3.3 EASTERN DRAINAGE OF MT.PINATUBO

3.3.1 GEOMORPHOLOGIC CHANGES

The total volume of pyroclastic flow deposits at eastern slope of Mt. Pinatubo where Sacobia-Bamban, Abacan and Pasig rivers originate were estimated at 1.42 billion m^3. 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 km^2 of the Sacobia River. The basin boundary map is shown in Figure 3.5. The catchment areas including tributaries of Sacobia-Bamban and Abacan rivers were enumerated below:

Sacobia-Bamban River		Abacan River	
Sacobia River	39.5 km^2	Sapangbato River	19.2 km^2
Sapang Cauayan River	20.8 km^2	Sapangbayo (Taug) River	14.1 km^2
Marimla River	67.5 km^2	Residual Basin	43.9 km^2
Sapang Balen River	21.7 km^2		
Residual Basin	57.4 km^2		
Total	206.9 km^2	Total	77.2 km^2

Note: The upstream reach of the Sacobia River of 23 km^2 was captured by the Pasig River in October 1993. The catchment area of the Sacobia River was 62.5 km^2 before 1993. While the catchment area of the Pasig River is estimated at 45 km^2 at Watch Point No.5 in 1995.

Lahars generated by heavy rain falling on erodible pyroclastic flow deposits pose continuing and grave danger to human lives and property in low-lying area of the Sacobia-Bamban and Abacan rivers 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;

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
Abacan	2,930	0	0	0	0	2,930
Pasig	3,700	600	500	3,000	1,900	9,700
Total	14,755	2,783	1,767	3,118	1,960	24,383

The table above shows the lahar disaster areas, where those of 1992 to 1995 show incremental disaster areas in comparison with the previous year. The chronological changes in lahar disaster area are shown in Figure 3.6.

3.3.2 SOCIO-ECONOMIC CONDITION

(1) Region III in Central Luzon

1) GDP Trend

In the latter half of 1980's, the Philippine economy has been lagging behind other ASEAN countries. At the initial stage of the Aquino regime in 1986, the economy of the Philippines went upwards with the inflow of foreign investment. But a number of unhappy incidents made it plunged down: military coup d'états in 1987-1990; the Gulf War in 1989; a drought, an earthquake and a big scale brown-out in 1990; the Pinatubo eruption and the closure of US military Bases in 1991.

The natural disasters and the political instability of the country have affected the Philippine economy. The Gross Domestic Products (GDP) growth showed negative in 1991 and nearly zero growth in 1992 (Table 3.4) and the per capita Gross National Products (GNP) of the Philippines was $836 in 1992.

In 1993, however, despite the bad weather and power shortage, the economy recovered after three years of depression and GDP attained an annual growth of 1.69%. This was mainly attributed to the effect of the Peso devaluation, which has enhanced the export flow and reduced the import amount.

2) Regional Economy

The Region III (Central Luzon) is characterized by the "ten-percent region" in the socio-economy of the whole Philippines: the population in 1990 was 6.2 million which corresponded to 10.2% of the whole Philippines; the GRDP of the Region contributed 9.0% of GDP in 1992. The land area of the Region occupies 6.1% of the national land. The Region constitutes a leading industrial area in the National Industrial Core Region. The manufacturing GRDP of the Region corresponds to 9.5% of the Manufacturing GDP. The Region is the rice granary of the Philippines: the share of rice production of the Region in 1992 was 20% of the whole nation. Another substantial share of agricultural products such as sugarcane, mango, eggplant and tomato are produced in the Region.

(2) Sacobia-Bamban River Basin

1) Economic Index

The GRDP in 1990 amounted to 22.7 billion Pesos in Pampanga and 10.6 billion Pesos in Tarlac. The former occupied 24% of the total GRDP of Region III and the latter 11% (Table 3.5). Regarding the structure of GRDP, the share of the agriculture sector of Pampanga was 16% and that of Tarlac was 32%. The share of the industrial sector was 42% in Pampanga and 32% in Tarlac. Tarlac has more agricultural area than Pampanga but Pampanga is more industrialized than Tarlac. The share of the industrial sector of Pampanga was higher than that of the regional average (39%) and the national average (35%). The per capita GRDP in 1990 showed 14,780 Pesos in Pampanga and 12,350 Pesos in Tarlac. Both of these were lower than that of the regional average (15,190 Pesos) and the national average (17,570 Pesos). In terms of the per capita GRDP, those of Zambales (19,110 Pesos) and Bulacan (17,420 Pesos) belonged to the highest in Region III.

2) Socio-Economic Change after Eruption

a) Population Changes after Eruption

The change in the population between 1990 and 1994 is observed in Table 3.6. The total population in the Study Area reduced by 57,200 from 736,100 in 1990 to 680,800 in 1994. The highest reduction was observed in Angeles City (the reduction was 26,700 between 1990 and 1994) followed by Bamban (17,600) and Mabalacat (15,700). The average family size was 5.1 in August 1994. The population density was 657 persons per square km and that of urban areas was 2,367. In addition to the above household population, there are resettlers who were forced to evacuate their houses and are moved to resettlement sites. The number of such resettlers are estimated at about 6,400 households i.e. about 32,000 peoples.

b) Resettlement and Livelihood

The number of houses totally destroyed by lahar is reported to have amounted to 8,260 in 1991 and 1992 and another 73,400 houses were partially damaged. Coupled with these incidents, the most serious problem is the massive migration of people from their houses to evacuation centers. Since facilities in the evacuation centers are temporary, the resettlement construction has been programmed and progressed so far. The completion of the resettlement sites and the transfer of all the evacuees to the settlement sites before the onset of the 1995 rainy season are given the highest priority in the action program of the MPC.

