT

The first priority project consists of hard and soft countermeasure:

- Sediment Control Facility Project for the K. Rejali basin.
- Debris Flow Warning System Project for the entire area.

3.1 FIRST PRIORITY SEDIMENT CONTROL FACILITY PROJECT

(1) Alternatives

The alternatives for the first priority sediment control facility project were drawn on the basis of the following considerations. Four alternatives were planned as shown in Table-2.

- The construction of the sediment control facilities should, in principle, be executed according to the work order given in the Plans.
- The frequency of disasters in the K. Rejali basin has increased since 1942 when the upper stream of the BS. Semut was diverted to the K. Rejali river system. Because of this, it would be desirable to execute the diversion work designed to transform the present overfit situation back to the original state existing before 1942. The diversion work should take precedence.
- According to the empirical judgement, sediment flooding at the head of the fan will cease when a half of the sediment discharged into the fan has been successfully controlled. After that, the construction of the sediment control facilities planned in the fan area can be started.

Among the alternatives, from the socio-economic and technical view points, the alternative P1-3 is the most feasible and selected as the first priority sediment control facility project.

Table-2 Results of Economic Evaluation for the First Priority Sediment Control Facility Project

Alter-natives	Combination of Facilities	Design Scope (Probability Year)	Economic Cost 10^6 Rp	Maintenance Cost 10^6 Rp/Year	I.R.R.	Total Benefit 10^9 Rp
Pl-1	1,5,9	13	17,591	2	8.55	77.8
Pl-2	1,2,3,4,5, 6,7,9	40	22,003	2	8.44	94.3
Pl-3	1,5,8,9	50	20,681	38	8.92	93.5
Pl-4	1,2,3,4,5, 6,7,8,9	90	25,093	38	7.58	96.6

Facility No.	Name of Facility	
1.	Curah Kobo'an Check Dam	No.6
2.	"	No.5
3.	"	No.4
4.	"	No.3
5.	Diversion Work Channel	
	K. Lengkong Check Dam	No.7
	"	No.3
6.	Curah Lengkong Check Dam	No.1
7.	"	No.2
8.	K. Leprak Sand Pocket	
9.	Intake and Channel	

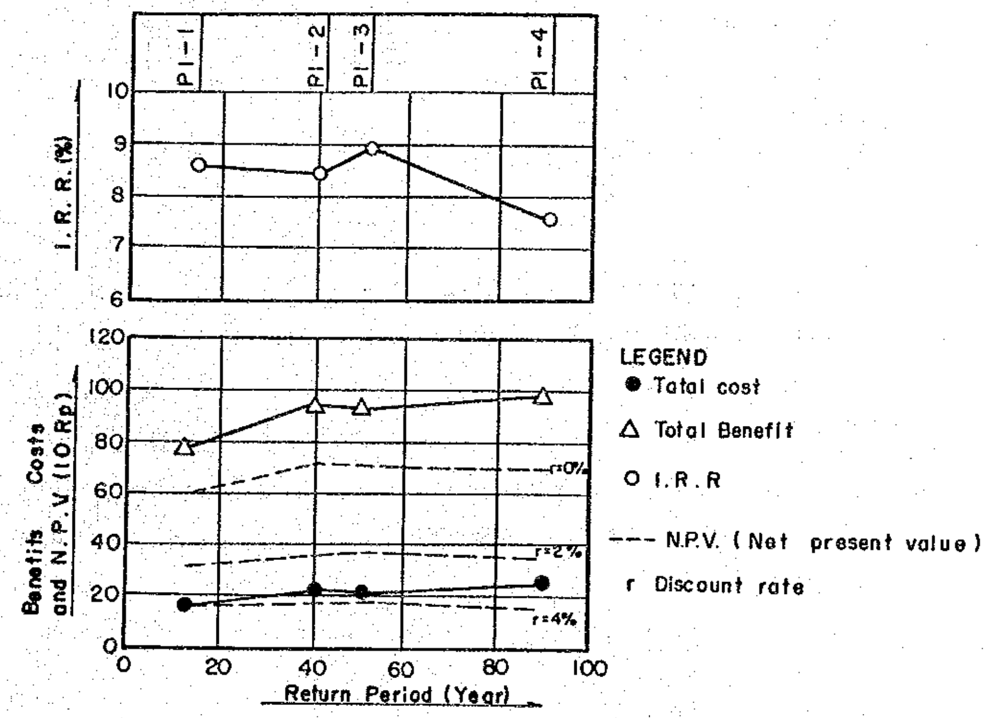


Fig.-1 I.R.R., Total Benefit and Total Cost of Alternatives for the First Priority Sediment Control Facility Project

(2) Outline of the First Priority Sediment Control Facility Project

Facilities to be constructed by the first priority sediment control facility project are summarized as shown in Table-3.

Table-3 Outline of First Priority Sediment Control Facility Project

Name of River	Name of Facility	Specifications	
K. Rejali	Curah Kobo'an CHD-6	H=23 m Vc=120,800m	L=438 m Vs=2,112,000m
	Diversion channel	L=1,350m Ve=566,000m	B=30m Vg=7300m
	K. Leprak Sand Pocket	Consolidation dam 3 Vc=14,300m Vem=155,000m	 Vs=4,300m Vg=15,000m
	Intake and Channel	L=430m	
K. Glidik	K. Lengkong CHD-3 (Pronojiwo Dam)	H=10m Vc=42,700m	L=2330 Ve=24,000m
	K. Lengkong CHD-7	H=10m Vc=4,670m	L=145m Ve=4,000m

H: Dam height
B: Width of channel
Vc: Concrete volume
Vem: Embankment volume
L: Length of dam or channel
Vs: Steel basket volume
Vg: Gabion work volume

(3) Project Work Schedule

The construction period of the first priority facility project is six years including surveying, detail designing and preparatory works. Refer to Table-4.

(4) Project Cost

According to the above-mentioned construction procedure, the project cost ammounts to be 29 billion Rp. and summarized as shown in Table-5.

Table-4 Work Schedule for the First Priority Sediment Control Facility Project

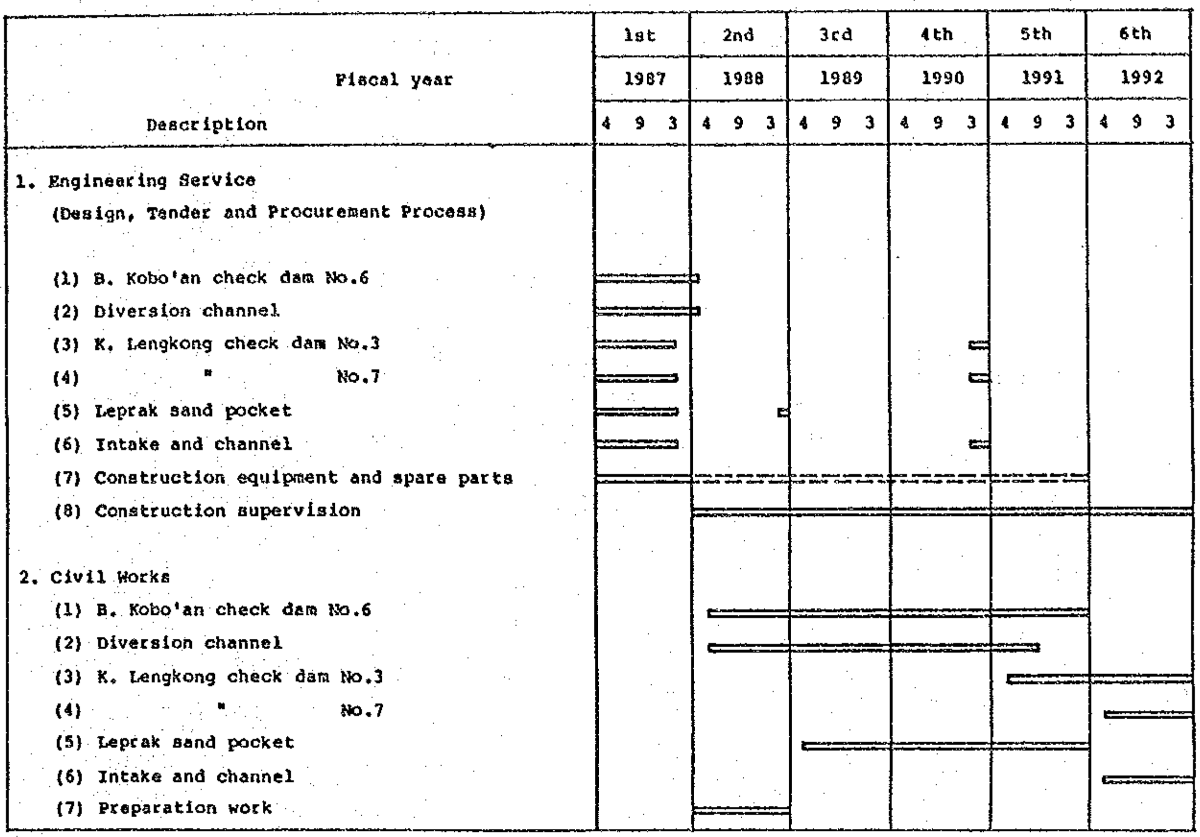


Table-5 Financial Cost of First Priority Sediment Control Facility Project

Item	Foreign Currency 10^6 Yen	Local Currency 10^6 Rp	Total 10^6Yen
1. Construction equipment	1,825	-	1,825
2. Spare parts and consumable materials	389	-	389
3. Civil works	1,029	9,538	4,561
4. Land acquisition	-	370	137
5. Engineering services	932	909	1,269
6. Government administration	-	584	216
7. Contingency	723	4,462	2,376
Total 10^6Yen	4,898	5,876	10,774
Total 10^6Rp	13,225	15,864	29,089
Total (%)	45.7%	54.7%	100%

(Based on the price level of fiscal year 1982)
Yen Evaluation: 1US$ = ¥240 = Rp650, 1 Yen = 2.7 Rp

(5) Project Evaluation

Economic benefit through execution of the first priority sediment control facility project consists of the direct damage mitigation effect, indirect damage mitigation effect and water conservation effect. As a result of the economic analysis using the refined plan, economic cost, economic benefit and I.R.R. (Internal Rate of Return) of the first priority sediment control facility project are concluded as follows;

Economic cost	$20,525 \times 10^6$ Rp
Econimic benefit	$90,760 \times 10^6$ Rp
I.R.R	8.8%

3.2 DEBRIS FLOW WARNING SYSTEM PROJECT

(1) Outline of the Debris Flow Warning System Project

The debris flow warning system project consists of the followings. Refer to Fig.-2.

① Information collection system

The information collection system gathers data which is required to predict the occurrence of a debris flow and to give warning for danger, and sends these data to the information processing center. It consists of the followings:

- Rainfall Observation System
  . 1 small radar raingauge station
  . 8 telemeter rainfall stations
- Water Level Observation System
  . 6 telemeter water level stations
- Debris Flow Observation System
  . 4 debris flow sensing stations
  . 2 debris flow visual measuring stations
- 1 repeater station

② Information Processing System

The information processing system is to process and control the data and predict the occurence of debris flow and give the evacuation warning. It will be concentrated on a information processing center installed at the Mt. Semeru Project Office.

③ Public Information System

The public information system is to address the evacuation warning by 11 speaker stations according to the judgement of the information processing center without delay to people living in the disaster areas.

(2) Project Work Schedule

The debris flow warning system project consists of the design & equipment procuration, civil work & installation and test operation. Execution of these works needs five years. The project work schedule is shown in Table-6.

(3) Project Cost

The project cost of the debris flow warning system amounts to be 5.7 billion Rp. and summarized in Table-7.

