Alternatives among Cases 1, 2 and 3 require maintenance dredging work of almost 1.5 million m^3 per year, while Case 4 requires that of 1.0 million m^3 per year, since thick erodible sand has accumulated in the river channels of the Bamban River and the Sacobia River. Even if sediment control structures are planned in the upper reaches of the Sacobia River to firmly consolidate the riverbed, the diluted floodwater could cause erosion in the lower reaches of both rivers in proportion to the sediment transport rate. The channel excavation of 1.0 to 1.5 million m^3 could be assumed to continue until the year of 2004.

The forecasted sediment volumes still have some uncertainty and error because of insufficient basic information on sediment transport mechanism, therefore continuous monitoring to clarify the sediment movement is essential for appropriately constructing the proposed structural measures.

6.1.9 LONG TERM RIVERBED CHANGES IN SACOBIA RIVER CHANNEL

(1) Model and Boundary Conditions

In the Sacobia model, the upstream end of the Sacobia river was set at Mactan gate located northwest of the Clerk Air Base. Although the drainage basin of Mactan gate site is 18 km^2 and the remaining basin of the Sacobia valley between Mactan and Maskup is 20 km^2, runoff from the drainage area of 38 km^2 was input into the entrance of the river channel at Mactan for simplicity of calculation.

Erosible depth of each section was set at the original river bed elevation of pre-eruption and sediment supply from the upstream entrance was given by sediment transport capacity at the section.

Since the model does not consider any lateral erosion rate, downcutting of the river channel would be overestimated than the actual condition if channel width is given as 100-150 m of normal channel condition. The cross section of the Sacobia valley forms double channels of a narrow low channel of 100-150 m wide and an inner terrace of some 400-600 m wide and 5-10 m deep. Then the cross section was assumed to be rectangular with the width of the terrace.

The downstream end was fixed at the present elevation of Maskup Gorge assuming consolidation works will be provided at the site.

(2) Riverbed Movement for 10 years

Figure 6.14 shows the riverbed profiles of 4 cases, 1994, one year, 5 year and 10 year afterward. This calculation does not consider the lahars from the basins upstream of Mactan. The simulation shows that riverbed erosion will first occur in the highest section and propagate downstream. Then the sections in the upper half reaches will be eroded to the original riverbed in 10 years. The annual sediment volume to be delivered from Maskup, the lowest outlet of the valley, is almost constant for 10 years since the slope of the 1994 condition is almost uniform along the valley and the lower portion will not be affected by the changes of the upstream sections in 10 years.

Since the model did not consider tributary flows and lateral erosions, it seems to be too simple to represent the actual conditions, then the results can be considered only as reference. In the study of sediment transport capacity, it was estimated that the annual rate was about 2.1 million m^3 at Maskup site, the actual sediment transport rate at the site would be between 1.2 and 2.1 million m^3.

6.1.10 LONG TERM RIVERBED CHANGES IN BAMBAN RIVER CHANNEL

(1) Model and Boundary Conditions

The Bamban River collects water from two river systems of the Marimla river (drainage area of 65 km^2) and the Sapang Cauayang river (21 km^2). In the model, the upstream end of the Bamban River was set at 3 km upstream of the previous Bamban Bridge site and it would receive runoff from the drainage area of 86 km^2 while flow from the remaining basin of 12 km^2 along the river channel was not considered in the model.

For calculation of river bed movement, the initial elevation of each cross section was set at the March 1994 condition and the river bed was allowed to be eroded or aggradated by river flow. Since the upstream end of the calculation was set at No.40, about 3 km upstream of the Bamban bridge site where the river bed was El.85.0 m and not affected by the eruption, any erosion was not allowed at the upstream end.

In consideration of normal vegetation coverage of the Marimla and Sapang Cauayang river basins, 1 mm/year of an average erosion rate or 86,000 m^3/year in volume was considered as an allowable sediment production rate from the upstream basins.

The water level at the downstream end was set at El.11.0 m which was average water table of the Rio Chico river in the rainy season.

(2) Riverbed Movement for 10 years

Figure 6.15 shows the longitudinal profile of the riverbed in 1994, in one year, 5 years and 10 years afterward. In the figure, Section No.181 is the downstream end, No.40 is the upstream end and San Francisco Bridge is located approximately at No. 100. The down cutting of the riverbed is obvious by 5 to 10 meters in upstream 5-6 km stretches and is lowered to the original riverbed in pre-eruption condition within 8-10 years.

On the contrary, riverbed would be elevated by some 2.5 meters in 10 years from 1994 near the San Francisco bridge. The speed of aggradation would be high in a few years and gradually slowing down afterward. The downstream reaches would be little affected by sediment transport and the effect would appear in longer time.

According to this simulation, it might be said that the riverbed movement of the Bamban/Parua river would be serious within the next 10 years and then gradually stabilized to the original riverbed elevation in pre-eruption condition. The maximum aggradation in long term period would be some 3 meters in middle reaches and 1 meter in the lower reaches.

Under the most critical condition of climate, however, 1 meter of aggradation within 1 year would be possible in middle and lower reaches according to the simulation based on 1972 rainfall condition which was the largest rainfall of 4,670 mm during 30 years of record period at Dagupan.

According to the observation in 1995, the riverbed movement at the Bamban bridge site was estimated at about 1 meter during 1994-1995 period, while the freeboard of the San Francisco bridge was 0.67 m on an average at the middle of October 1995 although the river channel was excavated about 500 m long, 100 m wide and 2 m deep before onset of the 1995 rainy season and it was obvious that the reaches near the San Francisco bridge was in a stage of river bed aggradation. The results of the simulation give generally good estimates.

6.1.11 EFFECT OF SACOBIA RIVER DIVERSION

(1) Model and Boundary Conditions

The Sacobia River is now flowing down on the flood plain developing in the right bank of the Bamban River below Maskup. In the Master Plan, the Sacobia River is planned to be diverted to the Bamban river by constructing a diversion channel from Maskup to Malonzo about 5 km upstream of the San Francisco bridge.

A consolidation dam is planned to be placed at the entrance of the diversion channel to stabilize the riverbed elevation at Maskup where is the outlet of the Sacobia valley and the river forms a narrow gorge. The crest elevation of the consolidation dam would be set at El.111.0 m. A diversion channel would be excavated from Maskup to Malonzo. The diversion channel would be a 5.5 km long artificial straight channel with a 1/180 of constant slope having a 150 m wide and 2.5 to 6 m deep single trapezoid section. The river bed of the channel is protected by a series of groundsill with a 500 m interval in the upper half reaches.

The sediment supply from the Sacobia valley was assumed to be 1.8 million m^3 per year in 1999 and afterwards (0.4 million m^3 from upper Sacobia and 1.4 million m^3 from the spindle shaped valley between Mactan and Maskup). In this study two alternative cases were examined ; 1) the sediment supply of 1.8 million m^3 is constant for 10 years, and 2) the sediment supply is gradually decreased from 1.8 million m^3 to 0.4 million m^3 for 10 years from 1999.

On the other hand, two alternative conditions of river training works were also examined for the Bamban river channel ; a) with no dredging work in the Bamban River, and b) with dredging works of 0.5 m deep in a 6 km long stretch downstream of the San Francisco bridge every year. In both cases, it is assumed that the river training works of the Bamban river channel is completed in 1999 and the riverbed profile is the same as that in 1994.

(2) Riverbed Movement for 10 years

(Case 1-a) Constant sediment supply and no dredging

In the case that no dredging works is carried out in the Bamban river after the Sacobia river is diverted to the Bamban river , the river bed of the Bamban river would be locally aggradated by another 1 meter at maximum in the lower reaches compared with the case of no diversion work but the effect is not generally significant. Figure 6.16 shows the river bed profile of the Bamban river with the Sacobia diversion and without dredging in the Bamban river channel. Figure 6.17 shows the river bed profile of the diversion channel for the same case. Some 2 m high sediment deposit would be expected in the upper half reaches of the diversion channel if sediment supply would be as high as 180 million m^3 throughout the 10 year period.

(Case 1-b) Constant sediment supply and with dredging

In the case that dredging works would be carried out in the Bamban river channel, the aggradation of the river bed in the Bamban river would be maintained to be some 1.5 meters on an average in the middle and lower reaches of the Bamban river as shown in Figure 6.18. Since the river bed at the confluence of the diversion channel and the Bamban river is affected little by the dredging works, the river bed profile of the diversion channel is almost the same as that of (Case 1-a) as shown in Figure 6.19.

(Case 2-a) Declining sediment supply and no dredging

If the sediment supply is declining year by year from 1.8 to 0.4 million m3 from 1999, the river bed aggradation is 2 meters less than Case 1-a in the middle reaches and 1 meter in the lower reaches as shown in Figure 6.20. Consequently, the lower river bed condition at the confluence of the diversion channel and the Bamban river would affect the river bed profile of the diversion channel. Downcutting of the diversion channel is expected in its lower stretch as shown in Figure 6.21. Groundsill should be extended to the lower stretch in 10 years.

(Case 2-b) Declining sediment supply and with dredging

Figure 6.22 shows the riverbed profile of the Bamban River in the case that dredging works would be carried out in the Bamban river channel under the condition of declining sediment supply rate. The aggradation of the riverbed in the Bamban River would be almost the same as that in (Case 1-b). Downcutting of the diversion channel would be a little deeper than that of (Case 2-a) as shown in Figure 6.23. Extension of groundsill would be needed in the lower stretch.

6.2 ABACAN RIVER BASIN

6.2.1 SEDIMENT DELIVERY SYSTEM

At the piracy point of Abacan and Sacobia rivers in 1992, so called as "Abacan Gap", a small escarpment had caused a degradation of 15 to 20 m which had eventually added to the Sacobia River catchment. The Abacan Gap formed an escarpment of 40 to 50 m in December 1993. No lahar flow was observed along the Abacan River since the degradation of Sacobia River at Abacan Gap in 1992.

In the early 1994, a small volume of pyroclastic flow deposit in 1991 remains in the upstream reach of the Abacan River which is regarded as the sediment source to the downstream reach of the basin in the future. The riverbed in the vicinity of the Capaya Bridge of North Super Highway, forms the intersection point between riverbed degradation in the upstream reach and riverbed aggradation in the downstream. The downstream reach of the Abacan River meanders in the flood plain.

6.2.2 SEDIMENT DELIVERY RATE

(1) Abacan Gap

The first major lahar in the Abacan River occurred on 15 June 1991, mainly rolling tephra-fall deposits along the Sapangbato River. Lahars in the 1991 monsoon season, more than 40 in all, destroyed or damaged all of the bridges across the Abacan River upstream of Mexico, including the Capaya Bridge across North Luzon Expressway, and caused bank collapse that has destroyed hundreds of houses in Angeles City. A piracy between the Abacan and Sacobia rivers used to occur at the Abacan Gap, which is located at the uppermost reaches of the Sapangbato River.

A secondary explosion took place in the afternoon of April 4, 1992. The secondary pyroclastic flow remained steaming hot for several days after deposition and warm for several months afterwards. After this event the riverbed of Sacobia River had been lowered in the vicinity of the Abacan Gap, and no lahar was observed in the Sapangbato and Abacan rivers since 1992. In 1994, the river channel of the Sacobia River forms deep elongated scarpment with a height difference of 50 to 60 m between the channel bed elevation of Sacobia River and the uppermost riverbed of Abacan River at Abacan Gap.

(2) Sediment Source

Only a small volume of pyroclastic flow deposit remains for the reach from the site of Sabo dam No.1 to No.3 in the upper catchment of the Sapangbato River, meanwhile the ashfall deposits are stored by sabo dams in the Taug (Sapangbayo) River.

The sediment source in the next decade might be organized into four categories, namely, (i) lahar deposits in the upper portion of the Sapangbato River, (ii) lahar and ashfall deposits filling in the river channels, (iii) the deposits arrested by the sabo dams, and (iv) soil erosion over the basin. The volume of unstable sediment as sediment source in the upstream area from the Friendship Bridge is estimated at 2.2 million m^3 for in-channel deposition and 1.5 million m^3 for arresting by sabo dams.

Although around 40% of total unstable sediment is stored in sabo dams, four dams partially or completely collapsed due to deterioration of the materials and local scouring at the front of their aprons during rainy season in 1994. Those collapses of the existing sabo dams caused some effects to their lower reaches. In fact, heavy lateral erosion and sediment deposition occurred in the lower reach of the Taug River due to the collapse of sabo dam TL-1 on July 27, 1994. Therefore, the restoration work for existing sabo dams is required to carry out continuously.

(3) Sediment Delivery System

Longitudinal profile and riverbed width in the upper reaches from the No. 9 sabo dam are shown in Figure 6.24. Along the Sapangbato River a series of narrow pass and wide riverbed are formed along the Sapangbato River. The river channel stores the sediment during large-scale floods and release the stored sediment gradually downstream during small to moderate scale flood. For the period of the lahar events in 1991 and early 1992, the river channel also functioned to store some part of the lahar flow. The riverbed elevation of the Sapangbato River, therefore, is higher than that in pre-eruption. While in the Taug (Sapangbayo) River, the flash floods which contained a mass of ashfall rushed to the downstream reach, then lower reach of the Taug River was heavily scoured by 1 to 2 in deep.

In the middle reach of the Abacan River, the riverbed gradient becomes gentle gradually down to the point between San Jose Malino and San Juan which is located at 9 to 10 km upstream from the confluence of the San Fernando River. The riverbed slope is changed from 1/250 to 1/730 where the Abacan River flows into the alluvial plain of the Pampanga Delta. Flood water level of the Abacan River is affected by backwater from the San Fernando River. Therefore, the lower reach of the Abacan River in the stretch of 9 to 11 km upstream from the confluence with the San Fernando River has a tendency of sediment accumulation.

Before the 1972 flood which was the most devastating flood recorded in the Central Luzon area, there was no high dike system from Capaya Bridge to San Juan, and floodwater was dispersed to low-lying areas in the middle reach resulting in the heavy siltation did not occur in the lower reach of Pampanga Delta. After the 1972 flood, a high dike system had been constructed to protect the surrounding areas from the floods, and the system was completed after 1991 and 1992 lahar events.

The sediment volume of 3.5 million m^3 remains in the river channel of 10 km long from San Jose Malino to the confluence with San Fernando River. The riverbed aggradation will continue in the next decade in this reach.

The continuous excavation/dredging work, therefore, is necessary to mitigate flood damage and improve the drainage system in the low-lying areas.

6.2.3 SEDIMENT YIELD

Although sediment yield caused by surface erosion is mainly depending on rainfall amount and intensity, land use, slope steepness and soil erodibility, annual sediment yield is estimated using the annual erosion rate referring to the experimental results in Japan as a preliminary estimate. According to the results, the annual erosion rate of bare land ranges from 10 to 1 mm per year, meanwhile the rate of firm land ranges from 1 to 0.1 mm per year. The following estimate is calculated using maximum value of the annual erosion rate.

The sediment source volume and annual sediment yield in the area upstream of Friendship Bridge are estimated as follows :

a) Volume of unstable sand

In-channel deposition	:	2.2 million m^3
Sabo dam	:	1.5 million m^3

b) Sediment yield

Surface and lateral erosion in lahar deposition	:	4,000 m^3/year (=10mm/year x 0.4 km^2)
Sheet and gully/rill erosion over the basin	:	33,000 m^3/year (= 1mm/year x 32.9 km^2)

According to the sediment balance among the annual sediment transportation volume, the remaining unstable sediment volume and annual sediment yield, the following assumptions were made in the Abacan River system :

- Although the unstable sand in the storage of sabo dam would be stable by the restoration works, those of in-channel deposition in the upstream reach will be transported downstream for several years.
- The predominanto riverbed materials will be organized into gravels and boulders in accompanying with sorting of the riverbed materials.
- As a result, the riverbed of upper reach from No. 9 sabo dam would be stable, then flood water will convey fine sand of about 40,000 m^3 per annum (4,000 m^3/year and 33,000 m^3/year) which is mainly produced by surface erosion in upper catchment.
- In accordance with reduction of sediment transport from the headwaters, the riverbed of middle reach will degrade gradually and forms the low water channel within the box-shaped channel which is presently formed along the Abacan River.

6.2.4 SEDIMENT TRANSPORT CAPACITY

Sediment load was calculated by Brown's equation at Friendship bridge and San Jose Malino in the Abacan river.

Table 6.3 shows the sediment load and concentration for selected flow rates between 10 m^3/s and 1,000 m^3/s and they are summarized that the sediment concentration was estimated at 0.2-1.7 % at Friendship bridge in the Abacan river.

6.2.5 ANNUAL SEDIMENT LOAD

Annual sediment load was calculated at the same locations as those selected above. Since no runoff record was available in the study area, runoff discharge was generated from daily rainfall record as the same manner of Sacobia-Bamban River.

Table 6.4 shows the annual sediment transport capacity at the selected locations for the average rainfall year. Sediment deposit volume was estimated assuming 40 % of porosity. The results show that the annual sediment deposits delivered from Maskup is 3.3 million m^3 which is well coincide with the 3-4 million m^3 sediment delivery from the Sacobia valley in normal flow condition in 1994 which was estimated by the study team based on the field survey. The annual sediment transport based on Clark Air Base in 1993 is almost the same as that based on Dagupan in 1989.

6.2.6 FUTURE RIVERBED MOVEMENT

A long term sediment movement in river channels was calculated in this section for evaluating changes in river bed elevation as time passes which would affect flood flowing capacity of the river channels. The annual changes were evaluated for 10 years based on topographic data obtained in March 1994 as initial conditions. The study was applied to the Abacan River channels from Friendship bridge to the confluence of San Fernando River at Mexico.

(1) Model and Boundary Conditions

In the Abacan model, the upstream end of the model was set at Friendship bridge and the downstream end was set at the confluence of San Fernando river. The total length of the river channel was 25 km. The drainage area upstream of the Friendship bridge was 33 km^2 and the following three tributaries join along the main channel in the model.

	Location	Distance	Drainage Area
Friendship bridge	(Upstream end)	25 km	33 km^2
Capaya bridge	(Tributary-1)	19 km	49 km^2
Culubasa	(Tributary-2)	15 km	62 km^2
San Jose Malino	(Tributary-3)	10 km	77 km^2
Confluence		0 km	77 km^2

The downstream end was located in lowlying area where was usually inundated during rainy season and the constant water table of EL.5 m was assumed. Runoff pattern in the basin is different from the Sacobia-Bamban river because major sub basins are located lower slopes of the alluvial fans and therefore flood runoff duration was assumed 15 hours.

Sediment field in the upstream reaches was estimated at 40,000 m^3 per annum and 1 meter deep of sediment deposit in the channel was assumed as allowable erosion depth.

(2) Riverbed Movement for 10 years

Figure 6.25 shows the river bed profiles of 4 cases, 1994, one year, 5 year and 10 year afterward under the 1989 rainfall condition.

Because of a concave sharp of river bed profile of the Abacan river, sediment transport capacity of the channel gradually decreases from upstream to downstream and sediment deposit is expected in the lower 10 km reaches. Desilting in the lower reaches would be needed.

Table 6.1 Sediment Transportation Capacity

LOCATION	Catch-ment area (km2)	Hydraulic gradient	Width (m)	Discharge (m3/s)	Depth (m)	Sediment transport (m3/s)	Concent-ration
(1) Sacobia							
1) Maskup	38	0.0100	100	10	0.11	0.07	0.69%
				50	0.29	0.77	1.54%
				100	0.44	2.18	2.18%
				500	1.14	24.41	4.88%
				1000	1.73	69.05	6.91%
2) Sand Pocket	61	0.0048	100	10	0.14	0.02	0.19%
				50	0.36	0.21	0.42%
				100	0.54	0.60	0.60%
				500	1.43	6.66	1.33%
				1000	2.16	18.85	1.88%
(2) Bamban							
1) Malonzo	93	0.0038	200	10	0.10	0.01	0.09%
				50	0.25	0.10	0.21%
				100	0.38	0.29	0.29%
				500	1.00	3.24	0.65%
				1000	1.52	9.17	0.92%
2)San Francisco Bridge	94	0.0027	200	10	0.11	0.00	0.05%
				50	0.28	0.06	0.11%
				100	0.43	0.16	0.16%
				500	1.12	1.75	0.35%
				1000	1.69	4.95	0.49%
3)Confluence	98	0.0015	200	10	0.13	0.00	0.02%
				50	0.33	0.02	0.04%
				100	0.50	0.06	0.06%
				500	1.32	0.65	0.13%
				1000	2.00	1.85	0.18%

* Depth : Uniform Flow (Manning's Formula)
: n=0.025
* Sediment : Brown's Formula
* Diamenter of sediment : 0.7 mm in Sacobia-Bamban river
: 1.0 mm in Abacan river
Density=2.60

Table 6.2 Annual Sediment Transportation Volume

LOCATION	Catch-ment area (km2)	Hydraulic gradient	Rainfall Station	Annual Runoff (million m3)	Annual Trans. Cap. (million m3)	Concen-tration	Annual deposit (million m3)
(1) Sacobia							
1) Maskup	38	0.0111 (1/90)	Dagupan Clark A.B.	59.9 59.6	2.0 2.1	3.4% 3.5%	3.4 3.5
2) Sand Pocket	61	0.0048 (1/210)	Dagupan Clark A.B.	96.1 95.7	0.9 1.0	1.0% 1.0%	1.6 1.6
(2) Bamban							
1) Malonzo	93	0.0038 (1/260)	Dagupan Clark A.B.	146.6 146.0	0.9 0.9	0.6% 0.6%	1.4 1.6
2) Sanfrancisco Bridge	94	0.0027 (1/370)	Dagupan Clark A.B.	148.1 147.5	0.5 0.5	0.3% 0.4%	0.8 0.9
3) Confluence	98	0.0015 (1/650)	Dagupan Clark A.B.	154.4 153.7	0.2 0.2	0.1% 0.2%	0.3 0.4

* Depth	: Uniform Flow (Manning's Formula)
	: n=0.025
* Sediment	: Brown's Formula
* Diamenter of sediment	: 0.7 mm in Sacobia-Bamban river
	: 1.0 mm in Abacan river Density=2.60
*Discharge	: Average Year =1989

Table 6.3 Sediment Transportation Capacity

LOCATION	Catch-ment area (km2)	Hydraulic gradient	Width (m)	Discharge (m3/s)	Depth (m)	Sediment transport (m3/s)	Concent-ration
Abacan							
1)Friendship Bridge	33	0.0067	200	10	0.08	0.02	0.17%
				50	0.21	0.19	0.38%
				100	0.32	0.53	0.53%
				500	0.85	5.94	1.19%
				1000	1.29	16.81	1.68%
2)San Jose Malino	77	0.0040	150	10	0.11	0.01	0.08%
				50	0.30	0.09	0.18%
				100	0.45	0.25	0.25%
				500	1.18	2.81	0.56%
				1000	1.79	7.94	0.79%

* Depth : Uniform Flow (Manning's Formula)
: n=0.025
* Sediment : Brown's Formula
* Diamenter of sediment : 0.7 mm in Sacobia-Bamban river
: 1.0 mm in Abacan river
Density=2.60

Table 6.4 Annual Sediment Transportation Volume

LOCATION	Catch-ment area (km2)	Hydraulic gradient	Rainfall	Annual runoff (million m3)	Annual Trans Cap (million m3)	Concen-tration	Annual deposit (million m3)
Abacan							
1) Friendship Bridge	33	0.0067 (1/150)	Dagupan Clark AB	51.2 48.0	0.3 0.3	0.6% 0.6%	0.6 0.5
2) San Jose Malino	77	0.0040 (1/250)	Dagupan Clark AB	119.6 112.2	0.6 0.5	0.5% 0.5%	0.9 0.9

* Depth : Uniform Flow (Manning's Formula)
: n=0.025
* Sediment : Brown's Formula
* Diamenter of sediment : 0.7 mm in Sacobia-Bamban river
: 1.0 mm in Abacan river
Density=2.60
*Discharge : Average Year =1989