Another problem of the evacuees is the livelihood program. Since majority are tillers, getting jobs for the evacuees has posed a real problem in the resettlement sites. Some "productivity centers" are being built in the resettlement sites to provide the settlers with job opportunities. But it is hard to find private firms which would invest in the productivity centers. So far the livelihood problem in the settlement sites is still a big problem to be solved.

c) Unemployment

Apart from the evacuees, the withdrawal of the US Army from the Clark Air Base (CAB) and the Subic Navy Base directly affected the Filipino employees who have worked at these US Bases. As of May 1989, it was reported that the number of Filipino workers at CAB was 4,500 direct employees while 37,900 were indirect employed. These included contractors, domestics and concessionaires. In addition, many businesses within the bases have closed shop. The CAB closure affected heavily Angeles City, Mabalacat and Capas. About 75 % of the total employee of CAB was estimated to come from Angeles City. According to the population survey conducted by the Angeles City Office in 1992, the total population of Angeles was reduced from 236,700 in 1990 to 206,800 in 1992. This reduction of population can be attributed largely, though not wholly, to the closure of CAB. The emigration of people were also noted at the Mabalacat Municipality Office. In Capas, there existed three US Bases including the Radio Transmission Facilities, the Camp O'Donnell and the Crow Valley Target Range. Unemployment was also pointed out as the biggest problem in Capas.

d) Damages to Irrigation Facilities

Since majority of the inhabitants in the Study Area are tillers, the damage to the irrigation facilities directly affects their livelihood. As the effect of siltation will be long term, there is an urgent need to study the counter measures to rehabilitate and improve the irrigation facilities as soon as possible.

(3) Land Use

1) Pre-Eruption

Agriculture was the dominant land use in the Study Area as shown in Figure 3.7. Rice and sugarcane were the extensively grown crops. Cassava, sweet potato, legume, fruits and commercial crops were also planted. Muskmelon and watermelon were grown at the Candaba Swamp during dry season. Rainfed and irrigated paddy rice, sugarcane, root crops, vegetables and fruit trees are grown on the lower river terraces and broad alluvial plains. Rainfed lowland paddy was also grown on the foot of volcanic hills and moderately sloping pyroclastic hills. Other upland crops were grown on these land management units. Forest, shrubs and grassland are extensive on the pryroclastic hill, volcanic hills foot and pyroclastic mountain. Most built-up areas were located on the broad alluvial plains, residual terrace and pyroclastic hills.

2) After Eruption

Figure 3.8 shows the land use map after the eruption. Agricultural lands were seriously damaged by lahar deposits and sedimentation from 1991 to 1993 in the study area. Total 10,602 ha were damaged in the Sacobia-Bamban river system, and total 2,593 ha were damaged in the Abacan river system. These areas affected by lahar deposits and sedimentation were mostly still remained or changed to grass land, some farmer were growing watermelon or sugarcane at the sediment crop land on trial.

The build-up area in Sacobia-Bamban river system, at both sides of Bamban bridge were completely damaged by lahar in 1991 and 1992, and barangays of Sta. Rita, Malupa, San Martin and Magao in Concepcion also damaged with thick of lahar deposits in 1991. On the other hand, stream bank erosion of Abacan River in Angeles City destroyed residential establishments in 1991, and in 1992 partially.

(4) Transportation

The Sacobia-Bamban river basin constitutes a strategic point for the transportation connecting the Northern Luzon and the Metro Manila. The present traffic in the Central Luzon is estimated as shown in Figure 3.9. Two main arteries can be observed running northwards from Metro Manila through the Region: one is the Manila North Road (Route No.3 or Mac-Arthur Highway) and North Luzon Expressway which join together at Mabalacat and run further northwards through Bamban, Capas and Tarlac; another is the Philippine Friendship Highway running from Bulacan northwards through Sta.Rosa.

According to a spot traffic survey conducted by the JICA/DPWH in August 1994 at the San Francisco bridge on the Route No.329 (Ninoy Aquino Byway), the total traffic was counted at about 8,000 vehicles in the daytime of 12 hours and 13,000 for 24 hours. The survey was also conducted in July 1995 as well as the data collection of traffic volume data in the North Luzon Expressway. The results show that 13,000 vehicles for 24 hours pass the San Francisco Bridge and 8,000 vehicles pass through North Luzon Expressway of which about 60 % vehicles comes from Metro Manila.

Judging from the above data, most of the traffic that has passed over the Bamban Bridge when it was passable seems to take the route crossing the San Francisco Bridge on the Route No.329. The importance of the San Francisco Bridge is accordingly increasing until the Route 3 is restored. However, the clearance of the San Francisco Bridge is reduced from 90 cm in June 1995 to 72 cm in October 1995. The DPWH commenced the construction works for new San Francisco Bridge in October 1995 under the ADB fund. During the dry season, some trucks and buses cross the Bamban River running in the shallow river water. According to the traffic survey of DPWH in November 1994, about 3,000 vehicles crossed the shallow Bamban River. During the rainy season, access roads to the San Francisco Bridge become inundated when a typhoon hits the area. In such cases, no vehicles can cross the Bamban River and all the vehicles going northwards are forced to detour through the Friendship Highway.

(5) Economic Activities

In the Sacobia-Bamban and Abacan rievr basin, the unemployment is the biggest social and economic problem. The result of the household sampling survey conducted by JICA in August 1994. The unemployment ratio was estimated as high as at 28% with a breakdown of 36% in Tarlac Province and 26% in Pampanga Province.

Meanwhile, the development of the Clark Special Economic Zone (CSEZ) is under going with the administration of the Clark Development Corporation (CDC). The fifteen companies including Taiwan, Korea, USA and the Philippines nationality are operating in the 54 hectares land area. Many of them are export oriented businesses. The number of workers is about 2,000 and it is expected to increase to 3,000 within 5 years. The plan of a Clark International Airport in association with the widening of the North Luzon Expressway between San Fernando and Santa Ines was also reported in 1994.

3.4 GOVERNMENT'S EFFORT

3.4.1 IMMEDIATELY BEFORE THE ERUPTION

(1) Activity of PHIVOLCS/USGS Team

Immediately before the eruption on May 13, 1991, a simple, multi-level description of unrest, and a 5-level scheme was introduced by PHIVOLCS/USGS team. One intent of the scheme was to provide a simple set of steps to which the OCD and military commanders could establish their response plans. Concerned agencies began to prepare contingency plan, each of which was loosely tied to alert levels. Most of the evacuations that were eventually ordered, including those of Aetas living on the lower flanks of Mt. Pinatubo, were based on a preliminary hazard map prepared by USGS and PHIVOLCS' recommendation of zones 10, 20, 30 and 40 km radius from the volcano.

