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JAPAN INTERNATIONAL COOPERATION AGENCY

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

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

MAIN REPORT

May 1996

NIPPON KOEI Co., Ltd., Tokyo Japan
in association with
CTI ENGINEERING Co., Ltd., Tokyo Japan

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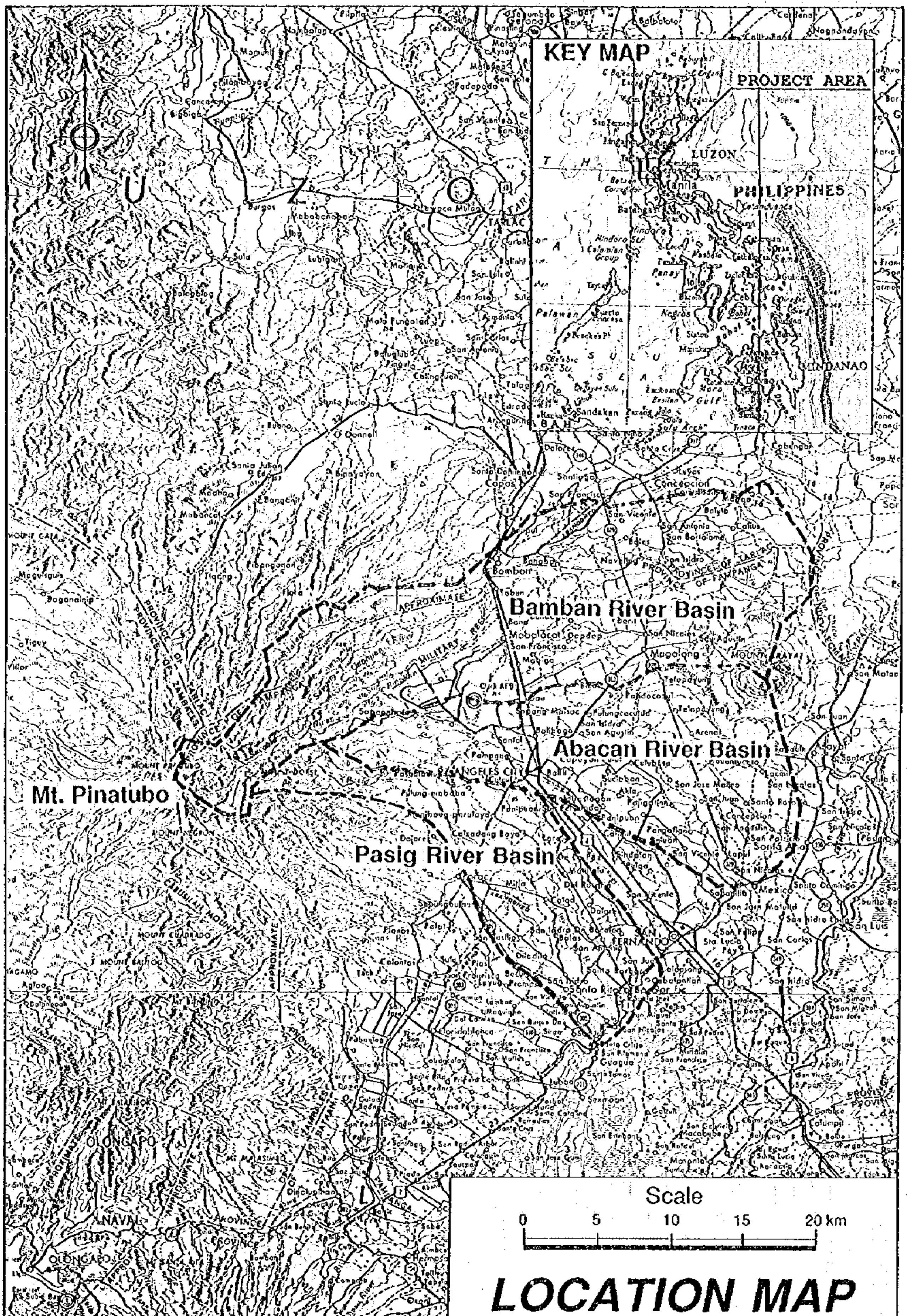
Remarks : The cost estimate in this Study was based on the November 1995 price level, and expressed in Philippine Pesos equivalent according to the exchange rate Philippine Peso 25.0 = Japanese Yen 100.0 (= US dollars 1.0) prevailing at that time.



LOCATION MAP

ABSTRACT

1. BACKGROUND

The June 15, 1991 eruption of Mt.Pinatubo, one of the largest eruption of the century, produced remarkable volume of pyroclastic flow and ash fall deposits. The pyroclastic flow deposits covered thousands of square kilometers and the volume was estimated at 6.7 billion cubic meters on the slopes of Mt.Pinatubo. Lahar generated by heavy rain falling on erosive pyroclastic flow deposits pose continuing and grave danger to human lives and property in the low-lying areas. Among the major rivers surrounding Mt.Pinatubo, the Sacobia-Bamban and Abacan rivers possess a great danger to the outlying areas, where Angeles City and Clark Field are located. The Government of the Philippines (GOP) requested the Government of Japan (GOJ) for technical cooperation to prepare a master plan on flood and mudflow control in the Sacobia-Bamban and Abacan river systems.

2. OBJECTIVES

The objectives of the technical cooperation are:

(1) to formulate a Master Plan for flood and mudflow control works in the Sacobia-Bamban and Abacan river basins and to carry out the Feasibility Study for the priority schemes identified in the Master Plan, and

(2) to transfer relevant planning and designing technologies to GOP's counterpart in the course of the Study.

As the Study progressed, the upper reach of the Sacobia River was annexed to the Pasig River in October 1993. In response to the request from the GOP in March 1995, the Japan International Cooperation Agency (JICA) agreed to include the monitoring of geomorphologic changes of the Pasig river basin into the scope of work of the technical cooperation in 1995.

3. STUDY AREA

The Study Area is Sacobia-Bamban, Abacan and Pasig river basins which drain from the eastern slope of Mt.Pinatubo. The Sacobia-Bamban river system traverses the east-northern sectors of Mt.Pinatubo. This river system is composed of four major tributaries, Sacobia, Marimla, Sapang Cauayan and Sapang Balen rivers. These rivers drained an aggregate of 245.1 square kilometers of watershed on the eastern slopes of Mt.Pinatubo. On the alluvial plains, the Bamban River formed a braided characteristics and it approached the Rio Chico River to the east.

The headwater tributaries of Abacan River originate at the mid-slope of Mt.Pinatubo. These headwater tributaries are the Sapangbato and Taug (Sapangbayo) rivers. Both flow eastward and dovetails with Abacan River at Angeles City. The Abacan River system has a total catchment area of 77.2 square kilometers. On the alluvial plain, the Abacan River flows eastward past Angeles City and then it slowly curves southeastwards.

Since the headwaters of the Sacobia River was annexed to the Pasig River in October 1993, tremendous volume of lahar avalanched to the downstream reach. In 1995, the upper stretch down to Angeles-Porac Road functioned as an area of sediment production, transport and deposition. The river channel of this stretch was incised into a gently sloping alluvial fan consisting primarily of pre-1991 lahar and alluvial deposits. While in the stretch from Angeles-Porac Road to Gapan-Olongapo Road, sediment deposition caused massive damage to farmlands and barangays. The Pasig River flows into the Pasac-Guagua River in the vast swamp of Pampanga Delta.

4. *MT.PINATUBO ERUPTION*

(1) 1991 Eruption

Mt.Pinatubo is surrounded by a highly dissected depositional apron of older pyroclastic flow, lahar, and associated stream deposits. According to the geological survey of the Philippine Institute of Volcanology and Seismology (PHIVOLCS) and the U.S. Geological Survey (USGS), older eruptive periods have been identified by ^{14}C dates on charcoal in pyroclastic flow deposits at about 2,500, 5,000 and 35,000 years ago. The last eruption has been dated at 460±30 years ago.

On June 15, 1991, after 400-500 years of dormancy, Mt.Pinatubo awoke with a climactic Plinian eruption. Mt.Pinatubo's summit was lowered from 1,745 meters to 1,449 meters. A caldera with a diameter of 2 kilometers and a summit crater of 600 meters deep were formed. Areas within the 40 kilometers radius danger zone of the Mt.Pinatubo bore the brunt of heavy ashfall. Pyroclastic flow deposit was estimated at about 6.7 billion cubic meters on the slope of Mt.Pinatubo. These hot deposits, as much as 220 meters thick in places, cover an area of about 120 square kilometers.

Lahar which were triggered by heavy monsoon or typhoon rainfalls on erosive erupted materials has been flowing into densely populated areas of central Luzon. For the past five years from 1991 to 1995, the most devastating lahar was generated during prolonged southwesterly monsoon rains that were induced by the passage of tropical typhoons in the vicinity of Luzon.

(2) Eastern Drainage

The total volume of pyroclastic flow deposits at eastern slope of Mt. Pinatubo where Sacobia-Bamban, Abacan and Pasig rivers originate were estimated at 1,420 million cubic meters. Of the volume, the pyroclastic flow deposits of about 950 million cubic meters (59.1%) remain in the upstream reach of the river basins as of November 1995.

The major piracies of river basins occurred a few times on the eastern slope of Mt. Pinatubo mainly due to secondary explosion. In October 1993, the relatively large-scale landslide which was triggered by secondary explosion had occurred in the pyroclastic flow deposits-filled valley. As a result, the Pasig River captured the upstream catchment of 23 square kilometers of the Sacobia River.

Lahar poses continuing and grave danger to human lives and property in low-lying area where possess a great danger to the outlying areas currently used for residential, commercial and industrial purposes. The lahar disaster areas in the eastern river basins of Mt.Pinatubo for the period from 1991 to 1995 are summarized below (Figure 1);

Lahar Disaster Area (Unit : ha)

River System	1991	1992	1993	1994	1995	Total
Sacobia-Bamban	8,125	2,183	1,267	118	60	11,753
	(150)	(80)	(65)	(8)	(4)	(307)
Abacan	2,930	0	0	0	0	2,930
	(50)	(0)	(0)	(0)	(0)	(50)
Pasig	3,700	600	500	3,000	1,900	9,700
	(50)	(40)	(55)	(130)	(45)	(320)
Total	14,755	2,783	1,767	3,118	1,960	24,383
	(250)	(120)	(120)	(138)	(49)	(677)

Note: Figures in parenthesis show the volume of lahar deposit from the pyroclastic flow deposit field in million cubic meters. The figures do not include the sediment volume due to secondary erosion.

5. *EXTENT OF DAMAGE*

The massive damage caused by the Mt. Pinatubo eruptions and the lahar flows that followed was placed at 10.6 billion Pesos at the end of 1991. The heaviest toll was on public infrastructure, including power, telecommunications, water supply systems and school and health facilities, estimated at 3.8 billion Pesos. Losses to agriculture was estimated at 1.8 billion Pesos; to commerce and industry, 851 million Pesos; and natural resources, 120 million Pesos.

The total cost for relief operations, evacuation and resettlement, rehabilitation and reconstruction was estimated at 30 billion Pesos. The cost of reconstruction and rehabilitation alone of vital infrastructure like roads, bridges and other facilities was placed at 9.5 billion Pesos.

About 489 kilometers of major national roads and 163 kilometers of municipal roads in Pampanga, Zambales, Bataan and Tarlac were covered under 20-40 centimeters of ash and sand. Six major bridges, namely Abacan, Pandan, Mancatian and Pabanlag in Pampanga, and Santa Fe and Umaya in Zambales collapsed immediately after eruption.

6. *SEDIMENT DELIVERY FORECAST*

(1) Sacobia-Bamban River

The annual sediment delivery rate in the eastern slope of Mt.Pinatubo from 1991 to 1995 shows no distinctive decay rate in the total sediment volume, in contrast that in the Sacobia River where sediment delivery rate are reduced rapidly after the river piracy by the Pasig River. The sediment yield for the period of 1995 to 1997 was forecast on the assumption that the annual rainfall is 2,500 millimeters on an average and the catchment area is constant as of 1994, while the erosion rate of 50 millimeters per annum was adopted to the estimation of lahar deposition after 1998. The monitored and forecast annual sediment yields in the Sacobia River are enumerated below:

Monitored and Forecast Sediment Yield in the Sacobia River (Unit : million m^3)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Volume	150.0	80.0	65.0	8.0	4.0	2.0	0.9	0.4	0.4	0.4

The surplus sedimentation due to the 1991 eruption may terminate in the rainy season in 1997 and the sediment yield after 1998 may be equivalent to the condition of pre-eruption.

(2) Abacan River

At the piracy point of Abacan and Sacobia rivers in 1992, so called as Abacan Gap, a small escarpment has caused a degradation of 30 meters in 1994 and has facilitated the piracy by the Sacobia River. No lahar flow occurred along the Abacan River ever since the piracy of the Sacobia River had occurred at Abacan Gap.

The volume of unstable sand in the upstream of Friendship Bridge are estimated at in-channel deposition of 2.2 million cubic meters and the storage by sabo dam of 1.5 million cubic meters. Assuming that the riverbed of upper reach from No.9 sabo dam would be stable, flood water will convey fine sand of about 40,000 cubic meters per annum which is mainly produced by surface erosion in upper catchment.

Also, a sediment volume of 3.5 million cubic meters remains in the river channel of 10 km long in the lower stretch. Sediment accumulation will continue in the succeeding years in this reach. Continuous excavation/dredging work is, therefore, necessary to mitigate flood damage and improve the drainage system in the low-lying areas.

(3) Pasig River

The annual sediment delivery rate in the Pasig River from 1991 to 1995 shows no distinctive decay rate in the total sediment volume as enumerated below:

Monitored and Forecast Sediment Yield in the Paasig River (Unit : million m^3)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Volume	50.0	40.0	55.0	130.0	45.0	47.0 (34.0)	34.0 (23.0)	25.0 (16.0)	18.0 (11.0)	13.0 (7.0)

Note : Figures in parenthesis show the lower forecast.

Before the onset of the 1996 rainy season, the remaining pyroclastic flow deposits is estimated at 430 million cubic meters. The sediment delivery of 34 to 47 million cubic meters from the source material and 21 to 41 million cubic meters by channel erosion are predicted for the 1996 rainy season. In total, 55 to 88 million cubic meters of sediment would be transported to the downstream reaches and bury the low-lying areas in case that proper countermeasures are not taken.

7. *POTENTIAL HAZARD AREA*

The purpose of hazard analysis was to assess the potential inundation area. 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, Abacan and Pasig rivers. 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. The potential inundation area was estimated at 14,300 ha for Bamban river basin, 7,700 ha for Abacan river basin and 17,600 ha for Pasig river basin as shown in Figure 2.

8. *PHASED DEVELOPMENT PLAN*

The master plan of mudflow and flood control works was formulated under the phase categories: namely, (i) urgent works which have been carried out by the Department of Public Works and Highways (DPWH) for the period from 1991 to 1993. Warning system by the Regional Disaster Coordinating Council in Region III (RDCC III) and the resettlement plan by the Mount Pinatubo Commission (MPC) are regarded as non-structural measure as a part of urgent works, (ii) short term plan to be carried out for the period from 1994 to 1996 before the implementation of permanent structures. As a part of short term plan, sand pocket structures at Bamban river basin were constructed by the DPWH before the onset of rainy season in 1994. The structures coped with the changes in natural condition because of uncertainties of producible volume of mudflow to low-lying areas, (iii) medium term plan which is composed of overall mudflow/flood control works and its alignment and combination of structural measures was formulated as permanent structures to ensure the safety against future flood and mudflow (iv) long term plan of rehabilitation and reconstruction of the affected areas. The structures are planned to accelerate the development strategy of the regional development plan.

9. *STRUCTURAL MEASURE*

(1) Sacobia-Bamban River Basin

A diking system has been constructed along the downstream reaches of Bamban River from 1992 to 1993, while sand pocket structures in the middle reach of the Bamban River was constructed before the onset of the 1994 rainy season. In 1995, the main problem noted was the reduction of clearance of San Francisco bridge in the Bamban River. The reconstruction work of San Francisco bridge was started in October 1995.

The reinforcement of sand pocket structures including the improvement works of Sapang Balen river is also required as a part of short term plan.

For the medium term plan, combination of structures was adopted on the basis of economic comparison. The objectives of putting up these structural measures are; (i) to keep the riverbed elevation in the stretch between Mactan and Maskup by the construction of a consolidation dam, (ii) to realign the Sacobia river channel into the Bamban River for the agricultural restoration of sand pocket area, and (iii) to maintain the present riverbed elevation in the whole stretch of the Bamban River. These structures were designed to ensure the safety against a flood with 20-year return period.

Principal features of the structural measures for the short and medium term plans are given in Table 1 and Figure 3. Project cost for the structures proposed in short and medium term plan was estimated at 2,834 million Pesos. Benefit-cost comparison showed the economic internal rate of return (EIRR) of 16.4% . The project was also justified by sensitivity analysis for varying both the benefit and cost of the Project. To carry out such plans, periodic topographic surveys and water samplings are required to elaborate the dimension of structures in accordance with geomorphologic changes and riverbed fluctuations.

After the completion of structural measure in medium term plan, (i) the extension of North Luzon Expressway, (ii) agricultural development in lahar disaster area, and (iii) tourism development will be possible as a part of long term plan.

(2) Abacan River Basin

Ten sabo dams were constructed in the tributaries of the Abacan River for the period from November 1991 to June 1993. Some sabo dams have been repaired almost every year due to deterioration of materials and local scouring. Reconstruction of the selected sabo dams with high priority for sediment retention are inevitable as permanent structures: namely, sabo dam No.9 in Abacan River, sabo dam No.6 in Sapangbato River and sabo dam TM-1 in Taug River. Retaining wall will also be constructed against bank erosion along tributaries.