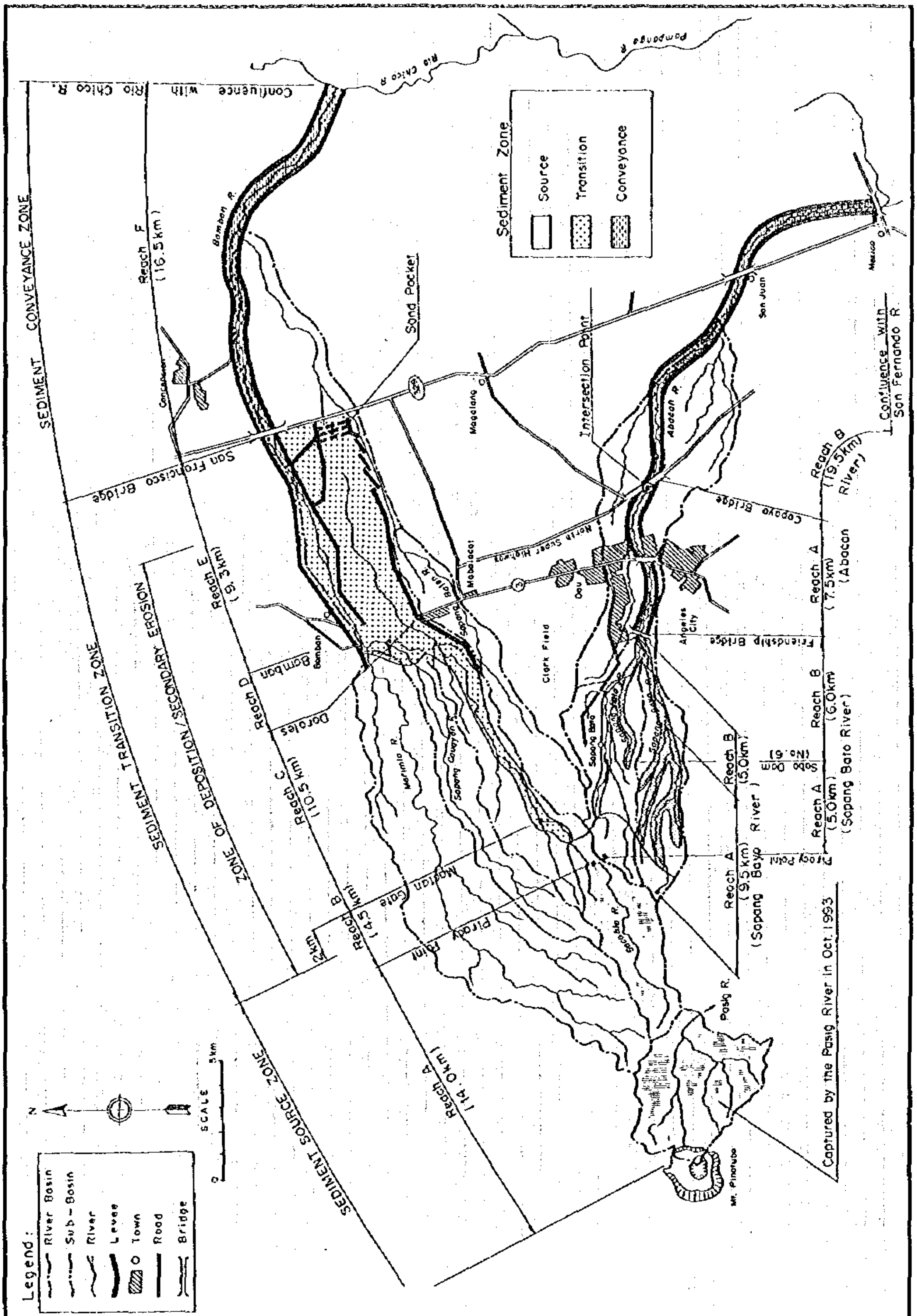

Figure 6.1 Sediment Delivery Zone in the Study Area

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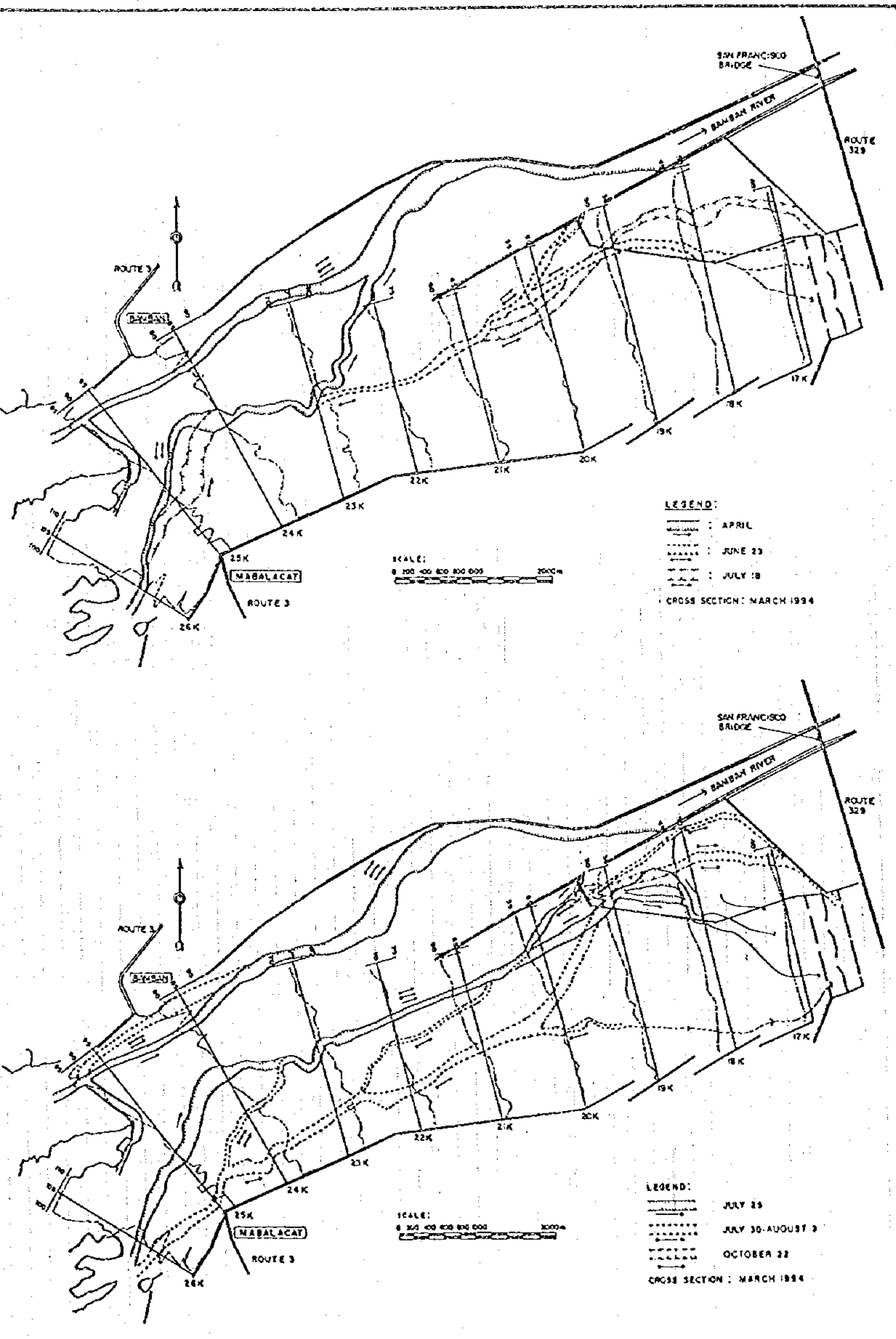

Figure 6.2

Chronological Changes of Sacobia-Bamban River Course in 1994

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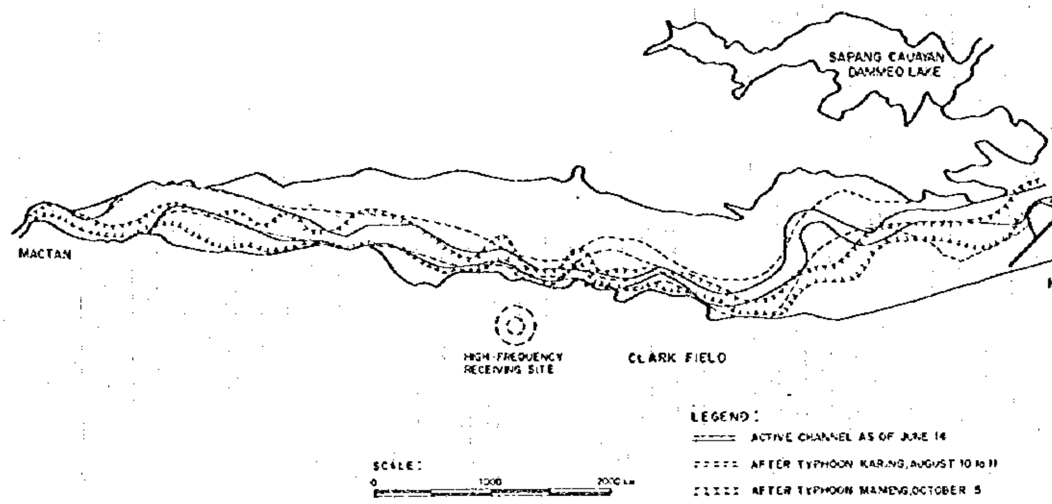
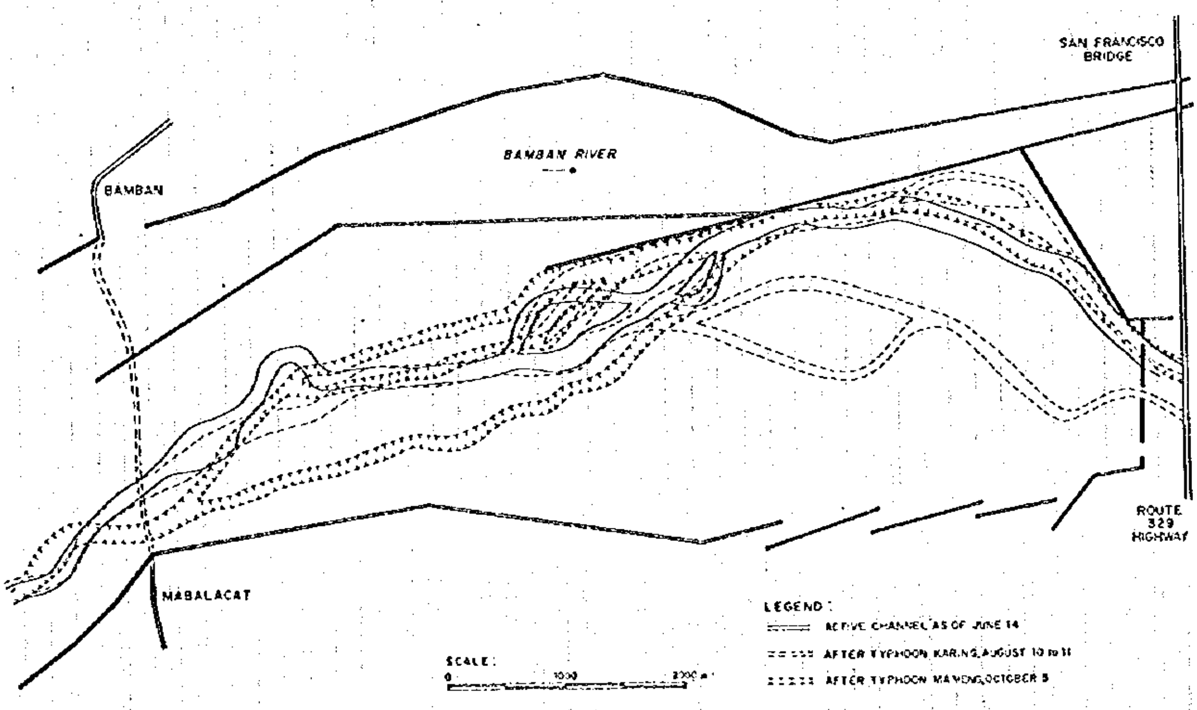


Mactan-Maskup



Mabalacat-Route 329

Figure 6.3

Chronological Changes of Sacobia River Course in 1995

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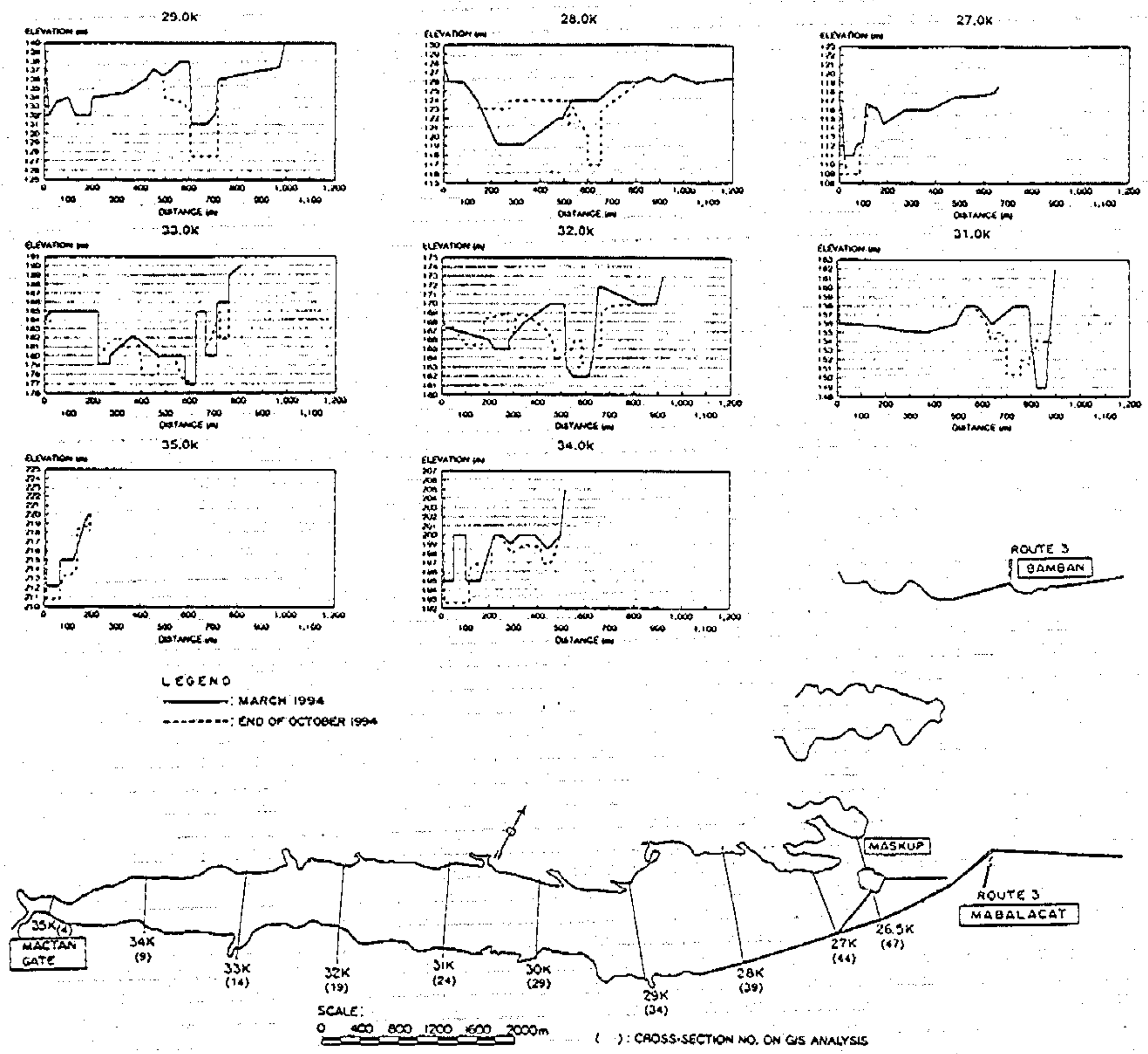

ESTIMATE OF CHANNEL EROSION

Cross Section	Distance (m)	Eroded Area (m^2)	Eroded Sediment Volume (10^3m^3)
26.5k		101	
27.0k	500	170	45
28.0k	1,000	-410	-120
29.0k	1,000	930	260
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	435
35.0k	1,000	200	465
Total	8,500		3,050

(As of Nov. 1, 1994)

Figure 6.4 Cross-Sectional Changes and Estimated Channel Erosion from Mactan to Maskup in 1994

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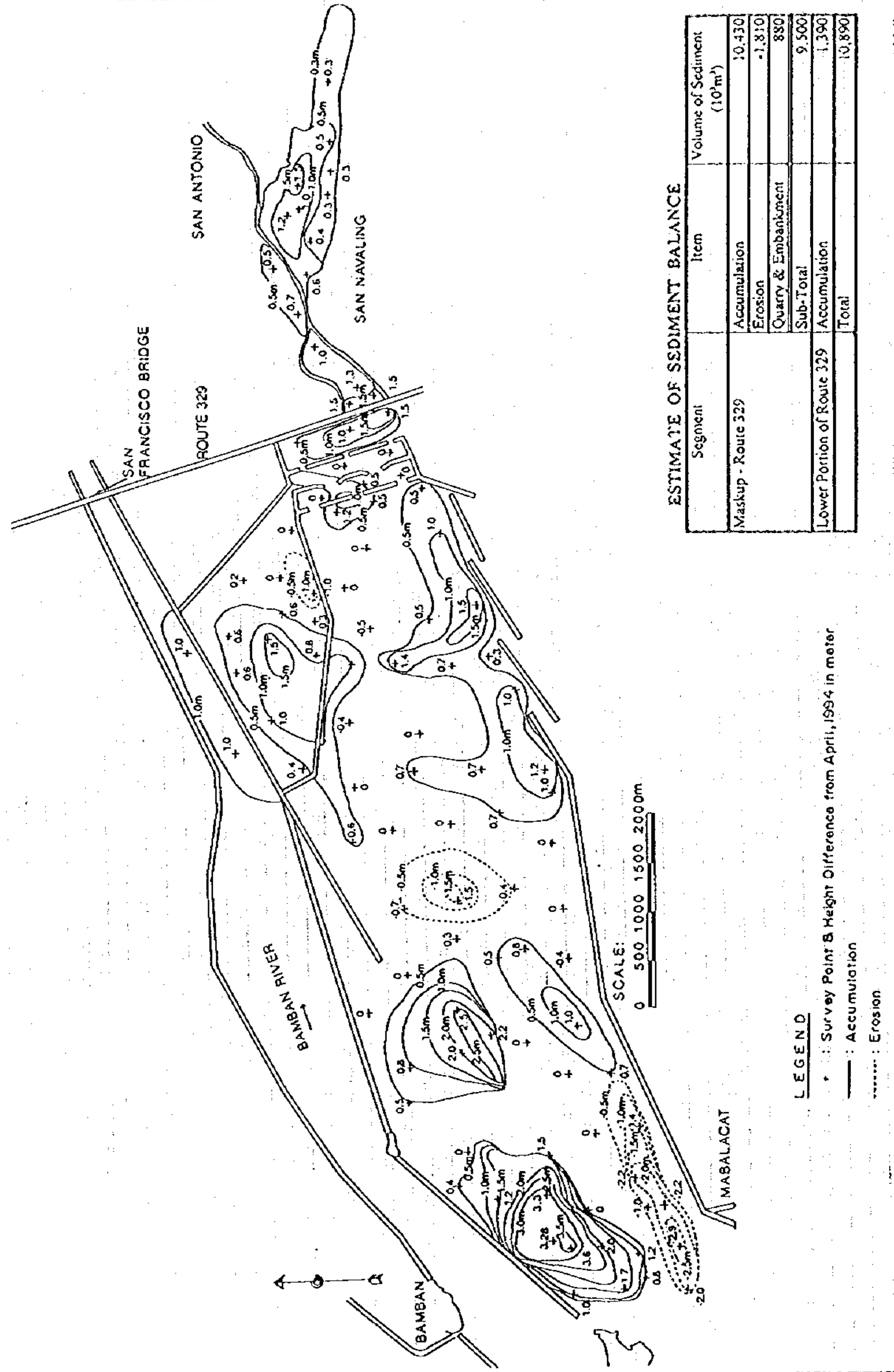

ESTIMATE OF SSDIMENT BALANCE

Segment	Item	Volume of Sediment (10^3m^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 6.5 Isopach Map of Sediment Deposition/Erosion in Lower Sacobia in 1994

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
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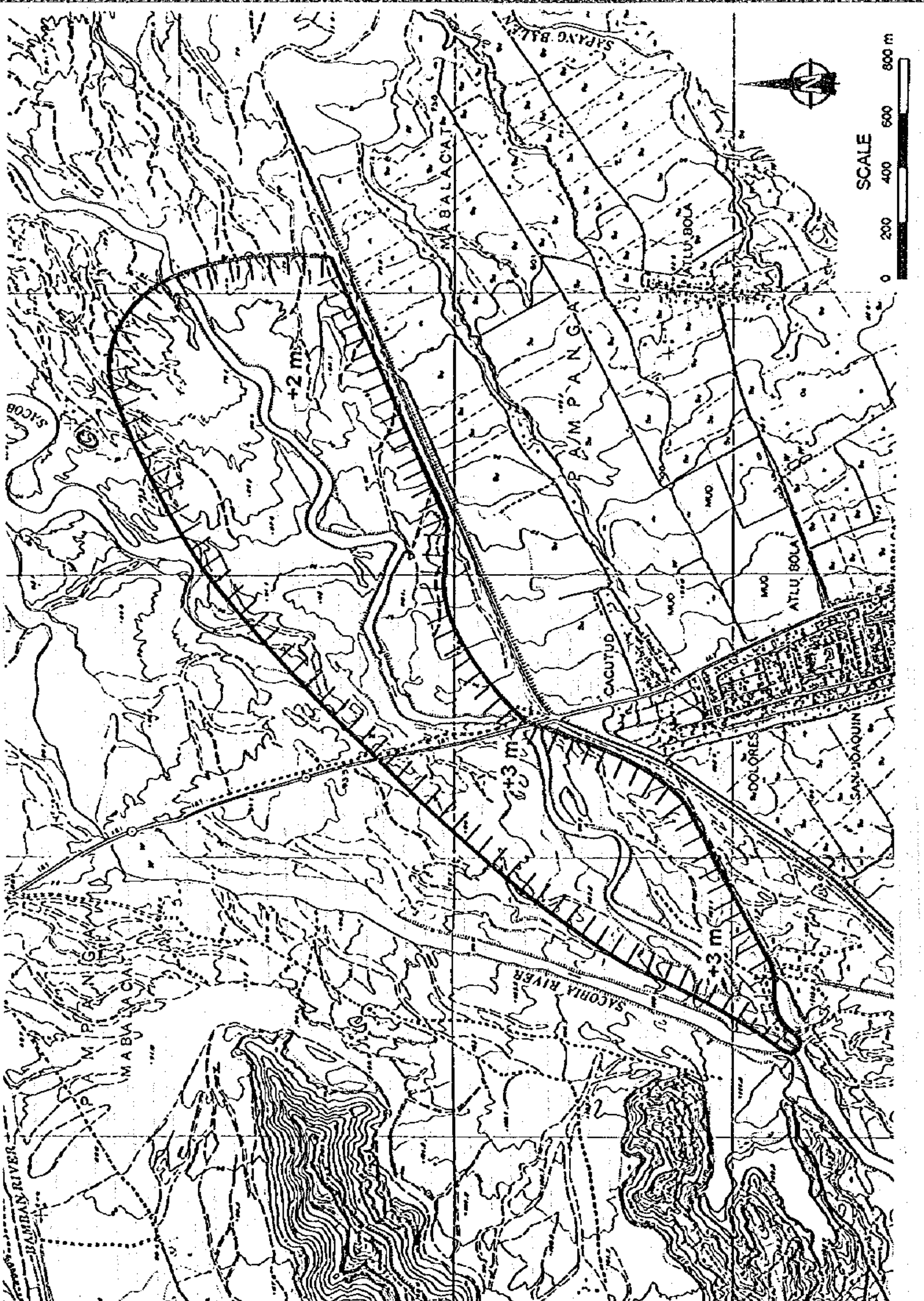

Figure 6.6

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
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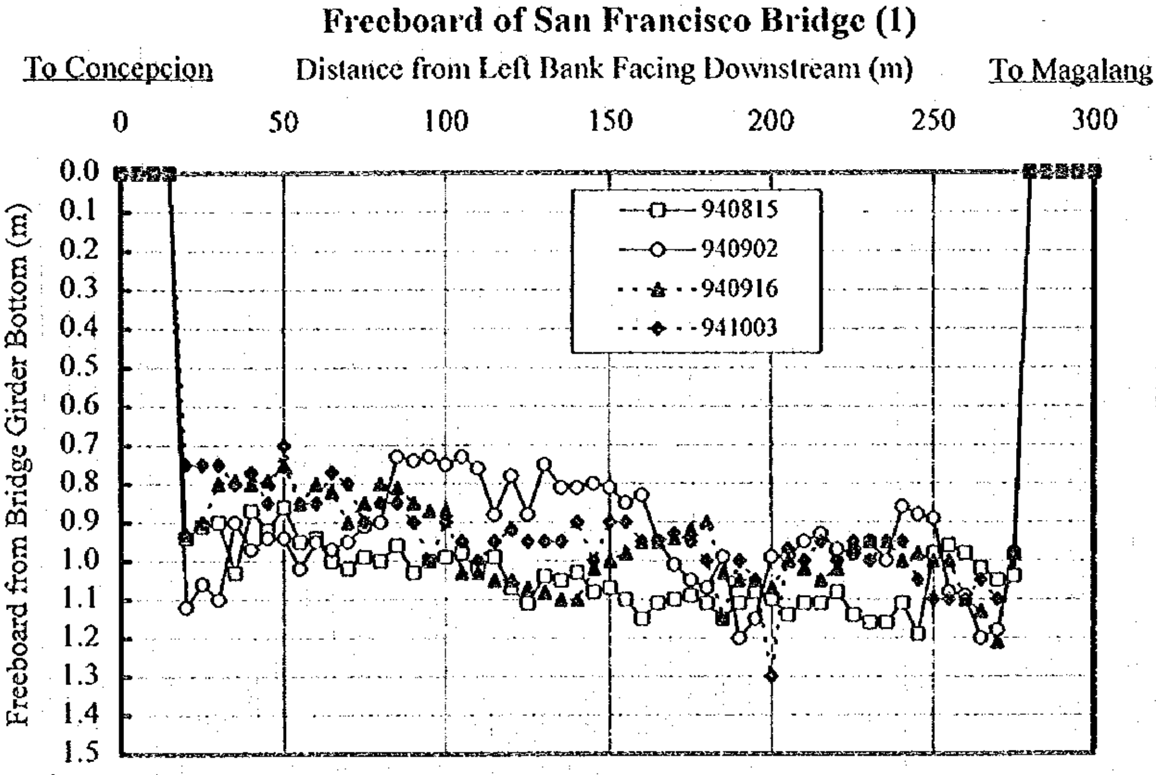