The tragedy of Nevado del Ruiz occurred because a perfectly good scientific identification of hazard was poorly understood or not believed by key officials, who were accordingly slow to order precaution to the people. Therefore, it was necessary to undertake an intensive public education to the eruption of Mt. Pinatubo. PHIVOLCS/USGS team prepared the videotape which entitled "Understanding Volcanic Hazards", and delivered to as many people including government officers as possible. Consequently, people did start to plan for a possible eruption.

(2) Hazard Mapping

In the warning of eruption of Mt. Pinatubo, the evacuation zone was defined not by predicted hazard map but by circular evacuation zone with the radius from the summit of Mt. Pinatubo under the following reasons.

PHIVOLCS has recommended traditionally evacuations around volcano's based upon radius from the summit of volcano. In a crisis situation, it is easier to use a familiar procedure than to develop new ones. In addition, officials and the general public really did not understand the nature of the hazards or hazard maps well enough to be confident that they were evacuating the right areas. RDCC-III also agreed that a radial hazard zone would be the easiest zone to implement. In fact, the circular evacuation zones could be easily expanded and seemed to be the only other portion.

3.4.2 EMERGENCY ACTIVITIES AND ORGANIZATIONS

(1) Presidential Task Force Pinatubo

Immediately after the eruption of Mt. Pinatubo, the Presidential Task Force Pinatubo was established on June 26, 1991 to put in place a concrete machinery and program which will guide rehabilitation efforts of government and coordinate those of the private sector and the international community as necessary. The organization chart is shown in Figure 3.10. Their reports, "Mt. Pinatubo Rehabilitation and Reconstruction Program (1992-1997)", emphasized that the continuous threat against lahar flow and/or flooding, the development framework for the rehabilitation program for lahar disastered areas and the priority programs for the period from 1992 to 1997.

(2) Mt. Pinatubo Commission

The Mount Pinatubo Commission (MPC) was established in October 1992. The MPC is mandated to assist victims in the communities damaged or destroyed or adversely affected by the eruption of Mt. Pinatubo and its after effects by i) extending aid, relief, resettlement, rehabilitation and livelihood, and ii) undertaking construction, repair and/or reconstruction of infrastructure; and to restore living conditions of Aetas and other members of the cultural communities in the affected areas. The Commission is composed of eleven members as shown in Figure 3.11. The MPC has a term of six years from October 1992, extendable by the President to a maximum of three years.

The MPC formulated "Integrated Plan for the Mount Pinatubo Affected Areas (Final Draft)" in July 1994. The Integrated Pan is organized into three (3) major rehabilitation programs; namely, infrastructure, livelihood and resettlement. In the preparation of plans and programs on river basin infrastructure, the "Integrated Plan" referred to the following related studies and plans; namely: (i) the PHIVOLCS/USGS studies and projections on pyroclastic deposits, lahar flows, areas at risk from lahar attack and flooding; (ii) US Army Corps of Engineers (USACE) Recovery Action Plan Report; (iii) Swiss Disaster Relief (SDR) Engineering Report on O'Donnell River, (iv) Japan International Cooperation Agency (JICA) Master Plan for Sacobia-Bamban/Abacan rivers (v) plans for settlements, growth centers and special economic zones; (vi) land use plan and spatial strategy for the area; and (vii) plans for the agricultural, industrial and trade sectors. The Integrated Plan is being updated through the discussion of "Expert's Meeting" and the "Workshop" for reviewing the Integrated Plan in June 1995.

3.4.3 STRUCTURAL REHABILITATION PLAN

The Department of Public Works and Highways (DPWH), an executive agency to carry out the infrastructure program which was promulgated by the MPC, has adopted a set of strategies within the affected areas. The rehabilitation and reconstruction program of the DPWH in the Mt. Pinatubo affected areas (Infrastructure Rehabilitation Plan 1992-1997) is focused on the following priorities:

1) *Keeping transport systems*, particularly major roads and river crossings, open in order to provide for uninterrupted movement of people, goods, and services to enhance speedy recovery and rehabilitation.

2) *Protection* of life, communities, agricultural and fishpond areas and infrastructure from further destruction, and mitigation of the effects of potential damage, especially from lahar and flood waters.

3) *Reconstruction and rehabilitation* of schools and other public buildings located outside areas affected by mudflows to restore the educational program and essential administrative services.

4) *Support to other rehabilitation activities* of other agencies by providing infrastructure support to resettlement and livelihood programs.

The priority for implementation was given to the affected areas according to the degree of risk of lahar based on the hazard map which was prepared by the PHIVOLCS.

1)	High-Risk Areas	Areas which are very likely to be buried by lahar were delineated taking into account topography and the enormous volume of potential lahar flow.
2)	Medium-Risk Areas	Areas which are likely to be affected by lahar and can be protected by normal engineering works.
3)	Low-Risk Areas	Areas at very little chance of being affected by lahar flow and may need only minimal engineering works.

All the engineering intervention measures were done by the DPWH based on the phased activities: (i) immediate repairing works of existing structures and river channel, (ii) intermediate rehabilitation works to reduce the volume of lahar to low-lying areas and to ensure the flow capacity of river channel during flooding, and (iii) detailed long-term plans which were studied by USACE, SDR and JICA to determine the size and type of project features which will provide the greatest value for reducing future damage.