Along the Urban Area of Angeles City, a channeling work to stabilize the channel alignment is proposed. The channel is designed as trapezoid-shaped with slope protection of wet stone masonry type. In the downstream reach of the Abacan River, some bridges are scheduled to be reconstructed while the excavation work for maintaining channel cross section was estimated to be 2 million cubic meters for 5 years.

Principal features of the structural measures for the short and medium term plans are also given in Table 1 and Figure 4. Project cost for the structures proposed in Short and Medium Term Plan was estimated at 1,005 million Pesos. Benefit-cost comparison showed the economic internal rate of return (EIRR) of 24.1% . The project was also justified by sensitivity analysis for varying both the benefit and cost of the Project.

10. NON-STRUCTURAL MEASURE

(1) Lahar/Mudflow Warning and Evacuation System

The RDCC-III is the inter-agency organization for flood/mudflow warning in the Mt. Pinatubo affected area. The system is mainly divided into three organizations: namely, (i) monitoring system, (ii) warning dissemination system and (iii) evacuation system. After receipt of the monitored information on lahar and heavy rainfall, the RDCC-III disseminates the lahar/flood warning information to government agencies in Region III. The warning message is also transmitted through the hot-line telephone system linking the radio stations in Manila.

(2) Resettlement Plan

The MPC was established in October 1992. The MPC is mandated to assist dislocated families in the communities damaged or destroyed by the eruption and its after effects. The MPC formulated an "Integrated Plan for the Mount Pinatubo Affected Areas" in 1994. The Plan was organized into three major rehabilitation programs; namely, infrastructure, livelihood and resettlement.

The MPC administered resettlement sites. In 1995, 11,600 families stayed in evacuation centers and 8,000 families were housed in the resettlement area. Since majority of the dislocated families are tillers, some expressed dissatisfaction on the land given them because of the inadequacy of land for the entire affected population. Most of the relocation sites merely provided homelots.

Livelihood support in the past four years showed that the need to provide facility requirements particularly housing in resettlement site has been given priority. Unemployment rate remained high among the affected and resettled families. First, this can be attributed mainly to the closure of the U.S. Military Bases which claimed 43,000 jobs. Secondly, the loss of agricultural lands due to lahar caused many farmers lose their basic source of livelihood. Finally, daily food rations resulted to dependence on external material assistance and less initiative to work. Productivity centers were also proposed by MPC to attract domestic and foreign investors within the resettlement sites and provide employment for settlers.

11. ENVIRONMENTAL ASSESSMENT

In 1994, the initial environmental examination (IEE) was carried out in the Study Area. The major purposes of the study was to enumerate the environmental changes by the 1991 eruption. There have been 2 times of workshops held in Pampanga and Tarlac Provinces between September to October 1994.

Following the IEE Study in 1994, the environmental impacts assessment (EIA) study was carried out in 1995 on the basis of the structural arrangement of the selected schemes for the feasibility study. The most notable performance they have made for the EIA Study was of conducting extensive public hearings in order to gather information and opinions on the Project from the local residents who are greatly concerned with the Project. There have been 26 times of public hearings and 2 times of workshops held between June and October, 1995.

A number of potential environmental concerns were considered from the viewpoint of biophysical and social environmental impacts. The major concerns include the effects that the dike and consolidation dam could have on traditional resource users and on biophysical resources. An important concern would also be the restoration of an irrigation system for agricultural products in sand pocket area and withdrawal of irrigation water.

Careful choice of work on location would minimize any existing impacts after eruption. The mitigative structural measures would be implemented during the realization of the concerns. As a result, cumulative and residual impacts would be insignificant. The positive effects would increase land settlement opportunities, improve living condition, and increase food production for domestic and export markets. Project effects would be essentially gender neutral in order to restore the social and economic activities before eruption.

12. SEDIMENT MONITORING IN PASIG RIVER

Lahar monitoring was commenced to establish the stations of around 40 sites inside of the tertiary dike using abandoned buildings, tree trunks and electric posts. After every lahar events, the depth of deposition and extent of deposits were verified by spot measurement at each station, interview survey to the residents outside of tertiary dike, and review the latest survey results done by PHIVOLCS and DPWH. The critical portions against lahar or flooding in 1996 (Figure 5) were specified as follows:

Low Possibility	:	(a) Lahar Avalanche into the Abacan River (b) Lahar Avalanche into the Porac River (c) Lahar Overtopping around the Angeles-Porac Road
High Possibility	:	(a) Dike Breach and Overflow along Gugu Tertiary Dike (b) Dike Breach along the Right Tertiary Dike (c) Flooding and Sediment Deposition along the Active Channel

In the 1995 rainy season, the river channel of the Pasig River incised deeply into the old alluvial deposits, and sharp meandering was observed frequently since the river bank material has a non-cohesive nature due to the lack of clay particles. In 1996, the sediment volume is expected to be about 80 million cubic meters: namely, 34-47 million cubic meters from pyroclastic flow deposit field and 40 million cubic meters due to the erosion of river channel. The continuous monitoring of geomorphologic change would play an important role to prevent serious flooding and sediment deposition in 1996.

13. RECOMMENDATION

(1) Structural Measure

Although the proposed plan was based on the sediment delivery forecast, there would still be uncertainties in the estimate of volume of sediment as well as changes in topography in the valleys, river channels and sand pocket area. It is recommended that periodical topographic survey and water sampling be carried out by the DPWH. In addition, although minimal, there are still some chances of recapture of the uppermost basin of the Pasig River, hence careful monitoring of the whole areas particularly the eastern slopes of Mt. Pinatubo is needed.

After the construction of the structural measures, maintenance works are indispensable to ensure the good condition of the structures and to serve their purpose as planned. Although sabo dams and dikes were designed as permanent structures, unexpected changes in the riverbeds or topography might occur and require reconstruction or removal of these structures as the opportunity arises. Review of the master plan would be carried out every 10 years.

(2) Non-structural Measure

The National Disaster Coordinating Council (NDCC) does not have at the moment enough capable personnel and the capability to establish disaster management plan because of financial constraint. The expansion of the NDCC will need experienced and knowledgeable officials to educate the local government units on this aspect.

Pinatubo hazard is characterized by predominant secondary disaster which is triggered by heavy rainfall. Major problem on rainfall observation network in the Philippines lies in the maintenance of the equipment, especially in the case of telemeter equipment. The rainfall radar system which will cover the Pinatubo hazard area will be one of the best solution in monitoring and in forecasting the rainfall for lahar/mudflow warning.

Remarkable activities in evacuation and resettlement have been carried out by the NGOs in and around Pinatubo hazard areas. Recently, an NGO network of disaster prevention is being expanded not only to Pinatubo hazard area but also to the entire country. It is necessary therefore for government agencies to coordinate with the network for efficient relief operation and evacuation.

Table 1 Principal Features of Proposed Structural Measures

<u>*SACOBIA-BAMBAN RIVER BASIN*</u>

(1) Reinforcement of Sand Pocket Structures		
a) Reinforcement of existing dike	Dike closing	3,050 m
	Reinforcement of dike	4,190 m
b) Lateral dike in sand pocket	First Row	1,110 m
	Second row	2,130 m
	Third row	2,720 m
c) Road dike on Route 329	Length	1,650 m
	Embankment volume	76,500 m^3
(2) Sapang Balen River Improvement	Channel excavation	240,000 m^3
(3) Muskap Consolidation Dam	Double wall type with steel sheet pile	
	Dam height 12.7 m (3.7m above ground)	
	Spillway width	150 m
(4) Sacobia training channel	Channel length	5,000 m
	Excavation volume	2,800,000 m^3
	Channel width	150 m
	Riverbed slope	1/180
	Groundsil (steel sheet pile)	7 pcs.
(5) Bamban River Improvement	Channel excavation	3,400,000 m^3
	Slope protection works	29,200 m
	Dike raising	6,000 m
	Dike reinforcement	12,500 m
(6) Sapang Cauayan River Improvement	Slope protection work	2,700 m
(7) Restoration of Route 3	Length	3,023 m
	Embankment volume	206,000 m^3
	Bamban bridge (PC girder type)	2,041 m
	Mabalacat bridge (PC girder type)	2,751 m

<u>*ABACAN RIVER BASIN*</u>

(1) Sabo Dam	a) Sabo dam No.6	double wall type
	b) Sabo dam TM-1	double wall type
	c) Sabo dam No.9	double wall type
(2) Bank Protection in upstream reach	Total length	3,400 m
(3) Lowflow Channel Excavation	Channel length	7,900 m
	Channel excavation	880,000 m^3
	Channel width	100 m
(4) Slope protection of existing dike	Total length	12,600 m
(5) Reinforcement of existing dike	Covered with soil	154,000 m^3
	Sodding	423,000 m^2
(6) Bridge	Hensonville bridge	150 m

Note : San Francisco Brideg in Bamban River and Pandan and Mexico Bridges in Abacan River are not mentioned because of the commencement of reconstruction works in 1996.

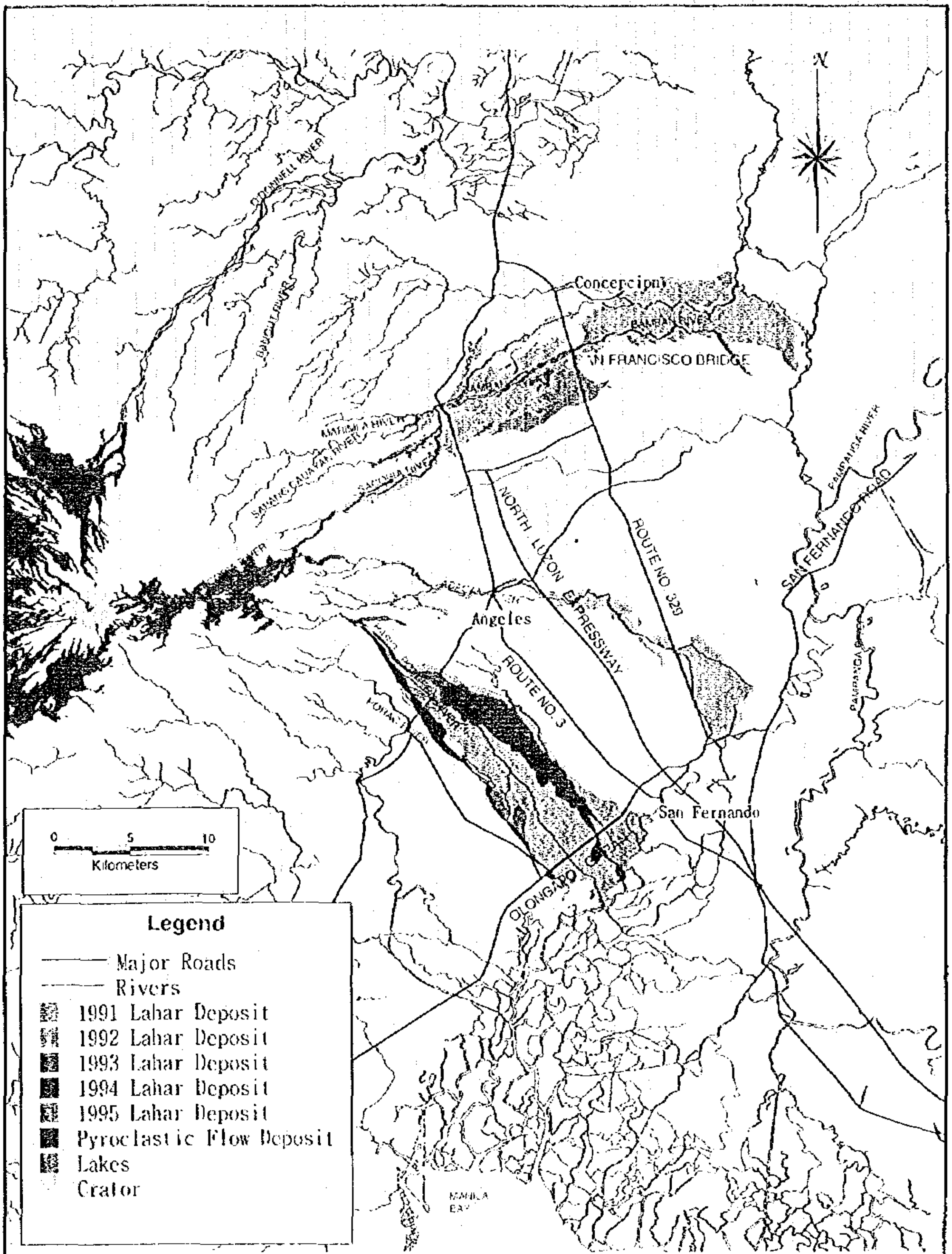


Figure 1 DISASTER MAP

THE GOVERNMENT OF THE PHILIPPNES
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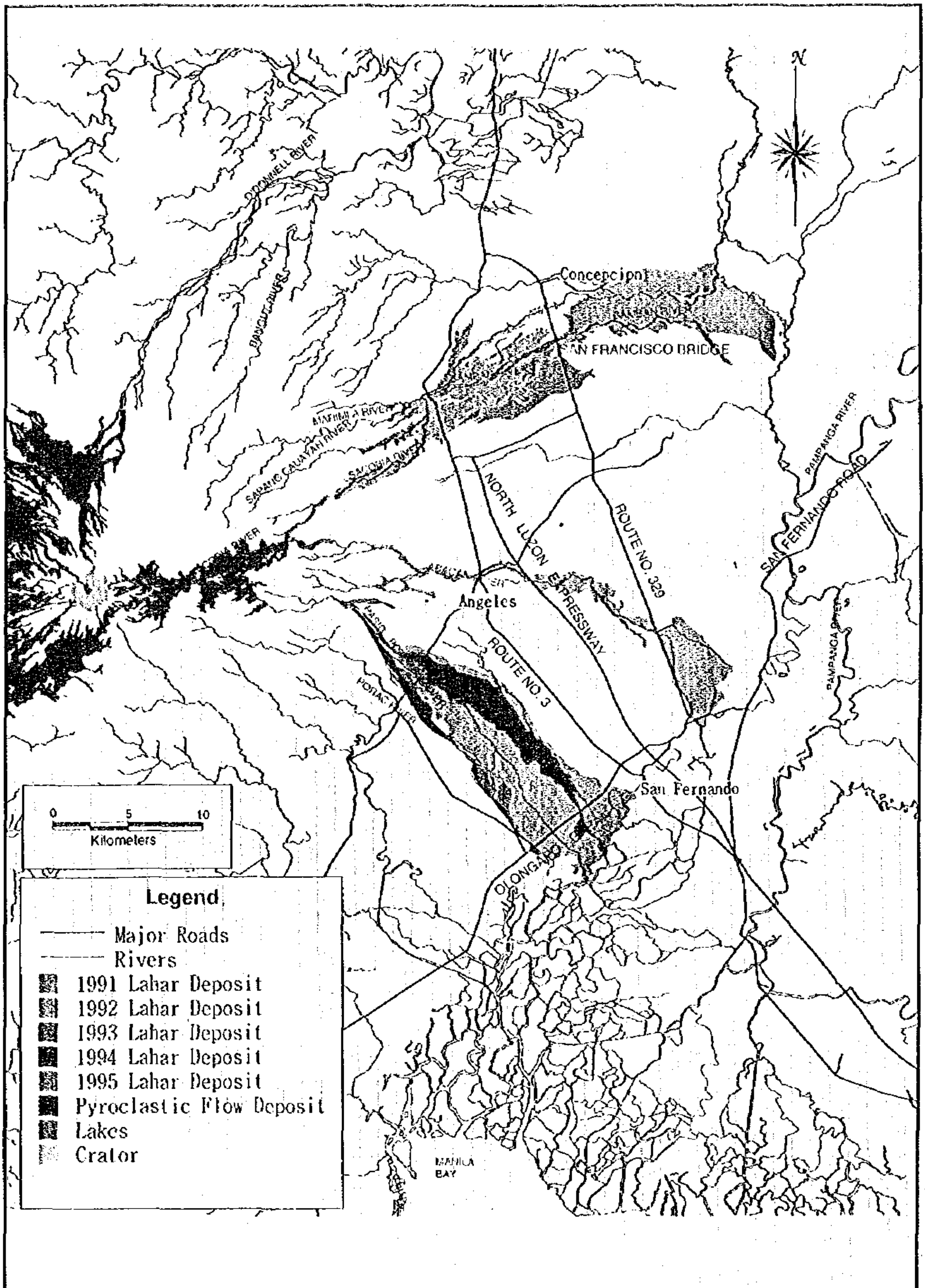

