5. Hydraulic Analysis of Sediment Transportation Capability

5.1 General

The purposes of this analysis are:

1) To set the allowable sediment volume to be used in the sediment control plan.

2) To obtain fundamental data for a sediment transportation plan on the Ciwulan river which makes use of the transportation capability of river.

For purpose 1 above, it is necessary to calculate the sediment volume taking into account the sediment runoff pattern such as by annual runoff and by flood runoff.

The sediment runoff pattern of S. Cikunir is considered to correspond to the former and all the rivers other than S. Cikunir (S. Ciloseh, S. Cisaruni, S. Cimerah etc.) are considered to correspond to the latter.

Long term hydrographs are necessary when analysis is to cover a full year. However, because data of water level from staff gauges is unreliable and the observation period for automatic recorders is 1 year and too short to be used, it was decided to calculate the runoff volume from rainfall data of Cibasuki station using the rational formula. The rainfall data goes back longer than any other data, 9 years.

The hydrograph of sediment runoff volume calculation by flood was made by extending the 50 year return period hydrograph calculated in chapter 4 in accordance to the catchment area proportion.

For purpose 2 above, topographical survey results are available from 6 reference points (2 km apart, total of 12 km) out of the entire section (from the river mouth to the Cikunir River confluence, approximately 100 km) selected as representatives. The cross section and gradient for the remaining sections were estimated from these results.

Along with the calculation of sediment runoff volume in the annual discharge and by flood discharge, the calculation of riverbed deformation using 1/50 year probability hydrographs was carried out to grasp the tendency of the longitudinal riverbed deformation (erosion, sedimentation) and sediment runoff tendencies from the upstream section to the downstream section of the river.

The classification of main works of this chapter is shown in Fig. - 5.1. The study flow of this chapter is shown Fig. - 5.2.

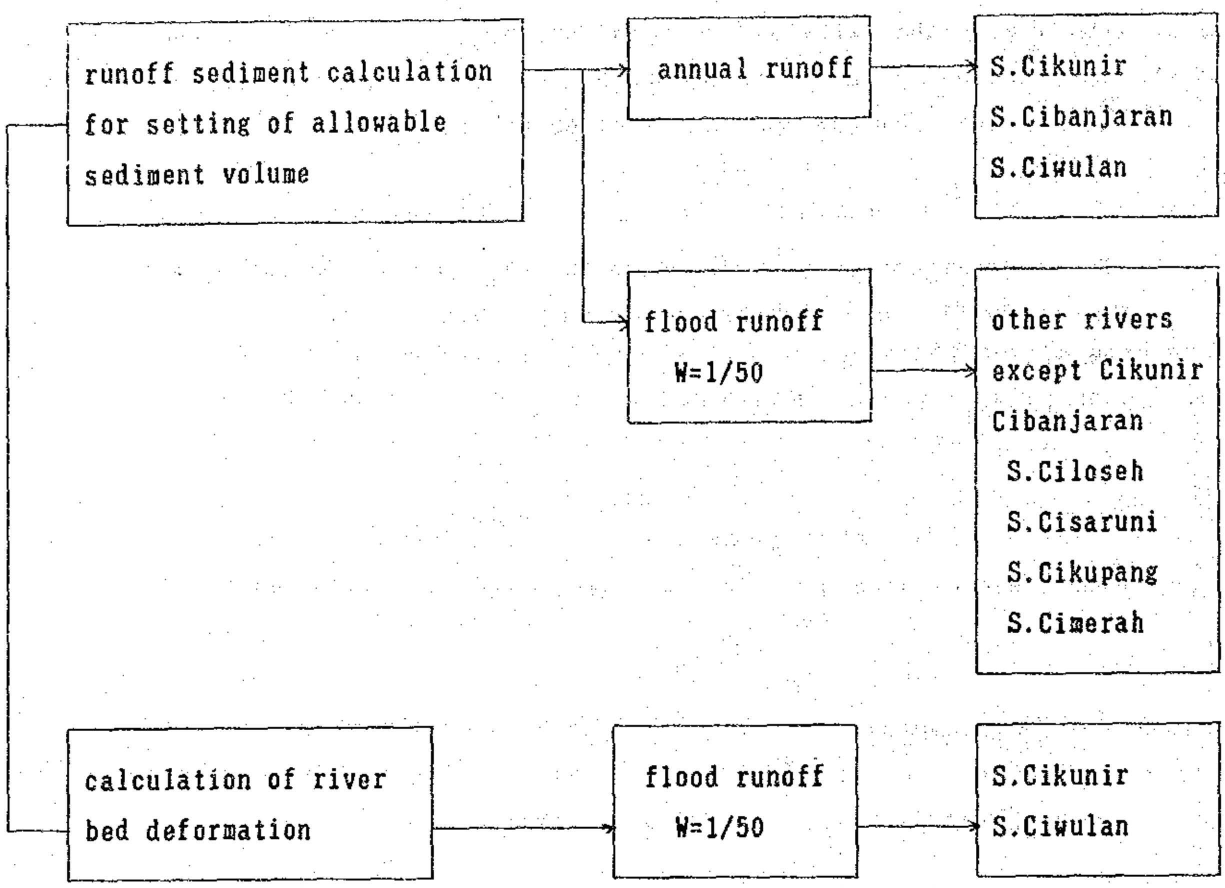


Fig. - 5.1 Classification of Study Items for Sediment Capability Analysis

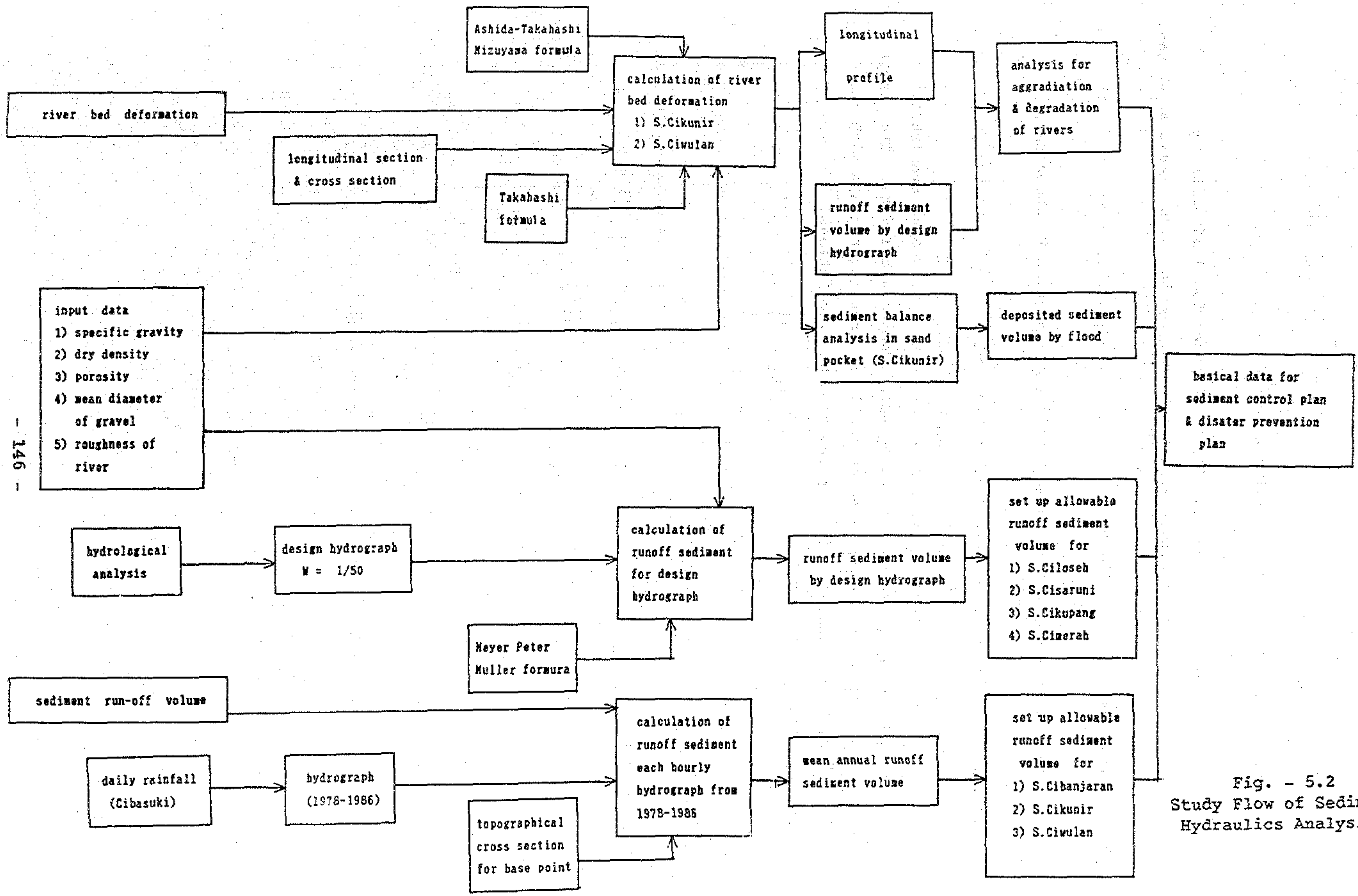


Fig. - 5.2
Study Flow of Sediment
Hydraulics Analysis

5.2 Calculation of the Runoff Sediment Volume

As described in the general (5.1), this section deals with the calculation of the annual runoff sediment volume and the flood sediment volume.

5.2.1 Outline of Calculations

The outline of runoff sediment volume calculation is shown below.

(1) Calculation of the Annual Runoff Sediment

As described above, there are no long term hydrographs available, making it necessary to calculate hydrographs from rainfall data. The runoff sediment volume is then calculated by combining these hydrograph with the runoff sediments formula. Below is the flow of calculations. (refer to Fig. - 5.3)

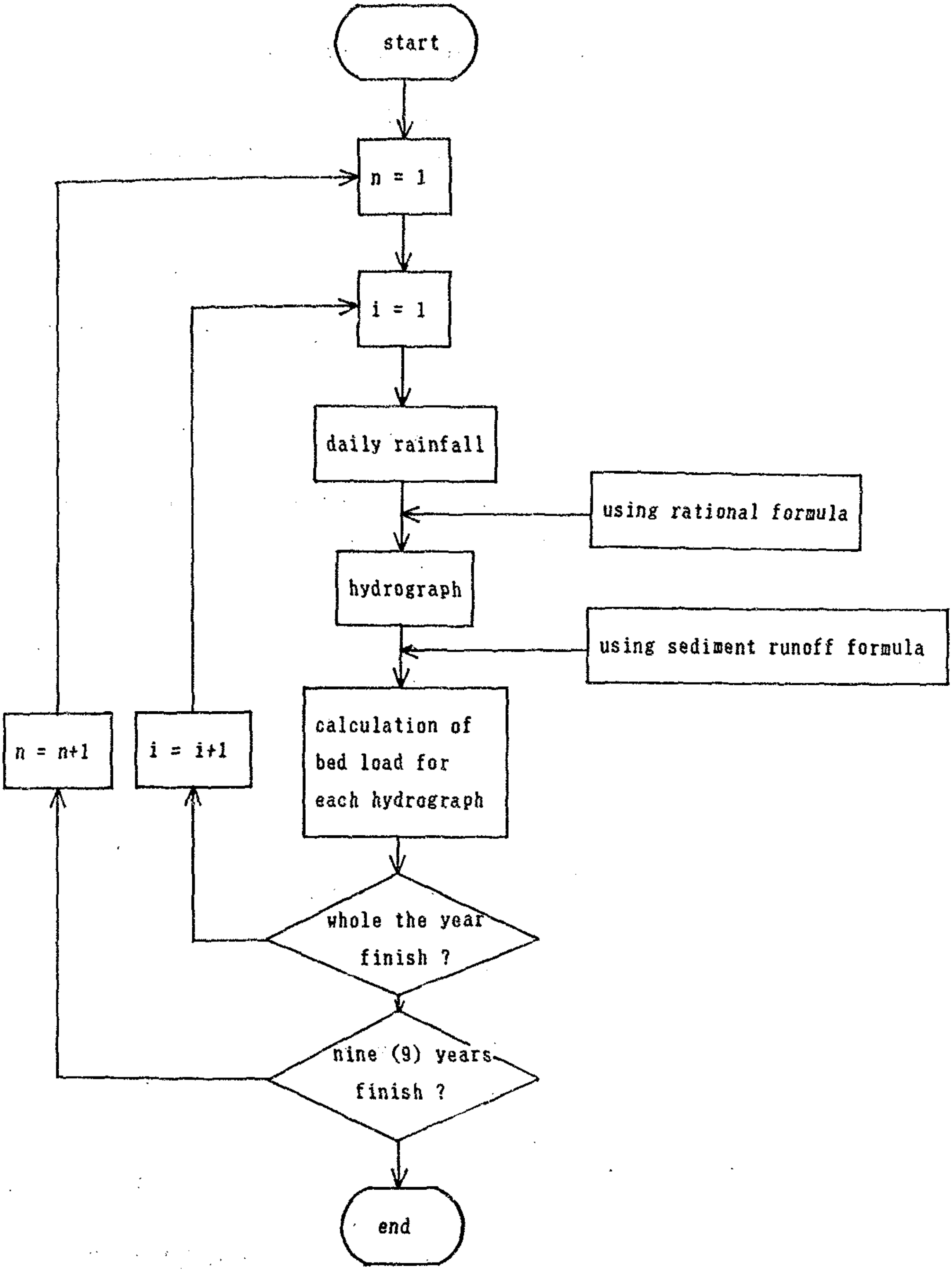


Fig. - 5.3 Calculation Flow of Annual Sediment Runoff Volume

(2) Calculation of Runoff Sediment Volume by Flood

When making per flood calculations, runoff sediment volume is calculated by combining the hydrographs made from the results of hydrological analysis and the runoff sediment formula.

5.2.2 Basic Items for Calculation

The basic items for calculation of the runoff sediment volume are shown below.

(1) Formula for Calculation of Runoff Sediment Volume

The Mayer-Peter - Müller formula was used as the sediment runoff volume formula. The following is an outline of that formula.

(a) Mayer-Peter Müller Formula (Bed Load Formula)

$$\Phi = 8\ (\tau^*e - 0.047)^{1.5} \quad \ldots\ldots\ldots\ldots\ldots (5.1)$$

Where:

$\Phi = q_B / \ (\sigma/\rho - 1)\ g\ .\ dm$

$T_*e = U_*e^2/(\sigma/\rho - 1)\ g\ .\ dm$

n_b = roughness expressing grain roughness

n = Manning roughness for entire flow

$U_*e = (n_b/n)^{3/4}\ .\ U_*$

q_B = Unit width of sediment runoff volume

σ = Density of gravel

ρ = Density of water

d_m = mean diameter of gravel

The friction velocity was calculated using the Manning formula by making an approximation the cross section of river to cross sections of rectangule.

$$Q = A/n \cdot R^{2/3} \cdot i^{1/2}$$

$$A = B.h \text{ and } R \neq h \text{ ....} \quad (5.2)$$

$$Q = B/n \cdot h^{5/2} \cdot i^{1/2}$$

$$h = (n \cdot Q/B \cdot i)^{0,6}$$

Where:

Q = Discharge (m^3/s)

A = Discharge area (m^2)

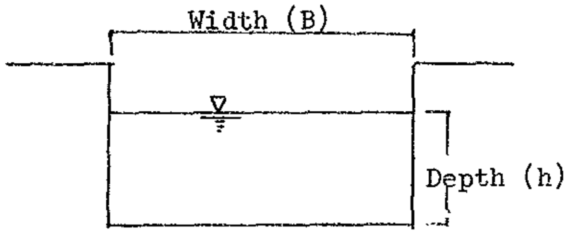
n = roughness

R = Hydraulic radius

i = Gradient

B = Width (m)

h = Depth (m)



Therefore, for friction velocity U_* the following formula was used.

$$U_*^2 = g \cdot i \cdot (n \cdot Q/B \ \ i)^{0,6} \text{.............} \quad (5.3)$$

The unit width of the sediment runoff volume (q_B) was calculated from the these formulas. It was multiplied by the width (B) to calculate the bedload, and the air porosity (λ) was used to obtain the total load.

$$[Q_B] = q_B \times B/(1 - \lambda) \text{ ....} \quad (5.4)$$

(2) making of Hydrographs

(a) For the Case of Annual Runoff

Hydrographs for annual runoff were made by the following procedure.

1) Rainfall intensity was calculated from the daily rainfall taking into account the concentration time. The formula used is found below.

$$r_t = R_{24}/24 \ (24/t)^{2/3} \text{ ....} \quad (5.5)$$

Where:

r_t = Rainfall intensity (mm)

R_{24} = Rainfall for 24 hours ($\neq R_{day}$) (mm)

t = Concentration time (hour)

2) The rainfall intensity from 1 above was used and peak discharge was calculated using an rational formula.

$$Q = 1/3.6 \cdot f \cdot r \cdot A \quad \text{................} \quad (5.6)$$

Where:

Q = Peak discharge (m^3/s)

f = Runoff coefficient

r = Rainfall intensity (mm/hour)

A = Catchment area (Km^2)

From the study results shown in Tables 5.1 and 5.2, runoff coefficient 'f' was considered to be 0.5.

3) The following triangular hydrograph was made based on the peak discharge. This will be known as the daily hydrograph.

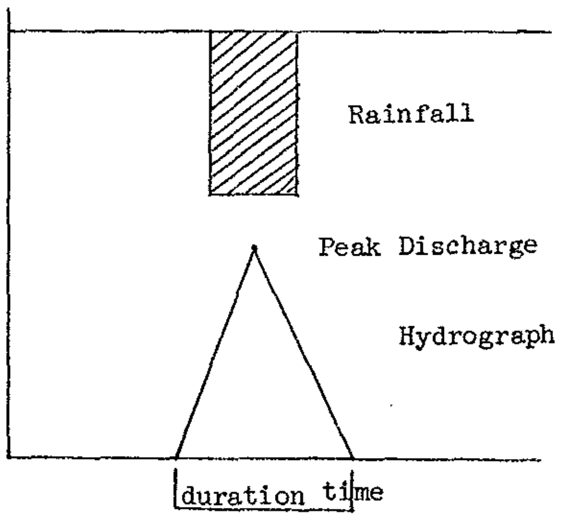


Fig. - 5.4 Making of Hydrograph

The adjustment between the volume of the rainfall and the hydrograph was made by lengthening or shortening the duration time.

The long term hydrograph for nine (9) year is show in Fig. - 5.5.

Table - 5.1 (1) Average monthly Rainfall

Unit : mm

Station	.JAN	.FEB	.MAR	.APR	.MAY	.JUN	.JUL	.AUG	.SEP	.OCT	.NOV	.DEC	.TOTAL
SINGAPARNA	321	312	350	351	257	173	147	129	160	274	316	374	3,231
TASIKMALAYA	360	364	370	266	269	162	170	121	170	324	328	376	3,294
Mean	341	338	360	309	263	168	159	125	165	299	322	375	3,263

NOTE : Data of Tasikmalaya : 1942 - 1985

Data of Singaparna : 1942 - 1985

Souce : Data Obtained from the Institute of Meteorology and Goephisics,

Department of Communications, JAKARTA

Table - 5.1 (2) Runoff Rate at Cipawitra of S. Cikunir

Month (1986)	Discharge [*1] Volume (10^6 m^3) (1)	Rainfall at Singaparna (mm) (2)	Rainfall at Singaparna (10^6 m^3) (3)	Runoff Rate (%) (4)=(1)/(3)	Remarks
JAN	4.86	353	8.70	55.9	
FEB	2.39	229	5.65	42.3	
MAR	5.18	577	14.23	36.4	
APR	4.57	374	9.22	49.6	
MAY	–	297	7.32	–	
JUN	5.36	287	7.08	75.7	
JUL	4.15	387	9.54	43.5	
AUG	3.20	267	6.58	48.6	
SEP	6.19	764	18.84	32.9	
OCT	5.98	390	9.61	62.2	
NOV	5.26	498	12.28	42.8	
DEC	13.60	165	4.07	(71.0)	not adopted
Mean		Total [*2] 4,588		Mean 49.0	

NOTE : (3) = (2) × (Catchment Area of Discharge Obaservation Site24.66 km^2)

= (2) × 24.66 × 10^3

*1 Source : "PENGUKURAN DEBIT SUNGAI CIKUNTEN DAN SUNGAI CIWULAN ..... 1986..... PUSLITBANG AIR"

*2 Average Annual Rainfall (1942 - 1985) = 3,231 mm

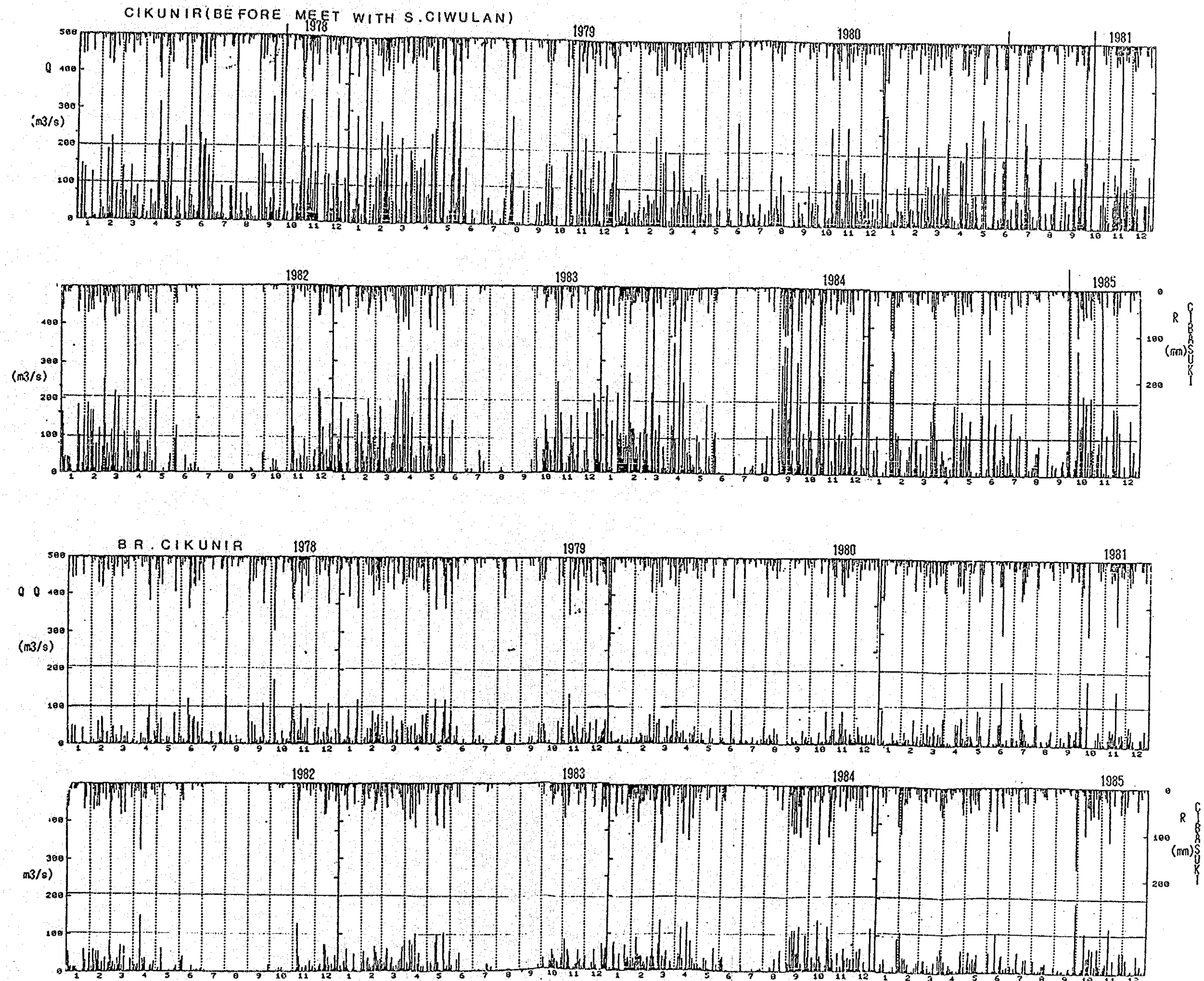


Fig. 5.5 Daily Hydrograph for Runoff Sediment Volume Calculation

(b) *For the Case of Flood*

Because a design hydrograph was already made in Chapter 3, the flood hydrograph was made by adjusting it in proportion to the catchment area.