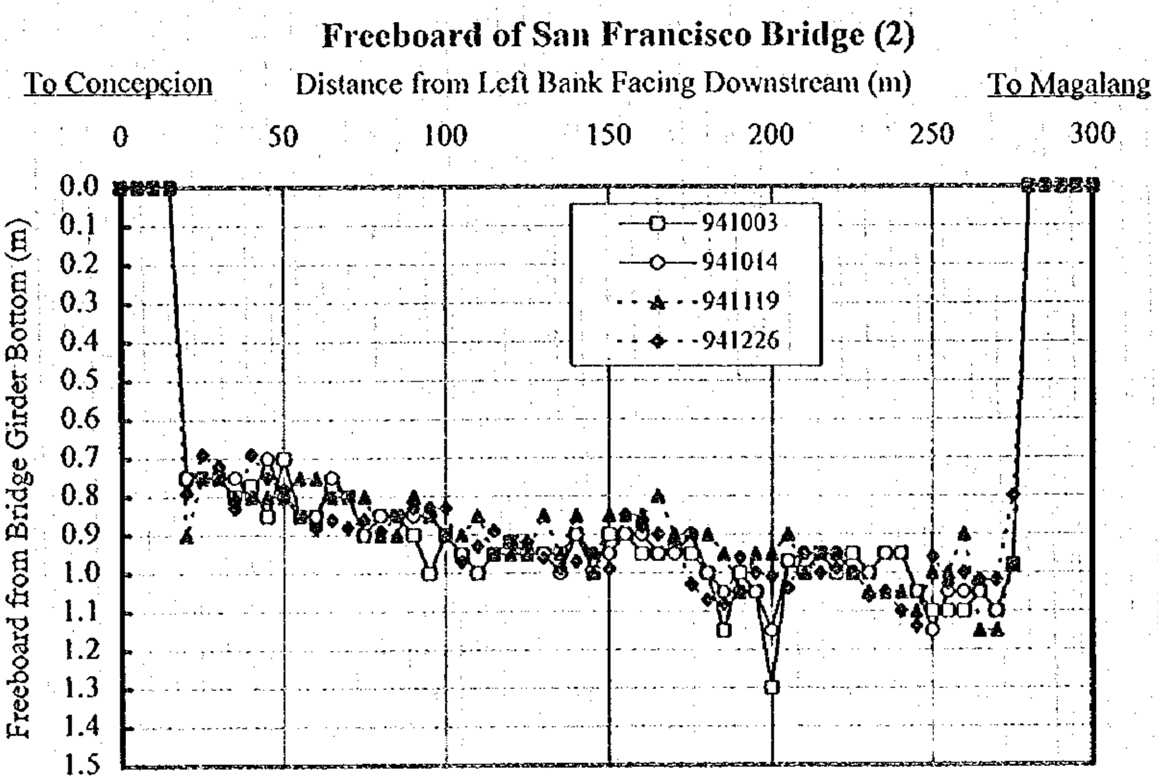

Figure 6.7

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

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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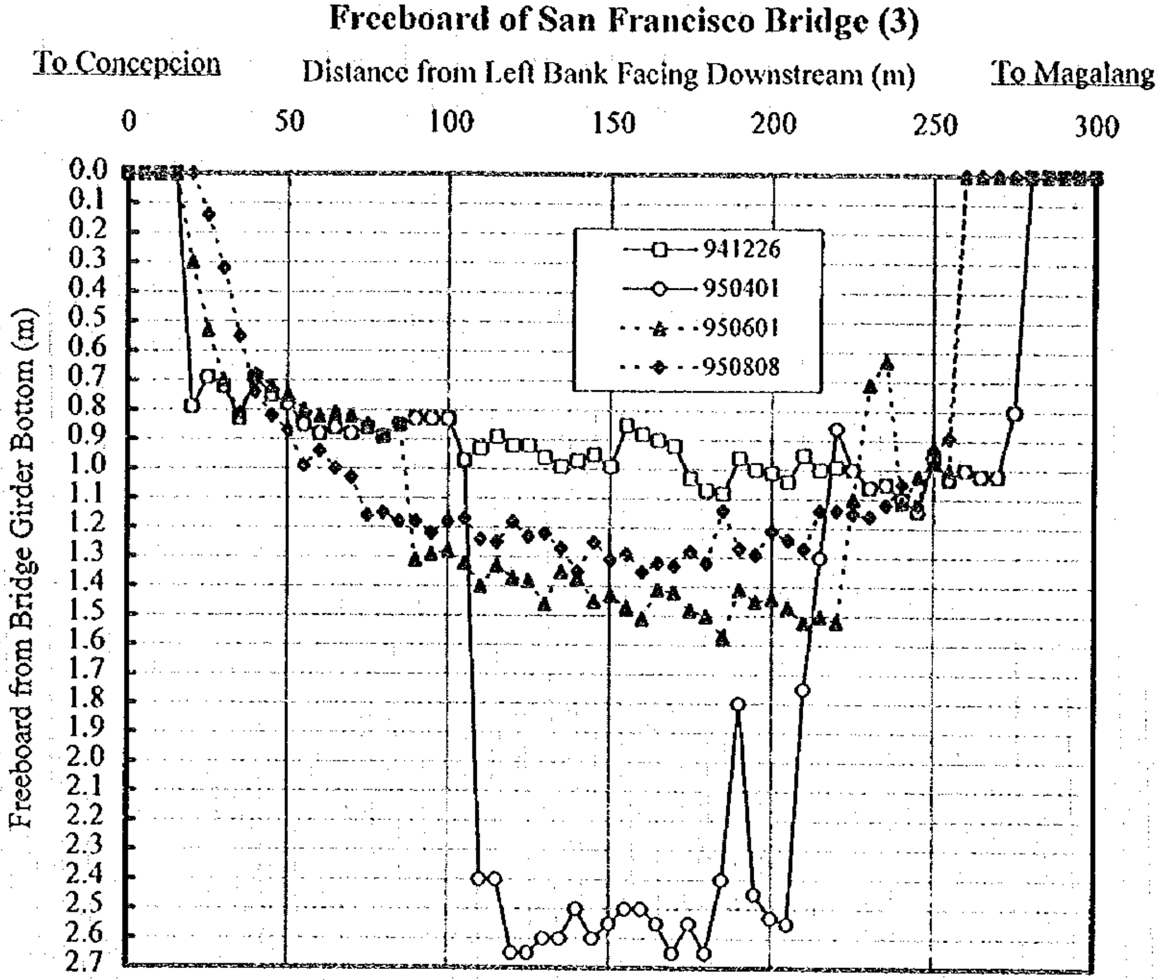


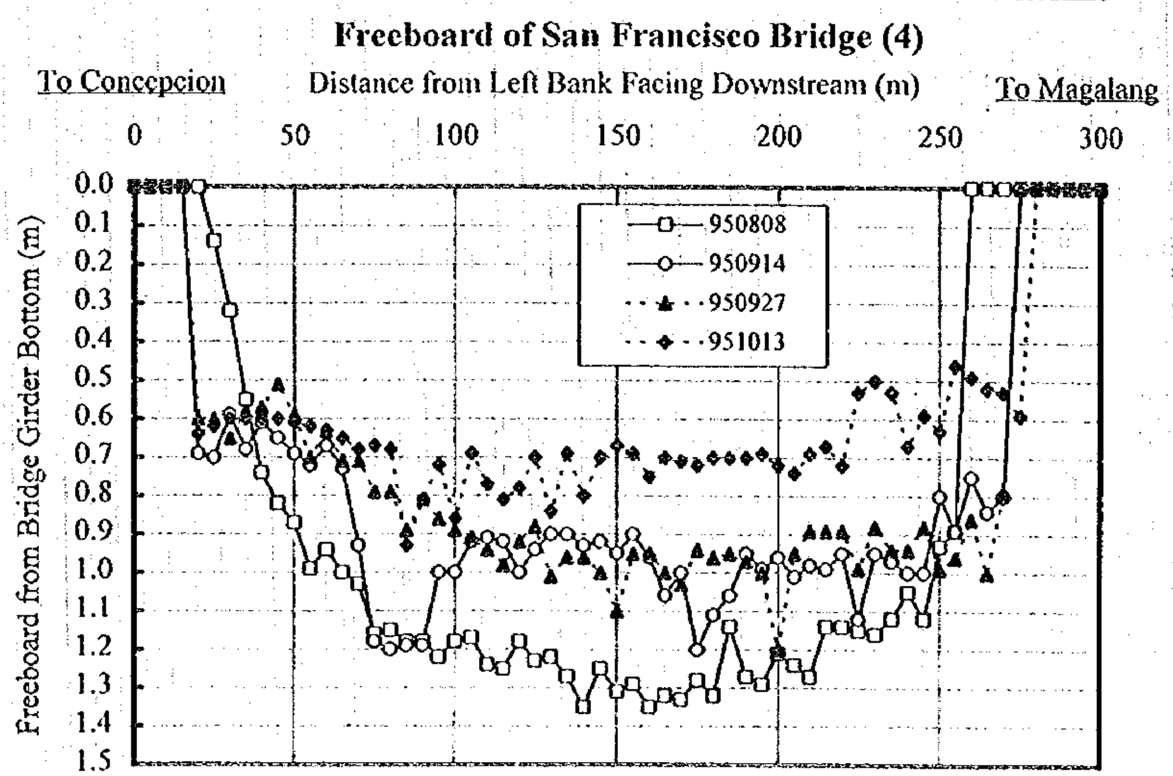
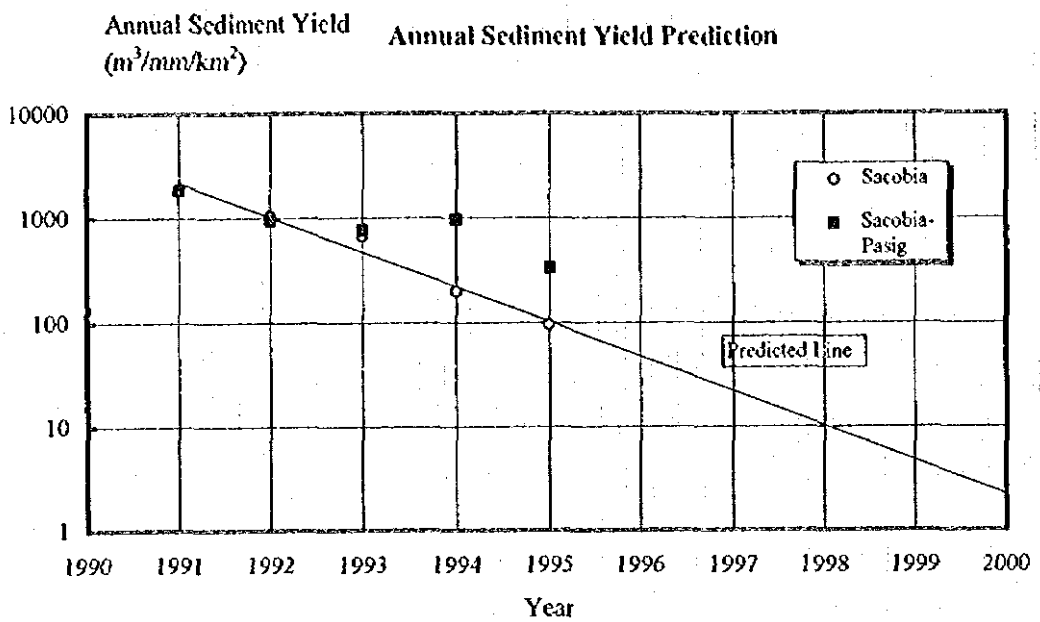


Figure 6.7

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

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 (10^6 m^3)			Volume of Lahar Deposits (10^6 m^3)				Annual Rainfall	Catchment Area of Headwaters (km^2)			Normalized Sediment Yields ($m^3/mm/km^2$)		
	Sacobia-Abacan	Pasig	Total	Sacobia	Abacan	Pasig	Total	(mm)	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 ($10^6 m^3$)	Accumulated Volume ($10^6 m^3$)
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 6.8
Prediction of Annual Sediment Yield from EPPFF

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
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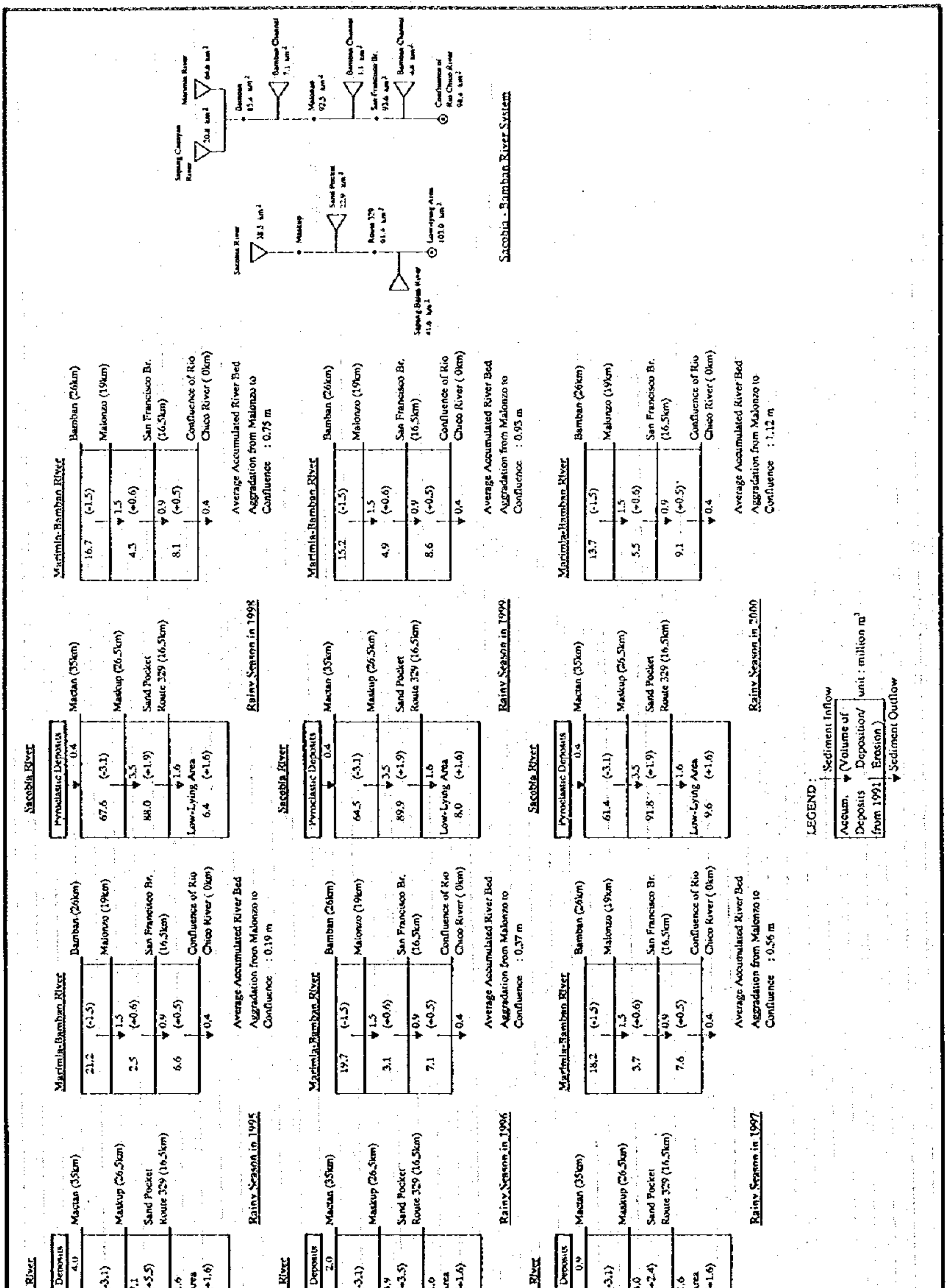

Figure 6.9

Sediment Balance Prediction under Present Conditions, 1995-2000

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
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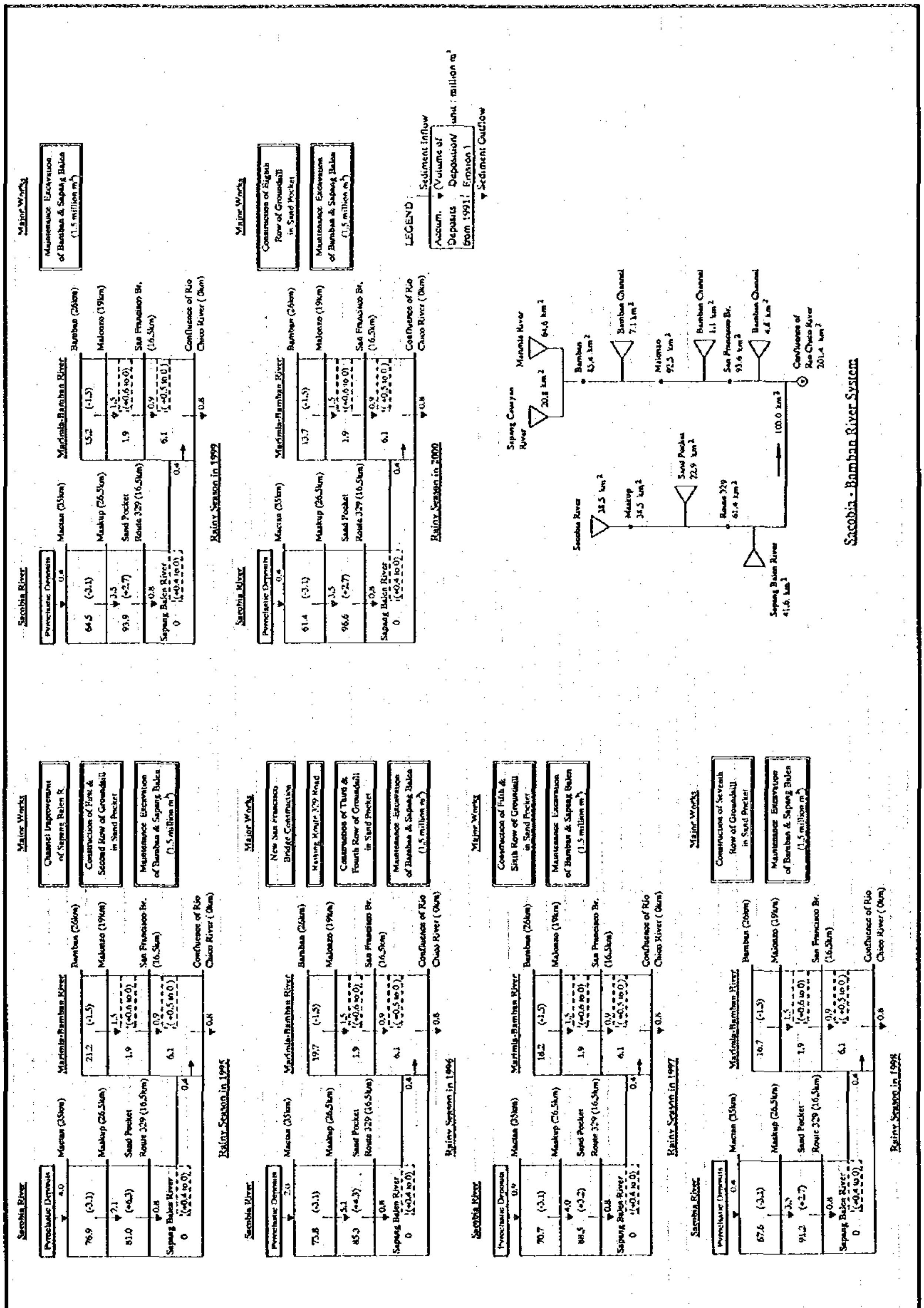

Figure 6.10

Sediment Balance Prediction on Permanent Use of Sand Pocket Alternative, 1995-2000

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

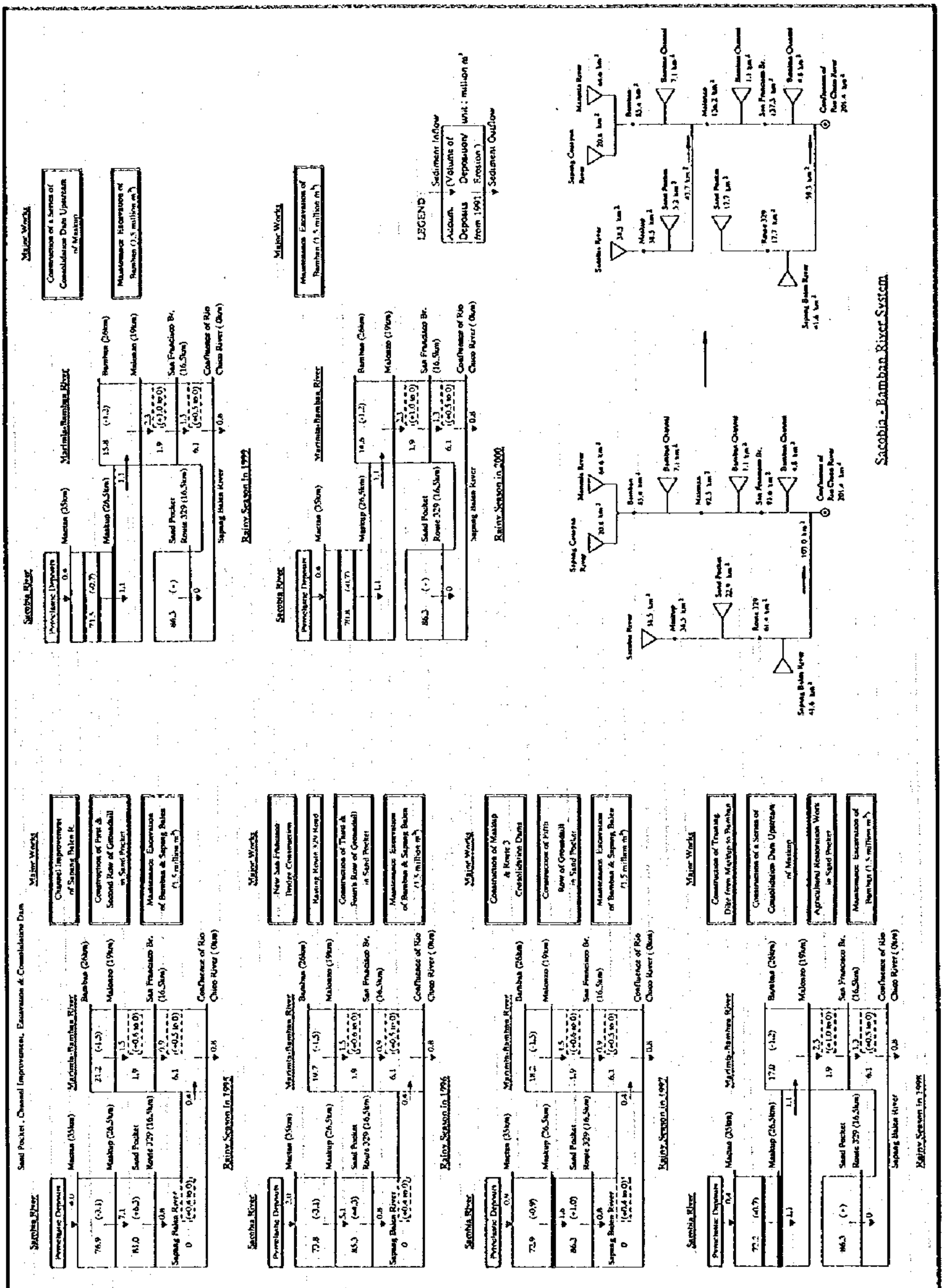

Figure 6.11

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
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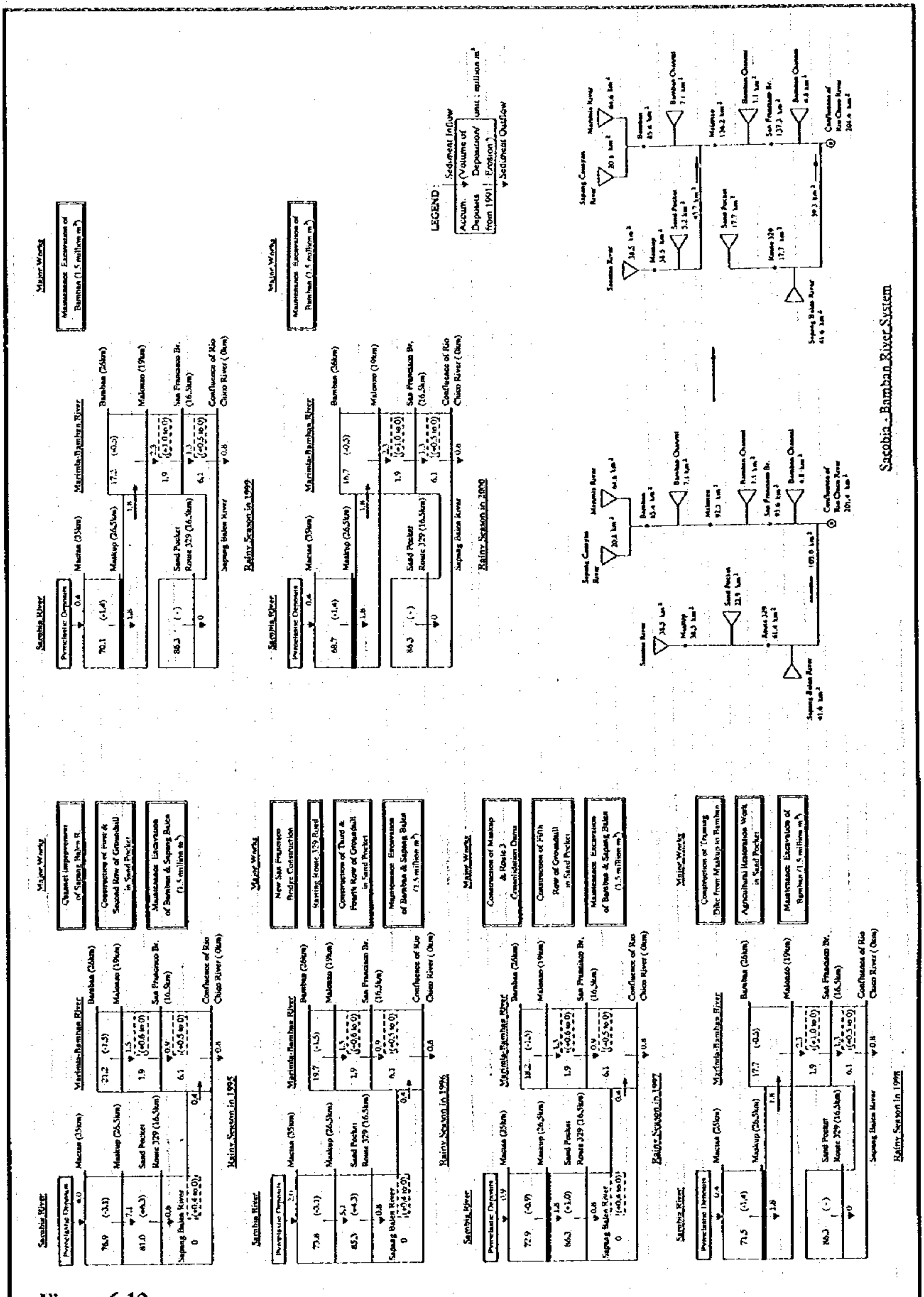

Figure 6.12

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
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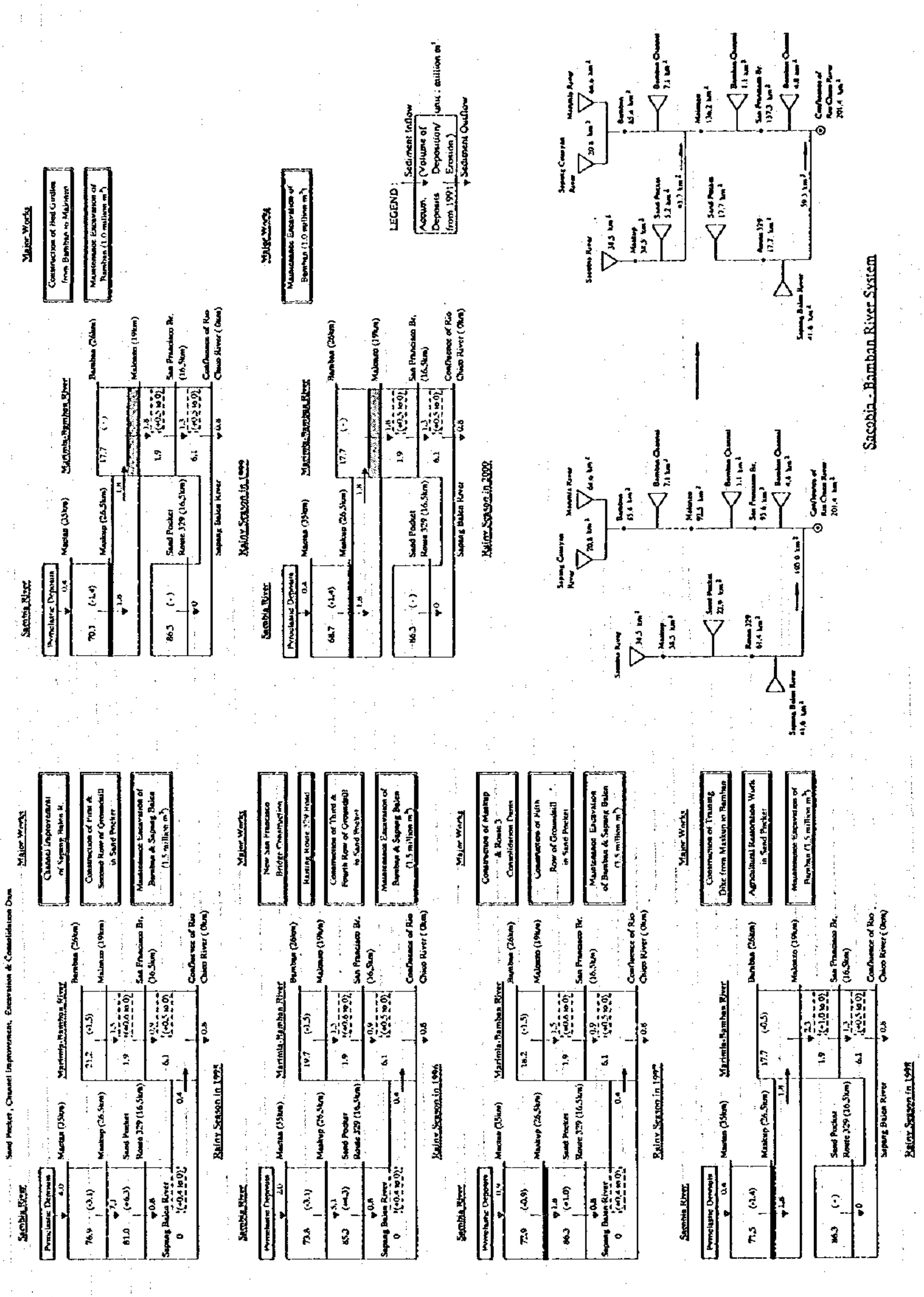