Figure 1 DISASTER MAP

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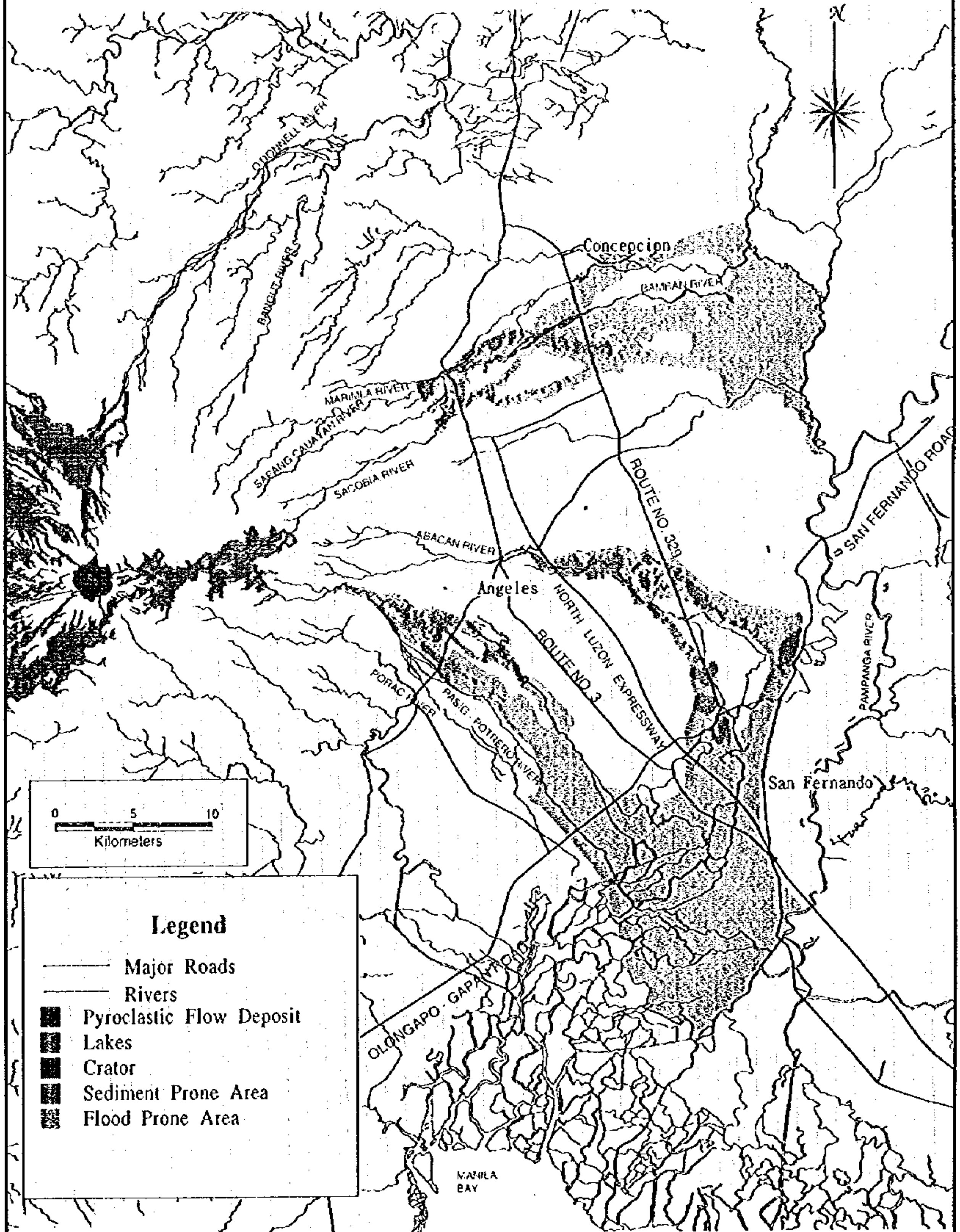

Figure 2 HAZARD MAP

THE GOVERNMENT OF THE PHILIPPNES
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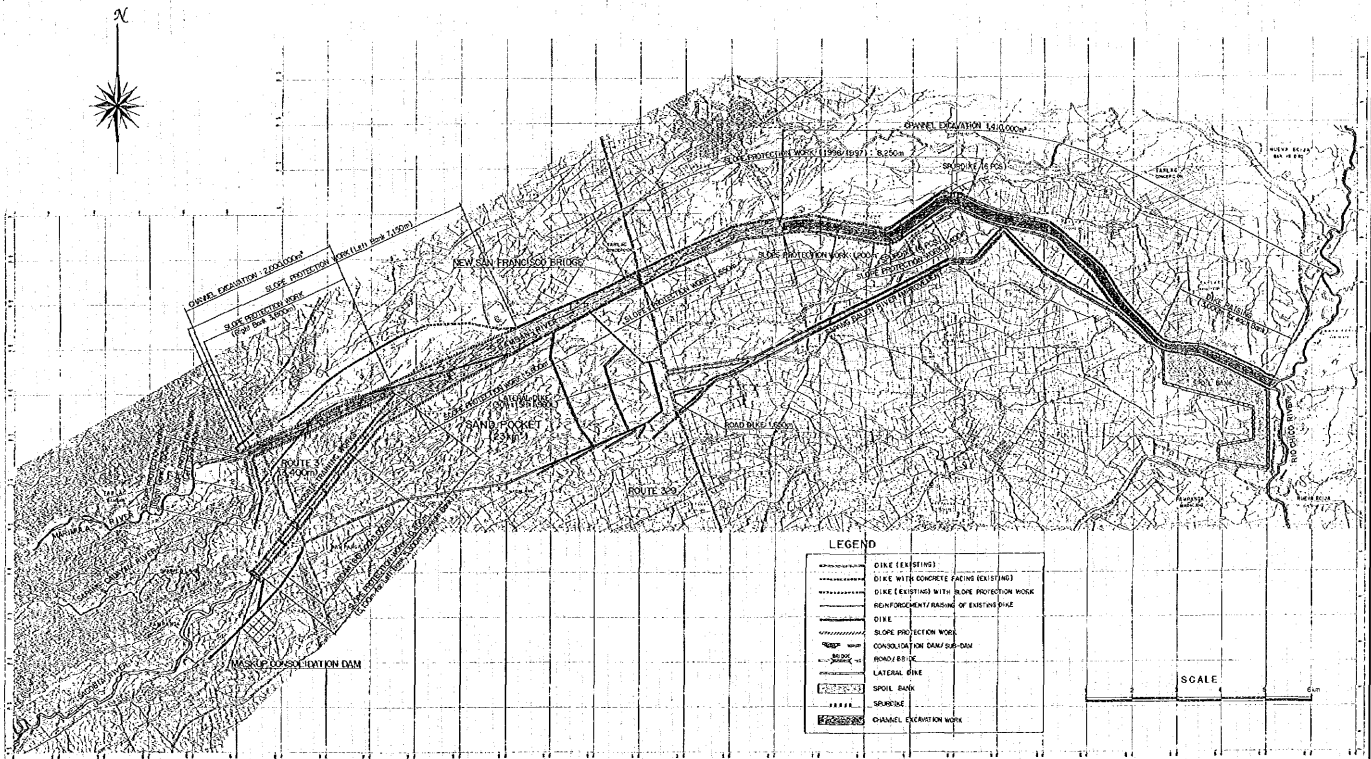

Figure 3 STRUCTURAL MEASURES IN SACOBIA-BAMBAN RIVER BASIN

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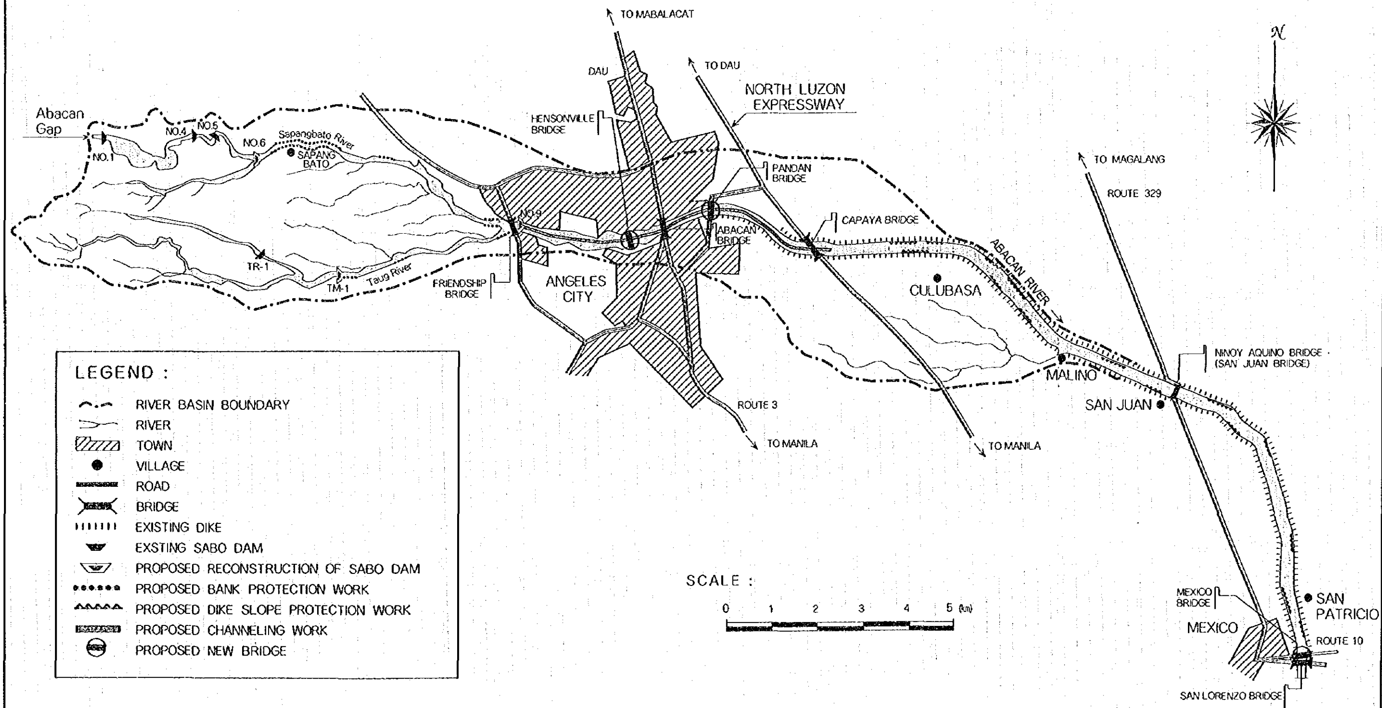

Figure 4 STRUCTURAL MEASURES IN ABACAN RIVER BASIN

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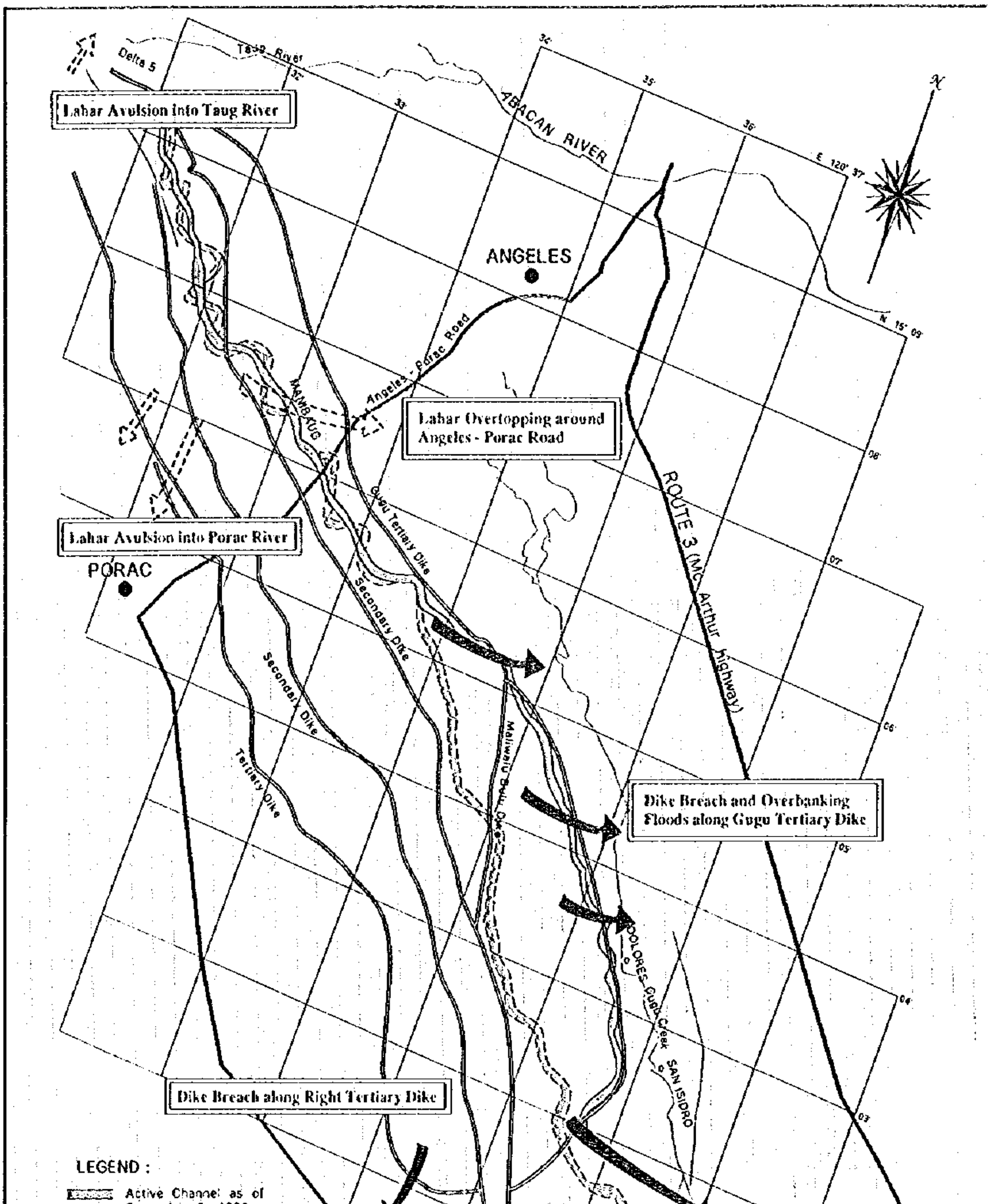

Figure 5

Critical Portions against Lahar and Flooding in the Pasig River Basin

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

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JAPAN INTERNATIONAL COOPERATION AGENCY

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ABBREVIATIONS

A	a.m.	-	ante-meridian (morning)
	ADB	-	Asian Development Bank
	AF	-	Acoustic Flux
	AFP	-	Armed Forces of the Philippines
	AFTA	-	ASEAN Free Trade Area
	ASEAN	-	Association of Southeast Asian Nation
	asl	-	above sea level
B	BBMP	-	Balog-Balog Multipurpose Project
	BDCC	-	Barangay Disaster Coordinating Council
	BCDA	-	Bases Conversion Development Authority
	BOT	-	Build-Operate-Transfer
	BRS	-	Bureau of Research and Standards
	BSWM	-	Bureau of Soils and Water Management
C	°C	-	centigrade
	CA	-	Catchment Area
	Ca	-	Calcium
	CAB	-	Clark Air Base
	CABCOM	-	Clark Air Base Commander
	CAD	-	Computer Aided Design
	CARP-IC	-	Comprehensive Agrarian Reform Program - Irrigation Component
	CDC	-	Clark Development Authority
	CEC	-	cation exchange capacity
	CFU	-	colony forming unit
	CIP	-	Communal Irrigation Project
	CIS	-	Communal Irrigation System
	Class GA	-	Domestic water supply
	cm	-	centimeter
	COMVOL	-	Commission on Volcanology
	CPDO	-	City Planning and Development Office
D	DA	-	Department of Agriculture
	DAR	-	Department of Agrarian Reform
	DBM	-	Department of Budget and Management
	DENR	-	Department of Environment and Natural Resources
	DILG	-	Department of Interior and Local Government
	DOH	-	Department of Health
	DOTC	-	Department of Transportation and Communication
	DPWH	-	Department of Public Works and Highways
	DSWD	-	Department of Social Welfare and Development
E	EPPFF	-	East Pinatubo Pyroclastic Flow Field
	EPZA	-	Export Processing Zone Authority
G	g	-	gram
	GIS	-	Geographic Information System
	GDP	-	Gross Domestic Product
	GOJ	-	Government of Japan
	GOP	-	*Government of the Philippines*
	GRDP	-	Gross Regional Domestic Product
	GTH	-	gifts, toys and housewares
H	ha	-	hectare

I	IEE	- Initial Environment Examination
	IRRI	- International Rice Research Institute
	ISF	- Irrigation Service Fee
J	JICA	- Japan International Cooperation Agency
K	K	- Potassium
	km	- kilometer
	km^2	- square kilometer
	km^3	- cubic kilometer
	km/hr	- kilometer per hour
	KPA	- Key Production Area
	kph	- kilometer per hour
	kWh	- kilowatt hour
L	LISR	- Luzon Island Strategic Road
	lps/m	- little per second per meter
	LTO	- Land Transportation Office
	LV	- Lahar volume
M	m	- meter
	m^3	- cubic meter
	m^3/sec	- cubic meter per second
	m^3/yr	- cubic meter per year
	mb	- millibar
	mbgs	- meter below ground surface
	M	- magnitude of earthquake
	MCM	- million cubic meter
	MDCC	- Municipal Disaster Coordinating Council
	meq	- milligram equivalent
	ml	- milliliter
	mm	- millimeter
	mm/min	- millimeter per minute
	mm/year	- millimeter per year
	MNR	- Manila North Road
	MPC	- Mount Pinatubo Commission
	MPN	- Most Probable Number
	MPR-PMO	- Mount Pinatubo Rehabilitation-Project Management Office,DPWH
	MSWD	- Ministry of Social Welfare and Development
	MTPDP	- Medium-Term Philippine Development Plan
N	Na	- Sodium
	NCR	- National Capital Region
	NDCC	- National Disaster Coordinating Council
	NEDA	- National Economic Development Authority
	NIA	- National Irrigation Administration
	NIC	- Newly Industrialized Countries
	NIP	- National Irrigation Project
	NIS	- National Irrigation System
	NGO	- Non-Government Organization
	NSO	- National Statistics Office
	NWRB	- National Water Resources Board
	NWRC	- National Water Resources Council
O	OCD	- Office of the Civil Defense

	OM	-	Organic Matter
	O&M	-	Operation and Maintenance
P	p.m.	-	post-meridian (afternoon)
	PDCC	-	Provincial Disaster Coordinating Council
	PDDP-IC	-	Pampanga Delta Development Project-Irrigation Component
	PAGASA	-	Philippine Atmospheric, Geophysical and Astronomical Services Administration
	PHIVOLCS	-	Philippine Institute of Volcanology and Seismology
	PIDIC	-	Pampanga Irrigation Development-Irrigation Component
	PIO	-	Provincial Irrigation Office
	PIP	-	Pump Irrigation Project
	PIS	-	Pump Irrigation System
	PMO	-	Project Management Office
	PNP	-	Philippine National Police
	ppm	-	parts per million
R	RAAMPE	-	Rehabilitation of Areas Affected by Mt. Pinatubo Eruption
	RDC	-	Regional Development Council
	RDCC	-	Regional Disaster Coordinating Council
S	SBMA	-	Subic Bay Metropolitan Authority
	SDR	-	Swiss Disaster Relief
	SO_4	-	Sulfade
	sq.km.	-	square kilometer
T	T.D.	-	Tropical Depression
	TDS	-	Total Dissolved Solids
	TLRC	-	Technology & Livelihood Research Center
	T.S.	-	Tropical Storm
U	USACE	-	Unites States Army Corps of Engineers
	USAID	-	United States Agency for International Development
	USGS	-	United States Geological Survey
W	WCLDP	-	West Central Luzon Development Program
	WHO	-	World Health Organization
Y	yr	-	year

CHAPTER 1

SCOPE OF THE STUDY

CHAPTER 1 SCOPE OF THE STUDY

1.1 BACKGROUND

1.1.1 STUDY BACKGROUND

Mt.Pinatubo is situated at approximately 15°08'N latitude and 120°21'E longitude. The drainage system around Mt.Pinatubo is mainly controlled by topography with a radial pattern. The Marella, Sto.Tomas and Bucao river systems drain from the western slope of Mt.Pinatubo into the South China Sea. Along the eastern slope of Mt.Pinatubo, the O'Donnell, Sacobia-Bamban, Abacan, Pasig-Potrero and Porac-Gumain rivers radiate outwards to the Luzon Central Plain.