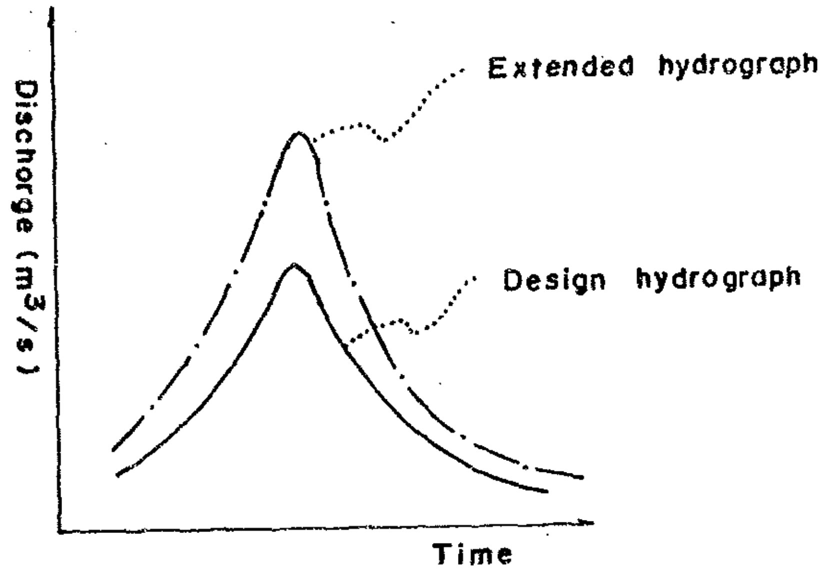


Fig. - 5.6 Extension of Hydrograph

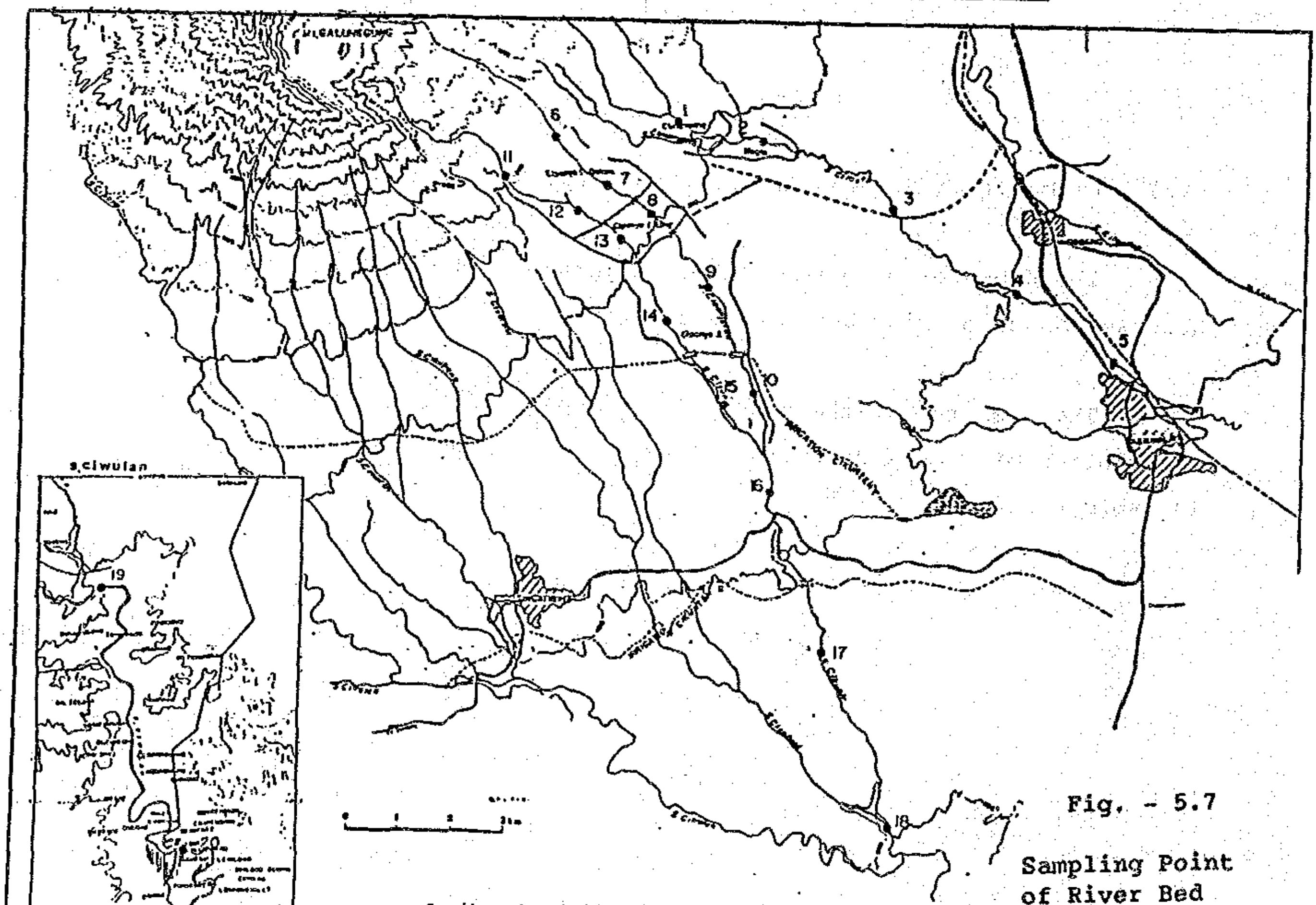
(3) *Diameter of Gravel, Specific Gravity, Dry Density, Air Porosity*

The diameter of gravel, specific gravity, dry density and air porosity were set based on riverbed materials survey.

The diameter of the gravel is the most important parameter in the calculation of runoff sediment volume. The results obtained for it are shown in Table - 5.2.

Table - 5.2 Mean Diameter of Gravel in Each Point of Rivers

Name of River	No.	Mean Diameter	Remarks
Ciloseh	1	11.8 mm	S.P Cimampang
	2	24.8	S.P Negla
	3	17.7	
	4	13.0	
	5	27.1	
Cikunir	6	21.0 mm	S.P Ciponyo I-D
	7	12.9	ditto
	8	10.9	S.P Ciponyo I-L
	9	20.0	S.P Ciponyo II
	10	9.6	ditto
	11	23.5	S.P Ciponyo I-D
	12	18.4	ditto
	13	13.3	S.P Ciponyo I-L
	14	14.4	S.P Ciponyo II
	15	9.5	ditto
	16	12.5	
	17	17.1	
	18	20.9	
Ciwulan	19	18.0 mm	
	20	23.3	



Sampling point of river bed-materials survey

Fig. - 5.7 Sampling Point of River Bed Survey

5.2.2 Calculation of Runoff Sediment Volume

(1) Reference Point and its Specifications

Table - 5.3 shows the reference point for the calculation of the sediment runoff volume and other specifications concerning the point.

The location of the reference point is shown in Fig. - 5.8 and in Fig. - 5.9 and 5.10 are shown longitudinal profiles of the major - rivers.

Table - 5.3 Specifications for Annual Runoff Calculation and Annual Runoff Sediment Volume

River	No.	Ref.Point	Area(km^2)	Concent. Time	Gradient	Width	Remarks
Cibanjaran	1	ciponyo I dalam	6.77	0.6 hr	0.0340	30 m	s.g=2.70,d.d=1.63
	2	ciponyo I luar	7.62	0.7	0.0340	40	p=0.39,dm=15mm
Chikunir	3	ciponyo I dalam	7.11	0.6	0.0259	30	s.g=2.70,d.d=1.66
	4	ciponyo I luar	7.90	0.7	0.0259	40	p=0.39,dm=15mm
	5	cikunir bridge	24.66	1.0	0.0165	35	
	6	conf. s. ciwulan	84.42	1.7	0.0130	75	
Ciloseh	7	cimampang	14.56	0.8	0.0180	25	s.g=2.70,d.d=1.71
	8	negla	32.07	1.1	0.0125	40	p=0.37,dm=17mm
	9	ciloseh bridge	38.16	1.7	0.0106	40	
	10	conf. s. citanduy	63.64	2.3	0.0065	35	
Cisaruni	11	nagras	6.26	0.5	0.0211	30	p=0.38,dm=15mm
Cikupang	12	kondang	3.40	0.6	0.0206	25	p=0.38,dm=15mm
Cimerah	13	bojungpel	10.95	0.8	0.0203	20	p=0.38,dm=15mm
Ciwulan	14	BDM 16	297.5	7.1	0.0066	65	p=0.43,dm=20mm
	15	BDM 13	535.3	8.8	0.0046	125	
	16	BDM 10	827.4	11.9	0.0034	140	
	17	BDM 7	906.9	12.7	0.0028	135	p=0.43,dm=10mm
	18	BDM 4	1025.3	13.9	0.0018	115	
	19	BDM 2	1044.0	14.1	0.0011	160	

Note)

s.g : Specific Gravity　　d.d : Dry Density

p : Porosity　　dm : Mean Diameter

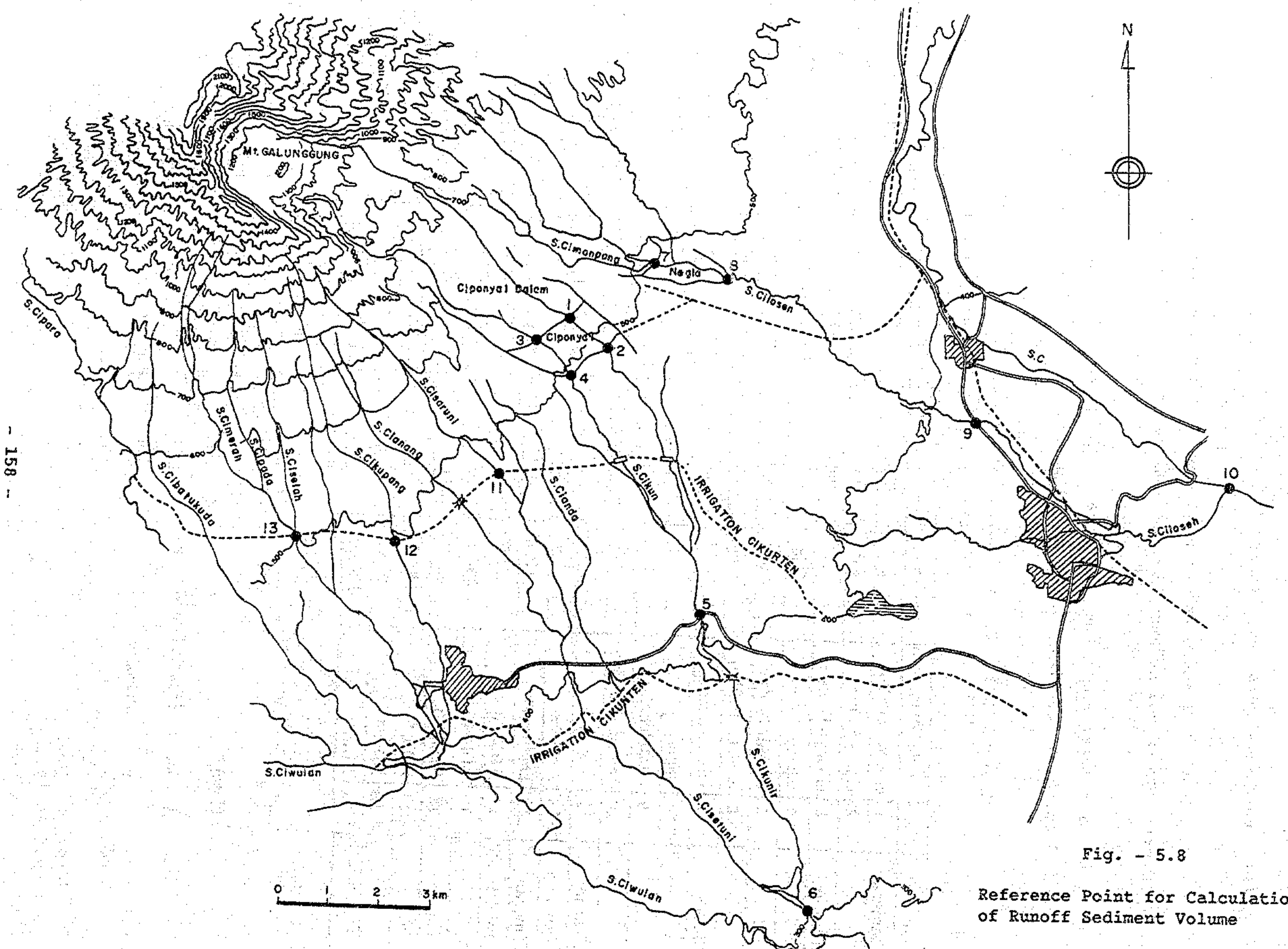


Fig. - 5.8

Reference Point for Calculation of Runoff Sediment Volume

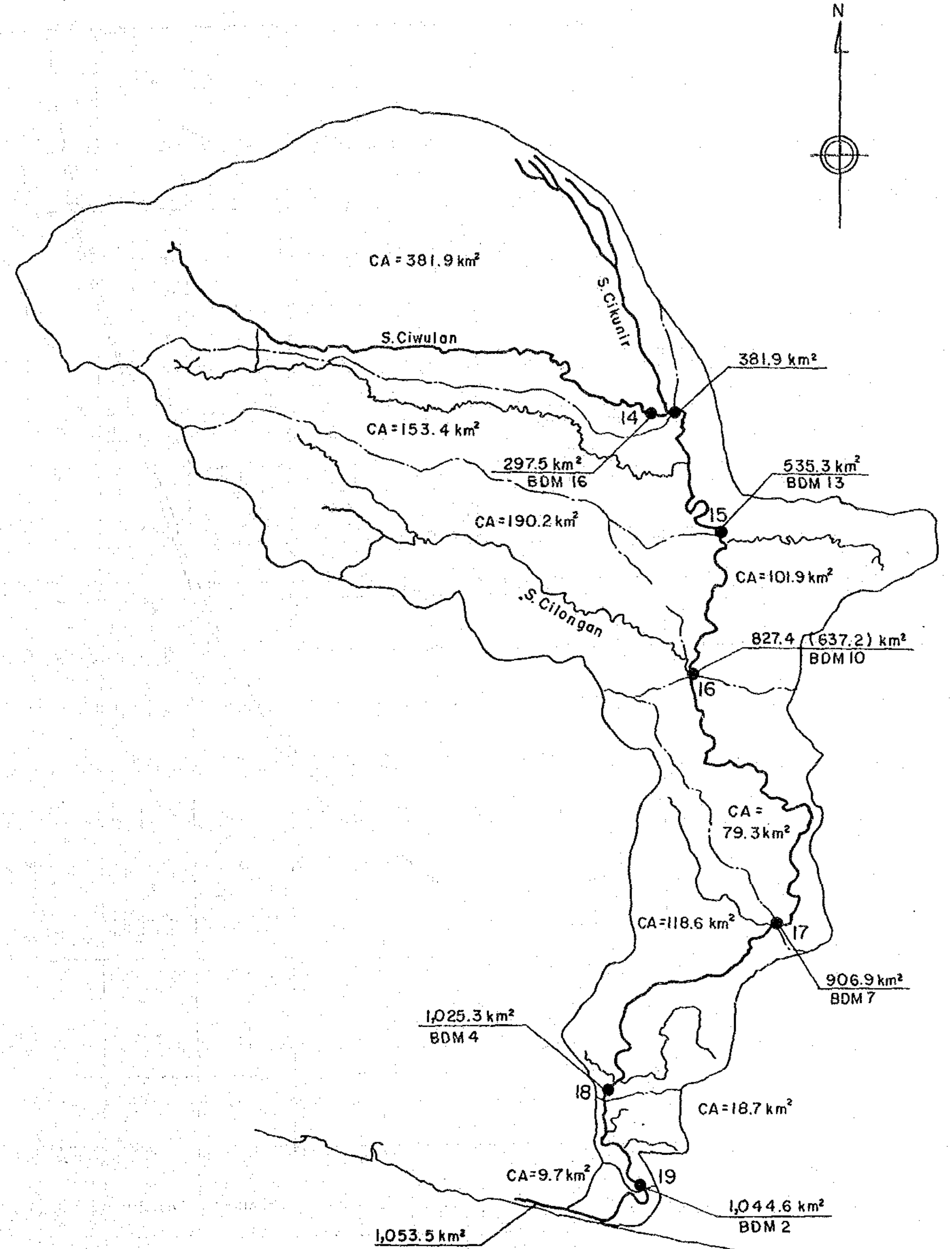


Fig. - 5.9 Reference Point for Calculation of Sediment Volume

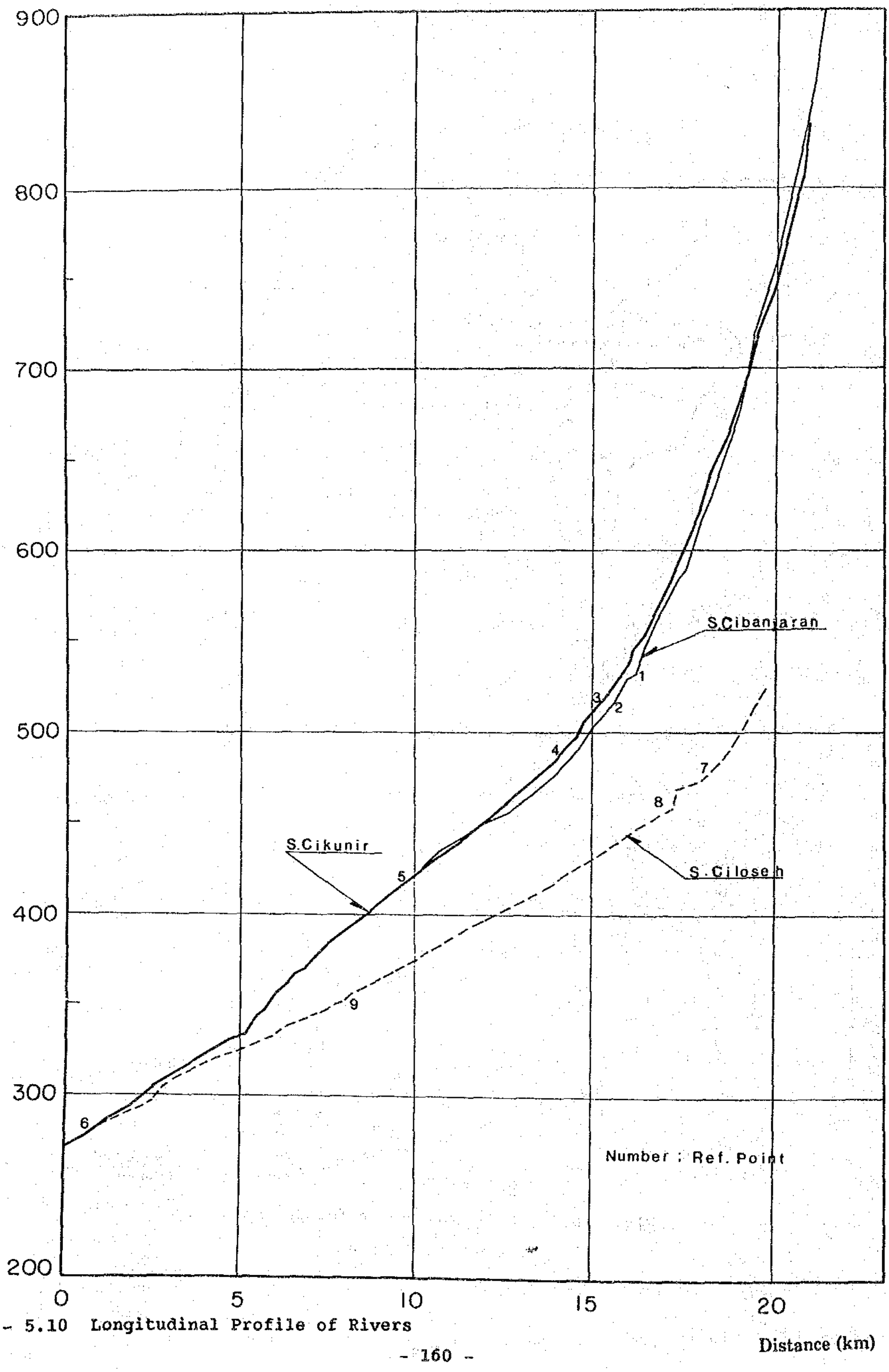


Fig. - 5.10 Longitudinal Profile of Rivers

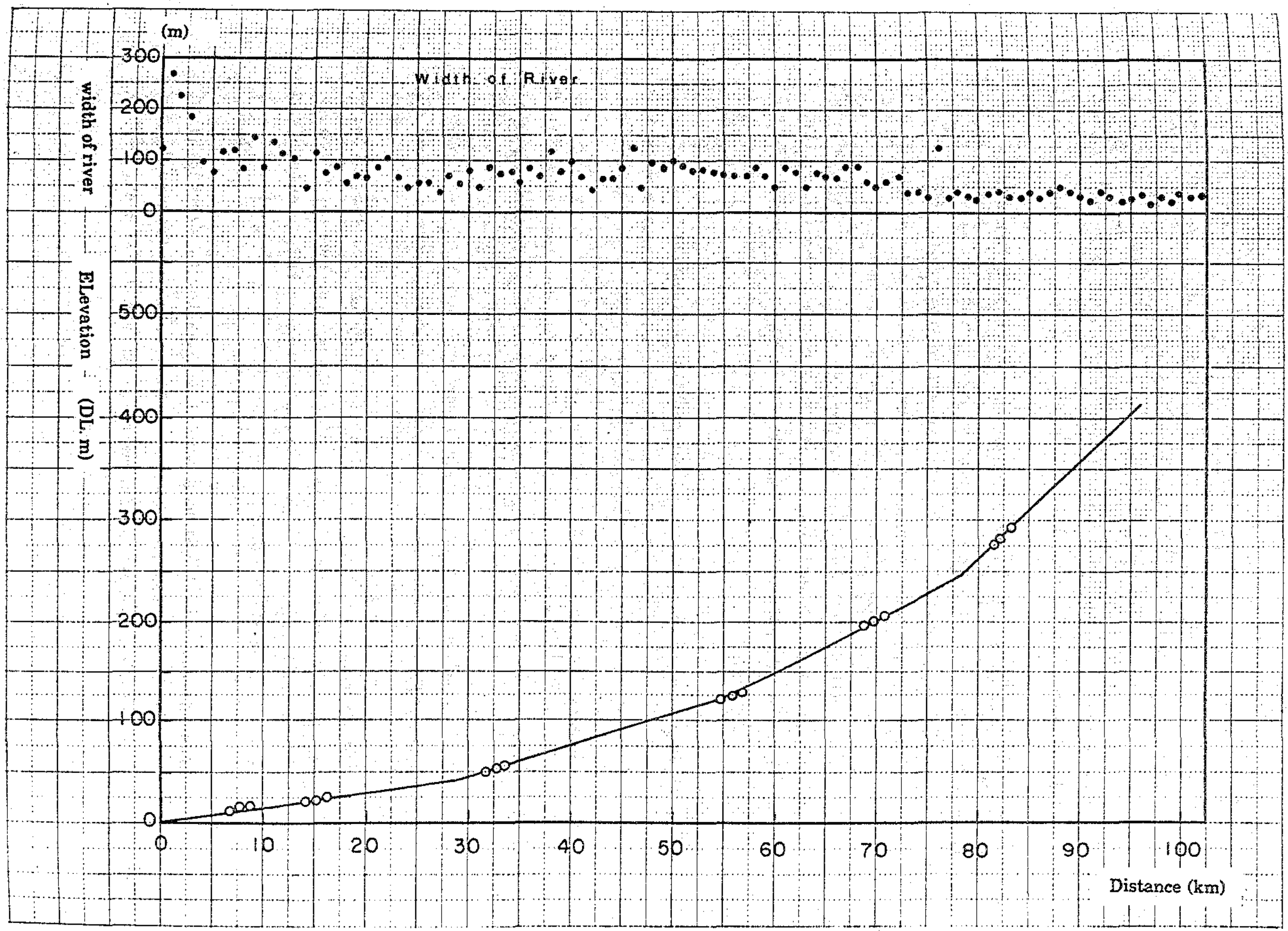


Fig. - 5.11 Longitudinal Profile of S. Ciwulan

(2) Annual Runoff Sediment Volume

The results obtained from calculation of the annual runoff sediment volume for S. Cikunir, S. Cibanjaran and S. Ciwulan.

The transportation capabilities for each river in Tables 5.4 and 5.5 are summarized as follows:

a. The average annual runoff sediment volume for S. Cikunir is approximately 410 $x10^3m^3$ (sediment concentration 1.7%) at the sandpocket Ciponyo I Luar (water way), approximately 680 $x10^3m^3$ (0.8%) at the Cikunir Bridge, and approximately 1,740 $x10^3m^3$ (0.6%) at the confluence with S. Ciwulan. Though its transportation capabilities increase as one moves downstream, the concentration of sediment becomes smaller, and therefore, the sediment transportation capabilities of the river decrease relatively.

b. The following results were obtained for S. Ciwulan : 1,550 $x10^3m^3$ at BDM 16 (Tonjong) before the confluence with S. Cikunir; 2,560-2,570 $x10^3m^3$ at BDM 13 (Sukaraja) and BDM 10 (Karsagalih) in the upper reaches; and 3,400 $x10^3m^3$ at BDM 7 (Sukarame) in the middle reaches. However, as one approaches the lower reaches (mouth of the river), the transportation capability becomes smaller. It is 2,160 $x10^3m^3$ at BDM 4 (Cikijing) and 900 $x10^3m^3$ at BDM 2 (Purungsela) near the mouth of the river. This makes it close to 1/3 that of the upper reaches.

c. The transportation capabilities of S. Ciwulan are summarized by BDM 4 and approximately 2,200 $x10^3m^3$ excluded for BDM 16, which is above the confluence with S. Cikunir, or for BDM 2, which is near the mouth of the river.

d. The average annual sediment runoff volume for S. Cibanjaran is 550 $x10^3m^3$ at Ciponyo I Dalam and 610 $x10^3m^3$ at Ciponyo I Luar. The sediment concentration is around 2.3 - 2.4%.

Table - 5.4 Runoff Volume of Water and Sediment Runoff Volume

River name	No.	Reference Point	Item	1978	1979	1980	1981	1982	1983	1984	1985	1986	Mean
Cibanjaran	①	Ciponyo I Dalam (6.77 km^2)	V	16,030	15,760	9,640	14,450	9,330	11,850	15,970	12,920	18,040	13,780
			V_B	(639)	(633)	(374)	(573)	(371)	(473)	(639)	(517)	(727)	(550)
	②	Ciponyo I Luar (7.62)	V	18,040	17,740	10,850	16,260	10,500	13,340	17,980	14,540	20,300	15,510
			V_B	(708)	(703)	(409)	(635)	(411)	(523)	(711)	(573)	(811)	(609)
Cikunir	③	Ciponyo I Dalam (7.11)	V	16,830	16,550	10,130	15,170	9,790	12,440	16,770	13,570	18,950	14,470
			V_B	(481)	(478)	(278)	(431)	(279)	(355)	(483)	(390)	(551)	(414)
	④	Ciponyo I Luar (7.90)	V	18,700	18,400	11,250	16,860	10,880	13,830	18,640	15,080	21,050	16,080
			V_B	(522)	(520)	(296)	(467)	(301)	(384)	(525)	(423)	(602)	(449)
	⑤	Cikunir Br. (24.66)	V	58,380	57,410	35,120	52,630	33,970	43,160	58,180	47,060	65,7[illegible]	50,180
			V_B	(789)	(784)	(455)	(707)	(453)	(583)	(792)	(639)	(903)	(679)
	⑥	Conf. S. Ciwulam (84.42)	V	199,870	196,530	120,210	180,150	116,290	147,740	199,160	161,120	224,940	171,780
			V_B	(2,019)	(2,009)	(1,154)	(1,809)	(1,169)	(1,489)	(2,030)	(1,635)	(2,321)	(1,737)
Ciwulan	⑭	BDM 16 (297.5)	V	704,080	629,530	423,610	634,820	409,780	520,590	701,790	567,740	792,640	605,310
			V_B	(1,804)	(1,832)	(908)	(1,605)	(1,019)	(1,303)	(1,865)	(1,458)	(2,168)	(1,551)
	⑮	BDM 13 (535.3)	V	1,267,320	1,246,180	762,270	1,142,330	737,380	936,780	1,262,830	1,021,620	1,426,310	1,089,220
			V_B	(3,009)	(3,066)	(1,449)	(2,667)	(1,678)	(2,145)	(3,131)	(2,421)	(3,651)	(2,579)
	⑯	BDM 10 (827.4)	V	1,958,870	1,926,190	1,178,220	1,765,670	1,139,740	1,447,950	1,951,920	1,579,090	2,204,610	1,683,580
			V_B	(2,994)	(3,058)	(1,373)	(2,646)	(1,646)	(2,100)	(3,140)	(2,397)	(3,672)	(2,559)
	⑰	BDM 7 (906.9)	V	2,146,610	2,110,800	1,291,140	1,934,100	1,248,980	1,586,720	2,139,000	1,730,440	2,415,900	1,844,940
			V_B	(3,940)	(3,959)	(2,135)	(3,520)	(2,258)	(2,883)	(4,009)	(3,198)	(4,625)	(3,391)
	⑱	BDM 4 (1025.3)	V	2,427,400	2,386,900	1,460,300	2,187,990	1,412,350	1,794,280	2,418,790	1,956,790	2,731,910	2,086,270
			V_B	(2,508)	(2,533)	(1,314)	(2,237)	(1,429)	(1,826)	(2,572)	(2,032)	(2,978)	(2,159)
	⑲	BDM 2 (1044.0)	V	2,471,670	2,430,430	1,486,660	2,227,900	1,438,110	1,827,000	2,462,900	1,992,470	2,781,740	2,124,320
			V_B	(1,054)	(1,077)	(463)	(930)	(571)	(727)	(1,112)	(840)	(1,303)	(897)

V : Run off volume of Water ($\times 10^3 m^3$)
V_B : Sediment Run off volume ($\times 10^3 m^3$)

Table - 5.5 Mean Annual Sediment Runoff Volume

River	NO.	Ref. Point	Area (km^2)	Annual Runoff of water	Sediment *2) Runoff ($\times 10^3 m^3$)	Sediment *1) Concentration (%)
Cibanjaran	1	Ciponyo I dalam	6.77	13,780	550 [336]	2.4
	2	Ciponyo I Luar	7.62	15,510	609 [371]	2.3
Cikunir	3	Ciponyo I dalam	7.11	14,470	414 [253]	1.7
	4	Ciponyo I Luar	7.90	16,080	449 [274]	1.7
	5	Cikunir Bri	24.66	50,180	679 [414]	0.82
	6	Conf. S. Ciwulan	84.42	171,780	1,737 [1,060]	0.61
Ciwulan	14	BDM 16	297.5	605,310	1,551 [884]	0.15
	15	BDM 13	535.3	1,089,220	2,579 [1,470]	0.13
	16	BDM 10	827.4	1,683,580	2,559 [1,459]	0.09
	17	BDM 7	906.9	1,844,940	3,391 [1,933]	0.10
	18	BDM 4	1,025.3	2,086,270	2,159 [1,231]	0.06
	19	BDM 2	1,044.0	2,124,320	897 [511]	0.02

*1) Sediment Concentration (%) = Sediment Runoff / (Annual Runoff + Sediment Runoff) × 100%

*2) Sediment Volume excluded Void

A representative diameter of gravel was set for these results based on studies of riverbed materials. The average annual transportation capabilities were calculated for the main reference point changing the diameters of the gravel and the results of those calculations are shown in Table - 5.6.

