FIGURES

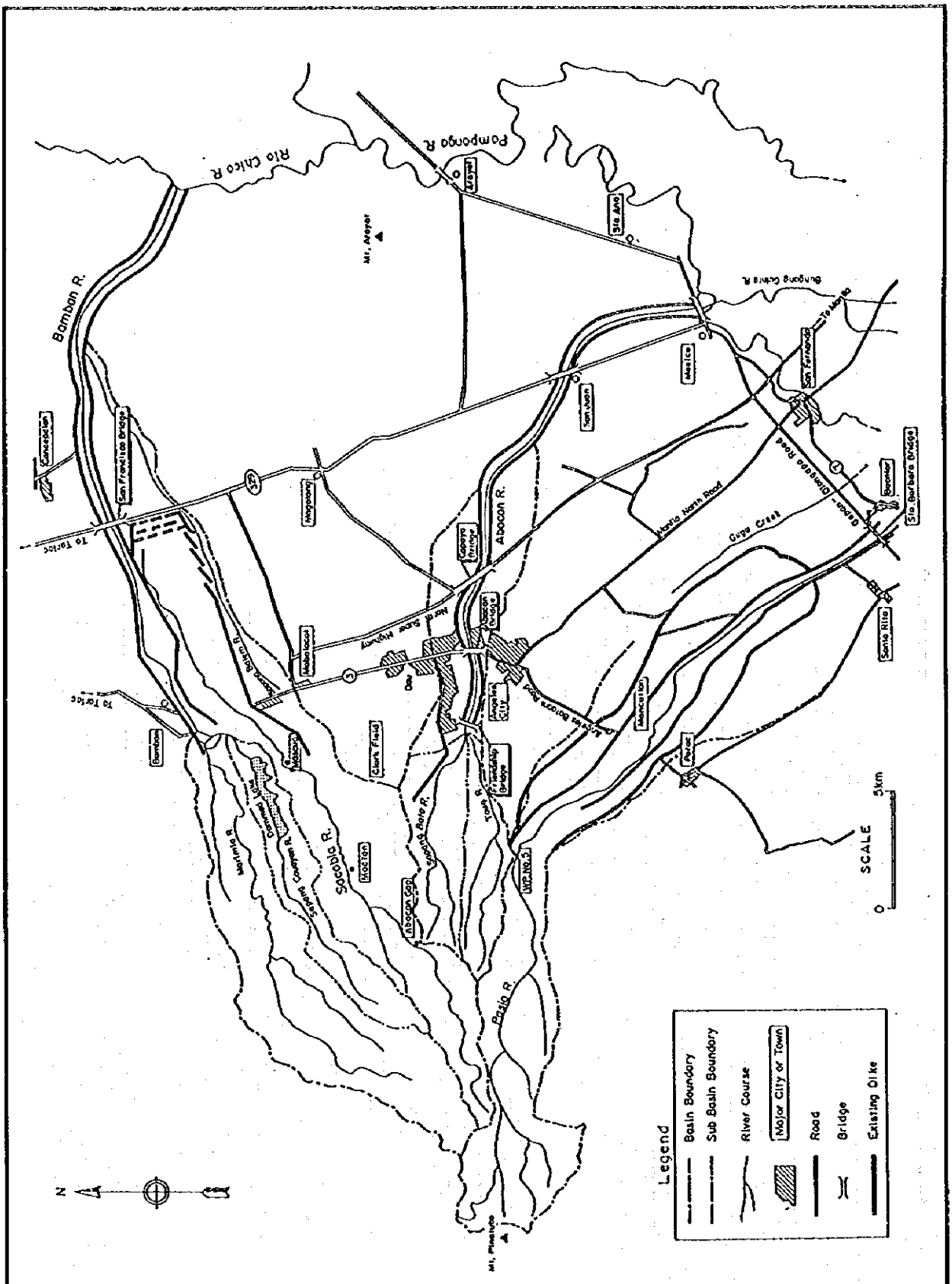

Figure F.1 Location Map of the Study Area

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

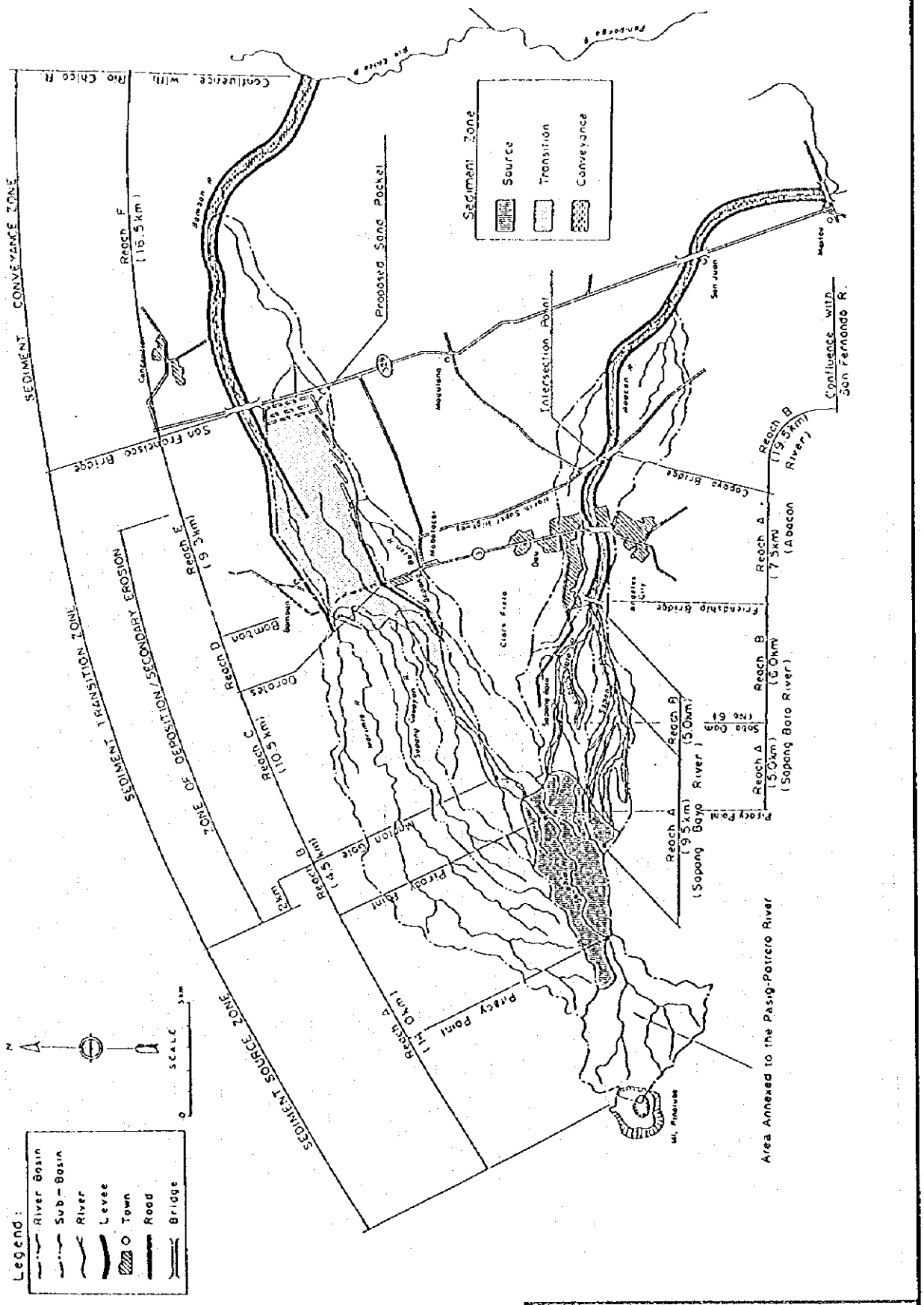

Figure F.2

Sediment Delivery Zone in Sacobia-Bamban and Abacan River Basins

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
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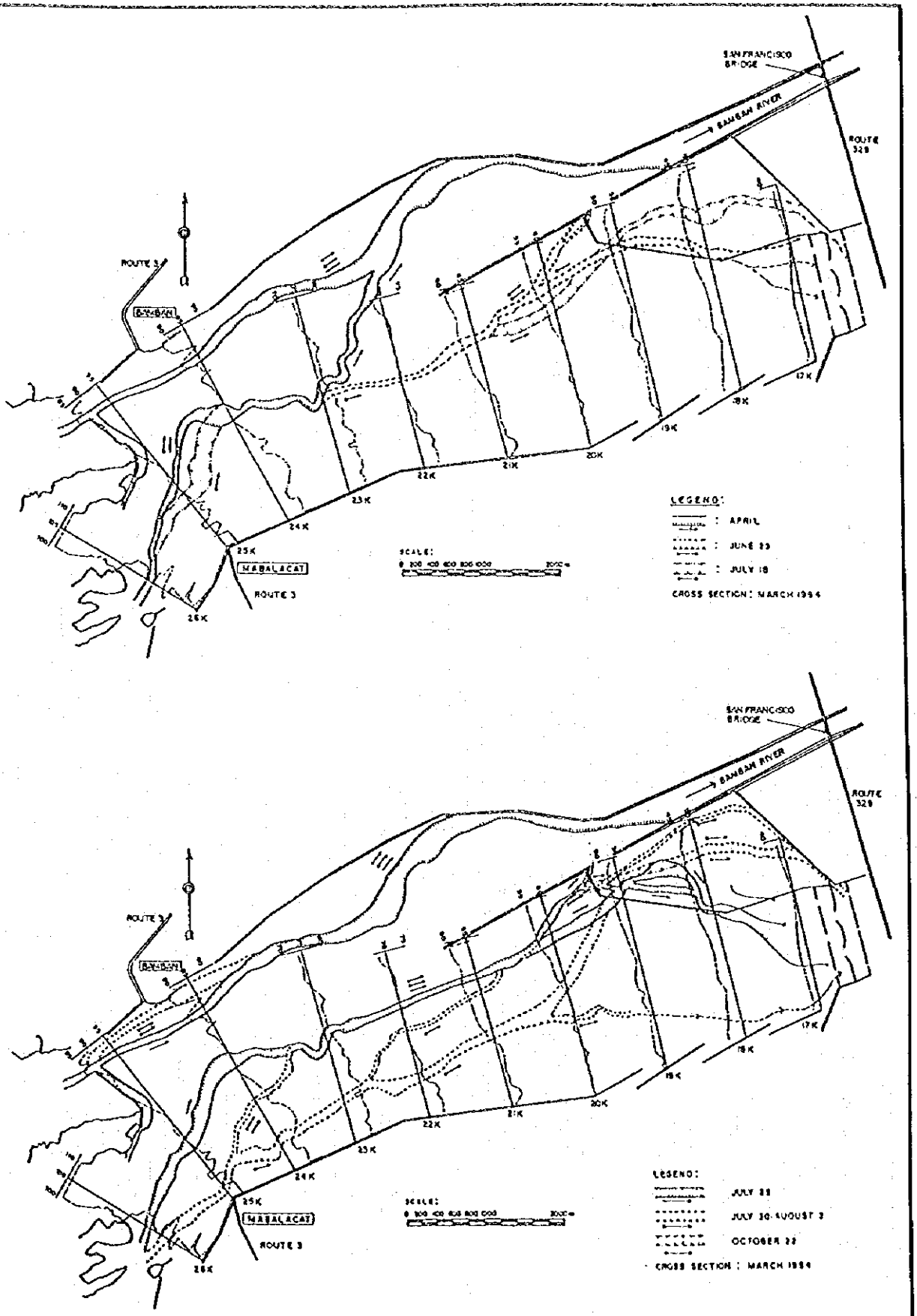
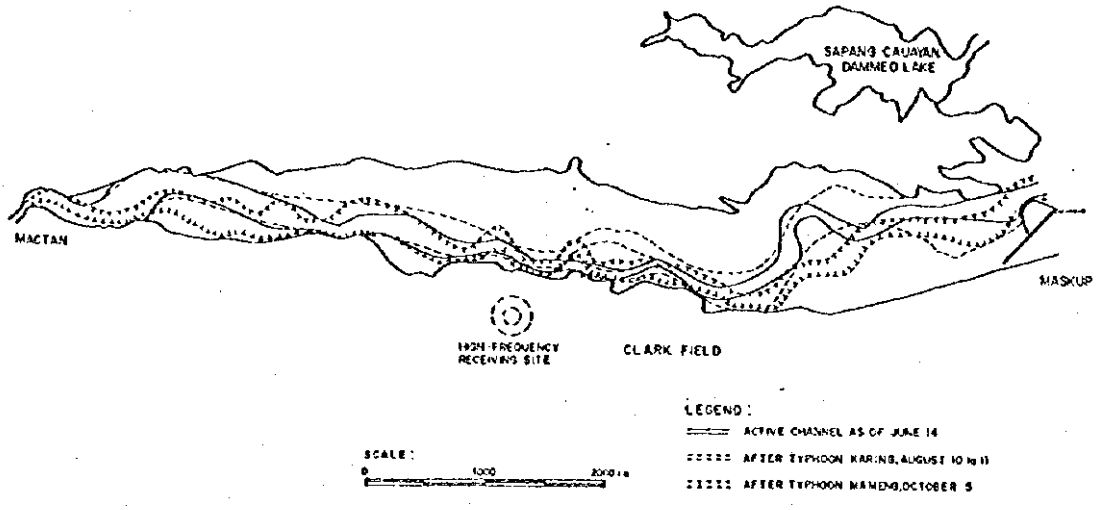
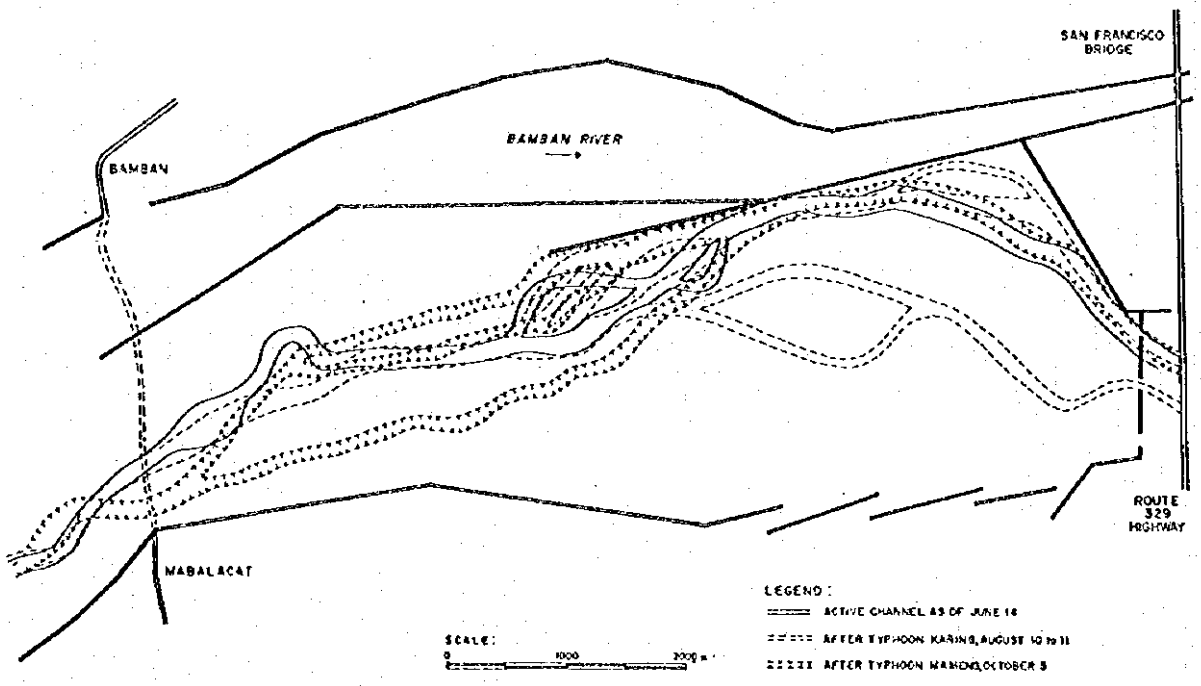


Figure F.3
Chronological Changes of Sacobia-Bamban River Course in 1994

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY



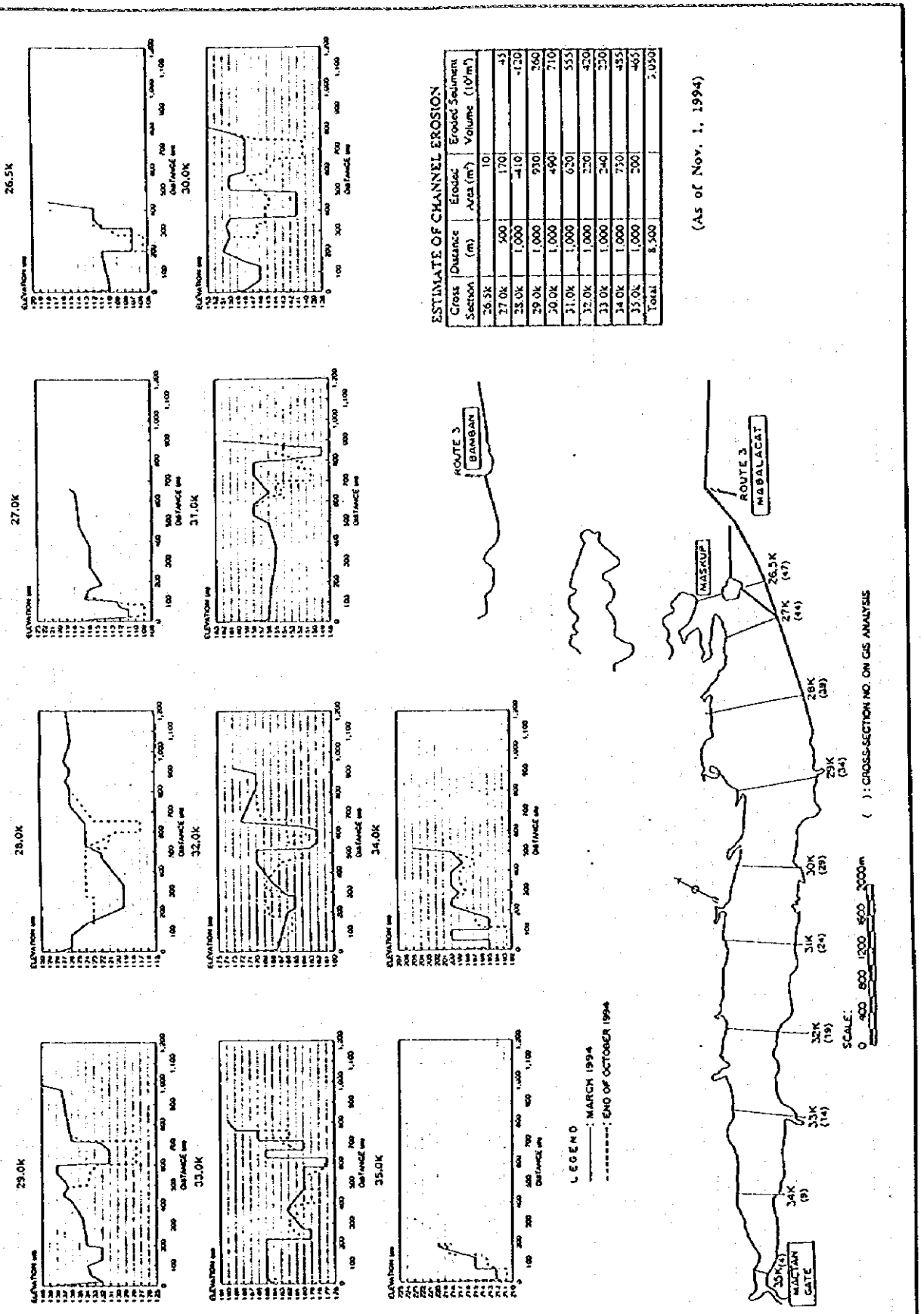
Mactan-Maskup



Mabalacat-Route 329

Figure F.4
Chronological Changes of Sacobia River Course in 1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY



Cross Section	Distance (m)	Eroded Area (m²)	Eroded Sediment Volume (10³m³)
26.5k		10	
27.0k	500	170	45
28.0k	1,000	-410	-120
29.0k	1,000	930	360
30.0k	1,000	490	710
31.0k	1,000	620	555
32.0k	1,000	220	420
33.0k	1,000	240	230
34.0k	1,000	730	485
35.0k	1,000	200	465
Total	8,500		2,950

Figure F.5 Cross-Sectional Changes and Estimated Channel Erosion from Mactan to Maskup in 1994

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT. PINATUBO
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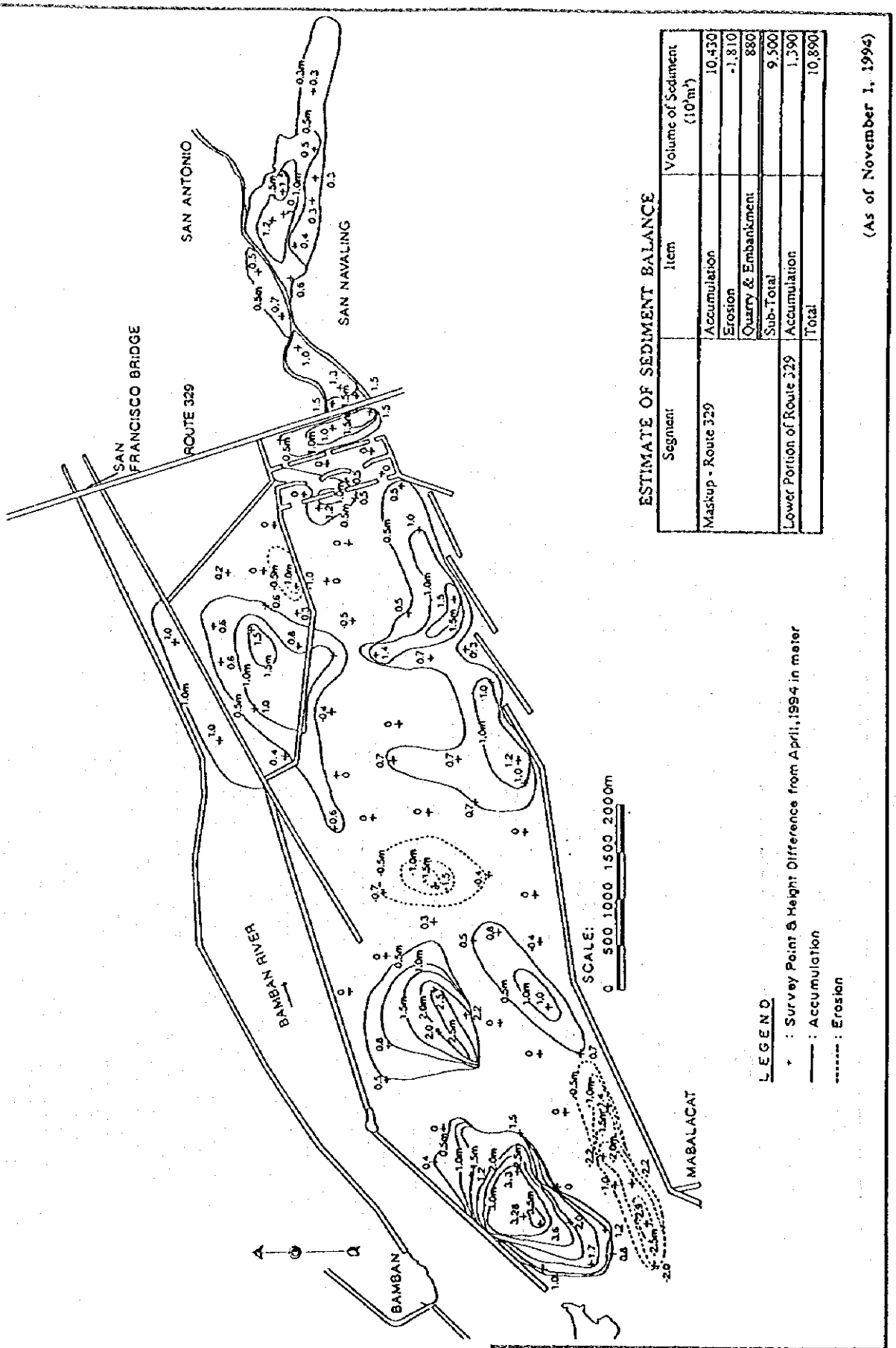

ESTIMATE OF SEDIMENT BALANCE

Segment	Item	Volume of Sediment ($10^3 m^3$)
Maskup - Route 329	Accumulation	10,430
	Erosion	-1,810
	Quarry & Embankment	880
	Sub-Total	9,500
Lower Portion of Route 329	Accumulation	1,390
	Total	10,890

(As of November 1, 1994)

Figure F.6 Isopach Map of Sediment Deposition/Erosion in Lower Sacobia in 1994

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
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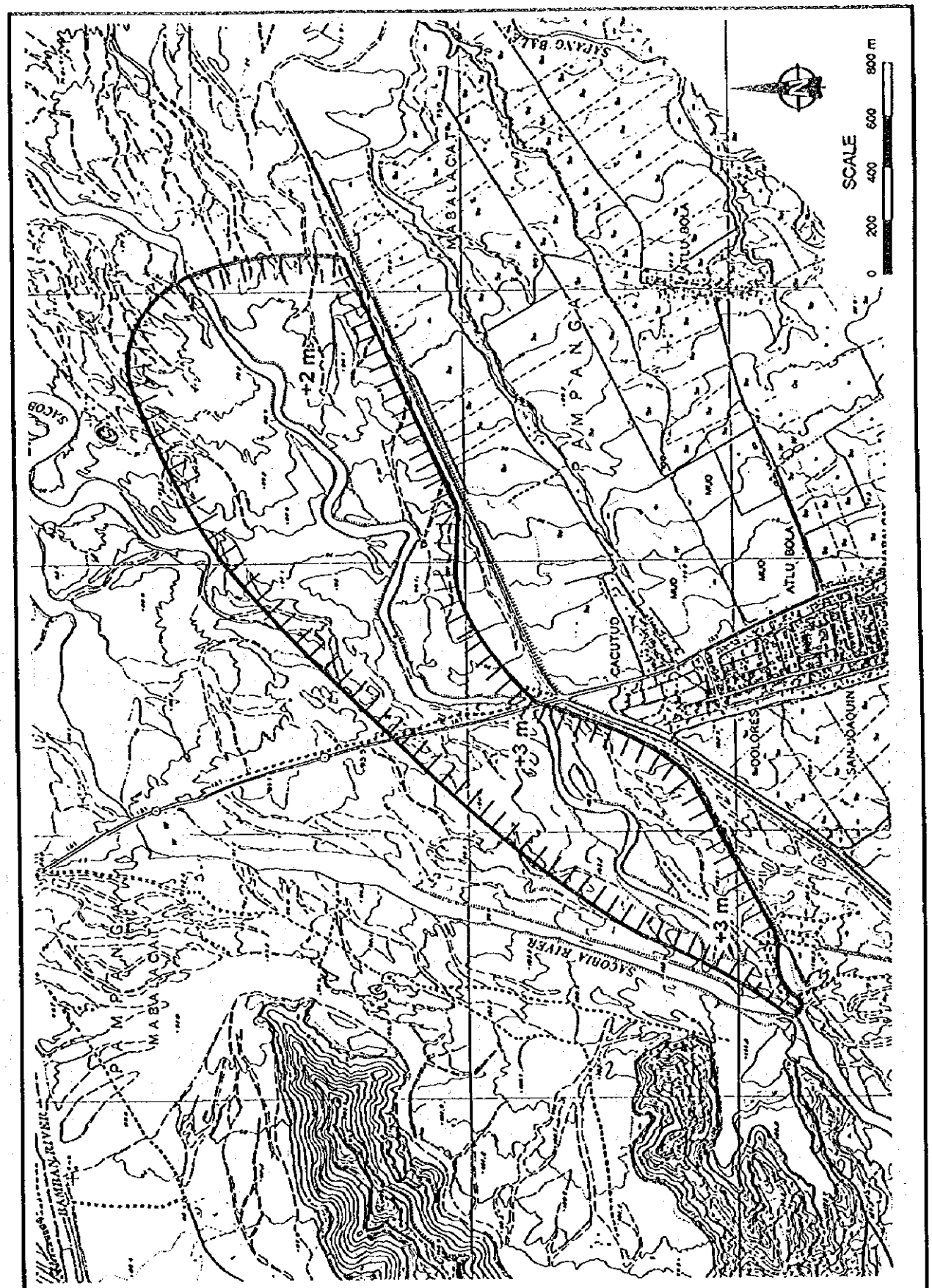


Figure F.7
Sediment Deposit during Typhoon Mameng on October 1, 1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

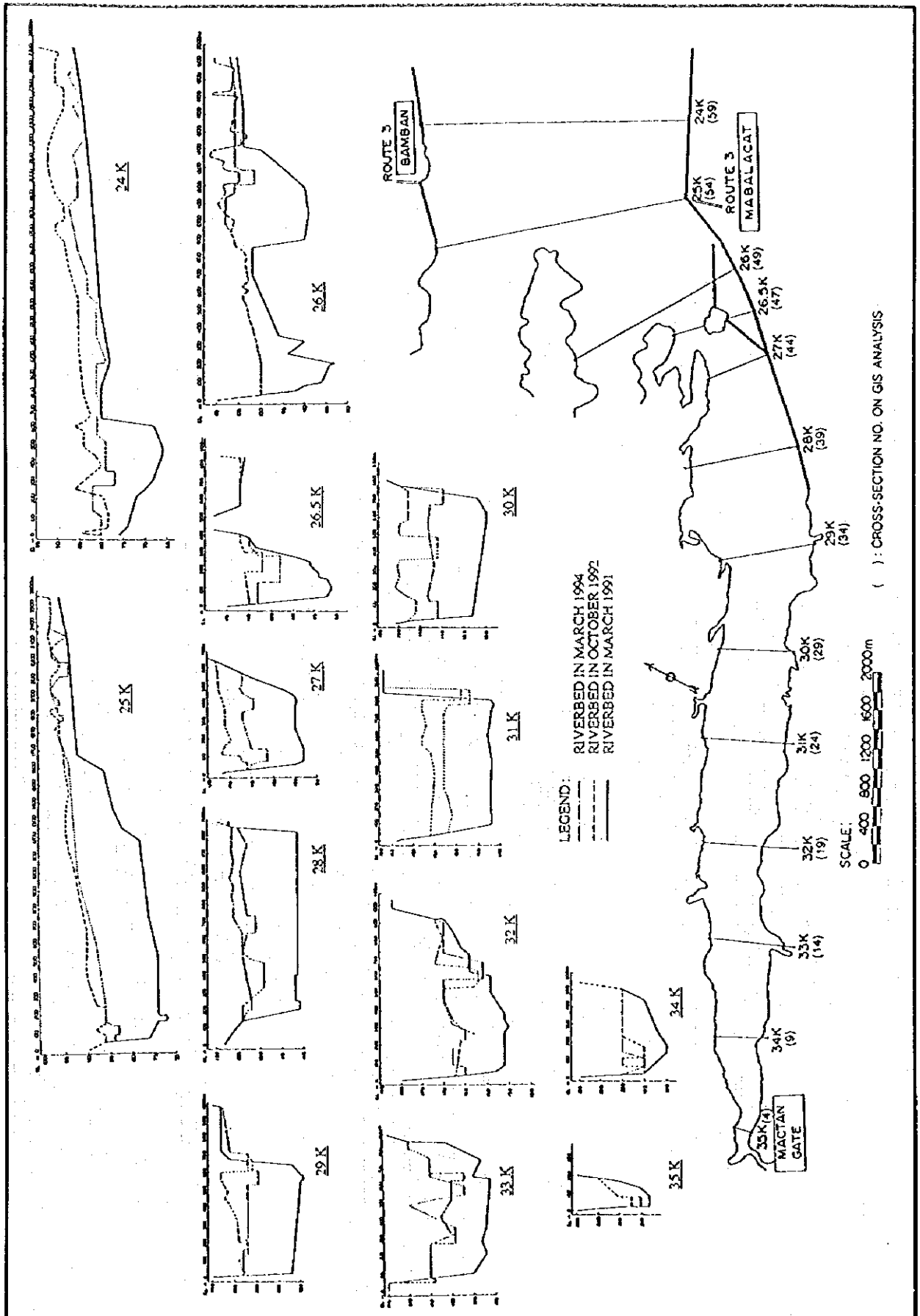
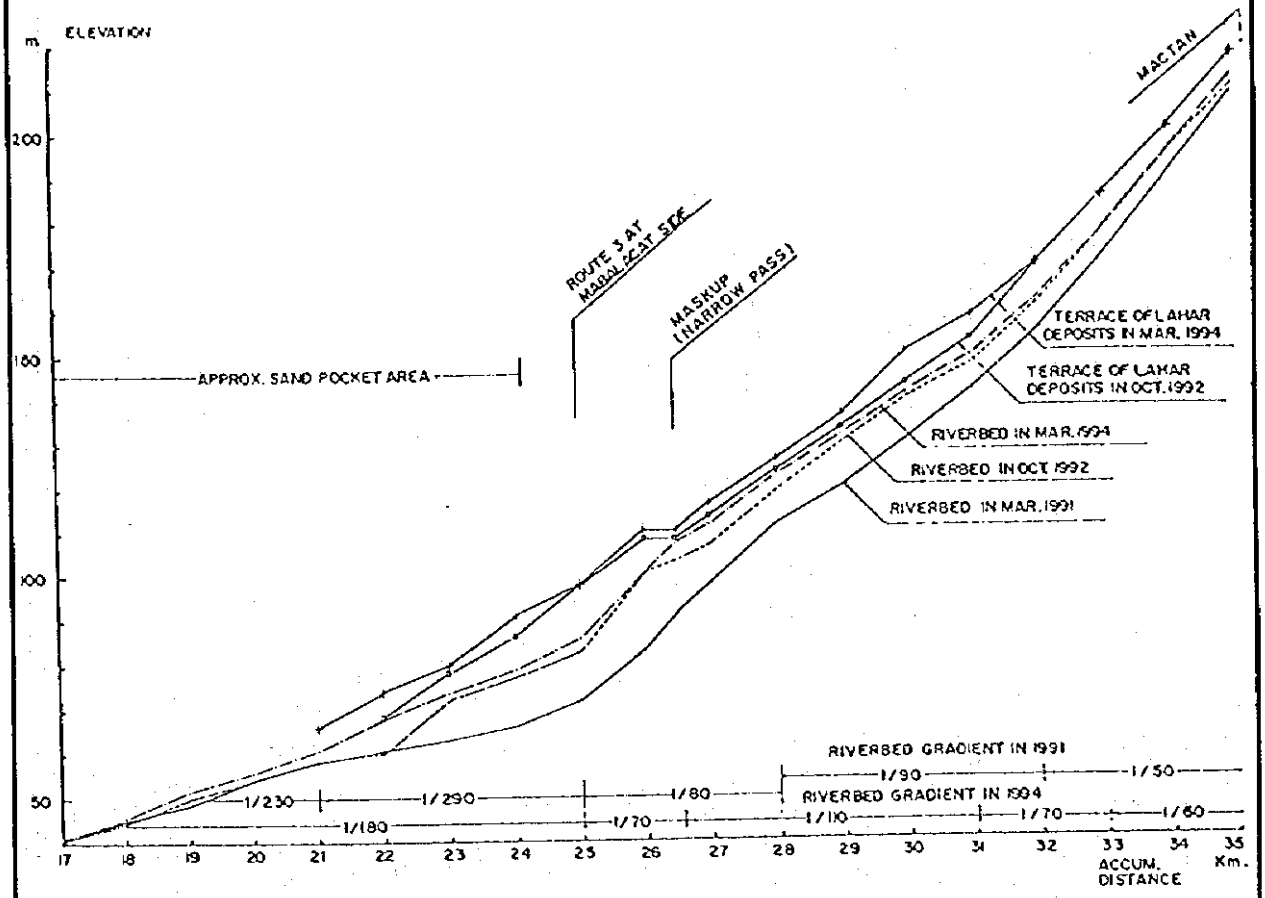