Figure 6.13

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

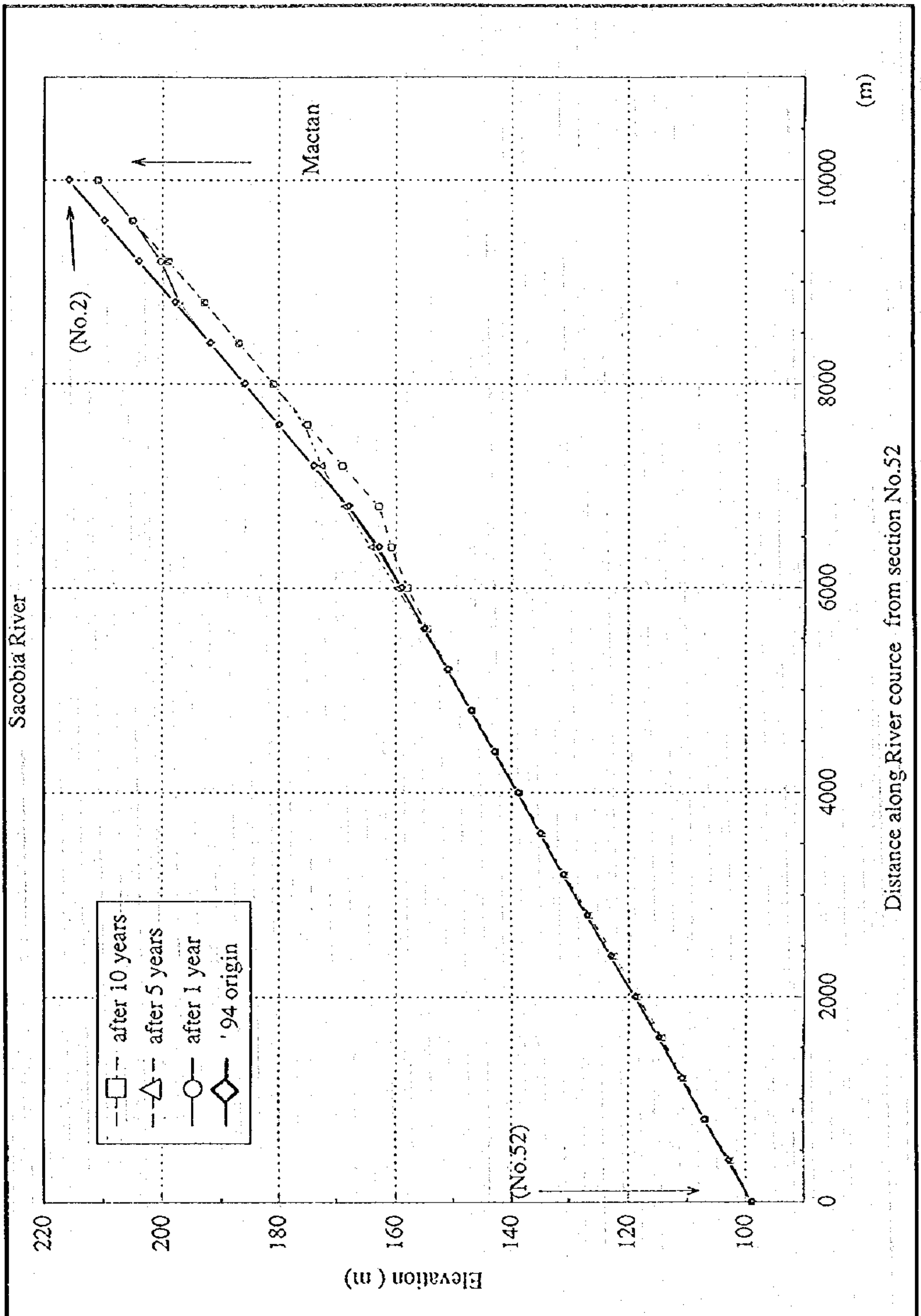

Figure 6.14

River Bed Profile of Sacobia 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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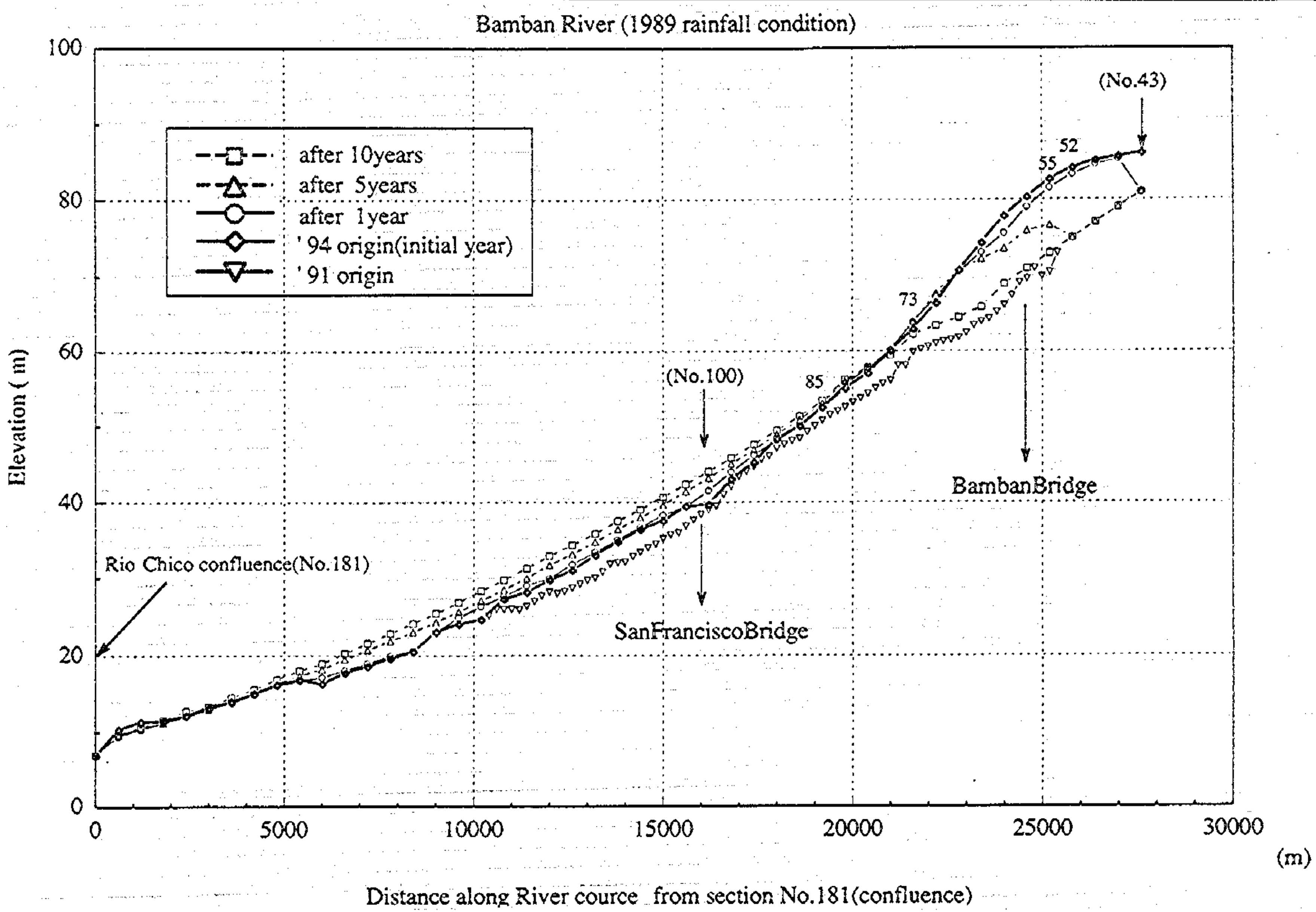

Figure 6.15
River Bed Profile of Bamban River

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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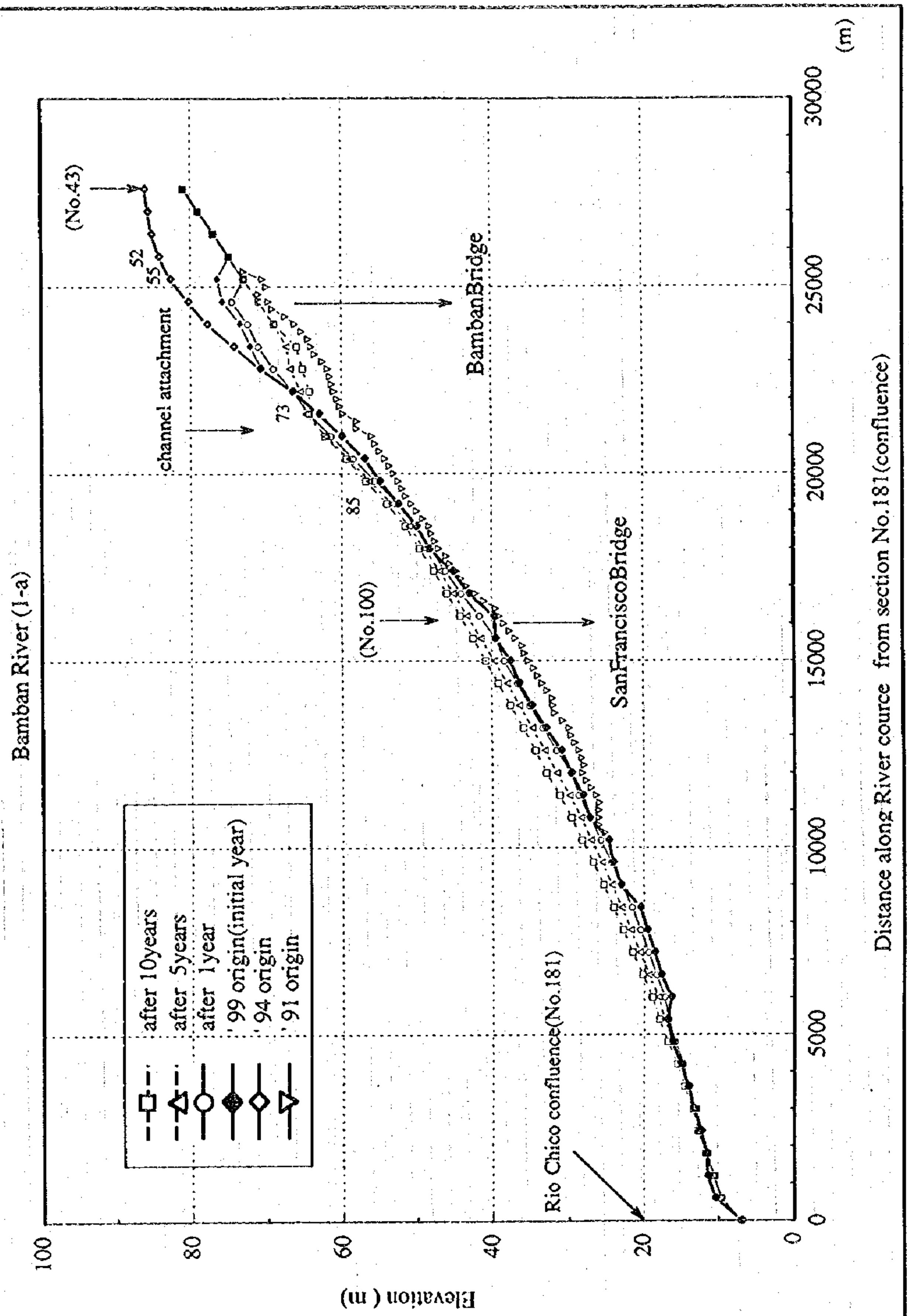

Figure 6.16

River Bed Profile of Bamban River with Sacobia Diversion Channel Case 1-a Constant Sediment and No Dredging

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

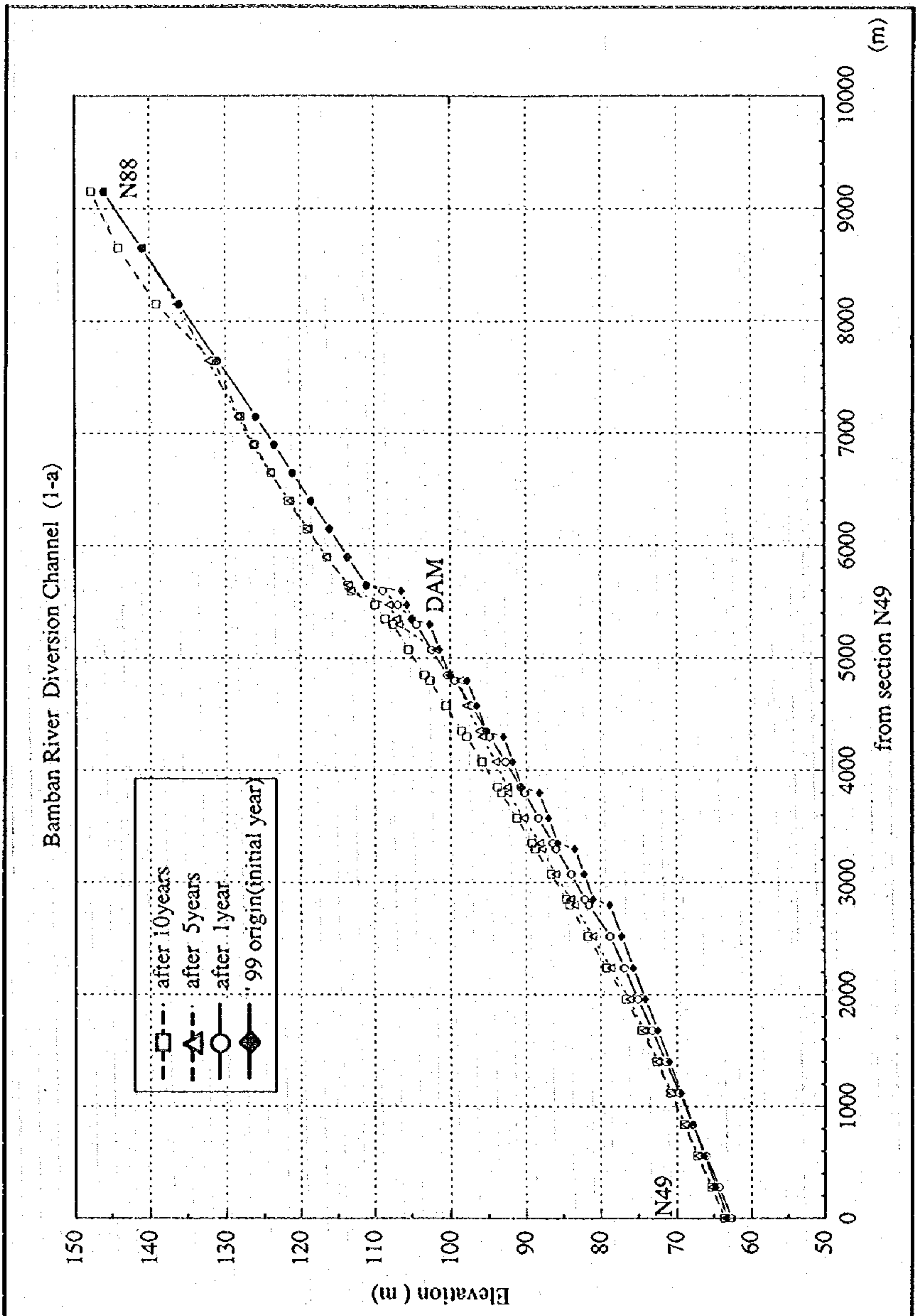

Figure 6.17

**River Bed Profile of Sacobia Diversion Channel
Case 1-a Constant Sediment and No Dredging**

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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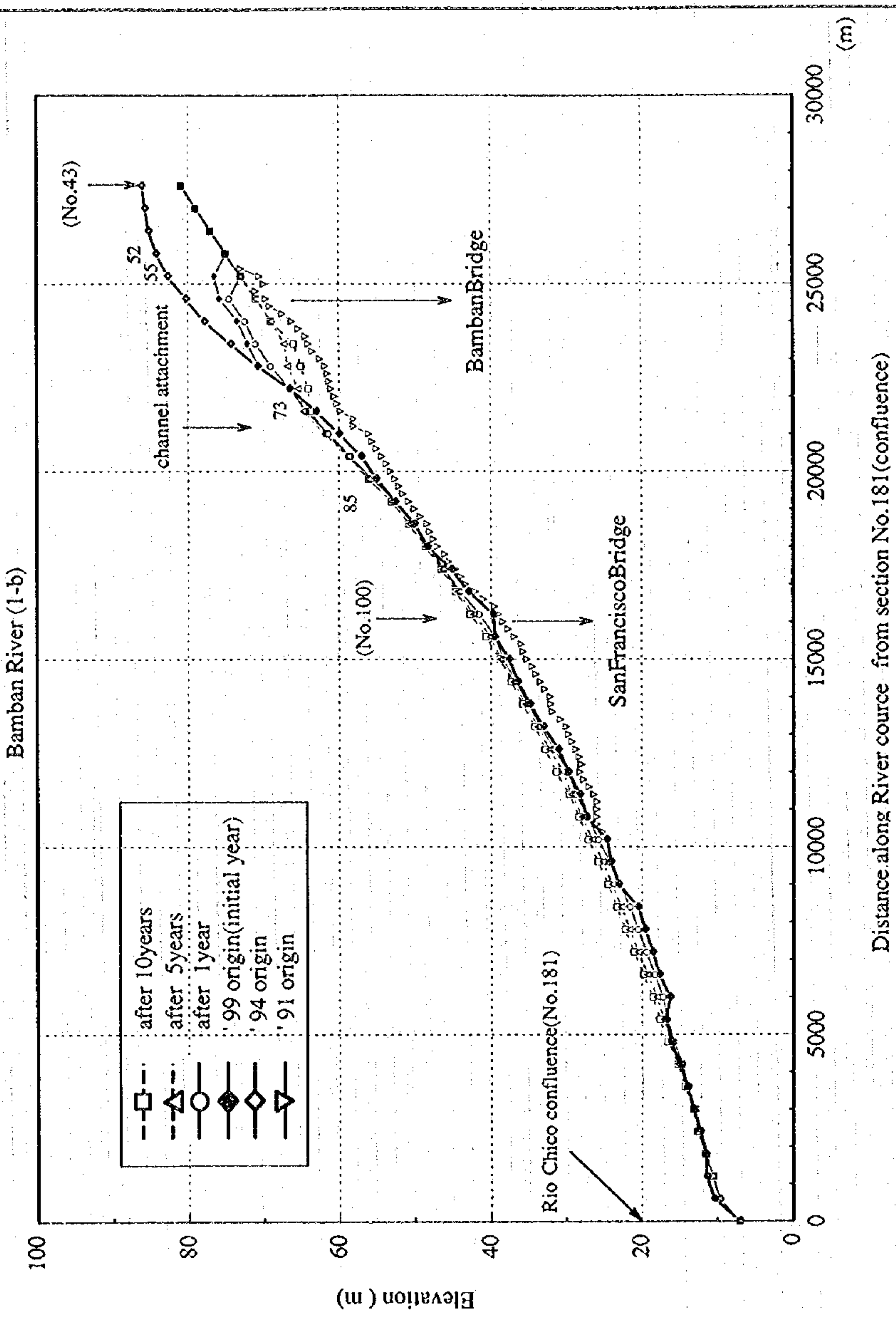

Figure 6.18

River Bed Profile of Bamban River with Sacobia Diversion Channel Case 1-b Constant Sediment and Dredging Works

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

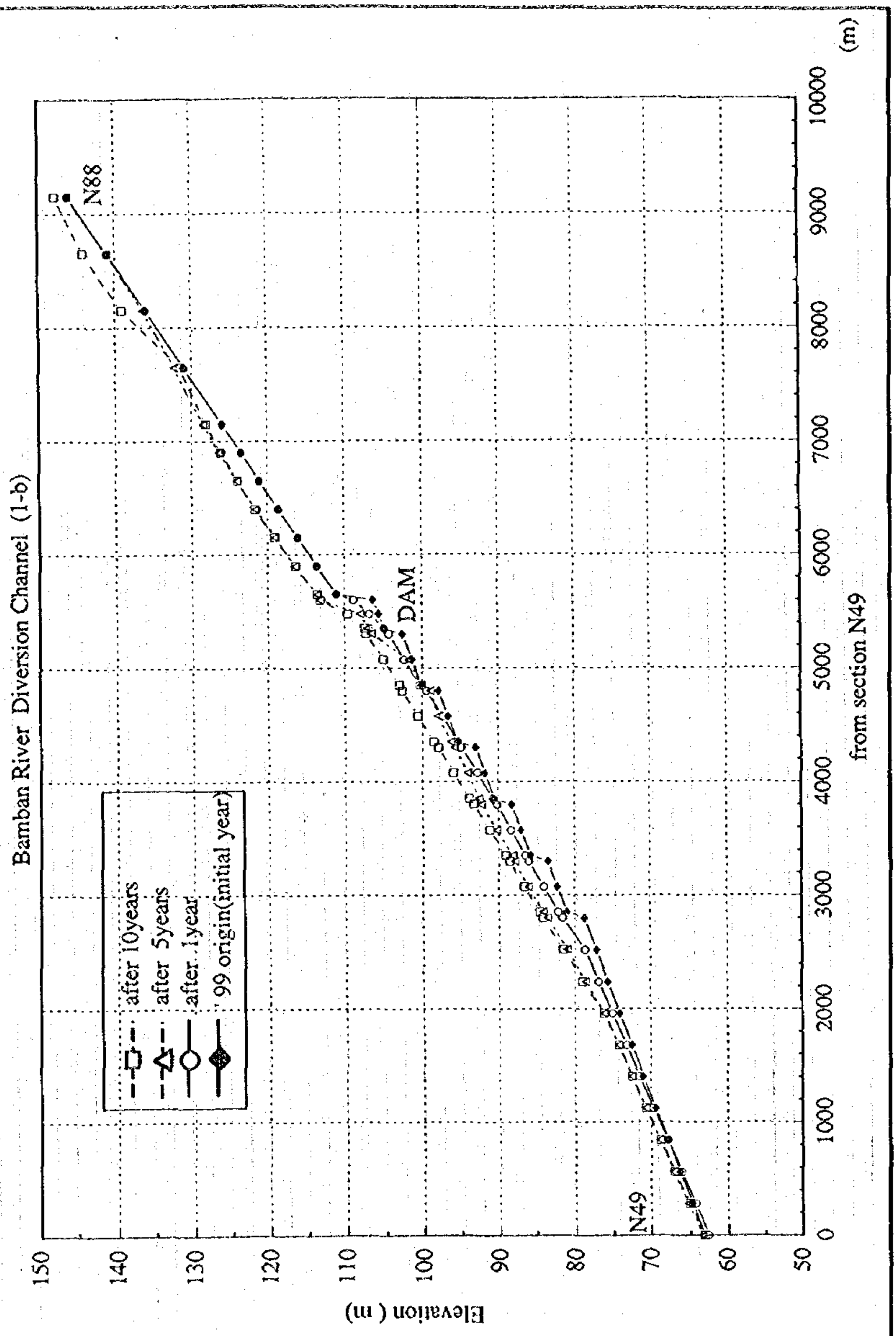

Figure 6.19

River Bed Profile of Sacobia Diversion Channel Case 1-b Constant Sediment and Dredging Works

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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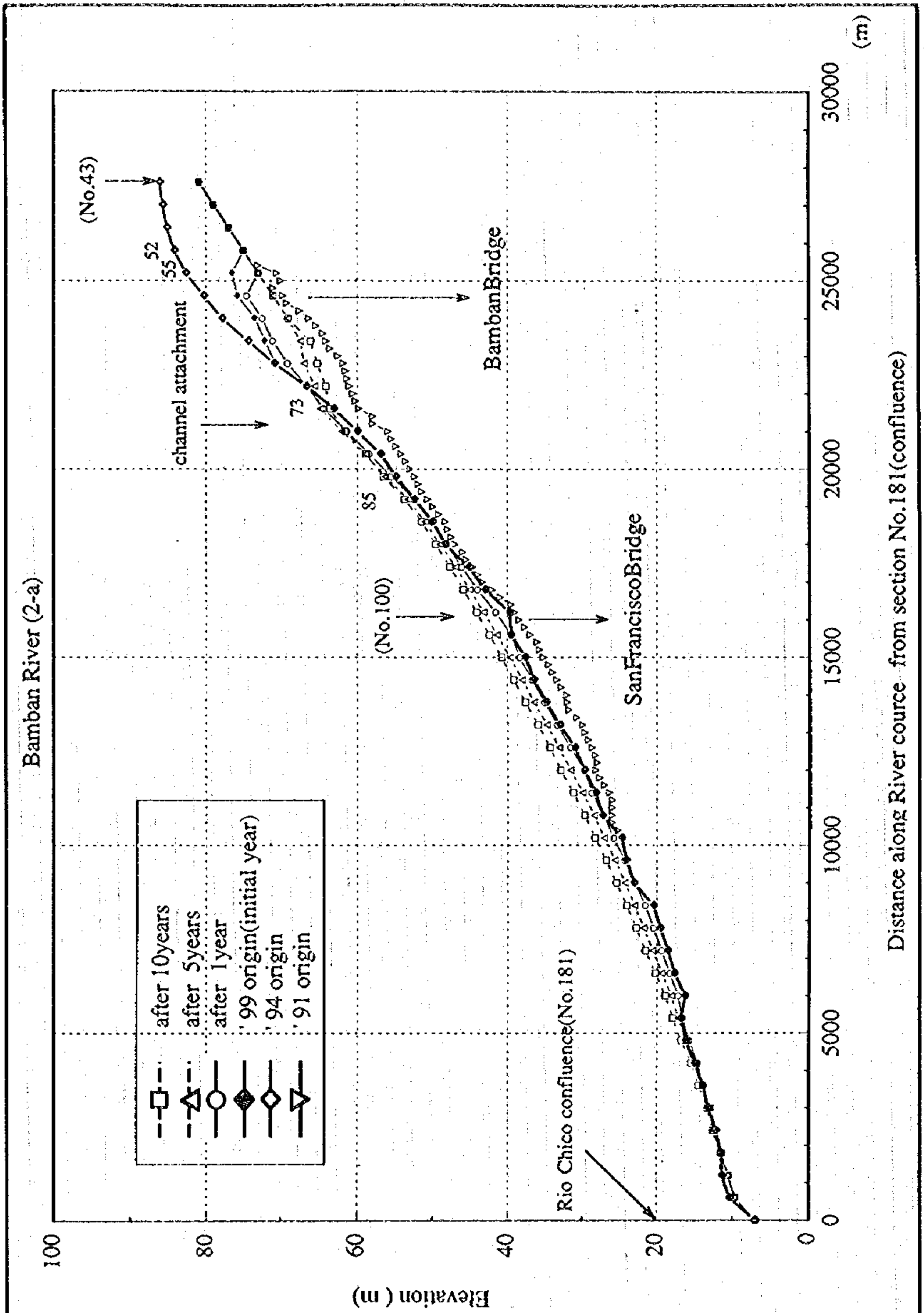