This leads to the following conclusions. (refer to Fig. - 5.12)

a. For S. Cikunir : 450-310 $x10^3m^3$ (sediment concentration 1.9 - 1.3%) within the range dm = 10 - 30 mm at *Ciponyo I Dalam* ; 1,930-1,260 $x10^3m^3$ (0.7 - 0.4%) within the same range at points above the confluence with S. Ciwulan.

b. *On* S. Ciwulan, in contrast to the 1,470 $x10^3m^3$ with dm = 5 mm at BDM 2, 90 $x10^3m^3$ when dm = 30 mm. The difference in the diameter of the gravel causes a great difference in transportation capabilities. At BDM 13 in the upper reaches the transportation capability is 3,800-1,700 $x10^3m^3$ (0.2 - 0.1%) within the range dm = 10 - 30 mm.

Table - 5.6 Mean Annual Sediment Runoff Volume for Each Diameter

River name	Reference Point	dm (mm)	Runoff Volume (×10^3m^3)	Sediment Runoff (×10^3m^3)	Sediment Density (%)
S. Cikunir	Meeting with S. Cisaruni (C. A=84.42km^2)	10	171,780	1,926 [1,175]	0.68
		15	171,780	1,737 [1,060]	0.61
		20	171,780	1,563 [953]	0.55
		30	171,780	1,258 [767]	0.44
	Ciponyo I Luar (C. A=7.9km^2)	10	16,080	502 [306]	0.87
		20	16,080	400 [244]	1.49
		30	16,080	316 [193]	1.19
	Ciponyo I Dalam (C. A=7.11km^2)	10	14,470	454 [277]	1.88
		20	14,470	376 [229]	1.56
		30	14,470	310 [189]	1.29
S. Ciwulan	BDM_2 (C. A=1,044km^2)	5	2,124,320	1,470 [838]	0.04
		10	2,124,320	897 [511]	0.02
		20	2,124,320	303 [172]	0.008
		30	2,124,320	88 [50]	0.002
	BDM_{13} (C. A=434.3km^2)	10	1,089,220	3,781 [2,155]	0.20
		20	1,089,220	2,579 [1,470]	0.14
		30	1,089,220	1,723 [982]	0.09

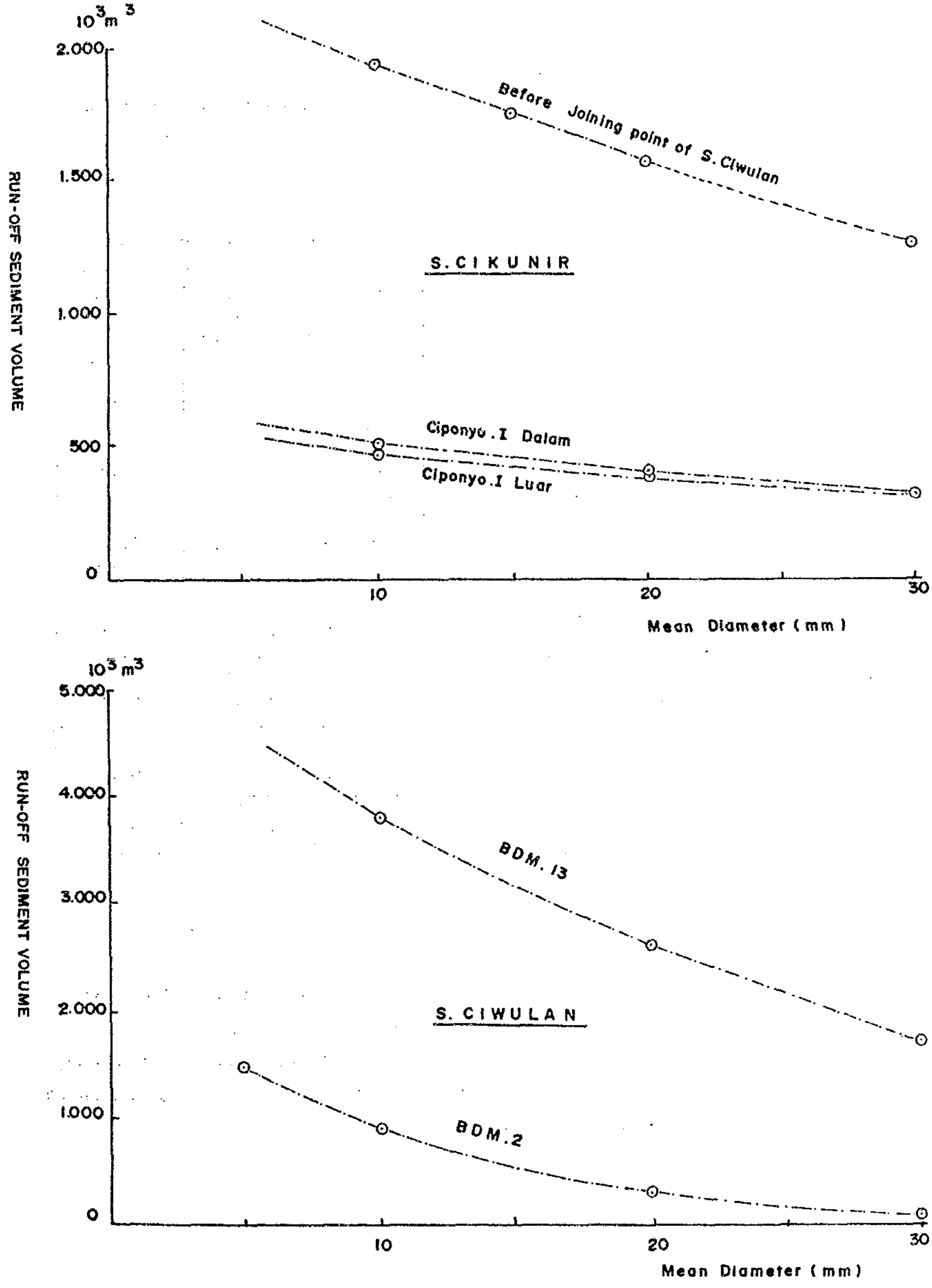


Fig. - 5.12 Sediment Runoff Volume in Each Mean Diameter

(3) Runoff Sediment Volume by Flood

The results of calculations to understand the runoff sediment volume by flood in the rivers dealt with in the sediment control plan are shown in Table - 5.7.

Table - 5.7 Runoff Volume and Sediment Runoff volume by Flood

River	No.	Ref. Point	Area (km^2)	Runoff Volume (x 10^3m^3)	Sediment Runoff (x 10^3m^3)	Sediment Density
Ciloseh	7	Cimampang	14,56	3,830	55 (20)	0.52
	8	Negla	32.07	8.440	78 (29)	0.34
	9	Ciloseh Br.	38.16	10.920	84 (31)	0.28
	10	Conf. S. Citan-duy	63.64	18.210	79 (29)	0.16
Cisaruni	11	Nagras	6.26	2.000	35 (13)	0.65
Cikupang	12	Kondang	3.40	1.090	17 (6)	0.55
Cimerah	13	Bojongpel	10.95	3.500	59 (22)	0.62

According to Table - 5.7, the sediment concentration is 0.5% in the upper reaches of S. Ciloseh. it gradually decreases until it becomes approximately 1/2 that figure, 0.2%, before the confluence with S. Citanduy. The sediment concentration is around 0.5 - 0.7% for S. Cisaruni, S. Cikupang and S. Cimerah in the southern basin.

5.3 Riverbed Deformation Calculation

Riverbed deformation calculations are made by inputting the hydrograph and the sediment volume, calculating the sediment balance (scouring, sedimentation, equilibrium riverbed etc.) and then calculating the deformation volume of the riverbed at the time a flood has ended.

This study was executed in order to grasp the longitudinal deformation tendencies (aggradation, degradation) of the riverbed, and the sedimentation tendencies in the sandpocket.

5.3.1 Calculation Method

Riverbed deformation calculations are made by simultaneously solving the following 3 formulas.

1) Stream motion equations (calculation of the tractive force)
2) Sediment discharge formulas (calculation of the runoff sediment - volume)
3) Sediment continuity equations (calculation of the amount of riverbed deformation)

Fig. - 5.13 shows the flow of calculations. The items shown below is a detailed explanation of each calculation.

(1) Calculation of the Tractive Force

It is assumed that flow type of river with steep gradient in the mountain area is regarded as quasi uniform flow. Hydraulic calculation is made using the Manning formula.

The procedure for calculating the tractive force is as follows:

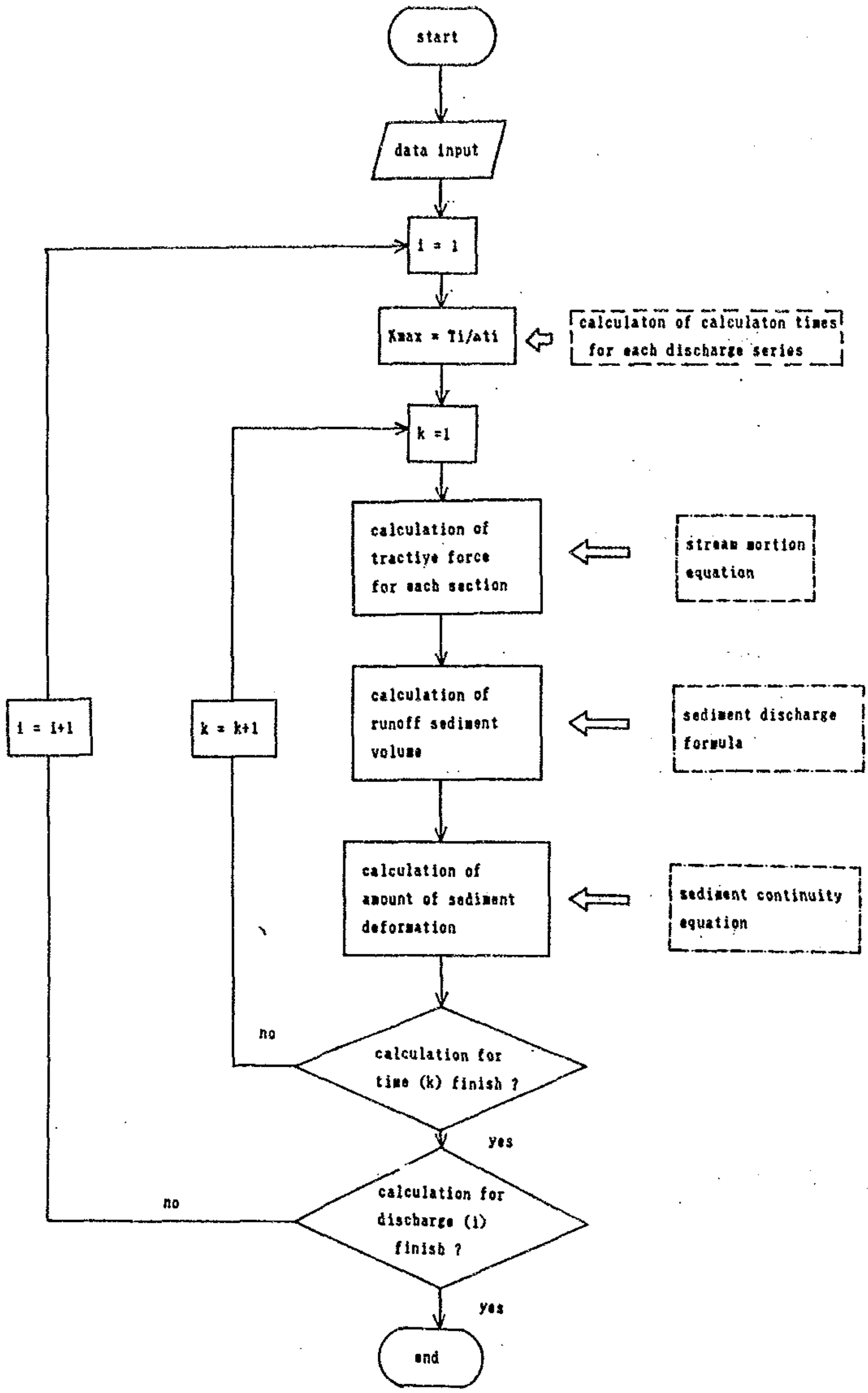


Fig. - 5.13 Calculation Flow of River Bed Deformation

1) Calculation of the River Gradient of Cross Section 'j'

The river gradient S_j for cross section 'j' is calculated using the formula below.

$$S_j = (E_j - E_{(j+1)} / \Delta x_j) \quad .... \quad (5.7)$$

The suffix refers to the number of the cross section as counted from the upper reach. In Formula 5.7, the gradient of downstream section from cross section 'j' is calculated. (See Fig. - 5.14)

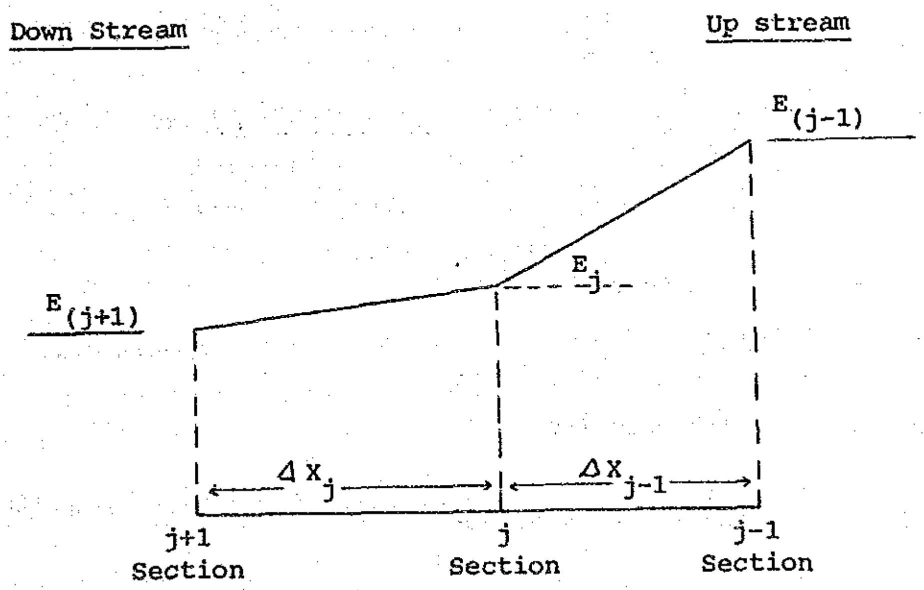


Fig. - 5.14 Longitudinal Model

2) Calculation of the Depth of Cross Section 'j'

The depth h_j of cross section 'j' is calculated using the Manning formula below.

$$h_j = \left(\frac{Q_j \cdot n_j}{B_j \cdot S_j^{1/2}}\right) \quad .... \quad (5.8)$$

Where:

- h = depth of water (j : suffix)
- Q = discharge
- n = roughness
- B = river width
- S = gradient

3) Calculation of Tractive Force and Friction Velocity

Tractive force τ_j and friction velocity u_{*j} are calculated by the following formulas.

$$\tau_j = \rho \cdot g \cdot h_j \cdot S_j \quad \text{.................. (5.9)}$$

$$U_{*j} = \frac{\tau_j}{\rho} = g \cdot h_j \cdot S_j \quad \text{............. (5.10)}$$

Where:

- τ = tractive force
- ρ = density of water
- g = acceleration of gravity
- U_* = friction velocity

(2) Calculation of the Runoff Sediment

The type of the sediment flow dealt with in this study is

1) Debris Flow
2) Bedload Flow

The mudflow is the intermediate flow between the debris flow and the bedload flow. It is difficult to determine the area section in which mudflow when calculating riverbed deformation. Its range is also very short. For these reasons it was not taken account of in calculations.

The following is an explanation of the runoff sediment formula used in the calculations.

1) Calculation of the Debris Flow

The Takahashi formula was used for the debris flow.

$$C_d = \frac{\rho \cdot \tan\theta}{(\sigma - \rho) \cdot (\tan\theta - \tan\theta)} \quad \ldots\ldots\ (5.11)$$

Where:

C_d = the bulk concentration of the debris flow as defined by the following equation.

$C_d = Q_B / (Q_W + Q_B)$

Q_B, Q_W = runoff sediment volume, flow for water only. (m^3/S)

σ, ρ = density of gravel and water. (t/m^3)

θ = Internal friction angle. (°)

$\tan\theta$ = riverbed gradient. The S_j of Formula 5.7 is used in this calculation model.

2) Calculation of the Bedload Flow

The Ashida/Takahashi/Mizuyama Formula below was used to calculate the bedload.

$$q_B / (\sigma/\rho - 1).g.d^3 = 12 \cdot \tau_*^{1.5}.(1 - 0.85 \cdot \frac{\tau_{*c}}{\tau_*}).(1 - 0.92 \cdot \frac{\tau_{*c}}{\tau_*}) \quad \ldots.\ (5.12)$$

Where:

q_B = sediment volume per unit width/unit time

τ = Non-dimensional tractive force expressed by the formula below

$\tau_* = U_* /^2 (\sigma/\rho - 1)\ g \cdot d \cdot$ .... (5.13)

τ_{*c} = Non-dimensional critical tractive force

τ_{*c} = 0.04 (for flat bed of uniform grain size)

d = mean diameter of gravel (m)

(3) Calculation of Riverbed Deformation

When the discharge of runoff sediment has been calculated for each cross section for a specific time, the riverbed deformation for each cross section is calculated using the following formula (5.14) which differentiates the continuity formula and the continuity formula of the runoff sediment.

$$\frac{\partial z}{\partial t} + \frac{1}{B.(1-\lambda)} \cdot \frac{Q_{\partial B}}{\partial z} = 0 \quad \ldots\ldots (5.14)$$

$$\frac{(Z_{n+1} - Z_n)_j}{\Delta x_{n+1}} + \frac{1}{B_j \cdot (1-\lambda)} \cdot \frac{Q_{z(j-1)} - Q_{Bj}}{\Delta XL_j} = 0 \quad \ldots\ldots (5.15)$$

In these formulas suffix 'j' refers to the cross section and suffix 'n' refers to the time.

Z = elevation (EL.m)

Q_Z = runoff sediment discharge (m^3/S)

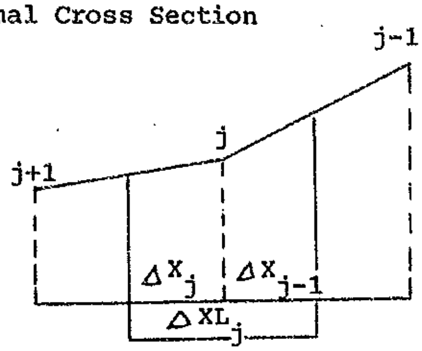
B = width (m)

λ = porosity

Δt = time (Sec)

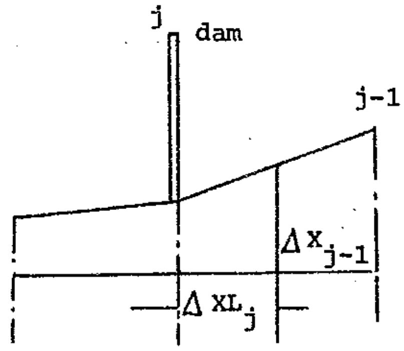
ΔXL_j = section represented by cross section 'j' and set as follows.

a. Normal Cross Section



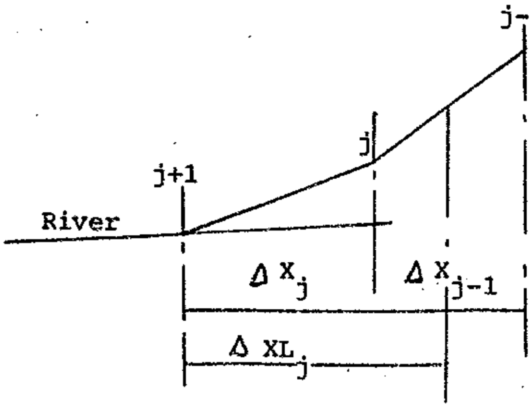
$$\Delta XL_j = \frac{1}{2} \cdot (\Delta X_j + \Delta X_{j-1})$$

b. Dam (in case of no deposited sediment)



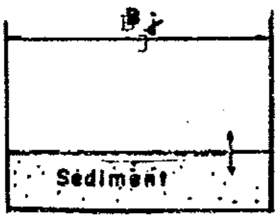
$$\Delta XL_j = \frac{1}{2} \cdot \Delta X_{j-1}$$

c. Confluence point



$$\Delta XL_j = \Delta X_j + \frac{1}{2} \cdot \Delta X_{j-1}$$

Because the cross section of river is imagined to be rectangular section it is assumed that sediment deforms uniformly in the river.



5.3.2 Setting of Calculation Conditions and Input Data

(1) Setting of Conditions for Calculation

The calculation conditions set for the riverbed deformation calculation for S. Cikunir and S. Ciwulan are shown below.

a. Setting of Model

The calculation model for S. Cikunir and S. Ciwulan is shown in Fig. - 5.15.

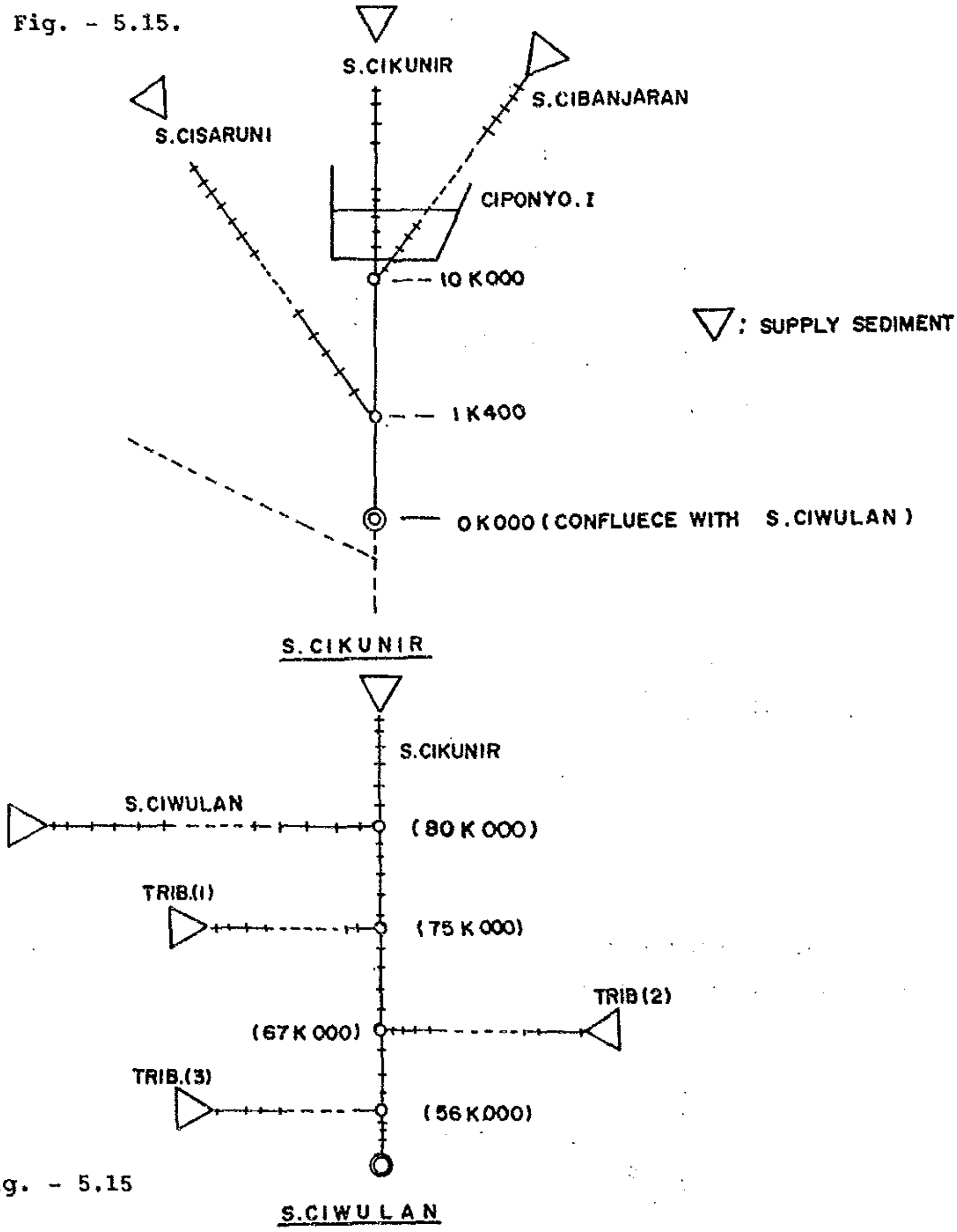


Fig. - 5.15

Calculation Model for S.Cikunir and S.Ciwulan

b. Supply Pattern of Sediment

The supply pattern of the sediment is similar to the flood hydrograph with debris supplied from the top of upper stream.