Figure F.8 Cross-Sectional Changes from Mactan to Mabalacat, 1991-1994

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY



VOLUME OF SEDIMENT DEPOSITION
MACTAN-MASKUP

Section	Distance (m)	Volume of Sediment Deposition (million m3)		
		'91-Oct.'92	Oct.'92-Mar.'94	Total
26.5-27 k	500	3.05	1.44	4.49
27-28 k	1,000	7.53	3.88	11.41
28-29 k	1,000	13.12	5.43	18.55
29-30 k	1,000	6.54	6.14	12.68
30-31 k	1,000	5.55	5.25	10.8
31-32 k	1,000	8.44	2.99	11.43
32-33 k	1,000	6.97	0.81	7.78
33-34 k	1,000	2.62	1.24	3.86
34-35 k	1,000	1.31	1.20	2.51
	Total	55.13	28.38	83.51

VOLUME OF SEDIMENT ACCUMULATION

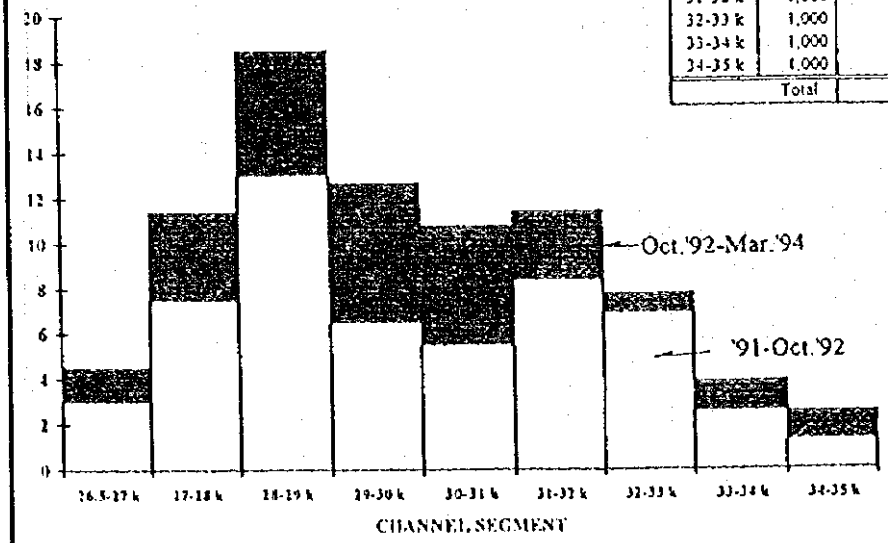
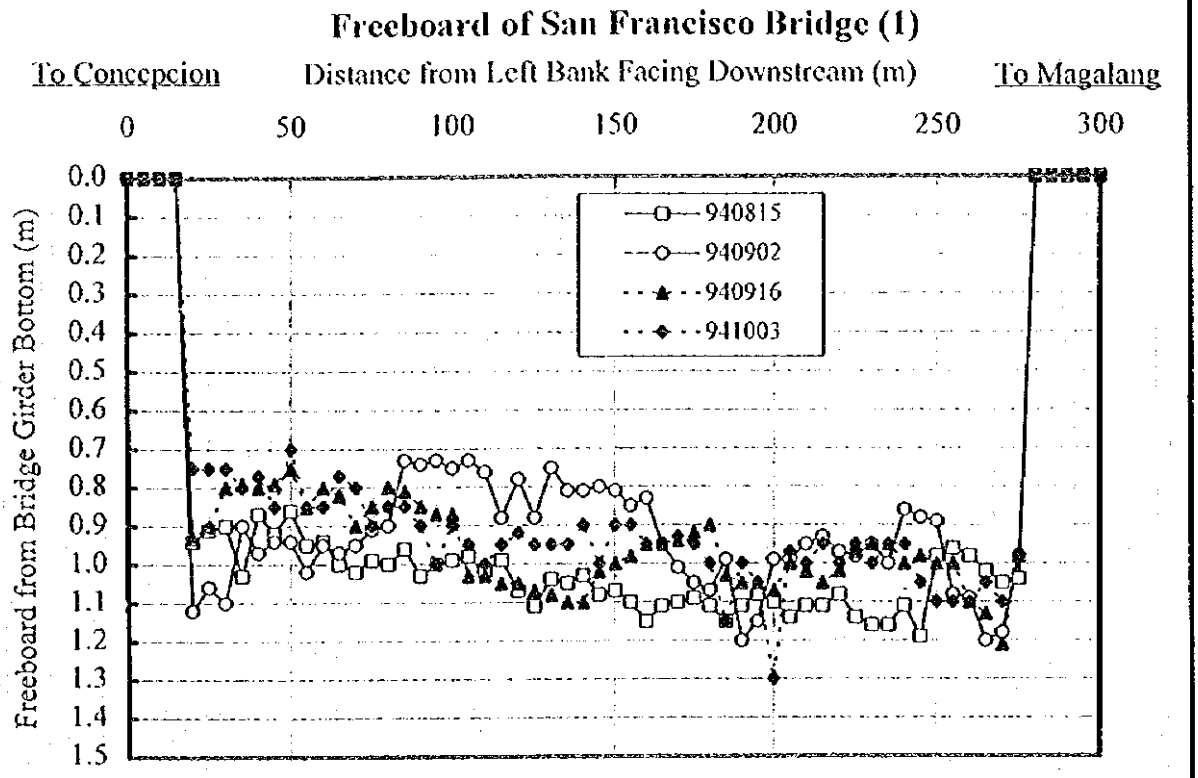


Figure F.9 Longitudinal Profile and Sediment Accumulation from Mactan to Maskup, 1991-1994

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY



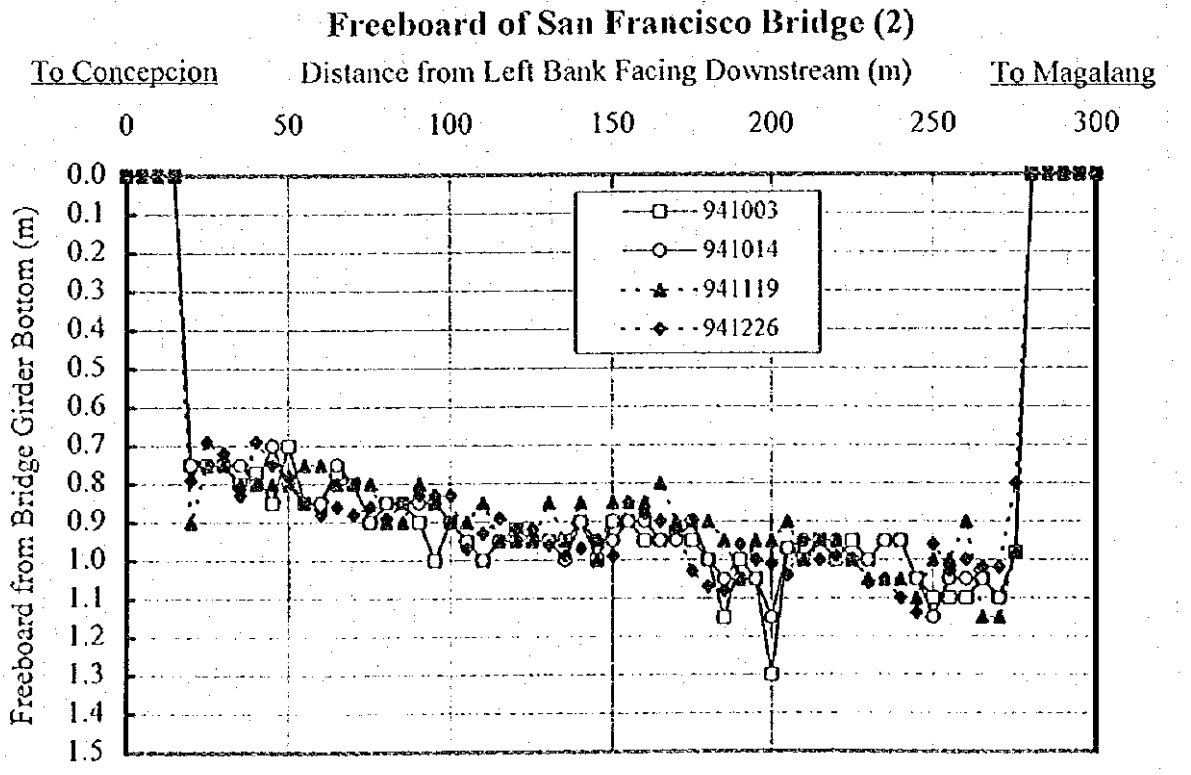
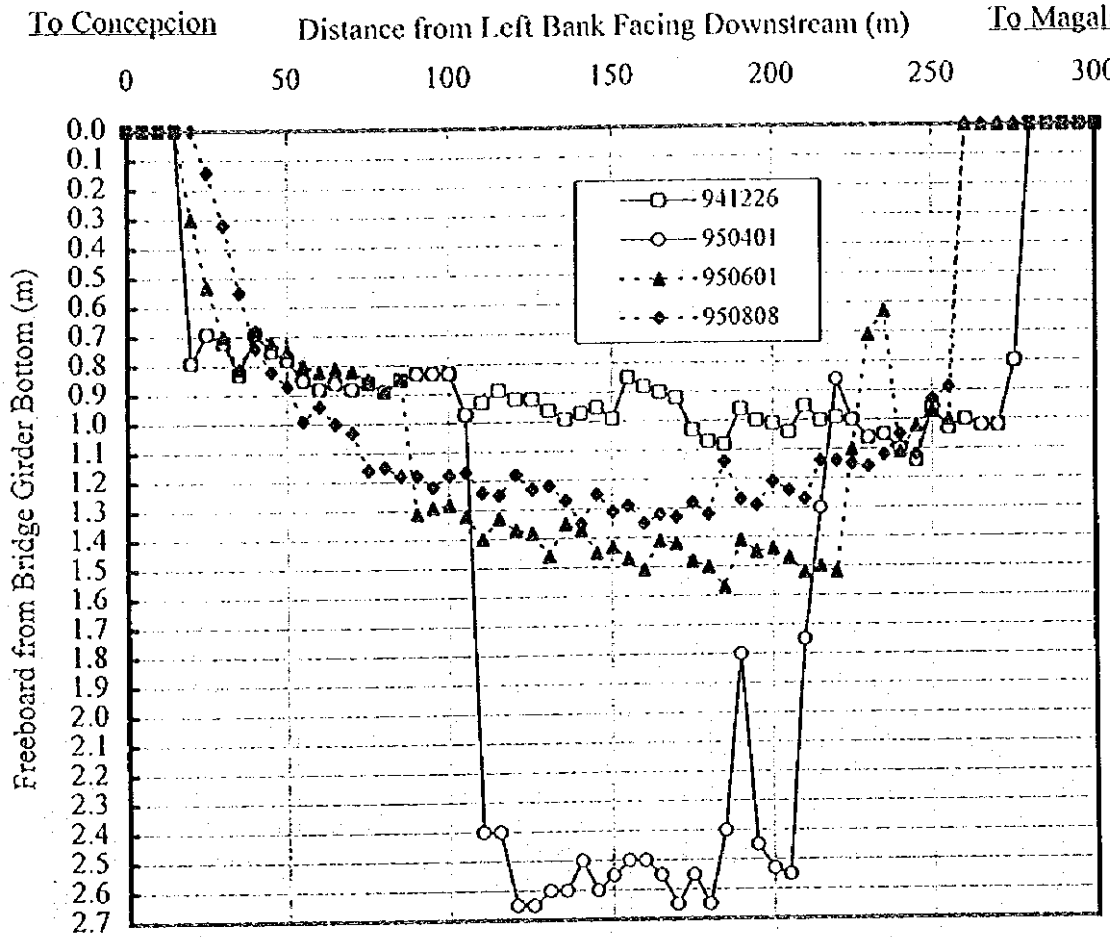


Figure F.10(1/2)
Changes of Freeboard and Cross-Section of San Francisco Bridge, 1994-1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY



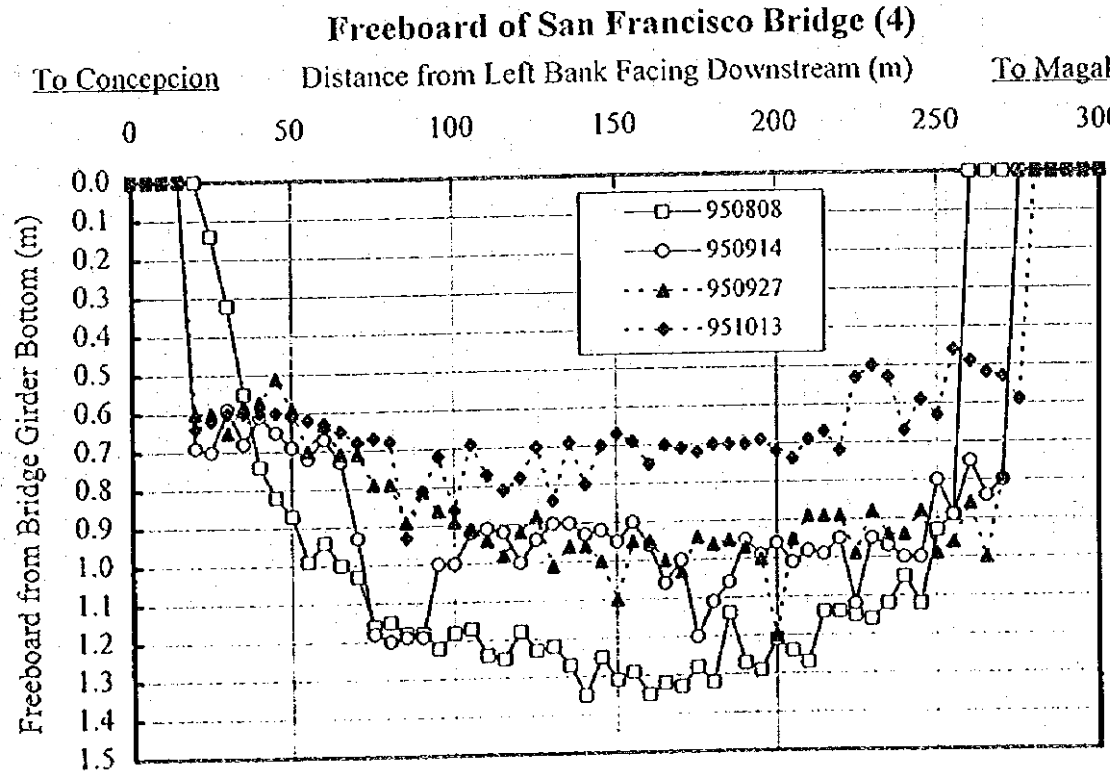


Figure F.10(2/2)
Changes of Freeboard and Cross-Section of San Francisco Bridge, 1994-1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

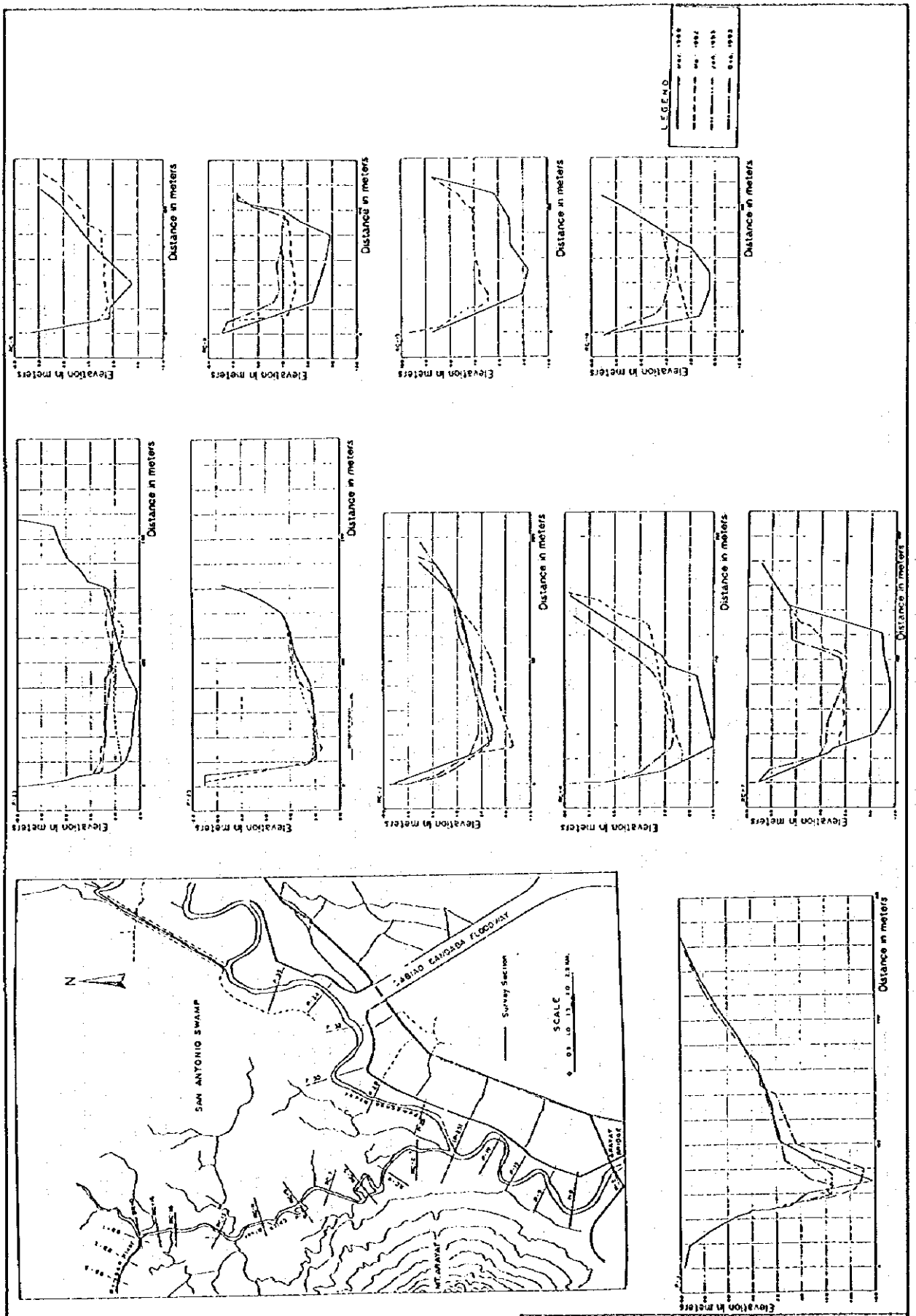
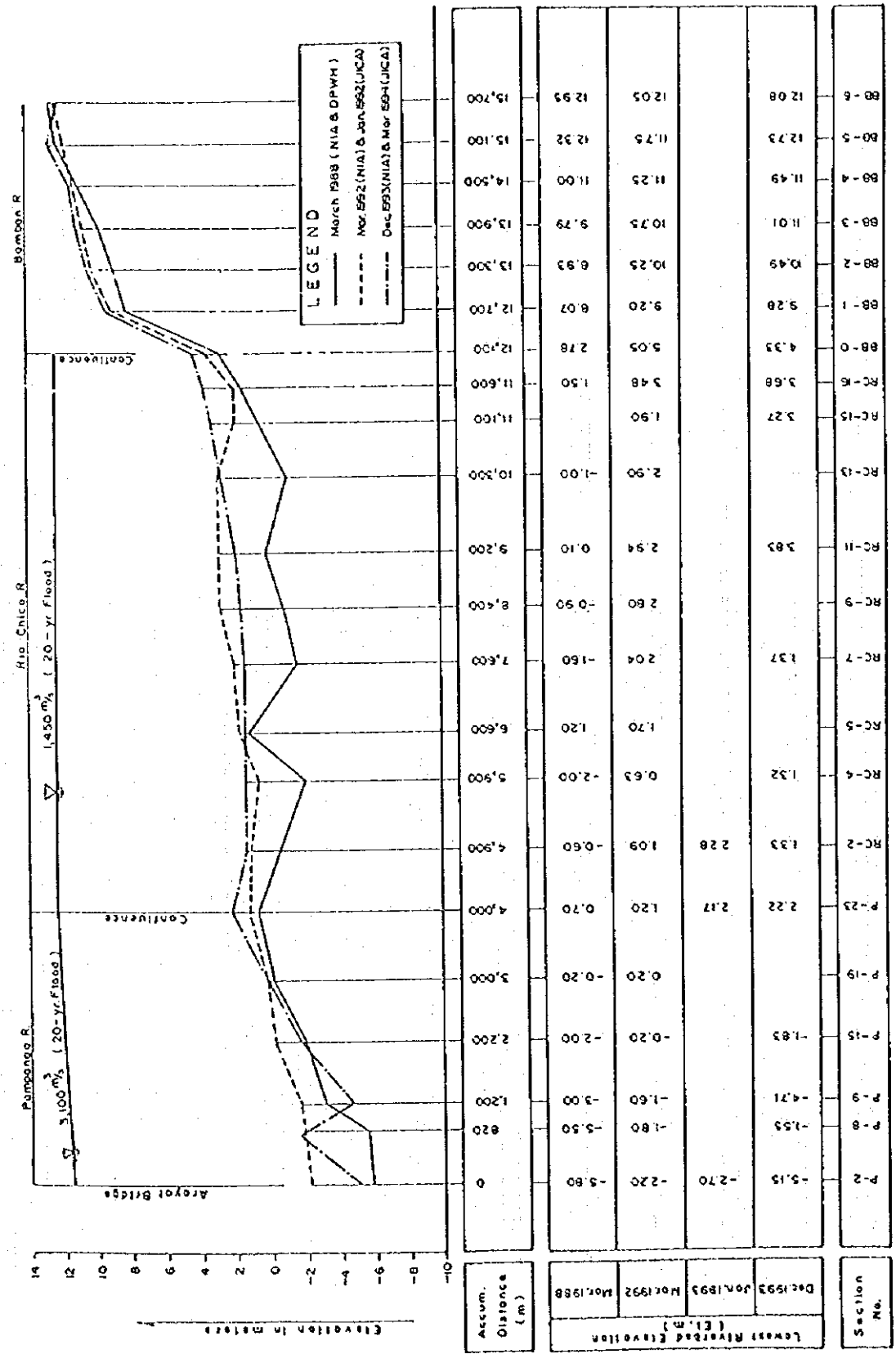


Figure F.11
Cross-Sectional Changes of Rio Chico and Pampanga Rivers

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY



Fugure F.12 Longitudinal Profile of Lowest Riverbed Elevation

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

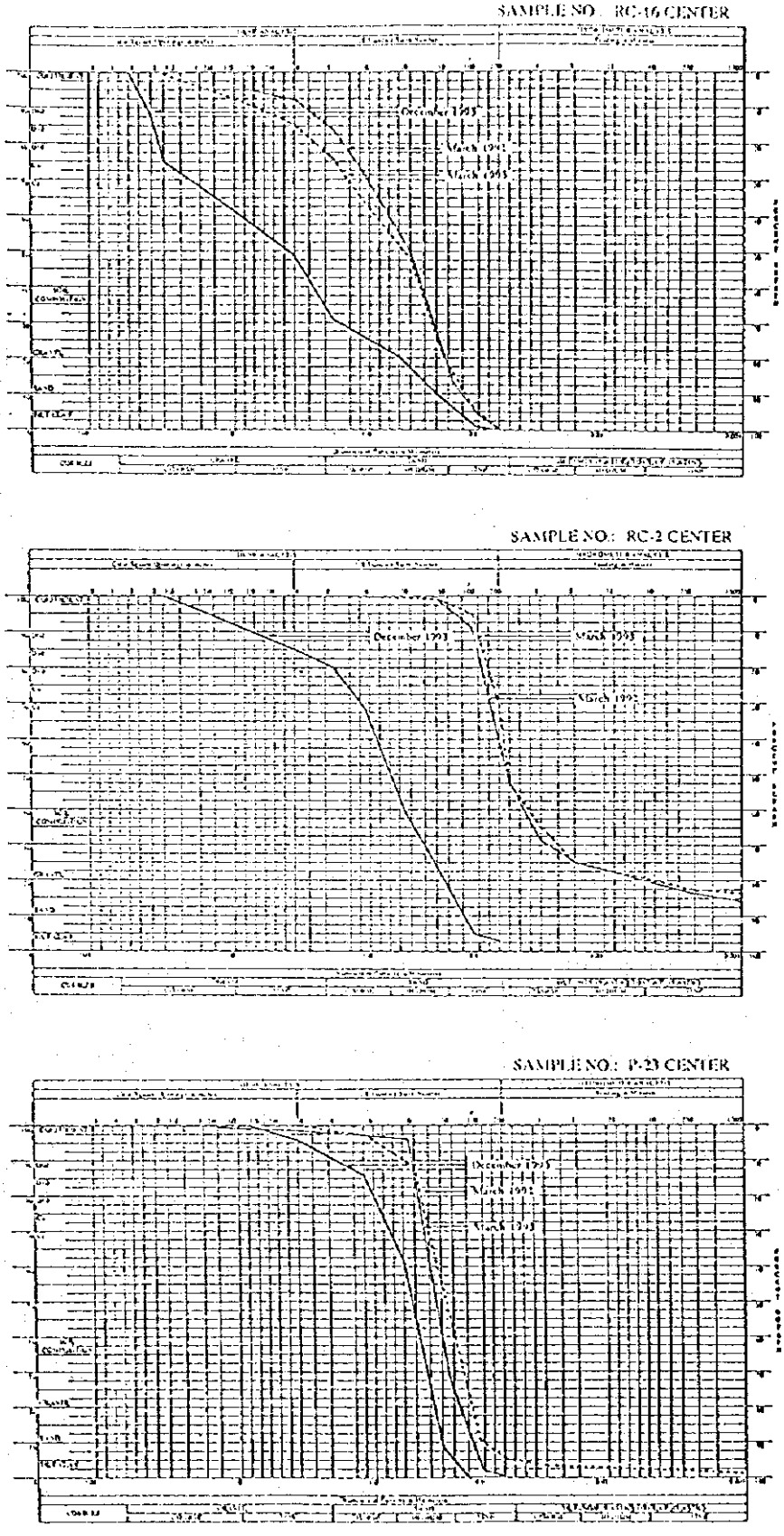


Figure F.13 Grain Size Distribution in Rio Chico and Pampanga Rivers

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
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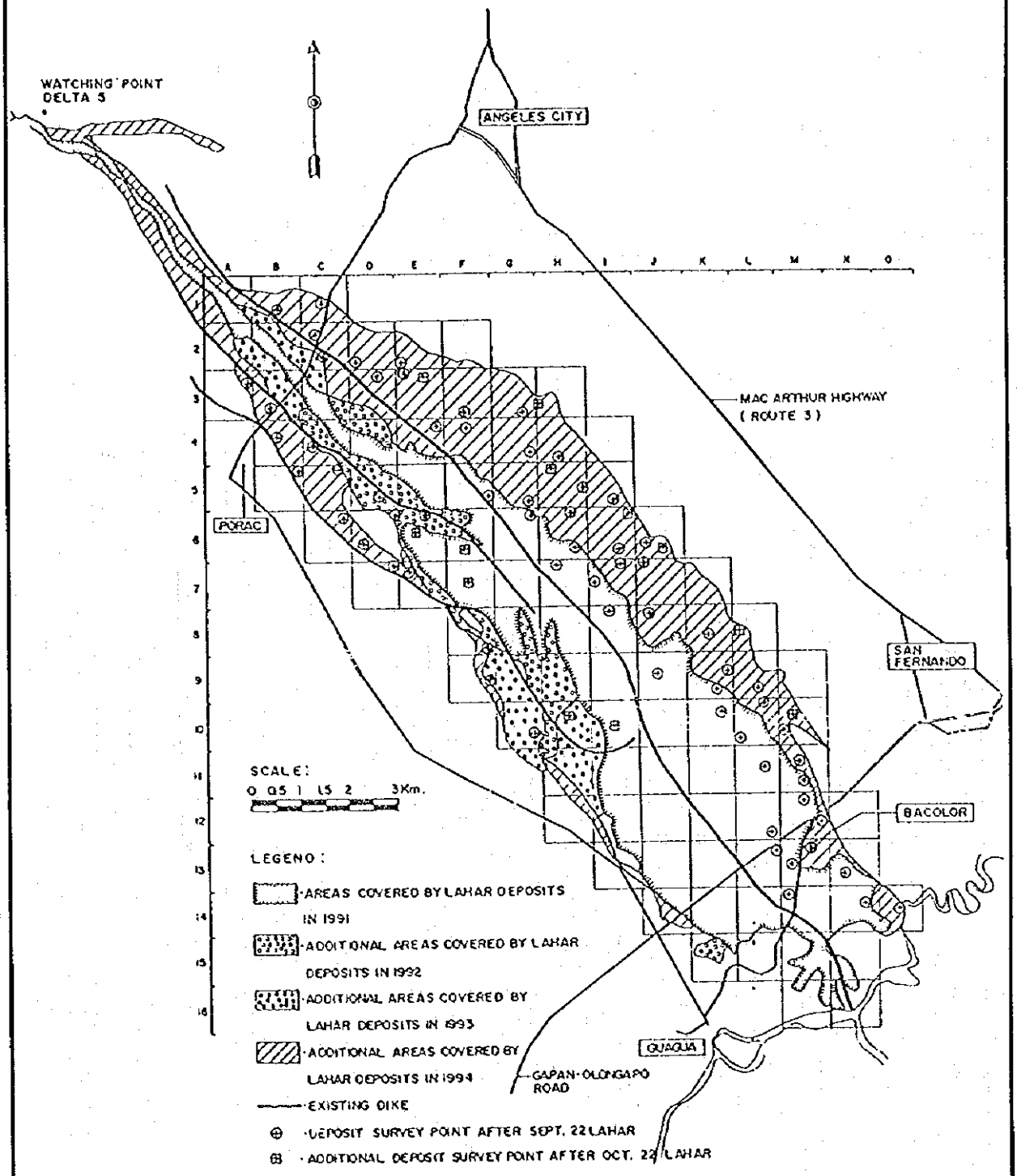
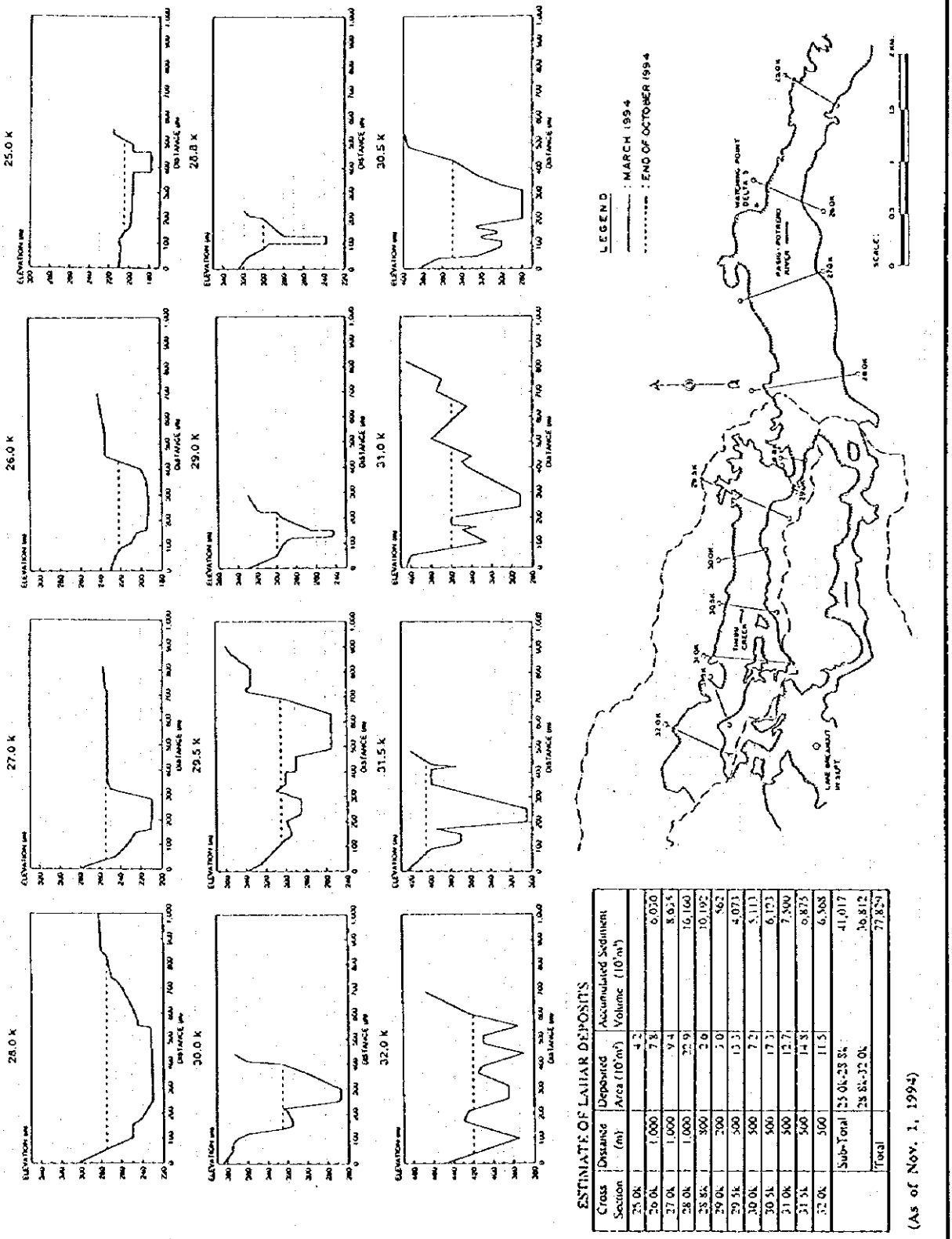