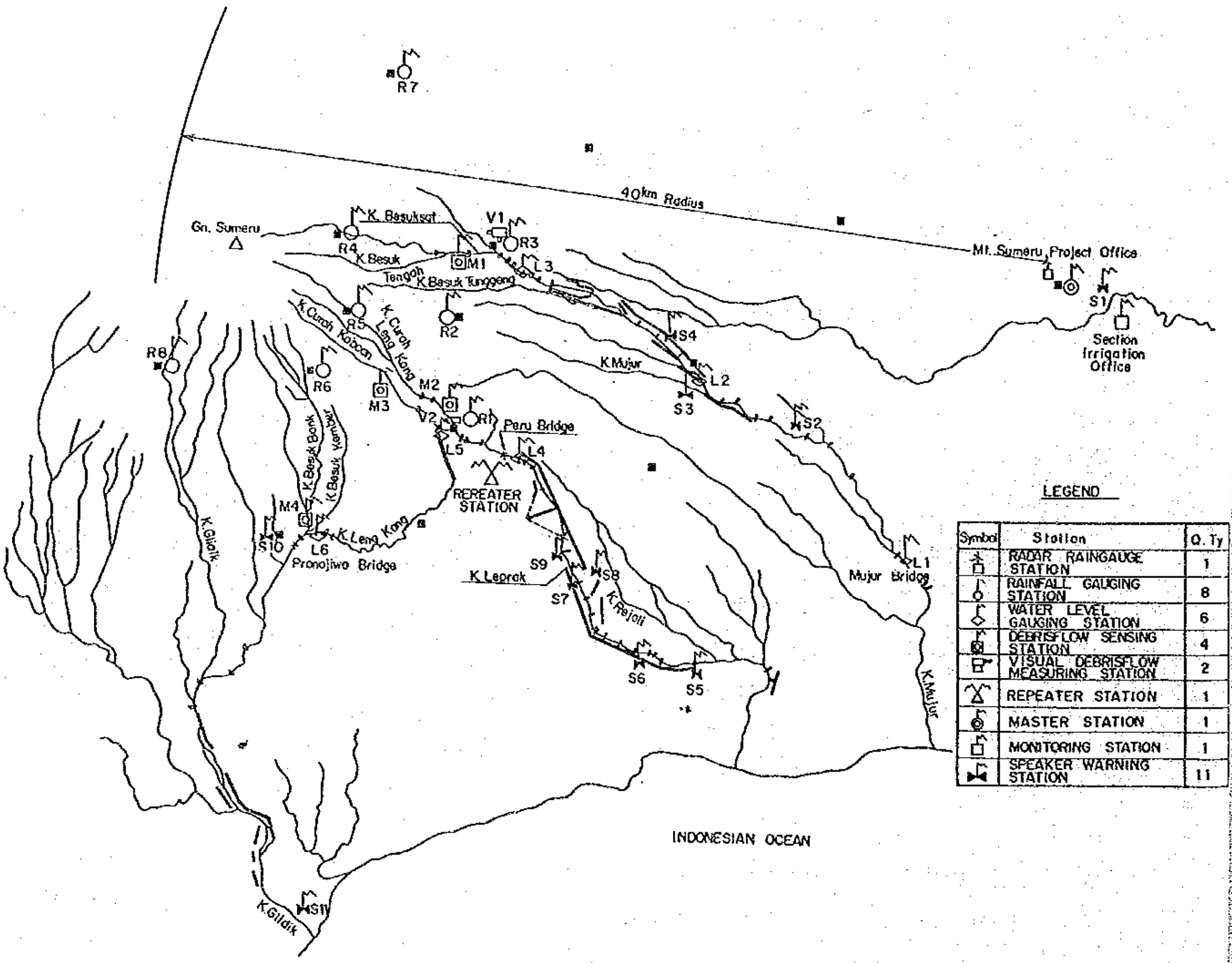


Fig.-2 Station Map of Debris Flow Warning System

Table-6 Work Schedule for Debris Flow Warning System Project

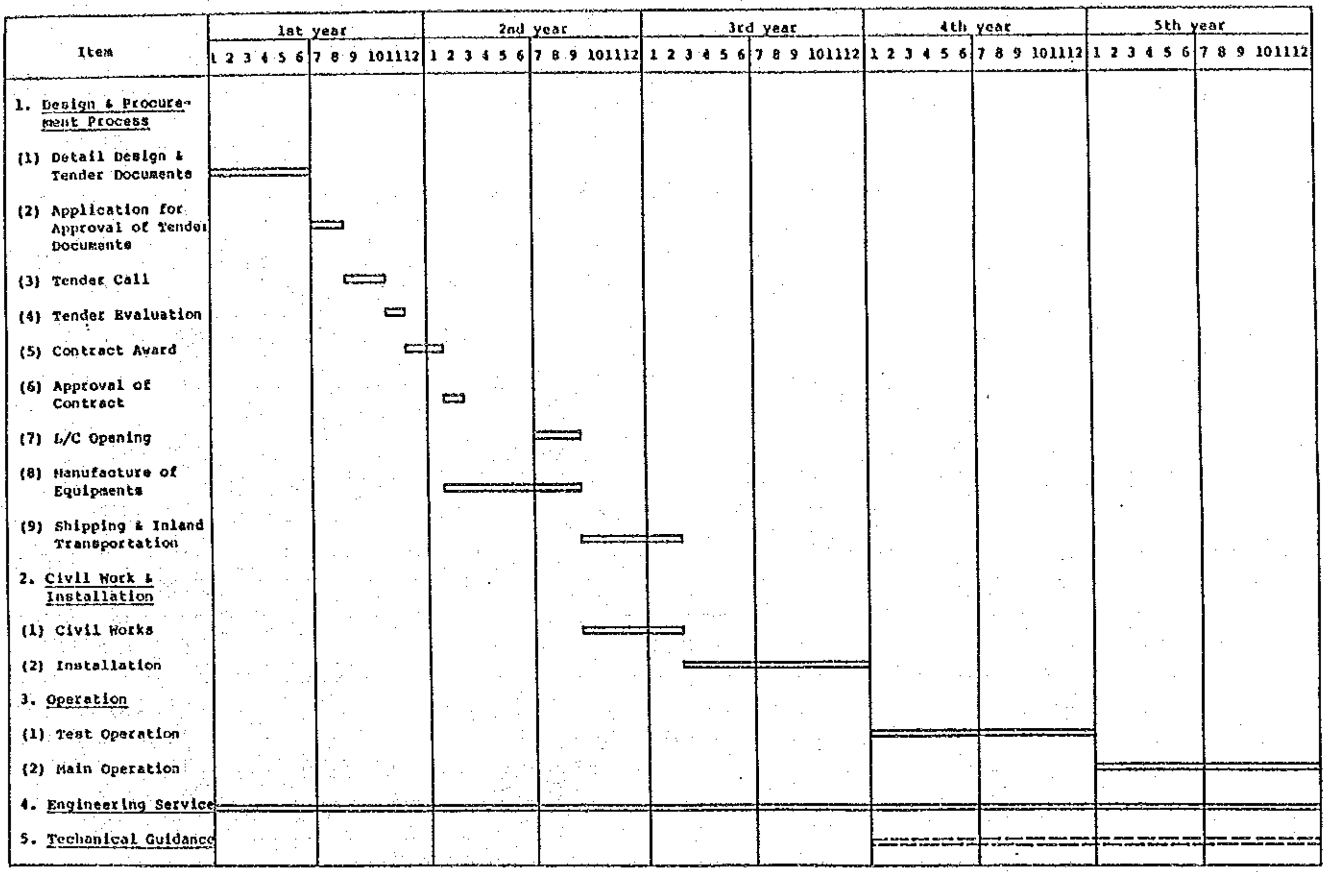


Table-7 Financial Cost of the Debris Flow Warning System Project

Item	Foreign Currency 10^6 yen	Local Currency 10^6 Rp	Total 10^6 yen
1. Equipment	905.8	0	905.8
1.1 Main equipment	747.2		
1.2 Test equipment & maintenance tool	158.6		
2. Spare parts & Accessories	66.7	0	66.7
3. Construction & Installation	119.0	124.9	165.2
3.1 Construction	7.9	104.4	
3.2 Installation	95.6	2.5	
3.3 Inland transportation of equipments	0	1.7	
3.4 Preparation work	15.5	16.3	
4. Land acquisition	0	0.2	0.1
5. Engineering service	519.7	422.3	676.1
6. Government administration	0	17.8	6.6
7. Contingency	230.8	122.3	276.1
Total 10^6Yen	1,842.0	254.6	2,096.6
Total 10^6Rp	4,973.4	687.5	5,660.9
Total (%)	87.9%	12.1%	100%

(Based on the price level of fiscal year 1982)

Yen Evaluation: 1US$ = ¥240 = Rp650, 1Yen = 2.7Rp

(4) Project Evaluation

The sediment disaster around Mt. Semeru tends to cause a great loss of lives as seen in the past records.

The establishment of the debris flow warning system will be able to protect human life from such disaster. Stabilization of inhabitant's livelihood also will be strengthened and social activity will be increased. People and properties in the area covered by the debris flow warning system are shown in Table-8.

Table-8 Property in the area covered by the Debris Flow Warning System

Item	Quantity	Item	Quantity
People	40,700 persons	School	32 houses
Mosque and church	82 houses	Hospital	1 house
Factory	16 "	House and office	8,600 "
Store	110 "	Cultivated field	3,300 ha

(5) Phasing Plan

Executing of the debris flow warning system project can be phased at 4 stages classified functionally, as shown in Table-9.

Table-9 Phasing Plan of the Debris Flow warning System Project

Stage	Structure of System		Project Period (month)	Financial Cost (10^6 Yen)
1	1 Rainfall gauging station	8 stations	24	1,021
	2 Debris flow sensing station	4 stations		
	3 Telemetering repeater station	9 stations		
	4 Supervisory equipment	1 set		
2	Above-mentioned systems 5 Small radar raingauge	1 set	29	1,408
3	Above-mentioned systems 6 Water level gauging station	6 stations	29	1,895
	7 Warning control equipment	1 set		
	8 Warning repeater equipment	1 set		
	9 Personal computer	1 set		
	10 Speaker warning station	11 stations		
4	Above-mentioned systems 11 Debris flow visual stations	2 stations	29	2,097
	12 Monitoring station	1 station		

4. SECOND PRIORITY PROJECT

(1) Alternatives

The facilities which have such functions as sediment yield suppression, sediment runoff regulation and sediment runoff storage are selected as a candidate for the second priority project among the Revised K. Mujur Master Plan. The construction order of the candidate facilities for the second priority project are decided on the basis of the following consideration.

① Sediment control facilities function effectively as a whole system of them including the all facilities completed upon to then. Therefore all the existing facilities are included in each alternative.

② The construction of the proposed facilities must be started with check dams situated at the upstream of the existing check dam. And the construction must be continued toward the upper stream.

③ After most of the check dams are completed, the construction of sandpockets situated in the fan area must be started from the top of the fan toward the down stream.

By dividing the construction order into some stages, six alternatives have been chosen as shown in Table-10.

Among the alternatives, from the socio-economic and technical view points, the alternative P2-3 is the most feasible and selected as the second priority project.

Table-10 Result of Economic Evaluation for the Second Priority Project

Alter-native Plan	Combination of Facilities	Magnitude of Plan (year)	Economic Cost: Capital Cost (10^6Rp)	Economic Cost: Maintenance Cost (10^6Rp/year)	I.R.R (%)	N.P.V.
P2-1	11, 12, 12, 3	10	5,339	0	6.48	12.1
P2-2	11, 12, 13, 1, 2, 3	20	5,902	0	5.91	12.1
P2-3	11, 12, 13, 1, 2, 3, 4, 5, 6	40	7,059	0	5.29	12.7
P2-4	11, 12, 13, 1, 2, 3, 4, 5, 6, 7	55	13,057	0	2.54	10.3
P2-5	11, 12, 13, 1, 2, 3, 4, 5, 6, 7, 8	75	22,462	40	0.51	2.9
P2-6	11, 12, 13, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10	90	23,786	107	0	-

No.	Facility name	No.	Facility name
1	BS. Sat check dam No. 5	8	Benda sandpocket
2	" No. 6	9	Kertosari sandpocket
3	" No. 7	10	Kloposawit sandpocket
4	" No. 8	11	BS. Sat check dam No. 2
5	" No. 9	12	" No. 3
6	" No. 10	13	" No. 4
7	Sumbersari check dam		

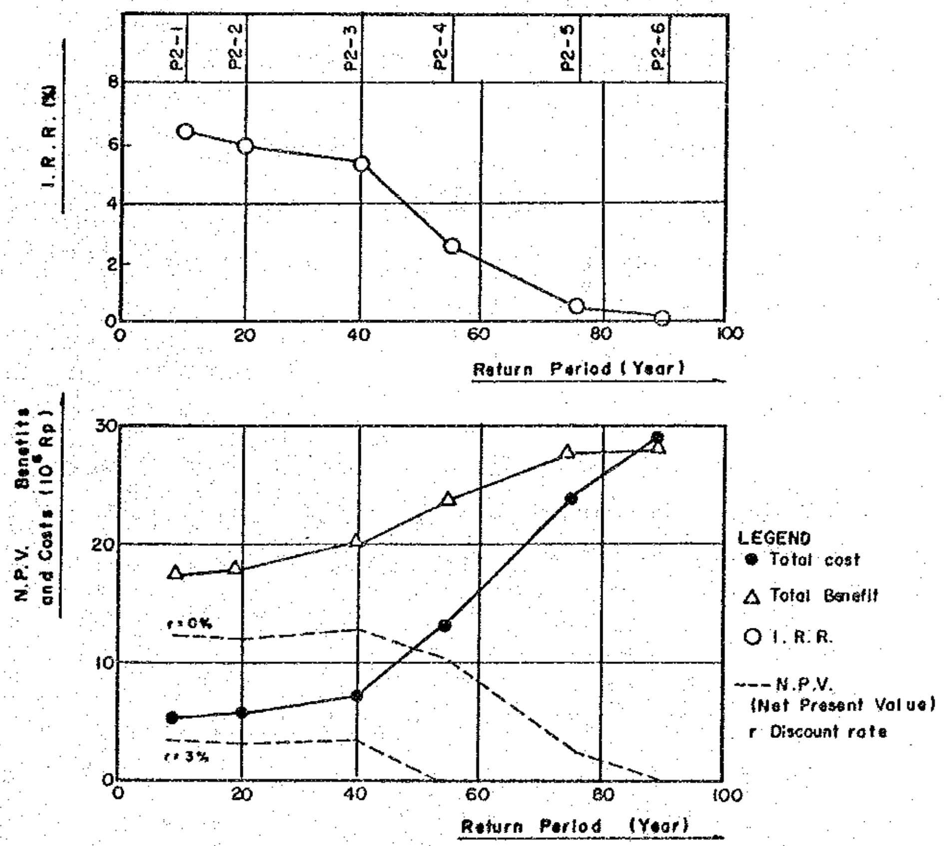


Fig.-3 I.R.R., Total Benefit and Total Cost of Alternatives for the Second Priority Project

(2) Outline of Project

Facilities to be constructed by the second priority project are shown in Table-11.

Table-11 Outline of Second Priority Project

No.	Facility	Specification		
1	BS. Sat check dam 5	H= 8m	L=190m	Vc= 7,800m^3
2	BS. Sat check dam 6	H= 8m	L=186m	Vc=10,000m^3
3	BS. Sat check dam 7	H=19m	L=320m	Vc=49,000m^3
4	BS. Sat check dam 8	H=11m	L=102m	Vc= 6,400m^3
5	BS. Sat check dam 9	H=17m	L=198m	Vc=18,000m^3
6	BS. Sat check dam 10	H=17.5m	L= 72m	Vc=12,000m^3
11	BS. Sat check dam 2	H=11.0m	L=197m	Vc=14,000m^3
12	BS. Sat check dam 3	H= 9.0m	L=200m	Vc=13,000m^3
13	BS. Sat check dam 4	H=10.5m	L=203m	Vc= 9,100m^3

H : Dam height
L : Dam length
Vc: Volume of masonry concrete
No.11, No.12, No.13: existing facilities

(3) Construction Schedule

The construction period of the second priority project is six years including surveying, detail designing, tender and preparatory works. Refer to Table-12.

(4) Project Cost

According to the above-mentioned construction procedure, the project cost of the second priority project amounts to be 10.2 billion Rp. and summarized as shown in Table-13.