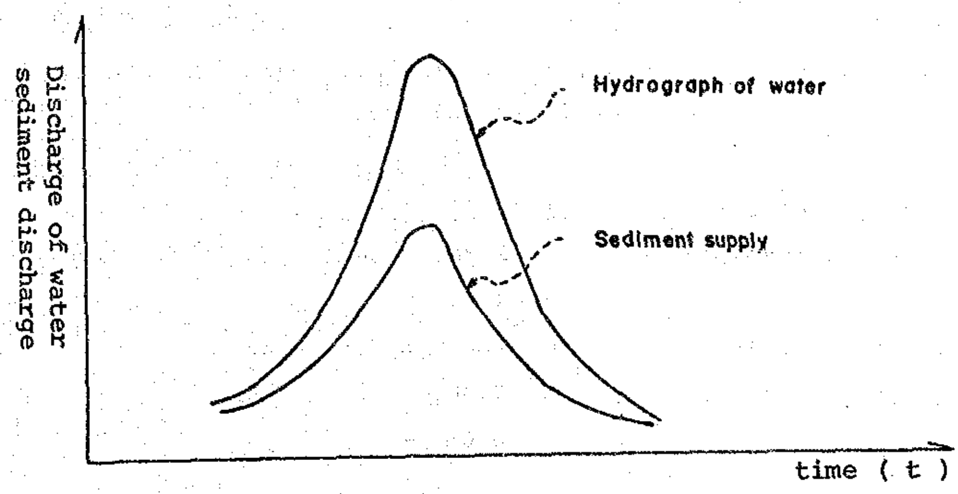


Fig. - 5.16 Supply Pattern of Sediment

c. Design Flood Hydrograph

A hydrograph in which the rainfall for September 16, 1986 was extended by the probable rainfall (daily rainfall = 250 mm/day) was used for the design flood hydrograph of calculation.

(2) Input Data

a. Cross Section Data

Based on the results of a topographic survey performed on S. Cikunir, by a JICA study team, the mean width of the channel and the mean channel elevation were input at a 200m pitch. However, because the cross section data for S. Ciwulan was not as precise as that for S. Cikunir, it was input at a 1 km pitch.

b. Diameter of Gravel

The diameter was considered to be the same for all gravel and the mean diameter (dm) was employed.

c. Other Input Data

Other input data for calculation is as follows:

bulk density of sediment	=	0.65
density of gravel (sediment)	=	2.70
density of water	=	1.0
internal friction angle	=	tan Ø = 0.6
specific gravity of gravel	=	2.70
roughness	=	0.04

5.3.3 Calculation Results

(1) Condition of Deposited Sediment for Design Hydrograph in Sandpocket Ciponyo I and Ciponyo II

The calculation results of deposited sediment for design hydrograph in sandpocket Ciponyo I and Ciponyo II, and the runoff sediment volume are shown in Table - 5.8.

The sediment supply conditions for the calculation of runoff sediment volume and deposited sediment volume are as follows.

1) CASE 1 1,380 x 10^3 m^3 (Design inflow sediment volume)
2) CASE 2 700
3) CASE 3 500
4) CASE 4 300

Table - 5.8 Sediment Balance by Calculation of Sediment Deformation

(unit: 10^3m^3)

Item No.		Calculation Case: Case 1	Case 2	Case 3	Case 4
1	Cikunir (6B)	713	443	295	177
2	Cibanjaran (16 AD)	666	307	205	123
3	Ciponyo I Dalam (Cikunir)	94	94	94	94
4	Ciponyo I Dlm (Cibanjaran)	105	105	105	105
5	Ciponyo I Luar (Cikunir)	73	73	73	73
6	Ciponyo I Luar (Cibanjaran)	104	104	104	104
7	Cikunir Bridge	142	142	142	142
8	Cisaruni	126	126	126	126
9	Meeting with Cisaruni	312	312	312	312
10	Cikunir	339	339	339	339
Sediment Balance	(1 + 2) - (3 + 4)	1.180	551	301	101
	(3 + 4) - (5 + 6)	22	22	22	22
	(5 + 6) - 7	35	35	35	35
	(7 + 8) - 9	-44	-44	-44	-44
	9 - 10	-27	-27	-27	-27

The calculation results for the 1,380 x10^3m^3 case in Table - 5.8 are found in Fig. - 5.17 as a schematic diagram.

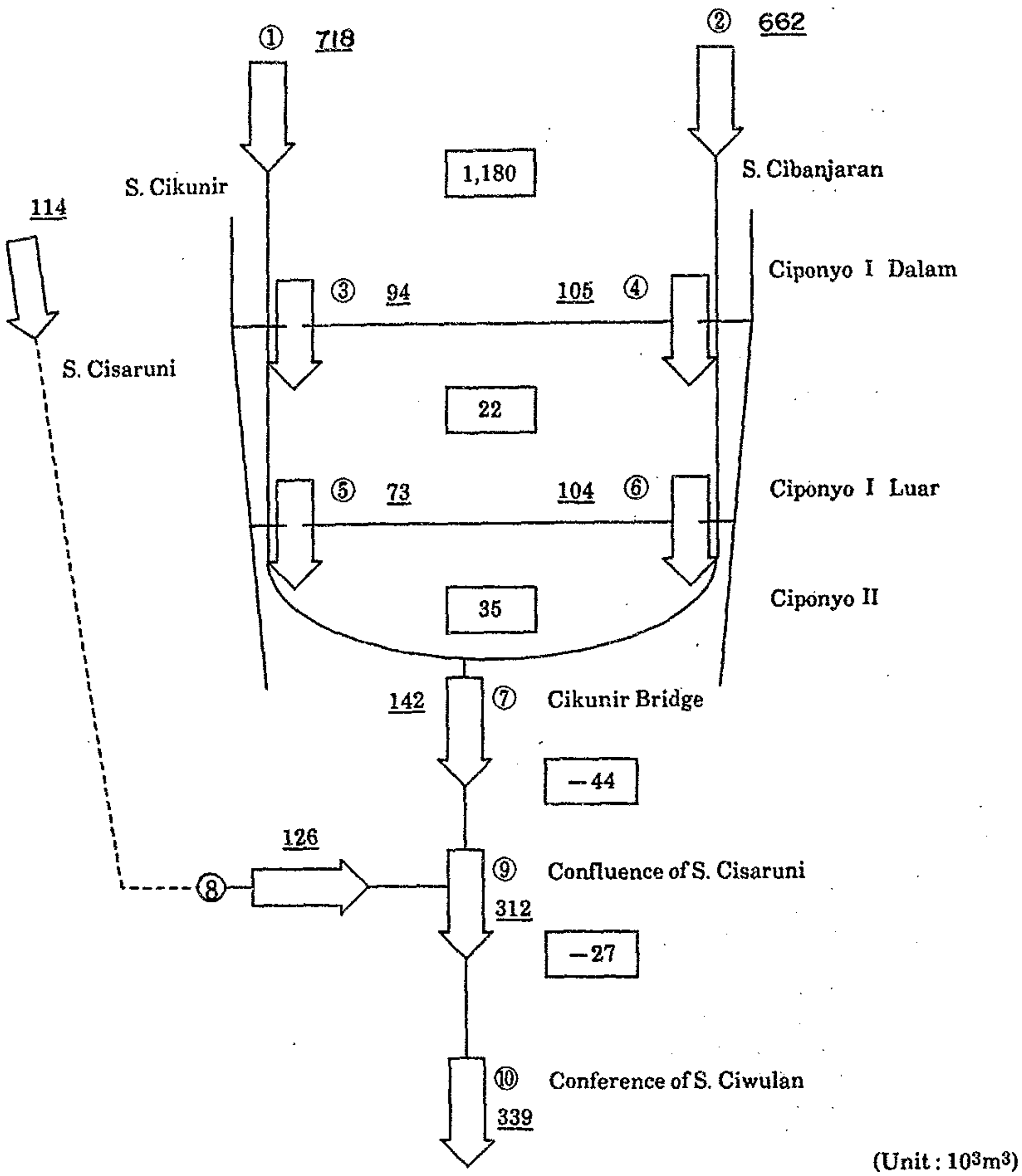


Fig. - 5.17

Sediment Balance by Calculation of River Bed Deformation at S. Cikunir

According to the calculation results, the sediment balance downstream from the point of Ciponyo I Dalam is all the same amount because of the sediment transportation capability at all points is controlled by that of Ciponyo I Dalam.

The sediment concentration at main base point are arranged as follows in Table - 5.9 on the basis of the calculation results of riverbed deformation.

Table - 5.9 Sediment Concentration of Flood Discharge (50 years of Return Period)

Item	River	Ciponyo I Dalam	Ciponyo I Luar	Cikunir Bridge
Runoff Sediment Volume (m^3) (1)	S. Cikunir	60,800	47,500	92,300
	S. Cibanjaran	68,300	67,600	-
	Total	129,100	115,100	92,300
Flood Discharge Volume (m^3) (2)	S. Cikunir	3,180,000	3,570,000	14,500,000
	S. Cibanjaran	3,260,000	3,920,000	-
	Total	6,440,000	7,490,000	14,500,000
Total Volume (m^3) (3)=(1)+(2)	S. Cikunir	3,240,800	3,617,500	14,592,300
	S. Cibanjaran	3,328,300	3,987,600	-
	Total	6,569,100	7,605,100	14,592,300
Sediment Concentration (%) (4)=(1)/(3)	S. Cikunir	1.9	1.3	0.6
	S. Cibanjaran	2.1	1.7	-
	Total	2.0	1.5	0.6

The sediment concentration is 2.0% at Ciponyo I Dalam, is 1.5% at Ciponyo I Luar and is 0.6% at Cikunir Bridge.

(2) Changes of Longitudinal Profile

a. S. Cikunir

Fig. - 5.18 shows the conditions of the riverbed gradient before and after riverbed deformation calculations.

At the top of Fig. - 5.18 is shown the supply sediment volume, in the middle the longitudinal profile of the riverbed before and after riverbed deformation calculation, and in the bottom the sediment balance.

On S. Cikunir, downstream of Ciponyo II after flooding, the deformation tendencies in the longitudinal profile of the riverbed, and the sedimentation tendencies are as follows:

1) The section 3 km from the confluence with Cibanjaran River, and the 5.0 km - 3.0 km are sections in which the riverbed tends to be scoured (degradation). On the other hand, the section between 6k200 and 5k200 and the section between 2k800 and 2k200 are sections in which there tends to be an aggradation of the riverbed.

2) The mean sediment concentration is around 1% near the confluence with S. Cibanjaran (10.4 km), 0.6% at the Cikunir Bridge - (8.7 km), 0.4% near 5.0 km and 0.5% near 2.0 km.

b. S. Ciwulan

Because cross section and longitudinal drawings have only been obtained for a total of 6 out of 90 km on S. Ciwulan, the longitudinal profile was set as follows.

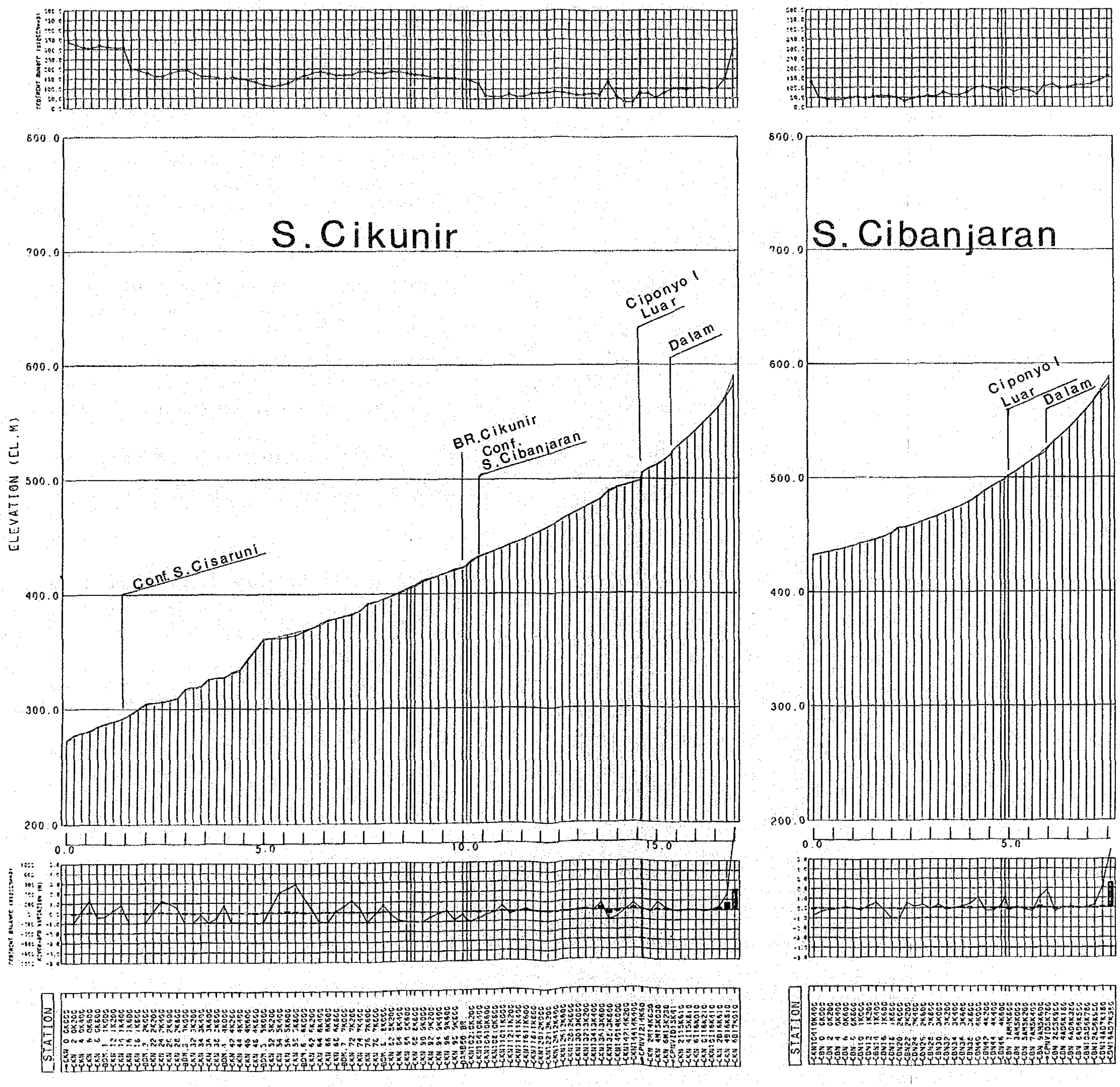


Fig. - 5.18
Calculation Result of
River bed Deformation
(S. Cikunir)

1) The longitudinal profile (elevation of riverbed) was estimated from the data between 2 reference points for which longitudinal drawings were made.

2) The cross section (river width) was estimated from measurements on a 1/25,000 topographic map.

The supply sediment volume was assumed to be an amount ($720 \times 10^3 m^3$) which would fit with the sediment transportation capabilities of the Ciwulan upper river channel.

The results obtained are shown in Table - 5.10 and Fig. - 5.19. Longitudinal tendencies such as riverbed aggradation and riverbed degradation show that the following sections tend toward degradation:
89 - 85 km, 71 - 68 km, 48 - 32 km, 16 - 134 km, 9 - 6 km.
Sections other than those tend toward aggradation, but particular mention should be made of the following: 83 - 72 km, 55 - 54 km, 29 - 28 km.

The sediment runoff volume is 500-800 $\times 10^3 m^3$ in the section upstream of 30 km. It decreases in the area downstream, becoming 200-300 $\times 10^3 m^3$, or almost 1/2 (see Table - 5.10).

The sediment concentration is 0.3 - 0.5% in the area upstream of 60 km, 0.2% downstream to 55 km, on 0.1% below that.

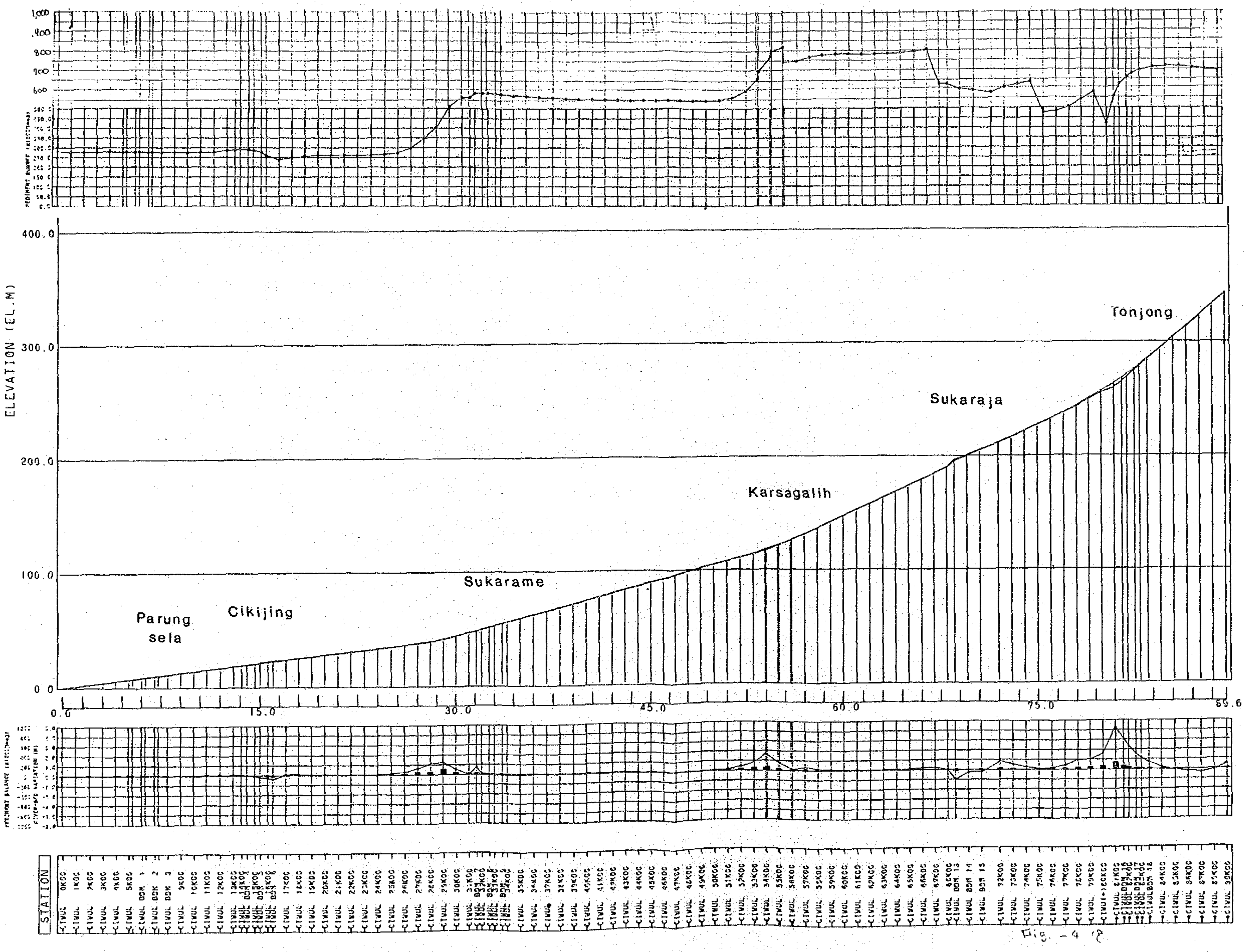


Fig. - 5.19

Calculation Result of River Bed Deformation (S. Ciwulan)

Table - 5.10 Depth of Fluctuation and Sediment Runoff Volume by Design Flood (1/50)

Distance From River Month	Depth of Fluctuation	Sediment Run off Volume	Sed. Concentration
90 km	0.50 m	696 $10^3 m^3$	0.5%
85	-0.10	717	0.5
Tonjong (BDM 16)	3.04	563	0.4
75	0.02	634	0.3
70	-0.26	600	0.2
Sukaraja (BDM 13)	-1.00	624	0.3
65	0.12	789	0.3
60	0.02	781	0.3
55	0.75	798	0.2
Karsagalih (BDM 10)	1.58	694	0.2
50	0.05	542	0.1
45	-0.01	545	0.1
40	0.02	549	0.1
35	-0.13	568	0.1
Sukarame (BDM 7)	0.71	558	0.1
30	0.52	514	0.1
25	0.13	266	0.1
20	0.01	260	0.1
15	-0.13	290	0.1
Cikijing (BDM 4)	-0.03	291	0.1
10	0.01	274	0.1
Parung Sela (BDM 2)	-0.01	276	0.1
5	0.00	277	0.1
0	-0.02	280	0.1

Note) In Depth of Fluctuation, (-) means degradation.

The relations between bank height and water level in the section of 81 km where shows a high aggradation is shown in Fig. - 5.20.

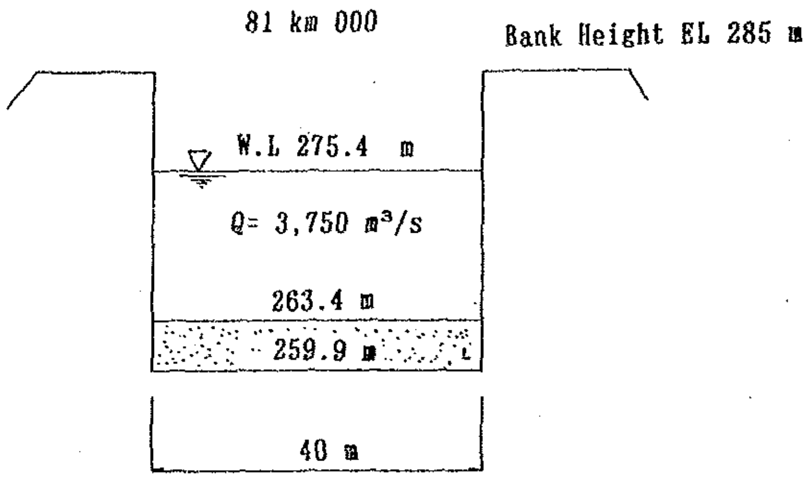


Fig. - 5.20 Deposited Sediment Level and Water Level in Section 81 km after Aggradation by Calculation of River Bed Deformation

In case of the discharge of 3,750 m^3/s, the water level shows EL 275.4 m and the deposited sediment level shows EL 263.4 m that rises 3.5 m from the original base line of river.

6. Actual Condition for Effective Utilization of Accumulated Materials in Sandpocket

The accumulated sediment capacity of the sandpockets constructed in the S. Cikunir - S. Cibanjaran area as well as S. Ciloseh - S. Cimampang area was almost in full condition at the period of August, 1987.

Sedimentation is considered to proceed further by the runoff sediment from the upper stream basin in future in these sandpockets.

In particular, the runoff sediment volume in the S. Cikunir, S. Cibanjaran area is larger than the one in the S. Ciloseh - S. Cimampang area.

The accumulated sediment volume at Sandpocket Ciponyo I and II in S. Cikunir - S. Cibanjaran will reach to 3,330 thousand m^3 during the coming 5 years, and 4,740 thousand m^3 during the coming 10 years according to the results of the sediment analysis. Also, in the S. Ciloseh - S. Cimampang - area, the sediment runoff volume of a return period of 50 years from Sandpockets Cimampang & Negla is estimated to be 1,380 thousand m^3.

An effective countermeasure is to excavate and carry out the accumulated sediment in the sandpocket for the restoration and the continuous maintenance of the sediment control function in it.

Furthermore, if it is possible to utilize accumulated sediment as the aggregate for construction, it is possible to keep the spare capacity of the sandpocket economically, and will be great help in the shortage of aggregate prospected in the future in Jakarta and surrounding area.

The excavation and the transportation of the accumulated sediment in the sandpocket were planned and executed from the first at the beginning of the construction of the sandpocket in 1982. At the same time, by the special budget of the President, the extension of railway for aggregate transportation between Babakan Jawa Station and Pirusa station was constructed.

Using this railway maintained by PJKA, about 1,000 m^3/day of sand excavated from the sandpocket is being transported to Jakarta as the aggregate for construction. However, this transportation capacity is extremely small in comparison with the sediment volume of about 40,000 thousand m^3 accumulated in the sandpocket or the sediment inflow volume of about 1,000 thousand m^3/year from the upper reaches.

To grasp the actual condition for the effective utilization of the accumulated sediment in the sandpocket of Mt. Galunggung area, the following surveys were executed.

1) excavation condition in the sandpocket area
2) transportation capacity from Pirusa station to Jakarta
3) market condition of aggregate to Jakarta

The reconnaissance survey concerning the actual condition of accumulated materials utilization in the sandpocket was carried out during the first work in Indonesia. The survey items are shown as follows:

1) companies excavated in the sandpocket and their excavation area
2) application procedure for materials excavation
3) excavation volume
4) transportation capacity
5) market price of aggregate
6) demand of aggregate

6.1 Companies Excavated in the Sandpocket and their Excavation Area

There are eleven companies which have the licence of excavation in the sandpocket. The excavation area for each sandpocket is divided into from two to four areas in proportion to the excavation area.