Figure F.14
Sediment Deposition Survey Area in Pasig-Potrero River, 1994

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY



ESTIMATE OF LAHAR DEPOSITS

Cross Section	Distance (m)	Deposited Area (10^3m^2)	Accumulated Sediment Volume (10^3m^3)	
25.0k		4.2		
26.0k	1,000	7.8		6,000
27.0k	1,000	9.4		8,600
28.0k	1,000	22.9		16,160
28.8k	800	2.9		10,192
29.0k	200	3.0		462
29.5k	500	13.3		4,073
30.0k	500	7.2		5,113
30.5k	500	17.3		6,123
31.0k	500	12.7		7,500
31.5k	500	14.3		6,875
32.0k	500	11.5		6,568
Sub-Total		25.0k-28.8k		41,017
		28.8k-32.0k		36,812
Total				77,829

(As of Nov. 1, 1994)

Figure F.15
Sediment Deposition in Upper Reach from Watchpoint Delta 5 in Pasig-Potrero River, 1994

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

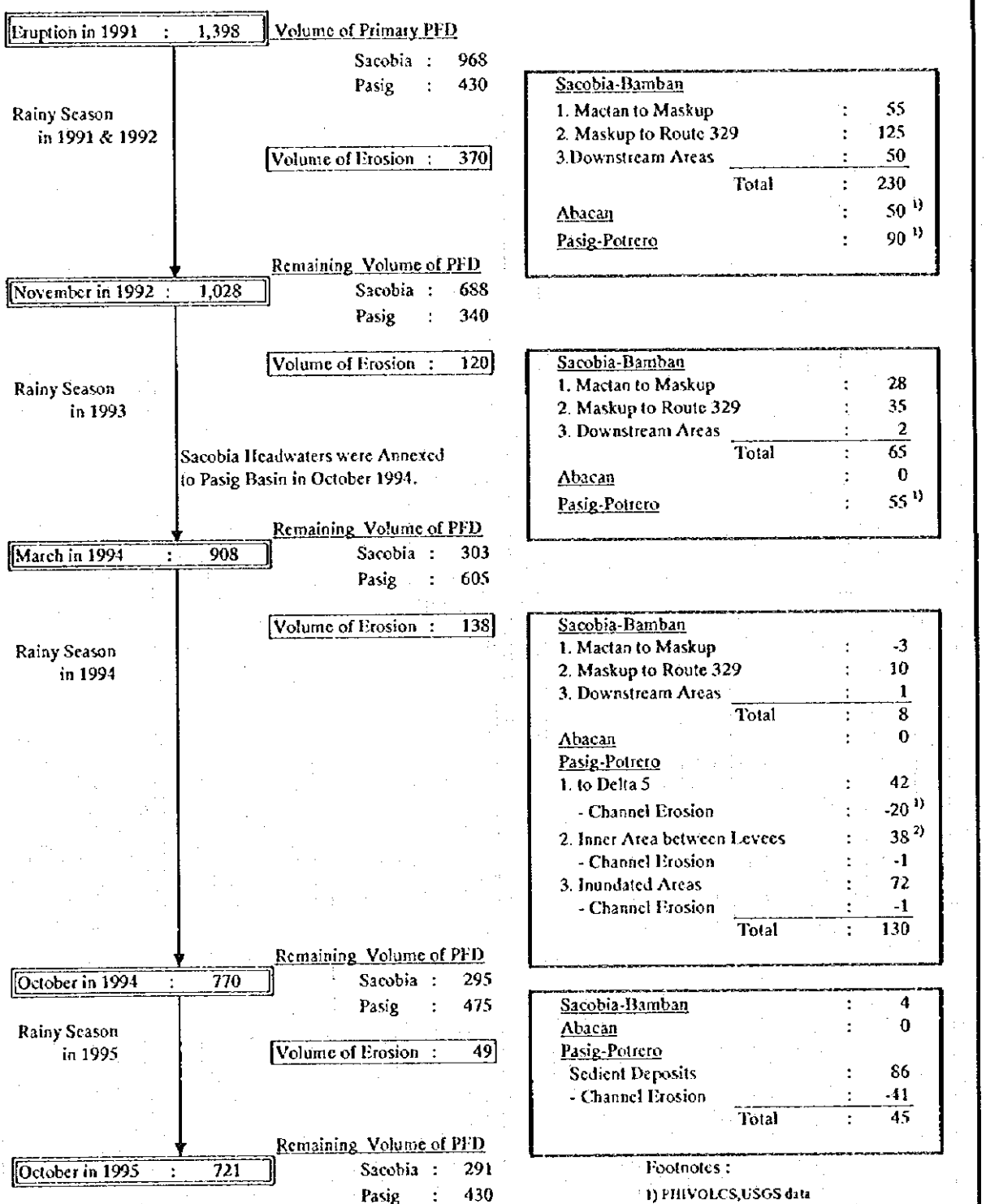
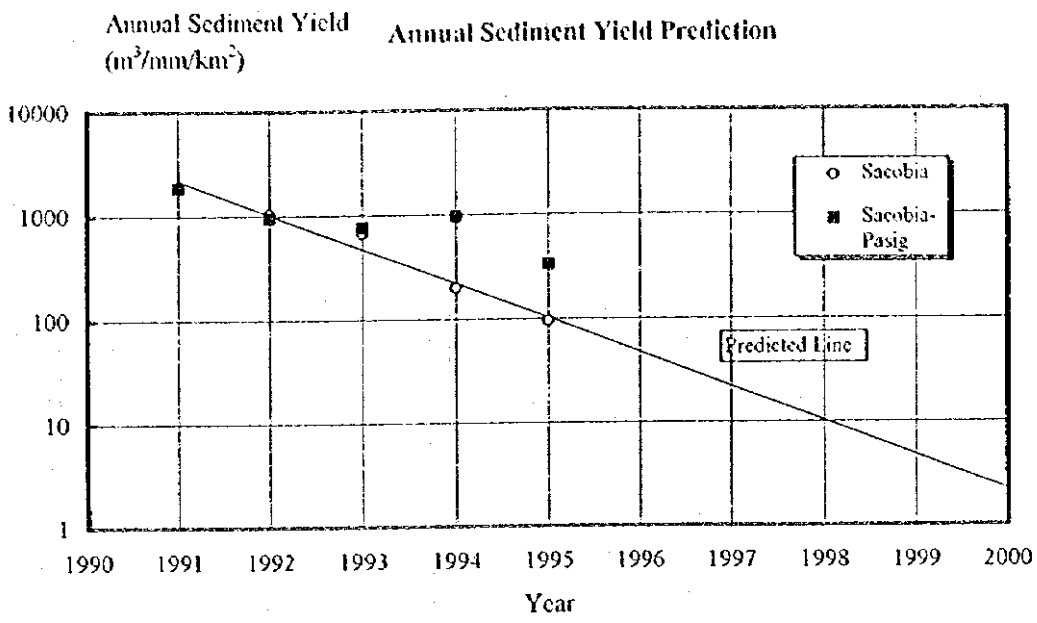


Figure F.16 Volume of Source Material, Erosion and Lahar Deposition, 1991-1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY



Volume of Source Material, Lahar Deposition, Rainfall and Catchment Area

Year	Volume of Pyroclastic Flow Deposits (10^4 m³)			Volume of Lahar Deposits (10^4 m³)				Annual Rainfall (mm)	Catchment Area of Headwaters (km²)			Normalized Sediment Yields (m³/mm/km²)		
	Sacobia-Abacan	Pasig	Total	Sacobia	Abacan	Pasig	Total		Sacobia	Pasig	Total	Sacobia	Pasig	Total
1991	968	430	1,398	150	50	50	250	2,250	35.3	24.5	59.8	1,889	907	1,858
1992	-	-	-	80	0	40	120	2,000	38.8	24.2	63.0	1,031	826	952
1993	688	340	1,028	65	0	55	120	2,500	38.8	24.2	63.0	670	909	762
1994	303	605	908	8	0	129	137	2,270	18.0	45.0	63.0	196	1,263	958
1995	295	476	771	4	0	45	49	2,360	18.0	45.0	63.0	94	424	330

Note 1) Volume of pyroclastic flow deposits and lahar deposits is obtained by combination of PHIVOLCS-USGS & DPWH data and the results of the Study.

2) Annual rainfall from 1991 to 1993 is refered to PHIVOLCS-USGS data, the value from 1994 to 1995 is refered to PHIVOLCS observation data at Upper-Sacobia gauge .

Prediction of Sediment Yield from EPPFF into Sacobia River

Year	Volume of Sediment Yield (10^6m³)	Accumulated Volume (10^6m³)
1996	2.0	2.0
1997	0.9	2.9
1998	0.4	3.3
1999	0.4	3.7
2000	0.4	4.1

Figure F.17
Prediction of Annual Sediment Yield from EPPFF

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

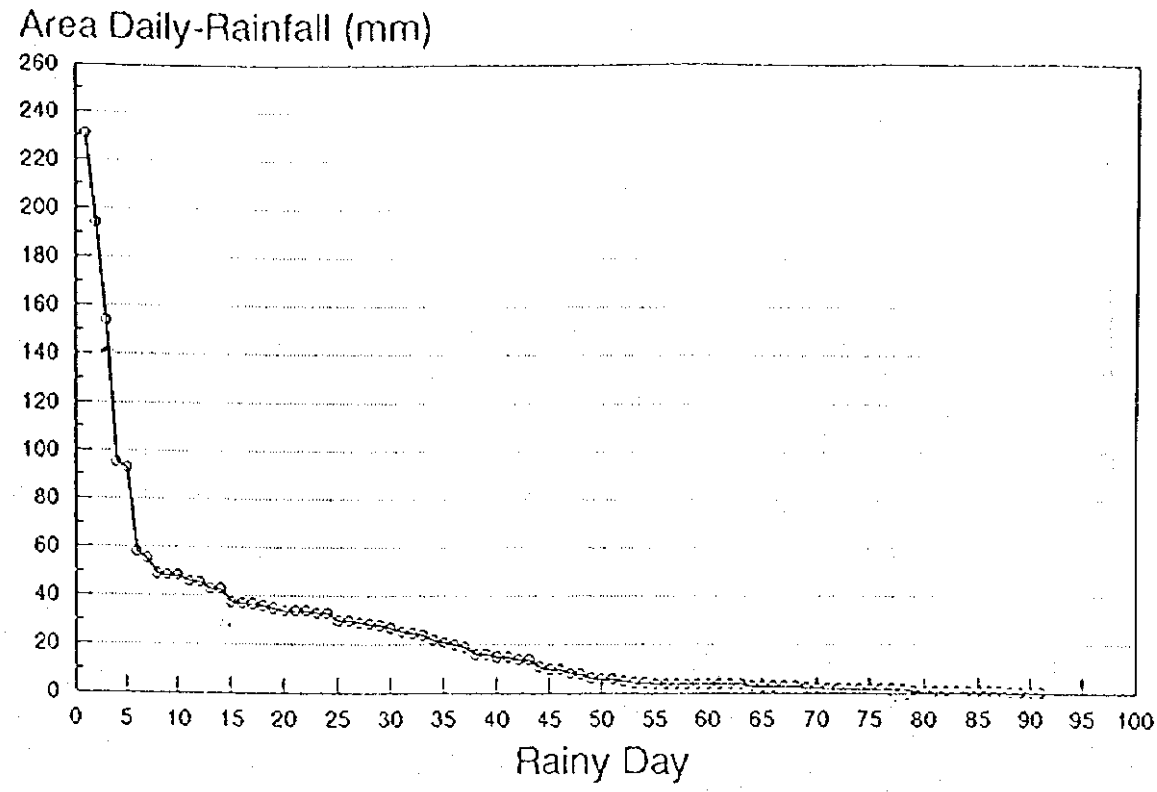


Figure F.18 Area Daily Rainfall in Average Year in Sacobia-Bamban River Basin

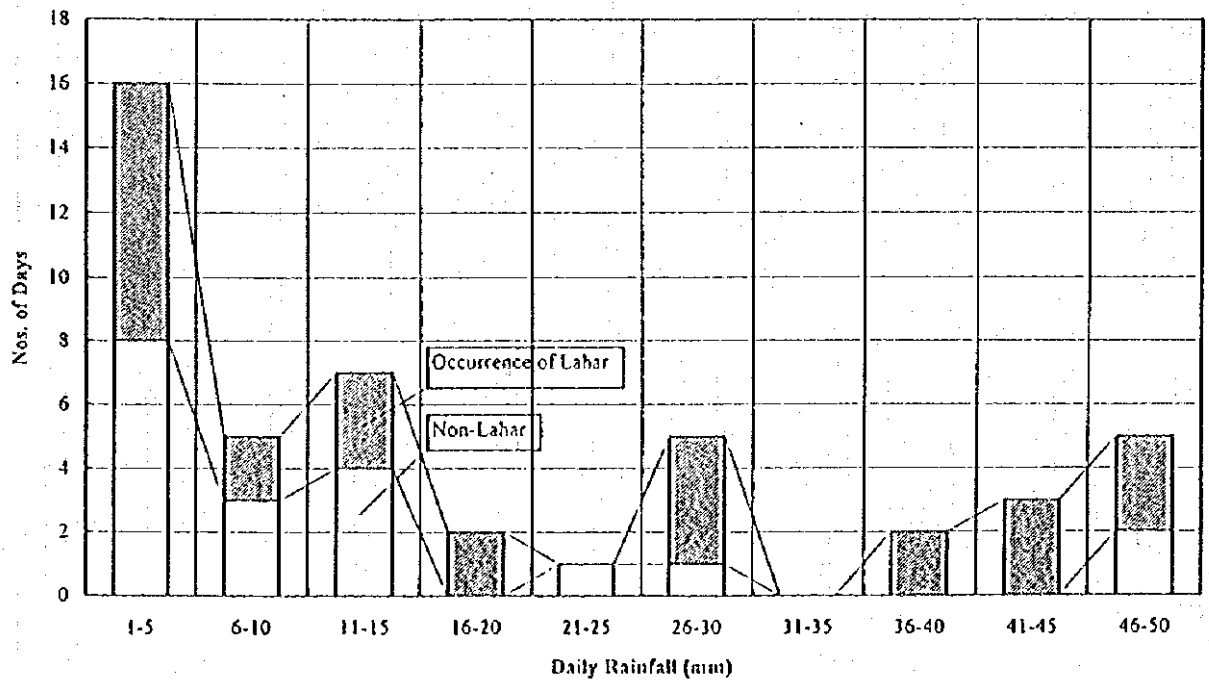


Figure F.19 Relation between Daily Rainfall at Upper-Sacobia Gauge and Lahar Events at Mactan Watch Point in 1994

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
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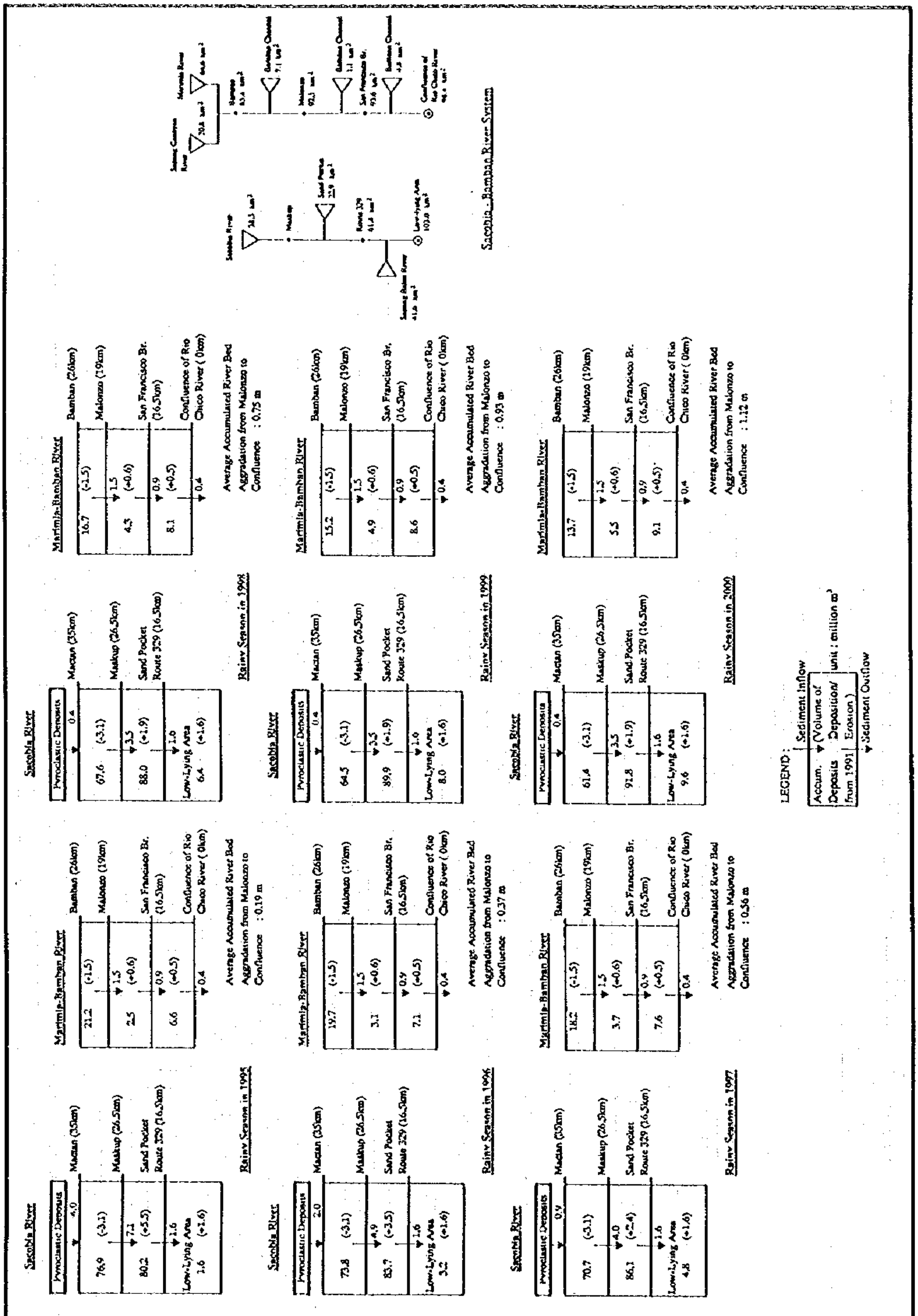


Figure F.20

Sediment Balance Prediction under Present Conditions, 1995-2000

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

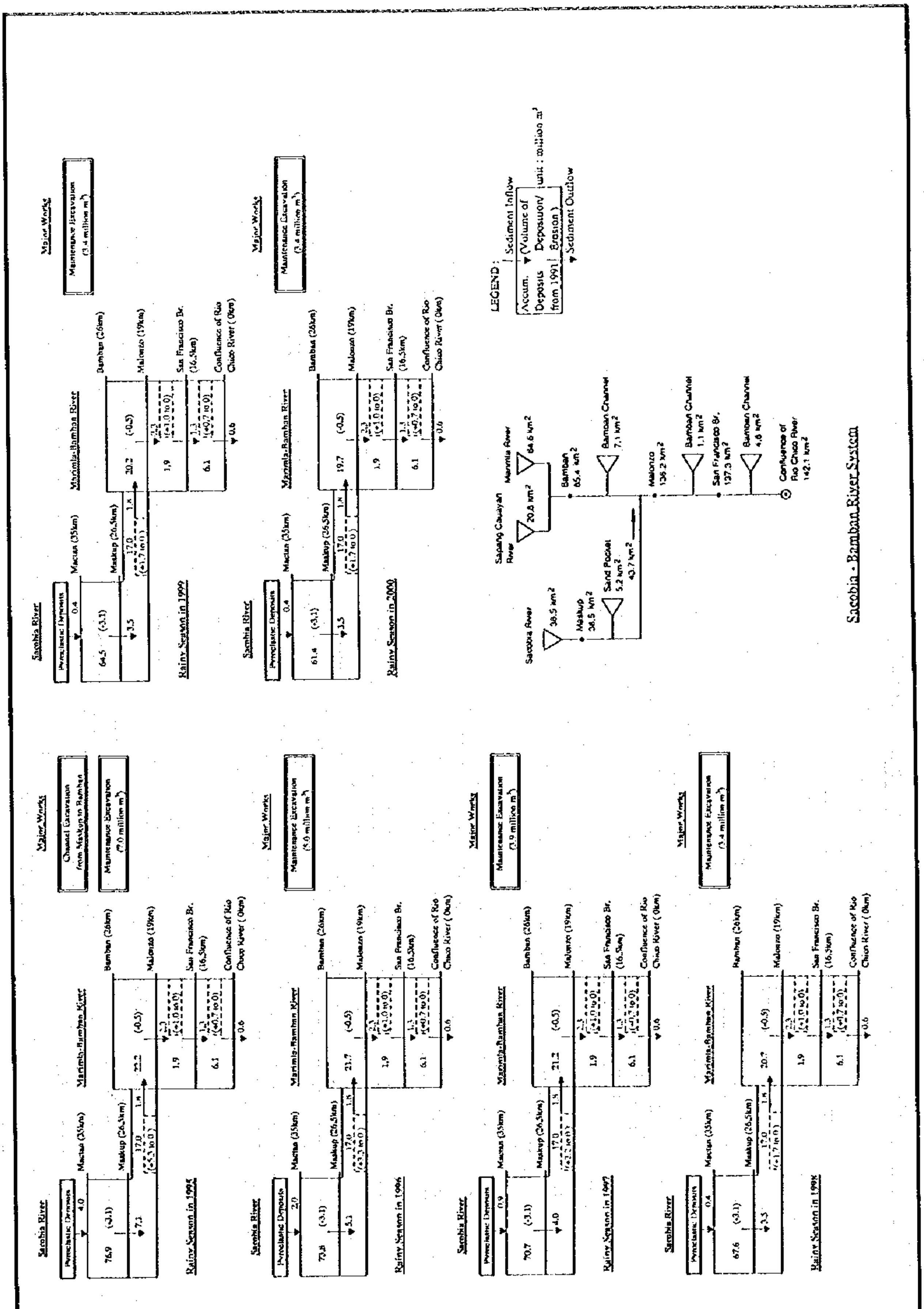


Figure F.21
Sediment Balance Prediction on Diversion and Dredging Alternative (Case 1), 1995-2000

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

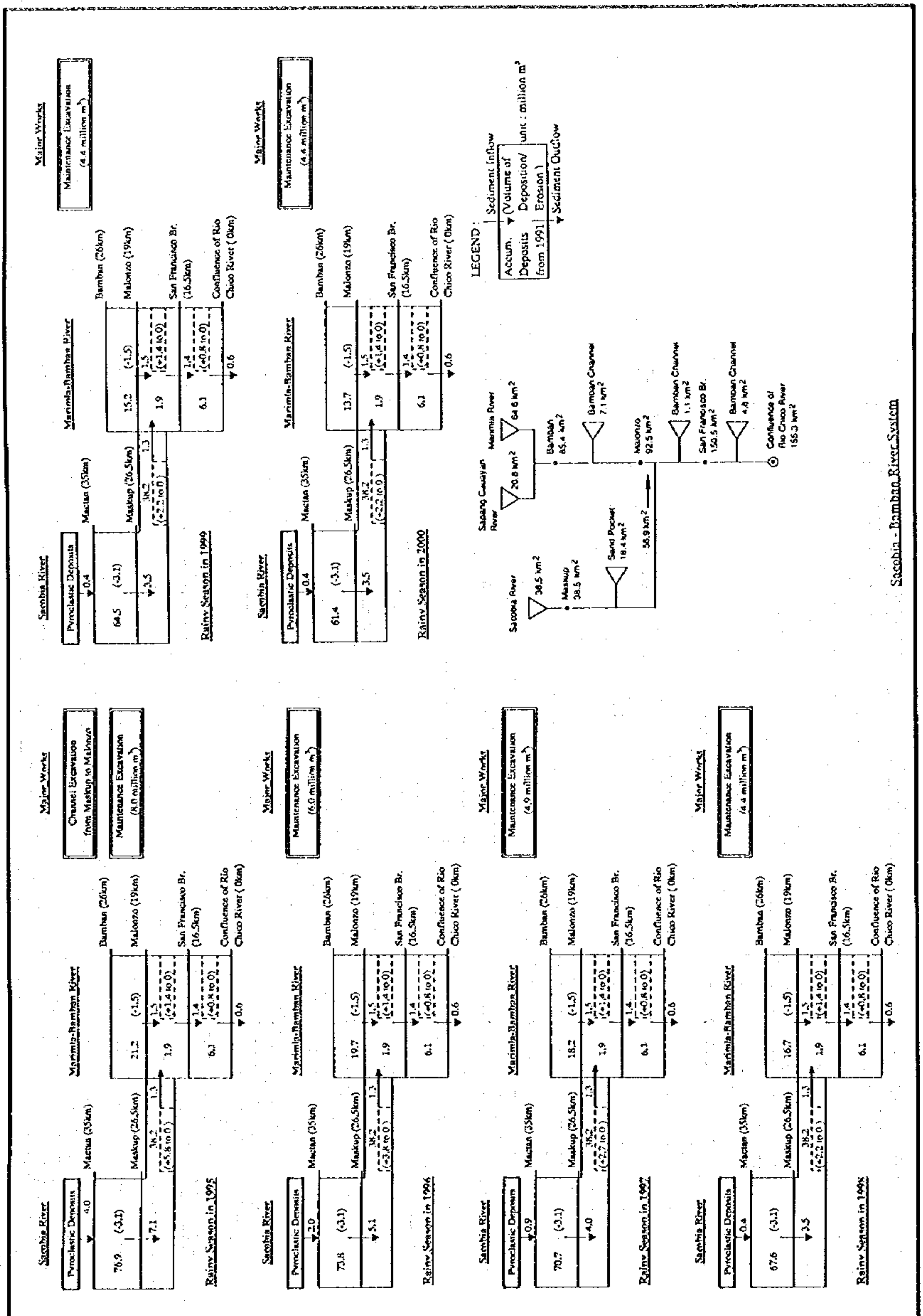


Figure F.22
Sediment Balance Prediction on Diversion and Dredging Alternative (Case 2), 1995-2000

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS

THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO

JAPAN INTERNATIONAL COOPERATION AGENCY

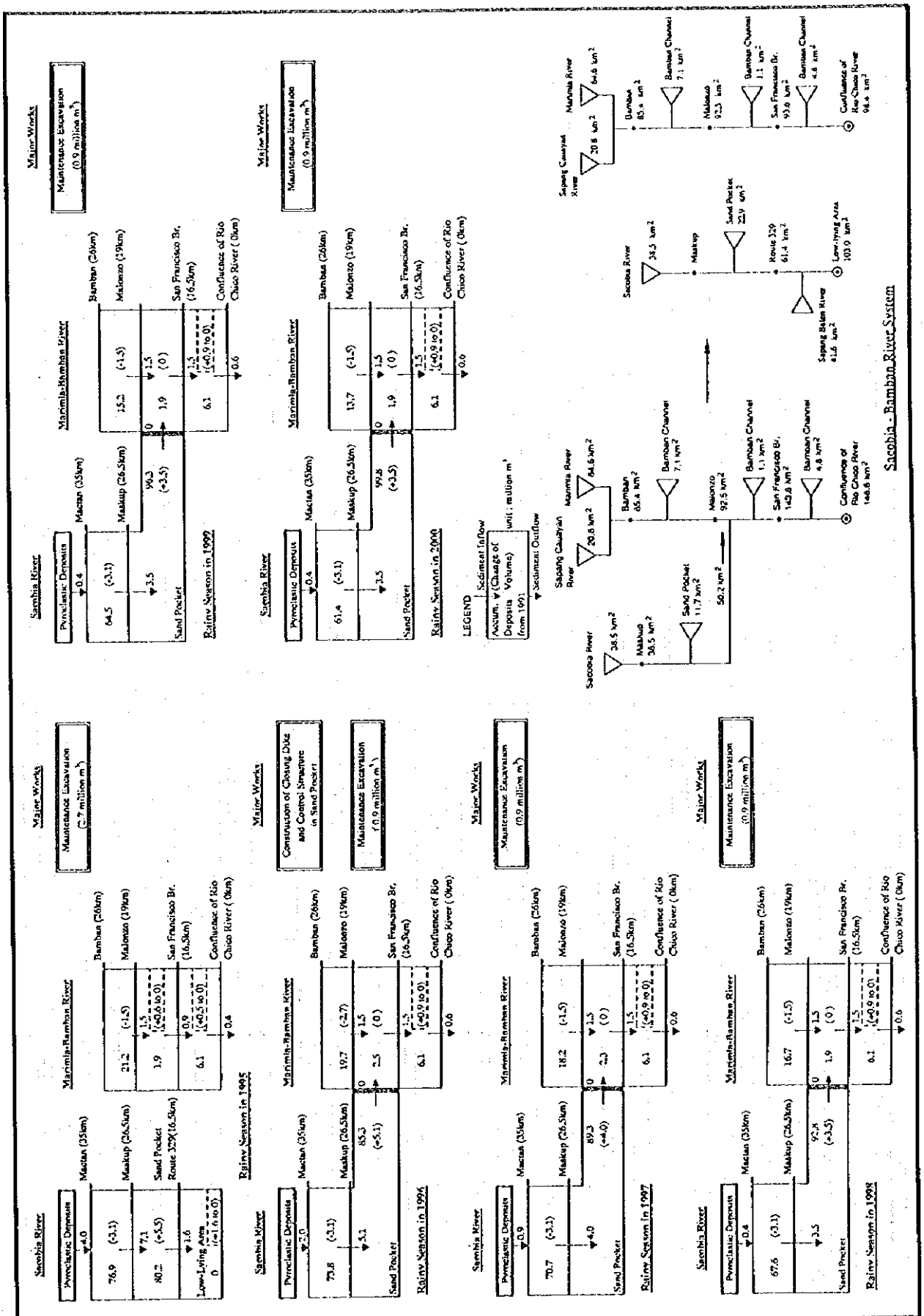


Figure F.23
Sediment Balance Prediction on Permanent Sand Pocket with Control Structure Alternative, 1995-2000

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

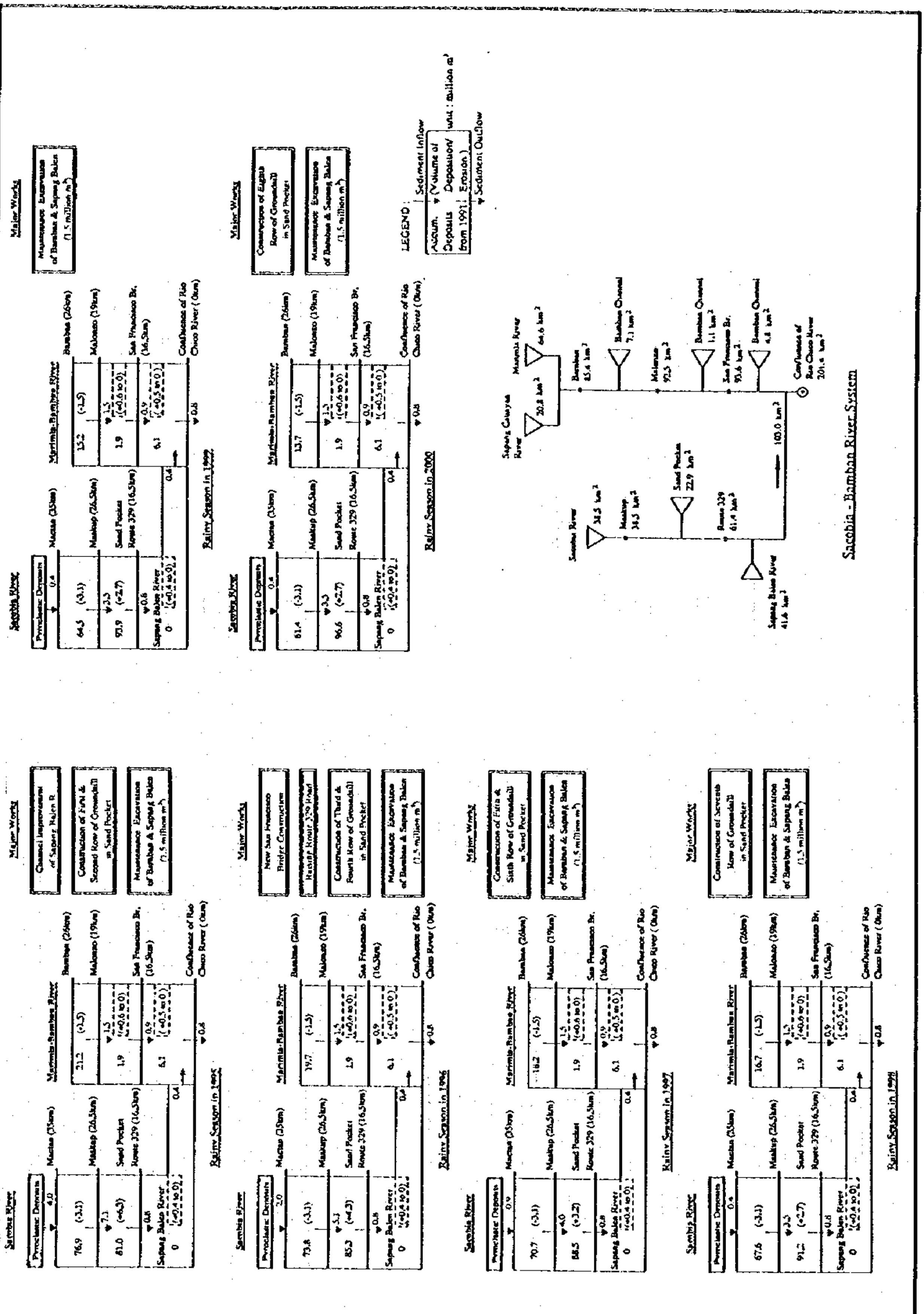


Figure F.24
Sediment Balance Prediction on Permanent Use of Sand Pocket Alternative, 1995-2000