Table-12 Project Work Schedule for Second Priority Project

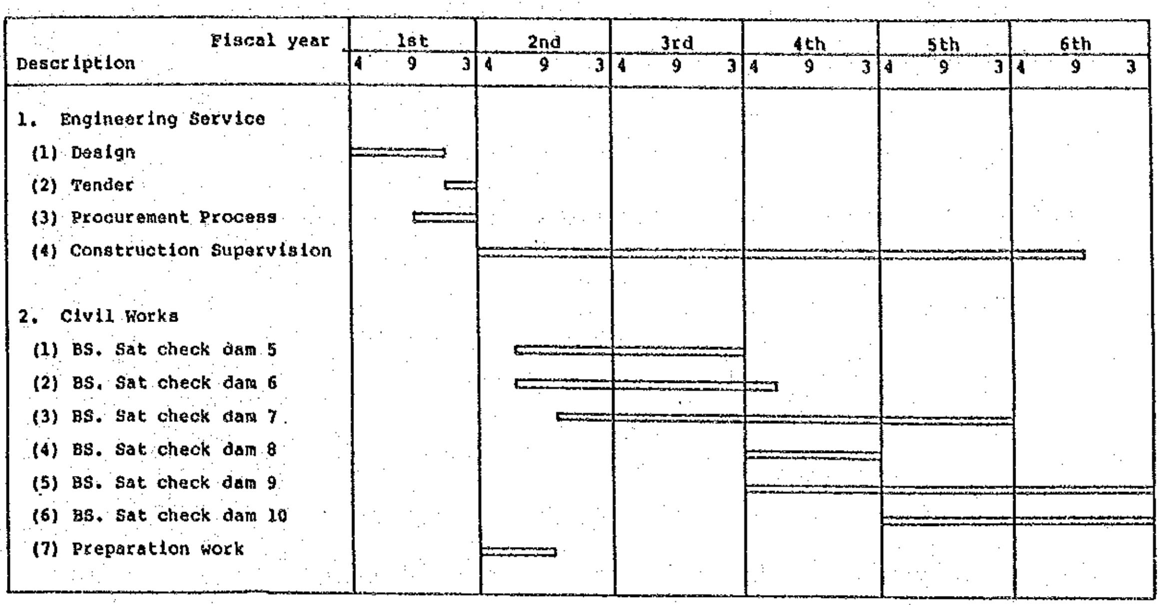


Table-13 Financial Cost of the Second Priority Project

Item		Foreign Currency 10^6 yen	Local Currency 10^6 Rp	Total 10^6 yen
1. Construction equipment		1,010	-	1,010
2. Spare parts and consumable materials		227	-	227
3. Civil works		224	3,169	1,398
4. Land acquisition		-	26	10
5. Engineering services		233	232	319
6. Government administration		-	248	92
7. Contingency		220	1,365	726
Total	10^6Yen	1,914	1,867	3,781
	10^6Rp	5,168	5,040	10,208
	(%)	50.6%	39.4%	100%

Based on the price level of fiscal year 1982.

Yen evaluation: US$1 = ¥240 = Rp650, 1 Yen = 2.7 Rp

(5) Project Evaluation

Economic cost, economic benefit and I.R.R. of the second priority project are concluded as follows;

Economic cost	$7,059 \times 10^6$ Rp
Economic benefit	$19,740 \times 10^6$ Rp
I.R.R	5.3%

5. PRELIMINARY PLAN FOR WATER CONSERVATION

(1) Preconditions for Planning

- Prevention of disaster in the area where the developed water has a beneficial effect should be assured as the sediment control works progress to a certain degree.
- The Pronojiwo dam should be constructed according to the diversion plan, which is an integral part of the first priority project, to secure safe and easy intake of water at that point.

(2) Water Resources Potential

Base flow of K. Glidik and K. Rejali

- Mean base flow discharge at the Pronojiwo dam of K. Glidik is 2.5 m^3/s.
- Mean base flow discharge at the K. Leprak No. 1 Dam of K. Rejali is 1.0 m^3/s.
- The total of the two points is 3.5 m^3/s.

Groundwater at K. Lengkong Fan area

The groundwater basin volume can be supposed to be some 100 x $10^6 m^3$ based on the above information, however the developable annual mean groundwater will be some 1.0 m^3/s at the maximum judging from the results of the groundwater simulation.

(3) Water Conservation Plan

The alternatives of water conservation project should include the following facilities:

Intake Facility
Able to take the base flow discharge of K. Lengkong and the exploited groundwater.

Groundwater Exploitation Facility at K. Lengkong Fan
Pumping Well (Well and Pump)

Water Conveyance Facility (1)
Tunnel or Open Channel

Hydro-electric Power Station

Hydro-electric power generation at the end of the water conveyance facility (1).

Water Conveyance Facility (2)

Open channel from K. Rejali to the irrigation area.

Cultivated Paddy Field

To facilitate the land improvement programme for the irrigation area, certain wastelands are reclaimed to be paddy fields in the K. Rejali and K. Pancing basins.

This water conservation project will produce the following effect:

Irrigation

The devastated area extending from the K. Rejali basin to the K. Pancing basin and not exceeding EL. 500m where there is no irrigation at present is chosen to be the target area for the irrigation programme. According to the amount of annual mean developed water, 3.5 m^3/s, 4.0 m^3/s and 4.5 m^3/s, areas of 3,500 ha, 4,000 ha and 4,500 ha will be irrigated through the year, respectively, as paddy fields.

Hydro-electric Power Generation

According to the amount of developed water, the electric-power shown in Table-14 will be generated.

Table-14 Hydro-electric Power Generation

Items \ Developed Water	3.5 $m^3/s/y$	4.0 $m^3/s/y$	4.5 $m^3/s/y$
Maximum output (KW)	2,200	2,200	2,200
Annual output of electric energy (10^9 KW)	16.7	18.5	19.5

(4) Alternatives of Water Conservation Plan

A number of possible water conservation plans can be developed based on a different combination of facilities.

Table-15 shows the alternative plans for water conservation and their respective economic evaluation. From the table the followings are summarized:

① Among the alternative plans, the plan B in which there is no groundwater development with the open channel water conveyance system shows highest I.R.R. of 16.19%;

② However, as the economic evaluation of each plan is carried out on the basis of the annual mean amount of the developed water, the stable water supply by the groundwater development during the dry seasons should be also evaluated reasonably in the next detailed study;

③ From the standpoint of maintaining the area's basis of livelihood as well as economic considerations, several of the water development plans examined are thought to be promising undertakings. Should it be judged desirable to execute such undertakings, it would be mandatory to confirm their feasibility by carrying out a more advanced study than the present one.

Table-15 Preliminary Economic Evaluation of Water Conservation Project

Alternative	Economic Cost (10^6Rp)	Maintenance Cost (10^6Rp/Y)	Developed Water (m^3/s)	Power Generation (10^6KWH/Y)	Internal Rate of Return (I.R.R.) (%)
A	23,832	155.4	3.5	16.747	10.41
B	14,482	99.4	3.5	16.747	16.19
C	25,416	718.4	4.0	18.500	9.56
D	16,064	662.4	4.0	18.500	14.61
E	26,998	1,282.0	4.5	19.473	8.65
F	17,646	1,226.0	4.5	19.473	12.97

6. CONCLUSION AND RECOMMENDATION

(1) Master Plans Review

As a result of the Master Plans review carried out based on the new survey data including the disaster of May, 1981, several problematic areas in the said plans were identified. Further, below-mentioned revisions and additions to cope with a number of problems found in the said plans are presented here.

① Basic changes in the volcanic debris control plan as well as revisions in the facility plan.

② Reinforcement of the current warning system.

③ Preliminary Plan for Water Development

We strongly believe that this plan would be embodied as part of the Master Plans finally authorized by Indonesian Government.

(2) First Priority Plan

The sediment control facility project for K. Rejali basin and the debris flow warning system project for the entire southeastern slope of Mt. Semeru has been chosen as the most feasible and recommendable first priority project.

(A) First Priority Sediment Control Facility Project

The project is composed of the following facilities and gives the beneficial economic effect of I.R.R. 8.8%.

- Three sabo dam (one at K. Rejali, two at K. Glidik)
- A set of diversion channel of 1.3km (Curah Kobo'an to K. Lengkong)
- One sand pocket at K. Rejali
- A set of water conservation facilities for paddy field irrigation of 1,000 ha.

This project to be completed in 6 years will cost as follows:

Financial cost: 29.1×10^9 Rp

Foregin currency portion: 13.2×10^9 Rp (45%)
(4.90×10^9 Yen)

Local currency portion: 15.9×10^9 Rp (55%)

After the completion of the project, the properties in the area of $40km^2$ and 15,000 inhabitants of K. Rejali would be protected.

(B) Debris Flow Warning System Project

This project composed of the following systems and the facilities in the system.

- Information collection system
  . 1 small radar raingauge station
  . 8 telemeter rainfall stations
  . 4 debris flow sensing stations
  . 2 debris flow visual measuring stations
  . 6 telemeter water level stations
- Information processing system
  . A set of information processing center at Mt. Semeru Project
  . A set of monitoring station office
- Public information system
  . 11 speaker stations

This project to be completed in 5 years including the two year's test operation, will cost as follows:

Financial cost: 5.7×10^9 Rp

Foreign currency portion: 5.0×10^9 Rp (88%)
(1.84×10^9 Yen)

Local currency portion: 0.7×10^9 Rp (12%)

This project would cover the entire southeastern slope of Mt. Semeru and protect 40,700 inhabitant's lives from the sediment disaster.

Execution of the debris flow warning system project can phased at 4 states classified functionally. The Project cost at each stage is 1,021 million yen, 1,408 million yen, 1895 million yen and 2,097 million respectively.

(3) Second Priority Project

The sediment control facility project for K. Mujur basin has been chosen as the recommendable second priority project. This project is composed of six check dams, and gives the beneficial economic effect of I.R.R. 5.3%. This project to be completed in 6 years will cost as follows:

Financial cost:	10.2×10^9 Rp
Foreign currency portion:	5.2×10^9 Rp (51%)
	(1.91×10^9 Yen)
Local currency portion:	5.0×10^9 Rp (49%)

After the completion of the project, the properties in the area $28km^2$ and 19,000 inhabitants of K. Mujur basin would be protected.

(4) Water Conservation Plan

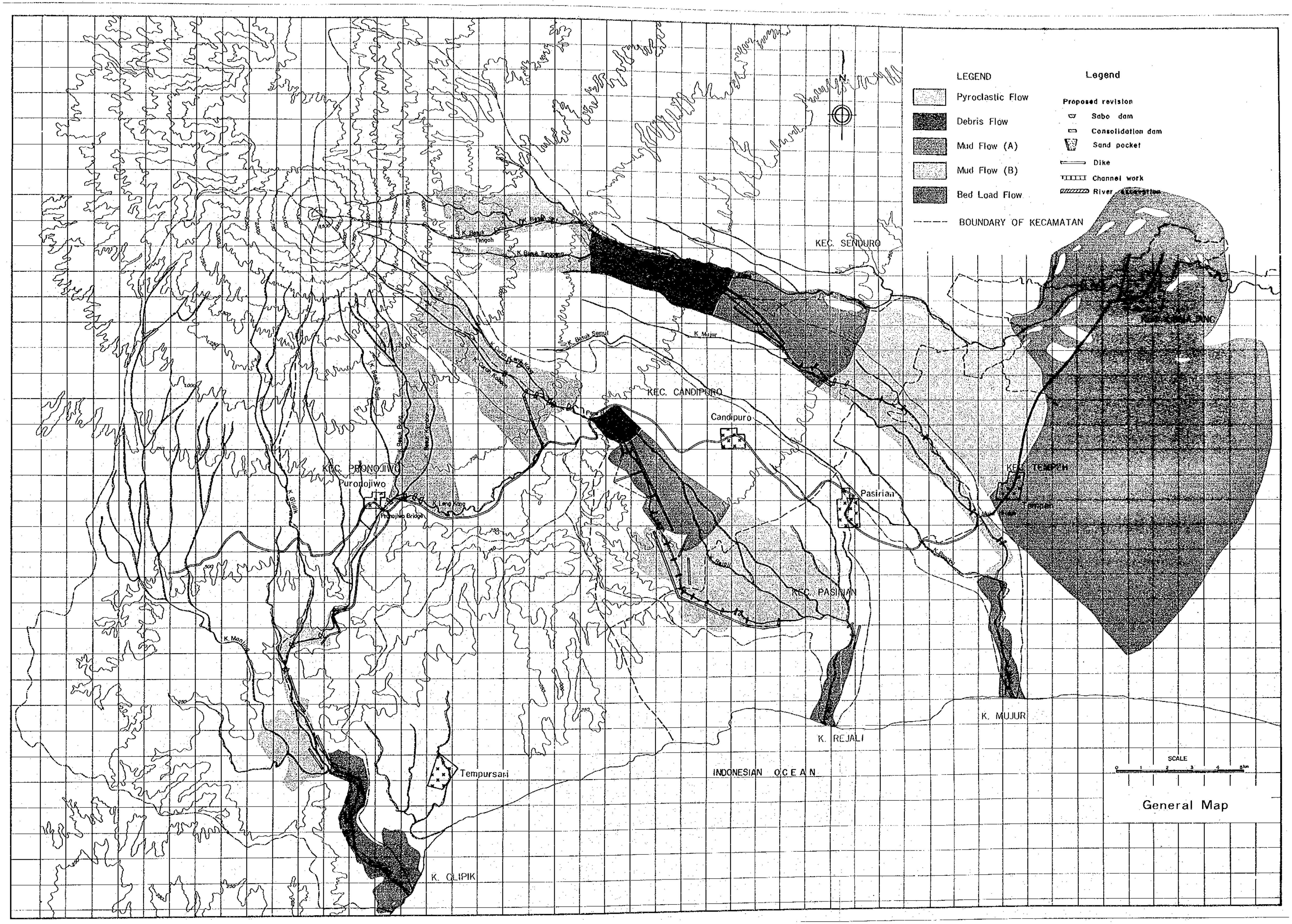
Assuming that the precondition of security against volcanic debris disaster in the target area has been guaranteed and further supposing water use of irrigation and production of electric power, I.R.R. of between 8.7% to 16.2% was obtained as a result of the preliminary economic evaluation for the six alternative preliminary plans.

From the standpoint of maintaining the area's basis of livelihood as well as economic considerations, several of the water development plans examined are thought to be promising undertakings. Should it be judged desirable to execute such undertakings, it would be mandatory to confirm their feasibility by carrying out a more advanced study than the present one.

(5) Proposed Project

Sediment control facility project for K. Rejali basin is hereby recommended for immediate execution as an urgent project to preserve and maintain human lives and properties as well as for stability and security of the area's living environment and livelihood.

Moreover, it would be also recommendable to execute the debris flow warning system project, which would greatly contribute toward safeguarding human lives always threaten by sediment disaster in the entire southeastern slope of Mt. Semeru, in parallel with the above-mentioned sediment control facility project.