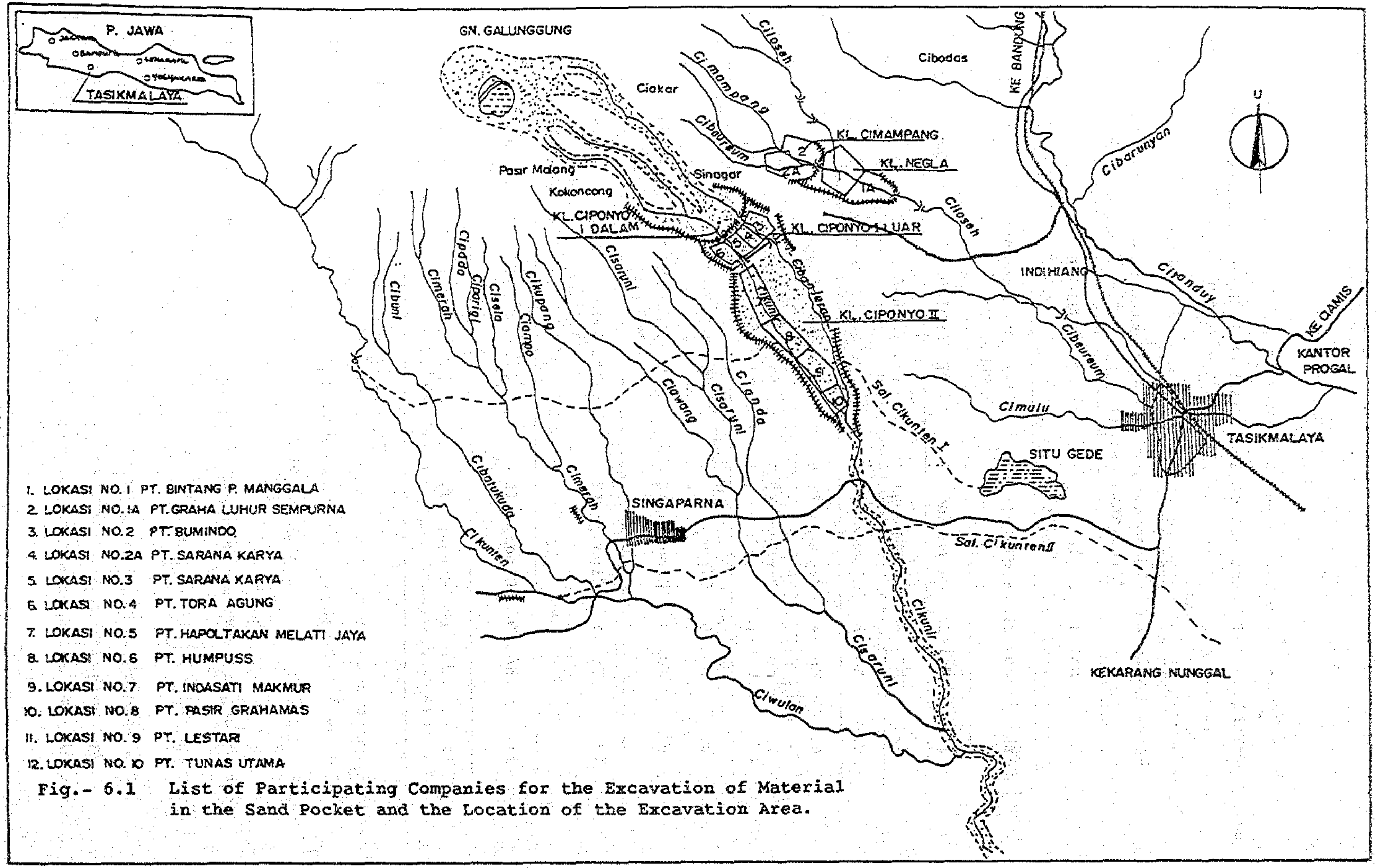
The excavation area and its company excavated in the sandpocket are shown in Table - 6.1 and Fig. - 6.1.

Only three companies excavate in the sandpocket as of October 1987. The other companies which have licence of excavation were watching the fluctuations in demand and cost in Jakarta, do not excavate in the sandpocket.

Table - 6.1 Excavation areas and the companies excavating in the sandpockets

No.	Name of Location	Name of Sandpockets (Excavation Area)	Name of Company	Remarks
1.	No. 1	Negla	PT. BITANG P. MANGGALA	
2.	No. 1A	Negla	PT. GRAHA LUHUR SEMPURNA	
3.	No. 2	Cimampang	PT. BUMINDO	* Operating
4.	No. 2A	Cimampang	PT. SARANA KARYA	* Operating
5.	No. 3	Ciponyo I. L	PT. SARANA KARYA	* Operating
6.	No. 4	Ciponyo I. L	PT. TORA AGUNG	
7.	No. 5	Ciponyo I. L	PT. HAPOLTAKAN MELATI JAYA	
8.	No. 6	Ciponyo I. L	PT. HUMPUSS	
9.	No. 7	Ciponyo II	PT. INDASATI MAKMUR	Cikunir Gede
10.	No. 8	Ciponyo II	PT. PASIR GRAPHA MAS	* Cikunir side Operating
11.	No. 9	Ciponyo II	PT. LESTARI	Cikunir side
12.	No. 10	Ciponyo II	PT. TUNAS UTAMA	Cikunir side

(D.P.U. Proyek Galunggung, Apr. 1987)



1. LOKASI NO. 1 PT. BINTANG P. MANGGALA
2. LOKASI NO. 1A PT. GRAHA LUHUR SEMPURNA
3. LOKASI NO. 2 PT. BUMINDO
4. LOKASI NO. 2A PT. SARANA KARYA
5. LOKASI NO. 3 PT. SARANA KARYA
6. LOKASI NO. 4 PT. TORA AGUNG
7. LOKASI NO. 5 PT. HAPOLTAKAN MELATI JAYA
8. LOKASI NO. 6 PT. HUMPUSS
9. LOKASI NO. 7 PT. INDASATI MAKMUR
10. LOKASI NO. 8 PT. PASIR GRAHAMAS
11. LOKASI NO. 9 PT. LESTARI
12. LOKASI NO. 10 PT. TUNAS UTAMA

Fig.- 6.1 List of Participating Companies for the Excavation of Material in the Sand Pocket and the Location of the Excavation Area.

6.2 Application Procedure for Materials Utilization

The application procedure of excavation for accumulated materials utilization in the same pocket are divided into three ways due to the area of excavation shown in the followings.

a) less than 1 Ha
b) more than 1 Ha up to 25 Ha
c) more than 25 Ha

Cases of more than 25 Ha of excavation area are shown as follows:

1) the company make an application to the governor

2) governor requests technical advice concerning the excavation in the sandpocket from the Mt. Galunggung project office and obtains its approval, the governor requests permission to excavate from the Department of Mining (DM) and obtain the permission

3) after permission from DM, the governor give official approval to the company

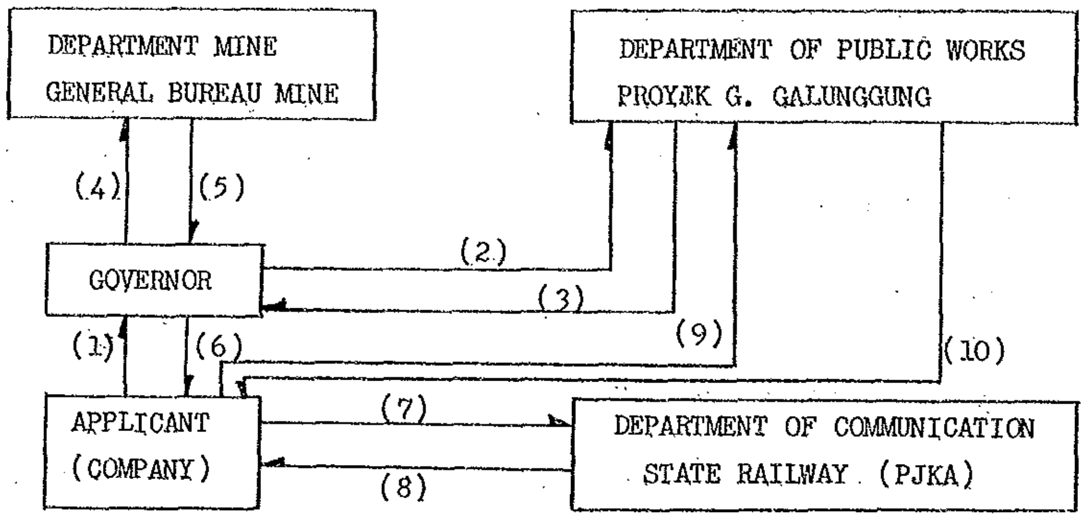
4) the company request the transportation of materials by train to PJKA (The Indonesian State Railways) and makes a contract with PJCA

5) after contract with PJKA, the company request the location of excavation in the sandpocket

6) Mt. Galunggung office assign to excavation area and supervise the excavation work.

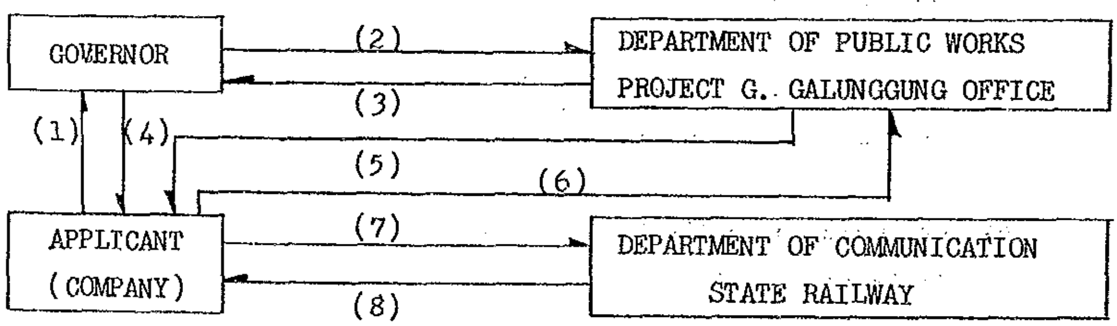
The application procedure including cases of more than 25 Ha is shown in Fig. - 6.2.

In case of excavation area more than 25 Ha



NOTE : (1) Request Licence
(2) Request for Technical Advice
(3) Given Technical Advice
(4) Request Permission
(5) Permission Given
(6) Given Licence
(7) Request for Train
(8) Contract/Agreement
(9) Request location for digging
(10) Supervission

In case of excavation area more than 1 Ha up to 25 Ha.

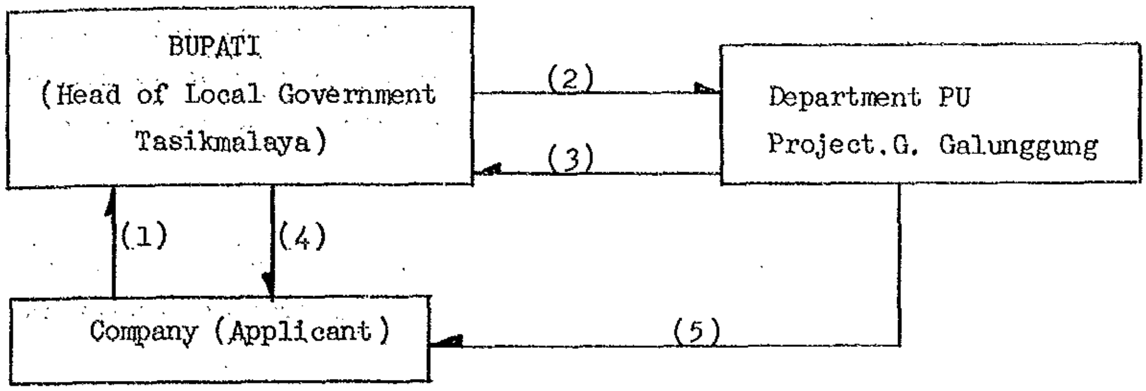


NOTE : (1) Applicant Request Licence
(2) Request for Technical Advice
(3) Technical Advice Given
(4) Given Licence
(5) Request Location for Escavation area
(6) Given Supervission
(7) Request for Train
(8) Contract/Agreement

Fig. - 6.2 (1)

Application Procedure for Excavation of Materials Utilities

In case of the excavation area less than 1 Ha



NOTE : (1) Applicant/Company request licence for Bupati
(2) Request for Technical Advice
(3) Given Tech.ical Advice
(4) Given Licence
(5) Supervission

Fig. - 6.2 (2)
Application Procedure for Excavation of
Materials Utilities

6.3 Excavation Volume

As mentioned in the beginning of this chapter, the excavation have been executed from 1982 in Mt. Galunggung area. The total excavation volume in the sandpocket of S. Cikunir and S. Cibanjaran reached 960 thousand m^3 up to the end of 1986.

The average volume of excavation in a day up to the end of 1986 is 430 m^3 in S. Ciloseh and 345 m^3 in S. Cibanjaran. The breakdown of excavation volume is shown in Table - 6.2.

Table - 6.3 shows the construction machine for each company excavating in the sandpocket.

Meanwhile, the excavation volume of the sand in Tangerang and Bekasi were estimated approximately from 10,000 m^3 to 12,000 m^3 based on the interview results to the dealers as of September 1987.

Table - 6.2 (1) Excavation Volume in Ciloseh River Site until End of December 1986

	Location	Excavation Volume/day	Total Working days	Total Excavated Volume
1.	Bendung Cigede	10 m^3	691 days	6,910 m^3
2.	Simpang - Sindanggalih	20 m^3	1,261 days	25,220 m^3
3.	Babakanloa (Check Dam III Ciloseh)	70 m^3	1,261 days	88,270 m^3
4.	Sukalaksana I	10 m^3	1,261 days	12,610 m^3
5.	Sukalaksana II	15 m^3	1,261 days	18,915 m^3
6.	Check Dam IV S. Ciloseh	10 m^3	1,261 days	12,610 m^3
7.	Jembantan Ciloseh (Belakang SMA II)	15 m^3	1,261 days	18,915 m^3
8.	Bojong (Leuwidahu) I	20 m^3	1,261 days	25,220 m^3
9.	Bojong (Leuwidahu) II	10 m^3	1,261 days	12,910 m^3
10.	Jembatan Ciloseh	20 m^3	1,261 days	25,220 m^3
11.	Pintu KA. Burujul	50 m^3	1,261 days	63,050 m^3
12.	Cipedes (Jl.RE. Martaditata)	80 m^3	1261 days	100,880 m^3
13.	Simpang Lima (Sebelah kiri sungai)	30 m^3	1261 days	37,830 m^3
14.	Simpang Lima (Sebelah kanan sungai)	80 m^3	1261 days	100,880 m^3
	T o t a l	430 m^3		549,140 m^3

(Data; D.P.U. G. Galunggung Project Office)

Table - 6.2 (2) Excavation Volume in Ciloseh River Site until End of December 1986

	Location	Excavation Volume/day	Total Working days	Total Excavated Volume
1.	Warung Sabeulah	70 m^3	1,261 days	88,279 m^3
2.	Cipawitra - Gunung Bango I	10 m^3	1,261 days	12,610 m^3
3.	Cipawitra - Gunung Bango II	80 m^3	1,261 days	100,880 m^3
4.	Cipawitra - Gunung Bango III	60 m^3	1,261 days	75,660 m^3
5.	Jembatan S. Cikunir (Jl. Raya Tasikmalaya - Singaparna)			
	Tempat pengambilan I	50 m^3	1,200 days	60,000 m^3
	Tempat pengambilan	30 m^3	1,200 days	36,000 m^3
	Tempat pengambilan III	20 m^3	1,261 days	25,220 m^3
	Tempat pengambilan IV	10 m^3	1,261 days	12,610 m^3
6.	Rancapaku	15 m^3	61 days	915 m^3
	T o t a l	345 m^3		412,165 m^3

(Data; D.P.U. G. Galunggung Project Office)

Table - 6.3 List of Construction Machinery

(As of July, 1987)

Company	Machine	Number	Maker	Capacity	Product Year	Machine type	Remarks
PT. SARANA KARYA	Excavator	1	MITSUBISHI	1.0 m^3	1987	MS 180-8	Ciponyo I Luar
	Loader	1	CATEOUKAR	1.6 m^3	1986	930	
	Bulldozer	1	KOMATSU	3.0 m^3	1982	D - 65	
	Dump Truck	5	MITSUBISHI	7.0 m^3	1983	FUSO	
PT. BUMINDO	Excavator	1	MITSUBISHI	1.0 m^3	-	MS 180	Cimampang
	Loader	1	FURUKAWA	2.6 m^3	-	FL 230	
	Dump Truck	5	TOYOTA	6.0 m^3	-	TOYOTA	
PT. PASIR GRAHA MAS	Bulldozer	1	CATAPILAR	3.0 m^3	-	D 7	Ciponyo II
	Loader	1	FURUKAWA	2.6 m^3	-	FL 230	
	Dump Truck	2	NISSAN	6.0 m^3	-	-	
PT. SARANA KARYA	Bulldozer	2	KOMATSU KOMATSU	3.0 m^3	1968	D 65 A W 70	Cimampang
	Loader	2	FURUKAWA	2.5 m^3	-	FL 220	
	Dump Truck	5	ISUZU	4.25 m^3	-	TSD	

(Data D.P.U. Gunung Galunggung Project Office)

6.4 Demand of Aggregate

The present and future demand of aggregates in Tasikmalaya, Bandung, Jakarta and others is not clear because there is no statistic data.

According to the results of the interview of the people concerned, the present demand of aggregates as of October 1987, in Jakarta, including Jabotabek area, is estimated as described below. Moreover, an increase of 3,000 m^3/day of demand is expected.

Jakarta	: 9,000 - 10,000 m^3/day
Jabotabek area	: 10,000 - 13,000 m^3/day

Recently, in Jakarta and its surroundings, many large scaled public works have been started such as the Urban Development Project, Metropolitan Express Way Project, International Airport, etc., guided by Master Plan of Jakarta in the year 2005.

Besides the public works, there are also plans for the Highway Construction Project in and around Bandung and the Road Development Project in and around Tasikmalaya.

Meanwhile, though sand from Tangerang and Bekasi area has been carried out in order to meet the demand for aggregate - use in the Jakarta area, environmental changes for the worse such as the destruction of land and the decrease of ground water level is occurring in these areas. Therefore, the government prohibited the excavation of sand and gravel in these areas, and the excavation of sand will be completely discontinued till 1988.

In consideration of this condition, the demand for the accumulated materials in the sandpocket of Mt. Galunggung southeastern area as the aggregate use for construction is considered to increase still more.

6.5 Market Price

The market price of aggregate in Jakarta was investigated to the dealer by interviews by members of JICA study team. Table - 6.4 shows the market price of aggregate in Jakarta for each quarry site such as Tangerang, Bekasi and Tasikmalaya (Mt. Galunggung) as of September 1987.

Table - 6.4 Market price of aggregate in Jakarta (September, 1987) for each quarry site

classification of sand	site of quarry		
	Tangerang	Bekasi	Tasikmalaya
fine sand (under 2 mm)	Rp 12,000/m^3	Rp 8,000/m^3	Rp 13,000/m^3
regular sand (2 mm - 5 mm)	8,000/m^3	6,000/m^3	no sales

The price of fine sand under 2 mm varies from 8,000 Rp/m^3 to 13,000 Rp/m^3. Regular sand from Tasikmalaya has no sales in Jakarta. The market price also shown in Table - 6.5.

Table - 6.5 Market Price of Construction Materials

No.	Kind of Materials	Unit	Market/Selling Price (Jakarta) (Rp)			
			Low Price	Low Price (Contract)	High Price	High Price (Contract)
1.	SAND					
	Sand Fill	m^3	14,000	10,000	14,500	11,000
	Sand Mortar	m^3	15,000	11,500	14,500	11,000
	For Concrete	m^3	16,000	12,500	17,000	13,000
2.	GRAVEL					
	For Concrete	m^3	19,000	12,500	20,000	13,000
	Regular	m^3	18,500	12,000	19,000	12,500
	Split	m^3	25,000	15,000	25,000	16,000
3.	STONE					
	River Stone (Pebble)	m^3	18,000	13,000	18,000	13,000
	Crushed Stone	m^3	18,500	13,000	19,000	13,500

Data: Pusat Informasi Teknik Pembangunam PU. Cipta Karya (as of Septembr 1987)

The following indicates the market price of construction materials due to type.

Sand (For Concrete) : 12,500 - 17,000 Rp/m^3
Gravel (For Concrete) : 12,500 - 20,000 Rp/m^3
Stone (Crushed Stone) : 13,000 - 19,000 Rp/m^3

The breakdown of market price in Jakarta from Tasikmalaya is shown in Table - 6.6.

Table - 6.6 Breakdown of Sand Price in Jakarta

(Rp/m^3)

Item	by train	by truck
1) excavation	3,100	800
2) transportation to stock yard	850	0
3) transportation to Jakarta	5,875 or 6,125	not clear
4) permission rate	225	50
5) sales tax (PPN)	0	500
6) others	or 2,700	not clear
Total price	13,000	(13,000)

6.6 Rail Transportation Capacity

Rail transportation by PJKA starts at Pirusa station near the Negla sandpocket, goes through Bandung and Cikampek, and on to Jakarta's Cipinang station. The distance between the two stations is 274 km and transportation, according to schedules, takes 7-8 hour. Railway network of PJKA in West Java is shown in Fig. - 6.3.

(1) Freight Cars

At present (as of July 1987), there are two types of freight cars which haul aggregate from the Galunggung region. The standard sizes of these freight cars is shown in Fig. - 6.4 as well as Table - 6.7.

Table - 6.7 Description of Freight Cars for Aggregate Transportation

Item	YYW	YW
Loading Weight	30 ton	15 ton
Empty Weight	31.1 ton	7.15 ton
Volume of Wagon	27 m^3	12 m^3
Loading Volume	20 m^3	9 m^3

(2) Train Composition

The composition of train which transport aggregate presently running to Jakarta and loading volume in Table - 6.8. Fig. - 6.5 shows the diagram from Pirusa station to Cipinang station in Jakarta. According to this train-schedule, the required transport time is 7-8 hours.

Fig. - 6.6 shows the possible operation number of trains (including freight cars) per day from Tasikmalaya to Jakarta via Bandung and actual operation record of train.

According to Fig. - 6.6, actual operation record of train per day is 22 times (in case of Hari Raya 24 times) between Tasikmalaya and Bandung as well as 36 times between Bandung and Jakarta.

Comparing with the actual condition and the possible operation number of trains, the possible operation number of trains is 24 to 49 times between Tasikmalaya and Bandung as well as 45 to 78 times between Bandung and Jakarta. A section of Ciawi and Cipeundeuy is almost full operation for possible operation number of train.

(3) Actual Shipped Volumes

Calculated from the number of freight cars that actually operated during the one year period from July 1987 to June 1988, the real volume of aggregate shipped to Jakarta is shown in Table - 6.9.

1) The cumulative shipped volume of aggregate over the one year period from July 1987 to June 1988 amounted to 428,000 m^3.

2) The greatest shipped volume for one month from within this one year period was April 1988 at 42,900 m^3.

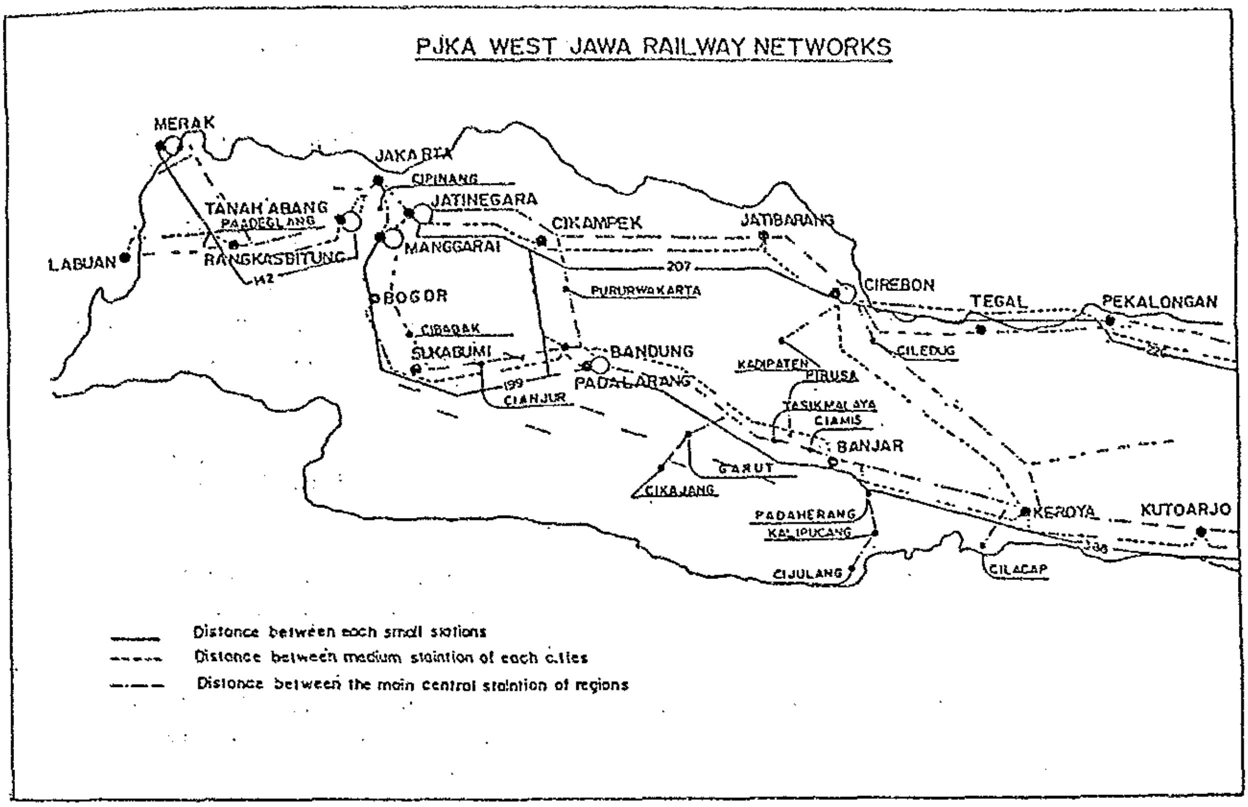


Fig. - 6.3 Railway Network of RJKA in West Java

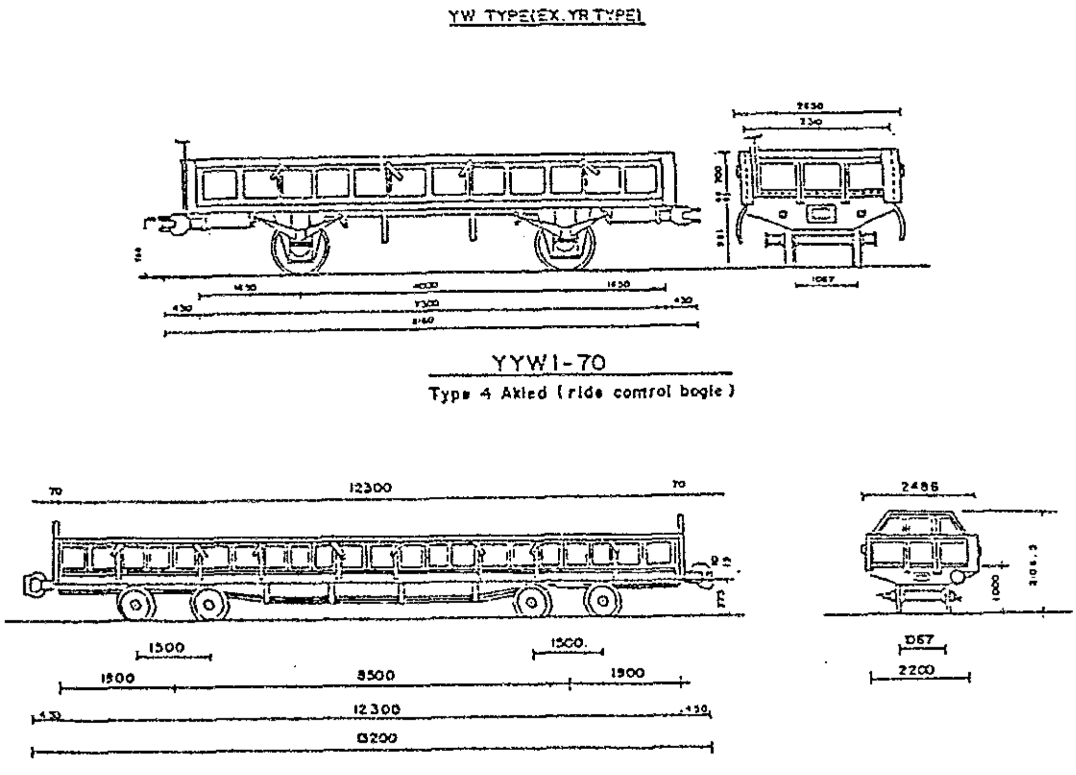


Fig. - 6.4 Profile of Wagon for Aggregate Transportation

Table - 6.8 Train Composition and Loading Volume

(Pirusa Station October, 1987)