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

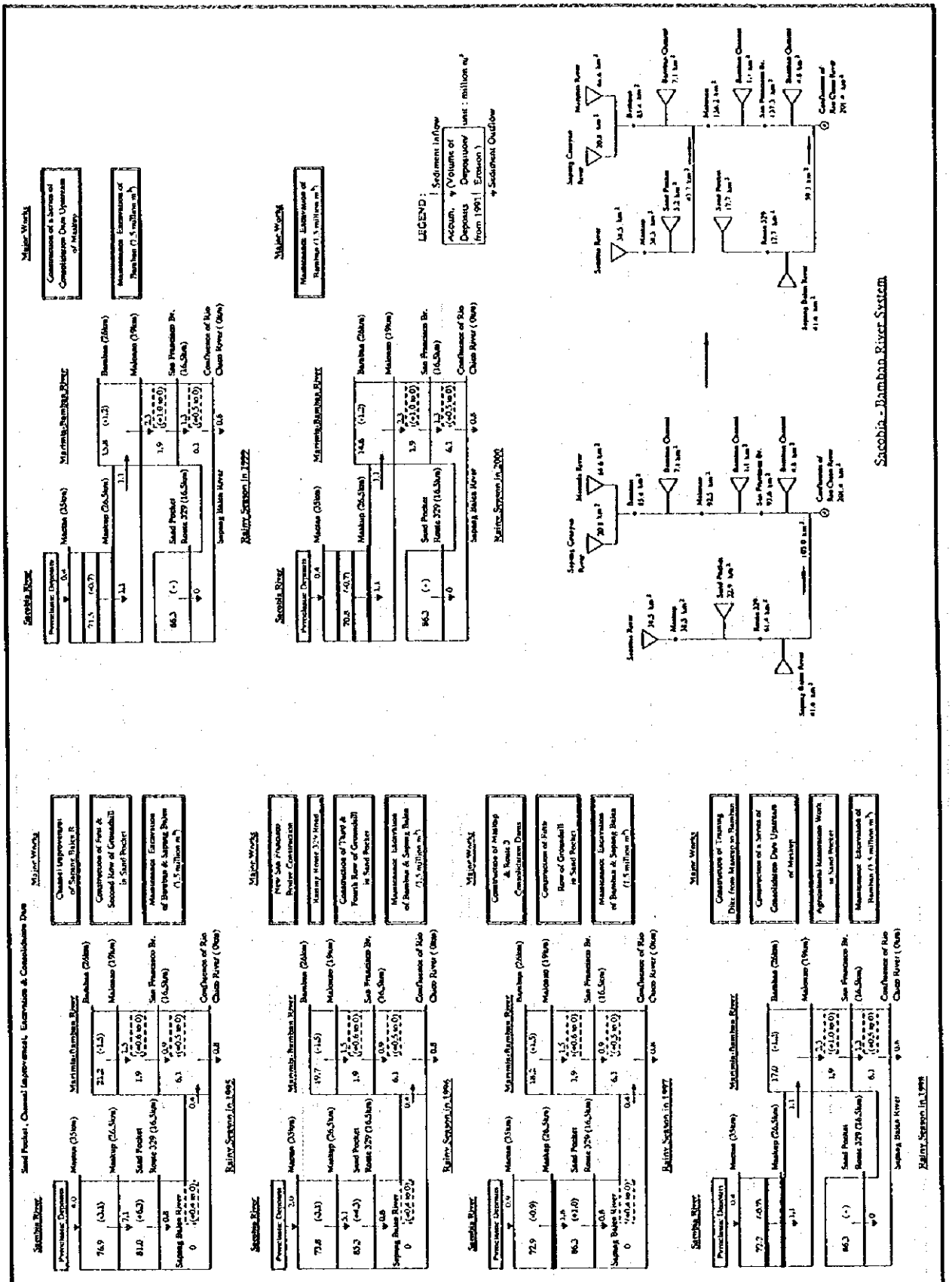


Figure F.25

Sediment Balance Prediction on Alternative Composed of Provisional Use of Sand Pocket and Series of Consolidation Dams from Maskup to Mactan, 1995-2000

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

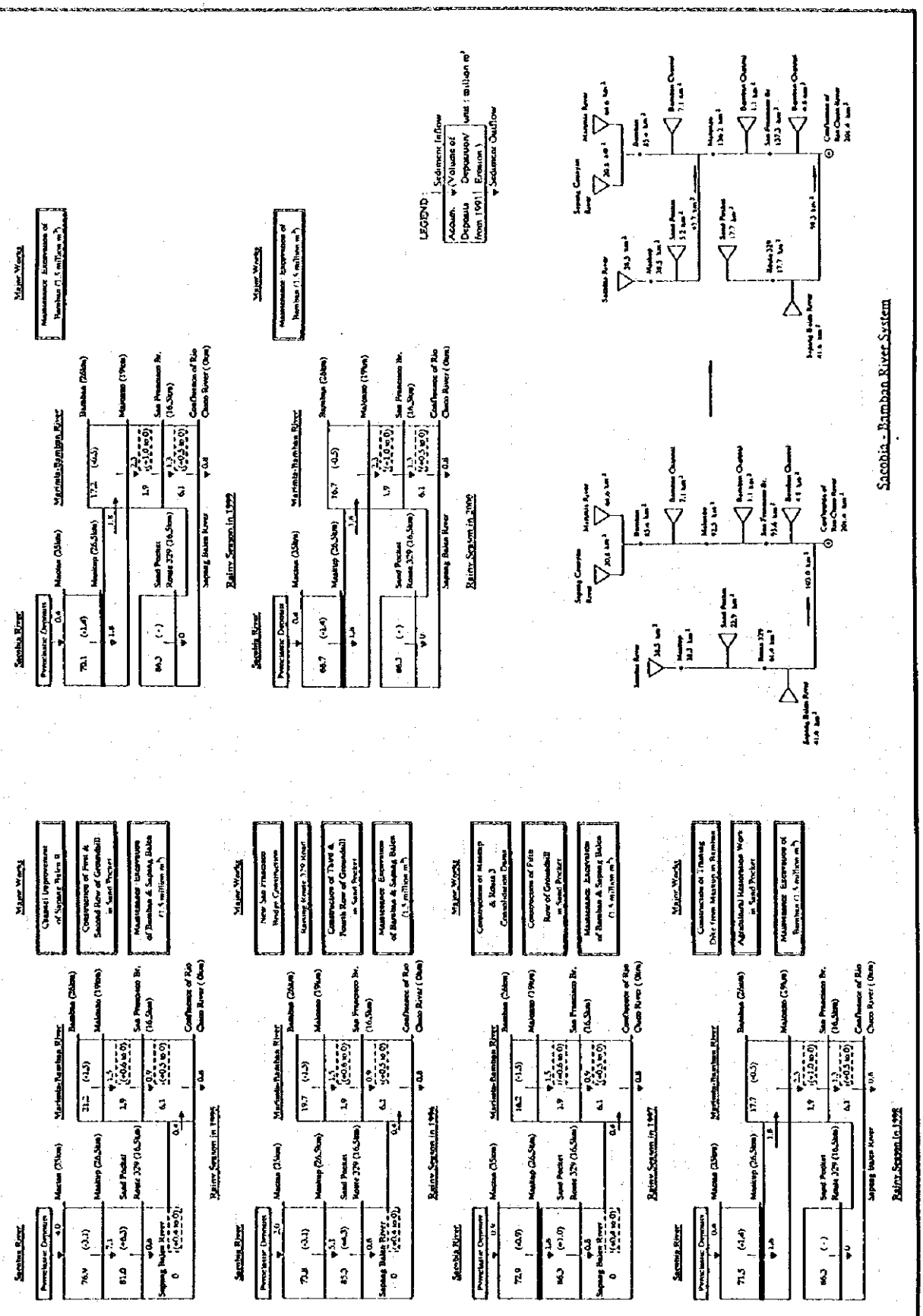


Figure F.26

Sediment Balance Prediction on Alternative Composed of Provisional Use of Sand Pocket, and Maskup and Route 3 Consolidation Dams, 1995-2000

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

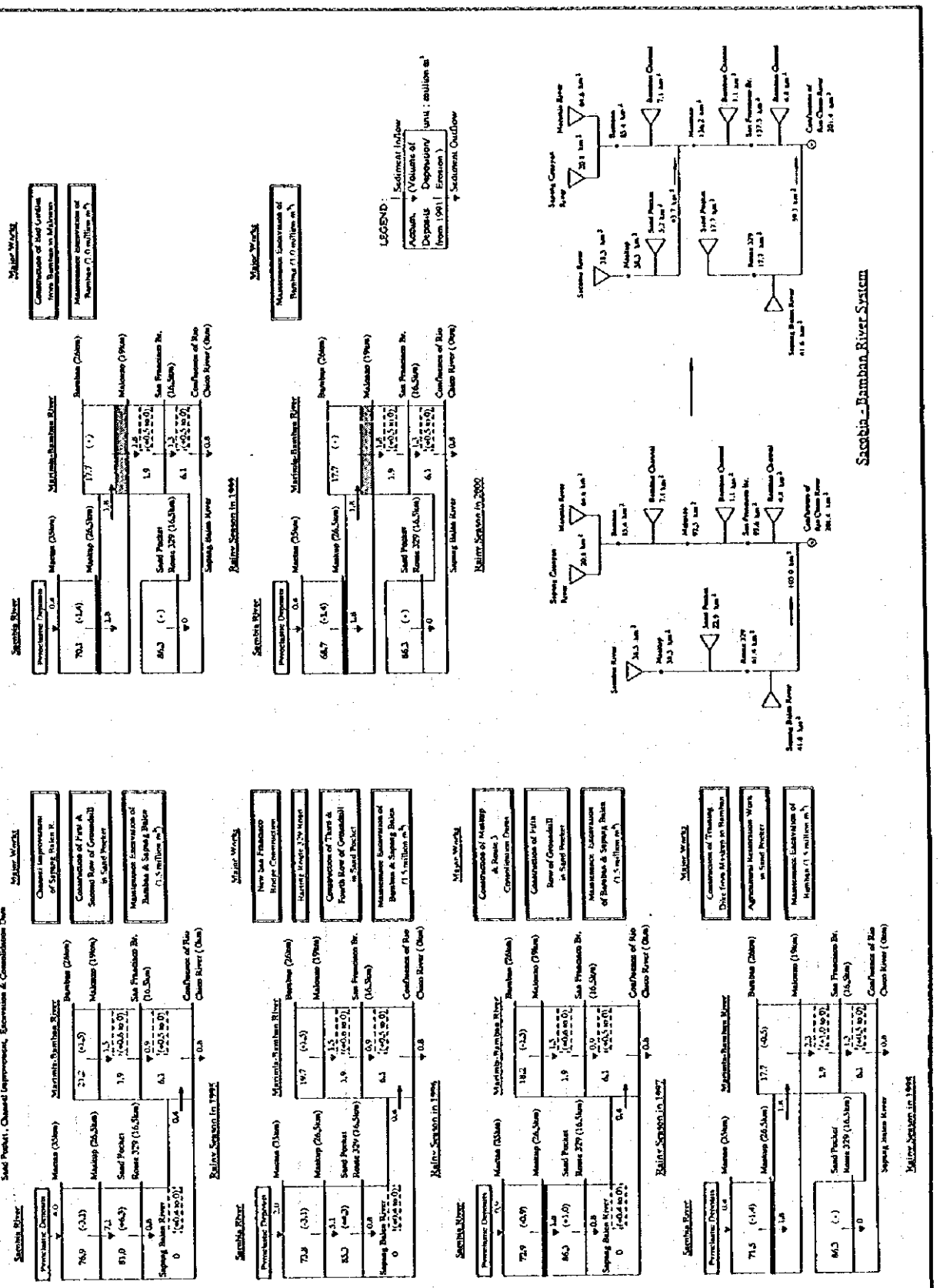
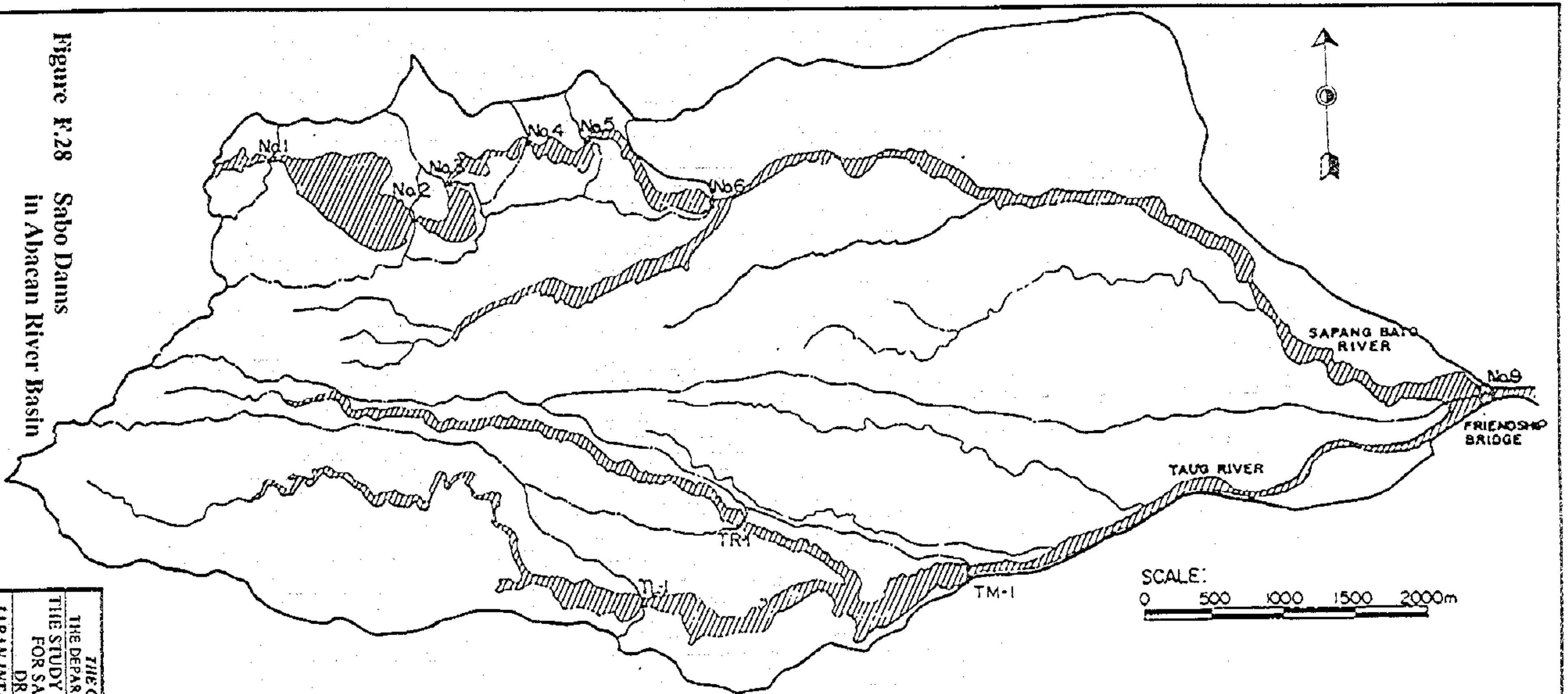


Figure F.27

Sediment Balance Prediction on Alternative Composed of Provisional Use of Sand Pocket, Maskup and Route 3 Consolidation Dams, and Upper-Bamban Groundsills, 1995-2000

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

Figure F.28 Sabo Dams in Abacan River Basin



Existing Sabo Dams in Abacan River

As of November 1994

Description		Unit	Sapang Bato River							Taug River		
			No.1	No.2	No.3	No.4	No.5	No.6	No.9	TR-1	TL-1	TM-1
Location	latitude		N15°10'23"	N15°10'10"	N15°10'16"	N15°10'26"	N15°10'30"	N15°10'12"	N15°09'26"	N15°08'57"	N15°08'42"	N15°08'47"
	longitude		E120°28'21"	E120°29'07"	E120°29'17"	E120°29'40"	E120°29'54"	E120°30'26"	E120°33'39"	E120°30'33"	E120°30'12"	E120°31'27"
Catchment Area		km^2	0.3	1.5	1.8	2.4	2.8	3.5	33.3	1.8	4.7	8.5
Main Dam												
1) Structure			Sand Bags	Sand Bags	Sand Bags	Gabions	Gabions	Gabions	Gabions	Gabions	Gabions	Gabions
2) Dam Height		m	10.5	4.0	4.0	10.0	5.0	3.0	4.0	6.0	6.0	5.0
3) Crest Length		m	11.0	68.0	29.0	25.0	67.0	50.0	106.00	79.0	79.0	124.00
4) Volume of Dam Body		m^3	4,300	2,000	2,400	2,300	2,800	1,100	2,800	3,200	4,400	3,200
Sediment Containment		m^3	35,000	83,000	-	104,000	48,000	71,000	405,000	140,000	173,000	456,000
Construction Period			1991. 11-12	1991. 11-12	1991. 11-12	1992. 3 - 4	1993. 4 - 6	1992. 3 - 4	1992. 4 - 5	1992. 5 - 6	1992. 5 - 8	1992. 5 - 11
Present Effective Dam Height		m	7.5	(Collapsed in 1994)	(Silted in 1992)	10.0	5.0	3.0	5.0	(Partially Collapsed in 1994)	(Collapsed in 1994)	3.0
Date of Restoration			1992 Jul.			1993 Mar. 1993 Nov	1993 Sep.	1993 Mar. 1993 Oct	1993 Apr 1993 Oct	1993 Jul		1993 Sep

THE GOVERNMENT OF THE PHILIPPINES
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THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

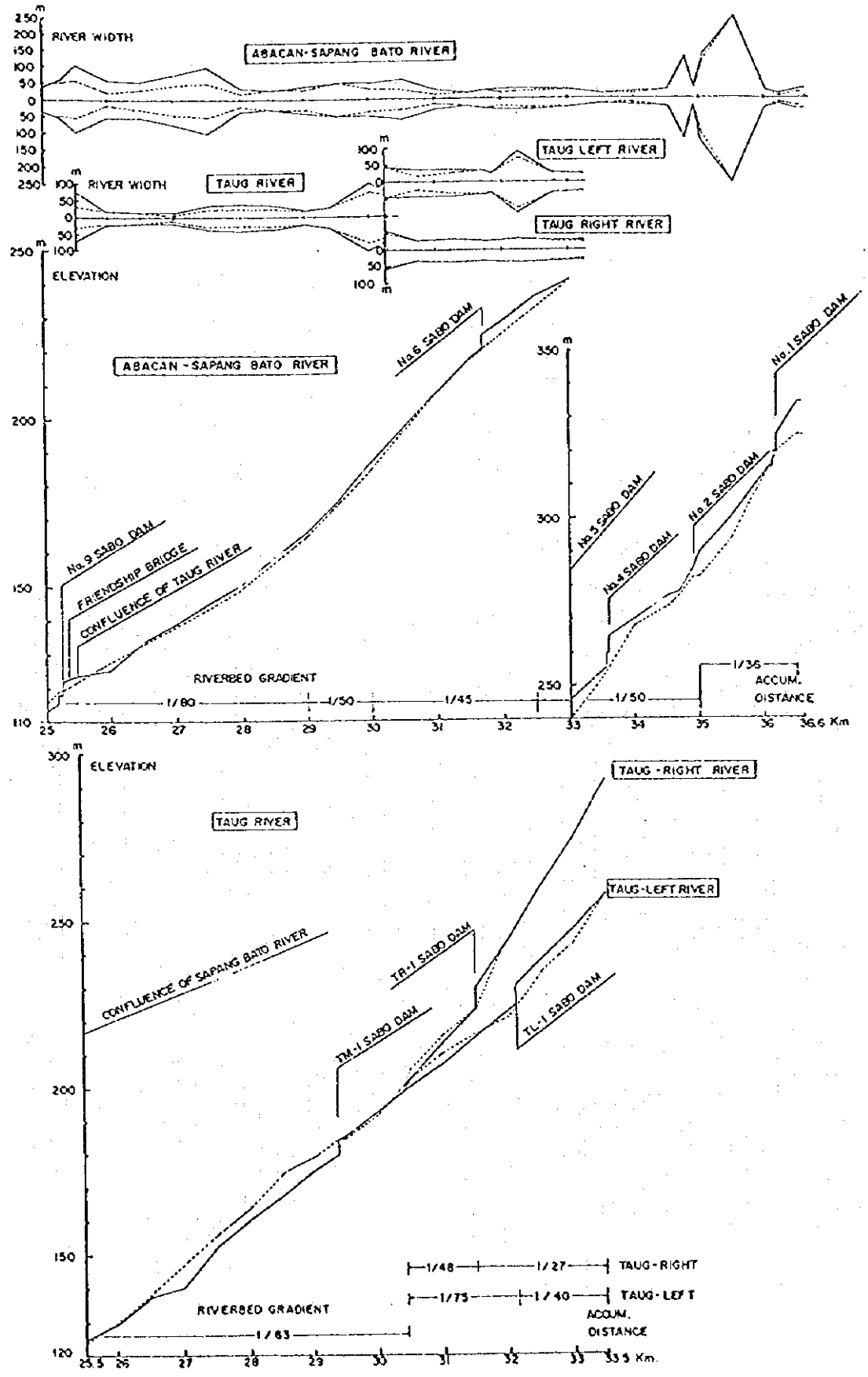

Figure F.29 Longitudinal Profile and River Width in Upper-Abacan River

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
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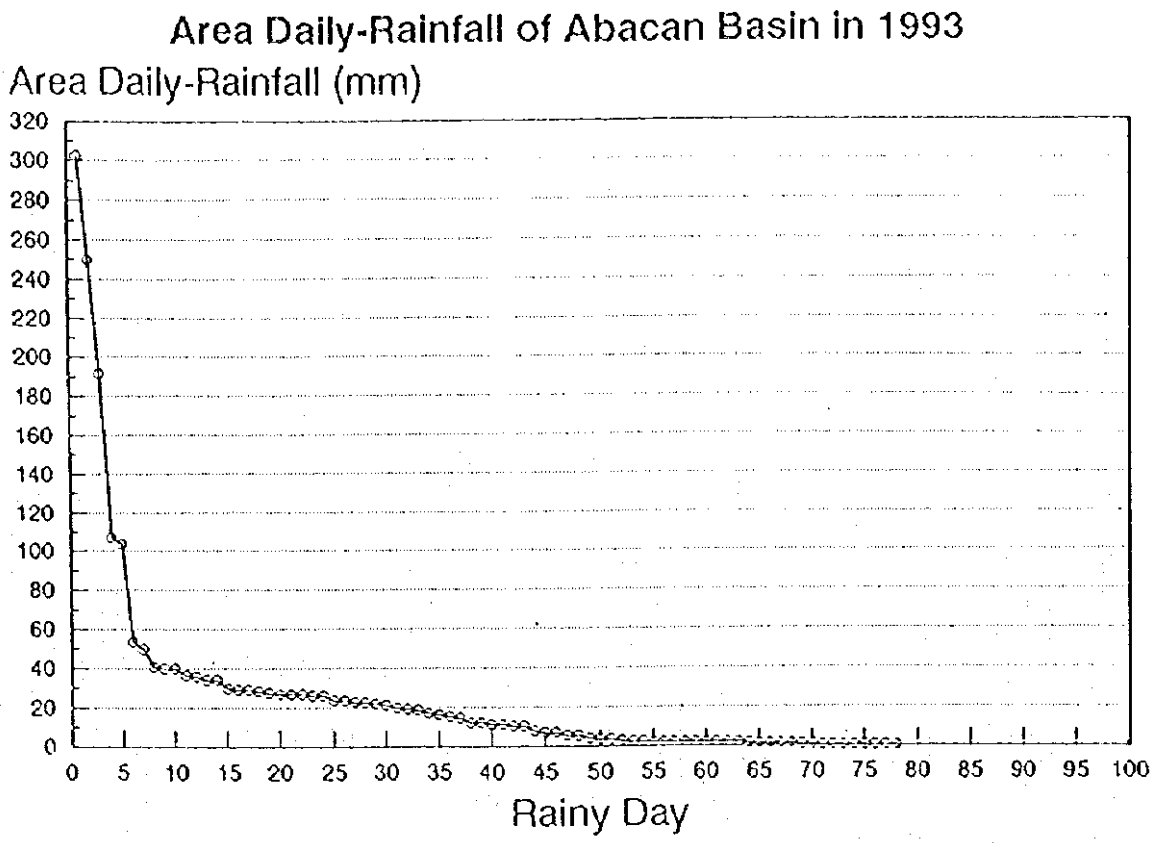
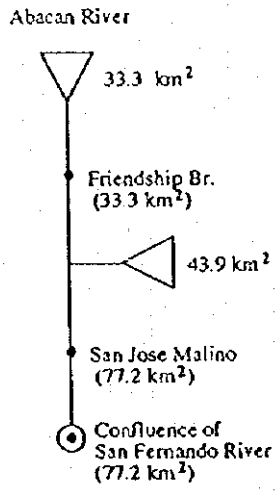




Abacan River System

Figure F.30
Area Daily Rainfall in Average Year in Abacan River Basin and Schematic River Basin