The June 15, 1991 eruption of Mt.Pinatubo, one of the largest eruption of the century, produced remarkable volume of pyroclastic flow and ash fall deposits. The pyroclastic flow deposits covered thousands of square kilometers and the volume was estimated at 7 billion m^3 on the slopes of Mt.Pinatubo. Lahar generated by heavy rain falling on erodible pyroclastic flow deposits pose continuing and grave danger to human lives and property in the low-lying areas. Among the major rivers surrounding Mount Pinatubo, the Abacan River and the Sacobia-Bamban River possess a great danger to the outlying areas, where Angeles City and Clark Field are located, currently used for residential, commercial and industrial purposes.

The Government of the Philippines (GOP) has requested technical assistance from the Government of Japan (GOJ) to study on flood and mudflow control in the Sacobia-Bamban and Abacan river systems. In accordance with the scope of work for the technical assistance which was agreed upon between the Japan International Cooperation Agency (JICA) and the GOP, the JICA dispatched the JICA Study Team in November 1993.

1.1.2 STUDY OBJECTIVES

The objectives of the Study as agreed upon between DPWH and JICA are the following:

(1) to formulate a Master Plan for flood and mudflow control works in the Abacan and Sacobia-Bamban river basins and to carry out the Feasibility Study for the priority schemes identified in the Master Plan, and

(2) to transfer relevant planning and designing technologies to Philippino counterpart in the course of the Study.

In March 1995, the GOP emphasized the necessity of urgent engineering study for Pasig river basin because of remarkable sediment accumulation in the basin after the piracy in October 1993. In response to the request from the DPWH, the JICA decided to include the monitoring of geomorphologic changes of the Pasig river basin into the scope of work of the JICA Study Team in June 1995. The objectives are;

(3) to clarify the likelihood of lahar avalanche from Pasig River into the Abacan River on the basis of the monitoring works of geomorphologic changes in the Pasig river basin,

(4) to identify the critical portion of existing structures against lahar avalanche, and

(5) to transfer the methodology of monitoring of geomorphologic changes to Philippino counterpart in the course of the Study.

1.1.3 STUDY AREA

The Study Area is Sacobia-Bamban, Abacan and Pasig river basins which drain from the eastern slope of Mt.Pinatubo as shown in Figure 1.1.

(1) *Sacobia-Bamban River Basin*

The Sacobia-Bamban river system traverses the east-northern sectors of Mt.Pinatubo. This river system is composed of four (4) major tributaries, the Sacobia River, Marimla River, Sapang Cauayan River and the Sapang Balen River. These rivers drained an aggregate of 245.1 km^2 of watershed on the eastern slopes of Mt.Pinatubo before eruption.

On the alluvial plains, the Bamban River formed a braided characteristics as it traversed portions of the town of Concepcion in Tarlac. As it approached the Rio Chico River to the east, the Bamban River splited into several smaller waterways that empty into the San Antonio Swamp. Surface water received by the San Antonio Swamp were drained by the Rio Chico River, one of the tributaries of the extensive Pampanga River. The confluence of Rio Chico and Pampanga rivers is located east of Mt.Arayat.

(2) Abacan River Basin

The headwater tributaries of Abacan River originate at the mid-slope of Mt.Pinatubo. These headwater tributaries are the Sapangbato and Taug (Sapangbayo) rivers. Both flow eastward and dovetails with Abacan River at the foot of Mt.Pinatubo. The Abacan River system has a total drainage area of 77.2 km^2.

On the alluvial plain, the Abacan River flows eastward past Angeles City and then it slowly curves southeastwards. It assumes a more southerly trend as it approaches the town of Mexico where it joins the San Fernando and Bungang Guinto rivers.

(3) Pasig River Basin

The headwaters drained to four streams, Bucbuc, Yangca, Timbu, and Papatac Creeks. The stretch from the confluence of Timbu and Papatac Creeks down to Angeles-Porac Road functioned as an area of sediment production, transport and deposition. The river channel of this stretch was incised into a gently sloping alluvial fan consisting primarily of pre-1991 lahar and alluvial deposits. While in the stretch from Angeles-Porac Road to about Highway 7, sediment deposition caused damage to farmlands and barangays.

The Pasig River flows into the Pasac-Guagua River in the vast swamp of Pampanga Delta. The gradient of river channel is flat and its material consists of silts and fine sand.

1.1.4 STUDY ORGANIZATION

The organizational setup for the Study is illustrated as shown in Figure 1.2. The DPWH, Mt.Pinatubo Rehabilitation - Project Management Office (MPR-PMO), is the executing agency of the Study. As formal channels of communications between DPWH and the JICA Study Team, a Steering Committee and counterpart groups have been formed.

The Steering Committee and the Advisory Committee are supposed to meet occasionally to discuss and resolve the issue related to the Study, while the counterparts group organized into the DPWH staffs worked together with the Study Team in the office of the Study Team in Clark Field.

1.2 THE STUDY

1.2.1 FIRST PHASE IN 1993

The Study Team commenced the Study in the Philippines on November 15, 1993. An Inception Report has been submitted to the Department of Public Works and Highways (DPWH) on November 17, 1993. The DPWH organized the Inter-Agency Steering Committee chaired by Undersecretary Edmundo V. Mir, the other member of which are listed on Table 1.1. The First Steering Committee Meeting was held on December 1, 1993 with the Study Team and the JICA Advisory Committee. The Inception Report was accepted in the meeting in general with some minor modifications. The contents and work schedule of the Study was also explained in the Mount Pinatubo Congress held on December 7 and 8, 1993. The flowchart of the Study is shown in Figure 1.3.

The Progress Report (No.1) was submitted on February 24, 1994. The Report described the urgent rehabilitation plan for existing flood and mudflow control structures to be carried out by the DPWH before the onset of the rainy season in 1994. The Interim Report (No.1) was also submitted on June 16, 1994. The Report described the preliminary configuration of the structural measures in the Master Plan.

1.2.2 SECOND PHASE IN 1994

The Study was carried out continuously in the field for the period from July to December 1994. The basic configuration of structural measure was established through the monitoring of geomorphologic changes during rainy season in 1994 referring to the latest topographic map with a scale of 1 to 10,000 which was newly prepared by JICA Survey Team on the basis of the aerophotograph in March 1994. Furthermore, the present socio-economic condition was reviewed through the resettlement/ population and initial environmental surveys. The Progress Report (No.2) was submitted on December 10, 1994 to summarize the above results.

The Interim Report (2), described the alternatives for the combination of structural measure for flood and mudflow control works on the basis of both field monitoring of sediment deposition and numeric simulation of lahar and flood flows, was submitted in March 1995. The results of cost-benefit analysis were also referred to the selection of priority schemes of structural measure.

1.2.3 THIRD PHASE IN 1995

The optimum development scale of selected structural measures is being scrutinized through the feasibility study period from June 1995 to January 1996. This Report, Progress Report (3), describes the interim results of the Feasitudy Study on the development scale of structural measures.

In the third phase, monitoring works of geomorphologic changes in the Pasig-Potrero River was included in the Scope of Works of the JICA's Study inresponse to the request from the DPWH in the Steering Committee Meeting held on March 25, 1995. The monitoring results of sediment deposition in 1995 and the future risk map for lahar avalanche are also described in this Progress Report (No.3).

The Draft Final Report was submitted in March 1996. The contents of Draft Final Report will be discussed not only in the Steering Committee Meeting on March 5 but in the seminor held by the JICA in Manila on March 6 and in Angeles City on March 8 1996. The Final Report was submitted in May 1996 with some modifications on the basis of the comments from the Steering Committee Meeting.

Table 1.1 Member of Steering Committee

Chairman

Mr. Edmundo V. Mir
Undersecretary
Department of Public Works and Highways

Vice Chairman

Mr. Florante Soriquez
Mount Pinatubo Rehabilitation
Project Management Office, DPWH

Member

1. Col. Antonio Fernando
   Executive Director, MPC

2. Dr. Raymundo Punongbayan
   Director
   PHIVOLCS

3. Mr. Ruben S. Reinoso
   Director
   Infrastructure Staff, NEDA

4. Dr. Leoncio A. Amadore
   Director
   PAGASA

5. Mr. Rodrigo Fuentes
   Director
   Environmental Management Bureau, DENR

6. Mr. Hadji Mastor R. Ibrahim
   Director
   PMO-Flood Control & Drainage, DPWH

7. Mr. Bienvenido Leuterio
   Director
   Bureau of Design, DPWH

8. Mr. Jose Gloria
   Director
   PMO-Feasibility Study, DPWH

9. Mr. Yoshiki Nagai
   JICA Sabo Expert, DPWH

10. Mr. Kenichi Matsui
    JICA River Expert, DPWH

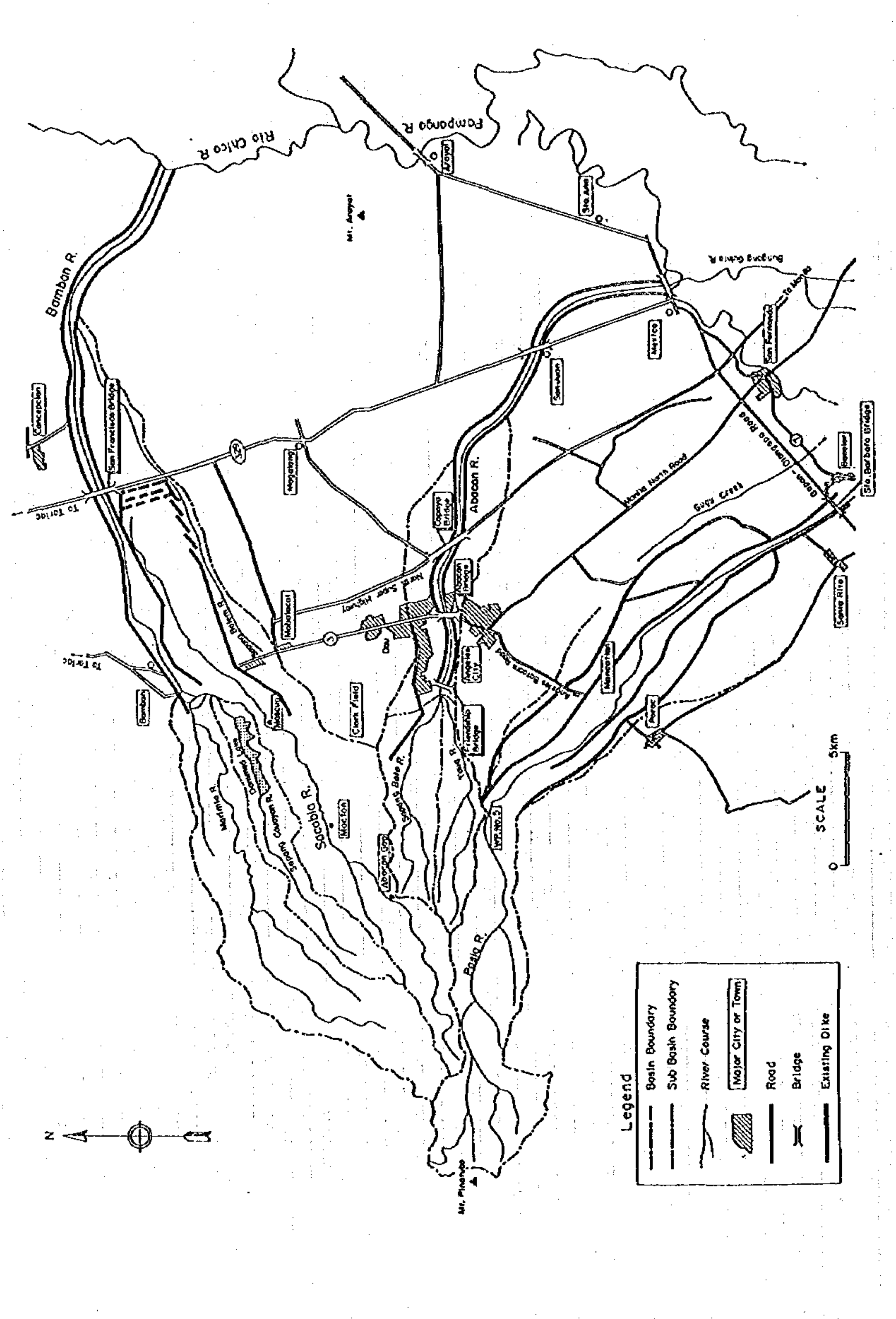

Figure 1.1 **Location Map of the Study Area**

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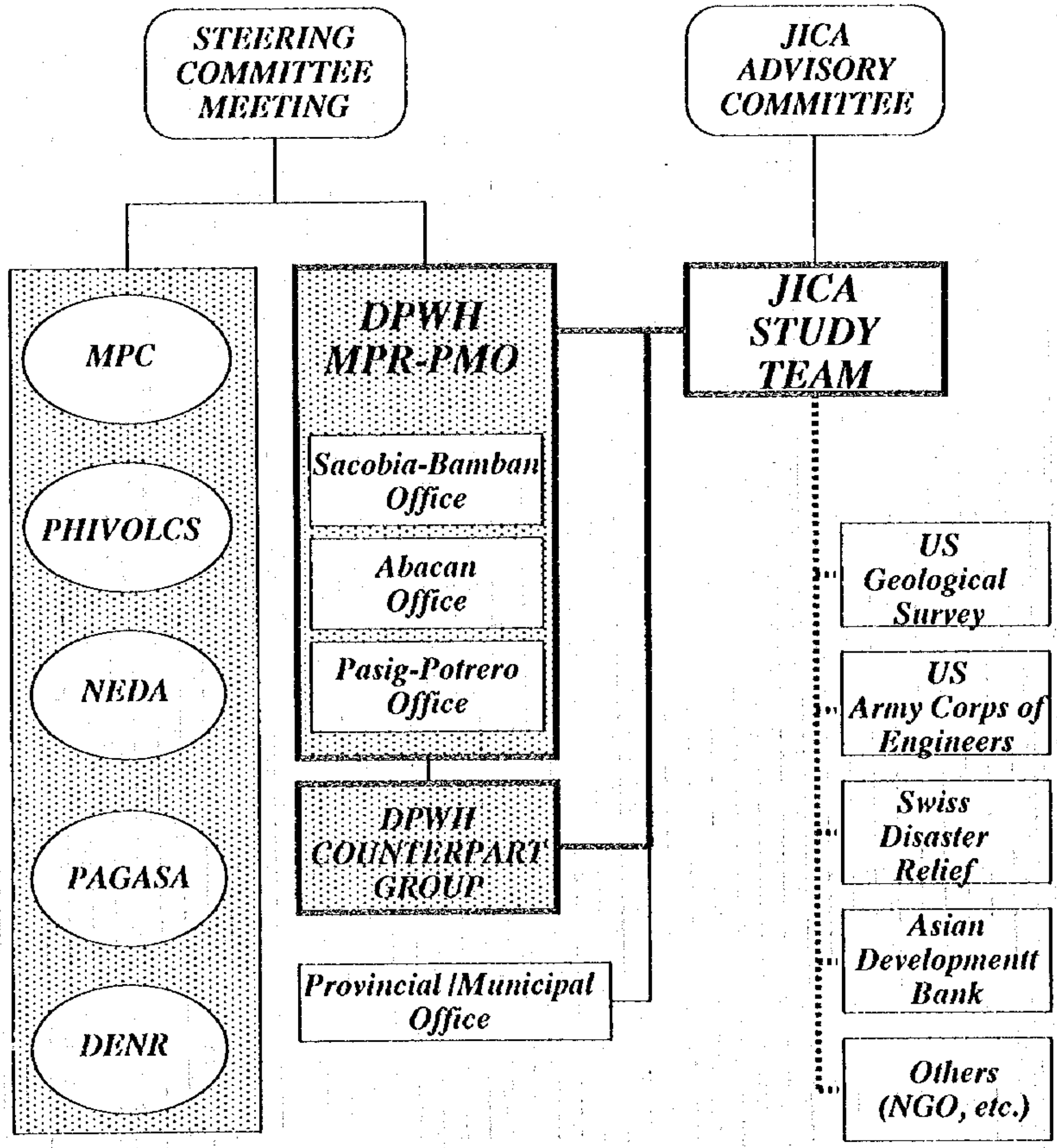