3.4.4 NON-STRUCTURAL MEASURES

(1) Flood/Mudflow Warning and Dissemination System

a) Warning Equipment

The Regional Disaster Coordinating Council in Region III (RDCC-III) is the inter-agency organization for flood/mudflow warning in the Mt. Pinatubo affected area. The office of RDCC-III was established at the Camp Olivas in San Fernando, Pampanga. Flood/Lahar monitoring system of RDCC-III is organized into 4 systems (Figure 3.12);

1) AFP/PNP lahar watchpoint,
2) PHIVOLCS/USGS lahar monitoring system,
3) PAGASA weather information, and
4) OCD/JICA lahar monitoring 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, PDCC, MDCC and BDCC. The warning message is also transmitted by hot-line telephone linking the radio stations in Manila.

b) Public Education about Lahar Hazard

For barangay leaders and the general public, illustrated flyers, posters, and leaflets were prepared and distributed by RDCC-III. One poster entitled "How to avoid becoming a victim of a mudflow", offered suggestions for what residents should do before, and when, they are warned of lahar. The RDCC-III emphasized the following points in the public education:

1. Stay away from potential mudflow channels when it is raining at Mt. Pinatubo and nearby hills,

2. If you live in a low-lying place, move immediately to high ground, keeping in mind that mudflows go to areas that are usually flooded during the rainy season,

3. Make your own "hill" at least 4 m high, and widen the top to serve as an evacuation center,

4. Make barriers, if possible, but be aware that mudflows can be fast and strong,

5. Each group of houses should have a watch-person on a nearby hill to sound mudflow alarms,

6. Be ready with flashlights and a radio,

7. Listen for warnings and pay attention to the authorities, and

8. Stay calm and do not be fooled by false news or rumors.

As well as the above public education, the relatively large scale of hazard map, as described hereinafter, enabled officials and residents to judge whether their barangays, town streets, and secondary roads were in relatively high or relatively low danger.

c) Hazard Mapping

PHIVOLCS

The first hazard map, released in August, showed a zone judged to be "subject to mudflows" as of July 30. The second, released in October, showed lahars that had occurred as of September 15 and a significantly larger zone of "subject to mudflows".

The map in October was the first of the lahar hazard maps to be printed and widely distributed and was very influential even though the evolving crisis required later expansion of its hazard zones. Many of the evacuation sites, resettlement sites, and other elements of recovery were based on that map and its subsequent revisions.

In July 1992, PHIVOLCS released a revised lahar hazard map with a scale of 1:50,000 on the basis of the assessment on barangay level.

Pinatubo Lahar Hazards Taskforce (PLHT)

Detailed hazard maps for the Santo Tomas and Bucao rivers were issued by PLHT in August and September 1991. The map for Santo Tomas river basin showed lahar disaster areas as of July, and organized into four hazard zones; (i) subject to lahars and moderate to heavy flooding, (ii) subject to overbank lahars and moderate to heavy flooding, (iii) prone to minor or moderate flooding, and (iv) subject to lahars escaping from filled irrigation canals. The another map for Bucao river basin in September 1991 used the similar zoning.

Bureau of Soil and Water Management (BSWM)

BSWM issued a GIS-based map of "Mudflow and Siltation Risk" in October 1991 showing three zones; they are, (i) a high risk area subject to moderate to severe mudflows and/or siltation, (ii) low risk area subject to low siltation and (iii) a non-risk area. These zones, which are larger than any of preseding maps, indicate the source of the fertile sandy loams throughout much of Central Luzon, but it neglects to note that this sediment has been supplied by many eruptions over geologic time. Thus risk appears to be exaggerated.

National Economic Development Agency (NEDA)

In August 1992, NEDA published a set of GIS-based maps of lahar hazard on the basis of the lahar observation data by PHIVOLCS. The map was substantially improved by delineating administrative boundaries, even those of barangays. Updating of the above map was carried out by NEDA/PHIVOLCS in December, 1992.

(2) Resettlement and Evacuation System

The Mount Pinatubo Commission (MPC) administered 9 lowland and 10 upland sites. Six sites started by local governments were eventually assisted by the MPC. The rest are administered by other national and local government agencies, such as the Department of Agrarian Reform, the Provincial and City governments, and Non Government Organizations (NGOs). In total, 21,004 units were prepared as of 1992. Additional 3,360 units were started under the 1993 program. With the 1994 lahar flow, the resettlement sites intended for 1991 to 1993 lahar victims were made to accommodate new victims from Porac and Bacolor. The 1994 Resettlement Program carried out by the MPC aimed to provide 8,732 additional housing units. In 1994, there are 34 resettlement sites (Figure 3.13) and 73 evacuation sites distributed in the following provinces.

Numbers of Resettlement Site and Evacuation Center

	Resettlement Site	Evacuation Centers
Pampanga	15	37
Tarlac	6	20
Zambales	8	16
Nueva Ecija	3	-
Off-site	2	-
Total	34	73

Since majority of the dislocated families are tillers, some are tilling their own land, they 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. Only the upland resettlements sites provided farm sites.

Productivity centers were proposed to attract domestic and foreign investors to invest within the resettlement sites and provide employment for settlers. Factory buildings and the required amenities have been introduced. The vital power and water supply needed, however, have not been installed. There are two successful productivity centers, both near Angeles City where garments, furniture and ceramics industries have been set up. The rest are temporarily used as evacuation sites.

(3) Livelihood

In spite of the many livelihood financing programs available, there were few takers. Business planning and employment preparation were lacking, Those who needed capital could not avail of them due to the loan requirements. They have to work for the daily sustenance. Unemployment rate is still very high among the affected and resettled families. First, the closure of the US Military Bases resulted in 42,617 lost jobs. Secondly, the loss of agricultural lands due to lahar, caused many more farmers to lose their traditional source of livelihood. Finally, daily food rations resulted to dependence on external material assistance and less initiative to work.

The initial livelihood programs which were undertaken by the GOP were essentially focused on the provision of job opportunities in the agricultural and industry sectors. They aimed to restore livelihood activities in the lahar affected areas, and to create new job opportunities. Livelihood support in the past four years shows that the need to provide facility requirements particularly housing in resettlement site has been given priority.

3.4.5 SUPPORT BY DONORS

Immediately after the eruption, not only the international donor community responded by giving immediate relief assistance to the affected area in the form of actual cash donations, goods, and services, but also monetary donations from foreign private individuals and organizations were received by the Office of the President amounting to 98 million Pesos as of December 1991. Following the above monetary assistance, the scientific and technical studies for engineering intervention measures were undertaken concerning to the rehabilitation of infrastructures.