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

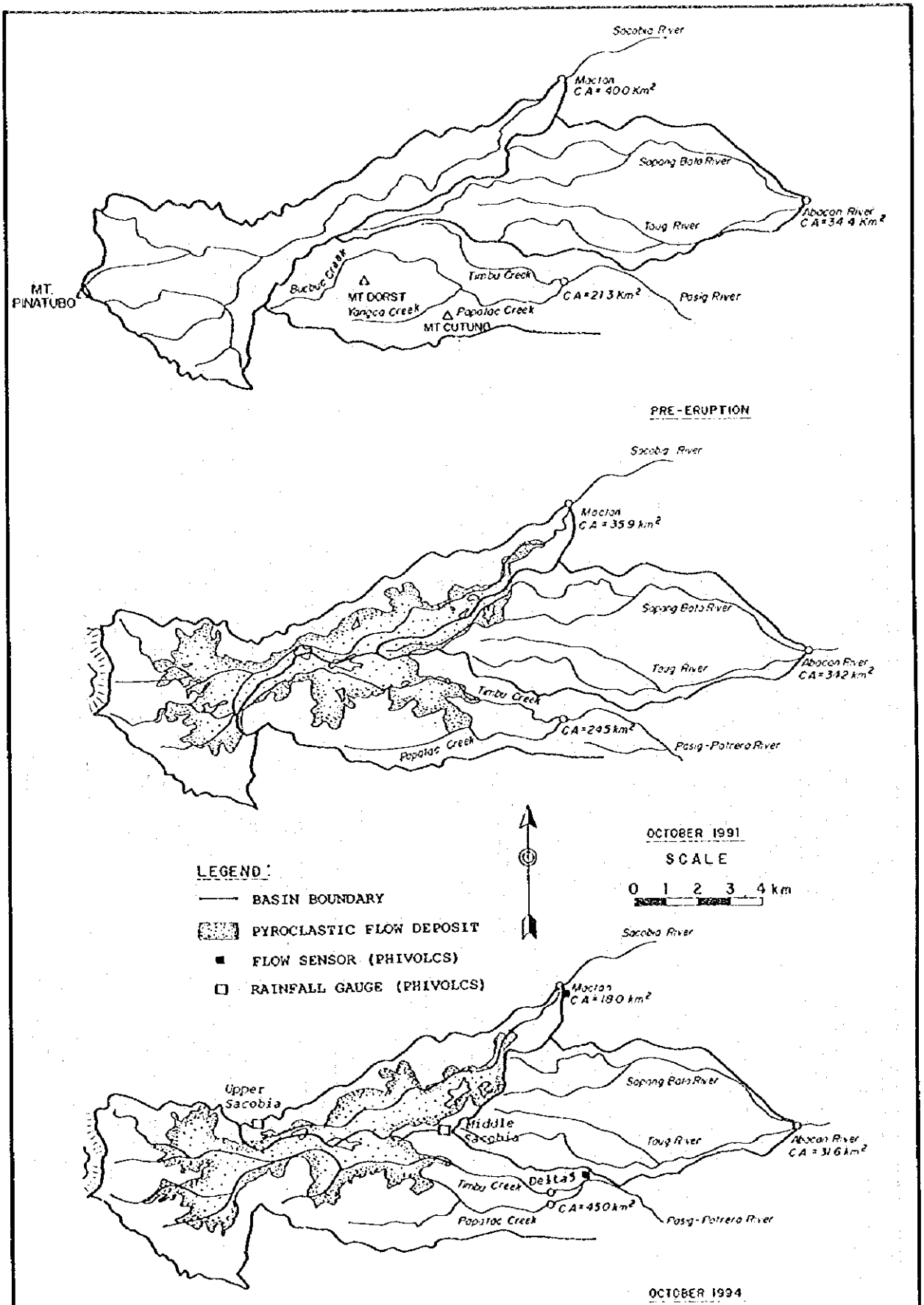


Figure F.31
Chronological Changes of Sacobia-Abacan-Pasig Headwaters

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

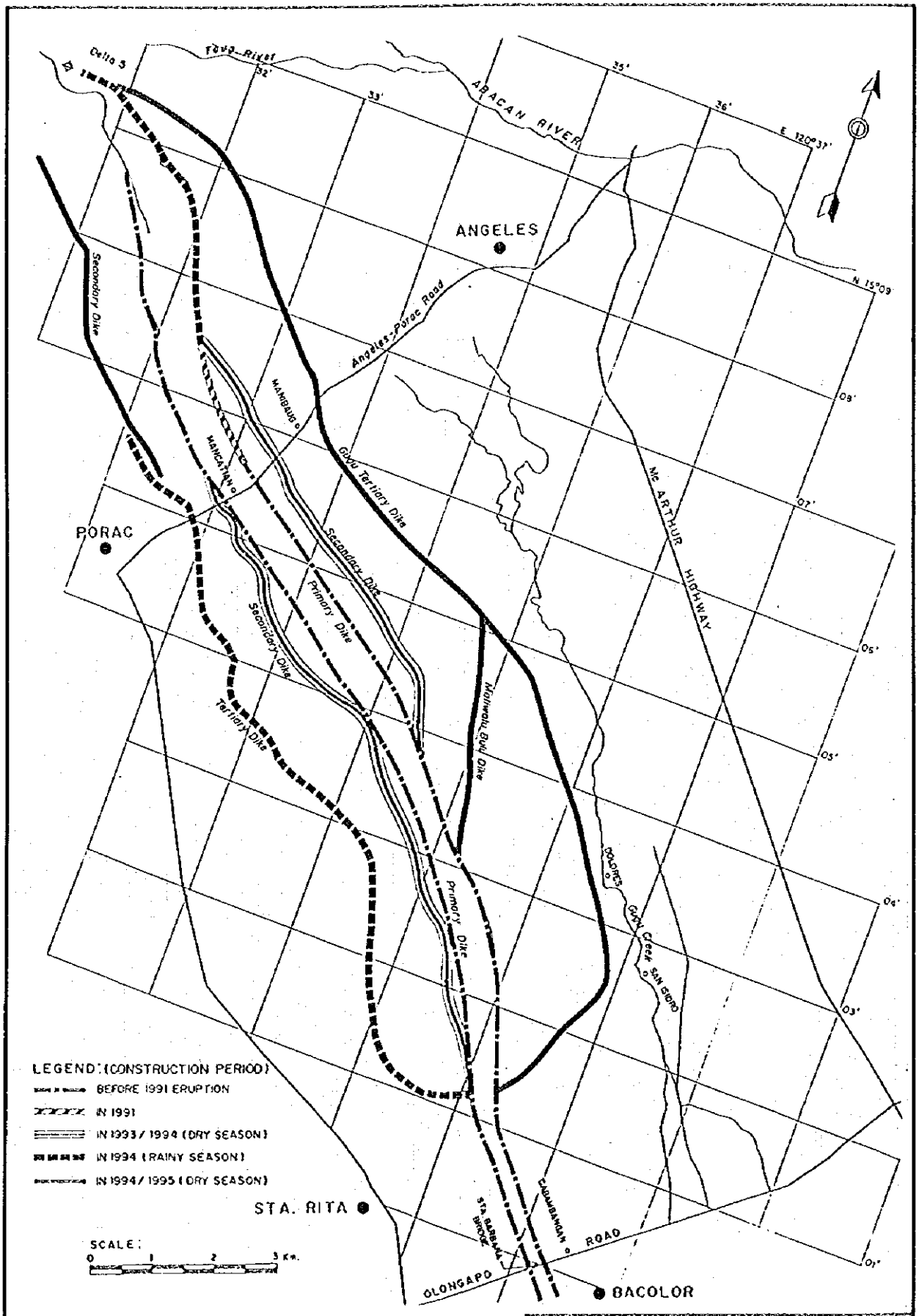


Figure F.32 Pasig-Potrero River Dike System

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

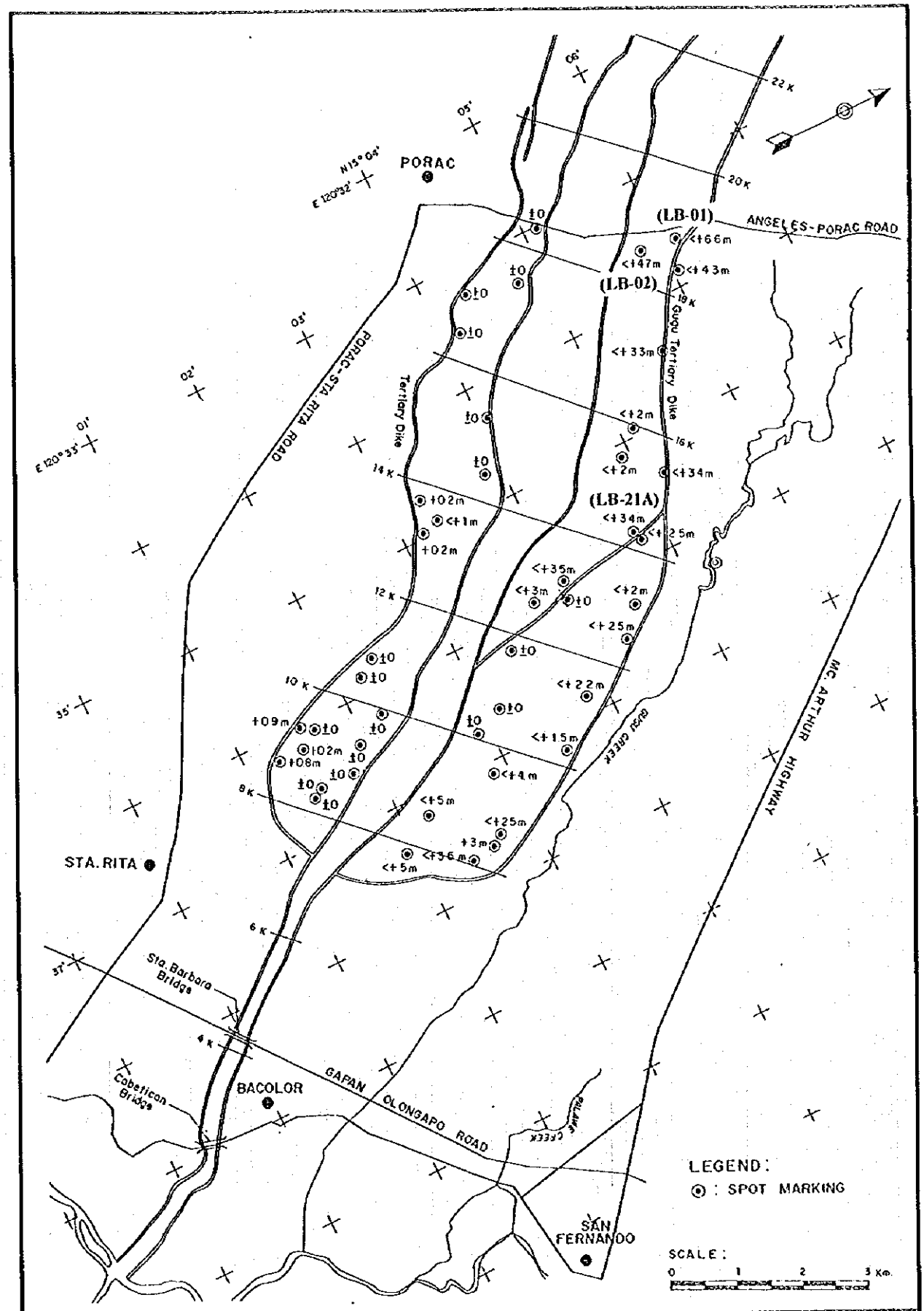
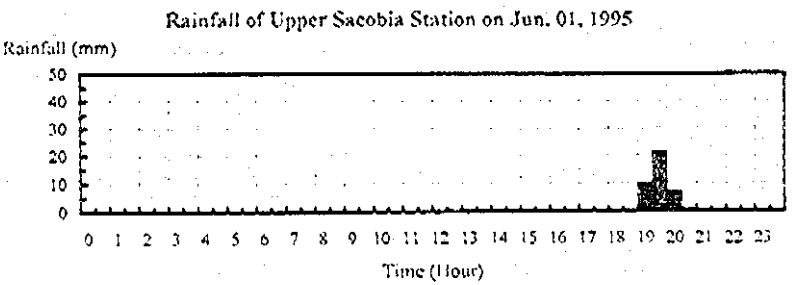
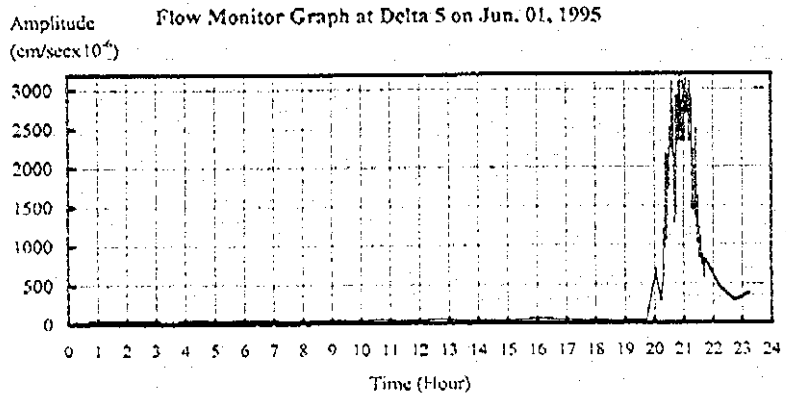
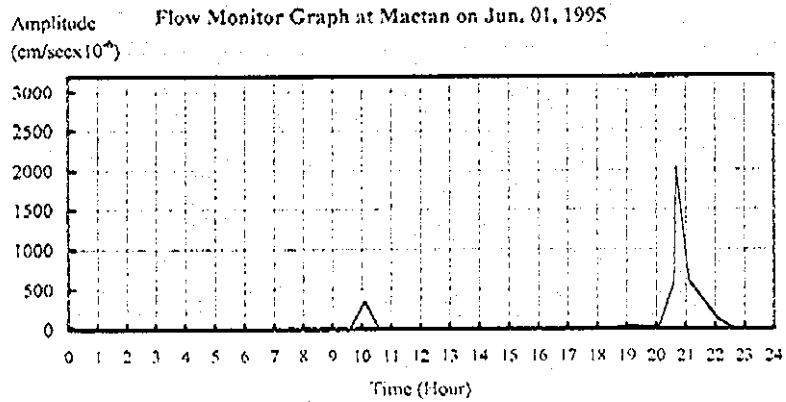


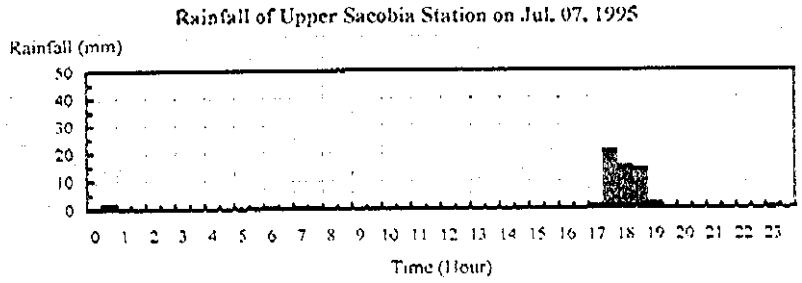
Figure F.33
Sediment Monitoring System and Accumulated Sediment in Pasig-Potrero River

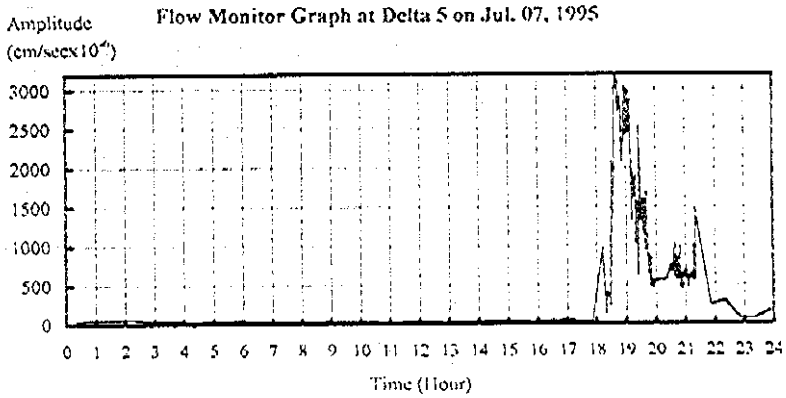
THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY











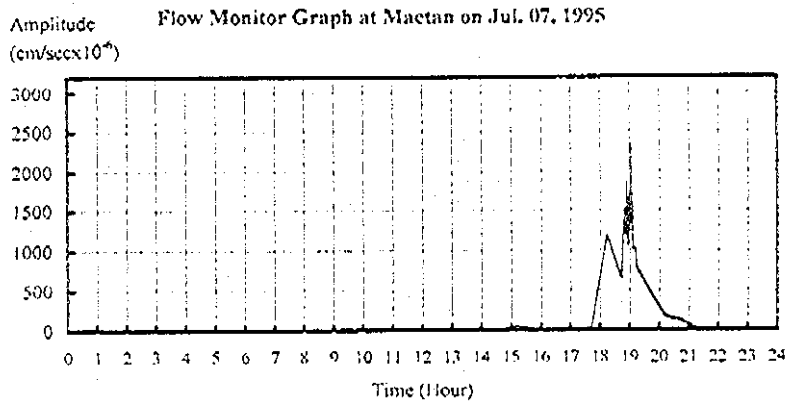
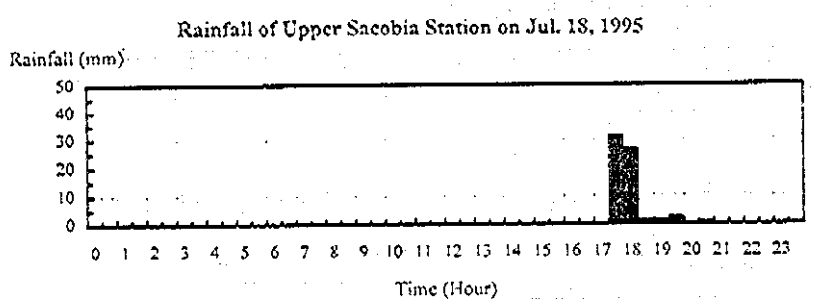
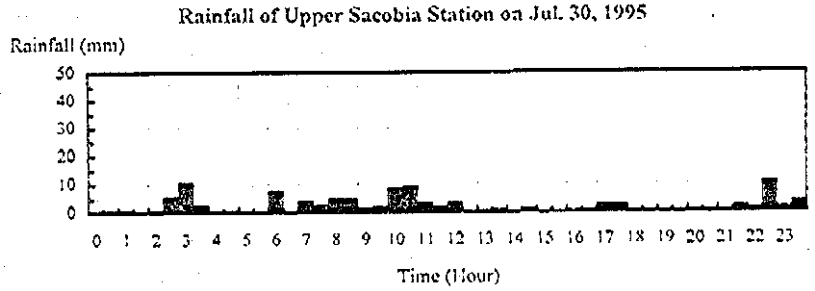


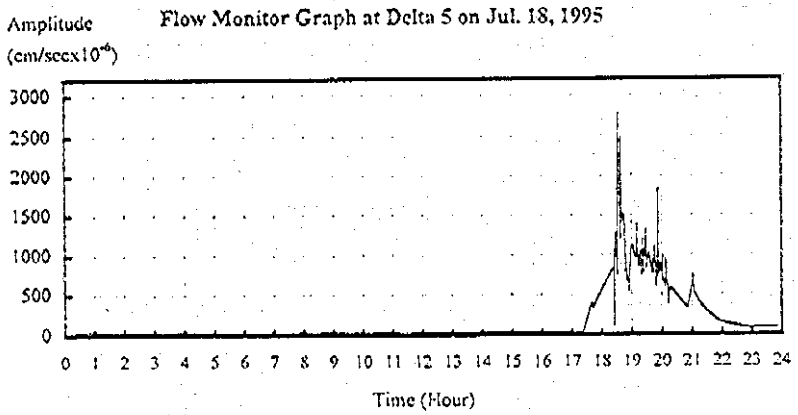
Figure F.34 (1/4)
Observed Record in 1995 Major Lahar Events

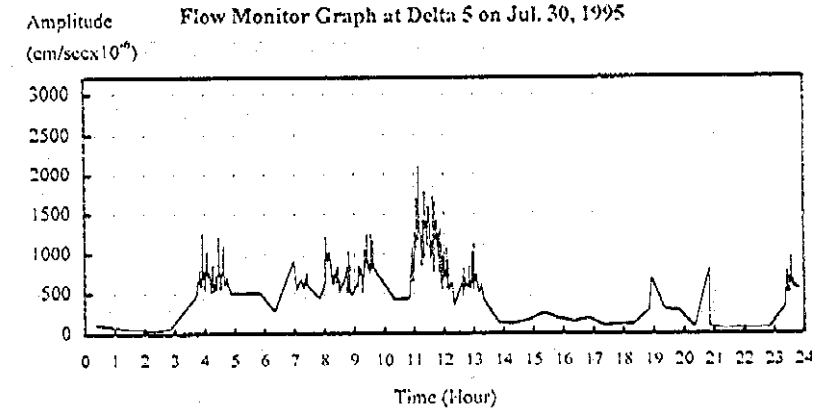
THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL
FOR SACOBIA-BAMBAN/ABACAN RIVER
DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

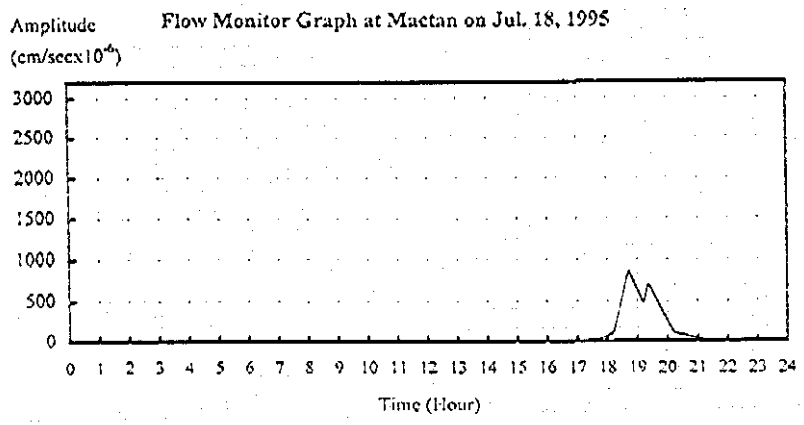
Figure F.34 (2/4)
Observed Record in 1995 Major Lahar Events

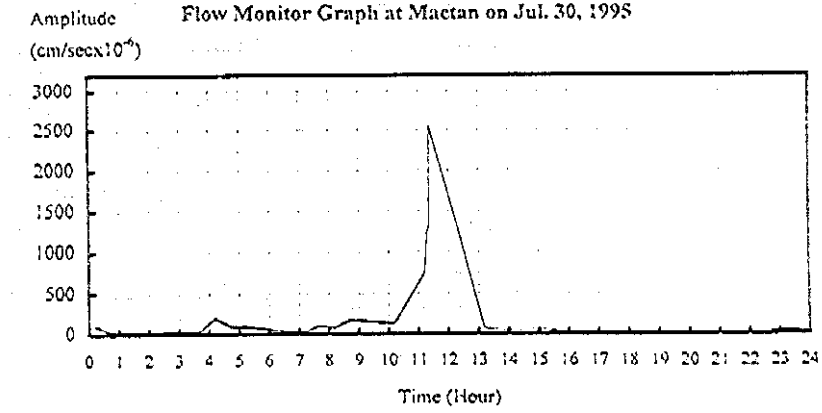












THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL
FOR SACOBIA-BAMBAN/ABACAN RIVER
DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

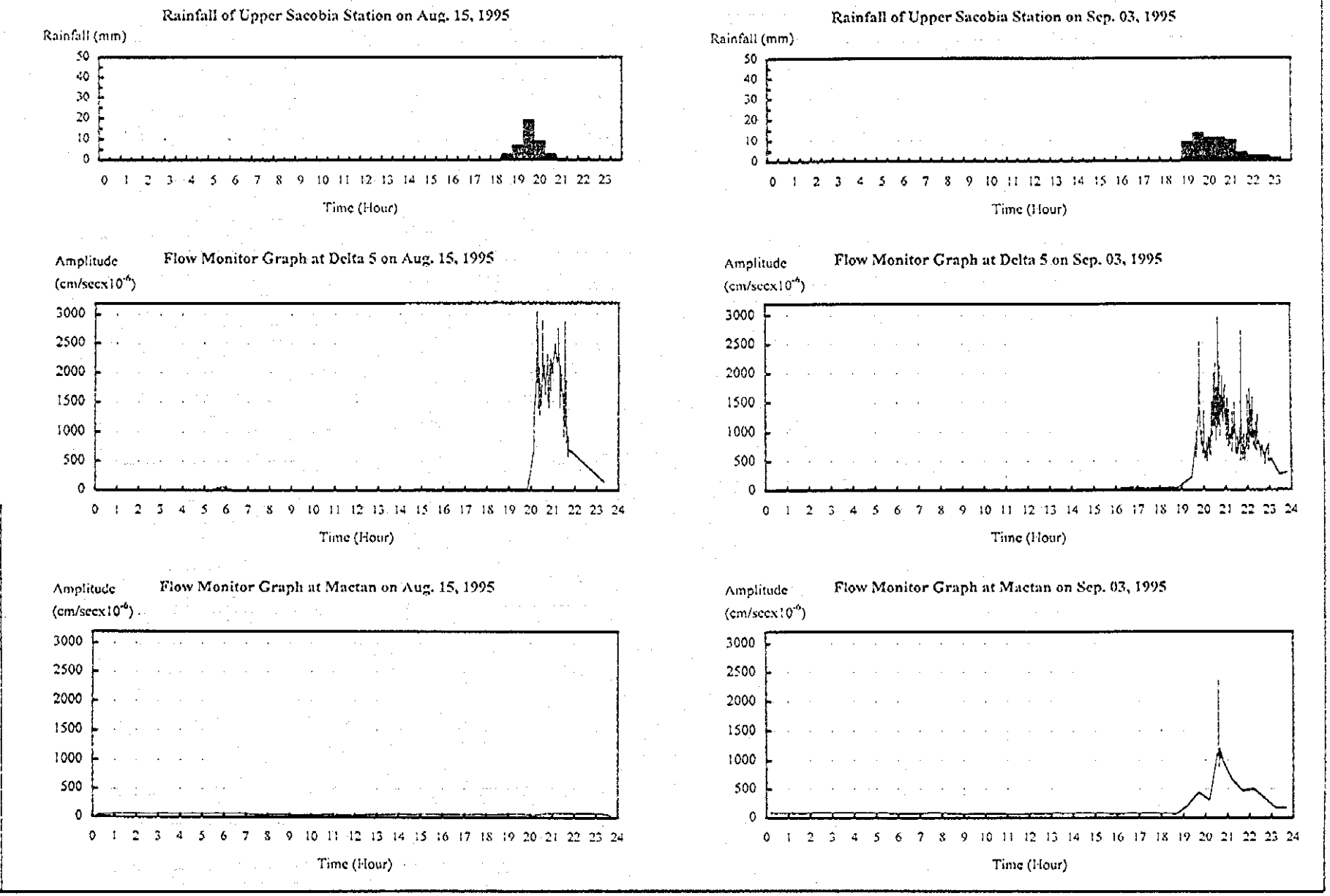
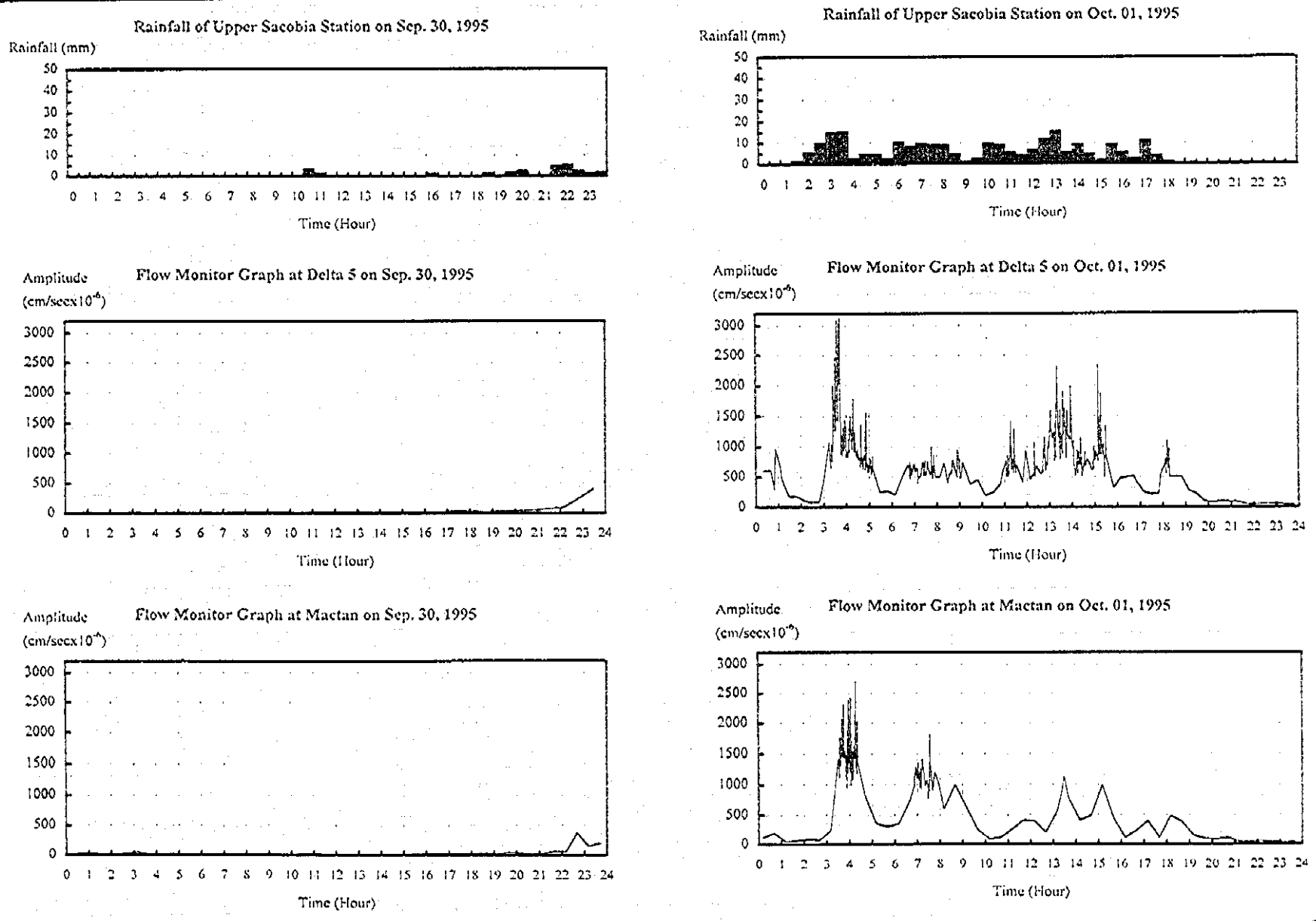


Figure F.34 (3/4)
Observed Record in 1995 Major Lahar Events

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

Figure F.34 (4/4)
Observed Record in 1995 Major Lahar Events



THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL
FOR SACOBIA-BAMBAN/ABACAN RIVER
DRAINING FROM MT PINATUBO
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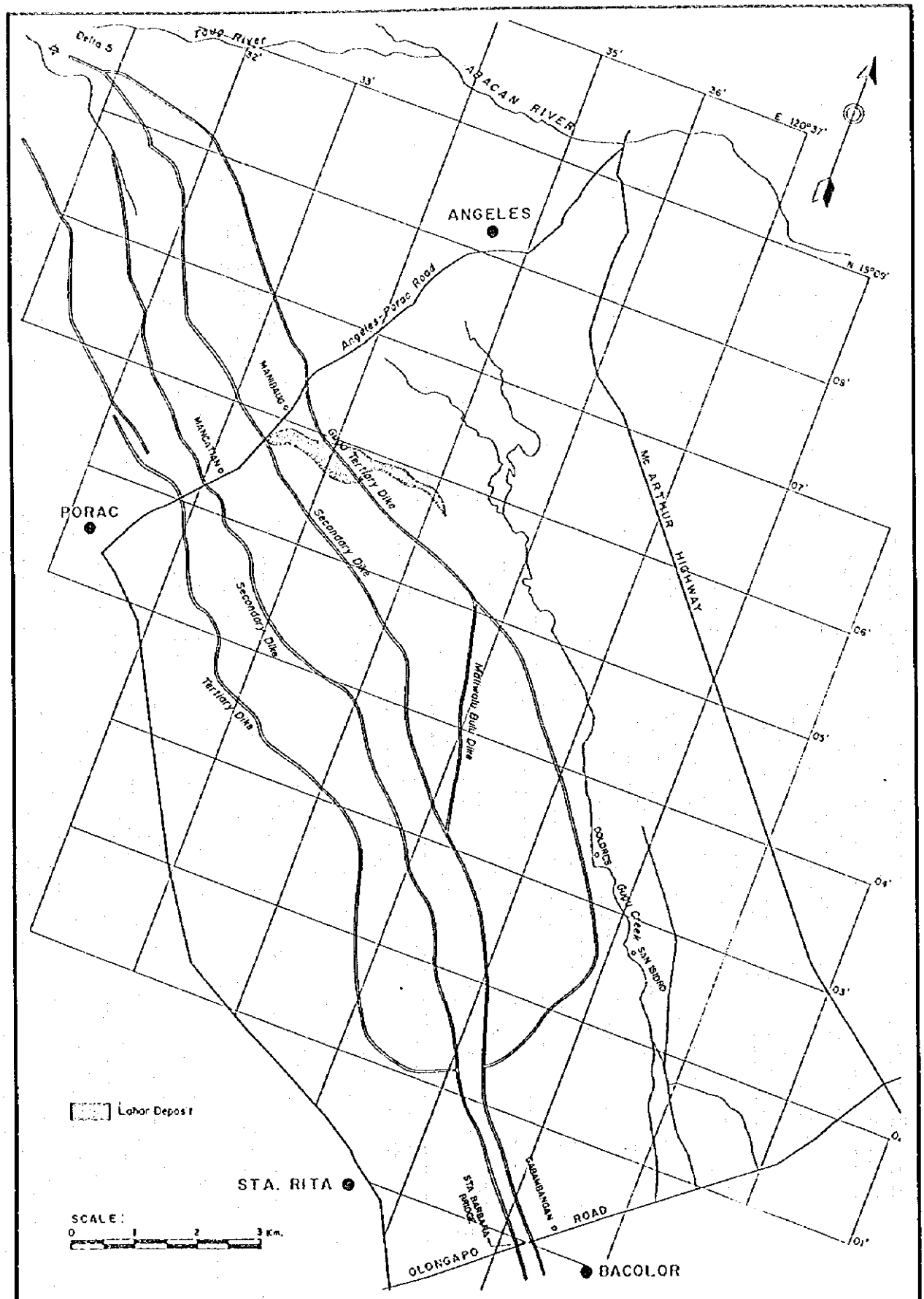

Figure F.35
Lahar Deposit in June 1 to 7 Event, 1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
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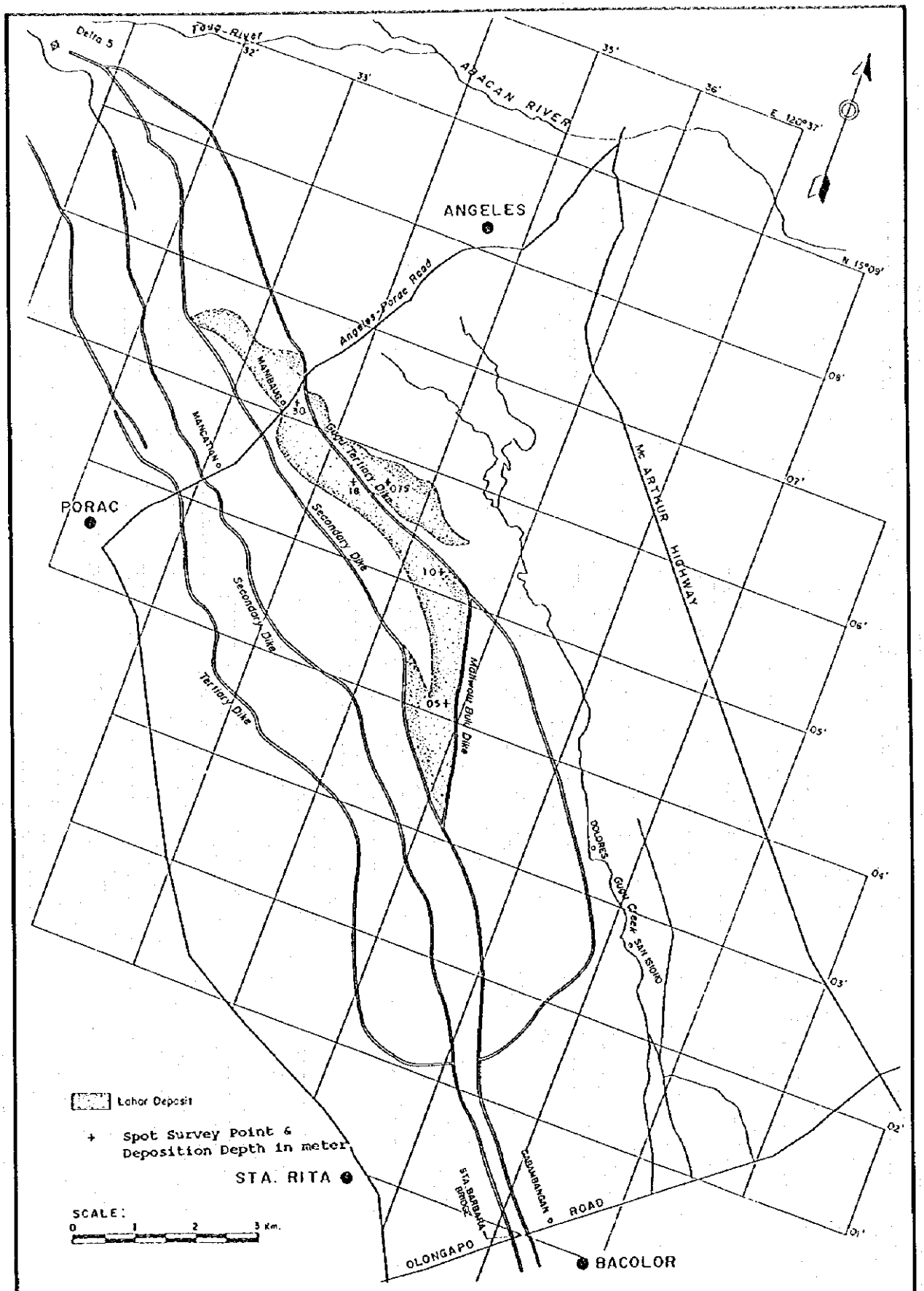

Figure F.36
Lahar Deposit in July 7 to 11 Event, 1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

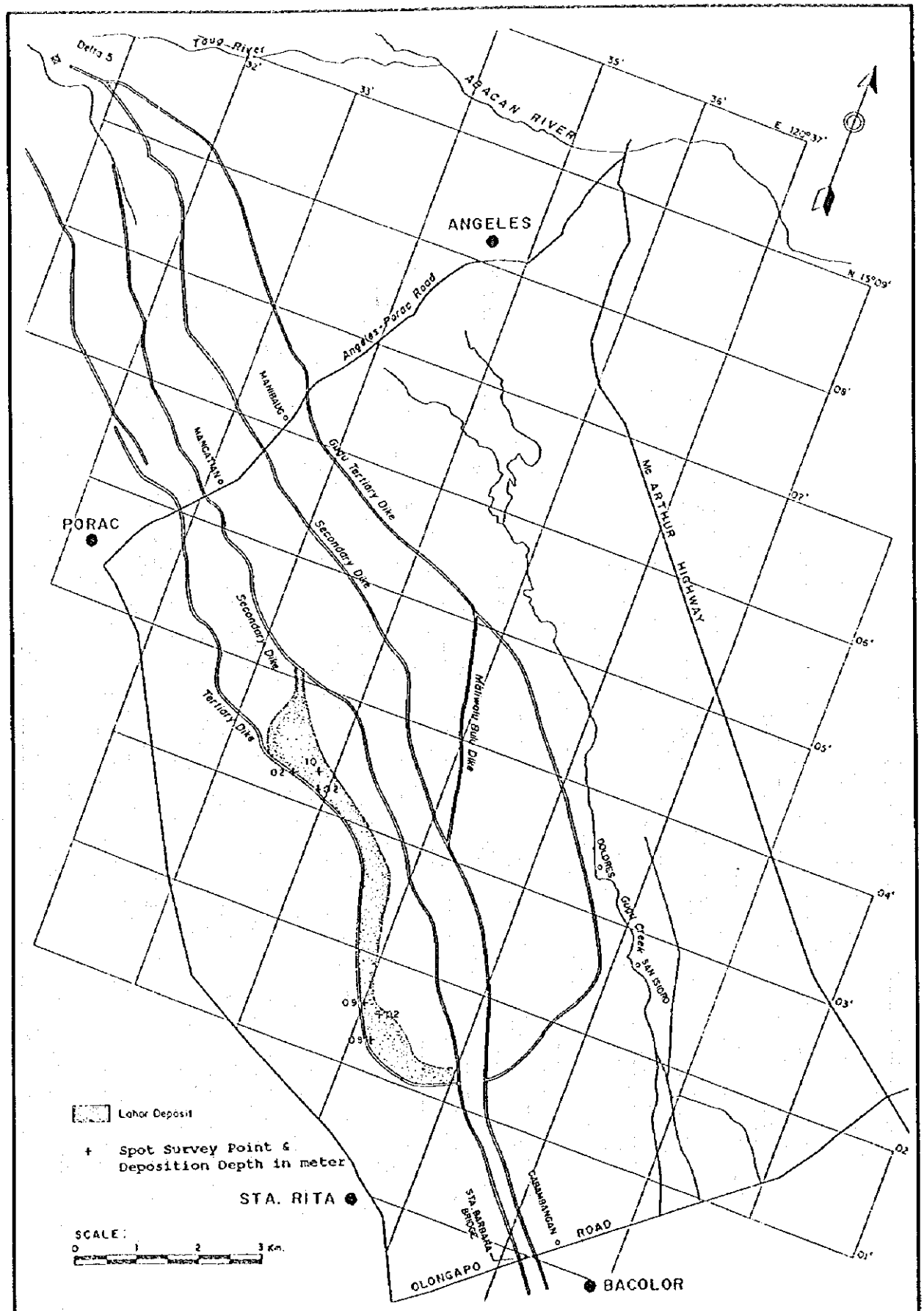

Figure F.37
Lahar Deposit in July 18 Event, 1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