Figure 1.2

Organizational Set-up for the Study

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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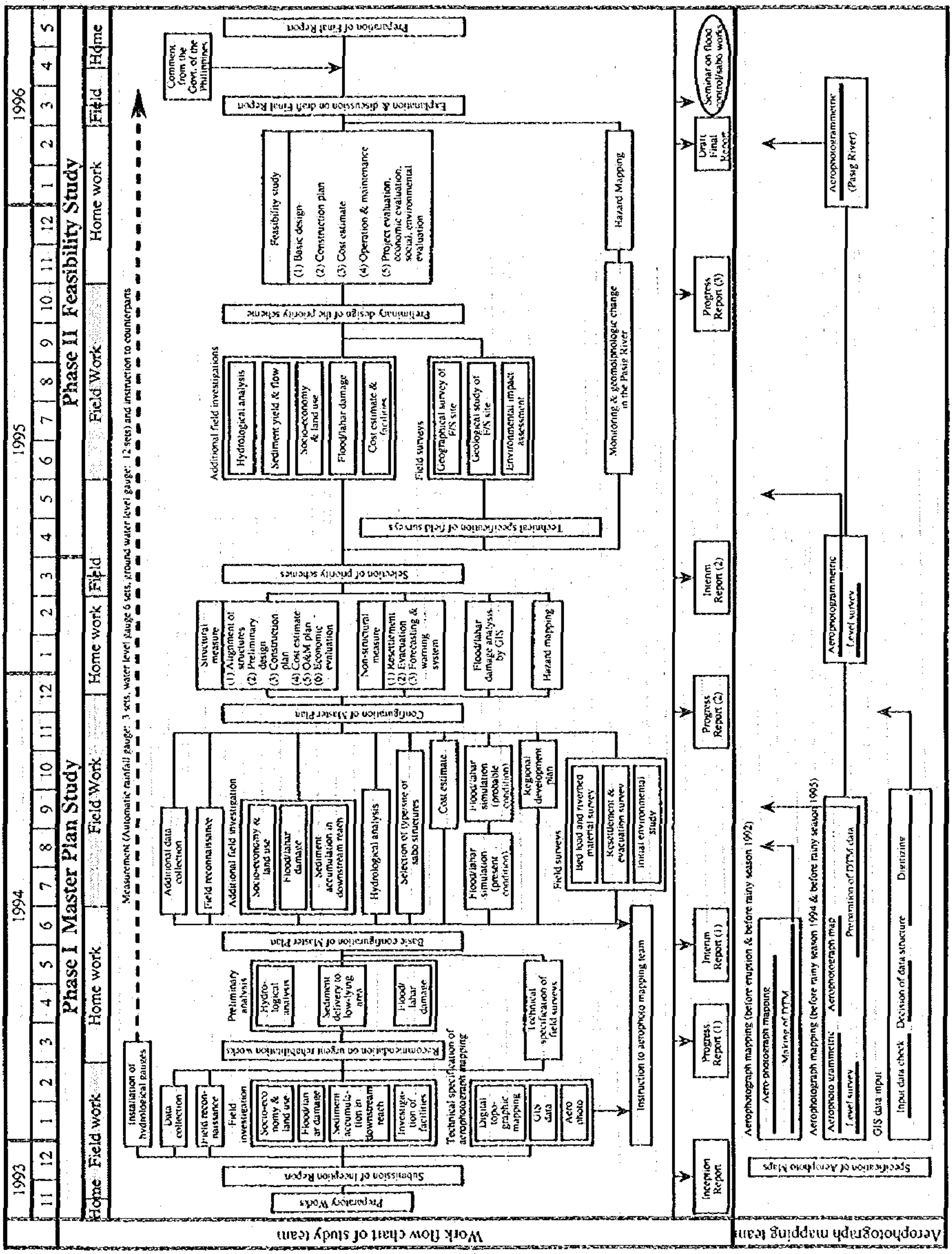

Figure 1.3 Work Schedule of Study

CHAPTER 2

PRE-ERUPTION NATURAL CONDITION

CHAPTER 2 PRE-ERUPTION NATURAL CONDITION

2.1 TOPOGRAPHY

Mt.Pinatubo, the highest peak along the Pinatubo-Mariveles volcanic trend in Central Luzon, stands about 1,745 meters above sea level. It is among the 21 most active volcanoes in the Philippines. It is situated at approximately 15°08"20' North latitude and 120°21"35' East longitude. The volcano is the reference point in defining the boundaries of the provinces of Pampanga, Tarlac and Zambales.

The irregularly planned volcano sits upon an older (Eocene) ophiolitic mafic-ultramafic rocks of the Zambales Mountain along the west coast of Luzon . The southern flank of the volcano is the steepest with regional slopes ranging from about 20° to 65° and its maximum radius is about 25 kilometers in its northeastern quadrant. The lower flanks, from 1,100 meters to about 300 to 200 meters, flattens to about 1/50 to 1/100. Generally, the regional slopes decrease from 12° to about 2° when it eventually meets with the swampy plains of the Central Luzon Valley.

Mt.Pinatubo is densely and deeply dissected by eight (8) major river systems, each characterized by radial drainage and ending in broad, gently sloping aprons of laterally coalesced alluvial fans which extend beyond the flanks. These major river systems are (clockwise, from the North): the O'donnell, Sacobia-Bamban, Abacan, Pasig-Potrero, Gumain, Santo Tomas, Maloma and Bucao rivers. These channels on the fans are shallow, unless they are artificially channeled or terraced. Channel gradients range from about 1/50 at fan heads to less than 1/50,000 in the marsh areas.

(1) Sacobia-Bamban River

The Sacobia-Bamban river system traverses the east-northern sectors of Mt.Pinatubo. This river system is composed of four (4) major tributaries, the Sacobia River, Marimla River, Sapang Cauayan River and the Sapang Balen River. These rivers drained an aggregate of 245.1 km^2 of watershed on the eastern slopes of Mt.Pinatubo before eruption.

Of these tributaries, Marimla and Sacobia originate from the uppermost slopes of the volcano. In the pre-eruption period, a longitudinal profile of the Sacobia River from the summit to an elevation of about 1,000 m show steep slopes measured at 10° to 30° and river channel was deep, narrow V-shaped canyon. Further down to elevations of about 200 m, the channel slope decreased from 6° to 1° as it cuts into the 600-300 year old non-welded pyroclastic flow deposits. At less than 200-m elevations (roughly 8 km downstream), slope angle decreased to 0.62° while the channel formed box-shaped. Here, the Sacobia River was 500 m wide and eroded into old lahar terraces and well-indurated fluvial deposits until it narrowed down to 30 m at an elevation of 100 m. At this point, about 25 km from the volcano, the Sacobia River was joined by Sapang Cauayan and the Marimla rivers. A few kilometers downstream, the Sacobia River joined the Bamban River.

On the alluvial plains, the Bamban River assumed a braided characteristics as it traversed portions of the town of Concepcion in Tarlac. As it approached the Rio Chico River to the east, the Bamban River splited into several smaller waterways that empty into the San Antonio Swamp. Surface water received by the San Antonio Swamp were drained by the Rio Chico River, one of the tributaries of the extensive Pampanga River. The confluence of Rio Chico and Pampanga river is located east of Mt.Arayat.

San Antonio Swamp has an elevation of 14-45 m above sea level. It serves as a depositional basin for silt and sediment as well as natural retention basin which holds rainy season overflow from the Bamban River as well as the Rio Chico River.

Southward, downstream of the San Antonio Swamp is a bigger wetland, the Candaba Swamp. The Candaba Swamp located adjacent to the Pampanga River acts as a natural flood retarding basin in wet season. Its natural retarding capacity is estimated at approximately 1.5 billion m^3.

Downstream of the confluence, the Pampanga River flows southward for another 72 km and merges with the complex drainage system of the Manila Bay estuary. This broad estuary is now extensively converted to aquaculture.

(2) Abacan River

The headwater tributaries of Abacan River originate at the mid-slope of Mt.Pinatubo. These headwater tributaries are the Sapangbato and Sapangbayo rivers. Both flow eastward and dovetails with Abacan River at the foot of Mt.Pinatubo. The Abacan River system has a total drainage area of 77.2 km^2.

On the alluvial plain, the Abacan River flows eastward past Angeles City and then it slowly curves southeastwards. It assumes a more southerly trend as it approaches the town of Mexico where it joins the San Fernando River.

(3) Pasig River

Before the 1991 eruption, the Pasig headwaters were drained by four streams; Bucbuc, Yangca, Timbu, and Papatac creeks. The Pasig River system has a upper drainage area of 21.5 km^2 at Watch Point No.5.

The stretch from the confluence of Timbu and Papatac creeks to about the Angeles-Porac road was an area of sediment production, transport and deposition.

The river channel was incised into a gently sloping alluvial fan consisting primarily of pre-1991 lahar and alluvial deposits. The stretch from the Angeles-Porac road to about Highway 7 has caused damage to farmlands and barangays. The Pasig River flows into the Pasac-Guagua River, which pours into Pampanga Bay. This delta reach is flat and consists of silts and fine sand.

2.2 *REGIONAL GEOLOGY*

The Quaternary Pyroclastics are the most extensively exposed rock unit in the Study Area as it covers most of the flanks of Mt.Pinatubo as shown in Figure 2.1. At least two facies are recognizable in this formation, namely, the pyroclastic flow facies and the lahar facies.

Northeast of the peak of Mt.Pinatubo toward the headwaters of the Sacobia River, the pyroclastics typically occur a jagged hills of dacitic ignimbrite deposits. The massive nature of the deposits and their erosional features suggest them to be old pyroclastic flow deposits.

In the vicinity of Bamban, the Quaternary Pyroclastic is composed of well bedded tuffaceous sandstone, conglomerate and lapilli tuff. The tuff beds are generally hard, medium to thick bedded and consist of well cemented fine grains of volcanic ash and lapilli. The beds strike generally northeast and dip gently about 3° to 10° toward the northwest. The sorting, sphericity of pebbles and regular and graded bedding suggest subaqueous deposition probably as lahar deposits. Stratigraphic relationships imply a Pleistocene age.

Quaternary Alluvium covers most of the Luzon Central Plain and part of the valleys of the rivers draining from Mt.Pinatubo. It consists mainly of unconsolidated sand, gravel, cobble and boulder.

2.3 CLIMATE

2.3.1 AIR STREAM AND TYPHOON

The river basins around Mt.Pinatubo are affected by a southwest monsoon for the wet months from May to October, while a northeast monsoon dominates during the dry months from November to March. The distinctive wet and dry seasons are brought about by these reversal monsoons.

The air mass of southwest monsoon is classified into equatorial maritime and is warm and very humid, having an average temperature of 26°C and a vapor pressure of about 30 mb. Among 16 tropical cyclones per annum which affects weather condition in the Luzon Island for the period from 1948 to 1991, 5 tropical cyclones on an annual average passed through in the Central Luzon.

2.3.2 METEOROLOGY

(1) Rainfall

The annual rainfall data at representative rainfall gauging stations (Manila International Airport, Dagupan meteorological station and Clark Air Base) which have rainfall records of more than 30 years were discussed about the fluctuation of annual rainfall. Figure 2.2 shows that a series of annual rainfall and 5-yr moving average for the above three stations.

The data shows that the remarkable volume of rainfall occurred in 1972. In fact, it was reported that a temporary "Central Luzon Lake" was formed due to prolonged and heavy monsoon rains which fell over several weeks, and flooded Pampanga and Agno river basins were joined together in one inland sea extending from Manila Bay to Lingayen Bay.

The monthly rainfall of 2,580 mm was recorded in July 1972 at Apalit, Pampanga. The annual rainfall had receded gradually for the period from 1972 to 1983 and the drought in 1983 caused a serious problems in economic activities in Central Luzon, such as shortage of drinking water and reduction of hydropower generation and low agricultural productivity. Those after 1983 has been restored by the level of annual average rainfall.

After the eruption of Mt.Pinatubo for the period from 1991 to 1993, the annual rainfall was almost equivalent to the annual average rainfall.

Isohyetal map of annual rainfall in Central Luzon is shown in Figure 2.3. It is indicated that the annual rainfall of more than 4,000 mm are experienced over Mt.Sto.Tomas of Benguet, west coast of Zambales and Mt.Angilo of Quezon. The reason for these large rainfall variations is partly topographical contrasts with the great altitudinal range, and partly the presence of large water bodies such as Pacific Ocean and South China Sea.

The variation of monthly rainfall at representative rainfall gauging stations in Central Luzon is shown in Figure 2.4. The data clearly shows that the Luzon Island receives two main types of rainfall patterns. Eastern part of Luzon Island receives no really driest month but wetter month in November/December, while in the western part, there is a distinctive wettest month in August and a driest month in January/February. About 90%

annual rainfall occurs for the period from June to October in the western part of Luzon Island.

An important feature that can describe the rainfall distribution is the number of rainy days. The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) defined a rainy day as a day having a rainfall of 0.1 mm or more. The mean monthly number of rainy days at various stations in Luzon Island is shown in Figure 2.5.

(2) Temperature

The variation of monthly average temperature at representative stations is shown in Figure 2.6. The monthly average temperature in Luzon Island varies for the range from 24.8 °C in January to 28.3°C in May. The diurnal change of temperature is about 10°C in the eastern part of Mt.Pinatubo as shown in Figure 2.7. The maximum temperatures for most places occur generally between 1:00 p.m. and 3:00 p.m. while the minimum temperatures occur between 5:00 a.m. and 7:00 a.m. The absolute maximum temperature recorded in Luzon Island was 42.2°C at Tuguegarao in April, 1912, and the absolute minimum temperature of 3.0°C was recorded at Baguio in January, 1903.

(3) Relative Humidity

The variation of monthly mean relative humidity shows the great difference between the western part of Luzon Island and eastern part as shown in Figure 2.8. The monthly relative humidity in western part varies for about 15%, generally for the range from 70% in April to 85% in August, while those in the eastern part is rather stable throughout a year at about 85%.

(4) Evaporation

Open pan evaporation data in Floridablanca (1986-1987) varies for the range from 119.6 mm in November to 204.2 mm in March. The annual evaporation amount is recorded at 1,736 mm.

2.3.3 RUNOFF

The ratio of runoff to rainfall volume was estimated on the basis of the monthly rainfall data at Basa Air Base station (1958-1972) and concurrent monthly average discharge data at Del Carmen (CA=111km^2).

While the evaporation data at Floridablanca (1985-1987) were referred. All the stations are located in the Porac river basin which originates at southern slope of Mt.Pinatubo and has similar characteristics to the Study Area. Figure 2.9 shows that the rainfall volume exceeds runoff for the months from May to October and the ratio of annual runoff to annual rainfall volume is estimated at 61.6% annual rainfall volume on an average.

2.4 SOIL RESOURCES

Soil map before the eruption in the Study Area is shown in Figure 2.10 Angeles series is the most extensive soil associated with land management units. This series occurs also in the infilled valley and residual terraces. On the hilly and mountainous landforms undifferentiated Angeles soils occur. The minor soils occurring on the plain are Quingua, La Paz, Bantog and Candaba series. The latter occurs only in the Candaba Swamp. The riverbed of Abacan and Sacobia-Bamban rivers is organized into Angeles coarse sand.

The soils of the Sacobia-Bamban river basin are Angeles fine sand, Luisita fine sand, Angeles sand, Angeles sandy loam and Angeles coarse sand. Angeles fine sand is located on the upper stream of the watershed, Luisita fine sand on mid-northern side of the river, Angeles sand in the mid-southern side of the river, Angeles sandy loam at the downstream of the watershed and the Angeles coarse sand on the terraces along the Sacobia-Bamban River and on the flood plain.

Angeles fine sand is a deep, well drained soil with loose and structureless fine sand surface with a small amount of silt and clay. Soil reaction is slightly acidic (pH 6.1). Subsoil is gravelly sand (up to 80 m or deeper).

Sugarcane and rice were commonly being grown on this soil. Luisita fine sand is similar to Angeles fine sand although its soil reaction is very slightly acidic (pH 6.6) and the subsoil has no gravel. Landuse is the same as Angeles fine sand. Angeles sand is a deep, well drained soil. The surface soil consists of coarse and medium sands with little amount of clay and silt. Soil reaction is moderately acidic (pH5.8).

Rice is the important crop of this soil with sugarcane, rootcrops and vegetables. Angeles coarse sand has uniform texture from the surface up to a depth of more than one meter. Soil reaction is moderately acidic (pH 5.6). Natural vegetation on this soil was talahib, bamboos and camachile.