(1) U.S. Geological Survey (USGS)

USGS has worked with PHIVOLCS, and its predecessor, the Commission on Volcanology (COMVOL), ever since COMVOL was established in 1951. The United States Agency for International Development (USAID) supported this collaboration at Mt.Pinatubo and brought geological and monitoring experience at Mt.St.Helens and a number of similar volcanoes around the Pacific Ocean. Immediately before the eruption of Mt.Pinatubo on June 15, 1991, USGS/PHIVOLCS forecast the disastrous volcanic activity of Mt.Pinatubo, and the community and civil defense officials convinced a skeptical population to move out of the way. Owing to the warning dissemination by USGS/PHIVOLCS, it was reported that more than 10,000 and perhaps as many as 25,000 people escaped certain death. The reports prepared by PHIVOLCS/USGS give the precious baseline data for volcanic activities and lahar avalanches.

(2) U.S. Army Corps of Engineers (USACE)

USACE conducted the Mt.Pinatubo Recovery Action Plan under USAID fund. The objective of USACE's study is (i) to evaluate existing pyroclastic and sediment deposits, (ii) assess the risks of future sedimentation, flood and lahars and (iii) develop recommendations of possible engineering alternatives for the eight major river basins draining Mt.Pinatubo. The output of the study are summarized in the following two (2) products:

1) The Interim Action Report, completed in December 1992, covering early development and implementation measures to mitigate potential impacts of the 1993 monsoon season for the Pasig-Potrero river basin.

2) The Long Term Action Report, the final report of which was completed in March 1995, addressing the long term flooding and sediment control measures for the eight river basins impacted by Mt.Pinatubo.

As for the structural plan in the eastern drainages of Mt.Pinatubo, the design condition on sediment yield was based on the pre-piracy condition. Thus the dimension of structural measure proposed in USACE's Study was rather large for Sacobia-Bamban river basin and rather small for Pasig-Potrero river basin. While, the structural measure in western river basins of Mt.Pinatubo, the DPWH followed the alignment of diking system proposed in USACE's Study.

(3) Swiss Disaster Relief (SDR)

The SDR conducted a study on lahars in the O'Donnell River. The objectives of the study are (i) to assess the present situation in the O'Donnell river system with regard to lahar hazards and to forecast the future development and (ii) to propose possible countermeasures to reduce the expected damage due to future lahars. In the Final Report of SDR's study which was submitted in January 1994, the several countermeasures which were organized into protective dikes, sediment retention dam, dredging works and monitoring system were recommended to be implemented.

3.4.6 SUPPORT BY NON-GOVERNMENT ORGANIZATION (NGO)

Non-government organizations have extended and may continue to provide technical assistance in developing resettlement projects and sourcing funds for this purpose. They can extend skills development training and business development, and assist community leaders to organize their communities for housing and livelihood projects.

As well as the Philippine Red Cross which also provides disaster preparedness and relief services, evacuation centers and resettlement areas., some resettlement areas are administered by the Non Government Organizations (NGOs) such as the Social Action Centers of Pampanga (SACOP) and Tarlac (SACOT), The Philippine National Red Cross (PNRC), the Philippine Bureau for Social Progress and Talete Kong Panulong Kapangpangan, Inc. and the Tribal Filipino Apostolate.

Table 3.1 PINATUBO LAHARS SEDIMENT DELIVERY, 1991-1994

WATERSHED	Volume of pyroclastic flow deposits (10^6 m^3)	Volume of erodible PF (10^6 m^3)	Erodible pre-eruption sediments (10^6 m^3)	Potential lahar sediment volume (10^6 m^3)	1991 Lahar deposits (10^6 m^3)	1992 Lahar deposits (10^6 m^3)	1993 Lahar deposits (10^6 m^3)	1994 Lahar deposits (10^6 m^3)	Lahar deposits to date (10^6 m^3)	%	Remaining source sediments (10^6 m^3)	%
O'Donnell-Bangut-Tarlac	600	240	24	264	100	20	30	12 [1]	162	61	102	39
Sacobia-Pasig-Abacan	1,600	640	64	704	210	110	100	143	563	80	141	20
Sacobia-Bamban	*900*	*360*	*36*	*396*	*100*	*70*	*45*	*8* [2]	*223*			
Pasig-Potrero	*500*	*200*	*20*	*220*	*50*	*40*	*55*	*135*	*280*			
Abacan	*200*	*80*	*8*	*88*	*60*	*0*	*0*	*0*	*60*			
Porac-Gumain	50	50	10	60	60	0	0	0	60	100	0	0
Marella-Sto. Tomas	1,300	650	65	715	185	195	125	60 [3]	565	79	150	21
Balin Baquero-Bucao	3,100	1,550	155	1,705	250	230	250	95 [3]	825	48	880	52
TOTAL	**6,650**	**3,130**	**318**	**3,448**	**805**	**555**	**505**	**310**	**2,175**	**63**	**1,273**	**37**

[1] Volume estimate by C.G. Newhall (1994)
[2] Volume estimate by JICA (1994)
[3] Volume estimate by PHIVOLCS, ZLSMG (1994)

Source : Phivolcs Assessment of the Volcanic Activity and Lahar Situation at Mount Pinatubo (As of 05 May 1995)

Table 3.2 Estimated Cost of Damages on Public Infrastructure in Region III, 1991

(As of 23 August 1991) (in thousand pesos)