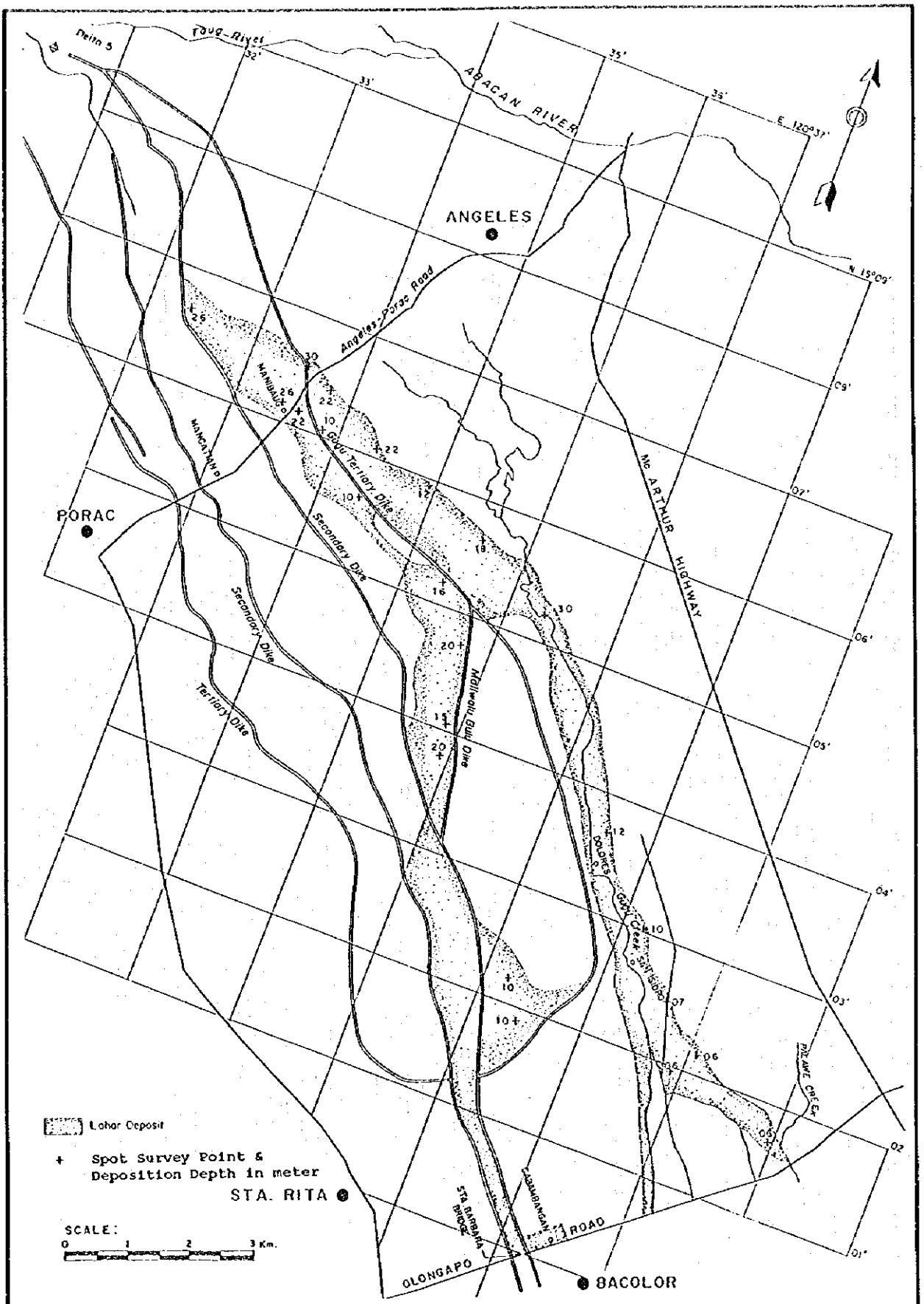

Figure F.38
Lahar Deposit in July 28 to 30 Event, 1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

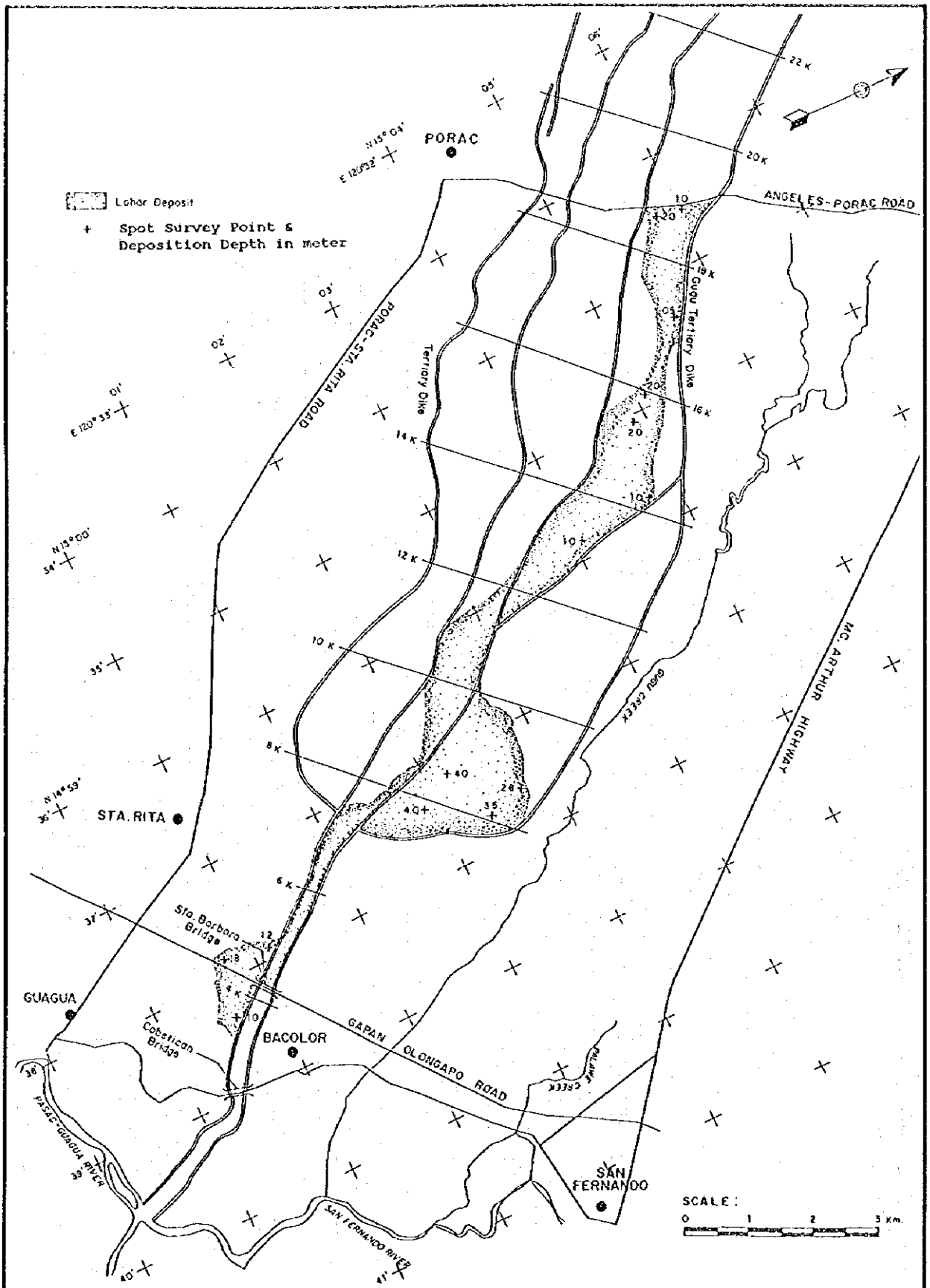

Figure F.39
Lahar Deposit in August 15 to 19 Event, 1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

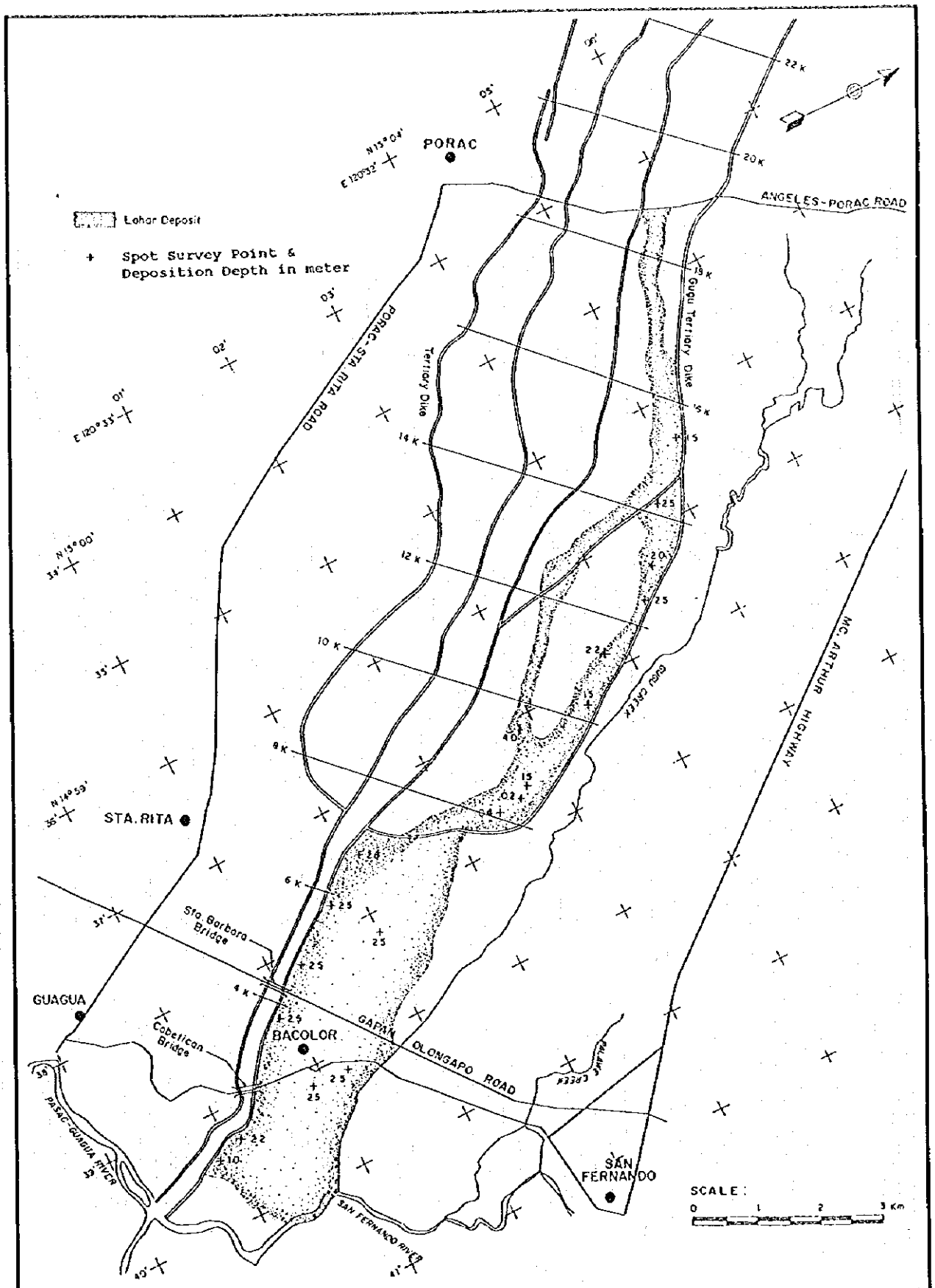

Figure F.40
Lahar Deposit in August 28 to September 3 Event, 1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

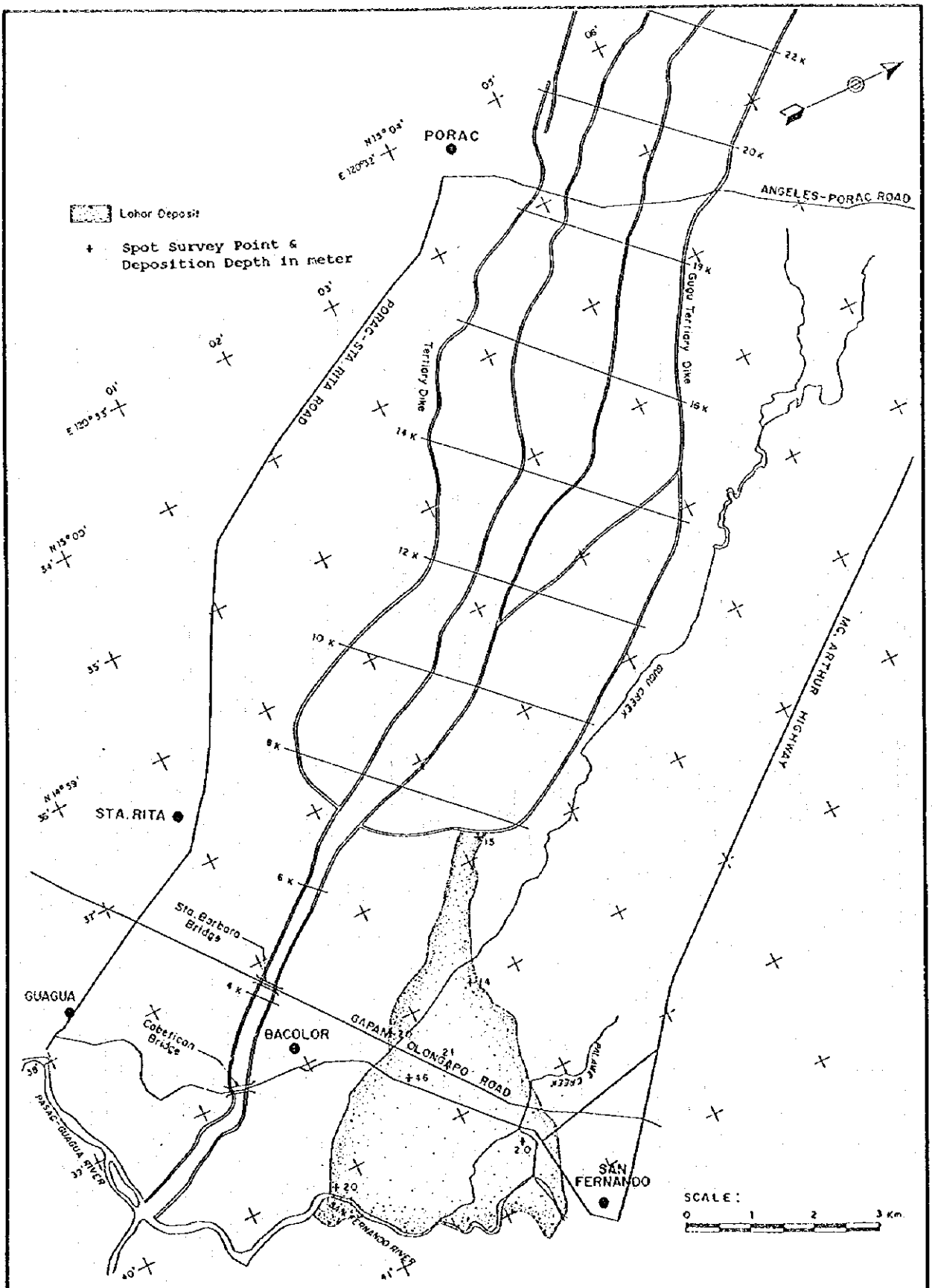

Figure F.41
Lahar Deposit in September 30 to October 1 Event, 1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

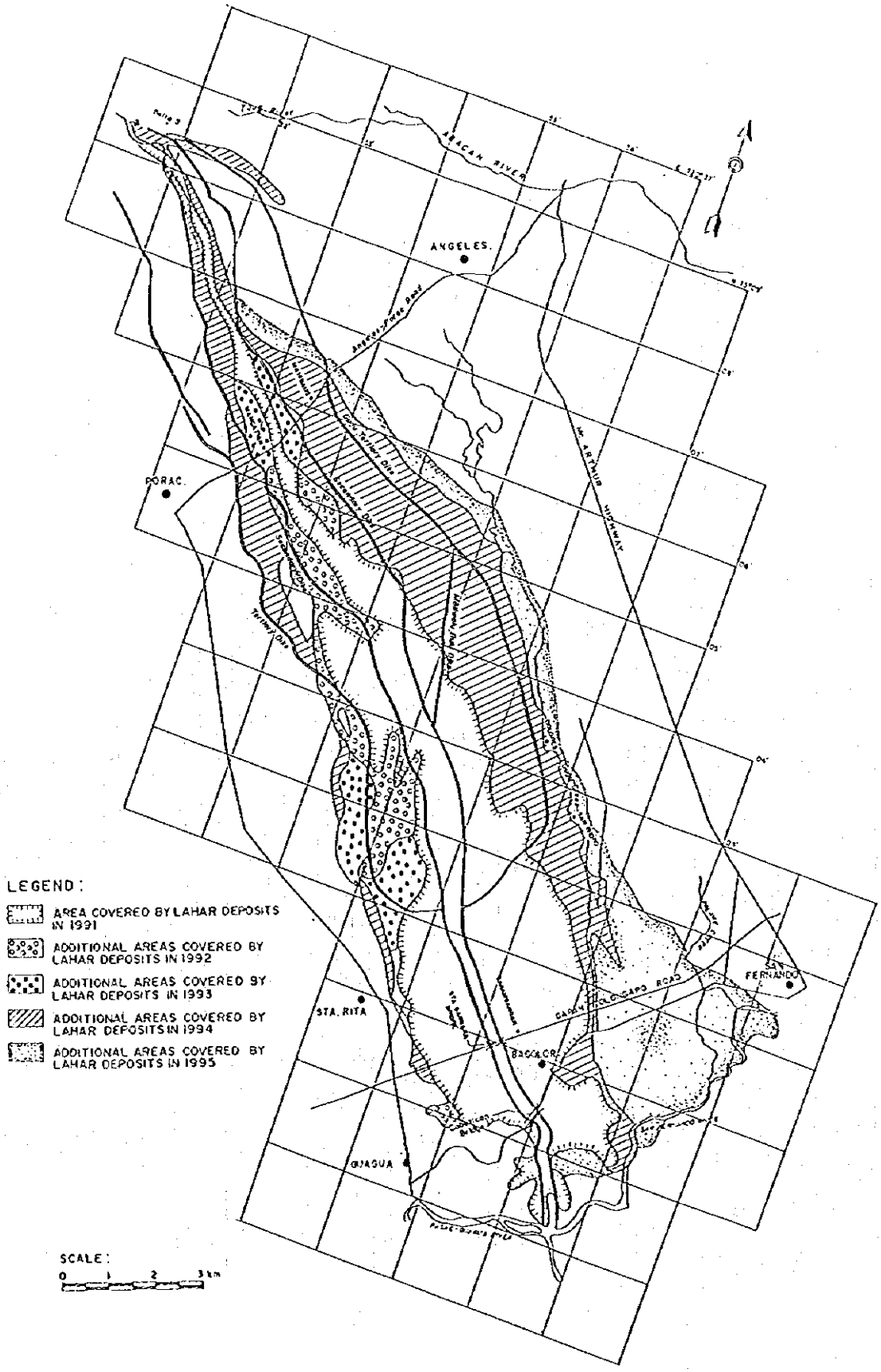

Figure F.42

Lahar Deposits after 1991 Mt. Pinatubo Eruption

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
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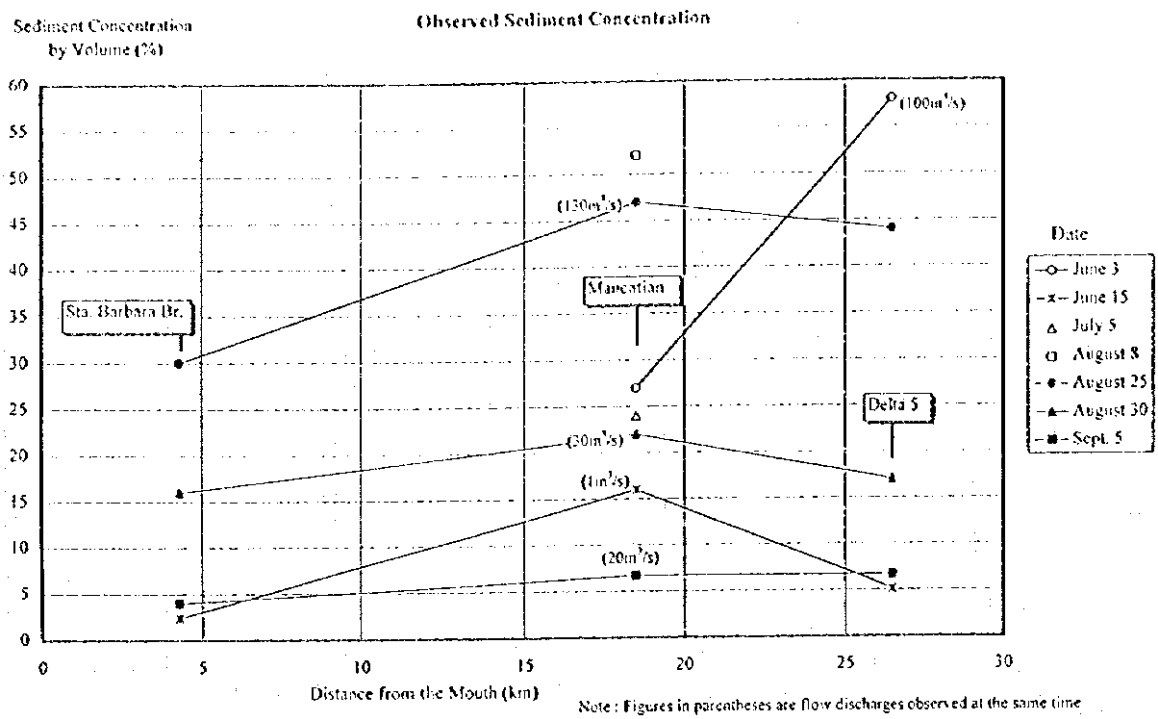
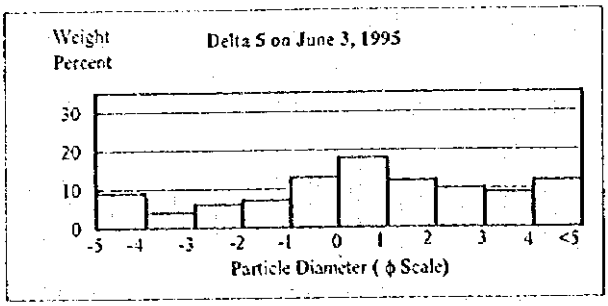
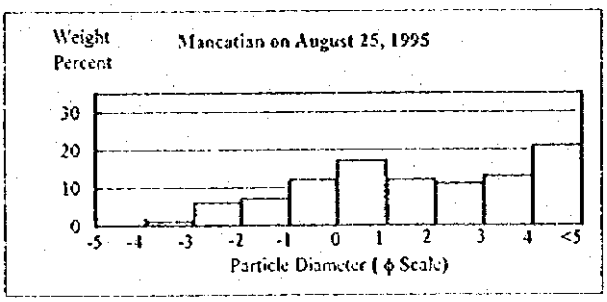






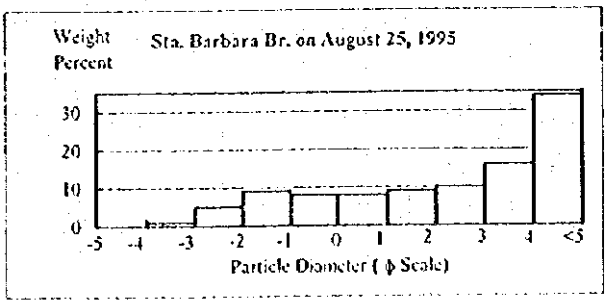


Figure F.43

Observed Sediment Concentration and Transported Material in Pasig-Potrero River

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

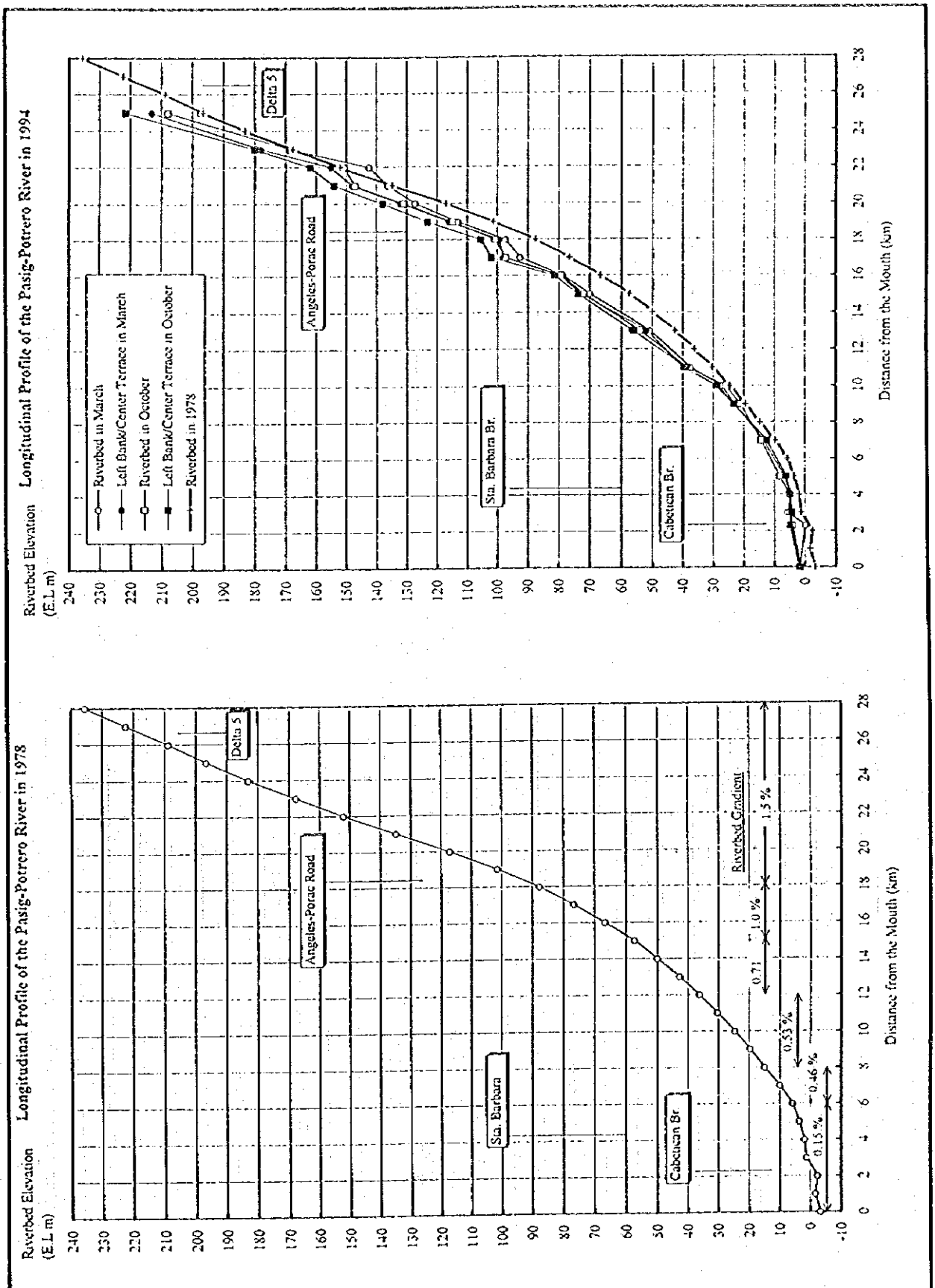
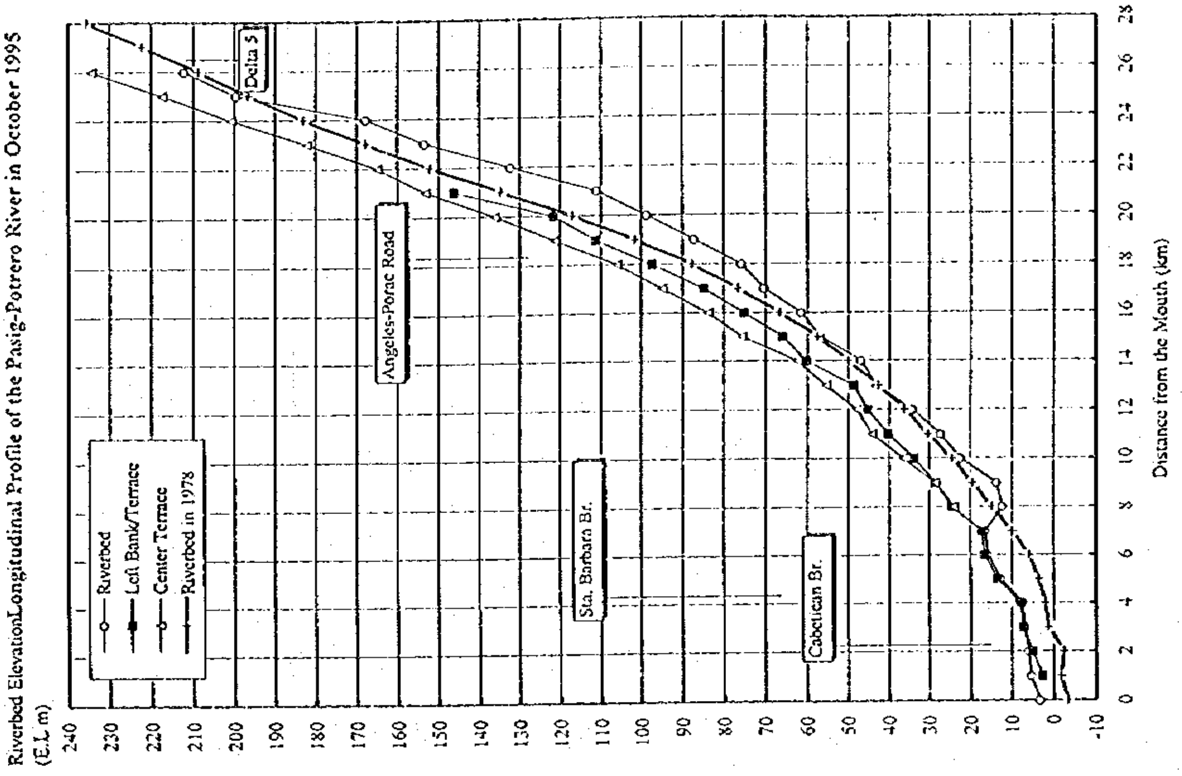


Figure F.44(1/2)

Changes of Longitudinal Profile of Pasig-Potrero River

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY



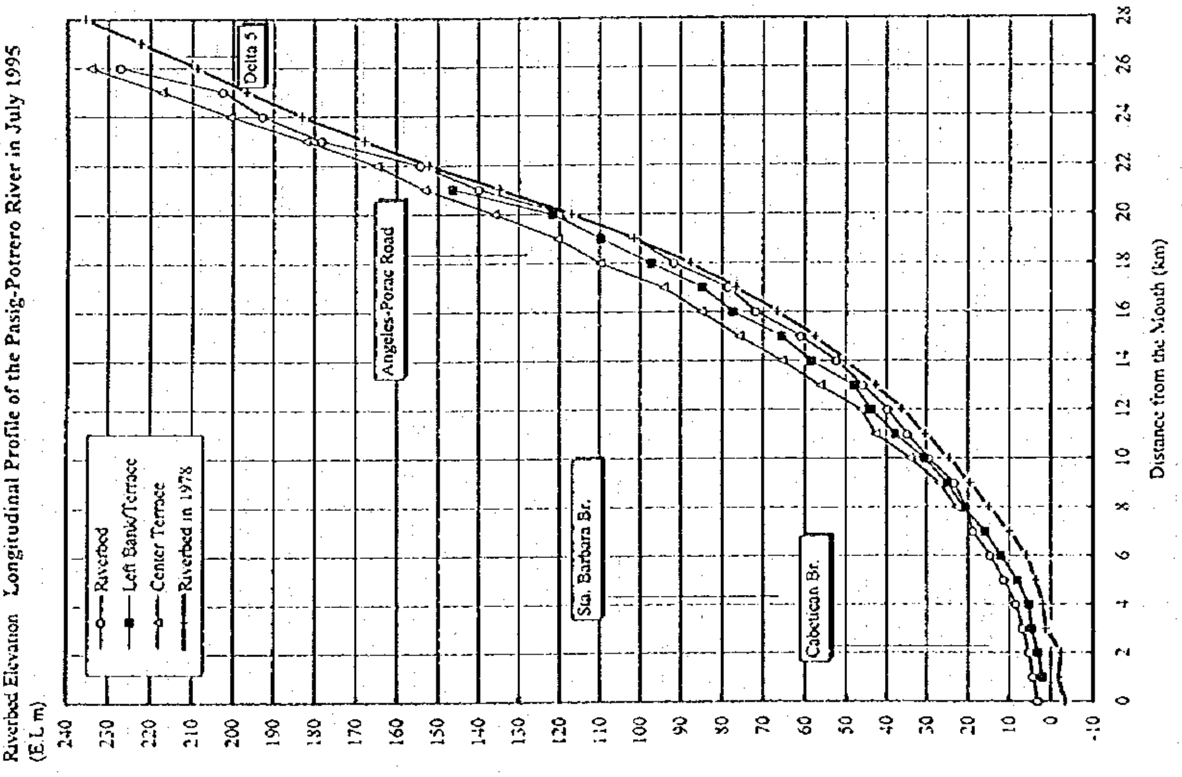


Figure F.44(2/2)

Changes of Longitudinal Profile of Pasig-Potrero River

THE GOVERNMENT OF THE PHILIPPINES THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