LEGEND
Pyroclastic Flow
Debris Flow
Mud Flow (A)
Mud Flow (B)
Bed Load Flow
BOUNDARY OF KECAMATAN
Legend
Proposed revision
Sabo dam
Consolidation dam
Sand pocket
Dike
Channel work
N
KEC. SENDURO
KEC. CANDIPURO
Candipuro
KEC. PRONOJIWO
Pronojiwo
Pronojiwo Bridge
Pasirian
KEC. TEMPEH
Tempeh
KEC. PASIRIAN
K. Glidik
K. Manjing
K. Mujur
Tempursari
INDONESIAN OCEAN
K. REJALI
K. MUJUR
K. GLIPIK
SCALE
General Map

1. INTRODUCTION

1.1 BACKGROUND OF THE STUDY

(1) Positioning of Sabo Work

The Directorate General of Water Resources Development (DGWRD), Ministry of Public Works (MPW) of the Republic of Indonesia gives the following three points as major objectives for the achievement of the national development shown by the Third Five Year Plan (1979/80 - 1983/84), which is the national plan of Indonesia.

① To maintain the safety of agricultural areas.

② To secure the fairness among people by the maintenance of safety in local areas.

③ To secure the stability of production activities by protecting industrial areas from disasters.

With a view to achieving these objectives, such policies as river improvement work, sediment control work, the prediction of flood and sediment disasters, the construction of dams and reservoirs to regulate floods and the maintenance and control of river structures have been implemented.

The sabo work is carried out not only as a part of the general river work but also as a part of the special projects, where the prevention of disasters accompanying the eruption of an active volcano is the main objective. A total of four projects, including the Mt. Semeru Project, are currently in operation as special projects on the islands of Java and Bali.

(2) Mt. Semeru Project

The Mt. Semeru Project was founded in 1976 by MPW as the fourth sediment control project for active volcano, when the volcanic activities of Mt. Semeru became active and a number of debris flows frequently occurred. The Project took over the original work conducted by the Provincial Government of East Java.

MPW supervise the Mt. Semeru Project Office through the Directorate of Rivers of DGWRD. At the time of a disaster occurring in the area, MPW carries out measures to prevent the spread of the disaster around Mt. Semeru in cooperation with the Ministry of Social Affairs, the Ministry of Transmigration, the Ministry of Defence and the Ministry of Mining and Energy.

The Mt. Semeru Project Office was opened at Lumajang in 1977 and has been conducting a series of work such as the construction of sediment control facilities, disaster relief activities and research and planning in order to protect people's lives and assets from sediment disasters.

(3) Background of the Present Study

The debris flow which occurred in May, 1981 caused extensive damage to the area in the southeastern slope of Mt. Semeru. 369 people were either killed or reported missing, 127 people were injured, 535 houses were damaged and 539 ha of paddy fields were flooded, resulting in serious social and economic after-effects in the area.

Concerned about the possibility of another large disaster caused by flood, occurring due to the large volume of sediment which had accumulated along the river channel and being easily dislocated, the Government of Indonesia requested economic aid for urgent rehabilitation project mainly centered on the K. Mujur Basin and, as a result, the Japanese and Indonesian Governments agreed on a loan from the Overseas Economic Cooperation Fund (OECF) to be given for the said project. The actual start of the work is currently being prepared.

Hoping to implement systematic disaster prevention measures in order that a similar disaster should not take place again in the long-term perspective, the Government of Indonesia also requested technical assistance in regard to this study - "The Feasibility Study on the Volcanic Debris Control and Water Conservation Project in the Southeastern Slope of Mt. Semeru" (the Study). Upon receipt of this request, the Japanese Government decided to carry out the study through the Japan International Cooperation Agency (JICA).

Prior to the Study, a preliminary study team was sent to Indonesia by JICA in December, 1981 and the "Scope of Work" (S/W) for the Study was prepared on the basis of the field survey. This S/W (refer to Supplement-1) was mutually agreed upon on December 18, 1981 between DGWRD of MPW and the preliminary study team.

1.2 OUTLINE OF THE STUDY

The Study was conducted for 31 months on aggregate, from the submission of the "Inception Report" in April, 1982 until the submission of the "Final Report" in December, 1984 by the study team headed by Dr. Koichi Hirao, organized by JICA (the Study Team) under the supervision of the Work Management Committee headed by Dr. Masayoshi Matsubayashi, in close cooperation with the Indonesian Government.

Names of the members of the Study Team and the Work Management Committee are listed in Supplement-2 and the minutes of major meetings are given in Supplement-3.

(1) Objectives of the Study

The objectives of the Study are to conduct a feasibility study on the project to prevent sediment disasters in the south-eastern slope of Mt. Semeru, and to assess the water resources potential to be developed in accordance with the actual implementation of the said project.

In addition, the transfer of planning and surveying technology to counter-parts of the Government of Indonesia through their direct participation in this Study should also be materialized.

(2) Study Area

The area to be studied (the Study Area) is the southeastern slope of Mt. Semeru, located in Kab. Lumajang, East Java Province and its area is approximately 730km^2. The major river systems in the Study Area are the K. Mujur, K. Rejali and K. Glidik river systems. Refer to Fig.-1.1.

(3) Procedures and Items of Study

The Study can be divided into the following four stages. The basic concepts for each stage are described below. Refer to Fig.-1.2.

① First Stage (March, 1982 - May, 1982)

- Draft the Inception Report and conceive a comprehensive plan for the Study.

② Second Stage (June, 1982 - May, 1983)

- Obtain the necessary data for the Study through field investigations.
- Review the existing Master Plan.
- Select the priority projects.
- Plan and design the First-Priority Project.

③ Third Stage (June, 1983 - March, 1984)

- Propose the Revised Master Plan.
- Evaluate the feasibility of the First-Priority Project and prepare its implementation program.
- Conduct a supplementary field survey for the evaluation of the Second Priority Project.
- Prepare the Interim Report.

④ Fourth Stage (June, 1984 - December, 1984)

- Evaluate the feasibility of the Second-Priority Project.
- Complete the Final Report on the Study.

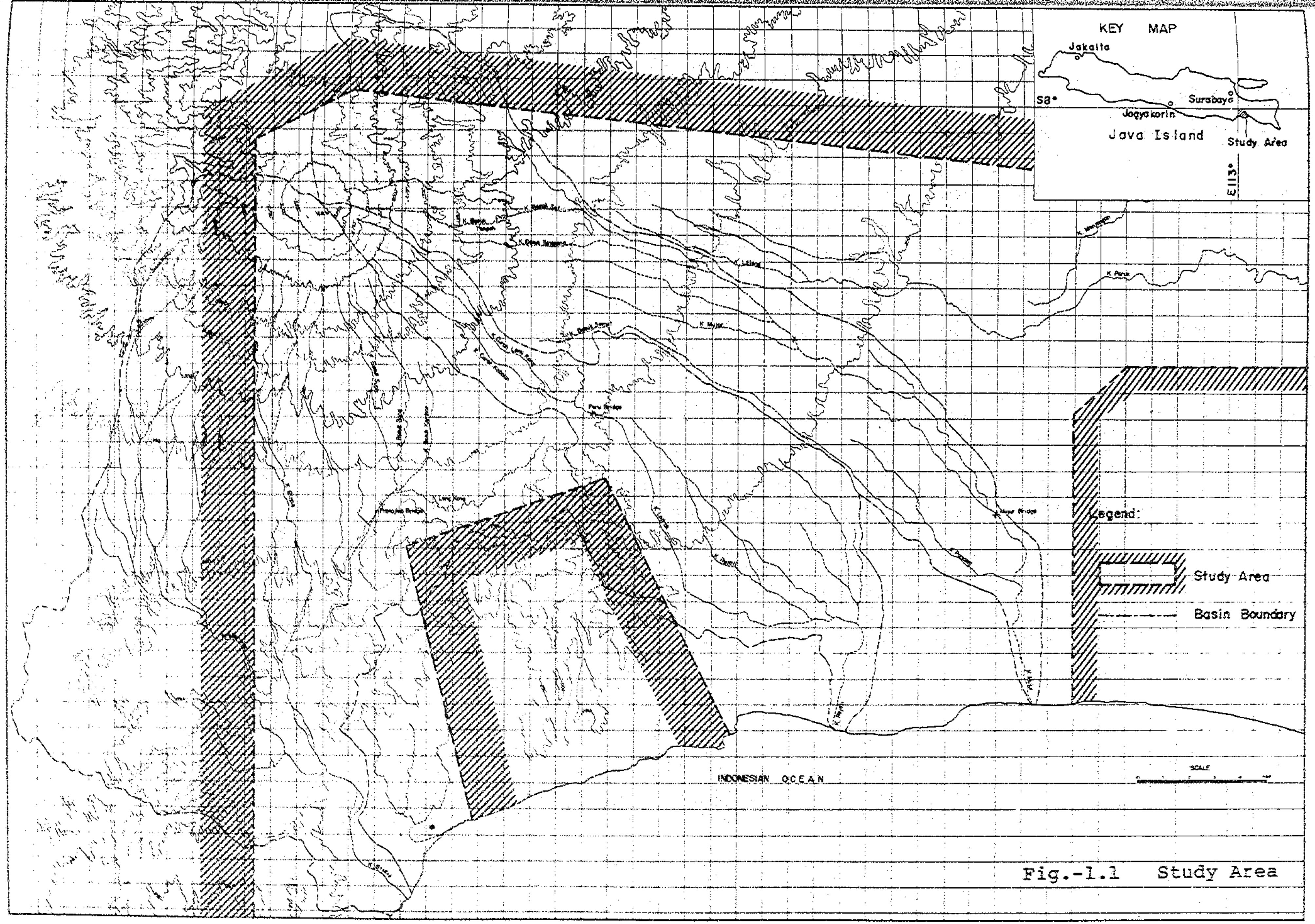


Fig.-1.1 Study Area

STAGE	YEAR MONTH.	MAIN MEETING AND REPORTS	STAGE TARGETS
1st STAGE	'82 MAR.		DECISION OF STUDY PLAN
	APR.	INCEPTION REPORT	
	MAY		
2nd STAGE	JUN.		(1) REVIEW OF EXISTING MASTER PLANS (2) SELECTION OF PRIORITY PROJECT (3) EXECUTION OF INVESTIGATION, STUDY AND ANALYSIS (4) PLAN AND DESIGN OF 1st PRIORITY PROJECT
	JUL.		
	AUG.	SELECTION OF PRIORITY PROJECT	
	SEP.	PROGRESS REPORT (1)	
	OCT.		
	NOV.	OUTLINE OF 1ST PRIORITY PROJECT	
	DEC.		
	'83 JAN.		
	FEB.		
	MAR.		
3rd STAGE	APR.		(1) EXECUTION OF COMPLEMENTARY INVESTIGATION ON 2ND PRIORITY PROJECT (2) PROPOSAL FOR VOLCANIC DEBRIS CONTROL PLAN (3) PROJECT EVALUATION ON 1ST PRIORITY PROJECT (4) PROPOSAL FOR IMPLEMENTATION PROGRAM (I/P) OF 1ST PRIORITY PROJECT
	MAY		
	JUN.		
	JUL.		
	AUG.		
	SEP.		
	OCT.		
	NOV.	PROGRESS REPORT (II)	
	DEC.		
	'84 JAN.		
	FEB.	INTERIM REPORT	
	MAR.		
4th STAGE	APR.		(1) PROJECT EVALUATION ON 2ND PRIORITY PROJECT (2) FINAL REPORT ON FEASIBILITY STUDY
	MAY		
	JUN.		
	JUL.	OUTLINE OF 2ND PRIORITY PROJECT	
	AUG.		
	SEP.		
	OCT.		
	NOV.	DRAFT FINAL REPORT	
	DEC.	FINAL REPORT	

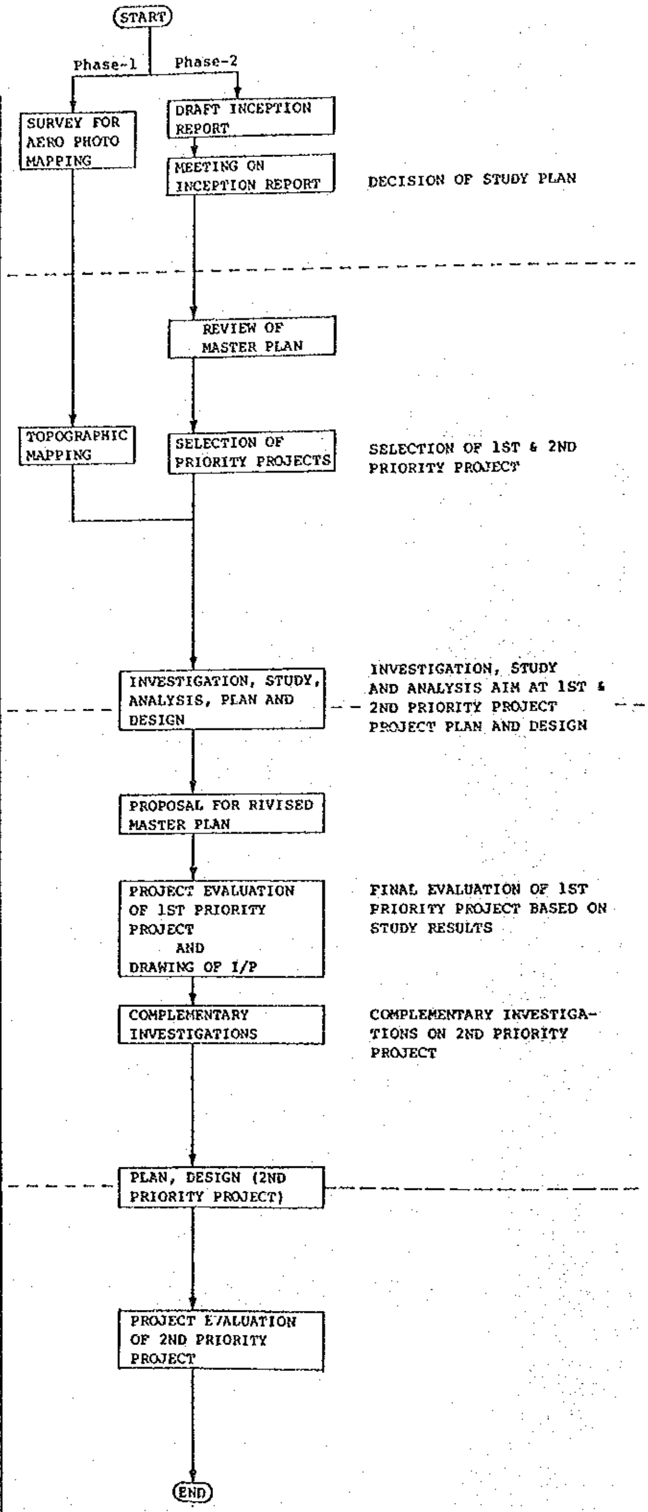


Fig.-1.2 Study Process

(4) Contents of the Study

The Study is divided into the following three phases.