Car No. and Type of Locomotive	Name of Company	Loading Volume/ time	Type of Car and Capacity
BC 4001 (CC 201/GE)	PT. BUMINDO	280 m^3/time	Capacity 20 m^3/Car, YYW Type (*) 14 Cars carried by 2 units Locomotive
BC 4003 (CC 201/GE)	PT. SARANA KARYA	252 m^3/time	Capacity 9 m^3/Car, YW Type (*) 28 Cars carried by 1 unit Locomotive
BC 4005	PT. BUMINDO	280 m^3/time	Capacity 20 m^3/Car, YYW Type 14 Cars carried by 2 units Locomotive
BC 4007	PT. BUMINDO	280 m^3/time	Capacity 20 m^3/Car, YYW Type 14 Cars carried by 2 units Locomotive
ELK/234	PT. SARANA KARYA	140 m^3/time	Capacity 20 m^3/Car, YYW Type 7 Cars carried by 1 unit Locomotive

Source: Pirusa Station October, 1987

ANGKUTAN PASIR GALUNGGUNG PIRUSA - CIPINANG 1000 METER KUBIK PERHARI DENGAN PENINGKATAN PUNCAK KECEPATAN
BERLAKU MULAI TANGGAL 5 SEPTEMBER 1987

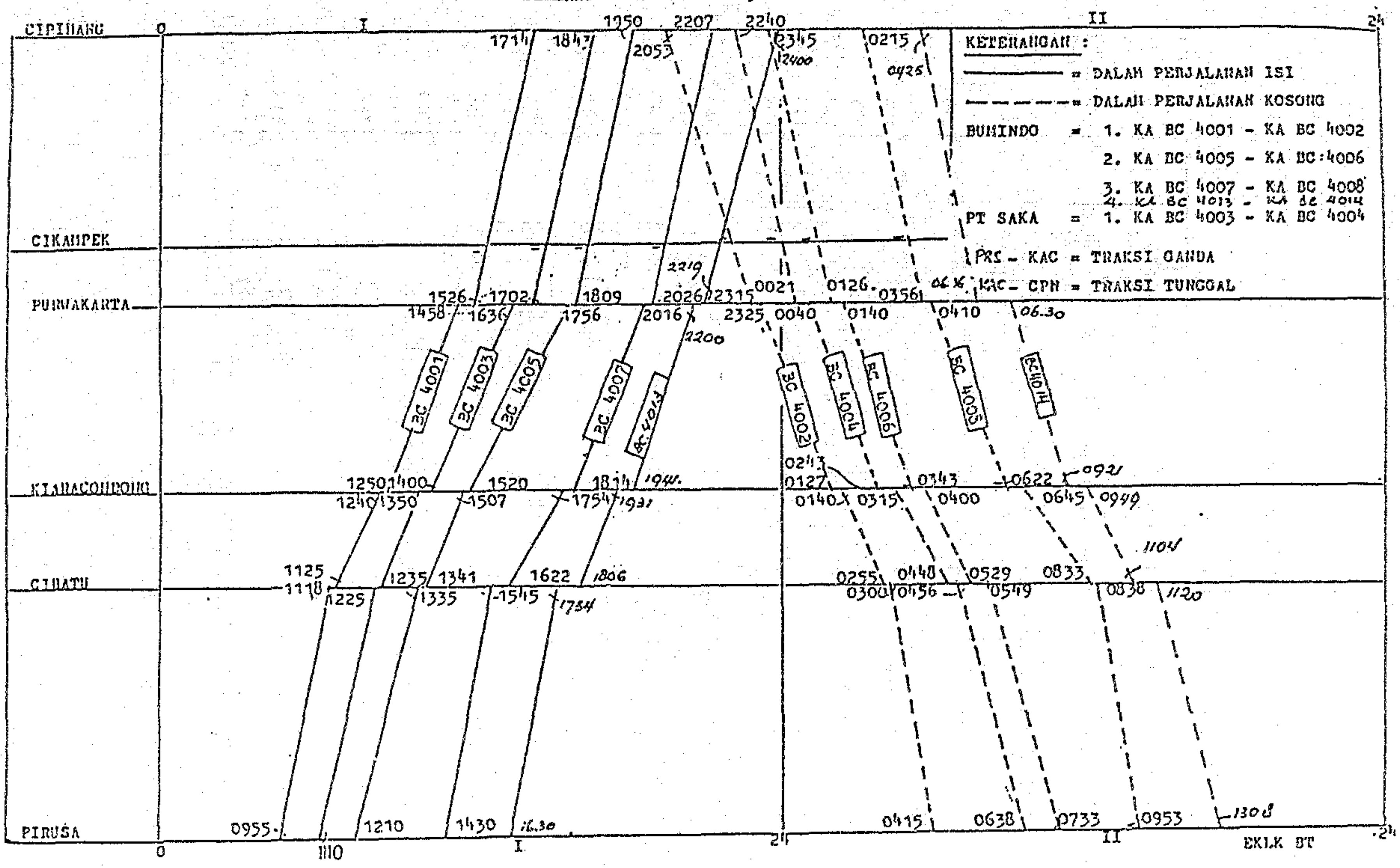


Fig. - 6.5 Diagram of PJKA from Pirsa Station in Tasikmalaya to Cipinang Station in Jakarta

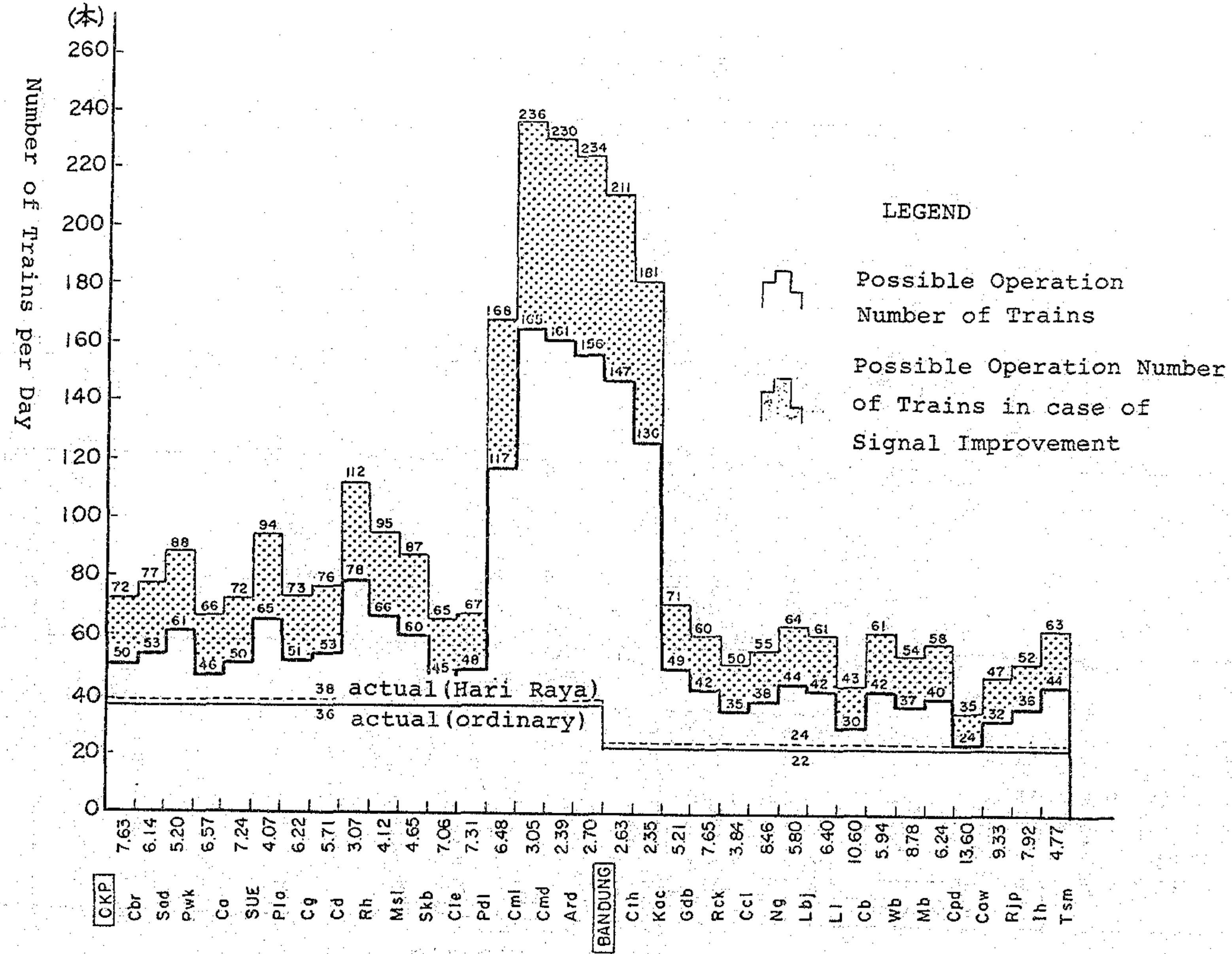


Fig. - 6.6 Possible Operation Number of Trains per Day and Actual Operation Number of Train from Tasikmalaya to Cikanpek

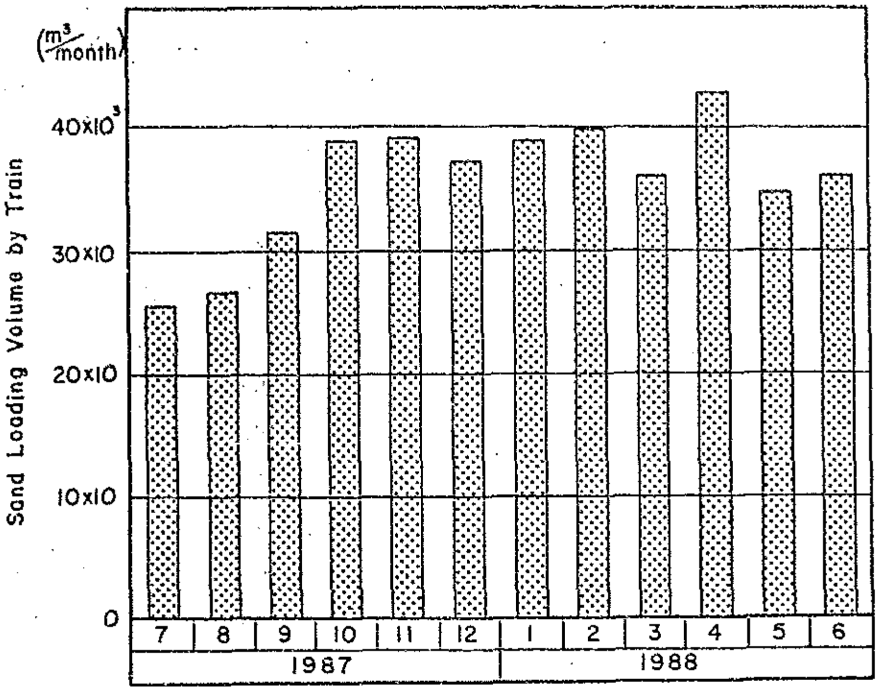


Fig. - 6.7 Total Sand Loading Volume at Pirusa Station

Table - 6.9 Sand Loading Volume by PJKA at the Pirausa Station

Month / Year	Kind of wagon			Number of wagon in a month	Total of sand in a month (m^3)
	Y	YY	BB		
July 1987	1,151	822	-	1,973	25,484.30
August 1987	698	1,049	-	1,747	26,779.67
September 1987	930	1,190	-	2,120	31,578.13
October 1987	837	1,522	-	2,359	38,997.06
November 1987	415	1,558	-	1,973	39,223.40
December 1987	-	1,862	-	1,862	37,390
January 1988	-	1,952	-	1,952	39,040
February 1988	-	2,004	-	2,004	39,980
March 1988	-	2,121	-	2,121	36,120
April 1988	-	2,125	-	2,125	42,920
May 1988	-	1,731	-	1,731	34,620
June 1988	-	1,806	-	1,806	36,120
Total	4,031	19,792	-	23,773	428,251.56
				Average	35,687.63

(4) Operation Diagram of Freight Cars

According to the railroad operation diagram, there are five Jakarta-bound trains per day. The operation diagram of freight cars is shown in Table - 6.10.

Table - 6.10 Operation Diagram of Train

(as of October, 1987)

station	Pirusa (Tasikmalaya)		Cipinang (Jakarta)
train No.	arrival time	dept. time	arrival time
1) BC 4001	4:15	9:55	17:14
2) BC 4003	6:38	11:10	18:43
3) BC 4005	7:33	12:10	19:50
4) BC 4007	9:53	14:30	22:07
5) ELK 234	13:08	16:30	24:00

6.7 Recommendations for Aggregate Use

The demand of sand in Jakarta and Jabotabek area is not clear because of no statistic data reliable for the study. According to the results of interviews of the dealer of aggregates, the demand of sand in Jabotabek area is estimated from 13,000 m^3 to 16,000 m^3 including increasing of sand in future.

Recently, in Jakarta and Jabotabek area, many large scaled project such as Urban Development Project, Metropolitan Expressway Project, International Airport Project, etc. guided by Master Plan of Jakarta in 2005 year are executed. Besides, the public works also plan the highway construction project.

The quality of sand from Mt. Galunggung is suitable for the construction materials of the high-rise building and road.

Meantime, Tangerang and Bekasi areas have been suppling Jakarta area with sand in order to meet the demand. The environment became worse because of traffic jams, the destruction of roads and the decrease of ground water level. The government prohibited the excavation of sand and gravel in some parts of this area, and the excavation of this area will be discontinued till the end of 1988.

The cumulative transportation volume of aggregate over the one year period from July 1987 to June 1988 amounted to 428,000 m^3 (average monthly transportation volume; 35,700 m^3).

The demand of sand as well as gravel from Mt. Galunggung area in Jabotabek area is considered to increase still more. In consideration of this circumstance, Mt. Galunggung area has a possibility of becoming a "Construction Materials Supply Center" of Java.

There are some problems to be solved in order to become "Supply Center". These problems are summarized as follows:

1) Establishment of a systematic excavation system

To ensure the sediment regulation capacity of sandpocket as disaster prevention facilities and to product not only sand but gravel efficiently, systematic excavation system excavation, hauling to the aggregate plant, production of aggregate, shipping, transportation, sales in Jakarta should be established.

2) Introduction of high quality production plant

To produce the high quality aggregate in proportion to demand, aggregate plant consisting of vibrating screen, classifier and stock yard, etc. should be introduced.

3) Increasing of transportation capacity by PJKA

According to the sandpocket management plan described in the Supporting Report II Chapter 3, annual excavation volume in the sandpocket area reaches about 600,000 m^3. This volume means the excavation volume in sandpocket Ciponyo I dalam only. The actual excavation volume in the four sandpocket except Ciponyo I dalam reaches about 430,000 m^3. It means that the total excavation volume in Mt. Galunggung area reaches about 1,030,000 m^3.

It is required to increase the transportation capacity by PJKA so as to correspond the increasing of aggregate excavation volume.

7. Warning and Evacuation System

7.1 General

The Warning and Evacuation System will transmit to the correspondent on warning information concerning the occurrence of a debris flow in regards to the management of rainfall and water level data, and urge an evacuation of residences. With the object of inducing the prevention of any human damage before anything happens.

The government of Indonesia requested to the JICA in June 1986 to have the government of Japan supply the equipment for a Lahar monitoring system as part of the disaster warning system for the Mt. Galunggung eruptions. The Japanese government decided to honor this request by following the equipment.

1) RADAR RAIN GAUGE
2) OPERATION AND DISPLAY UNIT
3) SHELTING SHED

The equipment had been set up by January 1983 and was delivered to Indonesia in February of the same year. Following that, in addition to the above equipment, a telemeter system to observe rainfall amounts and water levels, and a visual information system using television cameras were added to establish a comprehensive warning system according the debris flow (Lahar).

As the system was introduced, JICA dispatched experts several times to give instruction on the operation of the system and its maintenance, technical supervision of hydrological analysis using radar rain gauge and technical supervision of methods of setting warning and evacuation criteria according to the intensity of rainfall.

Though the voltage instability of the power source has caused the system to stop monitoring on several occasions, the compilation of data was accomplished. Unfortunately, the system was greatly damaged by lightning in October 1985. Operations were discontinued following that, and recommenced in August 1987.

The JICA study team judges an understanding of rainfall characteristics in the basin of the southeast slope of Mt. Galunggung to be of importance. From December 1987 to March 1988, the observation of rainfall was executed through the use of the radar rain gauge and the telemeter rain gauge system.

This chapter discusses the results of these observations and recommendations for the current and future operations of the system.

7.2 The State of the Warning and Evacuation System

The Warning and Evacuation System was established from an information transmission system which contacts local residents with predictions of the occurrence of debris flow. These predictions are based on observations gathered from the observation system which accumulates and manages the collective data concerning rainfall, water levels, etc.

(1) The Observation System

The Observation System is composed of the following subsystems.

Table - 7.1 Observation Subsystem and Kinds of Record

Name of Observation Instrument	Kinds of Record
1) Radar Raingauge	a) Rainfall Intensity Display Hard Copy b) Areal Rainfall and Cumulative Rainfall Display Hard Copy
2) Telemetering Raingauge	c) Hourly Rainfall a) Ciakar b) Pasiripis c) Sinagar
3) Telemetering Water Level Gauge	d) Hourly water level
4) Lahar Monitoring	e) Occurrence record

From looking at the conditions of the data collected, approximately 800 hours of rainfall records exist from (a) and (b) (from the period May 1984 to February 1988). For (c) only rainfall records were able to be taken. Few records were obtainable for water levels due to problems with the electric power generating equipment and for debris flow due to damage and runoff problems. At the current time (February 1988), all subsystems except the water level meters were in operation.

(2) The Information Transmission System

The Information Transmission System of the period of the eruption of Mt. Galunggung (1982-1983), as shown in Fig. - 7.1 is basically still existent at present (1988 at the time of writing). Running along this system, information of the occurrence (prediction) of debris flow is transmitted.

The Galunggung Project Office procures information and reports concerning the occurrence of debris flow, the behavior of the debris flow, rainfall (the scope of the rainfall, movements in the area of the rainfall, strength of rainfall, etc.), and water levels, and upon analyzing this data, relays the report to the correspondent agency. (Refer to Fig. - 7.2) These correspondent agencies transmit this information in the order Kecamatan - Desa - Kampung and advice residents on the necessity of evacuation.

In addition, through amateur shortwave (Ham) radio this information will be received at any time and will advise the local inhabitants on evacuation.

The Information Transmission System from the time of the disaster in 1982 has fundamentally been maintained, and thus it is though to have no particular problems.

However, at the time of the disaster, the number of instances where the amateur (Ham) radio system that went into effect was dependent upon commercial use electricity was high. As a result, emergency electric power sources - such as batteries - should be maintained in the future.

A) Reporting System (Information Flow in Administrative Organization)

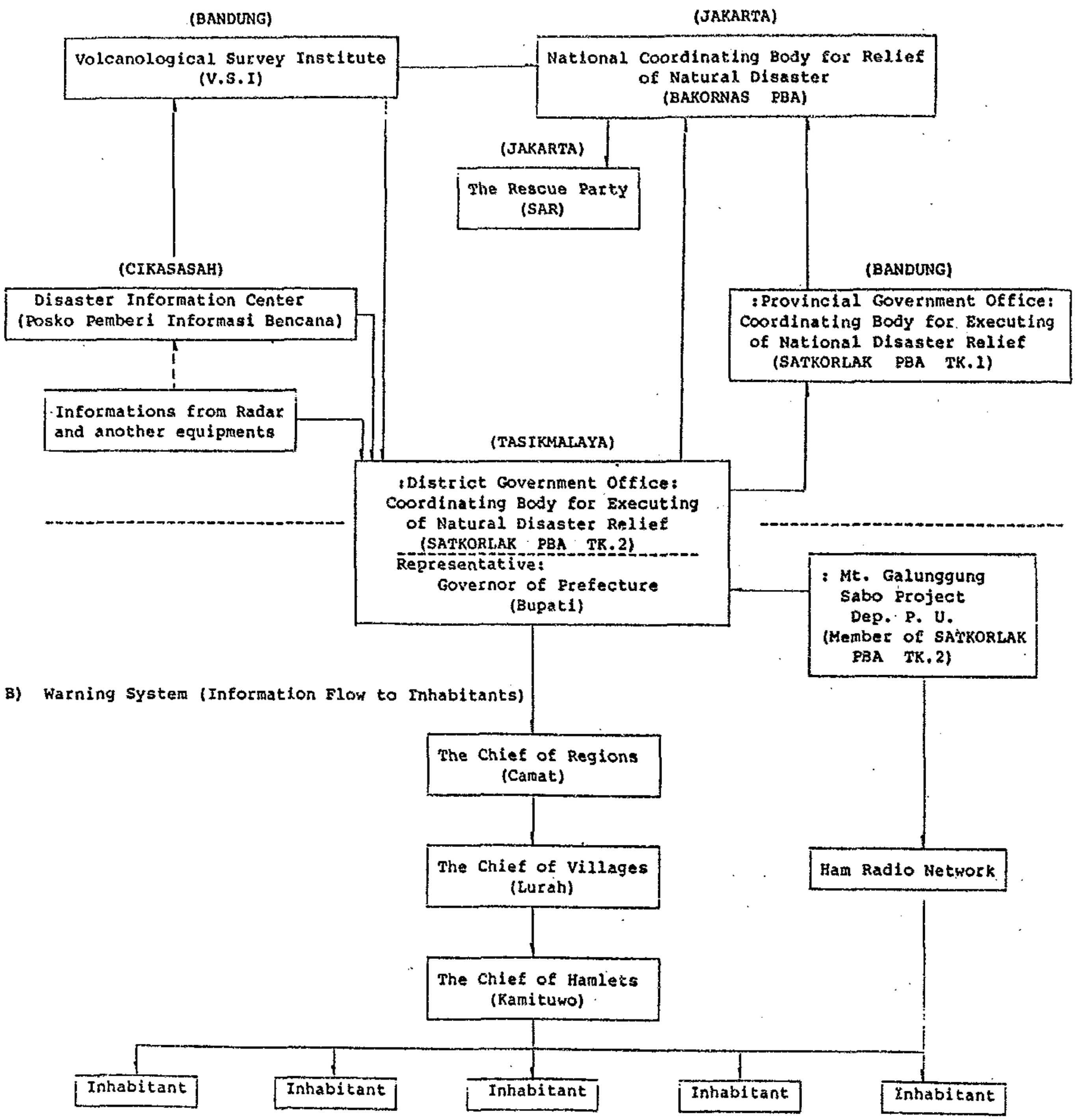


Fig. - 7.1 Organization Flow of the Disaster Information System

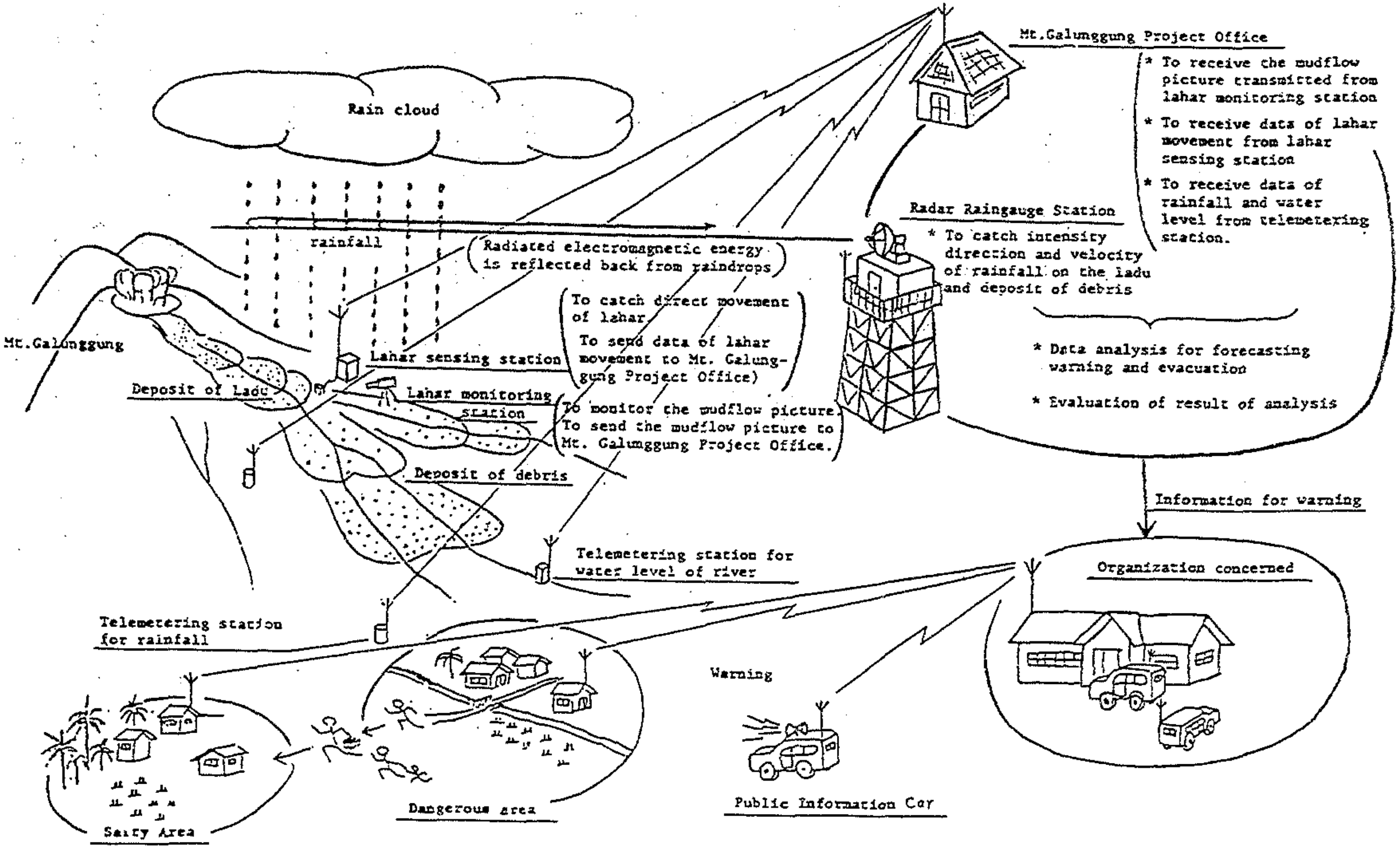


Fig. - 7.2 Outline of Monitoring and Warning Communication Network

7.3 Data Collection and Data Arrangement

Data collected through this study is Rainfall Data and Lahar Monitoring Data. Each type of data is described as follows.