Infrastructure Sub-Sector/ Facility	Western Areas				Eastern Areas				Other Areas			Grand Total	Percent Dist.
	Zambales	Bataan	Olongapo	Total	Pampanga	Tarlac	Angeles	Total	Bulacan	N. Ecija	Total		
TRANSPORTATION	185,320	69,660	67,546	322,526	208,676	36,502	509,650	754,828	32,309	40,245	72,554	1,149,908	30.0%
Roads and Bridges	170,320	69,660	67,546	307,526	183,676	25,502	475,650	684,828	32,309	40,245	72,554	1,064,908	27.8%
1. National System	98,893	63,164	9,300	171,357	111,526	10,375	475,650	597,551	13,460	15,220	28,680	797,588	20.8%
- Roads	33,093	63,000	9,300	105,393	31,666	6,725	14,000	52,391	9,160	13,120	22,280	180,064	4.7%
- Bridges	65,800	164	0	65,964	79,860	3,650	461,650	545,160	4,300	2,100	6,400	617,524	16.1%
2. Local Roads and Bridges	71,427	6,496	58,246	136,169	72,150	15,127	0	87,277	18,849	25,025	43,874	267,320	7.0%
- Provincial City	8,653	1,769	58,246	68,668	50	1,895	0	1,945	3,701	5,600	9,301	79,914	2.1%
- Municipal	27,500	270	0	27,770	16,100	255	0	16,355	0	555	555	44,680	1.2%
- Barangay	35,274	4,457	0	39,731	56,000	12,977	0	68,977	15,148	18,870	34,018	142,726	3.7%
Railway Facilities	0	0	0	0	25,000	11,000	34,000	70,000	0	0	0	70,000	1.8%
Airport Facilities	15,000	0	0	15,000	0	0	0	0	0	0	0	15,000	0.4%
COMMUNICATION	6,992	0	4,012	11,004	1,707	344	160	2,211	0	0	0	13,215	0.3%
Telecommunications Facilities	6,702	0	2,712	9,414	1,707	344	160	2,211	0	0	0	11,625	0.3%
Postal Communication Facilities	290	0	1,300	1,590	0	0	0	0	0	0	0	1,590	0.0%
POWER AND ELECTRIFICATION	22,571	2,938	3,244	28,753	14,771	11,095	298	26,164	0	0	0	54,918	1.4%
NPC Facilities	860	1,199	3,244	5,303	0	2,025	298	2,323	0	0	0	7,627	0.2%
Electric Cooperatives	21,711	1,739	0	23,450	14,771	9,070	0	23,841	0	0	0	47,291	1.2%
WATER RESOURCES	732,973	41,400	119,250	893,623	342,738	229,960	81,222	653,920	11,050	10,050	21,100	1,568,642	40.9%
Water Supply Facilities	17,306	2,000	65,000	84,306	25,205	3,447	10,000	38,652	0	0	0	122,957	3.2%
1. Water District Facilities	15,641	2,000	65,000	82,641	20,840	3,447	10,000	34,287	0	0	0	116,927	3.1%
2. Level I Systems	1,665	0	0	1,665	4,365	0	0	4,365	0	0	0	6,030	0.2%
Irrigation Facilities	57,895	12,982	0	70,877	79,990	31,547	1,897	113,434	0	0	0	184,311	4.8%
1. National Irrigation Systems	25,017	2,275	0	27,292	17,828	21,089	0	38,917	0	0	0	66,209	1.7%
2. Communal Irrigation Systems	32,878	10,707	0	43,585	62,162	10,458	1,897	74,517	0	0	0	118,102	3.1%
Flood Control/Drainage	657,772	26,418	54,250	738,440	237,543	194,966	69,325	501,834	11,050	10,050	21,100	1,261,374	32.9%
SOCIAL INFRASTRUCTURE	499,476	39,105	236,080	774,661	168,187	51,842	41,212	261,241	5,150	4,655	9,805	1,045,708	27.3%
School Buildings	409,690	33,475	141,930	585,095	129,811	13,050	11,940	154,801	5,050	3,155	8,205	748,102	19.5%
Health Facilities	16,200	3,120	14,650	33,970	7,730	4,810	24,150	36,690	0	0	0	70,660	1.8%
LTO Buildings	186	700	200	1,086	96	92	122	310	0	0	0	1,396	0.0%
Other Public Buildings/Structure	73,400	1,810	79,300	154,510	30,550	33,890	5,000	69,440	100	1,500	1,600	225,550	5.9%
Grand Total	1,447,332	153,103	430,132	2,030,567	736,079	329,742	632,542	1,698,364	48,510	54,950	103,460	3,832,390	100.0%
Percent Distribution	37.8%	4.0%	11.2%	53.0%	19.2%	8.6%	16.5%	44.3%	1.3%	1.4%	2.7%	100.0%	

Source : The Regional Task Force Secretariat/NEDA Regional Office III.

Table 3.3 Damages from 1991 to 1995

AFFECTED POPULATION AND FAMILIES in REGION III

ITEM		1991	1992	1993	1994	1995	TOTAL
Affected	Population	1,180,132	803,972	314,905	822,398	1,506,991	4,628,398
	Families	249,371	164,400	66,456	169,295	293,129	942,651
Casualties	Dead	934	18	11	21	50	1,034
	Injured	184	7	0	3	2	196
	Missing	23	1	4	2	0	30
	Total	1,141	26	15	26	52	1,260
Damaged House	Totally	41,979	3,140	1,684	264	1,722	48,789
	Partially	70,257	3,072	3,498	1,502	2,008	80,337
	Total	112,236	6,212	5,182	1,766	3,730	129,126

Source : as of October 27, 1995 by Office of Civil Defense (OCD)

EXTENT OF DAMAGE in REGION III (Unit:million Pesos)

Damages	1991	1992	1993	1994	1995	TOTAL
(1) Public Infrastructure	3,830	211	176	57	128	4,403
(2) Agriculture (by ashfall)	1,474	81	68	22	49	1,694
(3) Agriculture (by lahar)	453	25	21	7	15	521
(4) Natural Resources	120	7	6	2	4	138
(5) Trade and Industry	851	47	39	13	29	978
(6) Military Facilities	3,842	211	177	58	129	4,416
TOTAL	10,570	581	486	159	354	12,150

Source : Department of Social Welfare and Development (DSWD)

DISPLACED/RESETTLEMENT FAMILIES in REGION III

ITEM		1991	1992	1993	1994	1995	TOTAL
Displaced	Pampanga	8,480	7,857	2,123	7,156	11,455	37,071
	Tarlac	5,618	4,514	1,173	0	0	11,305
	Zambales	1,769	0	4,104	0	113	5,986
	Total	15,867	12,371	7,400	7,156	11,568	54,362
Evacuation Center	Pampanga	14,171		2,123	2,492	11,455	30,241
(temporary)	Tarlac	9,604		1,173	0	0	10,777
	Zambales	3,012		4,104	0	113	7,229
	Total	26,787		7,400	2,492	11,568	48,247
Resettlement	Pampanga			6,100	8,121	2,279	16,500
	Tarlac			1,412	5,340	1,498	8,250
	Zambales			672	832	227	1,731
	Offsite/Others			1,232	502	602	2,336
	Back to Brgy.				1,770	3,352	5,122
	Total			9,416	16,565	7,958	33,939

Source : CABCOM for Displaced/Evacuation center and MPC for Resettlement (as of October 27, 1995).