In general, the soils of the alluvial plain of the Sacobia-Bamban River basin had the following chemical properties: slightly acidic (pH 6.70), low organic matter content (1.12%), high cation exchange capacity (24.12 meq/100 g soil), high base saturation (73.46%), moderately available Phosphorous (11.6 ppm) and low exchangeable potassium (0.16 meq/100 g soil). The general fertility of these soils is moderate. The moderate natural fertility of the soils in the Sacobia-Bamban river watershed agrees with the characterization of the buried soils in Barangay Culatingan and San Vicente, Concepcion, Tarlac.

The soils of the Abacan river basin are : Angeles fine sand, Angeles sand, La Paz fine sand and Angeles coarse sand. Angeles fine sand and Angeles sand are located in the upper stream of the watershed while La Paz fine sand is located in the downstream of the watershed. Angeles coarse sand is located at the terraces adjacent to the river floodplain. The physico-chemical properties and land uses of Angeles fine sand, Angeles sand and Angeles coarse sand are similar to the same soils in Sacobia-Bamban river basin.

La Paz fine sand is a deep, well drained soil. Soil reaction is strongly acidic (pH 5.4). Sugarcane is the main crop of this soil. La Paz sand is similar to La Paz fine sand except the surface soil texture which is medium to coarse land. Soil reaction is moderately acidic (pH 5.6). Rice and sugarcane are the main crops of this soil.

In general, the soils of the alluvial plain of the Abacan river basin are acidic (pH5.08), low organic matter (0.12%), moderate cation exchange capacity (14.75 meq/100 g soil), moderate base saturation (45.00%), high available phosphorous (30.33 ppm, P), and low exchangeable potassium (0.11 meq/100g). These soils are moderately fertile. The characterization of the buried soil in Sapang Libutad, Angeles City and a soil profile in San Pablo, Mexico confirms that the moderate natural fertility of the former soils.

2.5 ENVIRONMENTAL CONDITION

2.5.1 LAND USE

Primary growth forest has been left only on the top half of Mt.Arayat while secondary growth forest is on the lower half of the mountain. Left bank of Sacobia River is also noted as secondary growth forest area.

Considerable number of the Aeta people lived in the Mt.Pinatubo above the present secondary growth area for the past several centuries. Their original life style of hunting and gathering has been replaced by shifting cultivation, and even by stationary agriculture, during the past decades. Thus their agricultural activities have reduced most of the forest area in the lower portion of Mt.Pinatubo. Further there have been intensive logging and cutting trees for fuel as the population of Aeta and lowland communities expanded.

The entire area of 200 m above sea level (asl) in the west to the area of 10 m asl in the east of Study Area, forming alluvial fan, was originally grassland. Large tract of grass land left in the former Clark Air Base at present is considered as the remnant of original grassland formed on the alluvial fan. Much of the grass land has been converted to agricultural area, or agro-ecological area, during the past decades. Rice and Sugarcane are the two major crops.

Majority of the population in the Study Area concentrates on the National Highway Route 3 dividing the agro-ecological area to the east and the grass land of former Clark Air Base to the west.

2.5.2 PLANT SPECIES

Plant species identified in the Study Area in 1981 counted for 128 species in Grassland and 15 species of them are wood type. The rest are herbs and shrubs. There are 55 species identified in the secondary forest area. No protected species are identified in the study area.

2.5.3 WILDLIFE

There are considerably few wildlife species identified in the Study Area as follows:

- Mammals	3 Species
- Bird	52 Species
- Reptiles	12 Species
- Amphibians	3 Species

This is due to the historical development of the Study Area for agricultural activities. No protected species or endangered species are identified in the Study Area.

2.5.4 NOTABLE ECOLOGICAL AREA

Mt.Arayat is a national park maintaining its primary forest area on the top half of the mountain. Itself is situated in the middle of plain as an independent volcanic cone and it is one of the wildlife rich area in Pampanga Plain. Scenic beauty of the mountain is also the important asset of Pampanga Plain.

To the east of Mt.Arayat is the Candaba Swamp. This is one of the important winter nesting area for birds migrating over the Pacific Flyway. At the same time the swamp is used for seasonal fertile rice planting area. It is this reason that the Candaba Swamp has been listed as significant wetland in the Philippines and being considered as one of the important wetland in Asia under the framework of Ramsal Convention, the worldwide convention for protection of wetland related to harbour wildlife.

San Antonio Swamp is located to the north of Mt.Arayat. This swamp is formed by the seasonal flood waters of Rio Chico and Bamban River and being used for seasonal rice growing area. Ecological uniqueness and its importance to the plant and the wildlife community in the swamp have not been thoroughly studied yet in this area.

Source : Feasibility Report on the Pampanga Delta Development Project (JICA, 1982)

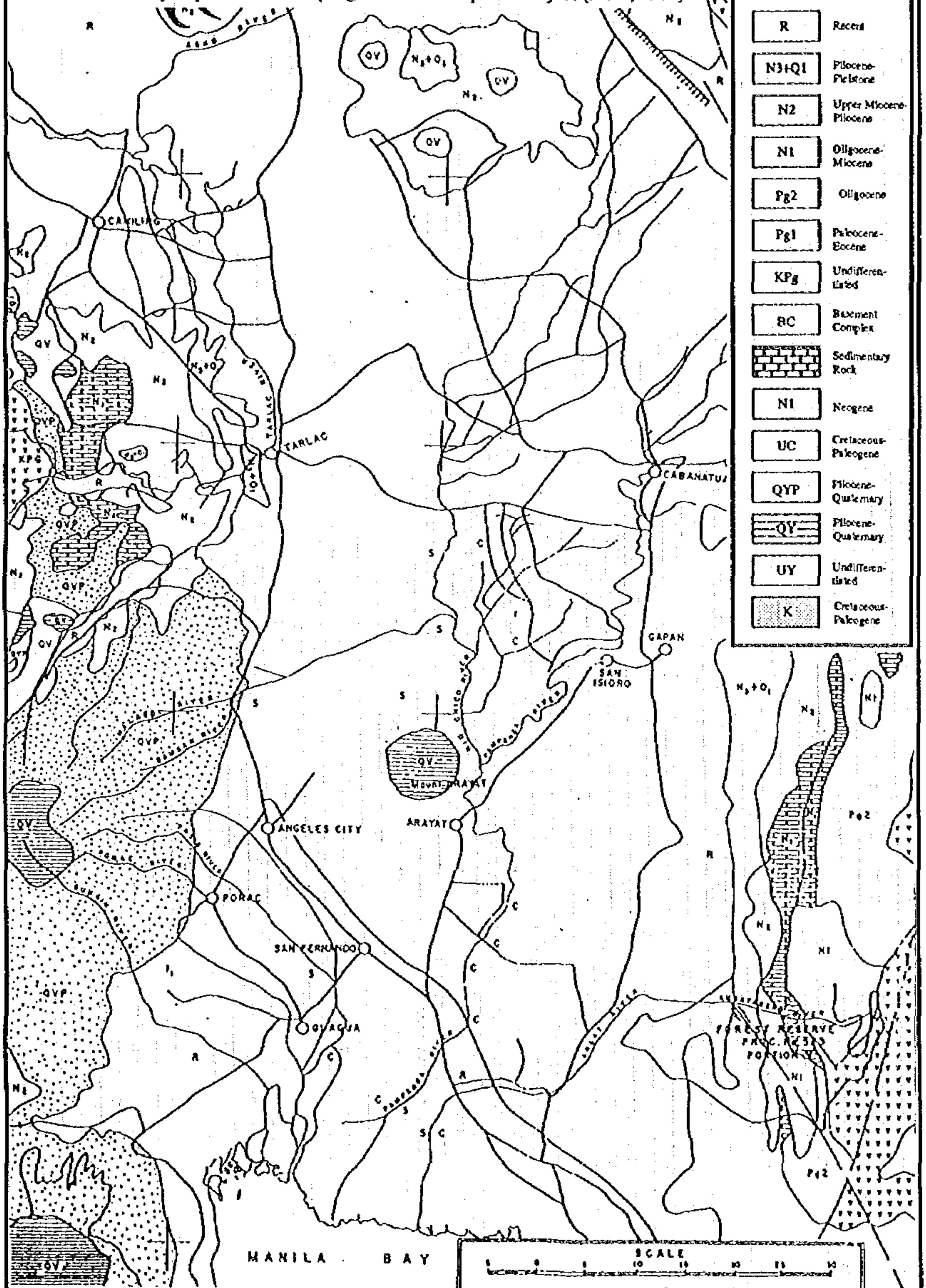

Figure 2.1
Geological Map in the Study Area

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

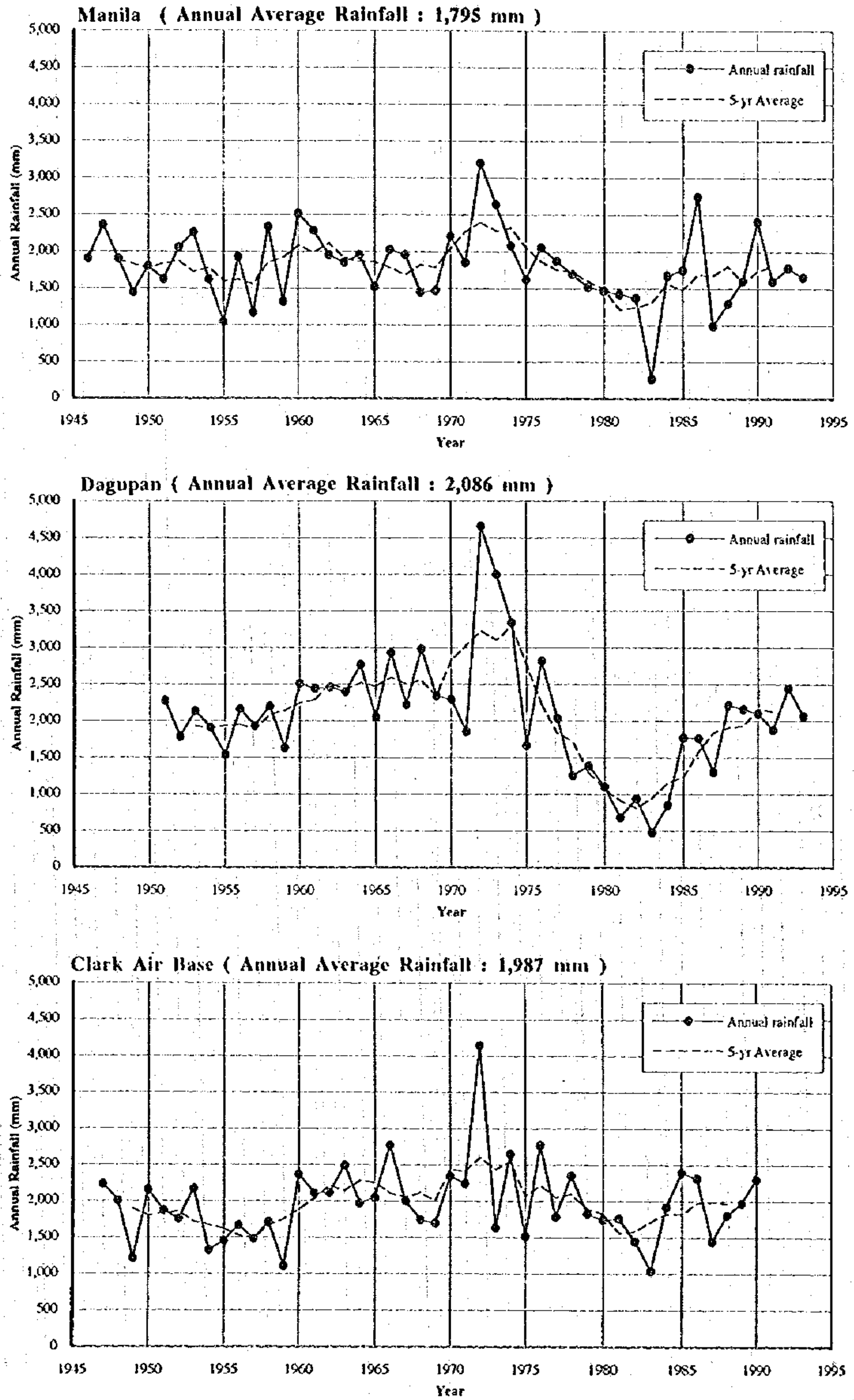

Figure 2.2 Variation of Annual Rainfall

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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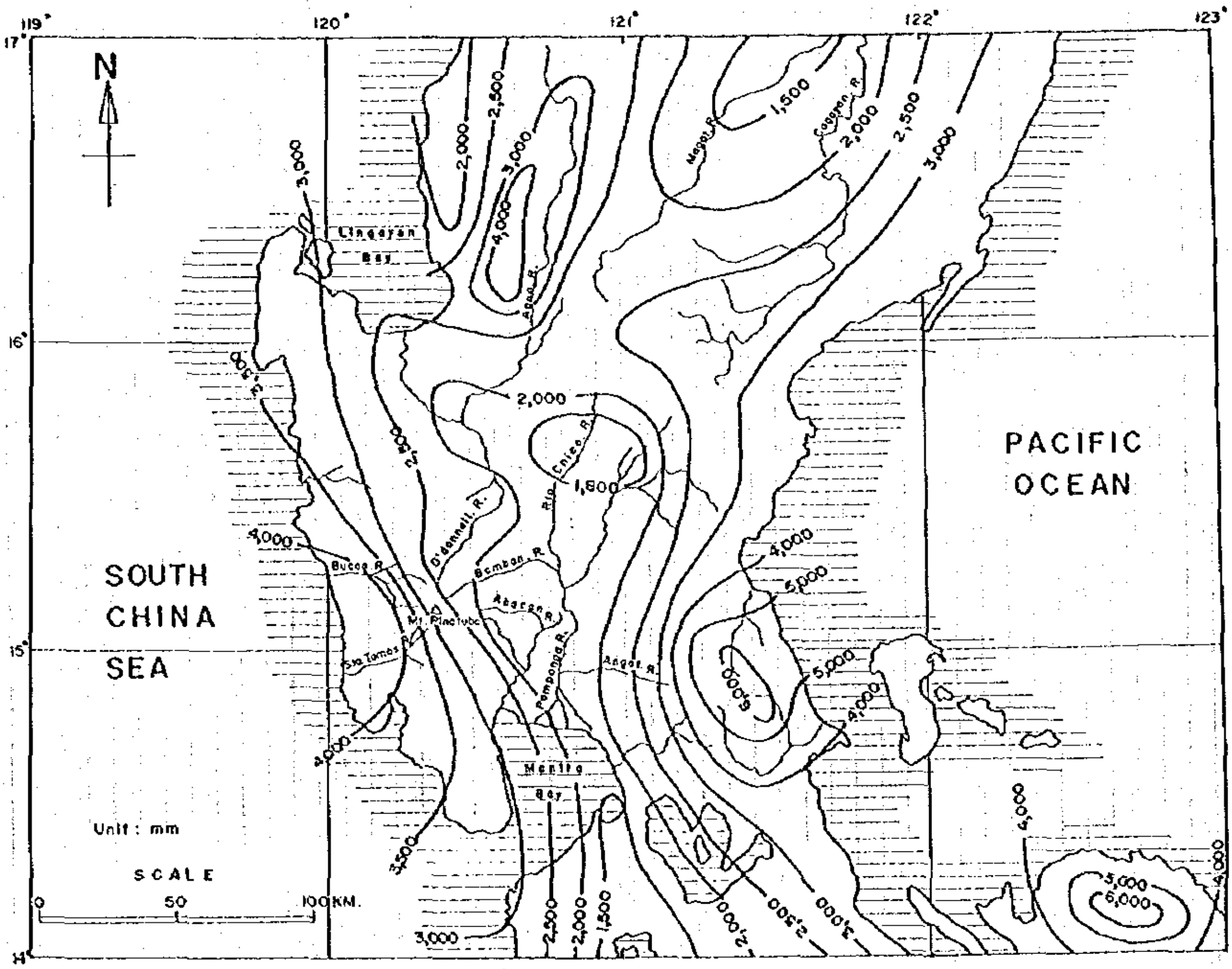