Figure 6.20

River Bed Profile of Bamban River with Sacobia Diversion Channel Case 2-a Declining Sediment and No Dredging

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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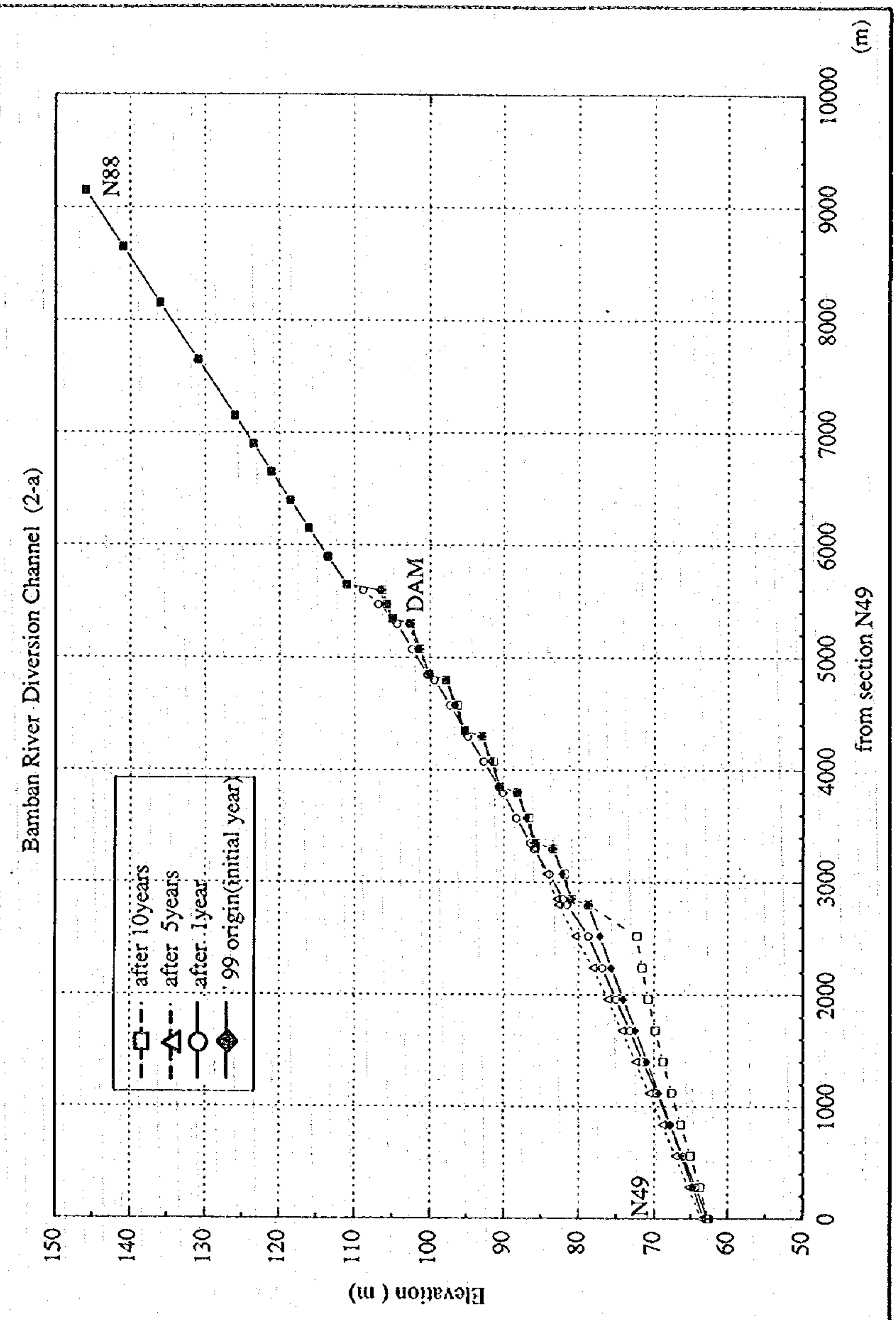

Figure 6.21

River Bed Profile of Sacobia Diversion Channel
Case 2-a Declining Sediment and No Dredging

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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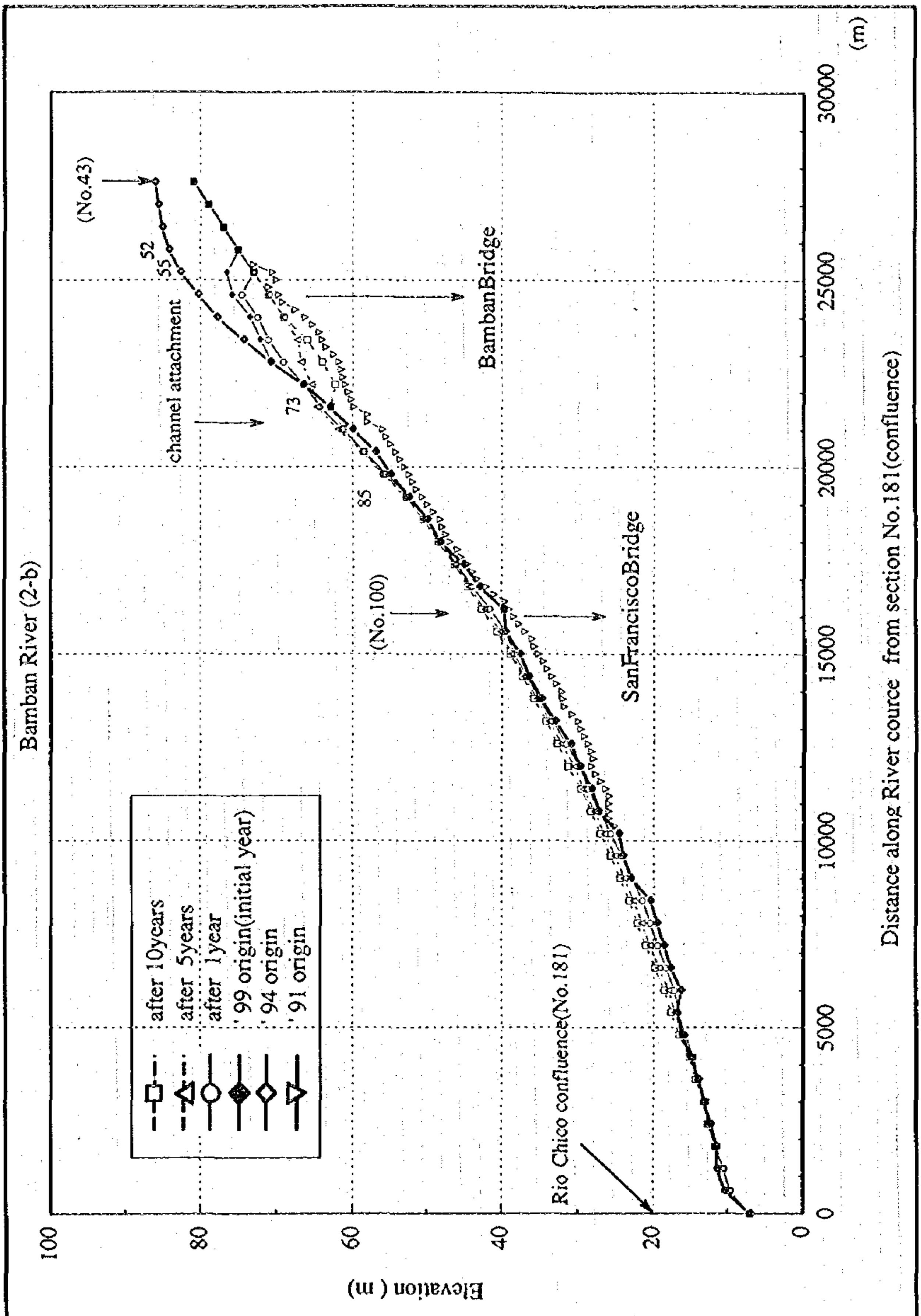

Figure 6.22

River Bed Profile of Bamban River with Sacobia Diversion Channel Case 2-b Declining Sediment and Dredging Works

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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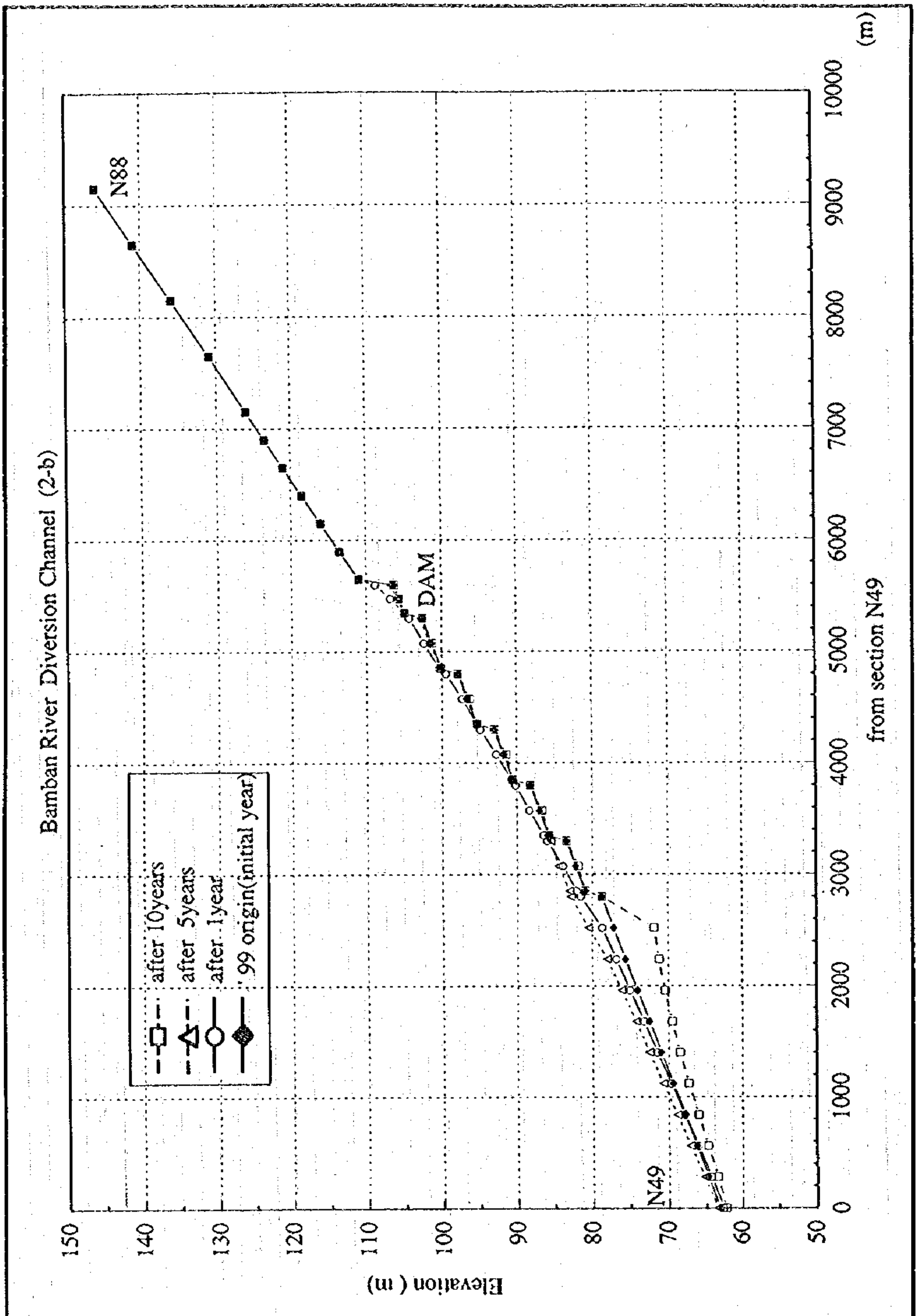

Figure 6.23

River Bed Profile of Sacobia Diversion Channel
Case 2-b Declining Sediment and Dredging Works

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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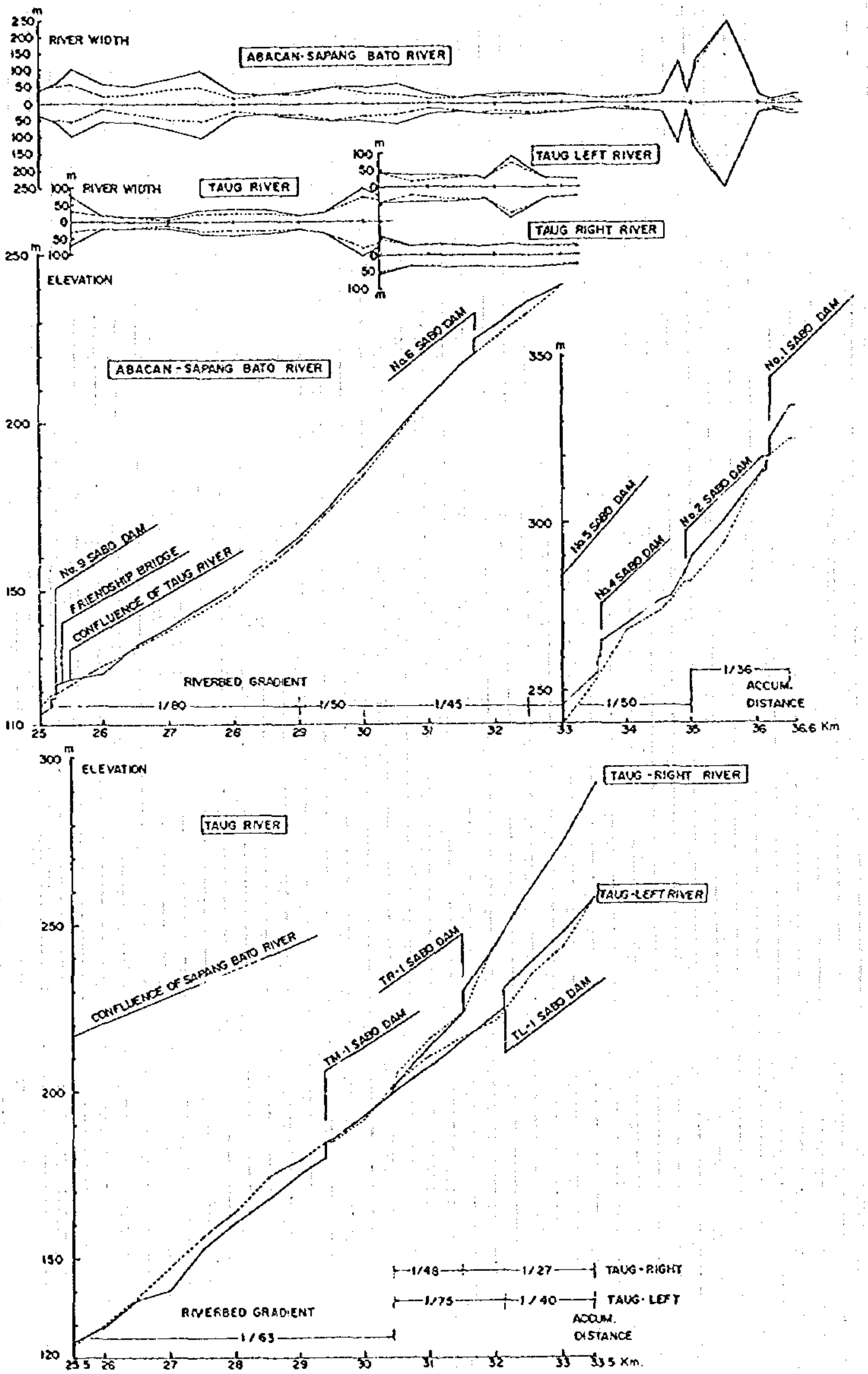

Figure 6.24 Longitudinal Profile and River Width in Upper-Abacan River

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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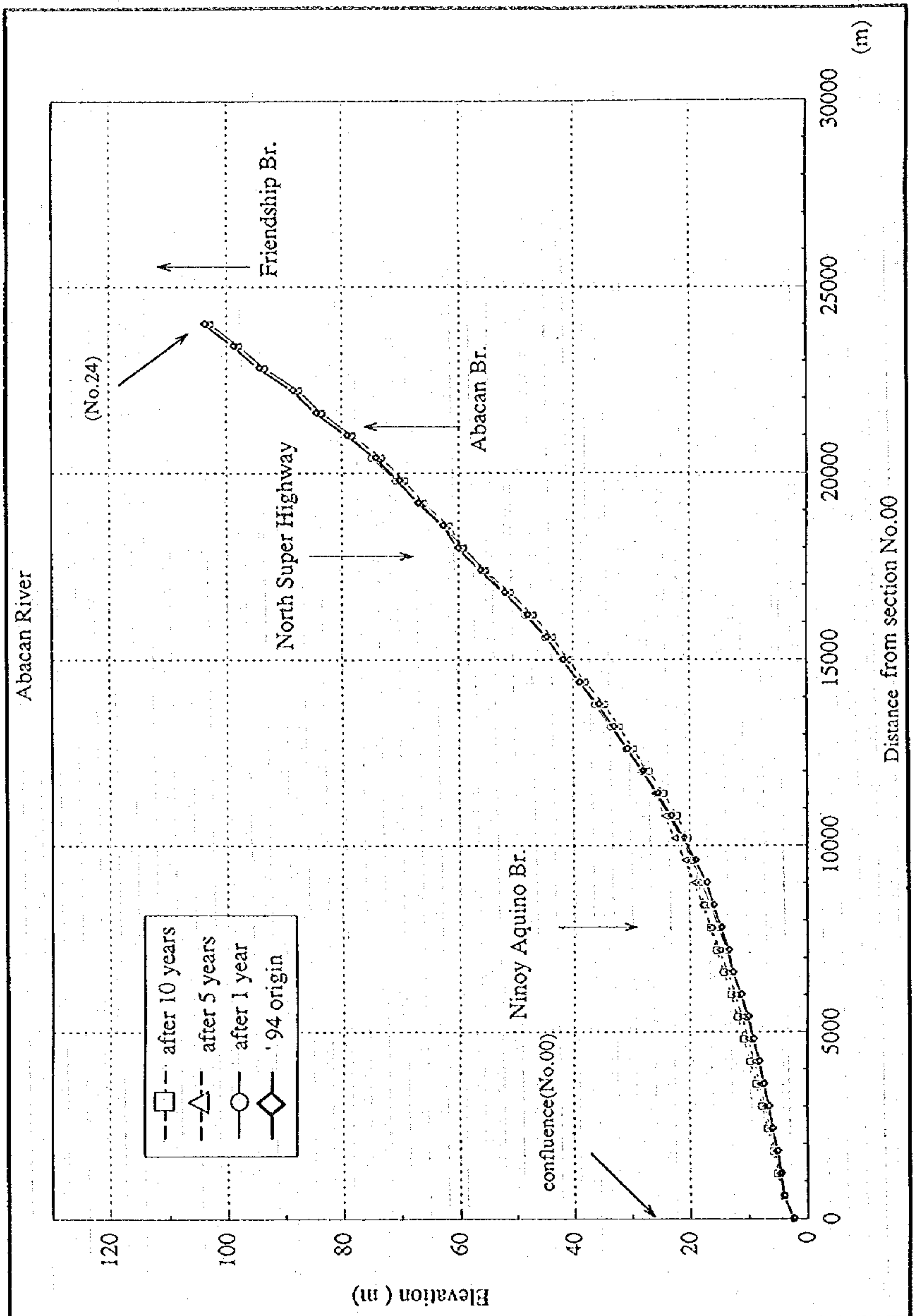


Figure 6.25

River Bed Profile of 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
JAPAN INTERNATIONAL COOPERATION AGENCY

CHAPTER 7

POTENTIAL HAZARD AREA

CHAPTER 7 POTENTIAL HAZARD AREA

7.1 PROBABLE FLOOD PEAK DISCHARGE

7.1.1 PROBABLE RAINFALL

The following table tabulates probable basin mean daily rainfall together with 24-hr rainfall which is computed assuming coefficient of 1.13 to convert daily rainfall into 24-hr rainfall.

(unit : mm)

Return Period	Sacobia-Bamban		Abacan	
(year)	Daily	24-hr	Daily	24-hr
100	440	497	443	501
50	397	448	404	457
20	353	399	365	412
10	295	333	311	351
5	231	260	251	283
2	180	203	202	228

The model hyetographs for the basin mean rainfall were developed taking into account the continuation times of actual rainfall more than 100 mm at the stations in and around the Study Area. In these stations, no difference are found in as for the rainfall duration. Consequently, the entire duration of the model hyetograph for the basin was set at 24 hours which is average continuation time of one flood of four (4) stations as shown in Figure 7.1. The hourly rainfall distribution for the Sacobia-Bamban and the Abacan river basins which are developed in the form of percentage of each hourly rainfall to the accumulated 24-hr rainfall.

7.1.2 PROBABLE FLOOD

Flood analysis was made for both of the Sacobia-Bamban River Basin and the Abacan River Basin. Under the assumption that the headwater (23 km^2) of the Sacobia River may be annexed to the Sacobia River in the future, the calculation was made one (1) case for the Abacan River, while two (2) cases for the Sacobia-Bamban River Basin as follows:

Case 1 The Sacobia River flows down into the sand pocket area.

Case 2 The Sacobia River will be joined to the Bamban River between the Road 3 and the Road 329.

The Storage Function Method was employed for the flood runoff analysis because this method can express the non-linearity of rainfall-runoff relation and it has been used widely for a long time to generate hydrographs. A basin runoff is constructed for each river based on the subbasin divisions and the topographic conditions. The distribution of probable peak discharges are shown in Figure 7.2 for Case 1 and Figure 7.3 for Case 2 for the Sacobia-Bamban River and design hydrographs for Case 1 are shown in Figure 7.4. Those for the Abacan River are shown in Figures 7.5 and 7.6.

7.2 TWO-DIMENSIONAL FLOOD INUNDATION ANALYSIS

7.2.1 INTRODUCTION

The purpose of two-dimensional analysis was to assess the inundation area, flow depth and duration, and sediment deposits depth in flood prone areas due to the overflow of streams due to large scale flood runoff for flood damage analysis as well as to assess the flood flowing capacity and topographic changes of sand pocket with the condition of control structures

The overflow of stream under the 1991 and 1994 topographic conditions in the Bamban river basin were firstly simulated to evaluate applicability of the model. Then flood flow and sediment movement in the sand pocket area were simulated under 1994 topographic condition and the effect of the structures proposed in the sand pocket was assessed. The potential hazard areas were also calculated based on probable flood hydrographs for Bamban/Parua river and Abacan river.

For the numerical simulation, the study applied the computer program of two-dimensional flood and mudflow analysis developed by Public Works Research Institute and Sabo and Landslide Technical Center of Japan.

7.2.2 BASELINE DATA

(1) Area for Simulation : The objective study area is divided into meshes of appropriate size depending on the purpose of the study and allowable number of meshes determined by computation capacity. For each time step, flow rate, flow depth, sediment load, changes in elevation are calculated by the above equations for every meshes of the model and the process is repeated in the next time step.

(2) Topographic data : Topographic data were produced from DTM (Digital Topographic Map of 1:10,000 scale) in 1991 pre-eruption and 1994 prepared by the Survey Team for Sacobia valley, Bamban river basin and Abacan river basin.

(3) Parameters : The same parameters in Brown's equation as the sediment transport capacity study in the previous chapter were applied in this study.

7.2.3 POTENTIAL INUNDATION AREA IN BAMBAN RIVER BASIN

Potential flood inundation over flood prone areas in the Bamban river basin was simulated under the following condition for 6 cases of probable flood hydroghaphs in different return periods.

The flood runoff was input at two locations, Maskup point in the Sacobia river and a confluence of the Marimla and Sapang Cauayang rivers upstream of Bamban bridge in the Bamban river assuming flood events of the same return period occur simultaneously in these basins.

Topographic data	: DTM in 1994	
	: Area of analysis	20 km x 8 km
	: Mesh size	100 m x 100 m

The flood hydrographs by return period at Maskup and Marimla+Sapang Cauayang was applied to the simulation. The flood peak discharges by return period are enumerated below:

Return Period	Peak discharge (m^3/s)	
	Maskup	Marimla+Cauayang
2-year flood	125	270
5-year flood	170	360
10-year flood	230	490
20-year flood	270	580
50-year flood	330	690
100-year flood	370	800

Sediment concentration is given by Brown's equation for the initial discharge

The potential inundation areas estimated in this study are summarized as follows:

Inundation Area in Bamban river basin (unit: ha)

Water depth (m)	2-year	5-year	10-year	20-year	50-year	100-year
0 < h < 0.2	8,360	8,150	7,860	7,500	7,580	7,590
0.2 < h <1.0	1,390	1,930	2,530	3,000	3,130	3,160
1.0 < h	70	80	110	150	170	200
Total	9,820	10,160	10,500	10,650	10,880	10,950

Total area of analysis : 16,000 ha

7.2.4 POTENTIAL INUNDATION AREA IN ABACAN RIVER BASIN

Potential flood inundation over flood prone areas in the Abacan river basin was simulated under the following condition. The flood runoff was input at Abacan bridge point.

Topographic data : DTM in 1994
: Area of analysis 20 km x 11 km
: Mesh size 100 m x 100 m

The flood hydrographs by return period at Maskup and Marimla+Sapang Cauayang was applied to the simulation. The flood peak discharges by return period are enumerated below:

Return period	Peak discharge (m^3/s)
2-year flood	180
5-year flood	240
10-year flood	310
20-year flood	370
50-year flood	430
100-year flood	490

Sediment concentration was given by Brown's equation for the initial discharge The potential inundation areas estimated in this study are summarized as follows:

Inundation Area in Bamban river basin (unit: ha)

Water depth (m)	2-year	5-year	10-year	20-year	50-year	100-year
0 < h < 0.2	6,080	6,170	6,120	6,010	6,400	6,940
0.2 < h <1.0	810	1,170	1,680	2,060	2,350	2,600
1.0 < h	20	20	30	40	50	60
Total	6,910	7,360	7,830	8,110	8,800	9,600

Total area of analysis : 22,000 ha

7.3 HAZARD AREA

7.3.1 SACOBIA-BAMBAN RIVER SYSTEM

Potential flood inundation over flood prone areas in the Bamban river basin was simulated for probable flood hydroghaphs in different return periods. The flood runoff was input at two locations, Maskup point in the Sacobia river and a confluence of the Marimla and Sapang Cauayang rivers upstream of Bamban bridge in the Bamban River assuming flood events of the same return period occur simultaneously in these basins. Topographic map in 1994 was used for the analysis.