① Field Investigation
(Mainly performed in the study area)

② Analysis and Examination
(Performed in Japan using the field survey data)

③ Planning, Design and Evaluation
(Make feasibility studies on the Priority projects)

The main study items in each phase and their study flows are shown in Fig.-1.3.

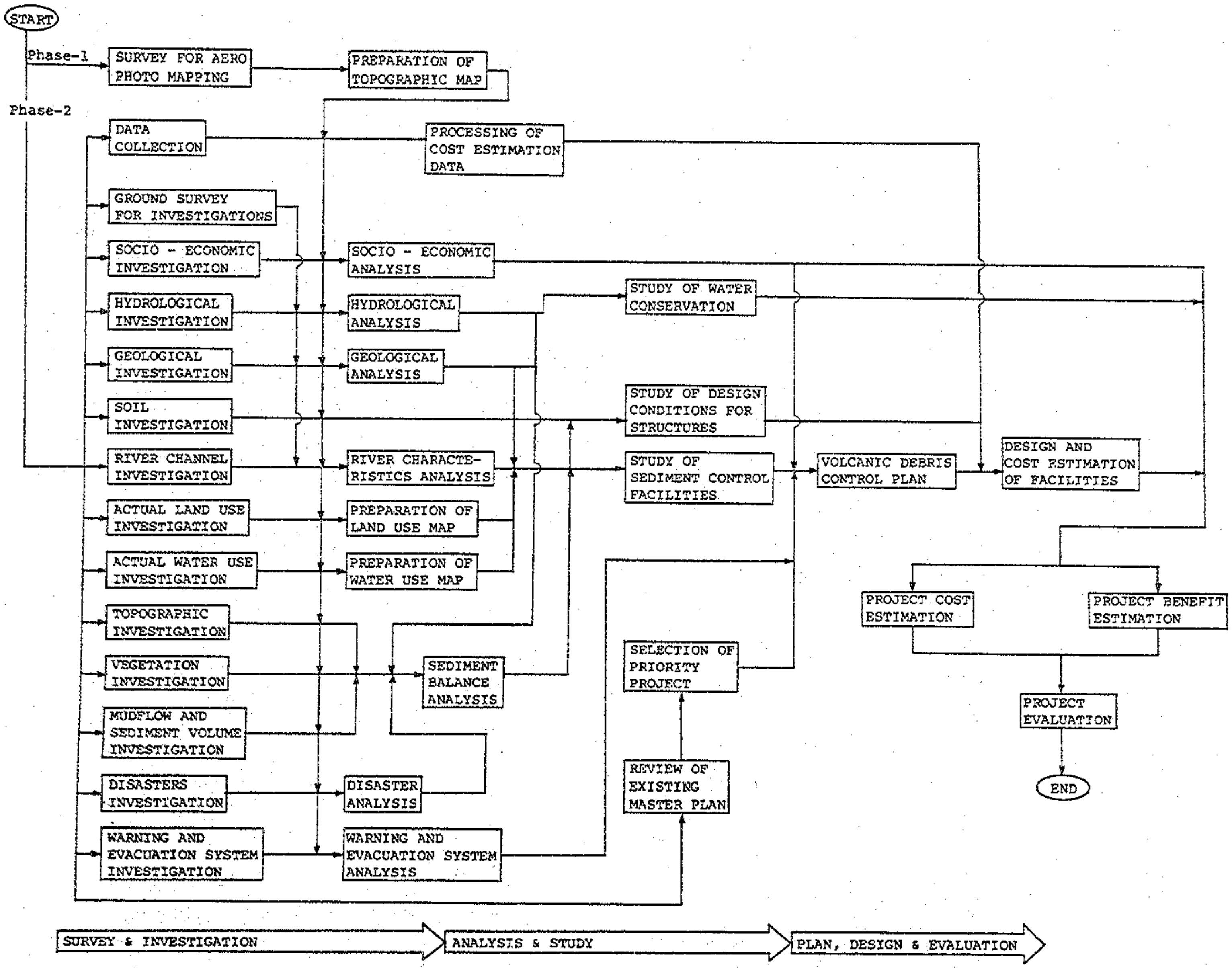


Fig.-1.3 Study Items and Study Flow

2. CONDITIONS OF THE STUDY AREA

2.1 NATURAL CONDITIONS

2.1.1 TOPOGRAPHY

Mt. Semeru, the highest mountain of EL. 3,767m in Java Island and an active stratovolcano, is located in the east of long and large Quaternary volcanic arc running from east to west in the center of Java Island called Solo Zone or Sunda Quaternary Volcanic Arc, and belongs to Tengger-Semeru Volcanic complex extending from north to south that is one of the volcanic complexes forming Solo Zone.

Tengger-Semeru volcanic complexes are morphologically classified into the following three units. (from A. SAKAI, I. SURYO, 1980) Refer to Fig.-2.1.

- Tengger mountain range
- Jambangan volcanic omplex
- Semeru volcano

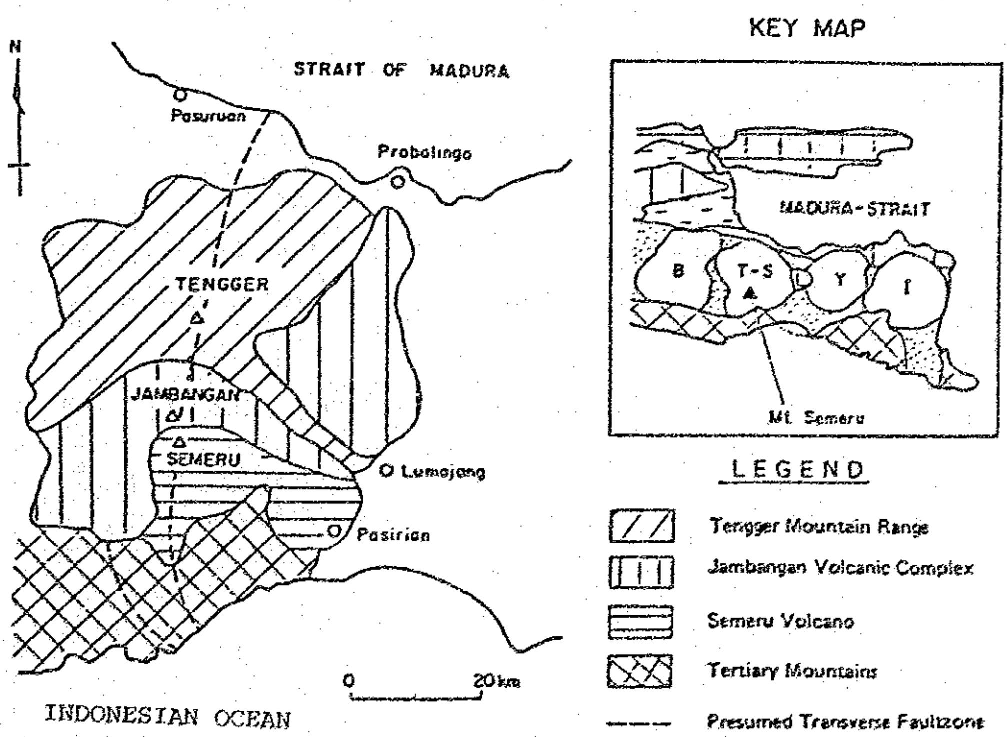


Fig.-2.1 Schematic Geomorphological Unit Map of Tengger-Semeru Volcanic Row

Among them Mt. Semeru is the youngest and is formed on the southern slope of the Jambangan volcanic complex which is the oldest among the 3 units. To the south of Solo Zone in the study area, the mountain range called Southern Mountains comprising the Tertiary system runs from east to west in parallel with Solo Zone.

The Study Area covers both Solo Zone and Southern Mountains and is roughly classified into the following 4 areas according to the geomorphological characteristics. Refer to Fig.-2.2.

Semeru Volcano	a. Main part of volcanic cone (EL. 1,500m to top)
	b. Volcanic fan (EL. 150 to 1,500m)
	c. Volcanic piedmont periphery (EL. 0 to 150m)
Southern Mountains	d. Mountains and hills

The volcanic activities of Mt. Semeru, which are the origin of the sediment disaster in the Study Area, are characterized as follows:

- Nuee Ardente and Lahar are concentrated on the southeastern and south slope.
- Judging from distribution of volcanic ejectaments (ex. ash falls, bomb, etc.), there seems to have been no large-scale eruptions in the past.
- Cycle of the active period and dormant period had been repeated many times.
- The crater is gradually shifting toward south.

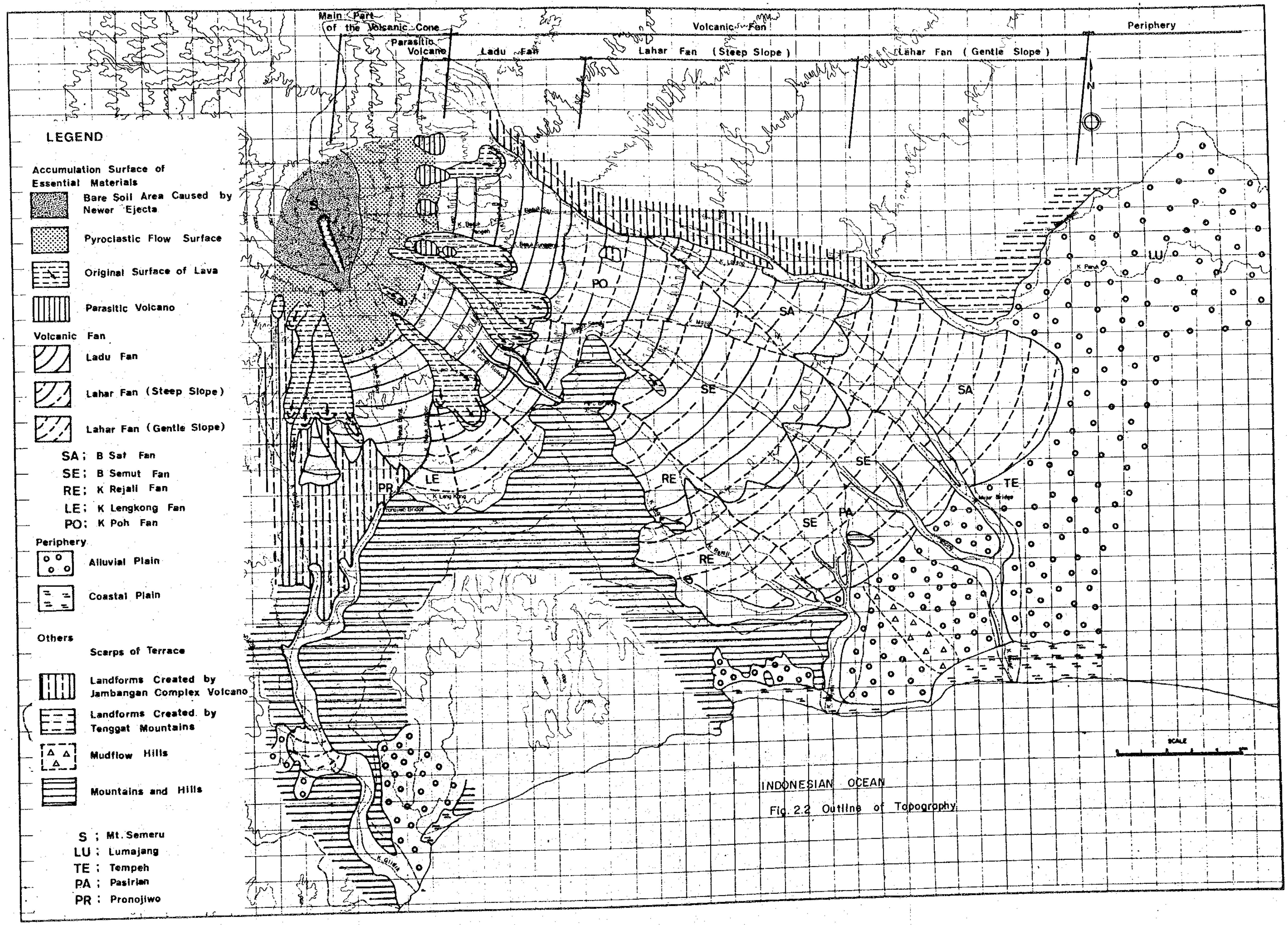


Fig. 2.2 Outline of Topography

2.1.2 GEOLOGY

Geology of the Study Area is largely divided into Tertiary system and Quaternary system. Quaternary system forms volcanic ranges including Mt. Semeru on the north side of the Study Area and Tertiary system forms steep mountains on the southwestern side of the Study Area. Refer to Fig.-2.3 and 2.4.

The Tertiary system comprises various volcanic rocks such as andesite, tuff and tuff breccia. The lowest layer is composed of the altered green tuff. There seems to be unconformity between these green tuff and the unaltered volcanic rocks lying over the former.

The Quaternary system is largely classified into older volcanic products, which are volcanic products of Jambangan volcanic complex, and younger volcanic products which are from Mt. Semeru. Most of the Study area is covered with younger volcanic products. The younger volcanic products can be also classified into the following types according to the composite material, mode of occurrence and compactness.

a. Primary volcanic products
b. Secondary volcanic products
   (Epiclastic volcaniclastic deposits):
   b1. Younger Lahar deposits
   b2. Older Lahar deposits
c. Alluvium

Primary volcanic products are composed of those directly from the center crater or parasitic volcanoes. They have not moved from the original place in spite of rain, etc. Most of them are distributed over the area above EL. 800m of Mt. Semeru.