Figure 2.3 Isohyetal Map of Annual Rainfall

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

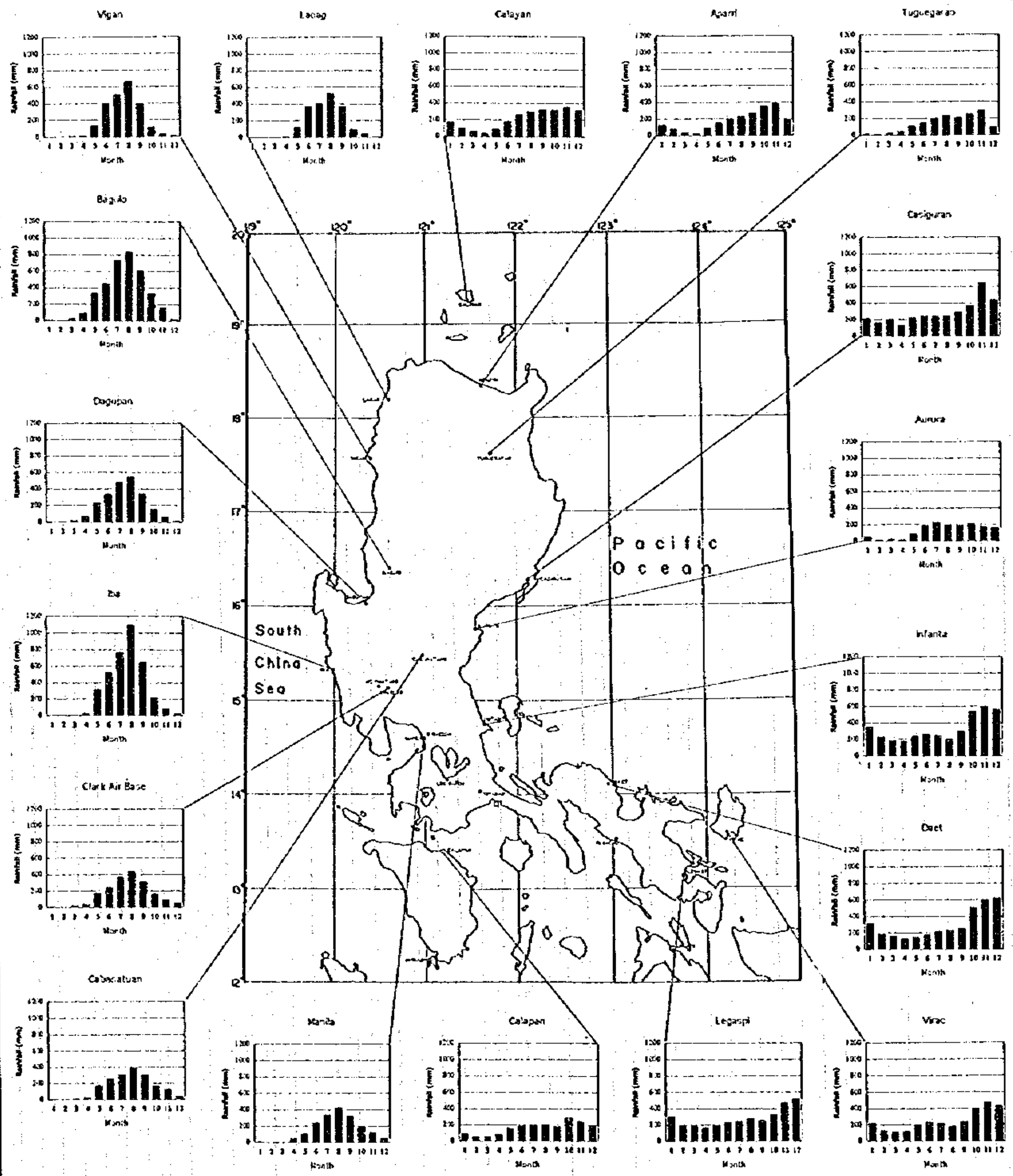

Figure 2.4 Monthly Average Rainfall

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

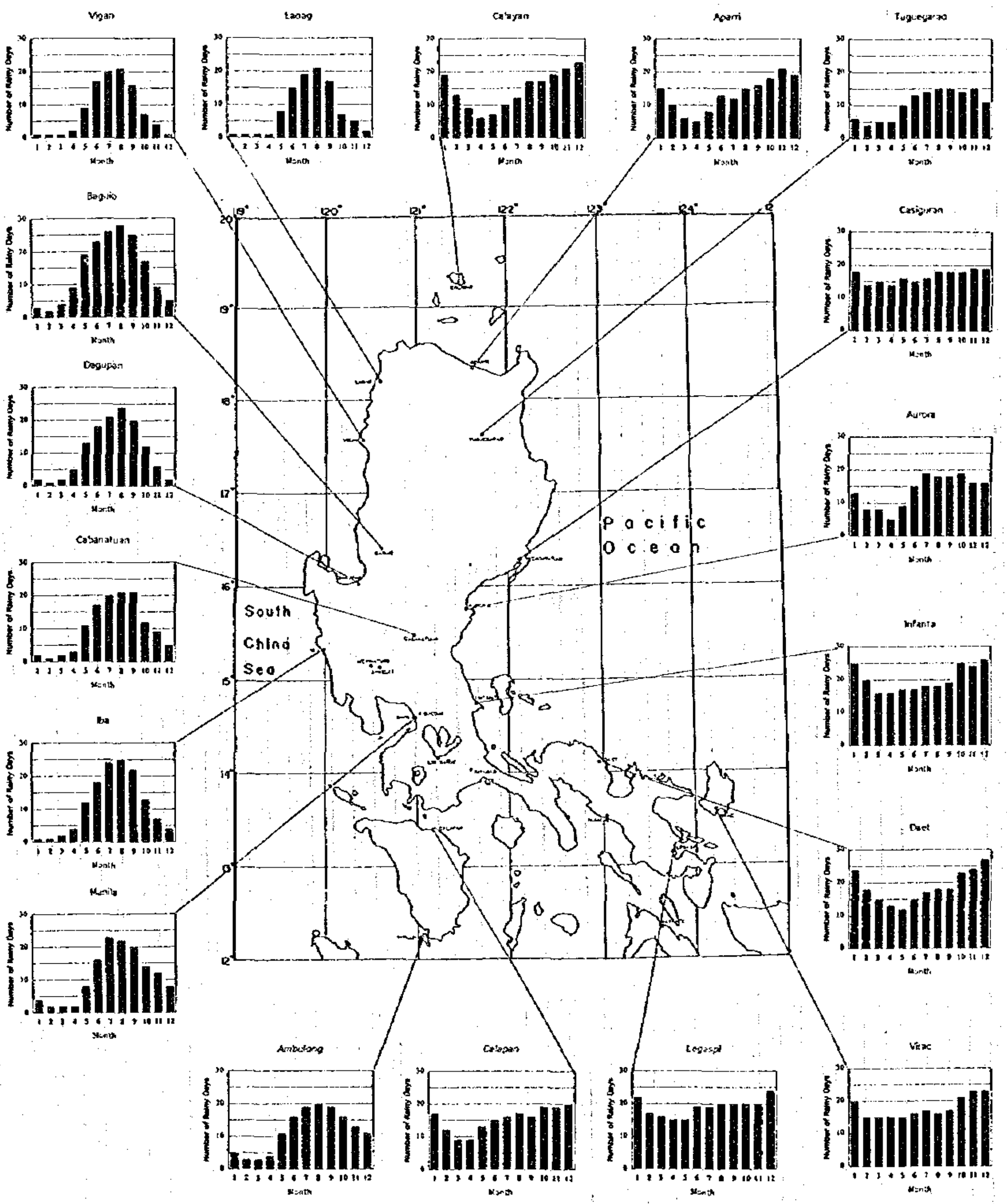

Figure 2.5 Monthly Number of Rainy Days

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

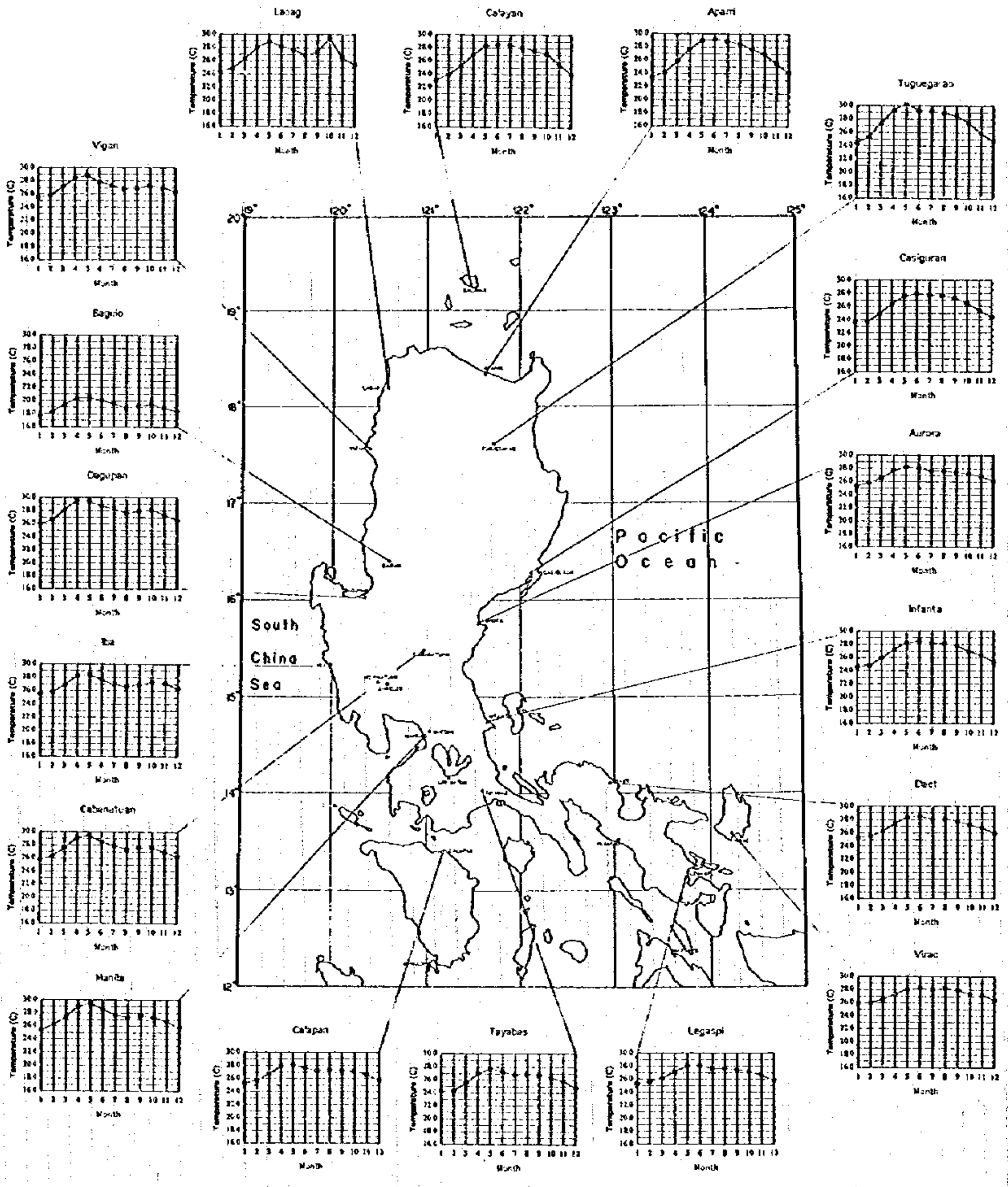

Figure 2.6 Monthly Mean Temperature

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

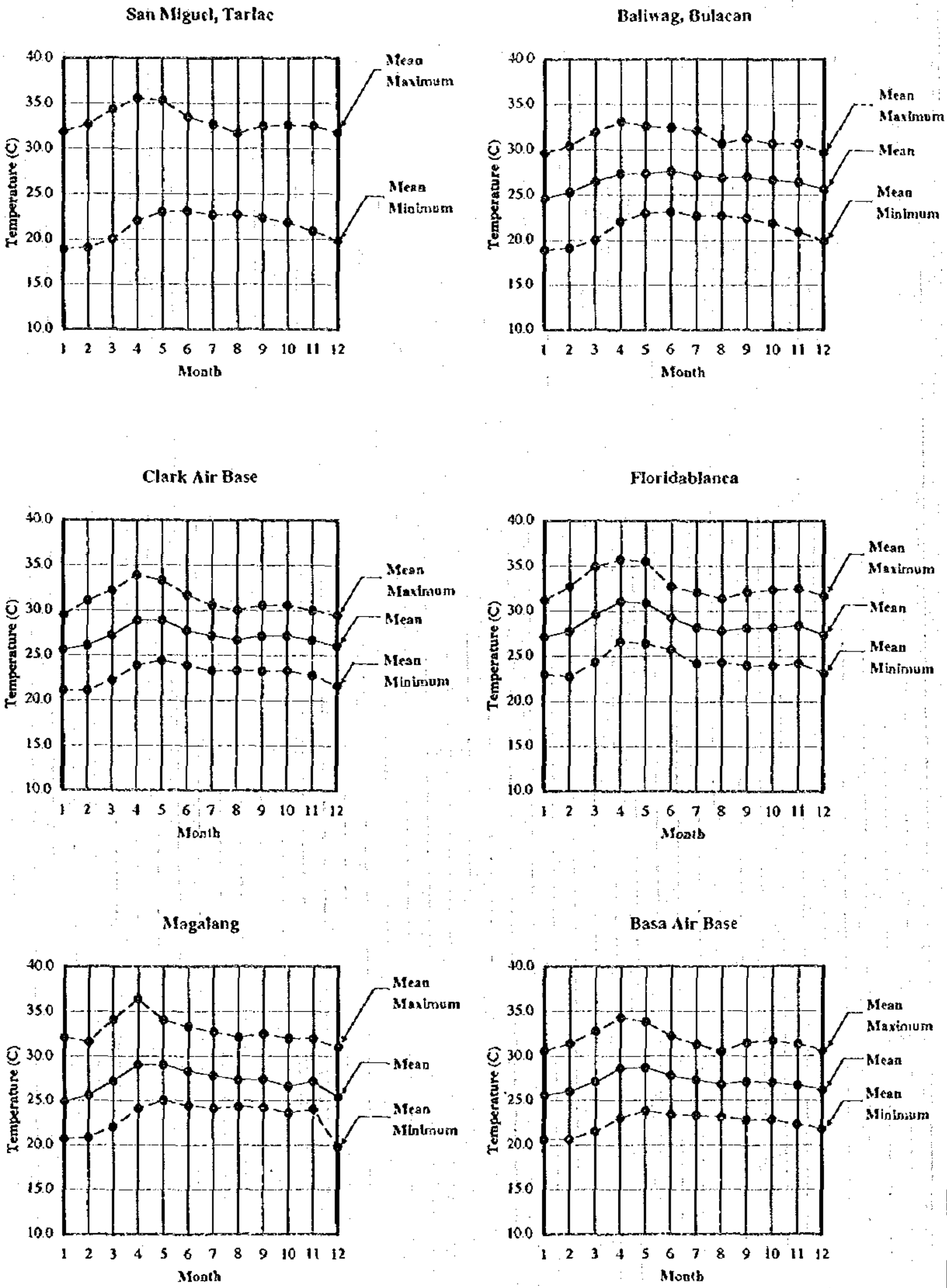

Figure 2.7 Variation of Monthly Mean Temperature

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

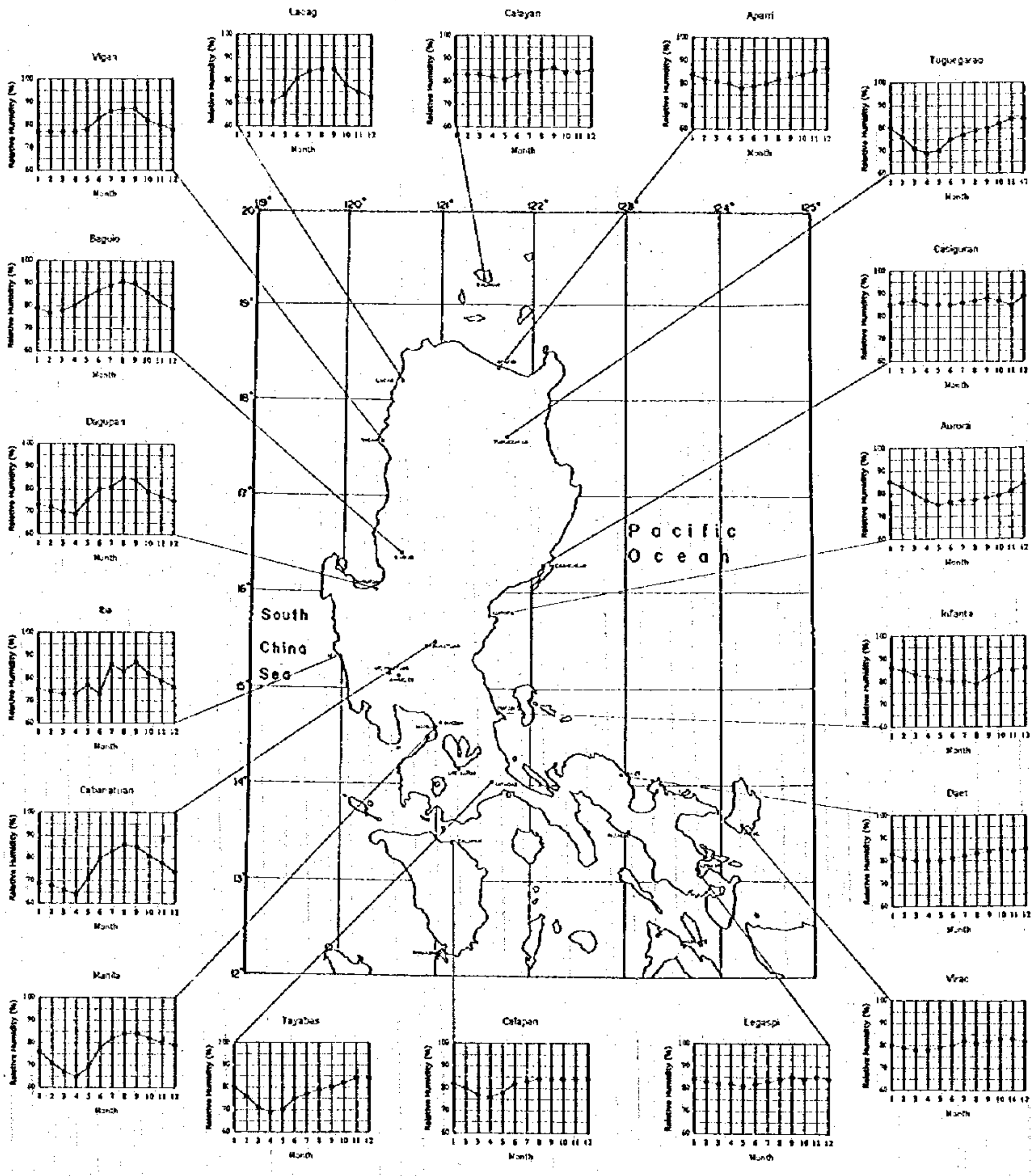

Figure 2.8 Monthly Mean Relative Humidity

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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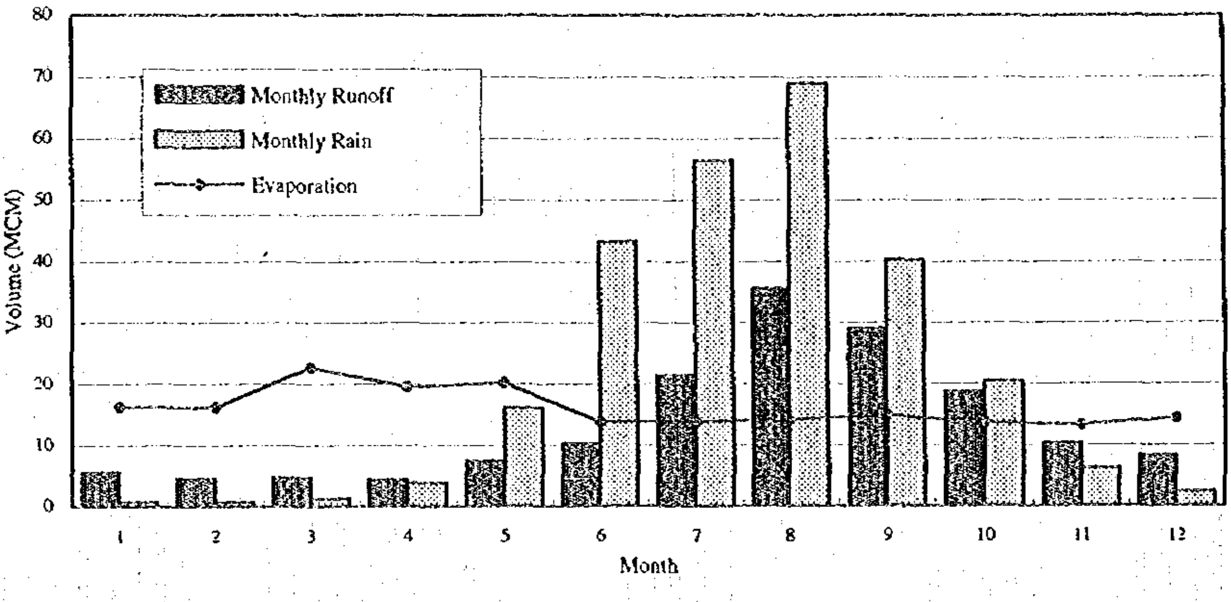
Monthly Variation of Rainfall, Runoff and Evaporation