The distribution of maximum water depth of every meshes is illustrated on topographic maps produced by GIS as shown in Figure 7.7 for 100 year floods.

7.3.2 ABACAN RIVER SYSTEM

Potential flood inundation over flood prone areas in the Abacan river basin was also simulated for probable flood hydroghaphs in different return periods.. The flood runoff was input at the location of Abacan Bridge. Topographic map in 1994 was also used for the analysis. The distribution of maximum water depth of every meshes is illustrated on topographic maps produced by GIS as shown in Figure 7.8 for 100 year floods.

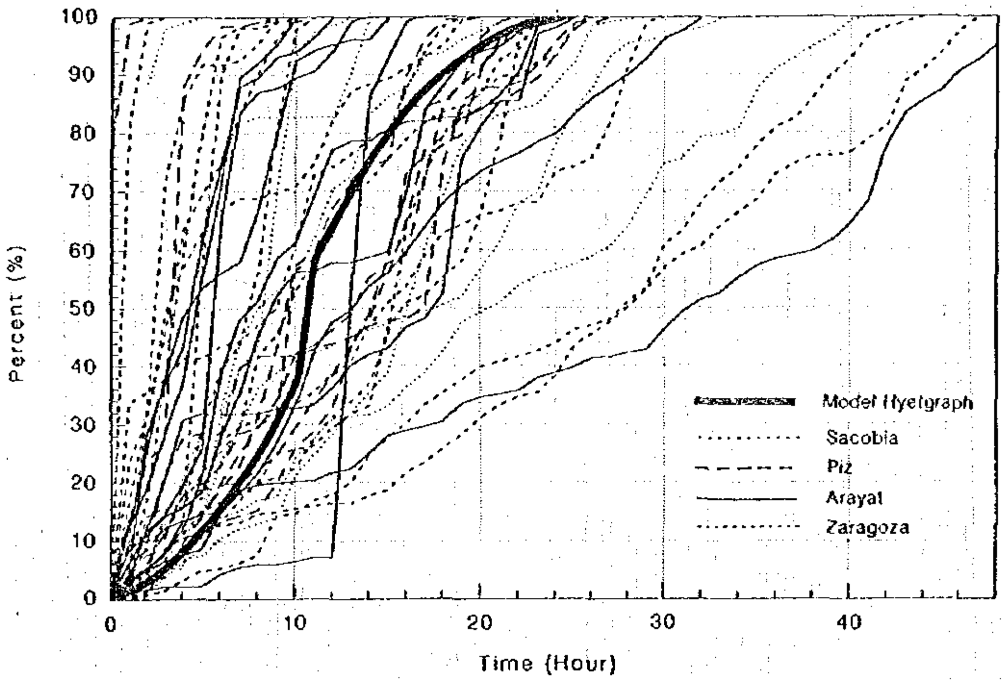
7.3.3 HAZARD AREA

Long-term flood and sediment hazard map was prepared for Sacobia-Bamban and Abacan river basins as a guide in disaster mitigation and development planning.

The flood and sediment prone areas were analyzed based on the topographic condition in March 1994, of which a part of areas are covered with lahar (disaster areas before March 1994), in particular, sand pocket area in the middle reach of the Bamban River and lower basin of the Abacan River. Those areas would not affected by flood and sediment hazards because that the ground surface elevation is already higher than the prone areas.

The data contains the sediment and inundation depth for each 100m x 100m cell in the simulation area. The maximum inundation areas for the entire Study Area with return periods 100 years were created by using both the results of numeric simulation and GIS techniques. The maximum inundation area for the flood with 100-yr return period is shown in Figure 7.9.

Rainfall Duration and Accumulated Rainfall Rate



Hourly Rainfall Distribution

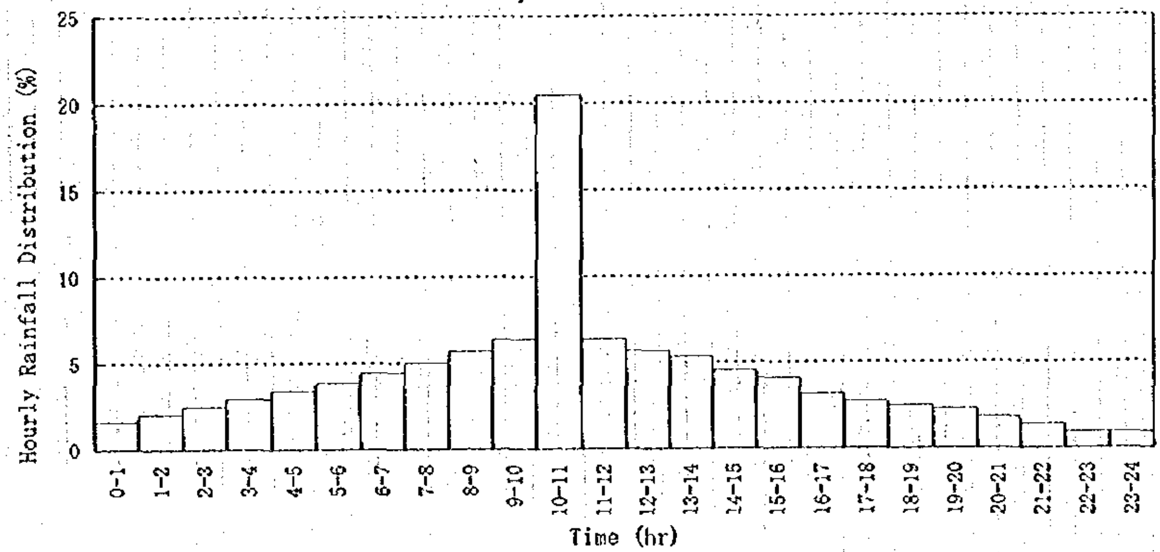


Figure 7.1 Model Hyetograph

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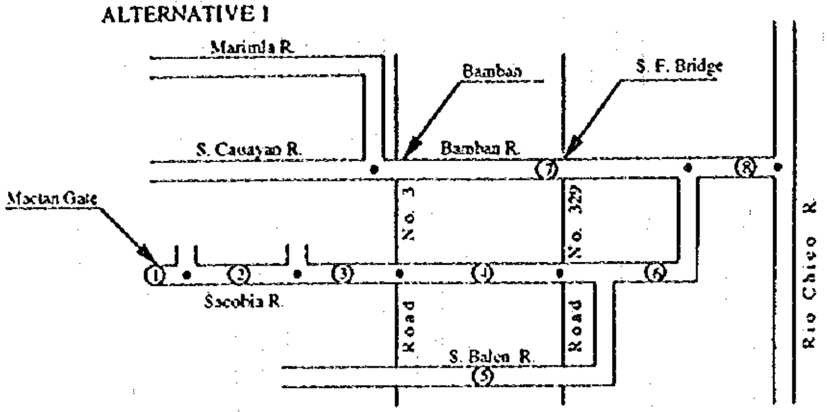

Pre-Piracy

Probable Peak Discharge Distribution

CASE 1-1 Unit :m3/s

Reach	Return Period 100	50	20	10	5	2
No.1	400	350	290	250	190	140
No.2	460	400	340	290	220	160
No.3	570	500	420	350	270	200
No.4	710	610	510	430	320	240
No.5	200	170	145	125	90	70
No.6	1010	870	720	610	460	340
No.7	750	630	520	430	320	240
No.8	1760	1480	1200	1020	750	550

Afetr Piracy

Probable Peak Discharge Distribution

CASE 1-2 Unit :m3/s

Reach	Return Period 100	50	20	10	5	2
No.1	180	160	135	115	85	60
No.2	250	220	180	155	115	85
No.3	370	330	270	230	170	125
No.4	520	440	380	320	240	175
No.5	200	170	145	125	90	70
No.6	850	730	610	510	380	280
No.7	760	640	520	430	320	230
No.8	1570	1320	1060	900	660	490

Figure 7.2 **Probable Peak Discharge Distribution in Sacobia-Bamban River**

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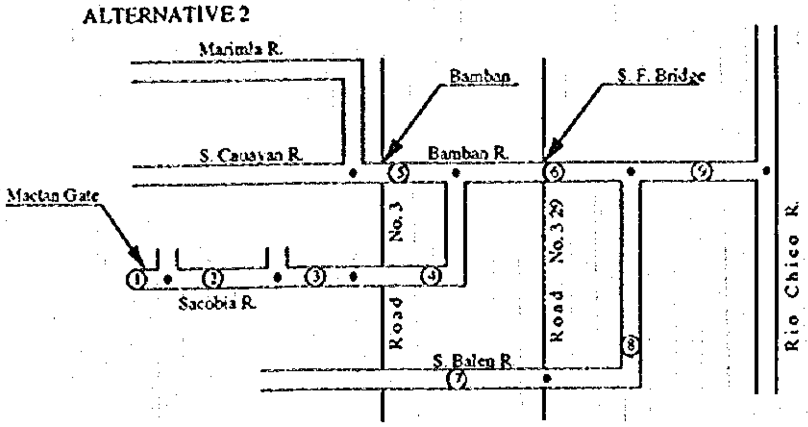
ALTERNATIVE 2



Pre-Piracy

Probable Peak Discharge Distribution

CASE 2-1 Unit :m3/s

Reach	Return Period 100	50	20	10	5	2
No.1	400	350	290	250	190	140
No.2	460	400	340	290	220	160
No.3	570	500	420	350	270	200
No.4	660	580	480	410	310	230
No.5	800	690	580	490	360	270
No.6	1440	1250	1040	870	650	480
No.7	200	170	145	125	90	70
No.8	440	380	310	260	195	140
No.9	1820	1540	1260	1070	780	580

Afetr Piracy

Probable Peak Discharge Distribution

CASE 2-2 Unit :m3/s

Reach	Return Period 100	50	20	10	5	2
No.1	180	160	135	115	85	60
No.2	250	220	180	155	115	85
No.3	370	330	270	230	170	125
No.4	470	410	340	290	210	160
No.5	800	690	580	490	360	270
No.6	1240	1070	890	750	560	410
No.7	200	170	145	125	90	70
No.8	440	380	310	260	195	140
No.9	1610	1360	1110	940	690	510

Figure 7.3 **Probable Peak Discharge Distribution in Sacobia-Bamban River**

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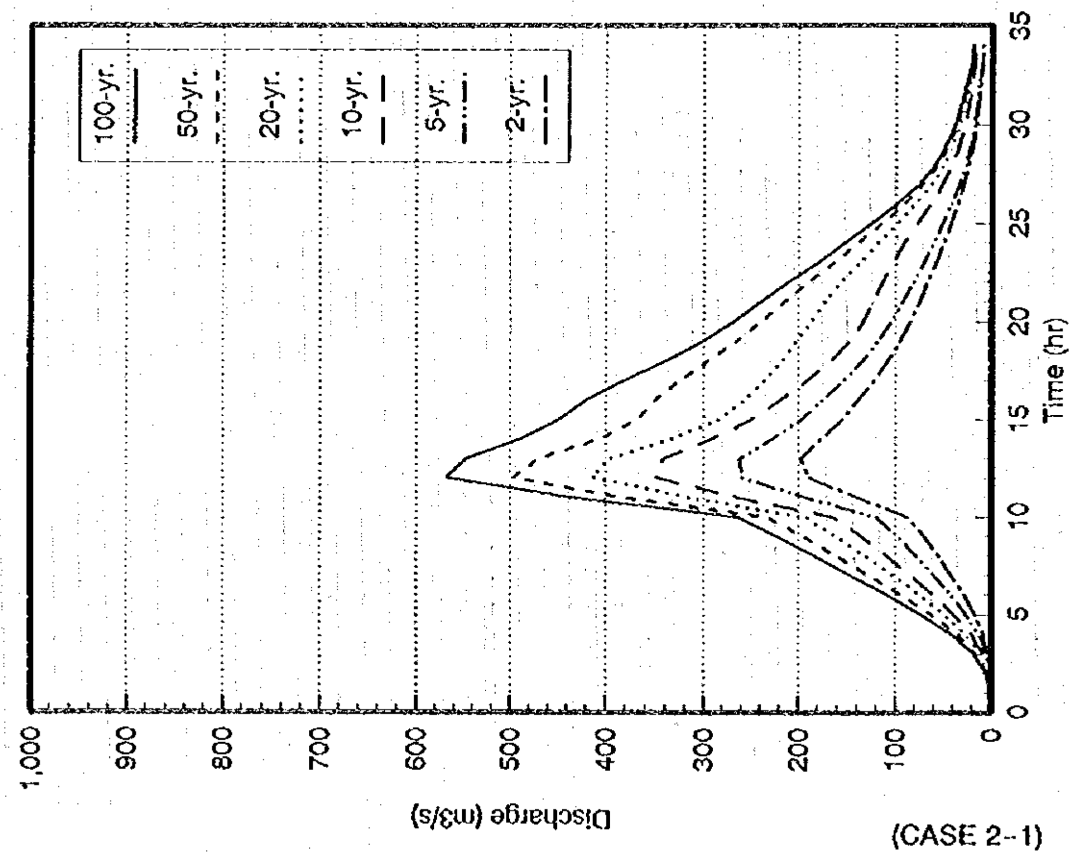
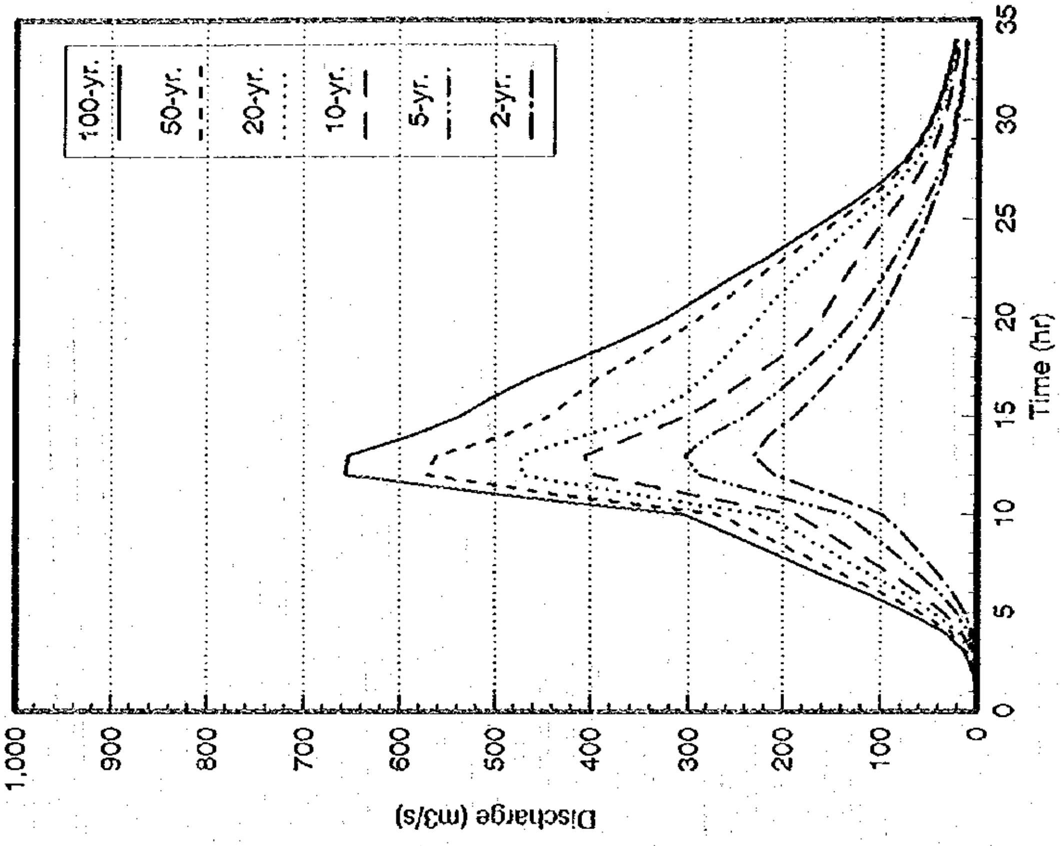


PROBABLE FLOOD RUNOFF HYDROGRAPH
AT MASKUP POINT



PROBABLE FLOOD RUNOFF HYDROGRAPH
AT LOWEST POINT OF SACOBIA RIVER

(CASE 2-1)

Figure 7.4 Probable Runoff Flood Hydrograph for Sacobia-Bamban River (1/3)

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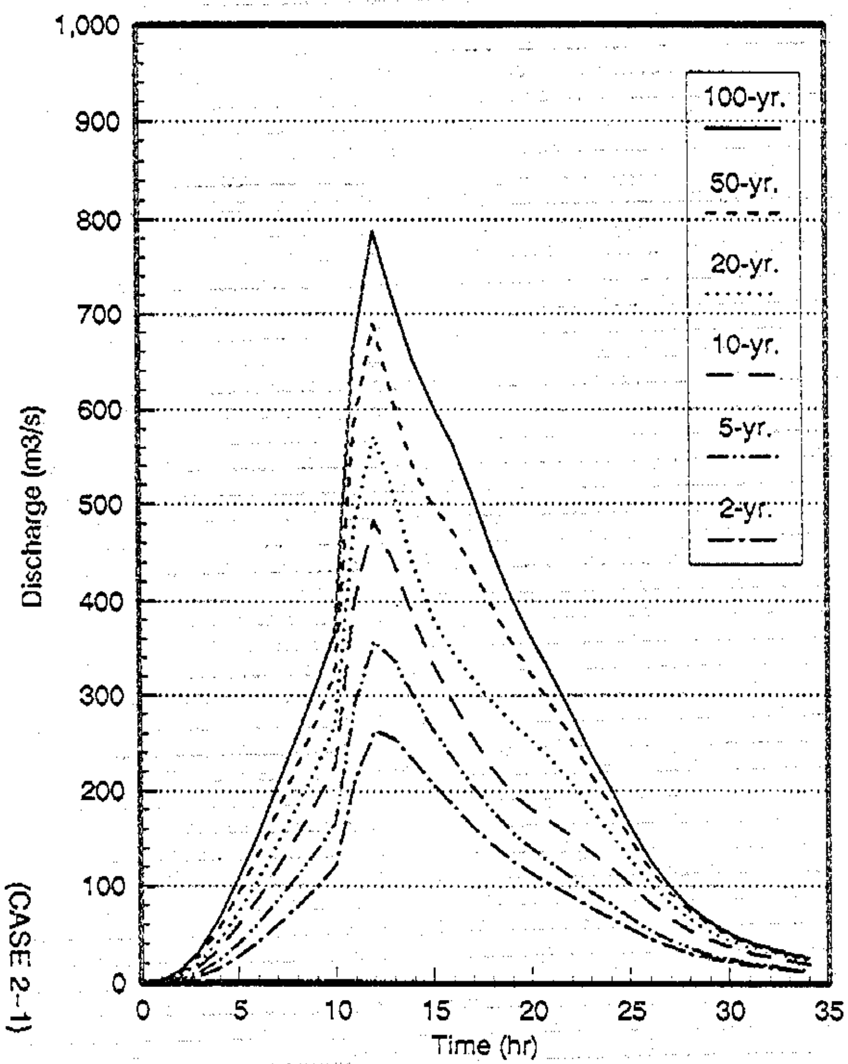
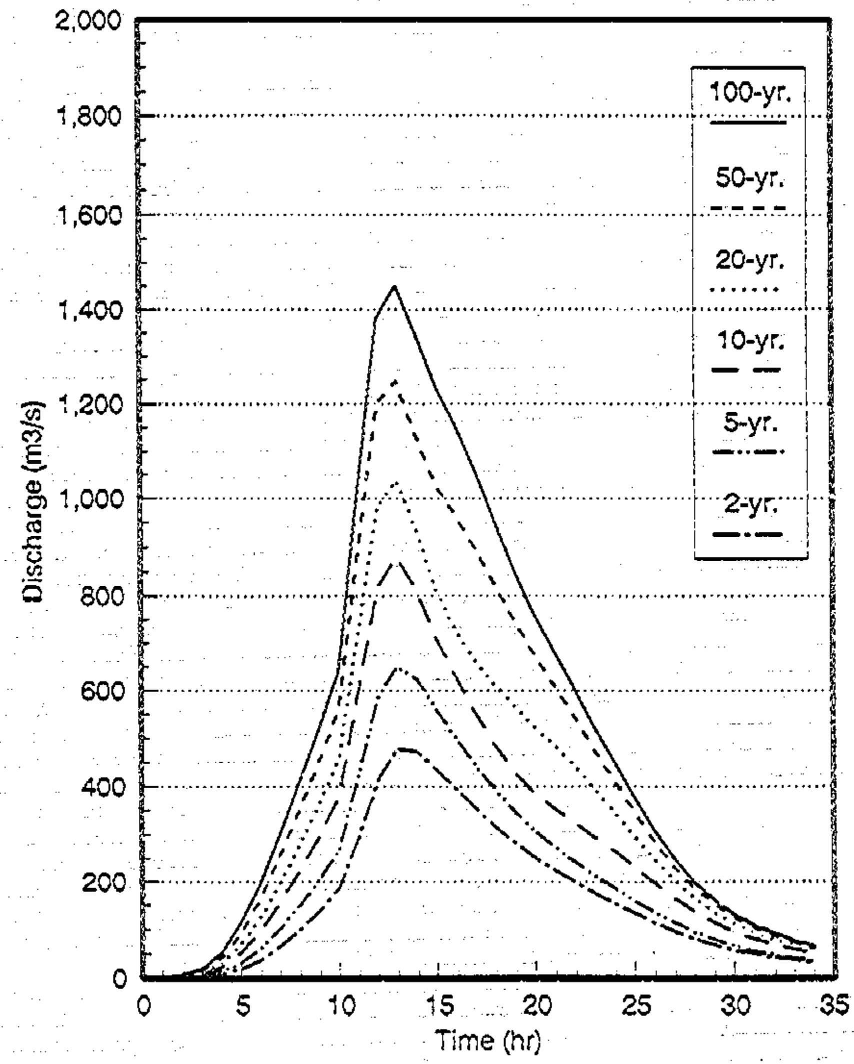


PROBABLE FLOOD RUNOFF HYDROGRAPH
AT ROUTE NO.3 OF BAMBAN RIVER



PROBABLE FLOOD RUNOFF HYDROGRAPH
AT SAN FRANCISCO BRIDGE OF BAMBAN RIVER

(CASE 2-1)

Table 7.4 Probable Runoff Flood Hydrograph for Sacobia-Bamban River (2/3)

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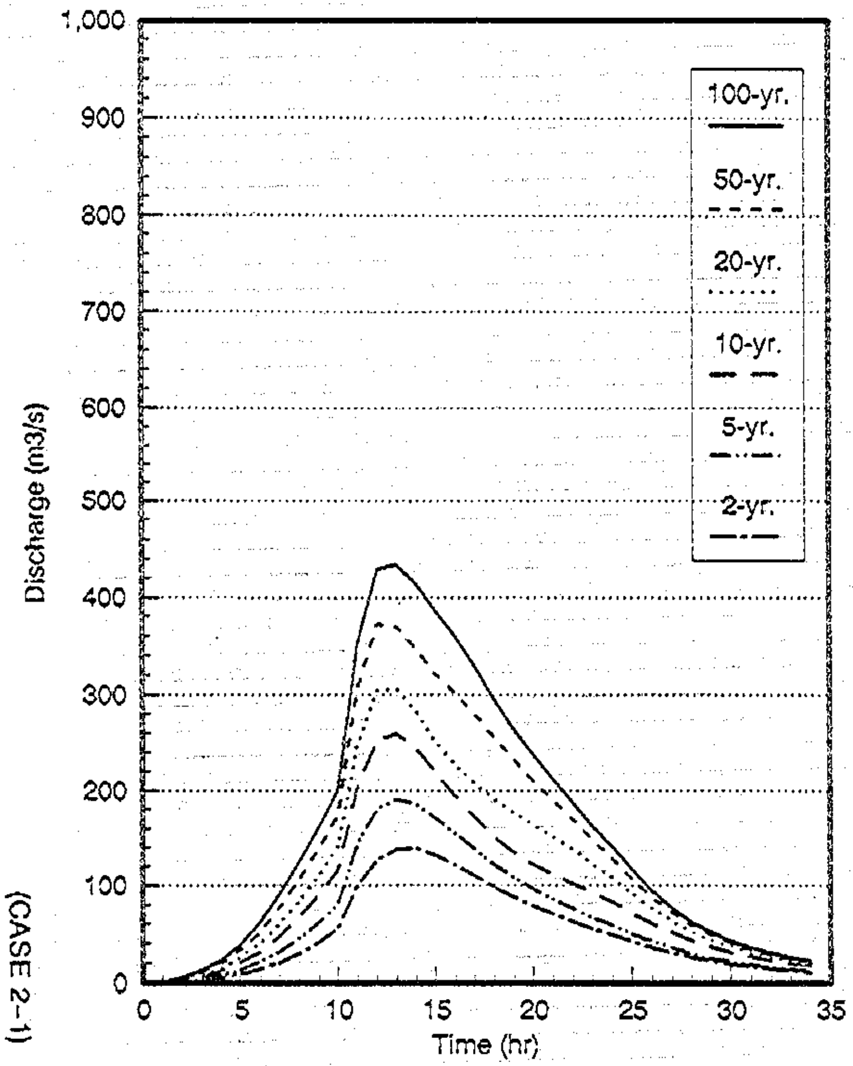
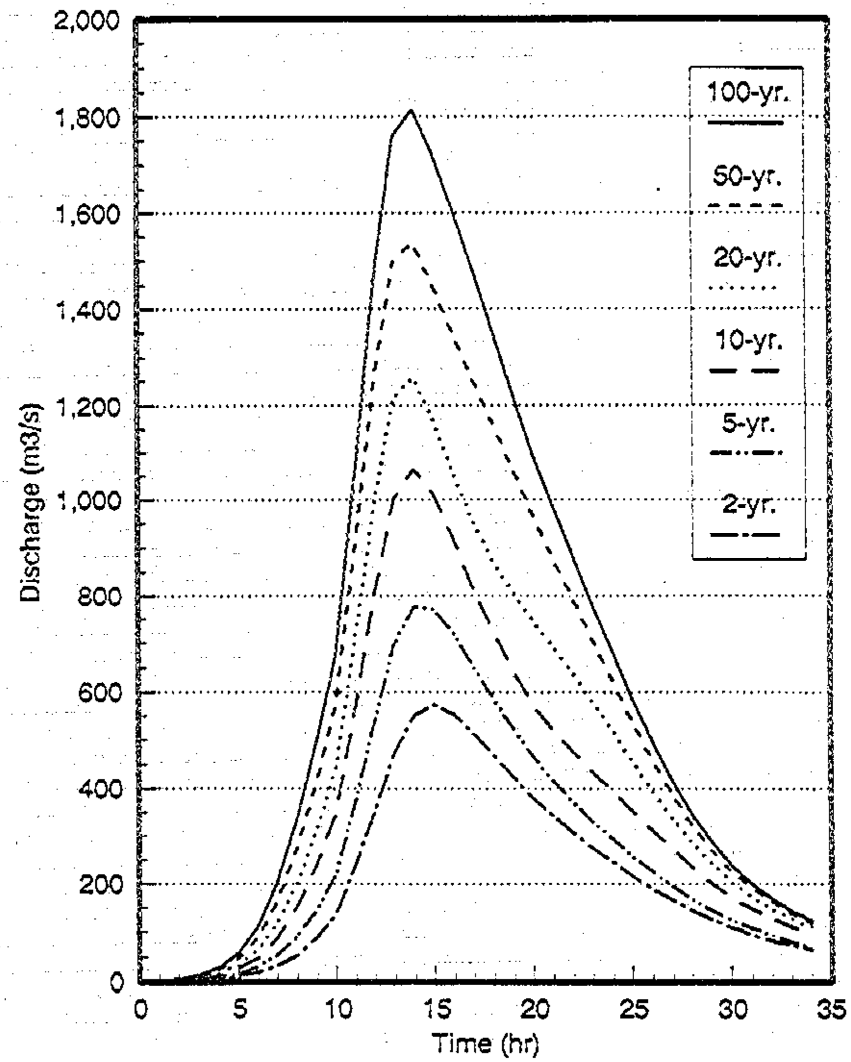