Secondary volcanic products (epiclastic volcaniclastic deposits in terms of volcanology) are those of the primary volcanic products which are moved with water and redeposited. They are collectively called Lahar deposits, and are distributed over the area from EL. 800 to 150m. Lahar deposit can be classified

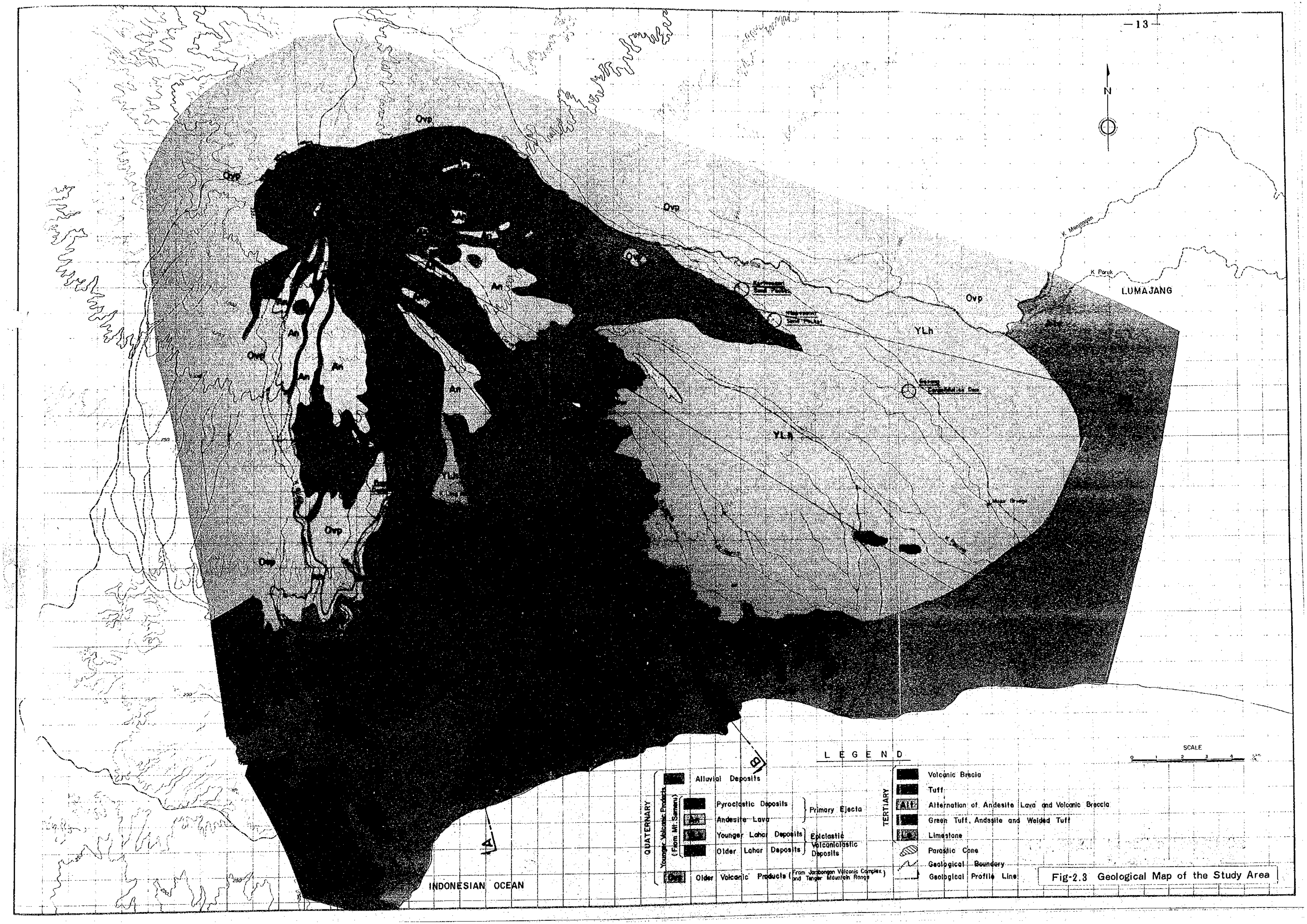


Fig-2.3 Geological Map of the Study Area

into loose younger Lahar deposits and well compacted older Lahar deposits according to the degree of compactness. Older Lahar deposits form an old volcanic fan such as K. Poh Fan and younger Lahar deposits form a new volcanic fan covering the old volcanic fan.

The stratified alluvium is distributed in the Volcanic piedmont periphery which surrounds the Volcanic fan and comprises round pebbles, sub angular pebbles, sands, silt and clay.

From a hydrogeological point of view, it appears that the Tertiary layer and the older volcanic products (Jambangan volcanic complex) form an impermeable foundation in the piedmont of Mt. Semeru and loose volcanic products from Mt. Semeru have accumulated on top of it forming a permeable layer. The general hydraulic structure of the aquifer is considered to be a stratified structure which is strongly regulated by the stratified structure of Mt. Semeru itself. Possible water veins there will be fragile lava, old valleys, a layer of lahar deposits with a large volume of pebbles.

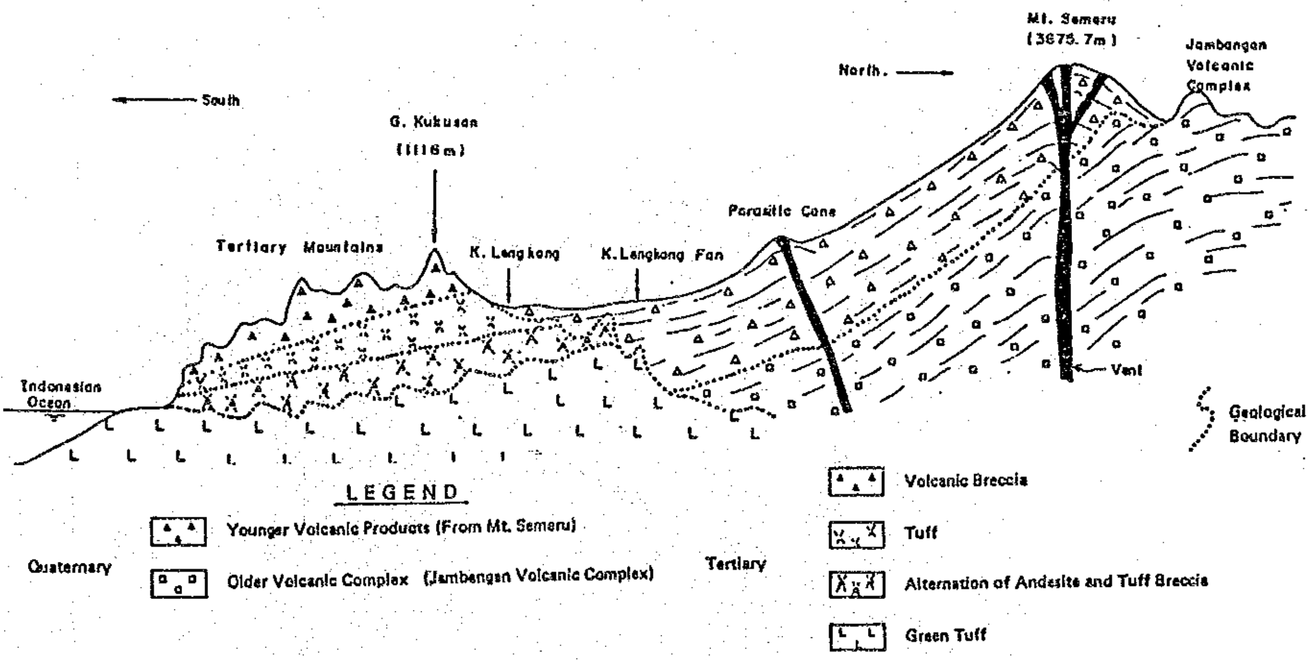


Fig.-2.4 Schematic Geological Profile of the Study Area

2.1.3 CLIMATE

The Study Area belongs to the Tropical Climate Zone and has distinctive rainy and dry seasons. The annual rainfall is from 1,500mm to over 4,000mm and the annual isohyetal lines shows a gradual increase almost parallel to the contour lines of Mt. Semeru (refer to Fig.-2.5).

The rainy season generally starts in November until April and the dry season extends from May until October. Although this distinction is clear at a low altitude, it gradually disappears in accordance with a higher altitude showing a lot of rainfall throughout the year (refer to Fig.-2.6). Daily rainfall of over 300mm has been observed at the Busk Sat Observation Station at EL. 795m (refer to Fig.-2.7).

According to the records of the Gunung Domas Hilir Meteorological Station, which is located in the eastern part of the Study Area, the mean annual temperature is 25.1°C. The mean monthly temperatures are between 23°C - 26°C, showing a narrow temperature range in this area. The annual mean relative humidity is as high as 90% with almost no monthly differentiation (refer to Fig.-2.8).