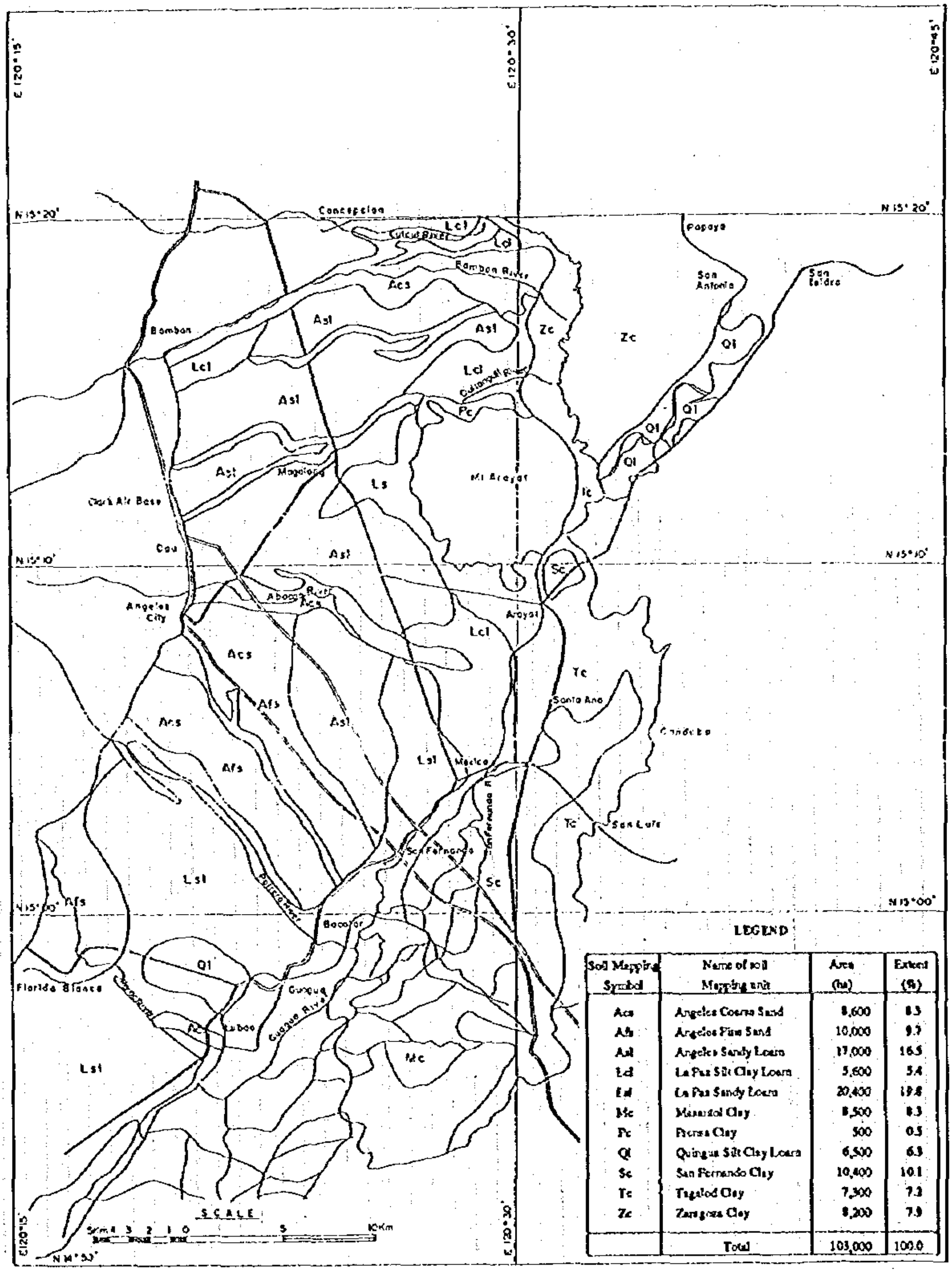
Ratio of Runoff Volume to Rainfall Volume at Porac River

DESCRIPTION	UNIT	MONTH												TOTAL
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Monthly Average Rainfall	mm	6	6	11	35	145	390	509	622	364	184	56	21	2,348
Monthly Average Rainfall Volume	MCM	0.666	0.688	1.265	3.863	16.128	43.257	56.466	68.998	40.360	20.446	6.205	2.331	260.672
Monthly Average Evaporation	mm	146	146	204	176	182	125	124	128	134	123	120	129	1,736
Monthly Average Evaporation Rate	MCM	16.206	16.162	22.666	19.514	20.180	13.820	13.797	14.208	14.874	13.642	13.276	14.352	192.696
Monthly Average Discharge	m3/sec	2.1	1.9	1.8	1.7	2.8	4.0	8.0	13.3	11.2	7.0	4.0	3.1	5.1 *
Monthly Average Runoff	MCM	5.649	4.565	4.757	4.316	7.433	10.358	21.406	35.676	29.059	18.730	10.358	8.324	160.630
Rainfall-Runoff Ratio	%	848.2	663.3	375.9	111.7	46.1	23.9	37.9	51.7	72.0	91.6	166.9	357.1	61.6

Remarks : Marked (*) means the annual average.
Discharge data at Del Carmen (111 km2) and rainfall data at Basa Air Base were recorded for 15 years (1958-1972).
Evaporation data was recorded at Floridablanca for1985 to 1987.

Figure 2.9 Ratio of Runoff Volume to Annual Rainfall

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



LEGEND

Soil Mapping Symbol	Name of soil Mapping unit	Area (ha)	Extent (%)
Acs	Angeles Coarse Sand	8,600	8.3
Afs	Angeles Fine Sand	10,000	9.7
Asl	Angeles Sandy Loam	17,000	16.5
Lcl	La Paz Silt Clay Loam	5,600	5.4
Lsl	La Paz Sandy Loam	20,400	19.8
Mc	Masantol Clay	8,500	8.3
Pc	Prensa Clay	500	0.5
Ql	Quingua Silt Clay Loam	6,500	6.3
Sc	San Fernando Clay	10,400	10.1
Tc	Tagalod Clay	7,300	7.1
Zc	Zaragoza Clay	8,200	7.9
	Total	103,000	100.0

Source : Feasibility Report on the Pampanga Delta Development Project (JICA, 1982)

Figure 2.10 Soil Map in the Study Area

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY

CHAPTER 3

MT.PINATUBO ERUPTION

CHAPTER 3 MT.PINATUBO ERUPTION

3.1 MT.PINATUBO ERUPTION

3.1.1 VOLCANIC ACTIVITIES

Mt.Pinatubo is surrounded by a highly dissected depositional apron of older pyroclastic flow, lahar, and associated stream deposits. According to the geological survey of the Philippine Institute of Volcanology and Seismology (PHIVOLCS) and the US Geological Survey (USGS), older eruptive periods have been identified by ^{14}C dates on charcoal in pyroclastic flow deposits at about 2,500 to 3,000, 5,000 to 6,000 and 35,000 years before present. The last eruption has been dated at 460±30 years ago.

On July 16, 1990, a M7.8 earthquake occurred along the Philippine Fault, about 100 km northeast of Mt.Pinatubo. The seismic records measured by the PHIVOLCS show that a M4.8 earthquake occurred about 10 km southeast of Mt.Pinatubo a few hours after the main shock. It was thought that the renewal of activity of Mt.Pinatubo may have been caused by an earthquake along Digdig Fault, a segment of the Philippine Fault Zone creating a landslide along the northwest side of the volcano.

Initial eruptive activity was characterized by minor steam and ash explosions 1.5 km northwest of the summit. Only a very thin layer of ash has been deposited over the area and the surrounding forests near the explosion vents have been devastated but no lahars have occurred as yet. It was only after major eruptive sequences on July 12 did the pyroclastic-fall and pyroclastic-flow deposits appear on the flanks of the edifice.

On June 15, 1991, after 400-500 years of dormancy, Mt.Pinatubo awoke with a climactic Plinian eruption. Mt.Pinatubo's summit was lowered from 1,745 m to 1,449 m as shown in Figure 3.1. A caldera with a diameter of 2 km and a summit crater of 600 m deep were formed. The caldera floor was partially filled by water to form lake. The early filling may have been attributed partly to groundwater seepage while the rest could be due to rainfall and leakages of brine from the pre-volcanic basement.

3.1.2 PYROCLASTIC FALL AND FLOW DEPOSITS

Areas within the 10-40 km radius danger zone of the Mt.Pinatubo bore the brunt of heavy ashfall blown all over the archipelago. Pyroclastic flow deposit was estimated at about 5 to 7 billion m^3 on the slope of Mt.Pinatubo. These hot deposits, as much as 220 m thick in places, cover an area of about 120 km^2. They completely filled the upper catchment of the rivers and formed broad depositional surfaces that extend as far as 16 km downstream from the vent. Pyroclastic flow deposit, lahar deposit as of 1991 and isopack line of ashfall are shown in Figure 3.2.

Total accumulation of pyroclastic flow deposits was greatest to the west and northwest in the Bucao River, but substantial deposition also occurred to the southwest in the Marella River, to the east in the Sacobia-Bamban River, and north in the O'Donnell River. The pyroclastic flow deposits are composed almost exclusively of pumice, with some denser lithic fragments in the early flows. Estimated volumes of pyroclastic flow deposits in major drainage systems around Mt.Pinatubo is given in Table 3.1.

Besides, the topographic maps for three (3) periods, that is, (i) before eruption in 1991, (ii) after eruption in 1992 and (iii) after eruption in 1994 were used for the estimation of the volume of pyroclastic flow deposit by Geographic Information System (GIS). The volume of pyroclastic flow deposit was estimated at 1.40 billion m^3 in the eastern slope of Mt.Pinatubo as shown in Figure 3.3.

3.1.3 *LAHAR*

(1) Lahar Characteristics

"Lahar" is an Indonesian term, defined as "... a rapidly flowing mixture of volcanic rock debris and water from a volcano". Lahars from Mt.Pinatubo which were triggered by heavy monsoon or typhoon rainfalls on erodible erupted materials has been flowing into densely populated areas of central Luzon since the major eruption of June 1991, although the toll of lives were small but enormous property losses and social disruption were caused. For the past four years (1991-1994), the most devastating lahars were generated during prolonged southwesterly monsoonal rains that were induced by the passage of tropical typhoons in the vicinity of Luzon. According to PHIVOLCS/USGS, characteristics of lahars in the Sacobia River for the period of 1991 to 1993 were summarized as follows,

Lahar discharge

* Surface flow velocities at Mactan (upper end of Clark AB): 2-15 m/s
* Surface flow velocities at Maskup (lower end of Clark AB): 1-5 m/s
* Travel time from Mactan to Maskup (8 km): 20- 70 min (avg. velocity of flow front and peak = 1.9 to 6.7 m/s, with large debris flows traveling fastest)
* Peak discharge at Mactan: 10-2,000 m^3/s (possibly as high as 5,000 m^3/s in 1991)
* Peak discharge at Maskup: 1-400 m^3/s measured, possibly reaching as high as 1,000 m^3/s in large flows
* Attenuation flows from Mactan to Maskup: small to moderate size are attenuated by 60-90% ; large flows are attenuated by 30-50%

Sediment

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

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

1) Debris flows typically had peak discharges of several hundreds to a thousand m^3/s, and contained about 60-65% (rarely, 70%) sediment by volume

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

(2) Grain Size Distribution

The grain sizes and specific gravity have a great influence on sediment transportation. Regardless of its origin as primary hyperconcentrated flows or as the runouts of debris flows, flows with hyperconcentrations of sediment volumetrically dominate the flow system and depositional records in the downstream reach.

Hyperconcentrated flow deposits in the eastern drainages of Mt.Pinatubo are dominated by sand-size phenocrysts from the pyroclastic flow deposits with an admixture of mineral grains from older deposits as shown in Figure 3.4. Pumice clasts are present but are volumetrically minor; most are preserved in coarse deposits near the surface.

3.2 EXTENT OF DAMAGE

3.2.1 DAMAGE IMMEDIATELY AFTER THE ERUPTION

The massive damage caused by the Mt. Pinatubo eruptions and the lahar flows that followed was placed at 10.6 billion Pesos at the end of 1991. The heaviest toll was on public infrastructure, including power, telecommunications, water supply systems and school and health facilities, estimated at 3.8 billion Pesos as given in Table 3.2. Losses to agriculture was estimated at 1.8 billion Pesos; to commerce and industry, 851 million Pesos; and natural resources, 120 million Pesos.

The total cost for relief operations, evacuation and resettlement, rehabilitation and reconstruction was estimated at 30 billion Pesos (US$1.034 billion). The cost of reconstruction and rehabilitation alone of vital infrastructure like roads, bridges and other facilities was placed at 9.5 billion Pesos.

About 489 km of major national roads and 163 km of municipal roads in Pampanga, Zambales, Bataan and Tarlac were covered under 20-40 cm of ash and sand. Six major bridges, namely Abacan, Pandan (Sapang Maraqui), Mancatian and Pabanlag in Pampanga, and Santa Fe and Umaya in Zambales collapsed immediately after eruption. Later, lahar flows destroyed the Bamban bridge in Tarlac, and a portion of Capaya bridge along the North Expressway in Angeles City. Two bridges along the Botolan-Capas road in Botolan, Zambales were inundated while the approaches of several bridges were also damaged. In all, 13 major bridges were destroyed or damaged.

Spans of four railway bridges in Angeles, Dau and between Mabalacat and Bamban were washed away by cascading lahar. Ten telegraph stations in Zambales, 13 in Pampanga, and 3 in Tarlac had either collapsed buildings or damaged telecommunications and office equipment and telephone lines.

3.2.2 DAMAGE FROM 1991 TO 1995

In the Abacan river basin, the lahar avalanche occurred only in 1991. No lahar was observed in the Abacan River since the Abacan Gap, small escarpment of 20 m deep, has been developed in the piracy point with the Sacobia River.

In the Sacobia-Bamban River, the lahar disaster area extended in the downstream reach by 1993. However, the lahar volume is diminishing year by year since the uppermost catchment of the Sacobia River was annexed to the Pasig River in October 1993.

Four years have passed since the eruption. Since the Pasig River has two times catchment area it had before the eruption, a large-scale lahar movement still occurs in Pasig river basin and has a temperature of 30 to 50°C. Lahar usually flows down with vapor since its temperature is higher than that of the surrounding air. It is called "Hot Lahar" or "Steaming Lahar". When lahar flows downstream on a gentle slope, lahar changes its form to mudflow, and the excessive sediment in the lahar accumulates in the river channel and the riverbed rises. When a flow contains a lesser amount of sediment, the flow then draws as much deposit sediment as possible and carries it to the downstream reach. This lowers the riverbed.

These condition occurs repeatedly, and lahar disasters extend to the downstream reach year after year. On October 1, 1995, a lahar avalanche in the Pasig River rolled over Gugu Creek and the San Fernando-Olongapo Road. Hundreds of houses were buried by lahar.

Table 3.3 shows the extent of damage for 5 years from 1991 to 1992.