Date (Month/ Day)	Secondary Explosion (Height in meter)	Daily Rainfall at Upper Sacobia (mm)	Lahar in Pasig (Observed Max. Amplitude and Lahar Scale)	Cross-Section at Delta 5
03/01				
03/02				
03/03			2760 MODER	
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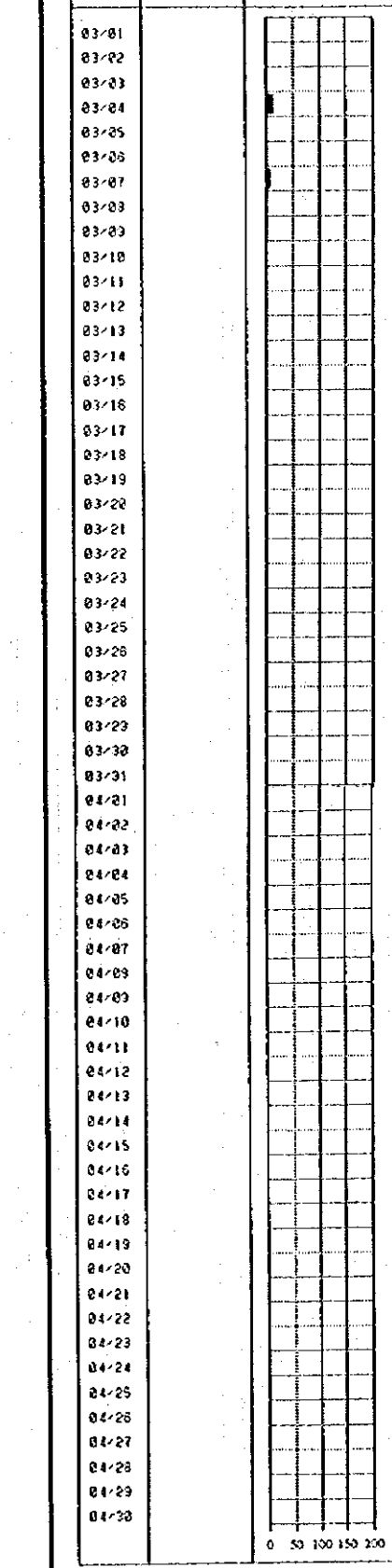

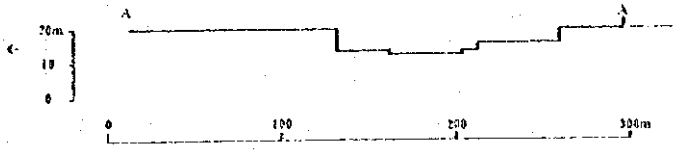

Figure F.45(1/4)

Cross-Sectional Changes at Watchpoint Delta 5 in 1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

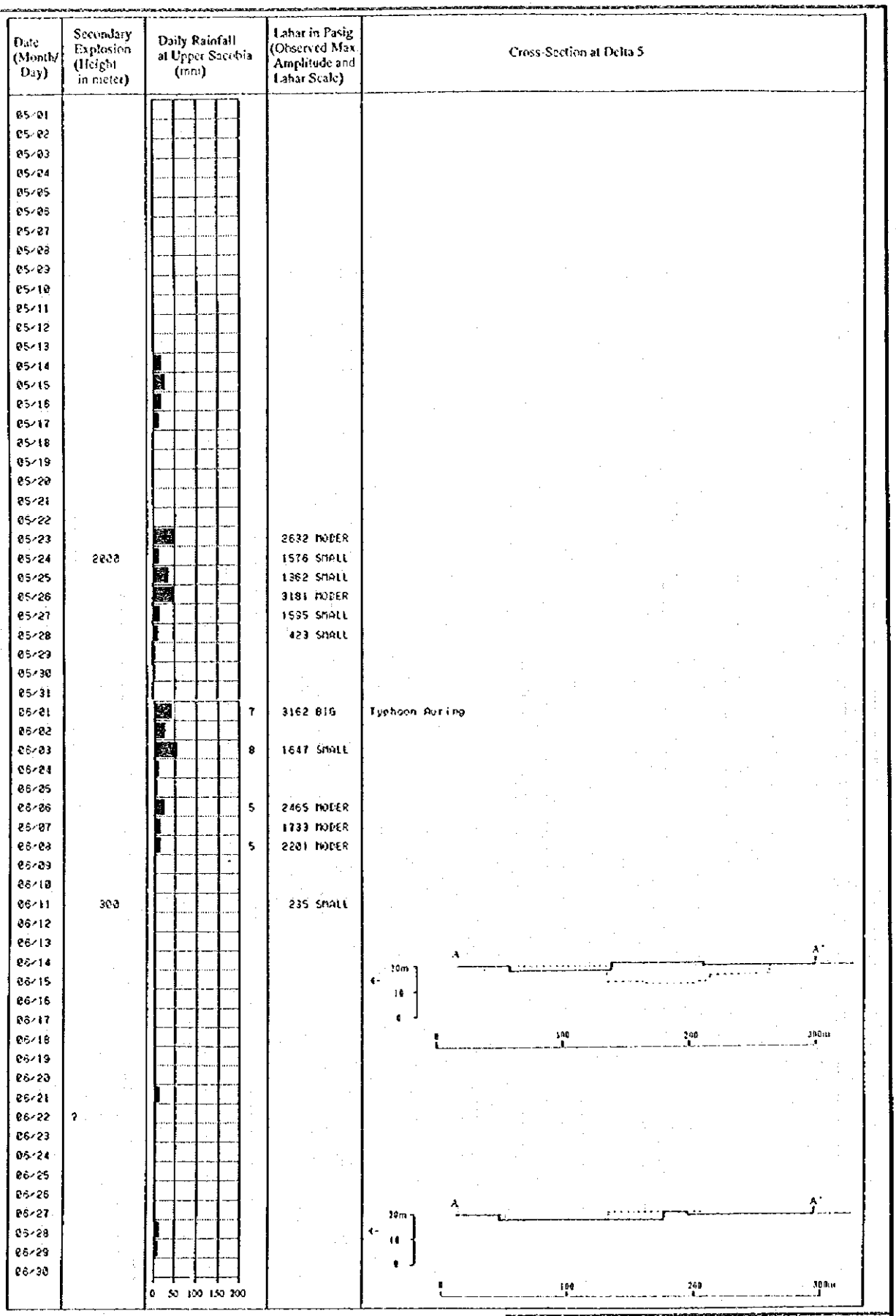

Figure F.45(2/4)

Cross-Sectional Changes at Watchpoint Delta 5 in 1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
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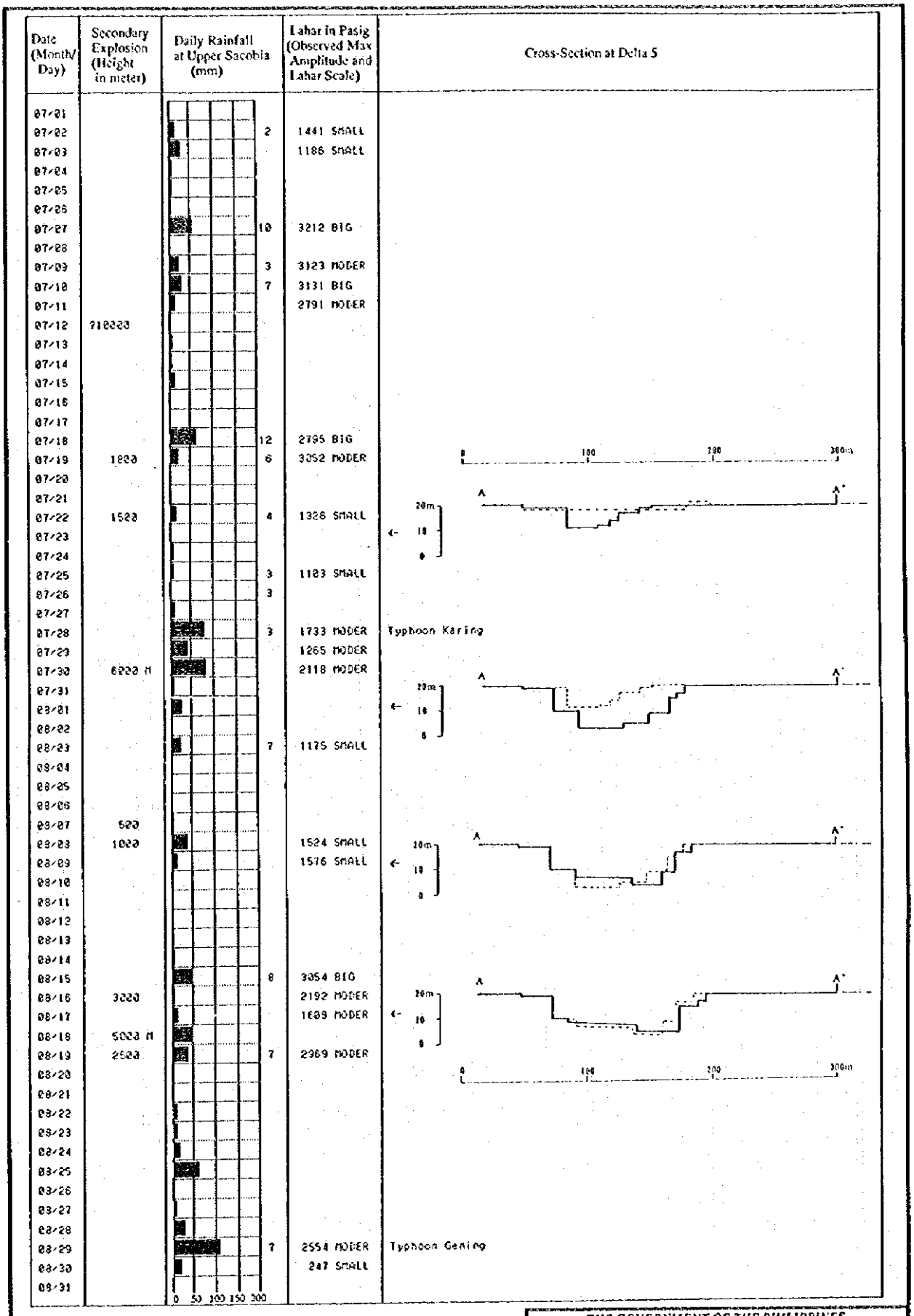

Figure F.45(3/4)

Cross-Sectional Changes at Watchpoint Delta 5 in 1995

THE GOVERNMENT OF THE PHILIPPINES
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THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

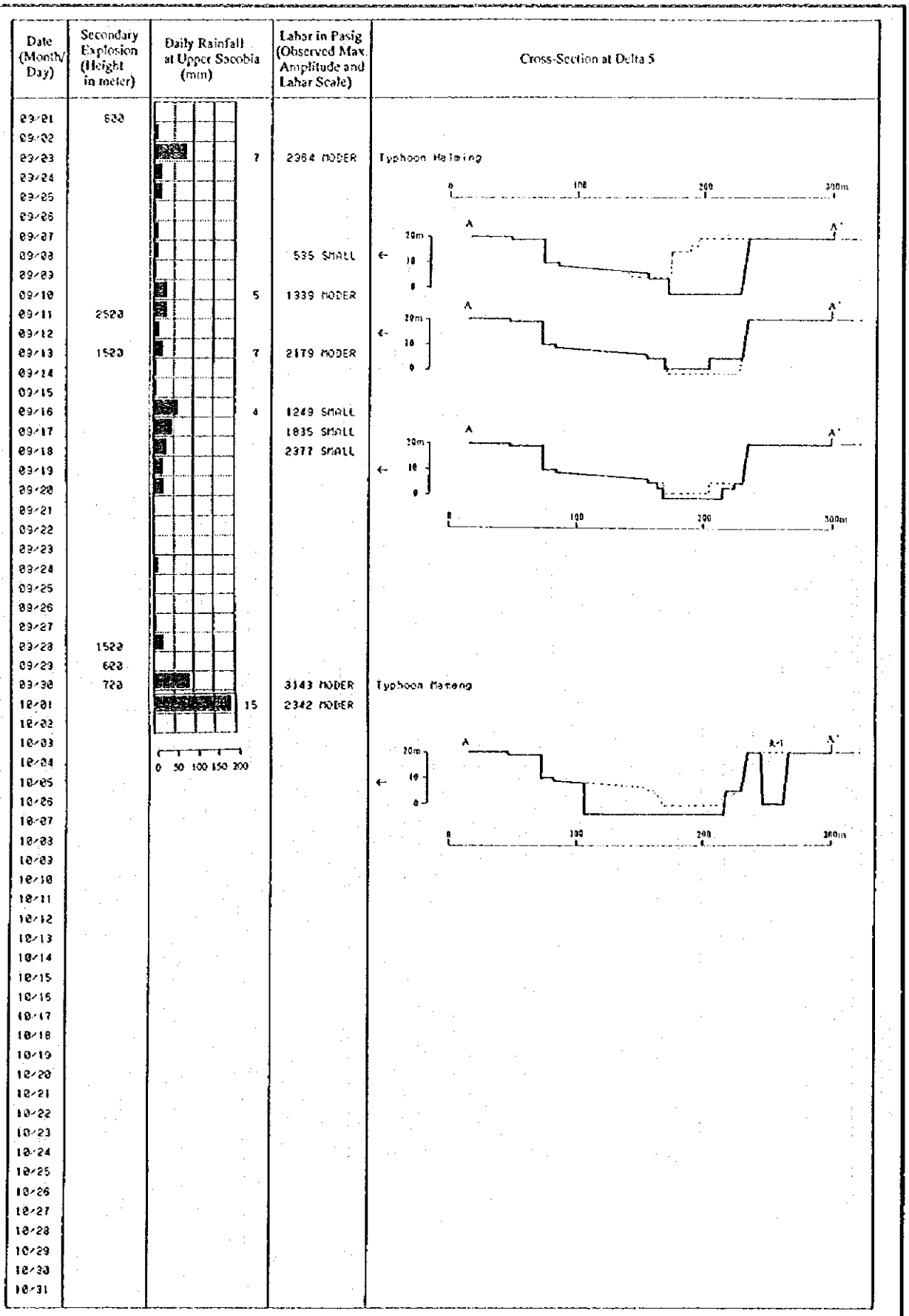

Figure F.45(4/4)

Cross-Sectional Changes at Watchpoint Delta 5 in 1995

THE GOVERNMENT OF THE PHILIPPINES
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THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY

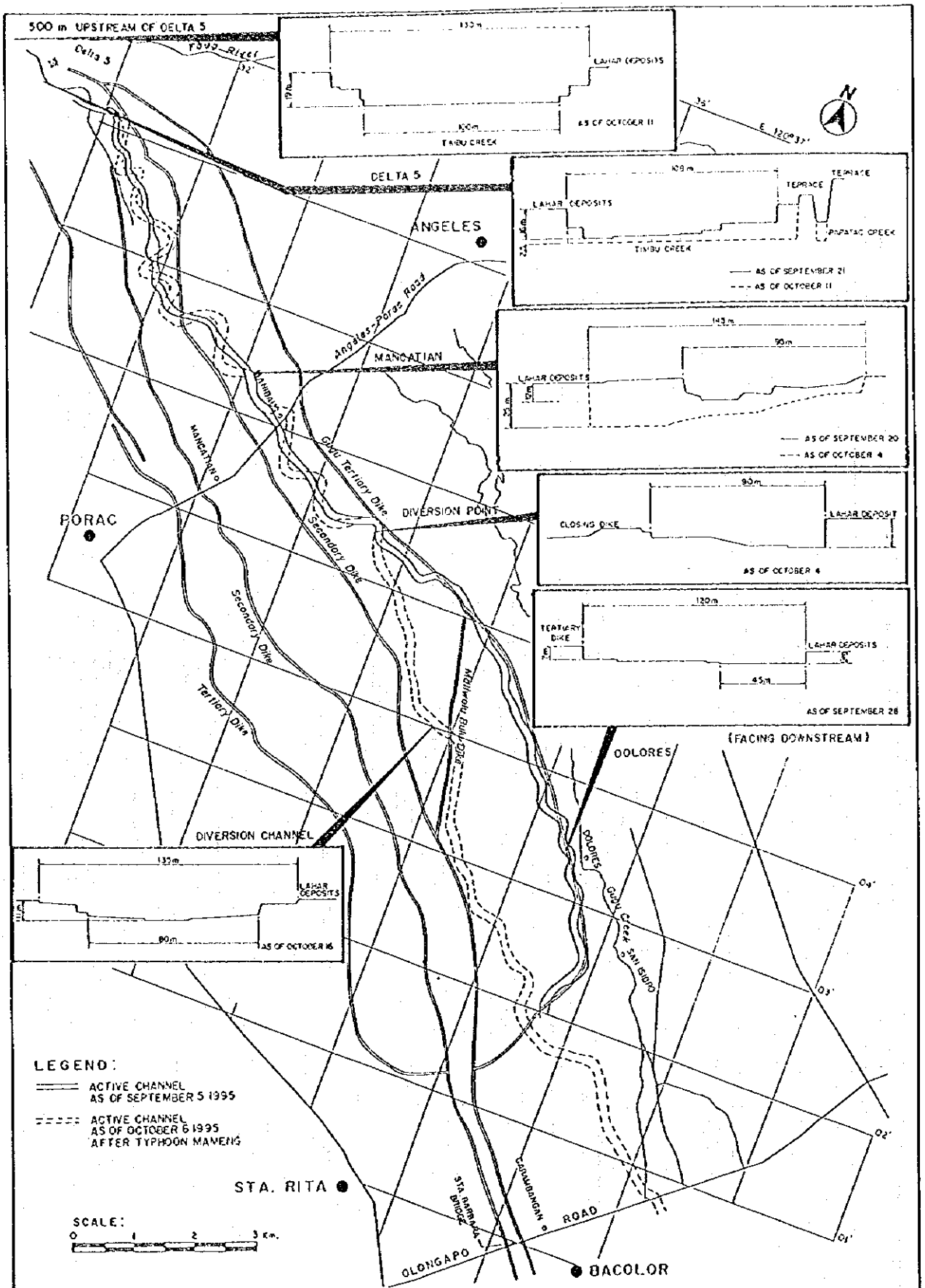
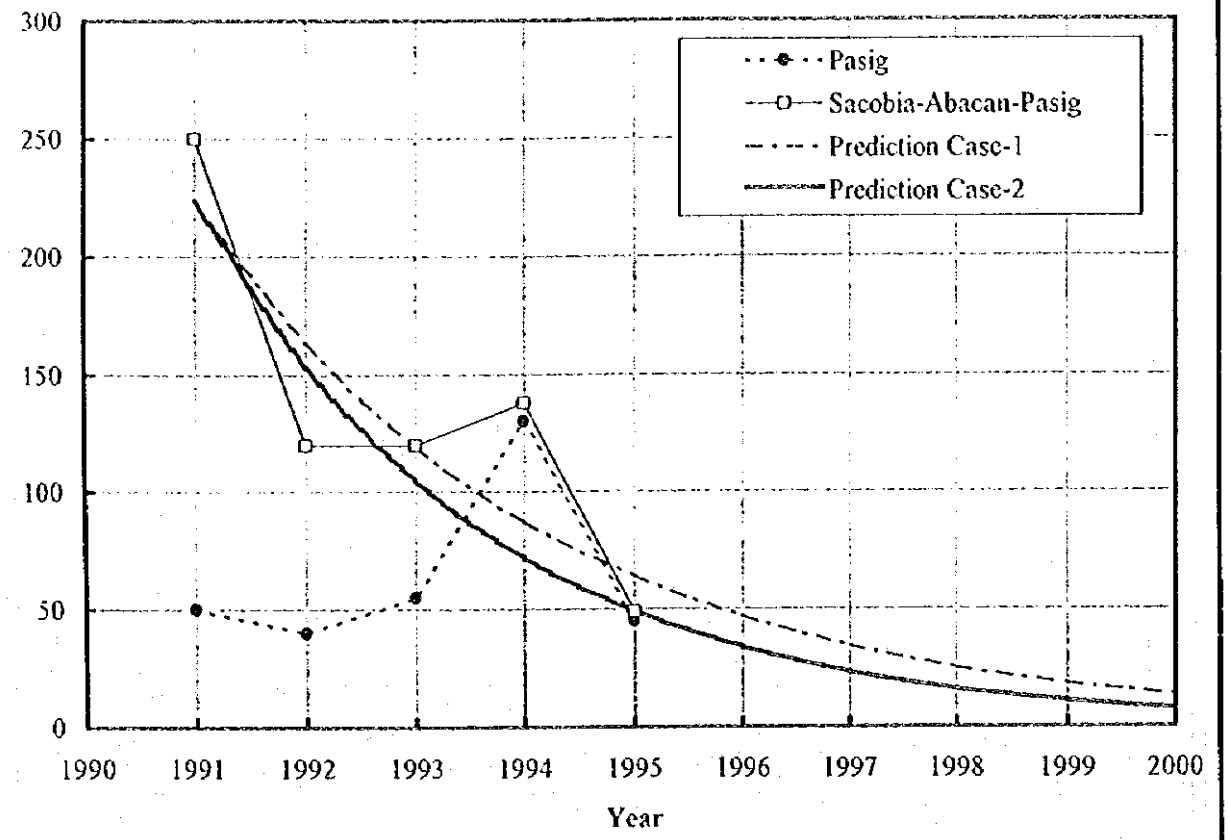


Figure F.46

River Course Meandering and Cross-Sectional Changes along Pasig-Potrero River in 1995

THE GOVERNMENT OF THE PHILIPPINES
THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO
JAPAN INTERNATIONAL COOPERATION AGENCY



Annual Sediment Delivery

Year	Actual		Prediction	
	Pasig	Sacobia-Abacan-Pasig	Case-1	Case-2
1991	50	250	223	223
1992	40	120	163	153
1993	55	120	119	105
1994	130	138	87	72
1995	45	49	64	49
1996			47	34
1997			34	23
1998			25	16
1999			18	11
2000			13	7

Note: 1) Case-1 is predicted using all actual data of Sacobia-Abacan-Pasig from 1991 to 1995.
2) Case-2 is predicted excluding the 1994 data as a extraordinary value.
3) Regression lines are as folows;
Case-1 : Y=304.6Exp(-0.312T) Correlation Coefficient = 0.846
Case-2 : Y=325.1Exp(-0.377T) Correlation Coefficient = 0.966

Figure F.47 Sediment Delivery Prediction

THE GOVERNMENT OF THE PHILIPPINES
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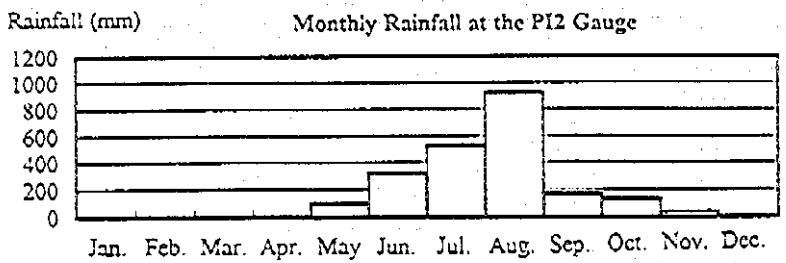
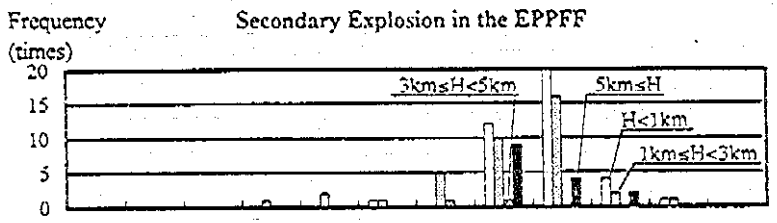
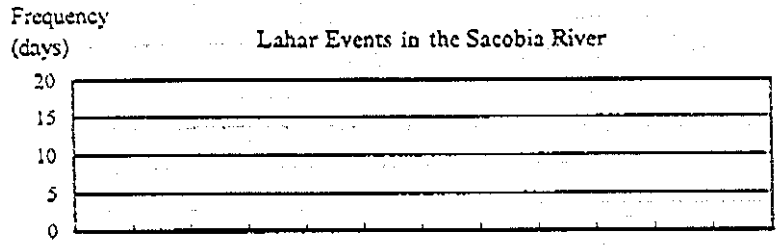
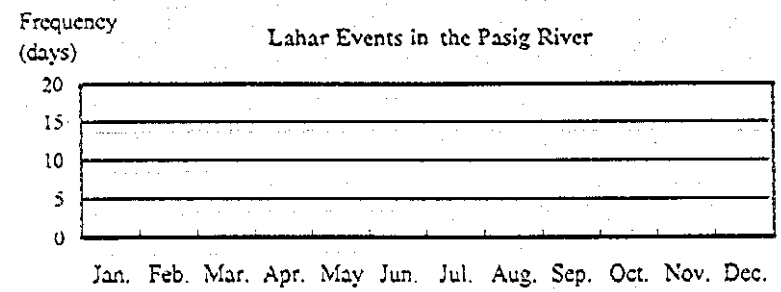
Figure F.48(1/2)

Summary of Lahar Events, 1992-1995

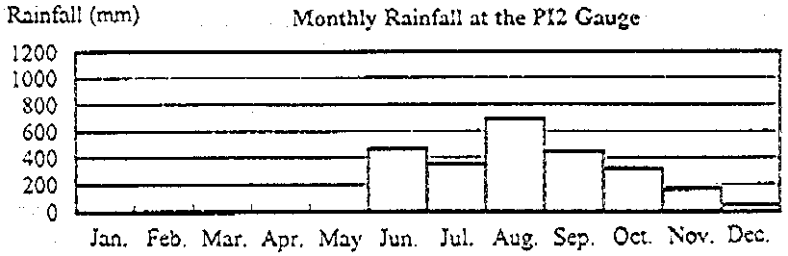


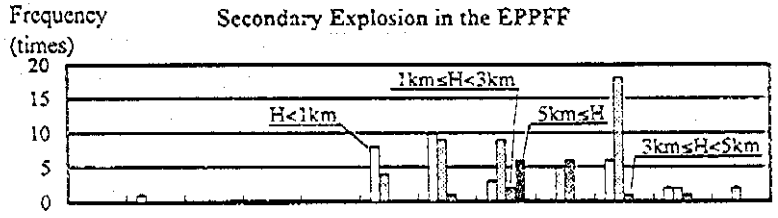


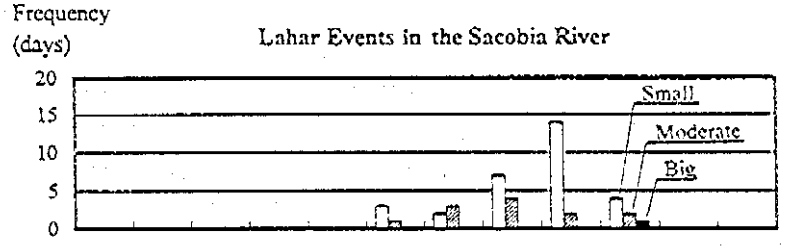


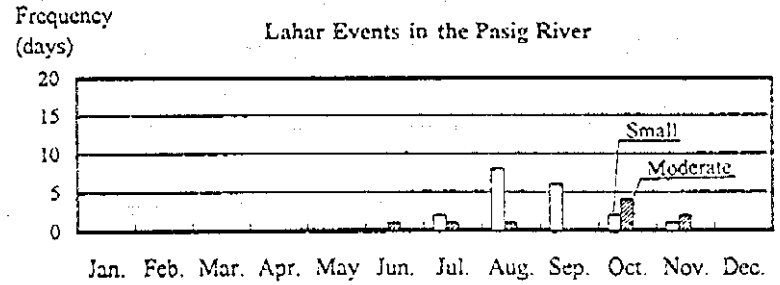


Lahar Events in 1992









Lahar Events in 1993

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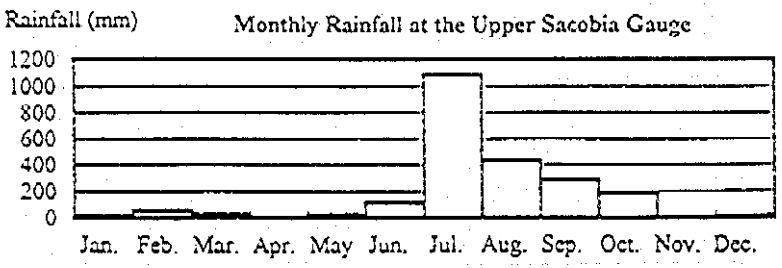
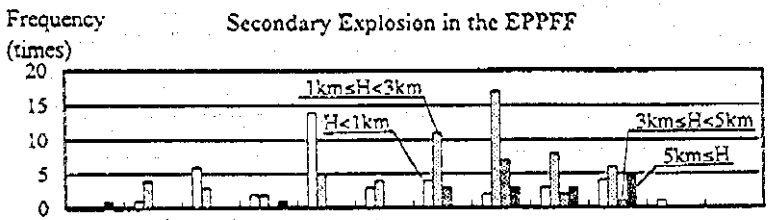
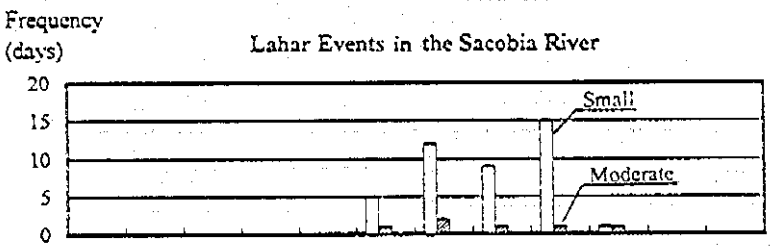
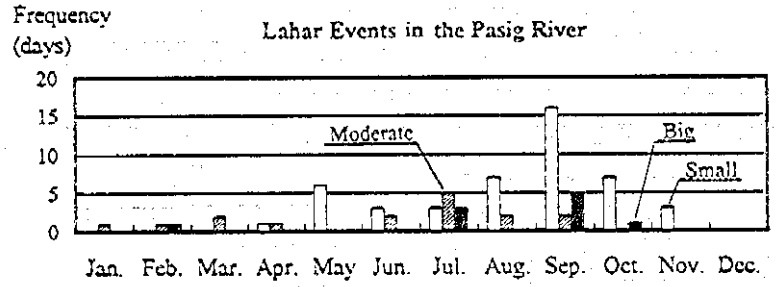
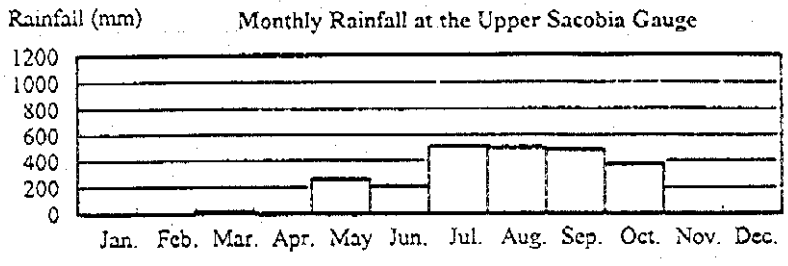


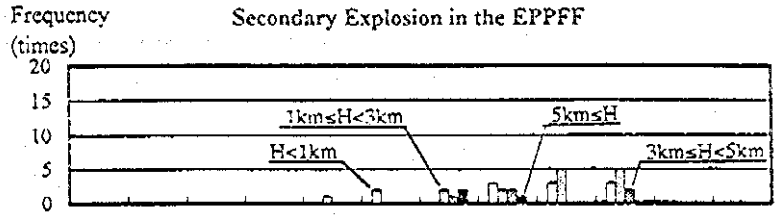


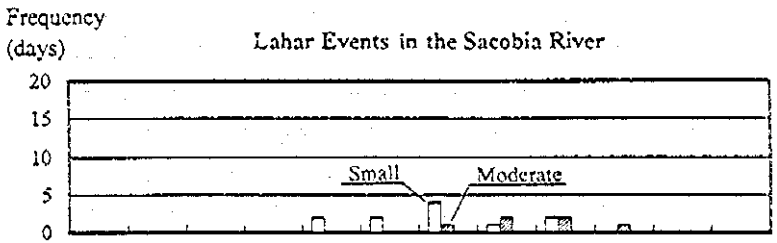


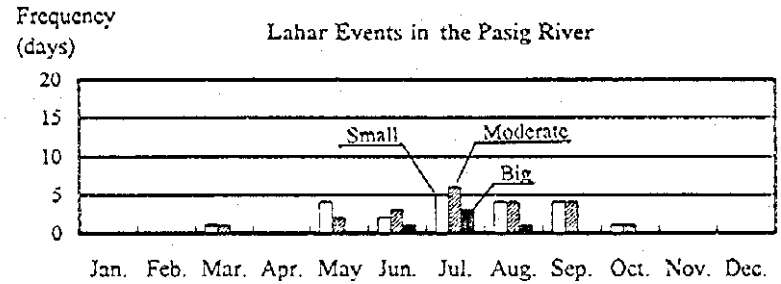


Lahar Events in 1994









Lahar Events in 1995

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JAPAN INTERNATIONAL COOPERATION AGENCY