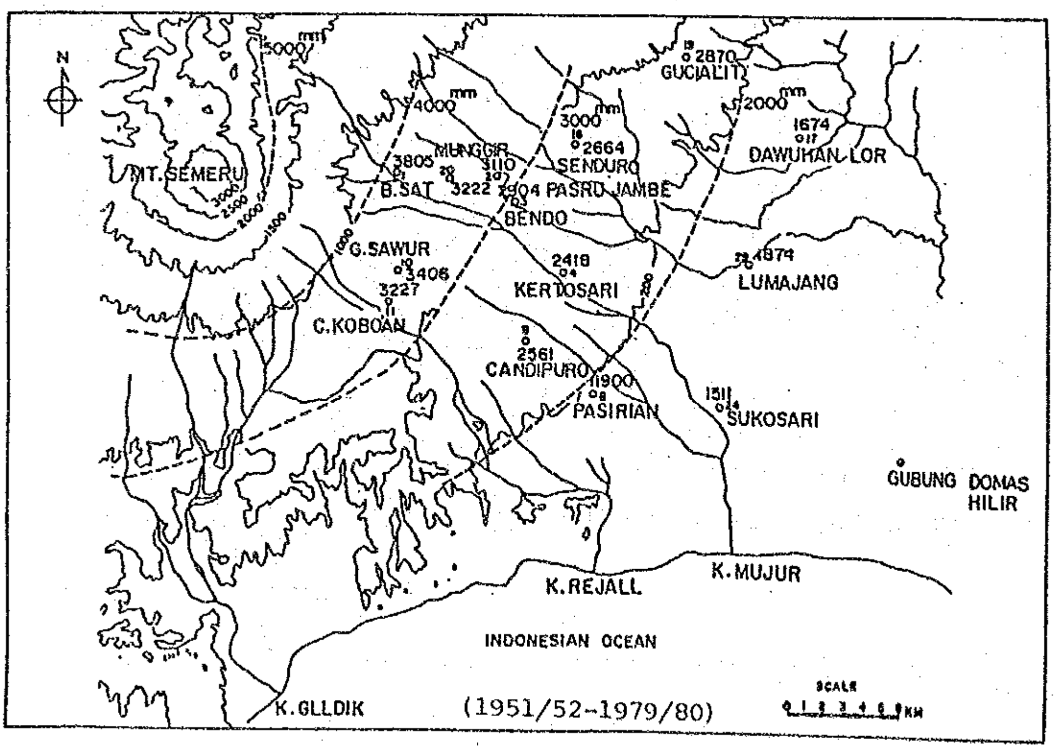


Fig.-2.5 Annual Isohyetal Map

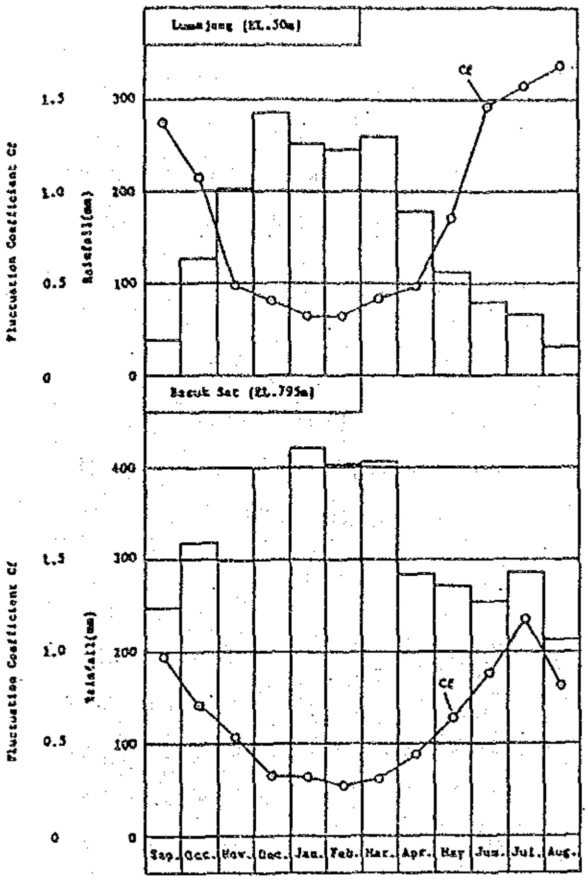


Fig.-2.6 Distribution of Monthly Rainfall

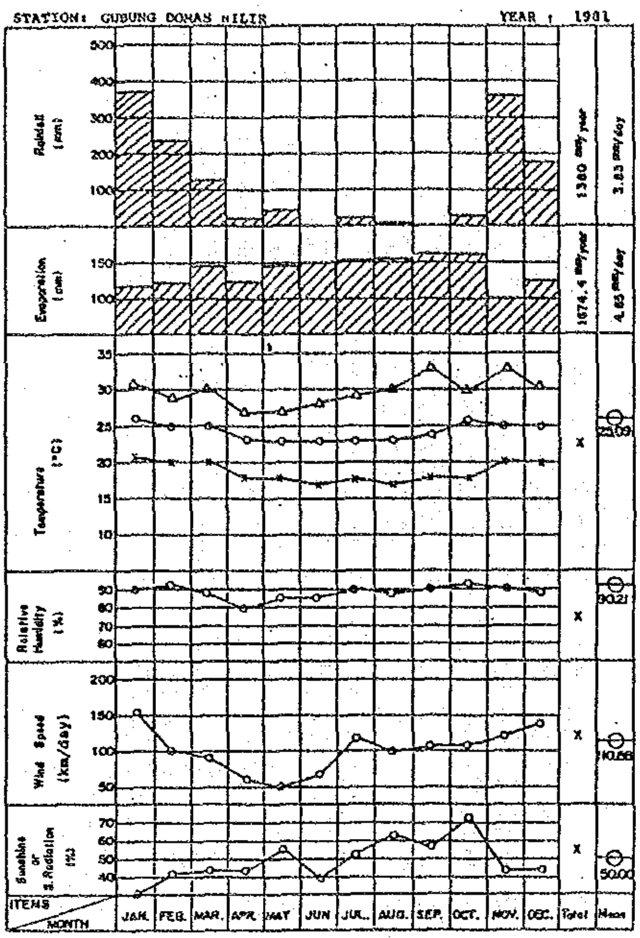


Fig.-2.8 Meteorological Data at Gubung Domas Hilir

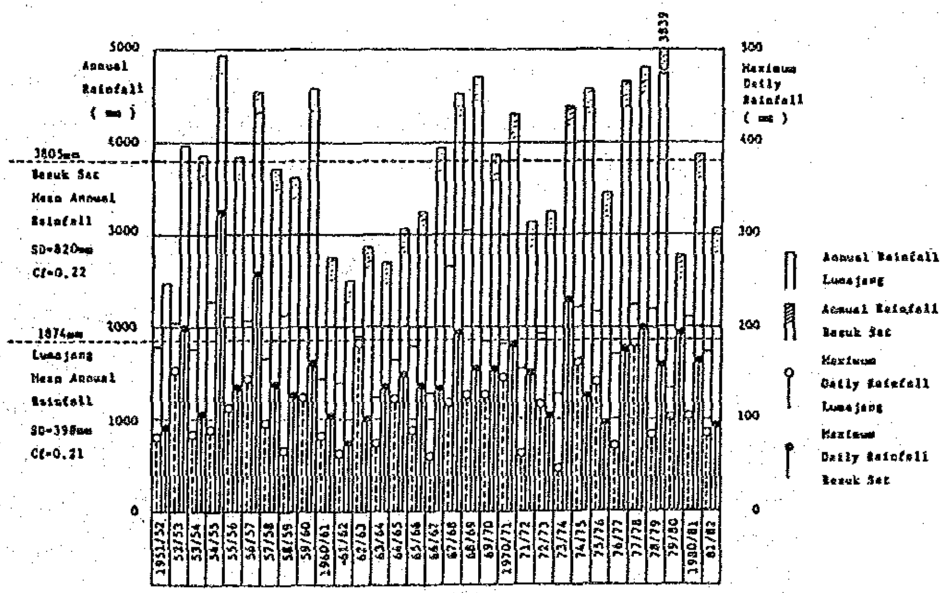


Fig.-2.7 Fluctuation of Annual Rainfall and Maximum Daily Rainfall

2.1.4 RIVERS

(1) River Channel Systems

The rain in the southeastern slope of Mt. Semeru radially cuts valleys into the mountainside, forming the K. Mujur, K. Rejali and K. Glidik river systems, located in this order from east to west in the Study Area. These rivers eventually pour into the Indonesian Sea (refer to Fig.-2.9).

K. Mujur river system

The K. Mujur, located in the eastern part of the Study Area, has the following main tributaries: B. Sat, B. Tompe, B. Tungeng, K. Poh, B. Semut and K. Pancing, forming the Poh fan, Sat fan and Semut fan.

Before the 1909 disaster, the B. Sat flowed into the B. Sat Rama (the old B. Sat) which ran almost at the center of the Sat fan. After the disaster, however, the K. Sat was artificially diverted to the K. Tsungen near the Keruto Sali village, located at the fan top of the Sat fan in order to prevent floods from advancing to the Lumajang area. As a result, the K. Mujur became a river with a large sediment flow as it incorporated the catchment areas for the B. Sat and the B. Tompe which had extensive sources of sediment yield upstream.

In the 1981 disaster, lahar destroyed the Leches dike at the diverting point of the channel, causing extensive damage to a wide area.

In 1941 and 1942, the lava flow from Mt. Semeru came down to EL. 800m of the B. Semut and completely buried the valley. As a result, the B. Semut and the K. Pancin, which were tributaries of the K. Mujur, lost the upper stream of the K. Cura Lengkong, which is now a tributary of the K. Rejali system, thus becoming underfit rivers. They are currently quite stable, however waste land, due to past disasters, spreads over the Semut fan.

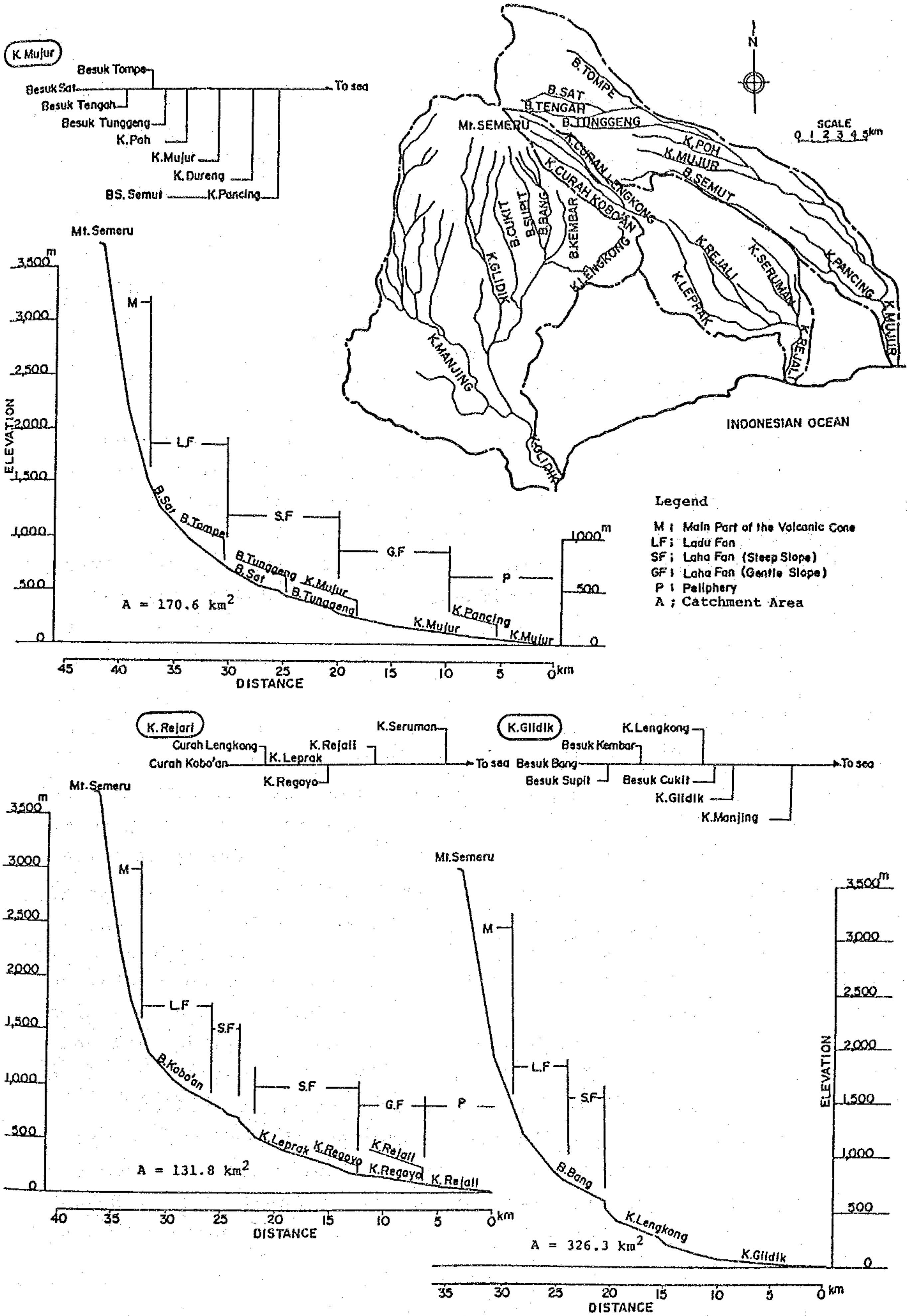


Fig.-2.9 River Systems of the Study Area

K. Rejali river system

The K. Rejali, located at the center of the Study Area, has tributaries with large sediment production, namely the C. Lengkong and the C. Kobo'an upstream. It runs through the Kobo'an valley, which is created in a tertiary mountain mass, forming the Rejali fan downstream.

Because of the large volume of sediment flow, the main stream which formally ran into the K. Rejali until 1976 changed its direction at the fan top and currently runs into the K. Leprak and the K. Regoyo which are located to the west of the fan.

The frequent occurrences of lahar disasters recently seen in the Rejali Fan are possibly explained by the following two reasons. Firstly, it has the C. Kobo'an, which gets a direct supply of sediment from craters at its head. Secondly, due to the change over of the upper river basin of the B. Semut to the C. Lengkong as a result of the eruptions in 1941/1942, the K. Rejali has become an overfit river where the increased flow of water and sediment exceeds the transportation capacity of the river channel.

K. Glidik river system

The K. Glidik, which is located in the western part of the Study Area, has the largest basin of the three river systems. It incorporates the K. Lengkong which runs east along the tertiary mountain mass into the main channel which runs south in accordance with the natural incline of the area.

The K. Lengkong currently produces the largest sediment flow as it incorporates the B. Supit, B. Bang and B. Kembar, which erode the pyroclastic deposits which are formed by volcanic ejecta daily produced by craters. The K. Lengkong shows a feature of an alluvial river upstream from the Pronojiwo Falls, as it meanders due to the gentle incline of the ground. Part of the river has become a lake as pyroclastic products from the 1976 eruption have blocked part of its channel. The Lengkong fan is formed to the north of channel and downstream of the falls, a deep V shape valley has developed as far as the confluence point with the main river.

At the middle and downstream of the K. Glidik, a narrow valley bottom plain, where the difference in relative height with the present riverbed is small, has been formed providing a vulnerable situation for the occurrence of sediment flow.

Downstream, to the west of the Tenpulu Sali Plain, has become a raised bed river, where the difference in relative height is some 30m, suggesting a current conspicuous rise of the riverbed when taking into account the almost non-existant river terraces.

(2) Supply Sources of Sediment

A direct supply of sediment into the channel system comes from valleys which are well developed at the main part of the volcanic cone. The characteristics of these valleys as supply sources of sediment can be classified as follows (refer to Table-2.1).

Volcanic Valleys

Those valleys where volcanic ejecta from craters can easily find a way to flow in, thus making a source of a large volume of sediment.

Degrading Valleys

Those valleys which have become the source of a large volume of sediment as they are situated next to a large area of degrading land at the river heads.

Stable Valleys

Those valleys which produce only a small volume of sediment as they have neither a direct inflow of pyroclastic products nor a large area of degrading land.

Table-2.1 Source Valleys of Sediment

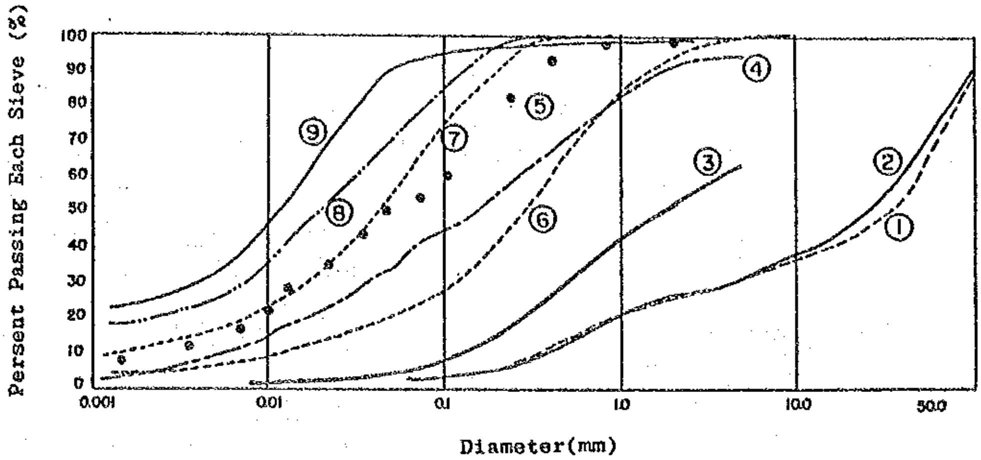
Category \ Channel System	K. Mujur	K. Rejali	K. Glidik
Volcanic Valley	-	C.Kobo'an	B.Bang B.Kembar B.Sarat
Degrading Valley	B.Sat B.Tengah B.Tunggeng	C.Lengkong	B.Spit B.Cukit B.Glidik
Stable Valley	B.Tompe K.Poh K.Mujur (upstream) K.Pancing B.Semut	-	K.Bening K.Lengkong

(3) Riverbed Materials

As shown by the grain size distribution of the riverbed materials for the three river systems (Fig.-2.10), the conditions are disadvantageous in view of the stable riverbeds since armouring coat has not been formed due to the extremely wrong distribution.

The grain size distributions of deposit at K. Lengkong fan and hill side of breaking zone are very similar to that of transport sediment as it contains a fair amount of fine sand. The floating sediment has a silt content of 70-90%.

The density of the riverbed materials and the results of the spot density tests are shown in Table-2.2. The vacancy rate at the river bed is found to be 40-50%.



Legend:

① Riverbed Deposit of K. Mujur

② Riverbed Deposit of K. Rejali

③ Riverbed Deposit of K. Glidik (Pronojiwo)

④ Deposit of K. Lengkong Fan

⑤ Erosion Sediment at the Upper Stream of BS. Tunggeng

⑥ Flowing Lahar Materials (At 11:20 on Feb. 9, 1983)

⑦ Flowing Lahar Materials (At 14:00 on Feb. 9, 1983)

⑧ Suspended Sediment of K. Mujur at the Mujur Bridge (At 17:25 on May 1, 1983)

⑨ Suspended Sediment of K. Lengkong (Pronojiwo) (At 14:00 on Feb. 15, 1983)

Fig.-2.10 Grain Size Distribution Curves

Table-2.2 Specific Gravity and Field Density

Classification	Location	Position No.	Specific Gravity	Field Density	Volumetric Density
Riverbed Materials	K. Rejali	R-2	2,777	1,535	0.55
		R-4	2,793	1,675	0.60
		R-12	2,824	1,435	0.51
Flowing Debris	K. Lengkong 11:20 Feb. 9, 1983		2,751	-	
Suspended Materials	K. Lengkong 14:40 Feb. 9, 1983		2,739	-	
	K. Lenkgong 14:00 Feb. 15, 1983		2,718	-	
	K. Mujur 17:25 May 1, 1983		2,806	-	
Hillside Materials	Landslide Zone at BS. Tunggeng		2,727	-	

* Given from specific gravity and field density.

(4) Record of Floods and Density of Runoff Sediment

Table-2.4 gives a list of floods where the discharge was over $200m^3/s$, which were observed from 1983 to 1984. It can be seen that frequent floods occurred in the K. Glidik. On May 3, 1983, a discharge in the order of $3,000m^3/s$ was observed at Pronojiwo on the K. Glidik which was a debris flow including a large amount of sediment. In respect to the K. Mujur, a flood of more than $100m^3/s$ did not occur during these two years.