PROBABLE FLOOD RUNOFF HYDROGRAPH
AT LOWEST POINT OF SAPANG BALEN RIVER



PROBABLE FLOOD RUNOFF HYDROGRAPH
AT LOWEST POINT OF BAMBAN RIVER

(CASE 2-1)

Table 7.4 Probable Runoff Flood Hydrograph for Sacobia-Bamban River (3/3)

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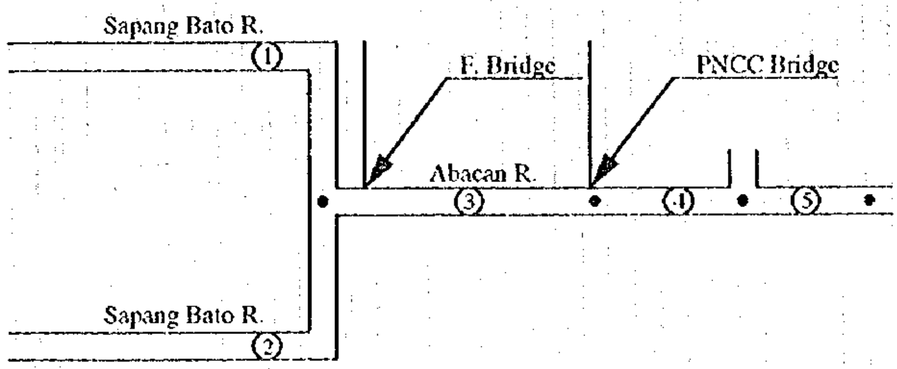
ABACAN RIVER



Probable Peak Discharge Distribution

ABACAN RIVER Unit :m3/s

	Return Period					
Reach	100	50	20	10	5	2
No.1	150	130	120	100	80	60
No.2	200	170	150	130	100	80
No.3	490	430	370	310	240	180
No.4	590	510	440	380	290	230
No.5	710	620	520	450	350	270

Figure 7.5 Probable Peak Discharge Distribution in Abacan River

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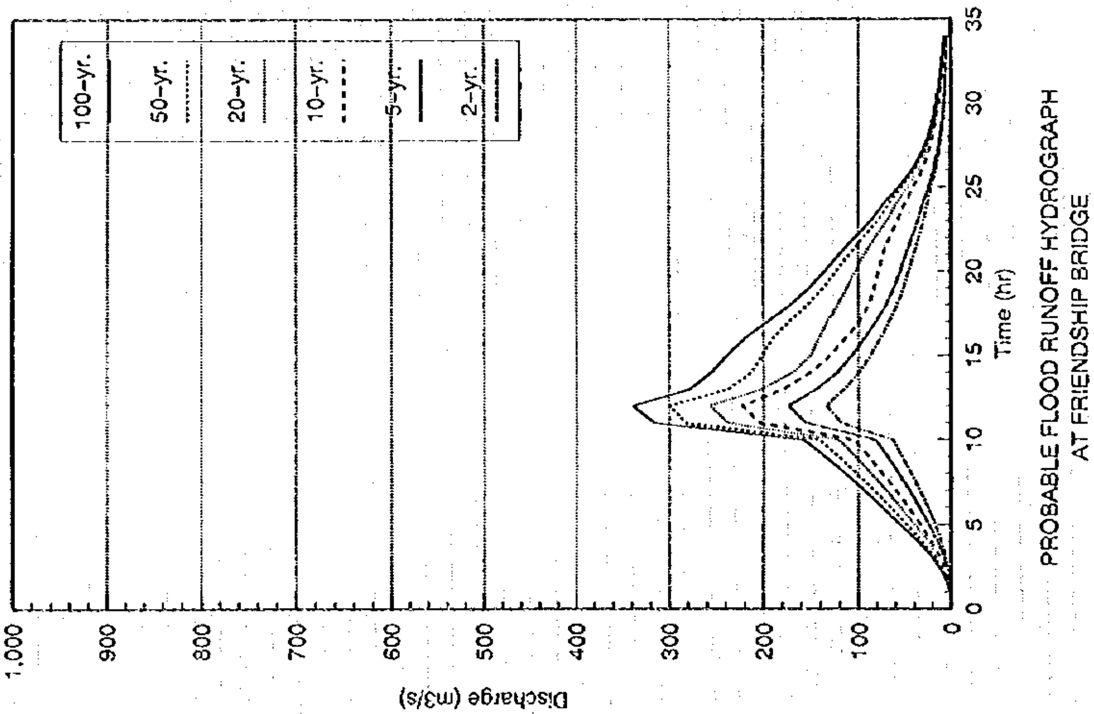

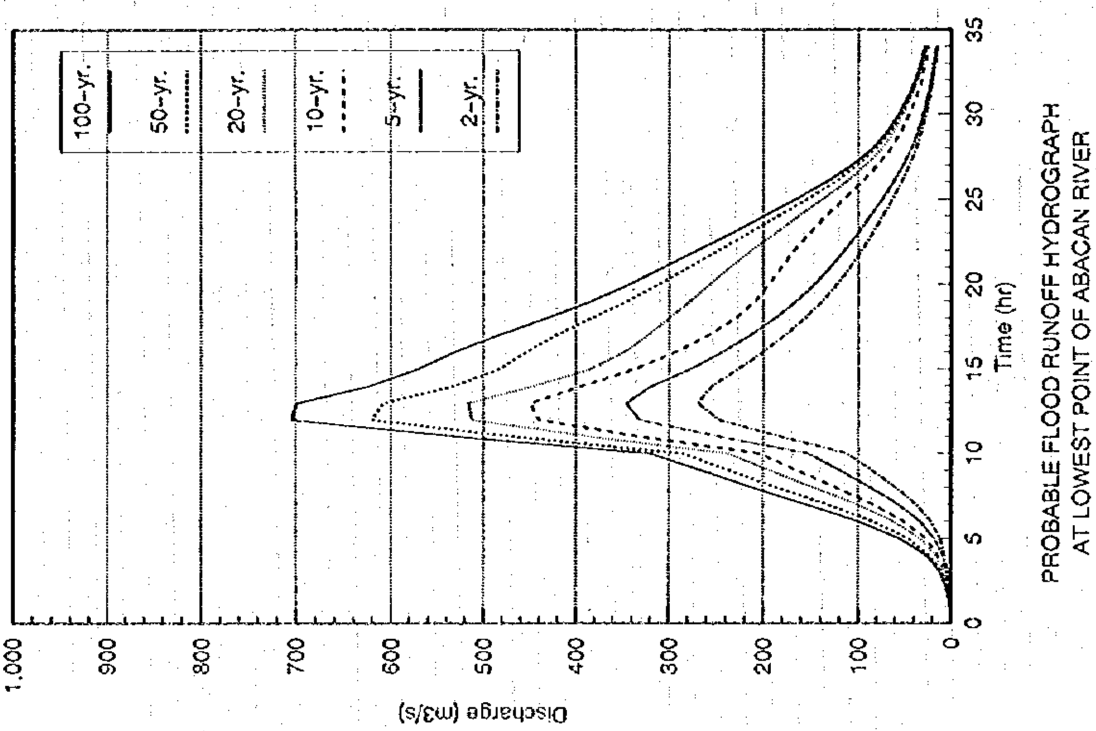

Figure 7.6

Probable Runoff Flood Hydrograph for Abacan River

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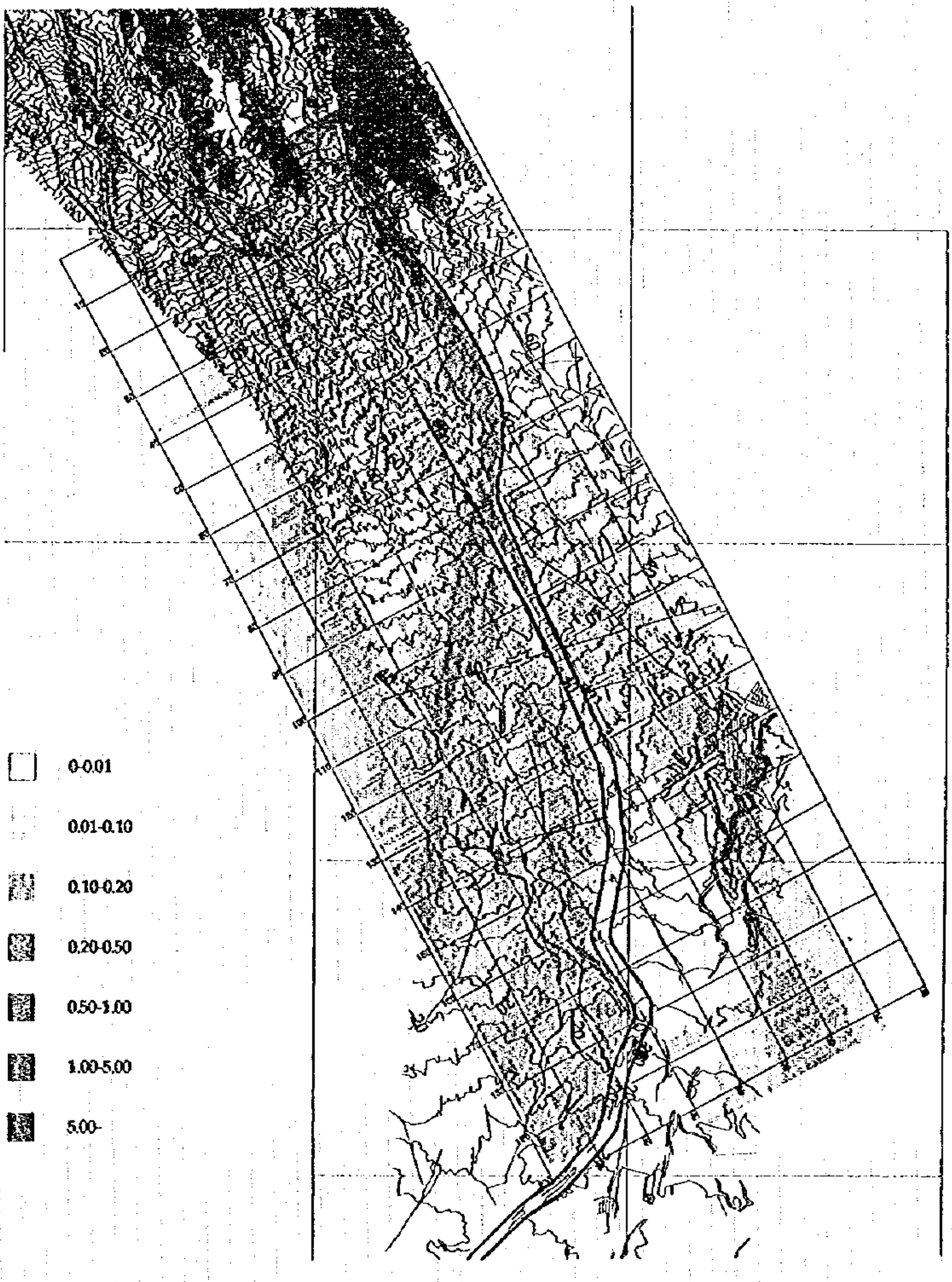
Peak discharge (m3/s)

Maskup(370) Marimla+Cauayang(800)

mesh size = 100m



	0-0.01
	0.01-0.10
	0.10-0.20
	0.20-0.50
	0.50-1.00
	1.00-5.00
	5.00-

Figure 7.7

Maximum Flow Depth on Topographic Map due to 100-year Flood in Bamban River Basin

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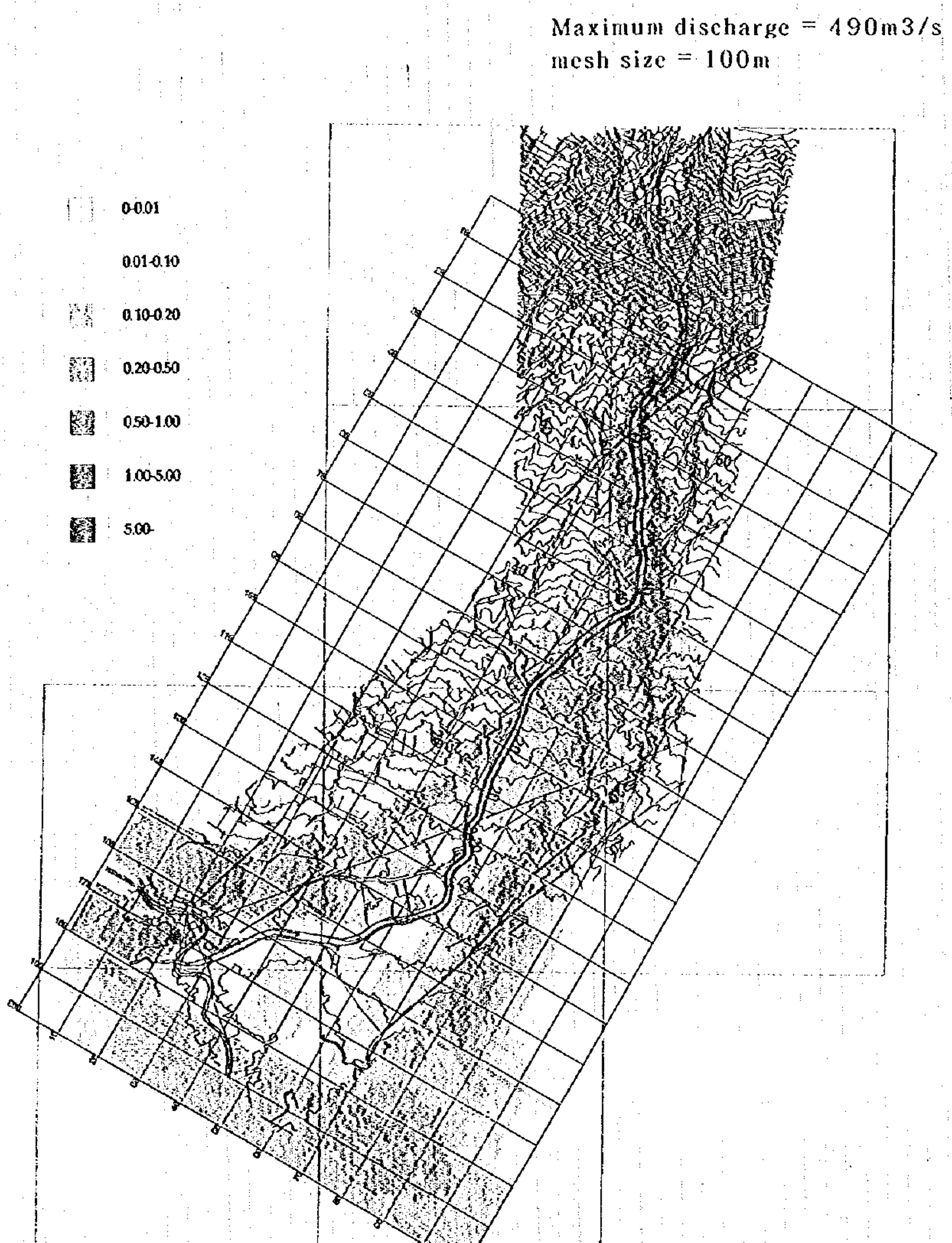

Figure 7.8

Maximum Flow Depth on Topographic Map due to 100-year Flood in Abacan River Basin

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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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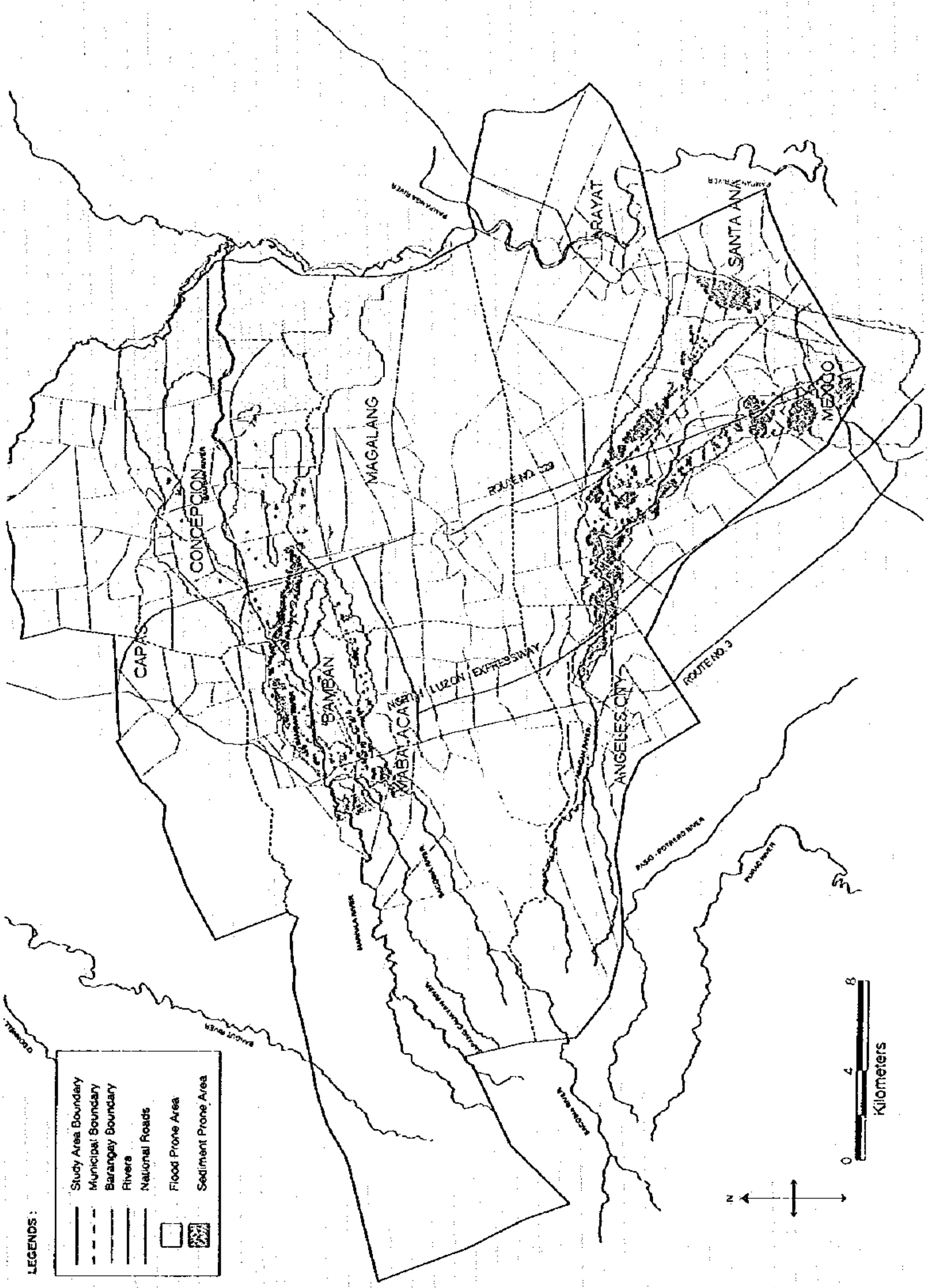

Figure 7.9 Hazard Map due to 100-year Flood

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CHAPTER 8

STRUCTURAL MEASURES IN SACOBIA-BAMBAN RIVER BASIN

CHAPTER 8 STRUCTURAL MEASURE IN SACOBIA-BAMBAN RIVER BASIN

8.1 PRESENT CONDITION

It is expected that the volume of sediment to be delivered from the pyroclastic field would be decreased by 40-50% every year to a certain level of the pre-eruption condition in the Sacobia river basin. The likelihood of re-capture of the headwater of Pasig River to the Sacobia River is apparently low within a decade. A large part of pyroclastic materials has been already eroded in the valley of the Sacobia River and remaining materials are deposited mostly on terraces and hills with relatively gentler topography. In the Marimla and Sapang Cauayan river basins, pyroclastic materials are scarcely remained and the river water contains a small proportion of sediment as the basins are well covered by vegetation.

There are about 110 million m^3 of sediment deposits in the valley upstream of Route 3 between Mactan and Maskup, while 100 million m^3 in sand pocket area between Routes 3 and 329 and in-channel deposition of 25 million m^3 in the upstream of San Francisco Bridge along Bamban river channel. These sediment deposits is remobilized by rapid currents and heavy rain drops, and transported further downstream. Although sediments from the headwater could be significant during a next few years, the major problem of the Sacobia-Bamban river basin might be the remobilization of sediment transported by flood waters.

The most critical problem in the Bamban River at present is the safety of the San Francisco Bridge. The clearance of the San Francisco Bridge is about 70 cm on an average in October 1995. The flood flowing capacity of the river at the bridge would be about 200 m^3/s which is equivalent to a moderate flood peak discharge of the Bamban River alone (20 cm of allowance is taken for waves). If the flood runoff is blocked by the bridge, there is a high risk that not only the bridge would be destroyed but also the blocked flood water would overtop or breach the dikes just upstream of the bridge.

Although the construction of a new bridge having 5 m clearance has just started at 30 m upstream of the existing bridge in October 1995, the new bridge would be serviceable in 1997. Thus, in the 1996 rainy season, sediment retention works will be required in the basin to obtain necessary flood flowing capacity.

When the sediment supply would become stable at a level of pre-eruption condition, the Sacobia River could be confined in a river channel of appropriate width of some 150 m and be joined with the Bamban River at the same elevation without any control structures. The sand pocket area could be utilized for productive purposes and the Route 3 would be restored.

Through the discussions above, it has been cleared that

1) The Sacobia River should not be diverted back to the Bamban River in 1996. It should be drained into the Sapang Balen River or other small creeks safely before the completion of the new San Francisco Bridge.

2) It is the most critical work that the Sapang Balen River is rehabilitated to have a sufficient flow capacity and to maintain the riverbed elevation by desilting works.

3) The sediment delivered from upstream reaches of the Sacobia River should be retained and stabilized in the sand pocket by structural measures to be provided upstream of Route 329.

4) Remobilization of the sediment deposits in the upper reaches of the Sacobia -Bamban River should be minimized.

5) The Sacobia River should be diverted back to the Bamban River at an appropriate location upstream of the San Francisco Bridge when the sediment supply from the Sacobia River is diminished to a certain level allowable for the desilting works in the Bamban River.

Based on the above consideration, the flood and mudflow control plan was formulated as a stepwise plan in accordance with the changes in natural conditions and the estimate of sediment balance resulted from actions taken. The plan also should clarify the procedure of implementation and the future prospect of the affected area.

8.2 ASSESSMENT OF PLANNING SCALE

The benefit to be accrued from the implementation of the Project was defined in this Study as the reduction of the direct and indirect damages caused by flood/mudflow. The probable direct and indirect damages were estimated under the without-project conditions at the end of 1994. The damage under the with-project conditions were assumed to be zero under the design flood of specified return period. Thus the project benefit constitutes the probable damage to be occurred by the flood of the designed scale.

The probable damage value for building, agricultural crops and infrastructures was computed based on the percentage of the affected area to the total barangay area. The average annual direct damage was obtained for each river after aggregating each property damage and is tabulated in Figure 8.1. Judging from the gradient of the curves shown under the above mentioned tables, the return period of 20 years can be said reasonable for the planning scale of structures because that the incremental ratio of direct damage is not in direct proportion beyond the scale of 20-year return period.

8.3 POSSIBLE STRUCTURAL MEASURE

8.3.1 Sediment Source Zone

1) Revegetation

Seeding/planting of suitable vegetation on the pyroclastic flow deposit fields is one of the effective method not only to avoid an excessive sediment yield due to sheet and gully/rill development but also to contribute the environmental conservation of mountain slope. The appropriate species for this purpose are characterized by robust perennial with vigorous rhizome and an extensive root system. Since the pyroclastic flow deposit is reported to be as hot as 500°C even in the year of 2000, the revegetation would be effective when the pyroclastic flow deposit fields become cool. The satellite images were analyzed in order to evaluate the rate of spreading growth of plant in centrifugal pattern on the pyroclastic flow deposit fields.

2) Simple Sabo Dam

A series of small-scale sabo dam at downstream end of tributaries would be effective in controlling the sediment yield from tributaries in the pyroclastic flow deposit fields. However, the construction works of these structures may involve some risks even in dry season, and the sediment control effect might be small comparing with the volume of secondary erosion in the middle stream of the Sacobia River.

8.3.2 Sediment Deposition/Secondary Erosion Zone

1) Sand Pocket

The construction of sand pocket structures was almost completed immediately after the onset of rainy season in 1994. Although a part of sandbagging dike system was washed out by flooding, the sand pocket structures functioned well to store the sediment inflow of 10 million m^3. On the other hand, the incomplete first (downstream end) row of lateral open dike, which was unable to construct in 1994 since the rainy season in 1994 has begun earlier than usual, resulted in the siltation of downstream channel of sand pocket structures. During flooding in August to September, the flood water breached the dike near Navaling due to insufficient flow capacity. About 110 ha of paddy field was affected by siltation.