ANNUAL LAHAR DELIVERED FROM SEDIMENT SOURCE AREA (Unit:million m3)

River Basin	1991	1992	1993	1994	1995	TOTAL
Sacobia-Bamban	150	80	65	8	4	307
Abacan	50	0	0	0	0	50
Pasig	50	40	55	130	86	361
TOTAL	250	120	120	138	90	718

Note : PHIVOLCS data for 1991 to 1993, and JICA Study Team for 1994 & 1995

LAHAR DISASTER AREA (Unit:ha)

River Basin	1991	1992	1993	1994	1995	TOTAL
Sacobia-Bamban	8,125	2,183	1,267	118	60	11,753
Abacan	2,930	0	0	0	0	2,930
Pasig	3,700	600	500	3,000	1,900	9,700
TOTAL	14,755	2,783	1,767	3,118	1,960	24,383

Note : Figures show the annual incremental disaster area

Table 3.4 National Accounts by Sector of Origin (Percentage Distribution of GNP and GDP)

(Unit : billion pesos)

Sector	Constant 1985 Prices						Current
	1987	1988	1989	1990	1991	1992	1992
Agriculture, Fishery & Forestry	150.4	155.3	160.0	160.7	160.5	159.9	290.3
	(24.7)	*(23.8)*	*(23.2)*	*(22.3)*	*(22.2)*	*(21.9)*	*(21.2)*
Industry	215.1	232.5	251.6	258.1	248.7	247.5	446.7
	(35.5)	*(35.7)*	*(36.5)*	*(35.8)*	*(34.4)*	*(33.9)*	*(32.6)*
Mining and Quarrying	11.2	11.7	11.4	11.1	10.8	11.3	16.2
Manufacturing	154.6	167.7	178.4	184.0	183.1	181.3	329.9
Construction	31.7	33.2	41.4	42.6	35.7	36.0	66.9
Electricity, Gas and Water	18.6	19.9	20.4	20.4	20.6	20.4	33.7
Services	253.1	270.6	286.8	298.5	303.1	305.3	606.0
	(41.6)	*(41.5)*	*(41.6)*	*(41.4)*	*(42.0)*	*(41.8)*	*(44.2)*
Transportation	35.1	37.9	40.2	41.2	41.4	42.1	77.9
Trade	90.0	94.6	99.3	101.4	102.9	104.5	185.4
Finance and Housing	56.2	60.5	66.3	70.1	69.4	69.8	139.9
Other services	71.8	77.6	81.0	85.8	86.6	86.1	202.8
Gross Domestic Product (GDP)	619.6	658.4	698.4	717.3	712.3	712.7	1,342.5
	(101.8)	*(101.0)*	*(101.3)*	*(99.5)*	*(98.6)*	*(97.7)*	*(98.0)*
Growth of GDP (% p.a.)	-	*(06.3)*	*(06.1)*	*(02.7)*	*-(00.7)*	*(00.1)*	
Net Factor Income from Abroad	-11.0	-6.2	-8.7	3.7	10.0	17.1	27.5
Gross National Product(GNP)	608.6	652.2	689.7	721.0	722.3	729.8	1,370.0
	(100.0)	*(100.0)*	*(100.0)*	*(100.0)*	*(100.0)*	*(100.0)*	*(100.0)*
Growth of GNP (% p.a.)	-	*(07.2)*	*(05.7)*	*(04.5)*	*(00.2)*	*(01.0)*	

Source : National Statistical Coordination Board
Inception Report of Master Plan Study for West Central Luzon Development Program

Table 3.5 Major Indices of Two Provinces Related to the Study

		Provinces		Region III	Philippines
		Pampanga	Tarlac		
1. Area	sq.km	2,181	3,053	18,230	300,000
2. Population (1990)	thousand	1,532.6	859.2	6,198.5	60,685.0
Density (1990)	/sq.km	703	281	340	202
Growth rate (1970-80)	% p.a.	2.54	2.09	2.88	
(1980-90)	% p.a.	2.63	2.24	2.57	2.32
Urban population (1990)	%	70.5	29.8	60.3	48.5
Employment in agriculture	%	22.9	54.9	35.4	44.5
3. Economic structure (1990)					
Agriculture	%	16.0	31.6	22.8	22.7
Industry	%	42.2	32.0	39.2	35.4
Services	%	41.2	36.5	38.0	41.9
4. Gross regional domestic products (1990)	mill.Peso	22,650	10,614	94,158	1,066,224
Per capita GRDP (1990)	P	14,779	12,353	15,190	17,570
5. Land classification - A & D land	ha (%)	164,912 (75.6)	184,975 (60.6)	1,051,908(57.7)	
Land use (1991) - Agriculture land	ha (%)	101,421 (47.9)	137,400 (45.0)	635,345 (34.9)	
Grass/shrub lands	ha (%)	(9.0)	(27.8)	(33.2)	
Wood lands	ha (%)	(7.3)	(17.8)	(19.8)	
Paddy harvested area	ha	42,800	97,990	499,870	
Paddy yield	t/ha	3.91	2.54	3.50	
Irrigation service area	%	70.7	55.2		
6. Physical infrastructure					
Road density (1990)	km/sq.km	1.07	0.80 (0.89)	0.72	0.54
Household electrification	%	82.9	68.1		
Access to improved water supply (1990)	%	80.4	61.8	63.0	
No. of telephones (1990)	/100 popul'n	0.63	0.34	0.49	
7. Social infrastructure					
Population per hospital bed		903	1,197	896	
Enrollment ratio - Primary	%	111	111	111	
Secondary	%	75	78	76	
8. Major towns		San Fernando (157)	Tarlac (79)		
(urban population in 1990)	thousand	Angeles (236)			
		Mabalacat (111)			
		Guagua (88)			
		Apalit (62)			
		Macabebe (55)			
		Bacolor (50)			

Source: Prepared based on "Inception Report of the Master Plan Study for West Central Luzon Development Program" JICA, Nov. 1993.