(1) Rainfall Data

Total rainfall of radar rain gauge data and telemetering rain gauge data for each month collected through this study is shown in Table - 7.2.

Table - 7.2 Total Rainfall of Radar R.G. Data for Each Month

(mm)

	Year	1987				1988	
	Months	Sep	Oct	Nov	Dec	Jan	Feb
Radar Rain Gauge	Area 1	-	* 89	* 160	139	* 64	**128
	Area 2	-	* 47	* 150	63	* 165	**155
	Area 3	-	* 27	* 140	135	* 74	**130
	Area 4	-	* 45	* 149	36	* 137	**152
Telemeter Rain Gauge	Ciakar	-	* 95	* 64	* 37	* 0	**128
	Pasiripis	-	* 141	* 511	* 529	* 778	** 0
	Sinagar	-	* 101	* 9	* 319	* 596	**242

*: Including unobserved day

**: Up to Feb. 20

The relation between "area" and observation stations is shown in Fig. - 7.3.

(2) Lahar Observation Data

Lahar observation has been carried out by watchmen for the three (3) rivers: Cikunir River, Cibanjaran River and Ciloseh River.
Lahar occurrence have not been reported yet during this rainy season.

7.4 Rainfall Characteristics Analysis

7.4.1 Basic Process for Prediction of the Debris Flow

The following steps are involved in the basic process that leads up to a prediction of the occurrence of debris flow.

Step 1

The rainfall characteristics - particularly the occurrence of rain zones and the status of their movements - are grasped for the specified area (especially for Ciponyo I from the sandpocket to the top flow area).

The analysis is as follows. First, while monitoring the image recorded in the hard drum of radar rain gauge and each of the rainfall unit measures on the television monitor, the movement of the rain zones and variations in the intensity of the rainfall is taken into account. At the sought for rate of 5-10 minutes, one image is selected, and the chosen image is recorded on the floppy disc or printed out. These selected images are then interpreted as a time series.

Step 2

The rainfall patterns of the study area (Hydrograph) which are drawn from the radar image will be compared and investigated as will the times of the predicted reference points downstream, the curve of the discharge (hydrograph) and the runoff sediment conditions (mud flow, sediment flow, bed load flow, suspended flow, non-flowing mud flow).

In undertaking the process for sections where there are occurrences of mud flow with rainfall and sections where there are not, it is extremely important to accumulate the records of Hydrographs.

Step 3

Based on the accumulation of data up to Step 2, a "Warning and Evacuation Standard" for debris flow as a standard based on rainfall intensity will be established.

Amount the above steps, for the matter at hand, the analysis of rainfall characteristics that occurs in step one is thought to be of great significance. From December 1987 to March 1988, these observations were carried out.

The subject observation area and the locations of the observation instruments are shown in Fig. - 7.3. Observed items include 1) size of the rain zone 2) the rate of movement of the rain zone 3) the direction of the movement of the rain zone, 4) a schedule of the occurrence of rainfall and 5) duration and depth of rainfall.

Using these data, the following analysis were carried out.

a) Rain Zone/Zone Movement
b) Rainfall Correlation
c) Rainfall Duration
d) Rainfall Occurrence

7.4.2 Rain Zone Movement Analysis

A summarization of 20 minute rainfall for main rainfall (where overall rainfall were over 80 mm), the size of the rain zone (at its largest), and the direction of movement of the rain zone are indicated in Table - 7.3.

Table - 7.3 Rainfall Zone and its Movement

No.	Date	Maximum Rainfall in 20 minute (mm)				Maximum Rainfall Area km^2	Rainfall Zone Movement Direction
		Area 1	Area 2	Area 3	Area 4		
1	7 Dec, 1987	14.0	0.8	20.6	1.4	50	NE
2	13 Dec, 1987	15.3	3.8	16.5	1.1	110	NE or E
3	5 Jan, 1988	8.6	29.5	6.5	11.2	80	SE or E
4	6 Jan, 1988	4.2	15.5	5.0	12.8	90	NE or N
5	11 Jan, 1988	0.8	4.2	4.0	17.0	40	N
6	15 Feb, 1988	0.3	4.5	0.2	18.8	60	E
7	17 Feb, 1988	19.5	14.8	0.0	3.8	60	SE or E
8	19 Feb, 1988	11.5	24.8	35.8	22.5	90	E

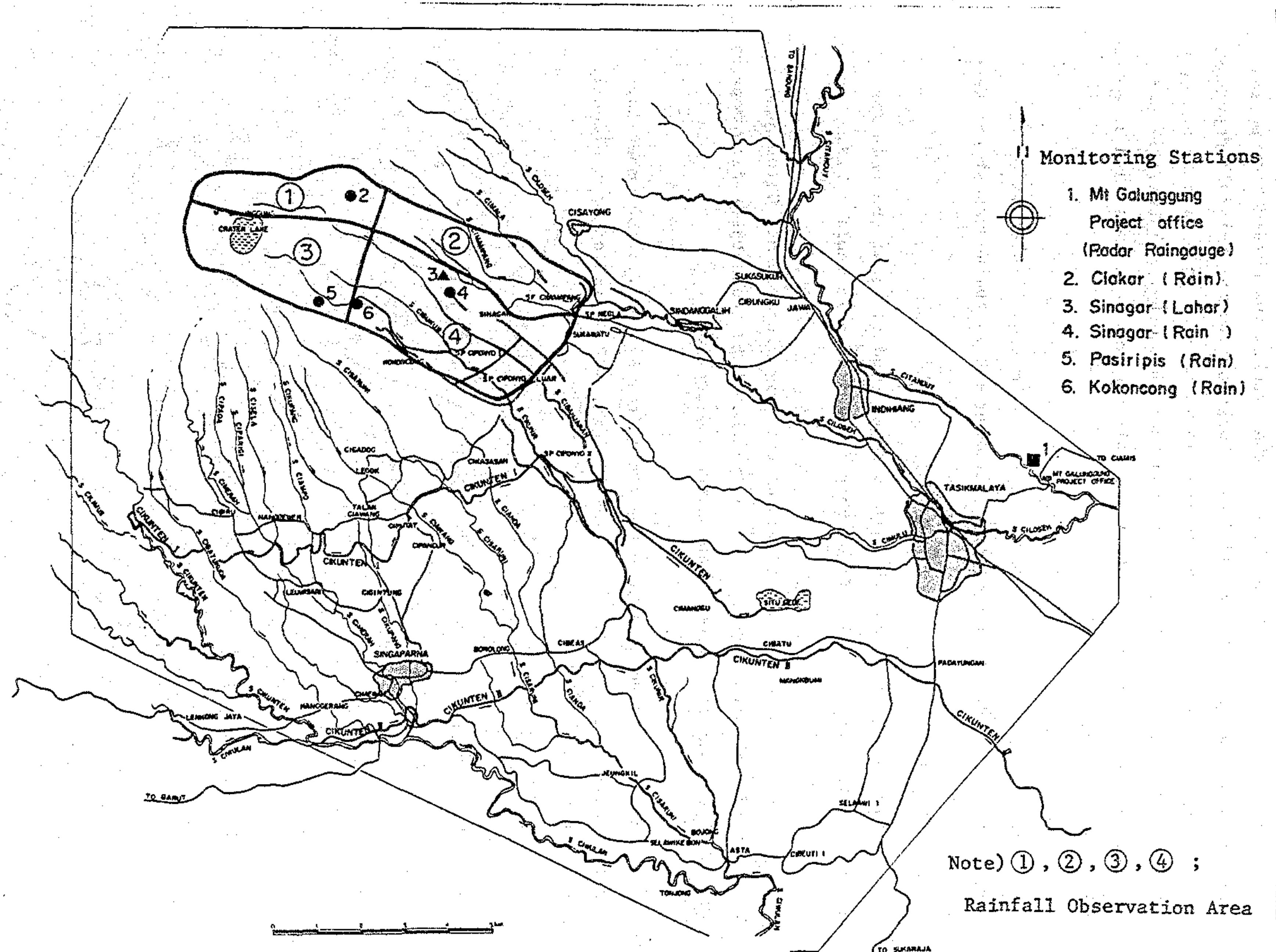


Fig. - 7.3 Area and Observation Stations

From Table - 7.3 it can be seen that within the observation period the maximum 20 minute rainfall was 35.8 mm. Looking into the rainfall depths in area 1 through area 4, the only one that shows uniform rain fall is number 8 rainfall. It can be understood from the fact that other rainfalls showed substantial variation in depth that the rain regions were small and large rain volume differences existed.

The largest rain zone size was 40-110 km (sq). In terms of the direction of the rain zone movement, the movement to the Northeast and East was most frequent.

Fig. - 7.4 shows the typical movement conditions of the rain zone during the February 19, 1988 flood that is indicated in Table - 7.3.

The rain zone which occurred on the west slope of Mt. Galunggung at 18:00 moved toward the east. After it reached into the subject flow zone at 19:30, it continued to move in an eastward direction.

The same trend is also borne forth from Fig. - 7.5 (December 12, 1987). The rainfall of October 31, 1987 (Fig. - 7.6) indicates a slightly different trend.

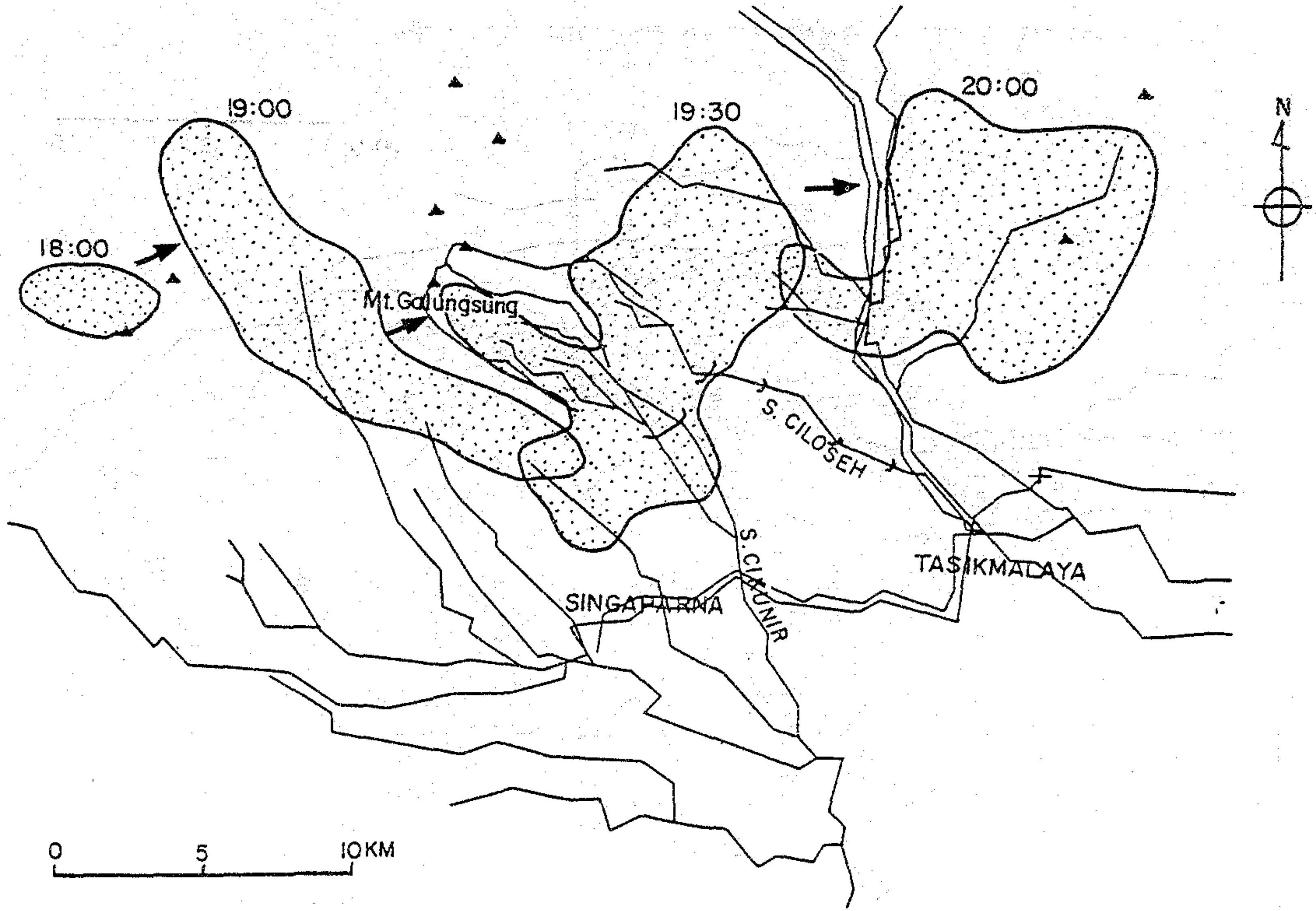


Fig. - 7.4 Rain Zone and Its Movement (February 19, 1988)

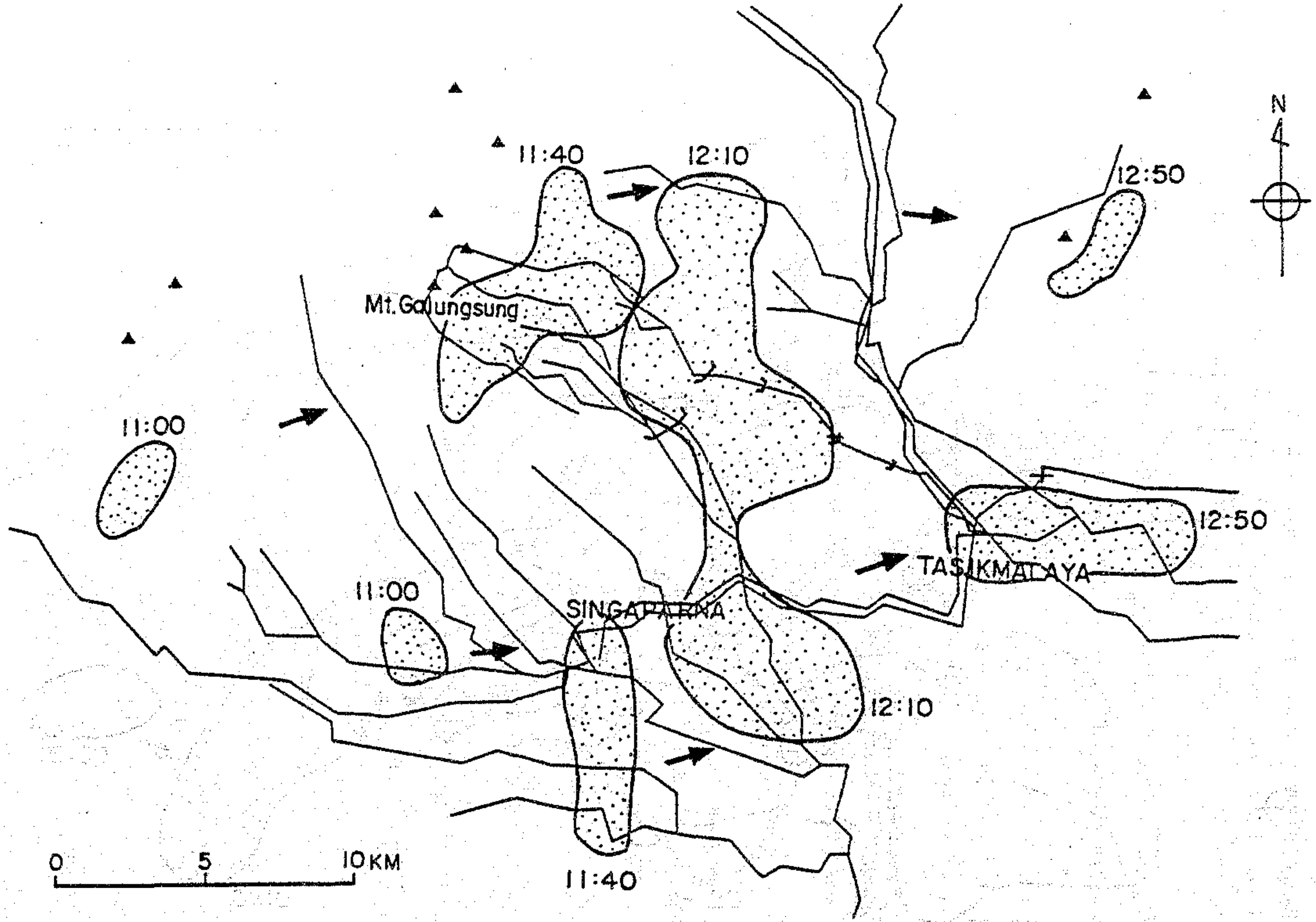


Fig. - 7.5 Rain Zone and Its Movement (December 12, 1987)

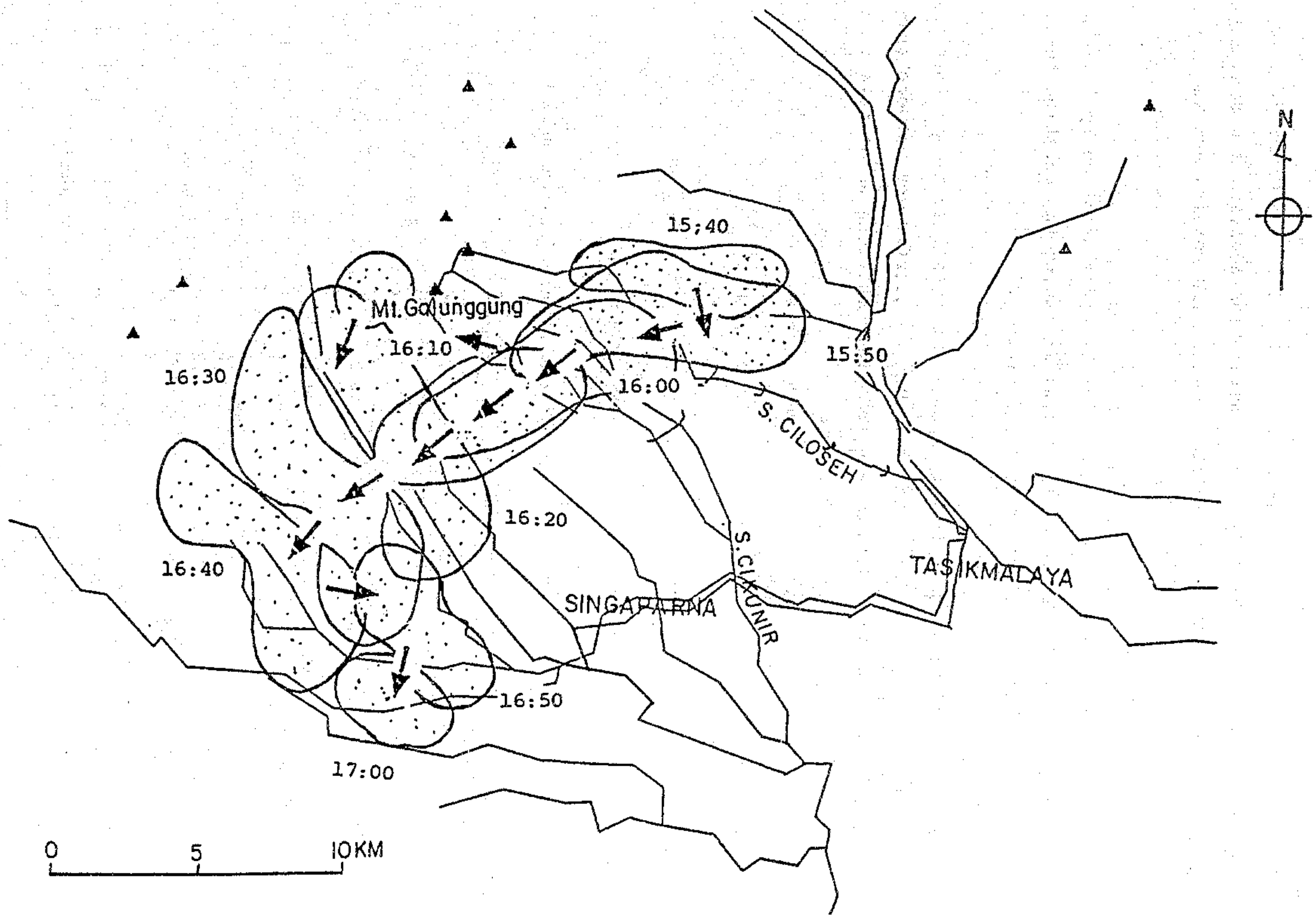


Fig. - 7.6 Rain Zone and Its Movement (October 31, 1987)

7.4.3 Correlation Analysis of Rainfall

To obtain the relation between rainfall of Radar Rain Gauge Data and rainfall of Telemetering Rain Gauge Data, correlation analysis was done using hourly rainfall data and 10-minute rainfall data. The results are shown in Table - 7.4.

1) From the results of 10 minute rainfall correlation analysis, the correlation coefficient (r) is low, in except the relation between area 1 and Sinagar and area 2 and Sinagar.

2) The correlation coefficient of hourly rainfall is higher than that of 10 minute rainfall. The correlation coefficient between area 2 and other stations and area 4 and other stations shows more than r = 0.7. (See Fig. - 7.7)

Table - 7.4 Results of Rainfall Correlation Analysis between Area Rainfall and Observation Station Rainfall

(1) 10 minute rainfall (more than 5 mm)

	Ciakar	Pasiripis	Sinagar
Area 1	a = 0.010 b = 9.708 r = 0.015 n = 14	a = 0.152 b = 11.885 r = 0.260 n = 11	a = 1.400 b = 1.300 r = 0.763 n = 6
Area 2	a = 0.150 b = 11.335 r = 0.086 n = 25	a = 0.409 b = 7.404 r = 0.330 n = 31	a = 1.174 b = 1.681 r = 0.727 n = 24
Area 3	a = 0.334 b = 11.376 r = 0.528 n = 8	a = 0.124 b = 9.551 r = 0.243 n = 12	a = 0.000 b = 7.000 r = 0.000 n = 3
Area 4	a = 1.074 b = 4.012 r = 0.593 n = 23	a = 0.612 b = 5.641 r = 0.504 n = 41	a = 0.249 b = 9.288 r = 0.162 n = 28

Note) Y = ax + b (a, b: constant)
r: correlation coefficient
n: number of data

(2) Hourly rainfall (more than 20 mm)

	Ciakar	Pasiripis	Sinagar
Area 1	a = 0.193 b = 51.533 r = 0.131 n = 10	a = 0.239 b = 27.474 r = 0.546 n = 7	a = 0.381 b = 40.341 r = 0.254 n = 6
Area 2	a = 1.212 b = 2.021 r = 0.748 n = 16	a = 0.789 b = 9.378 r = 0.701 n = 14	a = 2.102 b = 10.737 r = 0.661 n = 17
Area 3	a = 0.597 b = 68.185 r = 0.409 n = 7	a = 0.121 b = 43.517 r = 0.241 n = 5	a = 0.911 b = 83.506 r = 0.955 n = 4
Area 4	a = 1.736 b = 9.169 r = 0.888 n = 11	a = 1.207 b = 1.672 r = 0.809 n = 19	a = 1.423 b = 5.452 r = 0.747 n = 16

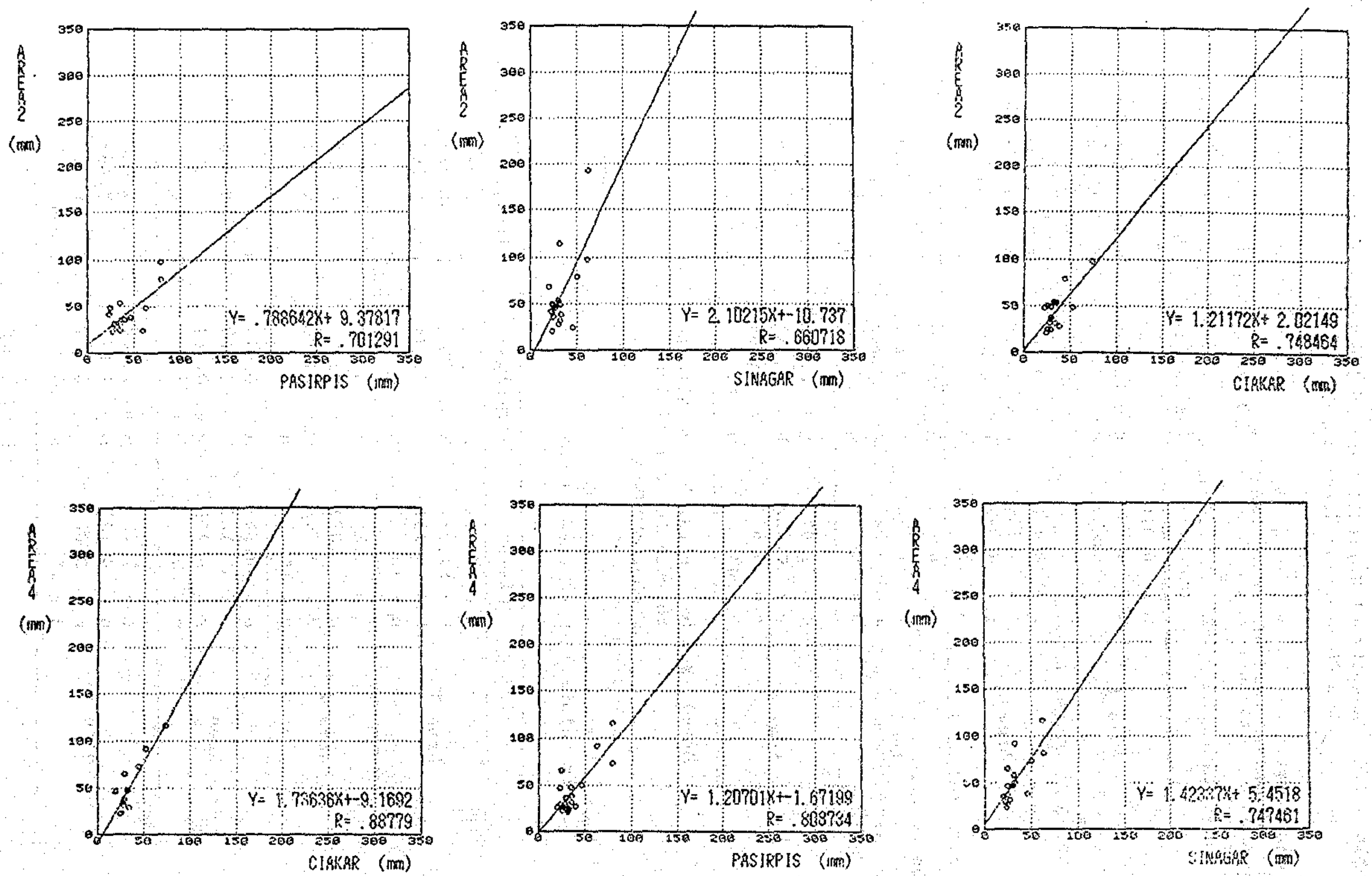


Fig. - 7.7 Results of Rainfall Correlation Analysis

7.4.4 Duration Analysis of Rainfall

To understand duration of rainfall in the study area, an analysis was done on Radar rain data (of more than 20 mm/h or more than 80 mm in all). The results of the duration analysis for each rainfall are summarized as Table - 7.5.