Through the observation and monitoring carried out by the Study Team in 1994, the following structures are also required to ensure the safety against flood/mudflow:

a) Slope protection work of closing dike of sand pocket structures,
b) A series of lateral groundsill in sand pocket area to trap a sediment,
c) A sump to trap fine particle immediately upstream of Route 329, and
d) Channeling works and maintenance excavation of the Sapang Balen River

2) Sabo Dam

Two (2) sabo dams were constructed in the Sacobia River for the period of November 1991 to March 1992. When a large secondary explosion had caused the aggradation of about 5 m in the Sacobia River, sabo dan No.1 was completely buried and sabo dam No.2 was filled to the brim. Although these sabo dams continued to store the remarkable volume of unstable sediment, these dams were completely washed out by lahar in 1993 because of lack of maintenance works and erosion of downstream face. The reconstruction of sabo dam at Mactan may be preferable to store the sediment. However, the storage capacity of the dam is estimated at 100,000 m^3 only which is equivalent to only 25 % of total sediment volume in the rainy season of 1995 in case of sabo dam with 10 m high. The reconstruction cost is estimated at 33 million Pesos which is not economically viable when it is compared with the cost of excavation works in the downstream reaches.

3) Consolidation Dam

A consolidation dam is effective in stabilizing in-channel deposition and also control sediment discharge to the downstream reach. The most suitable site for consolidation dam is located in the vicinity of Maskup where the Sacobia River forms narrow river channel. At present, sediment deposition of 80 million m^3 was stored in the spindle-shaped valley between Mactan and Maskup, and a remarkable sediment deposit will be eroded in the successive years. Therefore, the consolidation dam at Maskup is inevitable as a part of the overall sediment control system and restoration of Route 3 Highway between Mabalacat and Bamban. Furthermore, in order to construct a new bridge of the Route 3 Highway astride the river channel, a consolidation dam at Dolores site may be essential. On the other hand, a series of consolidation dams can be constructed so as to stabilize accumulated sediment in the spindle shaped valley. Although a series of consolidation dams are effective against secondary erosion, the construction cost may be costly.

4) Bed Girdle

A remarkable in-channel deposition still remains in the upper reaches of the Bamban River. The secondary erosion and re-deposition will occur repeatedly in the lower reach of the Bamban River. A series of bed girdles is the one of alternatives to regulate the secondary erosion of in-channel deposition. In 1995, the most critical problems in the Bamban River was the diminishing of freeboard at San Francisco Bridge. A series of groundsill in the upper reaches of the Bamban River would be effective in regulating the riverbed aggradation.

5) Training Works

As far as the Sacobia River flows into the sand pocket area, water channeling in the downstream reach from the sand pocket structures is required to ensure the safety for releasing flood water to the downstream reach.

On the other hand, the Sacobia River is expected to join with the Bamban River when the river water of Sacobia River does not contain much sediment and sand pocket structures had performed their role. Channeling works with protective dike system along the Sacobia River will be required for the reach from Maskup down to the confluence with the Bamban River.

6) Channel Excavation Works

The riverbed tends to aggradate gradually in the sediment deposition/secondary erosion zone as well as in the sediment conveyance zone. Annual excavation of the river channel is required to maintain the riverbed elevation to equal or less than to the existing one.

8.3.3 Sediment Conveyance Zone

1) Dike

Dike system in the lower reaches of the Bamban River for a stretch of 8 km from the confluence of the Rio Chico River was constructed before the eruption. The dike was made of clay soil with grass/shrub cover. On the other hand, in the upper portion of the Bamban River, the old dike system was completely damaged during lahar events in 1991. A newly constructed dike made of sandy lahar materials always suffered from lateral erosion by flood water during rainy season. Thus, the dike in the upper portionof the Bamban River shall be covered at least with mountain soil for slope protection.

2) Spur Dike/Groin

A spur dike/groin is placed at approximately right angle to the bank to control flow direction towards a center of the channel. A series of spur dike/groin is required to be placed at the meandering part to reduce the flow velocity along the dike.

3) Channel Excavation

Channel excavation is required to protect the dike system. Excavated materials will be placed to the spoil banks which is located at the left bank of the lower Bamban River.

Table 8.1 shows the summary of the evaluation of possible structural measures.

8.4 PHASED DEVELOPMENT PLAN OF STRUCTURAL MEASURES

8.4.1 SHORT TERM PLAN

The construction of sand pocket structures was almost completed immediately after the onset of rainy season in 1994. Although a part of sandbagging dike system was washed out by flooding, the sand pocket structures functioned well to store the sediment inflow of 10 million m^3. On the other hand, the incomplete first (downstream end) row of lateral open dike, which was unable to construct in 1994 since the rainy season in 1994 has begun earlier than usual, resulted in the siltation of downstream channel of sand pocket structures. Through the observation and monitoring carried out by the Study Team in 1994, the following structures are also required to ensure the safety against flood/mudflow:

a) Slope protection work of closing dike of sand pocket structures,
b) A series of lateral groundsill in sand pocket area to trap a sediment, and
c) Channeling works and maintenance excavation of the Sapang Balen River

The expected functions of the sand pocket are protection from secondary erosion of deposited lahars and retention of sediment inflow and prevention of dispersing sediment in the low-lying area. The effects of proposed control structures in sand pocket were examined under 1994 topographic conditions for the 20-year flood. As the control structures, separation dikes between Sacobia and Bamban rivers, lateral dikes in lower end of sand pocket, and Route 329 elevated by 3 meters and collect canals are considered. The flood flows in sand pocket were well drained into the Sapang Balen River and sediment materials were trapped at the lower lateral dike and sump as shown in Figure 8.2. Most of sediment deposits were deposited in upper part of the sand pocket. It means that sediment materials will not be transported downstream by a single flood event although it might be gradually transported by normal flows.

The sediment deposit is obvious in the upper half of the sand pocket as well as north east corner of the sand pocket. According to this long term changes and flow conditions due to the probable floods, major flood flow in the sand pocket would run along the separation dike between the sand pocket and the Bamban River. Reinforcement of the dikes along the possible water way should be considered as a part of Short Term Plan. In particular, road dike on Route 329 and a series of lateral dike are essential to ensure the safety for flood and sedimentation. However, the numbers of lateral dikes and its structure may be elaborated in accordance with the acual geomorphologic changes in the downstream end of sand pocket area and future agricultural land use of sand pocket area.

8.4.2 MEDIUM TERM PLAN

After completion of the structural measures proposed in the short term plan in 1997, the sediment supply from the Sacobia River will be maintained within the allowable amount to the Bamban River because of natural reduction of sediment yield in the pyroclastic flow field. Then, the situation of sediment balance will create some choices for the future improvement/development. The following are expected as issues to be solved in this period.

- Stabilization of riverbed covered with accumulated sediment and braiding river course
- Restoration of Highway Route 3 with bridges
- Restoration of lahar-affected area confined by existing dike system

These issues are crucial because they have to be linked tightly with the future development program, namely the long term plan. However, there will still be a considerable amount of transported sediment to the lower reaches of the Bamban River due to re-erosion of deposited sediment, in particular, in the spindle-shaped valley between Maskup and Mactan, and in the upstream channel of the Bamban River. Installation of sediment control facilities targeting these sediment accumulated areas is indispensable for realizing the restoration works mentioned above. The alternatives to be considered are composed of the places to plan the expected control structures and restoration work. The following are possible alternatives under the conditions created through execution of the short term plan, and Figure 8.3 illustrates the structural measures taken in each alternative.

a) Alternative-1 : Permanent use of sand pocket without restoration works

b) Alternative-2 : Provisional use of sand pocket and construction of Maskup and Dolores consolidation dams

c) Alternative-3 : Provisional use of sand pocket, construction of Dolores consolidation dam and series of consolidation dams between Mactan and Maskup

d) Alternative-4 : Provisional use of sand pocket, construction of Maskup and Dolores consolidation dams and Upper Bamban bed girdles

After the completion of structural measures in Alternatives , the annual excavation/ dredging works of 1.5 million m^3 until the year of 2000 for Alternatives 1, 2 and 3 and until the year of 1998 for Alternative 4 are required to maintain the riverbed elevation of the Bamban River.

Each alternative is usually evaluated on the basis of effectiveness of technical performance, social effects and economic efficiency. In this section, the evaluation of alternatives is executed focusing on effectiveness of technical performance. The following evaluation is summarized in Table 8.2.

a) Alternative 1

The expected functions of Alternative 1 are to retain sediment outflow from the Sacobia River and to stabilize the accumulated deposits to avoid dispersion of re-eroded sediment to the low-lying areas. The main source of sediment to be trapped by the sand pocket will be the valley between Mactan and Maskup where the volume of some 80 million m^3 has accumulated during serious lahar events in 1991 to 1993. Re-eroded sediment of some 3 to 4 million m^3 per year in this valley will continue to be transported into the sand pocket for a long period. Thus, the sand pocket has to be maintained continuously until the river course in the valley forms a stable channel.

The Sapang Balen River will encounter flooding and siltation problems because of muddy flood water from the Sacobia River in every rainy season, therefore, upgrading its flow capacity to 20-year flood is crucial for the protection of low-lying areas. The river channel has to be maintained through excavation/dredging of deposited sediment as well as construction of dikes and slope protection works.

Although Alternative 1 is composed of relatively simple and economical structural measures, continuous maintenance works such as excavation/ dredging and repair/extension of the sand pocket structures is inevitable to sustain the sediment retention and flood control functions for a long time. Furthermore, there is no chance for restoration of Highway Route 3 and the sand pocket area until the riverbed in the valley between Mactan and Maskup becomes naturally stable.

b) Alternative 2

Alternative 2 will solve the problem indicated by Alternative 1 through construction of Maskup and Dolores consolidation dams to partially stabilize the riverbed at the end of the valley between Mactan and Maskup. As the results of separation of the Sacobia River from the sand pocket area and stabilization of its channel by river training works, restoration work of Highway Route 3 and the affected area confined in the dike system can be started in 1999 at the earliest.

Excavation/dredging of 1.5 million m^3 per year still has to continue until the riverbeds of the Upper Bamban River and the valley become stable. Thus, continuous monitoring of sediment movement over the Sacobia-Bamban River basin is indispensable for judgment of appropriate direction to be taken by year.

c) Alternative 3

The main target area of Alternative 3 is the valley between Mactan and Maskup, where lahar flow accumulated sediment of 10 to 15 m in depth for the period of 1991 to 1993. Although a series of consolidation dams will firmly stabilize sediment deposits, the foundation of those dams will be placed on the erodible loose lahar materials, so that subsidence of dam body is expected due to heavy scouring of the front side, seepage, and piping beneath the dam body. Therefore, careful monitoring during heavy rains shall be executed to avoid a man-made disaster caused by collapse of the consolidation dam, since there are still uncertainties of the structural reliability between loose foundation and dam body.

Regarding excavation/dredging, the volume of 1.5 million m^3 also has to be excavated annually even though a series of consolidation dams are completed and firmly stabilize the riverbed of the valley because a remarkable volume of deposited sediment will be eroded from the Upper Bamban River channel. Thus, Alternative 3 can be placed at a lower priority compared with Alternative 2.

d) Alternative 4

The main target area of Alternative 4 is the in-channel area of the Upper Bamban River, where the volume of some 23 million m^3 hass accumulated during lahar events of 1991 to 1993. A series of bed girdles is effective to accelerate the formation of low-water channel and simultaneously stabilize the erodible sediment deposits. Furthermore, bed girdle is a low-height structure so that the side effects of scouring, piping and seepage can be held at the minimum.

Annual excavation/dredging volume will be reduced to 1.0 million m^3 due to stabilization of the riverbed. Compared with Alternative 2, both alternatives are preferable as optimum plan. The selection of the optimum plan shall be based on social and economic evaluation.

Four(4) alternative schemes are formulated in the Sacobia/Bamban Rivers according to the various component of the flood/mudflow control structures. The construction cost was estimated on the basis of the following preconditions:

a) the base period of cost estimate was set at the end of 1994
b) the exchange rates were assumed at US$ 1=Peso 25=Y 100
c) the estimate excludes tax and duties
d) the estimate does not include the price contingency for the future
e) the administration cost was estimated at 5% of the main construction cost
f) the physical contingency cost, administration cost and engineering servicescost were estimated at 25% of the main construction cost.

The reclamation cost of the sand pocket is not included in any alternative schemes because the cultivation of the lahar affected farm land is not deemed feasible at the present stage of the Study yet. The cost for desilting works were treated as the maintenance cost and scheduled to be disbursed in for nine (9) years for Sacobia/Bamban starting from the initial stage of the construction. The operation and maintenance costs of each alternatives were estimated at 0.5% of the total of the main construction cost. The financial cost of all alternatives are summarized in Table 8.3.

8.4.3 LONG TERM PLAN

(1) Agricultural Development Plan

1) Urgent Restoration Program

This may be considered as an urgent restoration program by the Local Government Unit (LGU) with coordinate to the Provincial Irrigation office under the NIA to restore and improve the agricultural production in the Study Area by rehabilitating all CIS which are still rehabitable and where protective measures to stave-off further damages due to lahar flow have already been in-place and/or can be easily installed. There are about 9 existing irrigation systems/projects within Tarlac province which are not directly affected by lahar flow. These systems/projects were damaged mainly due to increase in siltation brought about by ashfall and flush flood within their watersheds. Urgent restoration in nine (9) systems is necessary in order to attain crop production before the eruption.

	Name of Municipality	No. of CIS/CIP	Area (ha)
a.	Bamban	1	400
b.	Capas	2	702
c.	Concepcion	6	40,330
	Total	9	41,432

In Pampanga province, there are 22 existing irrigation systems/projects which are not directly affected by lahar flow. These systems/projects were damaged mainly due to increase in siltation brought about by ashfall and flood within their watersheds. Urgent restoration works for these 22 systems are also necessary in order to attain crop production before the eruption.

	Name of Municipality	No. of CIS/CIP	Area (ha)
a.	Angeles	1	120
b.	Mabalacat	3	303
c.	Magalang	3	136
g.	Arayat	7	782
i.	Mexico	1	180
j.	San Fernando	2	84
k.	Sta. Ana	1	28
l.	Candaba	3	754
o.	San Luis	1	206
	Total	22	2,593

The Selection Criteria in identifying the priority CIS/CIP for Urgent Restoration Program which are affected by Mt. Pinatubo eruption are as follows:

a) Systems that were programmed and/or on-going for rehabilitation prior to eruption but suspended/stopped due to the eruption,

b) Projects that were programmed and/or on-going but were stopped indefinitely due to the eruption, and

c) Systems/projects that had already availed of rehabilitation funds (RAAMPE, CARP-IC or MPC) but still need further rehabilitation/ restoration due to continuos flow of lahar or sediments caused by ashfall.

List of Priority CIS/CIP for Urgent Restoration Works in Tarlac Province and Pampanga Province is shown in Figure 8.4 and Table 8.4.

2) Restoration and Rehabilitation Project

A total of 6,240 ha of 9 existing irrigation systems/projects along Sacobia-Bamban and Abacan rivers was directory affected by lahar and mudflow. This systems/projects were damaged mainly due to increase in siltation brought by ashfall and flush flood within watersheds. In 1995, these areas are already safe from further lahar attack with the completion of both left bank/dike (with lining) and right bank/dike of the Bamban River. They would be safer because of the diversion of the Sacobia River to the Bamban River, while the flood flow is confined by diking system in the Abacan River.

In the areas where damage was minimal, farmers harnessed available rainfall and plain run-off including shallow well pumps for irrigation water supplement specially during scarce rainfall.

Location of proposed CIS/CIP for restoration and rehabilitation project is shown in Figures 8.5 to 8.7. The project description of proposed restoration and rehabilitation project for agricultural facilities in lahar and mudflow affected area are mentioned in Table 8.5, and typical section of proposed diversion dam is shown in Figure 8.8. However, due to insufficient hydrological data, it is recommended that further study be undertaken to ascertain water availability to meet irrigation requirement for the proposed development scheme. The principal features of the projects are enumerated below:

Description	Location (Municipality)	Irrigation Area	Water Source	Type /No of Intake
Sacobia-Bamban River Basin Area:		(ha)		
Bamban C.I.S.	Bamban	850	Bamban river	Ogree (1)
San Pedro C.I.S.	Bamban	130	Bamban river	- same -
Bangcu C.I.S.	Bamban	650	Bamban river	- same -
Magao C.I.S.	Concepcion	690	Lucung river	Checkgate (2)
San Vicente C.I.P.	Concepcion	810	Bamban river	Ogree (1)
San Bartolome C.I.S.	Concepcion	830	Sapang Balen creek	Checkgate (2)
San Isidro C.I.S.	Concepcion	650	Dalandanum creek	Checkgate (1)
Balutu C.I.S.	Concepcion	100	Parua Creek	Checkgate (1)
Calius Gueco C.I.P.	Concepcion	370	Balen creek	Checkgate (1)
Sub-total		5,080		
Abacan River Basin Area:				
San Juan C.I.P.	Mexico	460	Abacan river	Ogree (1)
San Patricio C.I.P.	Mexico	460	Abacan river	Ogree (1)
San Joaquin C.I.P.	Santa Ana	240	Joaquin creek	Checkgate (1)
Sub-total		1,160		
Total		6,240		

Source : These figures are estimated by GIS based on 1/10,000 (1994) of topographic maps.

Another alternative is an extensive groundwater irrigation due to the following reasons:

a) the area is already safe from lahar due to the construction of lahar/mudflow control infrastructure facilities,

b) the area is extensively planted with crops even with deficient irrigation facilities, and

c) in order to alleviate the living condition of the farmers and bring Government closer to the lahar affected families.

3) Santa Rita Pilot Agricultural Development Project

A Santa Rita pilot project located Concepcion in Tarlac province is being demonstrated an integrated agricultural development which is composed of restoration of agricultural facilities, land reclamation, resettlement works, construction of roads and others. Beside, a pilot demonstration farm to be established in the Santa Rita CIP area is envisioned to conduct experiments to determine suitable crops on lahar heavy covered areas of 1.5 to 2.5 m deep. It is also aimed to encourage lahar affected farmers to plant suitable crops based on the result of the crop experimental works. The selection criteria in identifying areas for the pilot demonstration farm are as follows:

a. Systems or areas which are of run-off-the-river type either partially or wholly covered with lahar but have strong potential for agricultural development,

b. Areas that are already safe from lahar flow where protective infrastructure has already been in-place, and

c. Areas were agricultural activities has resumed despite of deficient agricultural infrastructures.

The Project description is given in Table 8.5 and Figure 8.6, and summarized as follow.

- Location : Santa Rita, Concepcion, Tarlac province

- Potential Irrigation Area

present condition	:	non-cultivated by 1 to 2 m depth of lahar
future condition	:	200 ha of paddy field
		120 ha of upland crops field
		130 ha of agro-frustration field
		450 ha of total irrigated area

- Total Area : 560 ha (30 ha of build-up area)

- Water Source : Bamban River, an Ogree type of intake

4) Integrated Land and Agricultural Development Project in Lahar Disaster Area

Although the Bamban-Concepcion sand pocket area is being utilized as sediment catch basin for the Sacobia River, the area will be safe against flood and mudflow after diverting the Sacobia River in 1997. The proposed projects of 2,090 ha in total are organized into the following three (3) CIPs. The source of irrigation water wil be ensured by the diversion structure of the ogee-type in Sacobia and Bamban rivers. The Tabun and Maskup CIPs have a potential irrigable area of about 1,540 ha where lahar deposits is expected to be very deep. A portion of the proposed Marita CIP area, which was not damaged and/or covered with lahar of about 210 ha is being planted with rice through available rainfall and supplemental groundwater by shallow well pumps. The principal features of the projects are given in Table 8.5 and typical layout is shown in Figure 8.9, and summarized as follow.

(Unit : ha)

Description	Location (Municipality)	Total Area	Potential Irrigation Area		
			Paddy	Upland Crops	Agro-Forest
Sacobia-Bamban River Basin Area :					
Tabun C.I.P.	Mabalacat	220	0	100	120
Mascup C.I.P.	Mabalacat, Bamban	1,320	0	500	820
Marita C.I.P.	Concepcion	550	210	170	170
	Total	2,090	210	770	1,110

Source : These figures are estimated by GIS based on 1/10,000 (1994) of topographic maps.

The proposed cropping pattern and farming technology including the type of crops to be used in the proposed project will be based on the result and recommendation of the proposed crop experimental works by the Santa Rita Pilot Project.

5) Implementation Schedule of the Project

The agricultural development project is organized into the following phased categories which include i) short term plan to be carried out for the period from 1995 to 1998 by the Local Government Unit (LGU), ii) medium term plan which is composed of future study and design and construction works for restoration and rehabilitation project and iii) long term plan which is composed of future study, design and construction works for the land and agricultural development project in the heavy lahar affected areas. The following phased development is recommended in accordance with implementation schedule is given in Table 8.6.

a) First Phase : Short Term Plan for Agricultural Development

Restoration and Rehabilitation Program

a. 5,135 ha irrigation service area of 9 CISs/CIPs in Tarlac province
b. 7,730 ha irrigation service area of 22 CISs/CIPs in Pampanga province

b) Second Phase : Medium Term Plan for Agricultural Development

Restoration and Rehabilitation Project

a. 1,810 ha irrigation service area of 4 CISs/CIPs in Sacobia-Bamban river basin area
b. 960 ha irrigation service area of 3 CIPs in Abacan river basin area

Santa Rita Pilot Agricultural Development Project

a. 450 ha irrigation area of Santa Rita CIP, Concepcion
b. 560 ha of land reclamation area

c) Third Phase ; Long Term Plan for Agricultural Development

Restoration and Rehabilitation Project

a. 3,270 ha irrigation service area of 4 CISs/CIPs in Sacobia-Bamban river basin area

Land and Agricultural Development Project

a. 2,090 ha irrigation area of 3 CIPs in Sacobia-Bamban river basin
b. 2,650 ha of land reclamation area

(2) Road Network Development

1) Present Road Network

The Study Area is located at one of the most important parts to sustain the transportation system in the Central Luzon. Major trunk lines are organized into the north-south vital link such as North Luzon Expressway, Manila North Road (MacArthur Highway : Route 3) and Magalang-Concepcion Road (Route 329).

North Luzon Expressway provides toll motorway services between Metro Manila and Pampanga Province. The section between Metro Manila (Balintawak) and Valenzuela of 5.84 km long is organized into a north-bound 3-lane and a south-bound 2-lane carriageways. The section between Valenzuela and San Fernando of 50.4 km long has 4-lane for both directions, while those between San Fernando and Sta.Ines has been used as a temporary extension of 22.9 km long with 2-lane for both directions. Traffic growth on the North Luzon Expressway shows the annual growth rate of 1.9 % annum. According to the traffic volume data for a week from July 16 to July 24, 1995, the daily traffic volume at Dau is counted at 8,000 vehicles of which 60 % traffic volume bound for Balintawak.

Manila North Road (Route No.3 : MacArthor Highway) connects between Manila and Rasario, through San Fernando, Angeles City and Tarlac. The Abacan Bridge across the Abacan River in Angeles City was collapsed due to lahar avalanche immediately after the eruption of Mt.Pinatubo in 1991. The bridge was reconstructed in 1992. However, the segment between Mabalacat and Bamban of 3 km long was covered by lahar deposits and the all type of vehicles are unpassable during flooding period although the DPWH has embanked lahar materials every dry season for temporary road.

Route 329 (Magalang - Concepcion Highway) takes the most important role as a vital link between North Luzon and Metro Manila since the Manila North Road was buried with lahar after the eruption of Mt.Pinatubo in 1991. The traffic volume data counted for a week on July 16 to 24 in 1995 by the Study Team shows that 13,000 vehicles/day are passing through the San Francisco Bridge as shown in Figures 8.10 and 8.11. However, the section was designed as 2-lane for both directions and the traffic jam is experienced everyday at the junction of Magalan. Furthermore, the present road surface elevation is almost equivalent to the surface elevation at downstream end of sand pocket. All type of vehicles are unpassable during the flooding period.

The San Francisco Bridge on Route 329 astride the Bamban River at Concepcion is under the critical condition in 1995. Its freeboard was at 72 cm on October 10, 1995. The DPWH commenced the reconstruction works of New San Francisco Bridge at 30 m upstream of existing bridge. The clearlance is planned to be about 5 m above existing one.

2) Extension of North Luzon Expressway

The Project is introduced in the "Integrated Plan for the Mt.Pinatubo-Affected Areas " (MPC,1994). It aims to improve the capacity of the existing North Luzon Expressway and to provide a direct access route to Clark Special Economic Zone and the provinces of Tarlac and Pangasinan.

The Base Conversion and Development Authority (BCDA) designates the Clark Special Economic Zone as the future site for a premier international airport. Recently, the President agreed on the parallel development of the Clark

International Airport and the new international terminal building at the Ninoy Aquino International Airport (NAIA).

In the Central Luzon Regional Development Study (JICA, 1995) also gives the priority of the extension of North Luzon Expressway acrossing the Sacobia-Bamban River including a direct access to Clark.

The Project is organized into four (4) segments; these area, (i) Segment-1:Balintawak to Tabang (25 km), (ii) Segment-2: Burol to Sta.Ines (55 km), (iii) Segment-3: Dau to Bamban (10 km) and (iv) Segment-4 : Bamban to Rosales (82 km).

Among the segments, the segment-3 would traverse directly in the Study Area. An alternative route between Dau and Bamban is, therefore, delineated preliminarily taking into account the future development plan of Clark Special Economic Zone as shown in Figure 8.12.

a) Alternative-1 : Extension from Dau through Clark Special Economic Zone

An alternative route given the priority of accessibility to Clark International Airport. The expressway bifurcates at Dau to Clark and extends to north to Tarlac. The alternative involves the construction of a 400-m bridge across the Sacobia River and a 300-m bridge across the Bamban River.

b) Alternative-2 : Extension of Existing North Luzon Expressway

An alternative route given the priority of present alignment of the North Luzon Expressway. The expressway extends to north to Tarlac. The alternative also involves the construction of a 300-m bridge across the Sacobia River and a 300-m bridge across the Bamban River. The interchange is planned at Dau for the access to the Clark.

c) Alternative-3 : Extension from Dau to North

An alternative route given the priority of shortest alignment between Dau and Tarlac. The expressway bifurcates at Dau and extends to north to Tarlac. The alternative also involves the construction of a 800-m bridge across the Bamban River. The interchange is also planned at Dau for the access to the Clark.

Table 8.7 shows that the construction cost of Alternative-1 is estimated at two times that of Alternative-2.

(3) Tourism

Damming of Marimla and Sapang Cauayan rivers by the aggradation of the Sacobia River has led to the intermittent formation of lakes as shown in Figure 8.13. Although the damming of Marimla River was breached in 1991, the dammed lake at Sapang Cauayan River still remains with a storage of 7 million m^3 at El. 90 m. When the safety of the climbing Mt.Pinatubo is assured, then a volcano tourism with a sight-seeing network linking the mountains and lakes will become popular in this area. The water quality satisfy the criteria adopted by the Government of the Philippines.However, the dammed lake exists temporarily and will be smaller year by year because of the erosion of the lake outlet. The permanent structure such as consolidation weir might be required at the lake outlet in order to maintain the surface water level of lake. The land aquisition for the land submerged into the lake where many tillers cultivated their farm land before eruption will be required when the consolidation weir is constructed as permanent structure.