Table-2.3 gives the results of the density measurements of transport sediment conducted in February and March, 1983. In respect to the K. Glidik, a debris flow with a density volume of 50% and a fluid density of $1.85t/m^3$, was observed.

Table-2.3 Debris Density of Flowing Lahar

Date	Time	Station	Water Discharge (m /s)	Observed Volume			Estimated Value	
				① Total Volume (m)	② Soil (gr)	③ Water (gr)	④ Dd	⑤ D
Feb. 9, 1983	11:20	Pronojiwo Bridge II	598.0 (11:00)	530	612.350	315.125	0.41	1.75
Feb. 9, 1983	11:20	Pronojiwo Bridge I	598.0 (11:00)	530	710.875	270.075	0.49	1.85
Feb. 15, 1983	13:00	K. Lengkong II	19.2	1900	186.050	1862.800	0.02	1.08
Feb. 15, 1983	14:00	K. Lengkong I	3.78 (14:15)	1900	516.800	1652.075	0.13	1.14
Feb. 8, 1983	15:00	K. Leprak II	1.1	530	7.200	535.950	-	1.02
Feb. 8, 1983	16:00	K. Leprak I	1.1	530	18.375	524.625	0.01	1.02
Mar. 16, 1983	15:30	Mujur Bridge	10.8	2000	10.525	1995.450	0.00	1.00

D: Specific Gravity of Lahar $D = \frac{② + ③}{①}$

Cd: Volumetric density $Dd = \frac{① - ③}{①}$

* Estimated Value from Flood Mark

Table-2.4 Main Observed Floods

(K. Rejali)

Data (1983)	Peak Discharge (m^3/s) RP-4 K. Leprak No.1 Check Dam	10 G. Sawur	30 G. Leker	31 G. Pakis	32 Kamar A	33 Wonore-nggo	38(11) Curah Kobo'an
		Rainfall Stations & Thiessen Coefficient					
		0.02	0.36	0.06	0.18	0.03	0.35
1/May/83	422	o	x	x	x	o	o
26/May	289	o	x	x	x	o	o
24/Jan/84	307	o	x	x	o	O	o
7/Feb/	223	o	x	o	x	x	o

(K. Glidik)

Data	Peak Discharge (m^3/s) RP-3 Planned Pronojiwo Dam	30 G. Leker	31 G. Pakis	32 Kamar A	34(14) Prono-jiwo	38(11) Curah Kobo'an	42(13) Supit Urang
		Rainfall Stations & Thiessen Coefficient					
		0.01	0.02	0.34	0.16	0.09	0.38
26/Feb/83	720.5	x	x	o	o	x	o
3/Mar	468.4	x	x	o	o	x	o
13/Mar	436.0	x	x	o	o	o	o
19/Mar	436.0	x	x	o	o	o	o
20/Mar	517.0	x	x	o	o	o	o
29/Mar	232.6	x	x	x	o	o	o
19/Apr	243.7	x	o	o	o	o	o
28/Apr	221.6	x	o	o	o	o	o
1/May	2,956.8	x	x	x	o	o	o
3/May	221.6	x	o	x	o	o	o
6/May	421.0	x	o	o	o	o	o
7/May	532.0	x	x	o	o	o	o
13/May	243.7	x	x	o	o	o	o
25/May	998.2	x	x	x	o	o	o
27/May	243.7	x	x	x	o	o	o
14/Jan/84	456	x	x	o	o	o	o
16/Jan	244	x	x	o	o	o	o
15/Feb	758	x	o	x	o	o	o
6/Mar	244	x	o	o	o	o	o
14/Mar	244	x	o	o	o	o	o

Data available o: Yes x: No

2.2 SOCIO-ECONOMIC CONDITIONS

2.2.1 ADMINISTRATIVE DIVISION AND POPULATION

(1) Administrative Division

The area of Kab. Lumajang, which belongs to the East Java Province and incorporates the Study Area is 1,791km^2 and is a typical medium size Kabupaten in Java Island. Lumajang currently consists of 16 Kecamatans as the Kec. Pronojiwo was divided into two during the study period (refer to Fig.-2.11).

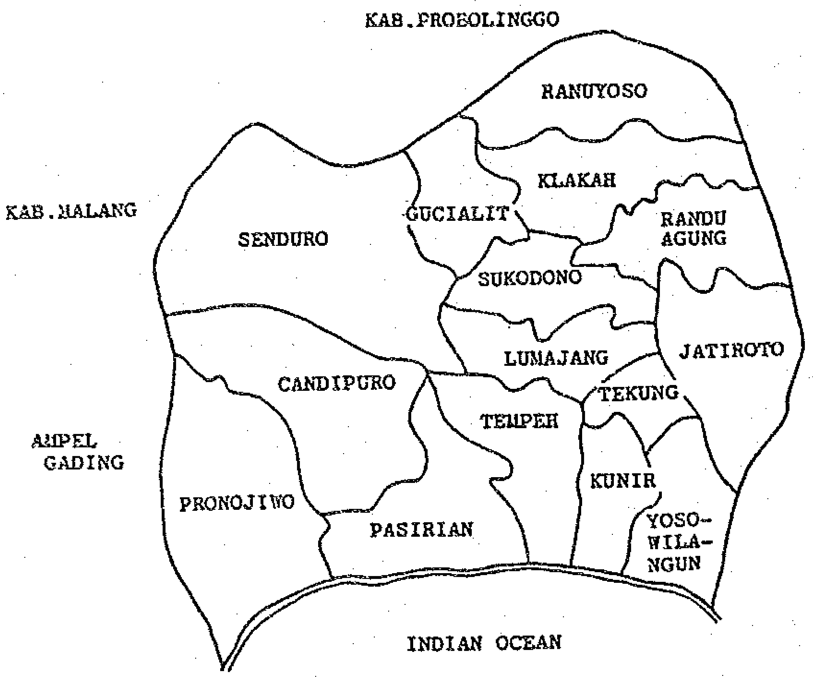


Fig.-2.11 Location of Kecamatans in Kab. Lumajang

(2) Population

As of 1980, the population of Kab. Lumajang is 874,000 with an average annual population increase rate of 1.17% and 1.36% for 1971-1980 and 1976-1980 respectively, which is fairly low in comparison with the population increase rate for Indonesia as a whole (2.32% for 1971-1980) and East Java Province (1.49% for 1971-1980). The population density of Kab. Lumajang is 488/km^2, which is lower than that of West Java Province (609/km^2).

One possible reason to explain Lumajang's low population increase is the migration of people out of the Kabupaten. This migration is caused not only by new employment or marriage but also by the administrative transmigration of people who have lost their means of livelihood due to disasters. Taking the disasters in 1976 and 1981 as examples, more than several thousand people moved out to resettle at Slawazi, North Sumatra, etc.

Some 10% of the total population of Kab. Lumajang is concentrated in Kec. Lumajang, where the local government offices are located, and the population density and population increase rate of the Kecamatan are 1,167 head/km^2 and 3.1% (1976-1980) respectively.

2.2.2 AGRICULTURE

The basic industry in Kab. Lumajang is agriculture. Based on the 1980 statistics, 118,000 households, more than half of the total 207,000 households in Kab. Lumajang, are engaged in agriculture. Agricultural land occupies 86% of the total land area of the Kabupaten, which is 1,654km^2. 356km^2 and 1,188km^2 are used for paddy rice fields and other crops respectively, showing that paddy fields take up about one fourth of all the agricultural land.

The production volumes of the major agricultural products in Kab. Lumajang are shown in Table-2.5. As the table shows, rice is by far the most important product and supports the local society and economy. The unit yield of rice is 4.7 ton/ha. with husk and is much higher than the average volume in East Java Province (4.3ton/ha.) or the Indonesian average (3.3 ton/ha.). This excellent yields is considered to be the result of plenti- ful water, stored by Mt. Semeru, and the good quality of the soil.

The paddy fields are irrigated using river water and spring water. Depending on the installation and management situation of the irrigation facilities, the distinction between technical irrigation, semi-technical irrigation or non-technical irrigation is made, responding to the respective case where these activities are conducted mainly by governmental organizations, jointly by governmental organizations and village, which is a beneficiary, or soley by village.

In the K. Mujur and K. Rejali basins, $57km^2$ of land has been irrigated by 20 intakes. $42km^2$, which accounts for 73% of the total irrigated area, has been subjected to either technical or semi-technical irrigation.

A representative cropping pattern is shown in Fig.-2.12 and two and a half crops or a maximum of three crops are carried out where adequate irrigation is available. In areas of inadequate irrigation, either double-cropping or single cropping of rice is carried out while corn, tobacco and beans are cultivated as secondary products.

In addition, the domestic livestock and poultry shown in Table-2.6 are raised for farming, transportation, food or for cash income.

2.2.3 SOCIAL FACILITIES

The transportation facilities in the Study Area consist of roads and railways. Road transportation has become the most important method of transportation due to the recent increase of automobiles. The major routes from Lumajang run north towards Proboringo, west towards Malan bypassing the Mt. Semeru and east towards Junbel. Although the railway consists of two lines, one running north to south connecting Proboringo and Pasirian via Lumajang and another running east to west branching at Lumajang towards Jenbel, the services are infrequent and the maintenance situation is not very good.

The electric power supply cannot be said to be adequate for the demand and the supply and demand is regulated by periodical blackouts.

Water and sewage facilities are almost non-existant. Wells and spring water are relied upon in daily life while the water channels and rivers around inhabited areas are used for sewage.

Table-2.5 Production of Major Crops - 1980

(ton)

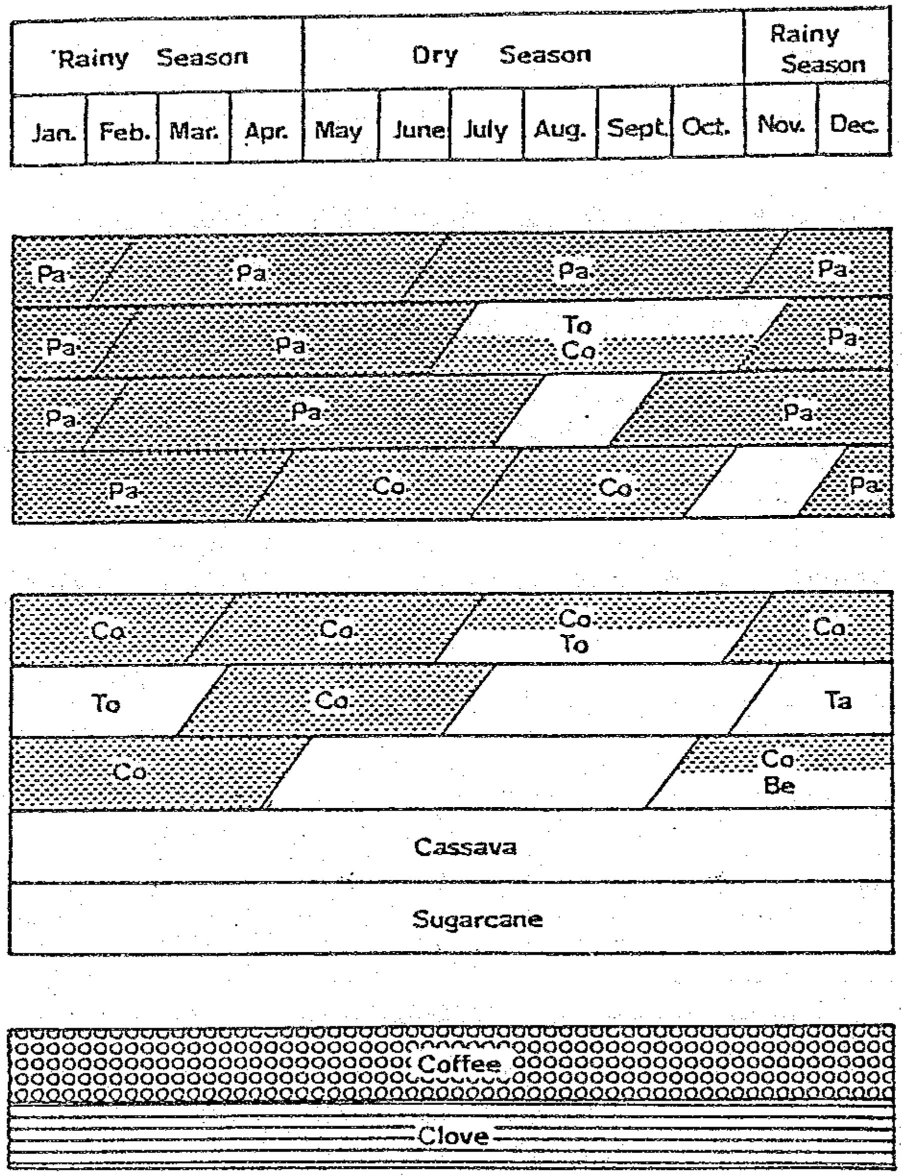
Kecamatan	Rice	Maize	Soy Bean	Cassava	Coffee
1. Lumajang	29,839	2,485	570	830	-
2. Sukodono	19,196	6,374	2,136	4,013	-
3. Senduro	14,045	7,207	977	780	759
4. Gucialit	133	4,846	354	3,107	140
5. Klakah	7,314	14,918	2,978	8,553	10
6. Ranuyoso	-	10,488	2,742	8,393	4
7. Randuagung	15,979	8,403	2,250	920	8
8. Pasirian	32,437	6,126	11	1,187	21
9. Tempeh	21,274	3,742	281	1,661	-
10. Candipuro	41,334	2,020	17	1,362	580
11. Pronojiwo	11,814	423	-	14,697	904
12. Yosowilangun	26,636	4,478	1,647	594	-
13. Jatiroto	25,404	2,543	676	4,400	-
14. Kunir	11,109	4,968	1,587	880	-
15. Tekung	12,012	1,849	805	590	-
Total	268,094	80,870	17,032	51,966	2,426

Source: Statistic Lumajang 1980

Table-2.6 Livestock and Poultry in Kab. Lumajang (1980)

(head)

Buffalo	Cow & Ox	Horse	Goat	Sheep	Pig	Duck	Chicken
5,830	90,105	2,369	40,838	20,196	2,915	68,241	688,724



Pa ; Paddy Ta ; Tobacco Co ; Corne B ; Beans

Fig.-2.12 Typical Cropping Patterns in the Study Area