Table 7.5 Rainfall Duration (more than 20 mm/h or more than 80 mm in total)

		Time						Total	Remarks
		30M	1H	3H	6H	12H	24H		
7/Dec/87	Rain (mm)	8.2	25.4	29.7	29.7	29.7	29.7	35.5	Area 1
	%	23.1%	71.5%	83.7%	83.7%	83.7%	83.7%		
13/Dec/87	Rain (mm)	20.1	21.9%					21.9	Area 1
	%	91.8%	100.0%						
9/Dec/87	Rain (mm)	18.6	28.7					28.7	Area 2
		64.8%	100.0%						
5/Dec/87	Rain (mm)	20.3	62.4					62.4	Area 2
	%	32.5%	100.0%						
6/Dec/87	Rain (mm)	1.5	1.7	32	59.1	59.9		59.9	Area 2
	%	2.5%	2.8%	53.4%	98.7%	100.0%			
11/Dec/87	Rain (mm)	27.9	35.6	36.6	36.6	36.6	42.1	78.4	Area 3
	%	35.6%	45.4%	46.7%	46.7%	46.7%	53.7%		
7/Dec/87	Rain (mm)	20.8	40.3	42.6	42.6	42.6	43.3	43.3	Area 3
	%	48.0%	93.1%	98.4%	98.4%	98.4%	100.0%		
13/Dec/87	Rain (mm)	19	20.5					20.5	Area 3
	%	92.7%	100.0%						
11/Dec/87	Rain (mm)	24	24.3					24.3	Area 4
	%	98.8%	100.0%						

Note) rain = cumulative rainfall
(%) = percentage for total rainfall

According to table - 7.5, though little data was collected, the following can be said;

-; The duration of rainfall is mostly within one day.

-; The duration of rainfall is usually, to 3 hours.

7.4.5 Occurrence Time Analysis of Rainfall

In order to know the occurrence time of rainfall, analysis was done on Radar rain data of more than 5 mm/h. The results are shown in Fig. - 7.8. From the figure the following can be known.

(1) Most of the rainfall occurred in the afternoon from 1 p.m to 9 p.m.

(2) The high level of rainfall is concentrated from 2 p.m to 5 p.m.

(3) The occupation rate of the frequency in the four hours for the duration of rainfall, from 2 p.m through 5 p.m, is about 50 percent shown as follows;

- Area 1: 46.4%
- Area 2: 59.7%
- Area 3: 48.9%
- Area 4: 55.3%

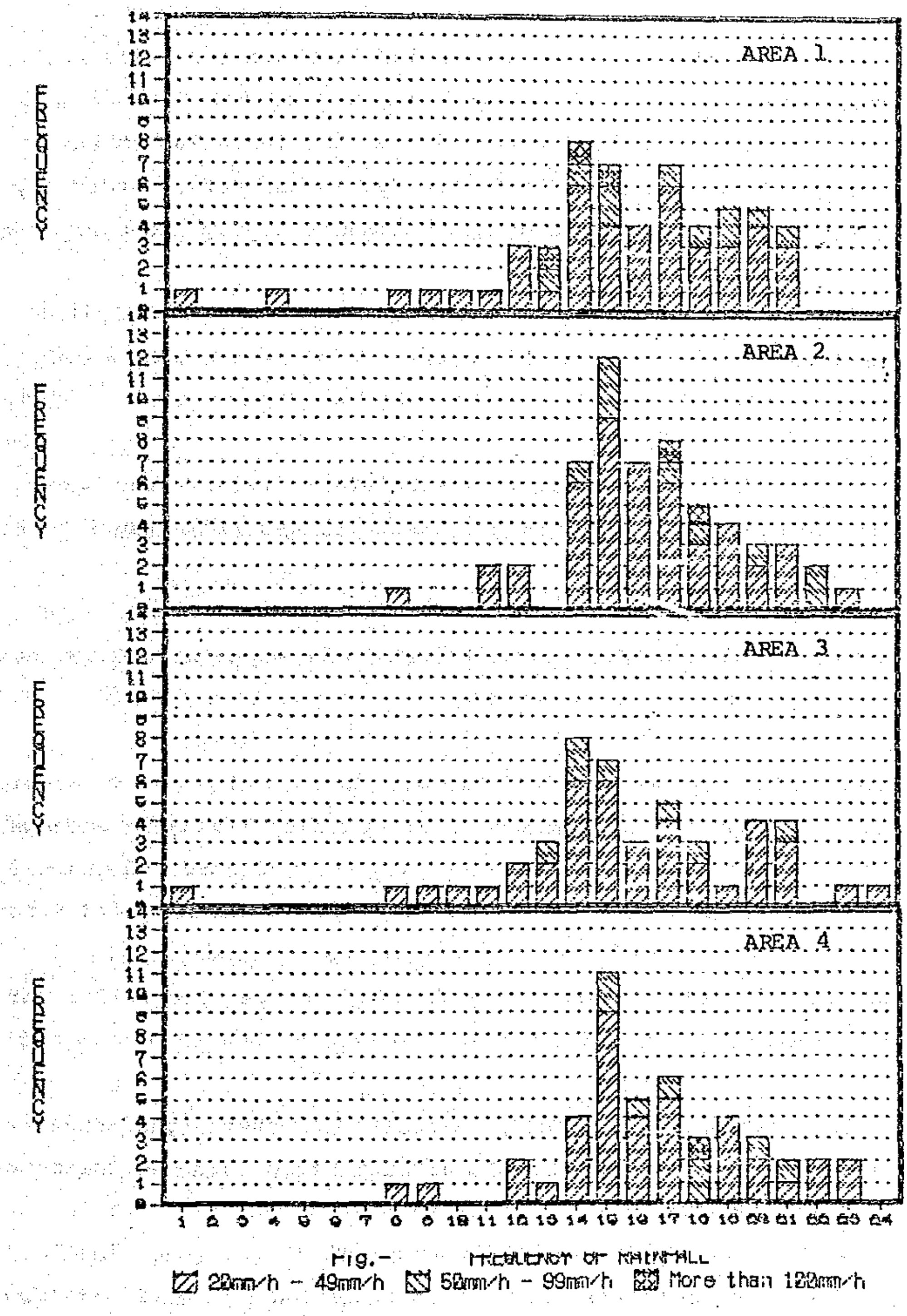


Fig. - 7.8 Frequency of Hourly Rainfall

7.5 Recommendations for Operation of Warning and Evacuation System

7.5.1 Present Condition and Results of Rainfall Characteristics Analysis

Since the Warning and Evacuation System was installed at the Mt. Galunggung Project Office in 1983, the System has not recorded any complete data because of unstable commercial power supply and equipment trouble.

Therefore, the purpose of this system at present can be mainly said as follows;

(1) To collect data for setting up the Rainfall Criteria for Lahar Forecasting and Evacuation based on the basic process from Step 1 to Step 3 shown in 7.4.1.

(2) To give rainfall conditions to the authorities concerned to have the inhabitants evacuated from endangered area.

After setting up the Rainfall Criteria for Warning and Evacuation, this Criteria can be relied on to protect the inhabitants living in endangered areas. However, the data collection has just started anew and there is insufficient data to set up the Rainfall Criteria for Warning and Evacuation.

The following was obtained from the study of December, 1987 through February, 1988 although the data is insufficient.

1) The correlation of hourly rainfall is rather higher than that of 10-minute rainfall using Radar Rain Gauge Data and Telemetering Rain Gauge Data.

2) The relation between Radar Rain Gauge Data (Area 2 and Area 4) and Telemetering Rain Gauge Data are strong for hourly rainfall.

3) Most of the rain zone area is less than 100 km^2, mainly, concentrated in 40 - 70 km^2.

4) Most of rain zone move at a speed of about 10 km/h, in the direction of north or east.

5) Most of the rain is concentrated in the afternoon, especially in the three hours from 2 p.m. through 5 p.m.

7.5.2 Recommendation concerning the Future Operation of the System

Taking into account the status of the warning and evacuation system mentioned in section 7.2 and based on the results of rainfall observations of section 7.4, the following are recommendations for the future operation of the system.

(1) The Observation System

Radar rain gauges can be considered the optimal observation equipment in areas such as the Galunggung basin where the rainfall area is small and rainfall is distributed unevenly in the basin.

This metering equipment should continue to be utilized in the future for the main rainfall observation in the basin. The radar rain gauges are capable of real-time measurement of the range of rainfall areas, area movement, and rainfall intensity. Through the recording of this data on floppy discs, this becomes an effective method in grasping rainfall characteristics and predicting rainfall. For such observations, a rain gauge installed on the ground is used to calibrate the radar gauge.

Rainfall predictions become possible when the data from the radar gauges is prepared and interpreted. However, in order to grasp the relation between rainfall and the occurrence of debris flow, which is the ultimate object of this project, it is necessary to watch and record debris flow by human observation.

Future observation and management of data will be conducted in accordance with the following policies.

1) Hard copy from the data rain gauge shall be kept and accumulated so as to serve as the basic data for the management of rainfall zone range, zone movement, and direction of movement information and also for rainfall prediction.

2) The relation of rainfall depth and runoff amounts (hydrograph) will be determined. At that time, the analysis of cumulative rainfall data including antecedent rainfall before main rainfall shall be considered.

3) Data on the occurrence of debris flow shall be accumulated. Through an understanding of the relation between this and rainfall intensity, a "Warning and Evacuation Standard" shall be established as a rainfall depth standard to allow the prediction of debris flow occurrence 30 minutes to one hour beforehand. From among the above, the accumulation of data in (1) is considered highly significant, and it is hoped that this observation shall be continued in the future.

(2) Warning Transmission System

Because the organization of the Warning Transmission System which existed at the time of the disaster in 1982 has basically been maintained, there are no particular problems with it. For the residents who live within the sandpocket in sediment or flood regions, the security of an evacuation plateau is considered necessary in addition to the Warning and Transmission System in the future.

As mentioned before, the role that the amateur (Ham) radio network plays in the transmission system is quite important. As a result, the strengthening of an emergency energy system by such means as battery back-up is considered necessary for the future.

8. Socio Economy

8.1 Administrative Area

This study area is located in the north - central part of Kabupaten Tasikmalaya. The study area of southern - east slope of Mt. Galunggung consists of 6 Kecamatan, such as Kecamatan Indihiang, Kecamatan, Leuwisari Latter-three Kecamatan consist of the city of Tasikmalaya, (refer to Fig. - 8.1 and Table 8.1).

Study area of southern-west slope of Mt. Galunggung consists of 3 Kecamatan, such as Kecamatan Leuwisari, Kecamatan Singaparna and Kecamatan Cigalontang. These area have 21 Desa (Village) and 6,845 ha approximately. However this value of area includes 6 Desa which overlap the study area of the southern-east slope of Mt. Galunggung. Those contents are also in Table - 8.1.

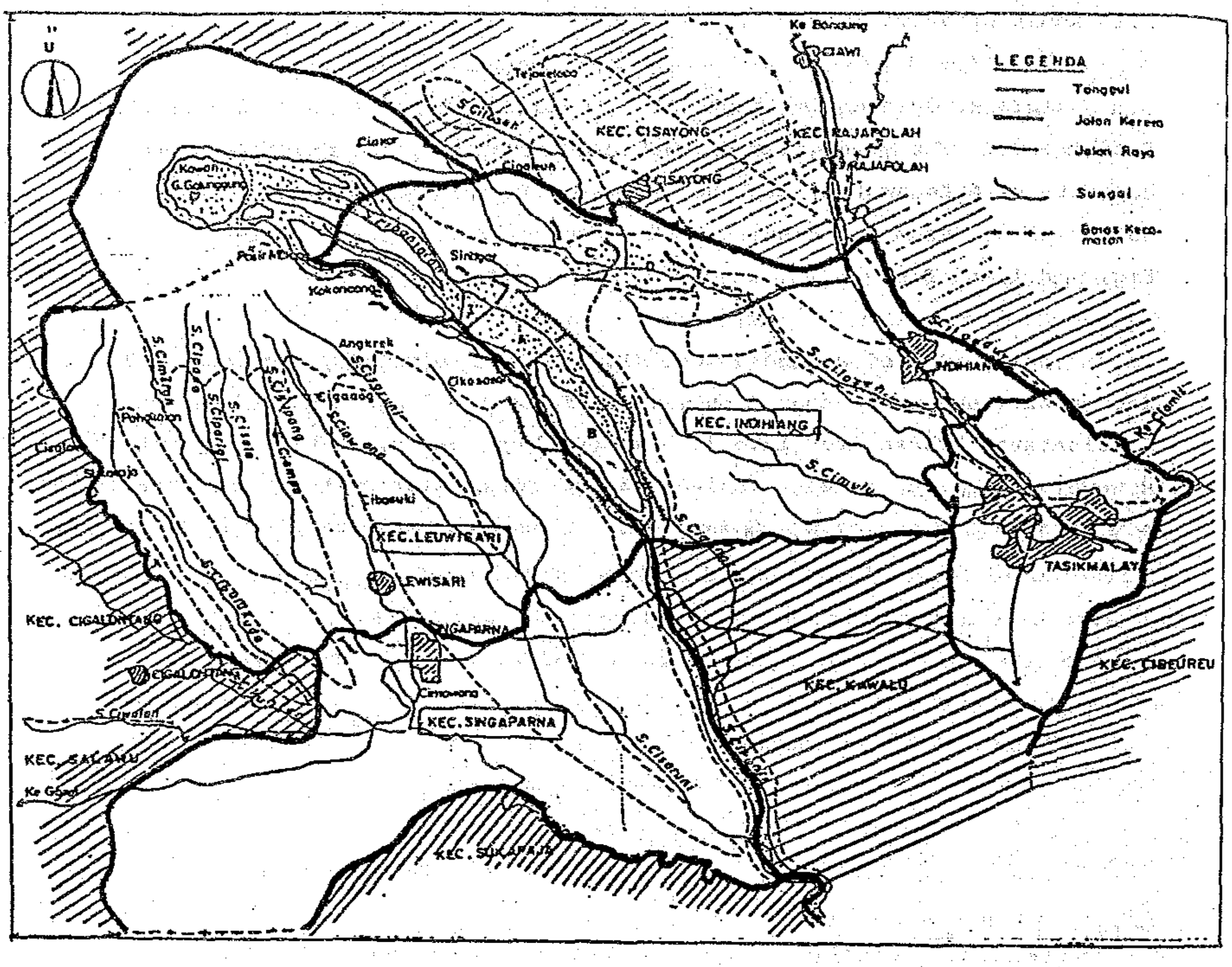


Fig.- 8.1 Study Area - Kecamatan Objected

Table - 8.1 Administrative Area of Study Area

1) (Southern - East Slope)		Area (ha)
Kecamatan	Desa	
Indihiang	Sukamahi, Sukarindik, Sukajava, Sukamulya, Sukalaksana, Bungursari, Tawangbanteng, Sinagar, Panyingkiran, Sukaratu, Bantarsari, Gunungsari, Sukagalih, Linggarjati, Cibunigeulis	
Leuwisari	Mekarjaya*, Rancapaku*, Cisaruni*, Cilampung Hilir*	
Singaparna	Cikunir*, Sukarame*	
Cipedes	Sukamanah, Nagarasari, Cipedes, Panglayungan	
Cihideung	Yudanegara, Argasari	
Tawang	Tawang, Lengkongsari, Empangsari	

2) (Southern - West Slope)		Area (ha)
Kecamatan	Desa	
Leuwisari	Mekarjaya*, Rancapaku*, Cisaruni*, Cilampung Hilir*, Arjasari, Ciawang, Sukamulih, Linggawangi, Sukaharja, Jayaratu, Sariwangi, Linggasirna	4,713
Singaparna	Cikunir*, Sukarame*, Cigadog, Cipakat, Cikunten, Singaparna	1,496
Cigalontang	Sukamanah	276

Notes: (1) Rancapaku, Jekarjaya, Cisaruni, Cilampung Hilir, Cikunir, and Sukarame are overlap above two study areas, that are marked and which is 2,082 ha approximately.

(2) Desa Jayaratu is including Desa Jayaputra.

(3) Desa Singaparna is including Desa Singasari.

8.2 Population

The largest population of the study area in these six years was recorded in 1982 when Mt. Galunggung erupted. Every Kecamatan had their population decrease after the eruption. One of the reasons why the population decreased was because of the transmigration from these areas to other areas such as Sumatra, Kalimantan, Sulawesi and other areas in Java.

From 1983 up to now, the population of this study area has been gradually decreasing as shown in Table - 8.2.

The rate of decrease for 1986/1982 is 0.9% in this study area. Otherwise, the population of Kabupaten Tasikmalaya has increased 1.4%.

Table - 8.2 Population by Kecamatan

Kecamatan	1980	1981	1982	1983
Singaparna	85,544	97,294	97,030	96,092
Leusari	71,471	75,818	73,664	73,404
Indihiang	79,488	85,365	80,155	79,818
Cipedes	50,756	50,092	52,495	51,709
Cihideung	50,535	58,281	52,653	55,537
Tawang	49,893	55,965	55,324	54,904
Sub-Total	387,687	422,815	411,321	411,464

Kecamatan	1984	1985	1986	1986 / 82
Singaparna	96,205	95,852	95,766	0.987
Leusari	73,321	73,047	73,992	0.991
Indihiang	80,015	79,316	79,486	0.992
Cipedes	49,842	49,885	49,610	0.945
Cihideung	55,162	54,854	55,570	1.055
Tawang	54,680	54,296	54,235	0.980
Sub-Total	409,225	407,250	407,659	0.991
Kab. Tasikmalaya	1,587,606	1,589,466	1,609,386	1.014

Source: "Tasikmalaya Dalam Angka 1985 & 1986"
Kab. Tasikmalaya, Kantor Statistik

The study area of southern-east slope of Mt. Galunggung has 187.1 thousand people in all Desa on September 1987. At the same time, about 133 thousand people live in the greatest possible disaster area. That is 70 percents of the all Desa in this study area. It should be mentioned that 100 thousand people live in the city of Tasikmalaya by Desa. This means the concentration to the urbanized area, especially the city of Tasikmalaya, is 53.6 percent in the all Desa. (Refer to Table - 8.3).

The other study area of the southern-west slope of Mt. Galunggung has 88.7 thousand people in all Desa. But, this number includes the overlapped population of the southern-east slope area, that is 31.7 thousand people. Therefore, the total population in both study areas is 244,200 persons approximately.

Table - 8.3 Population of Study Area

	(Southern - East Slope)	Population	Remarks
(A)	Population of all Desa	187,106	
(B)	Population of the possible greatest disaster Area	132,765	71.0% of (A)
(C)	Population of Tasikmalaya City by Desa	100,272	53.6% of (A)
	(Southern - West Slope)	Population	Remark
(D)	Population of all Desa	88,748	
(E)	Population of overlapped Desa	31,652	
(Grand Total)			
(F)	(A) + (D) - (E) by Desa	244,202	

8.3 *Gross Regional Domestic Product*

The gross regional domestic product (GRDP) of Tasikmalaya on 1986 is 607,876 million rupiah, which shows an annual growth of 17%. Compared with 1983, GRDP shows the growth in 1986/1985 of 1,552 on current price and the growth of 1,325 on constant price of 1983. (Refer to Table - 8.4.)

According to the each Industrial sector, the primary industrial sector shares 29.9%, the secondary industrial sector occupies 27.5% and the tertiary industrial sector shares 42.6%. It can be further broken down that the agricultural sector is 29.7%, the manufacturing sector is 13.8%, the constructing sector is 12.9% and the commercial sector is 20.6%.

GRDP per capita is Rp 379.853 and its Growth rate (1986/1985) is 16.1%. Income per capita in 1986 is Rp 336,588, that means the total added value of products which were produced in 1986 per capita in Tasikmalaya area.

Table - 8.4 Gross Regional Domestic Product

(Million Rupiah)

Year	Current Price			Constant Price of 1983		
	GRDP	Index	Growth Rate (%)	GRDP	Index	Growth Rate (%)
1983	391,608.7	100.0	-	391,608.6	100.0	-
1984	478,743.5	122.3	22.25	439,505.5	112.2	12.23
1985	519,552.6	132.7	8.52	458,141.9	117.0	4.24
1986	607,875.7	155.2	17.00	518,882.4	132.5	13.26

GRDP by Industrial Sector

($x\ 10^6$ Rp)

Classification	Current Price 1986	%	1983 Constant Price 1986	%
1. Primary	181,768.4	29.9	166,393.5	32.1
2. Secondary	167,032.4	27.5	139,531.1	26.9
3. Tertiary	259,074.9	42.6	212,957.8	41.0
Total	607,875.7	100	518,882.4	100.0

GRDP per Capita

Item (Unit Rp)	Current Price 1985	Current Price 1986
GRDP per capita	327,082.3	379,853.7
Regional Income per capita	289,827.7	336,588.4
Regional Income per capita growth rate (%)	8.4	16.1

8.4 Agricultural Activities

Agriculture is the main industry of this area. Concerning the related 6 Kecamatan with the study area, total area of paddies is 16,380 ha and it production is 92,686 ton.

Agricultural land is mainly occupied by paddy fields. Rice paddies are about 70% of all the agricultural land. In this area, almost all farmers do not use their land to produce secondary crops. If some farmers grow secondary crops, such as ubi kayu (Cassava), it will be in small volume only for self consumption, or because of a certain accident, like a broken channel to supply water, as in the case of damage due to the eruption of Mt. Galunggung. Vegetables and fruits are transported from the neighboring area of Kabupaten Tasikmalaya.

The production volume of rice paddies are shown in Table - 8.5. The unit yield of rice with husk (Gabah Kering) is about 5.7 ton/ha. This excellent yield is considered to be the result of plentiful water stored by Mt. Galunggung, the rainy climate of this area and the good quality of the soil. This is the main reason why the farmers have no intention to produce secondary crops and they can have two or three crops of rice a year.

The rice paddies are almost all irrigated using river water and spring water, especially from the two representative irrigation channels located in this study area, i.e. Saluran Cikunten I and Cikunten II. Saluran Cikunten I is directly concerned with this disaster prevention planning project area. 4,500 ha of land have been irrigated by Cikunten I. The other wide area has been irrigated from each river, such as 200 ha of Muhara and 769 ha of Cigede by River Ciloseh.

Another noticeable characteristic of agriculture is this area is many fish ponds. Fish which are raised in the fish pond are very popular for dishes such as Mas, Nilem, Mujair, Tambak, Tawes, and Gurame. There are especially many fish ponds in this study area in the basin of S. Ciloseh and S. Cikunir compared with other area in Kabupaten Tasikmalaya. Usually seed fish which are grown-up about 40-days are put into the fish-pond and after about three months they are brought to the market. In Kabupaten Tasikmalaya the eight main fishes produce 21 thousand tons and 24,260 million Rupiah.

Table - 8.5 Rice Paddies and Their Products

Kecamatan	Paddies Field (ha)	Production (ton)	Production/ha (ton/ha)
Singaparna	4,021	22,720	56.5
Leuwisari	7,403	43,051	58.2
Indihiang	3,073	16,643	54.2
Cipedes	1,122	6,114	54.5
Cihideung	360	1,944	54.0
Tewang	401	2,214	55.2
Total	16,380	92,686	56.6

Source: "Tasikmalaya Dalam Angka 1986"
Kantor Statistik Kabupaten Tasikmalaya

Note : Production measured by Gabah Kering

8.5 Damage by Disaster

Mt. Galunggung erupted on April 5th, 1982. Past eruptions were in 1898 and 1922, therefore it erupted after being dormant for 60 years.

From April to October 1982, Mt. Galunggung erupted 57 times. From November 1982 to May 1983, Mt. Galunggung did not erupt, but disasters were caused by lahar and banjir. On April 8th 1982 (the second eruption), the number of evacuees recorded was 69,000 people. It was reported that the ejected material was 19 million m^3 and most of it was deposited in the Cikunir and Cibanjaran River, that is, about 3.2 million m^3 still remain at the upper basin of river Cikunir, Cibanjaran, Cisaruni, Ciloseh, Cimampang, etc.

Table - 8.6 Total Amount of Damage

(Unit: Rp)

a) Social Sector	
- Elementary school buildings, 82 were destroyed, 123 badly damaged and 32 partly damaged.	Rp. 3,359,679,000.-
- High school buildings, 3 were destroyed.	Rp. 27,000.000.-
- Mosques, 103 were destroyed/badly damaged.	Rp. 141,000,000.-
- Islamic schools, 116 were badly damaged.	Rp. 45,173,000.-
- Islamic colleges, 21 were badly damaged.	Rp. 13,000,000.-
- Public health centers, 1 was destroyed, 9 were badly damaged.	Rp. 21,357,000.-
- Public Utilities, 189 were destroyed.	Rp. 12,029,000.-
- Houses, 7,740 damaged.	Rp. 4,119,200,000.-
Sub-Total	Rp. 7,818,815,000.-
b) Economic Sector	
- Agriculture	Rp. 18,141,396,500.-
- Plantation	Rp. 3,645,802,500.-
- Forestry	Rp. 11,761,650,000.-
- Fishery	Rp. 3,664,186,100.-
- Livestock	Rp. 1,713,812,750.-
- Commercial	Rp. 232,617,000.-
- Industry	Rp. 195,210,000.-
- Road, Bridge, Irrigation channel	Rp. 3,372,550,000.-
Sub-Total	Rp. 42,727,550,309.-
c) General Sector	
- The loss of Government Income	Rp. 1,641,749,811.-
- Government	Rp. 110,450,000.-
Sub-Total	Rp. 1,752,119,000.-
Grand Total	Rp. 52,298,253,000.-

Source; "GALUNGGUNG Evaluasi Bencana & Usaha Rahabilitasi 1985
Kab. Tasikmalaya

The above is based on "Laporan Bencana Alam Gunung Api Galunggung serta Usaha Penanggulangannya sejak 5 April 1982 s/d September 1987" by Kepala Cabang Dinas Sosial, "Evaluaso Bencana dan Usaha Rahabilitasi 1985" and some reports about the damages of Mt. Galunggung by Kabupaten Tasikmalaya, DPU, etc.

Table - 8.7 Damages of Agriculture

Kecamatan	Areal Width and Amount of Damage					
	Rice Paddies		Dry Field		Total	
	Width (ha)	Value (Rp x 10^3)	Width (ha)	Value (Rp x 10^3)	Width (ha)	Value (Rp x 10^3)
Indihiang	889	2,776,662	75	150,000	959	2,926,622
Cisayong	300	942,126	-	-	300	942,126
Kawalu	1	3,140	-	-	1	3,140
Leuwisari	650	2,041,000	35	70,000	685	2,111,000
Cigalontang	87	273,000	-	-	87	273,000
Total	1,922	6,035,888	110	220,000	2,032	6,255,888