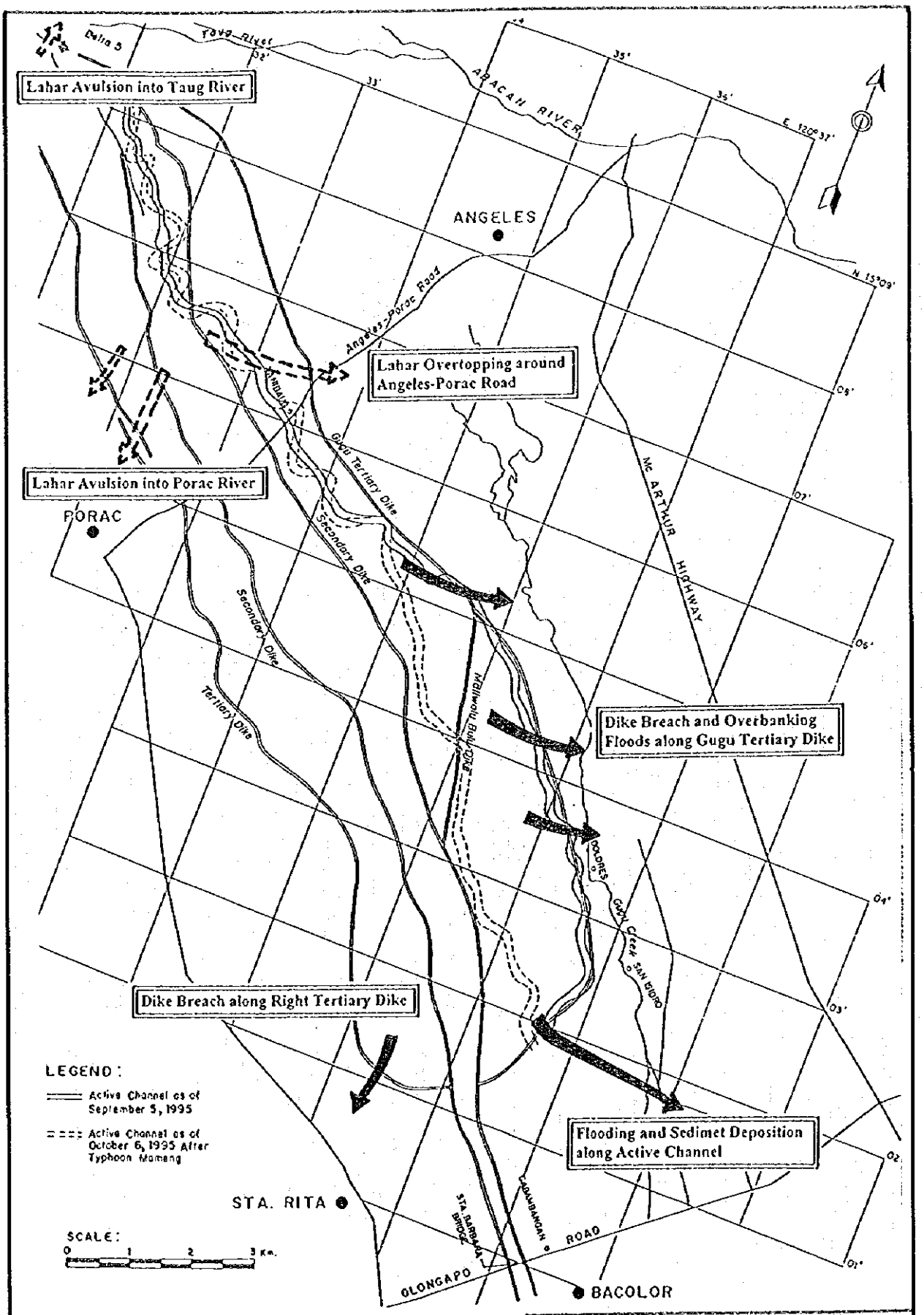

Figure F.49
Critical Portions along Pasig-Potrero River Course

THE GOVERNMENT OF THE PHILIPPINES
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JAPAN INTERNATIONAL COOPERATION AGENCY

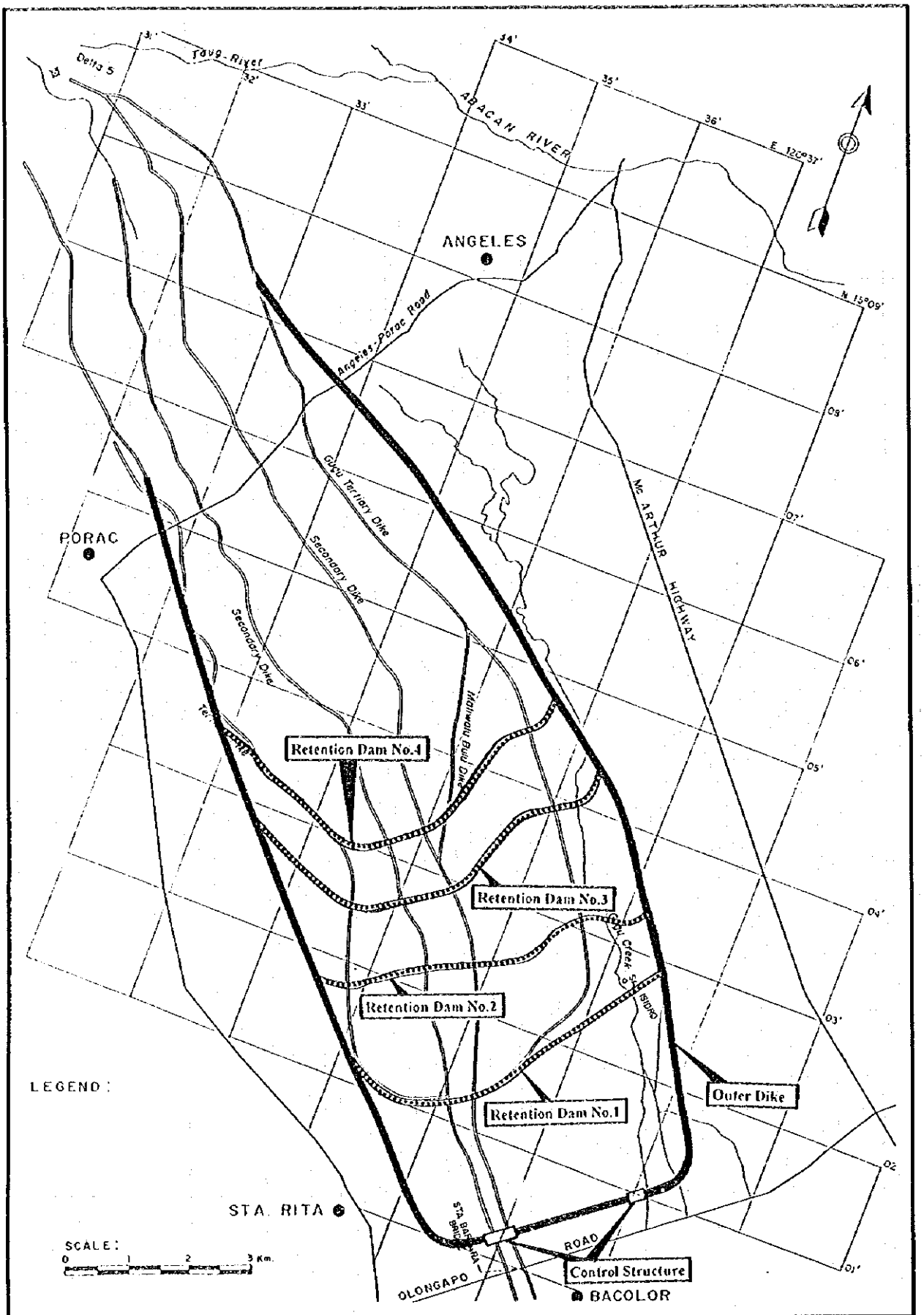

Figure F.50 DPWH Outer Dike System

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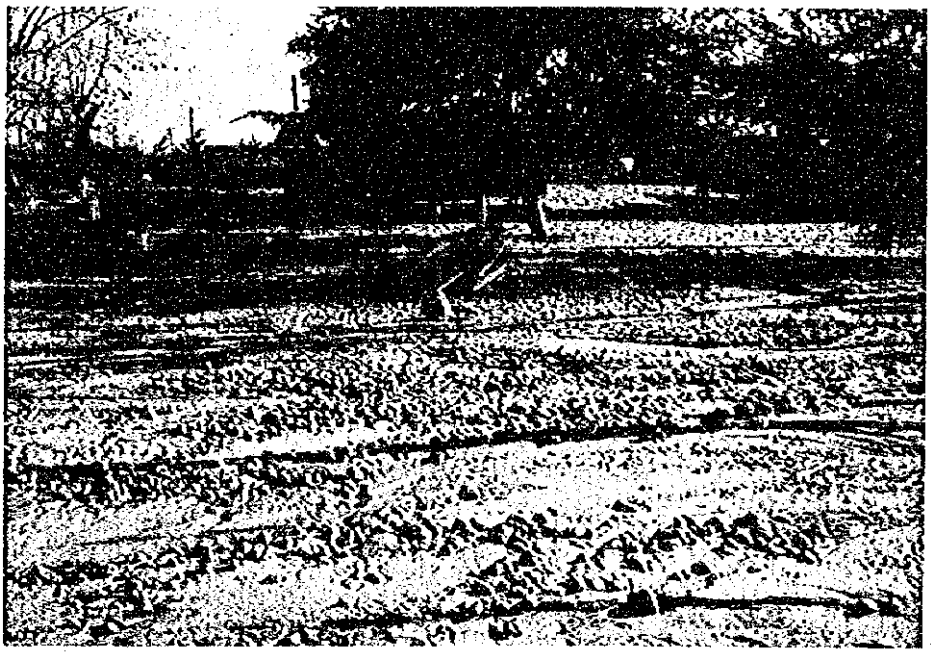
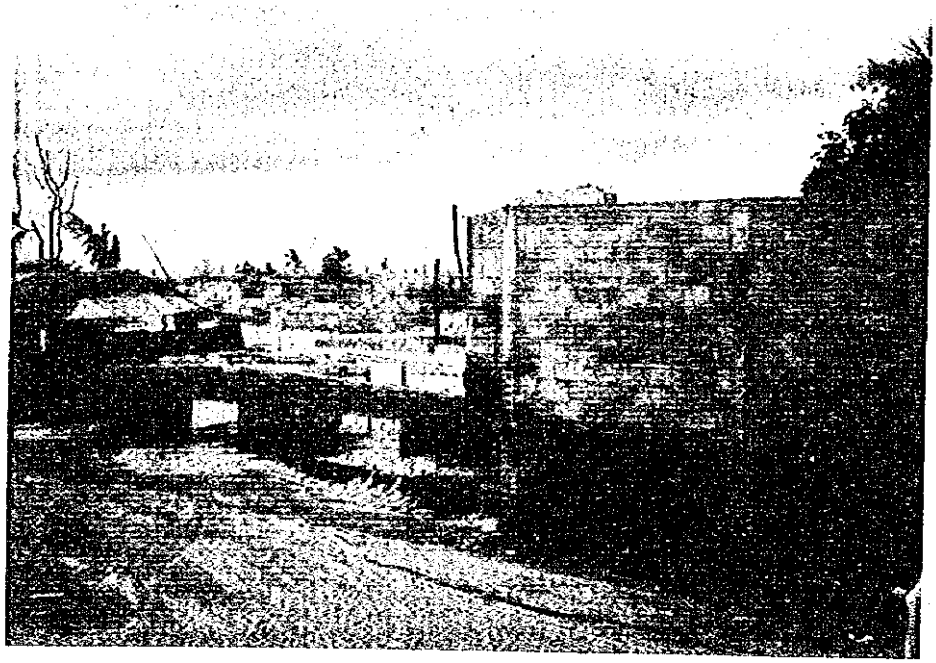
Photographs

Station LB-1 near the Angeles-Porac road (refer to Figure F.33)
Established on July 6, 1995
Height : 2.0 m

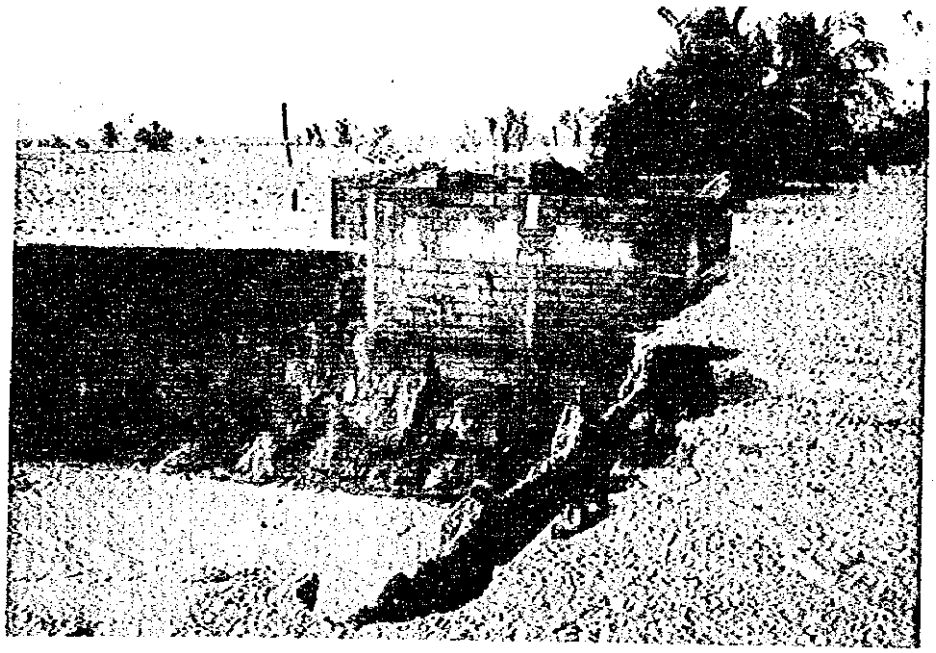


Surveyed on July 14
Completely buried by more than 3 m thick during the July 7 to 11 lahar event

Photograph F.1 (1/5) Sediment Deposition Observed at Monitoring Station

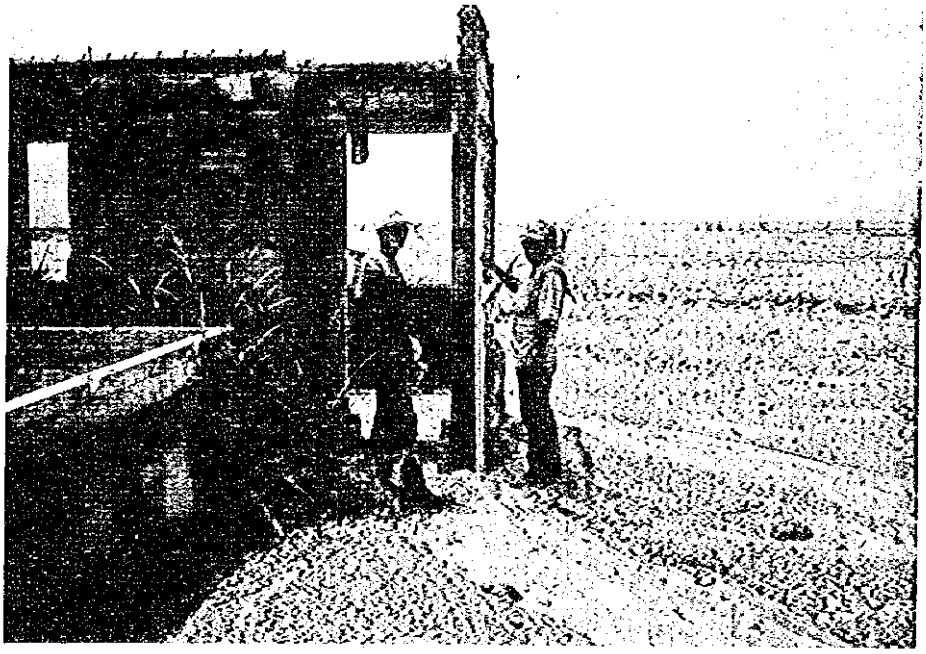


New station LB-1 beside the previous station
Established on July 26
Height : 2.0 m



Surveyed on July 31
Completely buried by 2.7 m thick during the July 28 to 30 lahar event

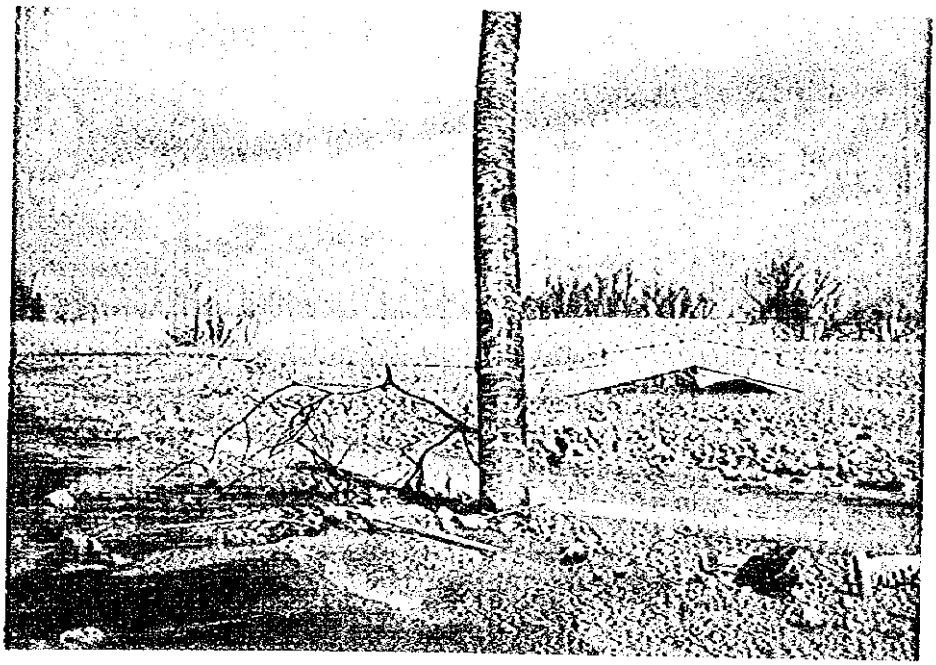
Photograph F.1 (2/5) Sediment Deposition Observed at Monitoring Station



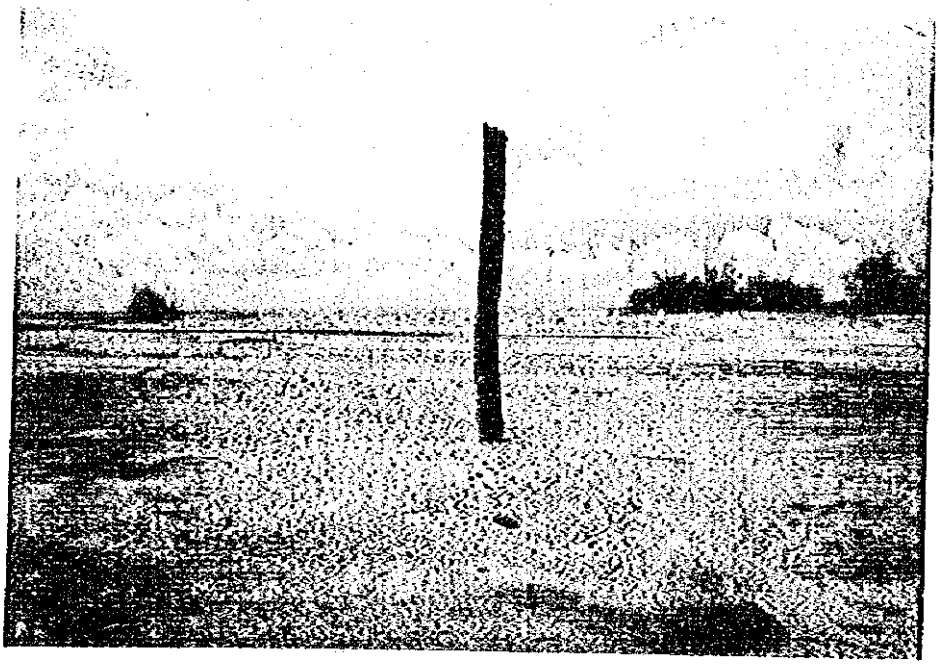
Station LB-2 near the Angeles-Porac road (refer to Figure F.33)
Established on July 6, 1995
Height : 2.0 m

Surveyed on July 26
Almost buried by 1.8 m thick during the July 7 to 11 lahar event

Photograph F.1 (3/5) Sediment Deposition Observed at Monitoring Station

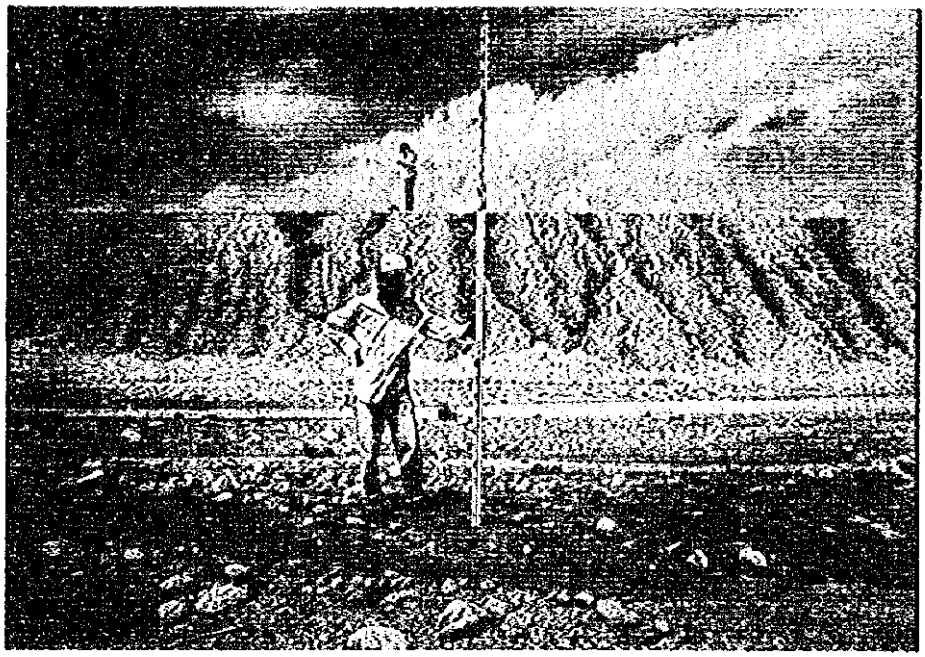


New station LB-2 beside the previous station
Established on August 1
Height : 2.0 m



Surveyed on August 22
Almost buried by 1.5 m thick during the August 15 to 19 lahar event

Photograph F.1 (4/5) Sediment Deposition Observed at Monitoring Station



Station LB-21A just upstream of the Maliwalu-Bulu dike (refer to Figure F.33)
Surveyed on July 10, 1995
Dike height : 3.4 m

Surveyed on July 31
Completely buried during the July 28 to 30 lahar event

Photograph F.1 (5/5) Sediment Deposition Observed at Monitoring Station

APPENDIX G

LAHAR ANALYSIS

APPENDIX G

LAHAR ANALYSIS

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G.1 Introduction

1.1 BACKGROUND

The 1991 eruption of Mt. Pinatubo produced remarkable amount of pyroclastic materials and ashfall deposits. PHIVOLCS estimated that some 5-7 billion m^3 of pyroclastic material deposited on and around the slopes of Mt. Pinatubo. On the eastern slopes of Mt. Pinatubo, three river systems including the Sacobia-Bamban river, the Abacan river and the Pasig river drain toward the Pampanga delta areas. The Study Team estimated that some 1.4 billion m^3 of pyroclastic materials deposited on the eastern slopes. These materials have been delivered toward lowlying areas in the form of lahars generated by heavy rainfall as well as secondary explosions which were usually triggered by rainfall. The Study Team estimated that some 48% of pyroclastic deposits has been already delivered since 1991 eruption.

At present five rainy seasons after the eruption, considerable numbers of inhabitants and areas still face to serious risks of lahars in some river basins while in other river basins major problems are shifting to secondary movement of sediment deposits in valleys and river channels which would gradually decrease flood carrying capacity of river channels in middle and lower reaches of the river systems. The lahar activities might cease rapidly in a few years but the secondary movement of sediment due to river runoff would last much more longer period.

The Study Area originally covers the Sacobia-Bamban river basin and the Abacan river basin draining the eastern slopes of Mount Pinatubo, and it was extended to the Pasig river basin in the 1995 study period. During the 1994 rainy seasons, a few times of lahar events were observed in the Sacobia river basin and lobes of mudflow reached only to the upper parts of the sand pocket area developing in the right side overbank of the Bamban river while a small scale lahar was observed only once during the 1995 rainy season. Because of small amount of erosible pyroclastic materials remaining in the upper reaches of the basin, it is expected that the number of lahar events would be rapidly reduced in 1996 afterwards. On the other hand, there are a few hundred million cubic meters of sediment deposits in the valleys and river channels of the Sacobia and Bamban rivers. Thus the major concern of the sediment in the Sacobia-Bamban river would be secondary erosion of sediment remaining in the valleys and river channels.

In the Abacan river basin, any lahars have not been observed since 1992 and major future problems would be lateral erosion of river channels in upper reaches and siltation in the lower reaches.

In the Pasig river located on the south of the Abacan river basin, however, lahar events were still active in 1995. Tremendous amount of pyroclastic materials were delivered toward lowlying areas and caused serious damages to human lives and properties in the affected areas. The situation would still continue in 1996 rainy season. Careful monitoring and appropriate assessment of risks are needed in the Pasig river basin.

1.2 OBJECTIVES OF THE STUDY

The objectives of the Study are:

1) to understand and clarify the characteristics of the sediment movement in the affected area by the 1991 eruption,
2) to forecast the future movement of the sediment in the affected area as well as the lowlying areas and to assess potential flood and sediment hazard areas
3) to evaluate the effect of countermeasures (or structural intervention) proposed in this master plan and feasibility study.

1.3 STUDY CONTENTS

As discussed in the previous section, lahar events have been drastically reduced in the Sacobia and Abacan river basins and the major problems in these areas at present and in future would be secondary erosion of sediment materials deposited in valleys, river channels and the sand pocket area developing right overbank of the Bamban river and their transport toward lower areas.

Thus, in the Sacobia and Abacan river basins, heavy rainfall and/or secondary explosion may generate lahars in the coming few years but the risk of occurrence and magnitude of lahar events would be much smaller than those observed in 1994 and 1995. Thus, the major status of sediment movement to be considered in the planning of this study was sediment transport by normal flow.

The study contains followings three analyses

(1) Sediment Transport Capacity
(2) Long Term Forecast of River Bed Movement
(3) Two-dimensional Flood Inundation Analysis

Sediment Transport Capacity Analysis simply estimated annual sediment carrying capacity at some selected locations of the Sacobia, Bamban and Abacan rivers based on runoff hydrographs generated from daily rainfall record. The results was applied to the sediment balance study in planning purpose.

Long Term Forecast of River Bed Movement assessed temporal changes of longitudinal profiles of river channels for 10 years and more under the present condition of the river as well as the condition with river diversion works of the Sacobia river to the Bamban river. The results show the propagation process of erosion and aggradation of a river channel and were basis of design of the river training and diversion works and planning of maintenance works of the river channel.

A two-dimensional Flood Inundation Analysis clarified the areas to be affected by a large scale flood runoff when it inundates overbank areas along the river channels. The study shows potential flood inundation areas and depth and duration of flow and sediment for some selected scales of probable flood hydrographs generated by Hydrological Analysis. The results were utilized as essential materials for preparing flood and mud water hazard maps in damage analysis.

In the Pasig river basin, however, several lahar events occurred in 1995 and caused a large scale topographic changes. The affected area extended toward left-hand side in the middle reaches and lowlying areas downstream of GSO(Gapan-San Fernando-Olongapo) highway.

In this Study, a two-dimensional analysis was carried out to simulate the topographic changes of the middle reaches of the Pasig river between the out let of the hilly area near Delta 5 watching point and GSO highway in 1995. A potential flood inundation areas was evaluated on the basis of the two dimensional analysis.

G.2 Lahar Observation and Future Prospect

2.1 LAHAR CHARACTERISTICS

Lahar characteristics including flow status, sediment concentration, properties of particles are described in Appendix F "Sediment Balance", and Appendix L "Lahar Material Survey".

Topographic changes due to the 1991 eruption, succeeding secondary explosions and lahar events, and quantitative estimates of sediment deposits are described in Appendix C "Geomorphology", Appendix F "Sediment Balance and Monitoring", and Appendix R "GIS Analysis".

The study team did not have any chances to observe actual large scale lahars in the Sacobia river in 1994 and 1995. According to PHIVOLCS-USGS, (Ref.2, Progress Report 1994), characteristics of lahars in the Sacobia River for the period of 1991 to 1993 were summarized as follows:

Lahar discharge

* Surface flow velocities at Mactan (upper end of Clerk AB): 2-15 m/s
* Surface flow velocities at Maskup (lower end of Clerk AB): 1-5 m/s
* Travel time from Mactan to Maskup (8 km): 20-70 min (avg. velocity of Flow front and peak = 1.9 to 6.7 m/s, with large debris flows traveling fastest)
* Peak discharge at Mactan: 10-2,000 m3/s (possibly as high as 5,000 m3/s in 1991)
* Peak discharge at Maskup: 1-400 m3/s measured, possibly reaching as high as 1,000 m3/s in large flows
* Attenuation Flows from Mactan to Maskup: small to moderate size are attenuated by 60-90%; large flows are attenuated by 30-50%

Sediment

* Sediment contents: 40-70 % by volume, highest in large debris flows
* Wet sample bulk density: 1.5 - 2.1, highest in large debris flows
* Temperatures of hot lahars: typically 50-85 °C; highest recorded, 98 °C
* Both erosion and deposition occur at Mactan and at Maskup, with net deposition at both locations. During single flows, there can be several meters of erosion or deposition, or even alternation of several meters each of erosion or deposition.
* Strong lateral erosion by hyperconcentrated flows.

They classified lahars into the following two types depending on rheology of flow:

1) Debris flows typically had peak discharges of several hundreds to a thousand m^3/s, and contained about 60-65% (rarely, 70%) sediment by volume
2) Hyperconcentrated flows typically had peak discharges of several tens to several hundreds m^3/s and contained about 50% sediment by volume. Hyperconcentrated flows are numerically more common, but the large debris flows carry a large part of the sediment that is deposited to downstream.

One special type of lahar, that from lake breakouts, bears only an indirect relation to the amount of rainfall. Most lake breakouts to date have occurred during heavy rain, when occurred.

On the basis of sediment deposits data given in "GIS analysis" and annual rainfall at Clerk Air Base, chronological changes of average concentration of sediment delivered from the pyroclastic deposit field were roughly calculated as follows, in which annual runoff coefficient was assumed at 0.65.

$$\text{Annual Average Concentration} = \frac{\text{annual sediment deposit}}{(\text{annual sediment deposit}+\text{annual runoff})}$$

River	Area	Sediment Deposit (million m^3)					Average Concentration (%)				
	(km^2)	1991	1992	1993	1994	1995	1991	1992	1993	1994	1995
Sacobia	40 (18)	150	80	65	8	4	72	61	50	23	12
Abacan	33	50					51				
Pasig	25 (45)	50	40	55	130	45	58	55	58	66	38
Annual rainfall (mm)							2,250	2,000	2,00	2,300	2,400

( ): Drainage area after the piracy in Oct.1993

It is obviously shown that the average concentration in 1994 was rapidly decreased in the Sacobia river and it was in the order of sediment transport by normal flow in 1995 while it is still high in the Pasig river.

Sediment transport process by normal flow (muddy water) is an usual phenomena observed in any river channel. When sediment materials exist enough to meet the sediment load capacity of a river channel, the concentration of 20 % might be possible in sleep channels in upper reaches of the Sacobia river. In the middle and lower reaches of the Sacobia and Bamban river where slopes are less than 1 %, sediment concentration is usually less than 5 %. Observations of sediment and flood water are insufficient in the study area, continuos observations are indispensable for any planning purposes.

2.2 FUTURE PROSPECT

The sediment production in the mountain slopes are analyzed and evaluated in Appendix F "Sediment Balance and Monitoring".

Based on the analysis of normalized sediment yields, the Sediment Balance study proposed a regression curve for the headwaters of the Sacobia river after reduction of drainage area due to capture of summit areas by the Pasig river. The study forecasted that the erosion in the pyroclastic field of the Sacobia basin would be gradually decreased and would reach to constant condition in 1998 and afterwards. The constant annual erosion rate was estimated at 50 mm/year for the area covered by pyroclastic materials. The table below shows the annual sediment yield in the Sacobia river.

Monitored and Forecasted Annual Sediment Yield in Sacobia River (million m^3)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Volume	150.0	80.0	65.0	8.0	4.1	1.8	0.9	0.4	0.4	0.4

Since the sediment yield from the upper reaches of the Sacobia river will be decreased and stabilized to a normal level in a few years, the sediment deposits in the Sacobia valley between Mactan and Maskup which is about 80 million m^3 in total as of end 1994 will be the major supply sources. Although some mathematical analyses were carried out in this study to estimate sediment movement in the valley, it is very difficult to predict how much amount of the deposits will be eventually eroded from the valley because of easy lateral cutting in a wide sediment filled valley. Continuos monitoring and observation of floods and sediment movement in the valley would be essential for planning any control measures in downstream areas.

G.3 Sediment Transport capacity

3.1 INTRODUCTION

Sediment transport capacity at a selected point of the river system is estimated for the sediment balance study and planning of control measures. Annual sediment transport volume is calculated based on hourly runoff rate generated by rainfall record of a selected year.

3.2 METHODOLOGY

(1) Models

The status of sediment transport mechanism is defined as individual sediment transport by normal stream flow.
The sediment transport volume is calculated by Brown's equation which is an experimental formula and gives total sediment load including suspended and bed loads. Total sediment load per unit width q_B is given as follows:

$$q_B = 10 \cdot (sgd^3)^{1/2} \cdot \tau_*^{2.5}$$

where:

- g : acceleration due to gravity = 9.8 m/s^2
- s : $(\sigma/\rho - 1)$
- d : grain size of sediment
- τ_* : shear stress $= u_*^2/(sgd)$
- u_* : shear velocity $= (ghi)^{1/2}$
- σ : density of sediment grain
- ρ : density of water
- i : hydraulic gradient
- h : flow depth

Flow depth (h) is given by Manning's equation assuming uniform flow in a rectangular cross section of channel:

$$v = 1/n \cdot i^{1/2} \cdot h^{2/3}$$

where:

- v : flow velocity = Q/(bh)
- n : Manning's roughness coefficient
- Q : flow rate
- b : width of a rectangular cross section

(2) Parameters

A sieve analysis of lahar materials in the study area was carried out in this study in 1994 and the results are summarized in Appendix L. According to the analysis, the sediment materials have relatively uniform grain size ranging 0.2 to 2 mm. On the basis of the analysis, grain size of 0.7 mm was adopted as a medium size in the Sacobia-Bamban river and 1.0 mm in the middle and lower reaches of the Abacan river. Specific gravity of sediment materials was obtained to be 2.6 g/cm^3 while density of water was assumed to be 1.0 g/cm^3.