Table 3.6 Estimated Change in Population in the Study Area between 1990 and 1994

City/Municipalities	Population 1990	Population 1994	Change in 90-94	Ratio of Change (%)
I. Pampanga Province				
Angeles (20/33)	236,700	210,000	-26,700	88.7
Arayat (9/30)	73,200	77,500	4,300	105.9
Mabalacat (20/27)	121,100	105,400	-15,700	87.0
Magalang (12/27)	43,900	44,600	700	101.6
Mexico (15/43)	69,400	69,300	-100	99.9
Sta. Ana (7/14)	32,500	33,700	1,200	103.7
Pampanga Total (83/174)	576,900	540,400	-36,500	93.7
II. Tarlac Province				
Bamban (13/15)	35,600	18,000	-17,600	50.6
Capas (7/8)	25,800	20,000	-5,800	77.5
Concepcion (24/43)	97,800	100,500	2,700	102.8
Tarlac Total (44/66)	159,200	138,500	-20,700	87.0
Pampanga and Tarlac Total (127/240)	736,100	678,900	-57,200	92.2

Sources : NSO Census of Population in 1980 and JICA Survey for 1994.
Notes : Figures in parentheses show the number of barangay whose population decreased in the period of1990-1994 toward the total number of barangay in the city/municipalities.

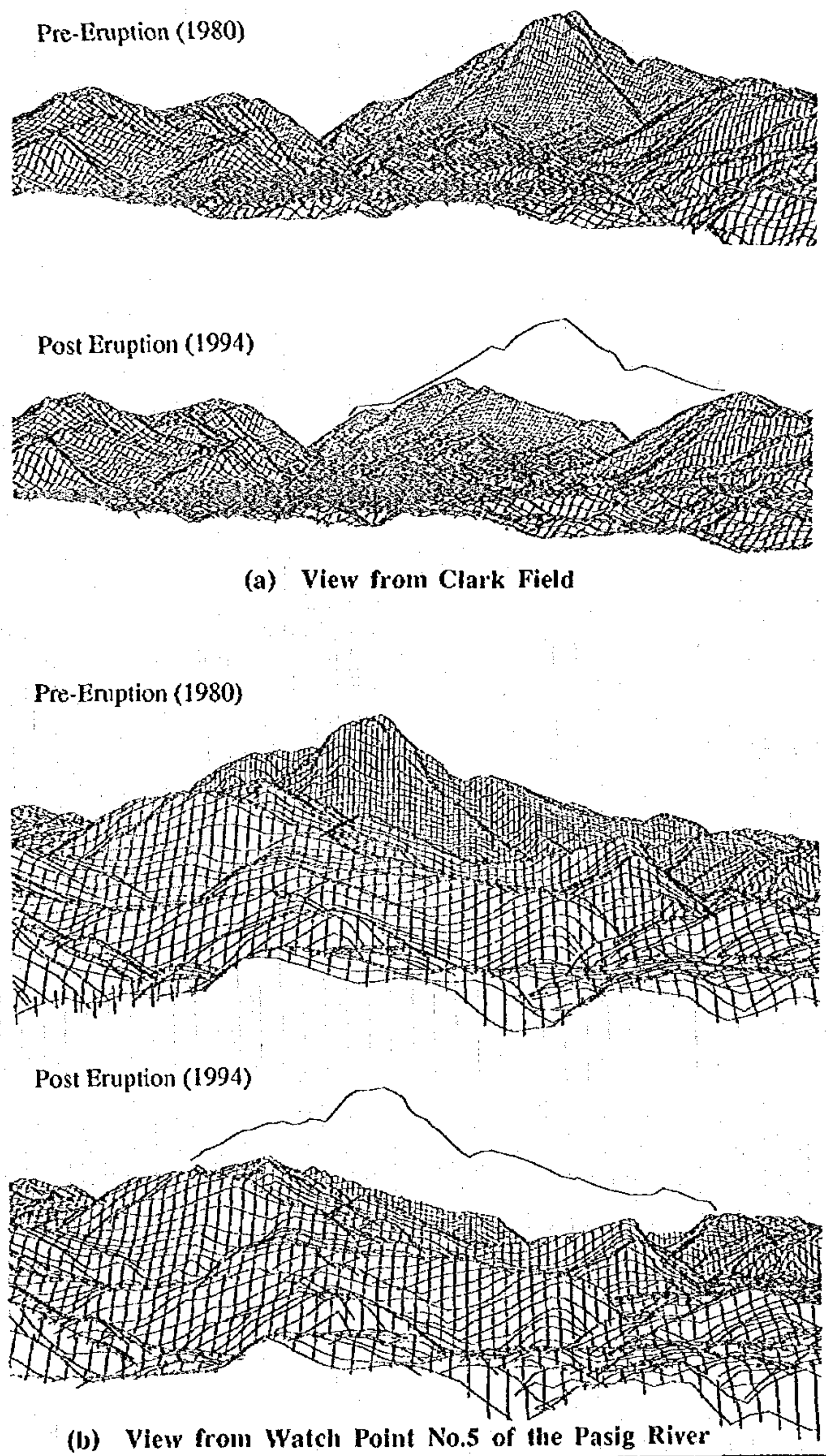


Figure 3.1.

Bird's-Eye View of Mt.Pinatubo

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

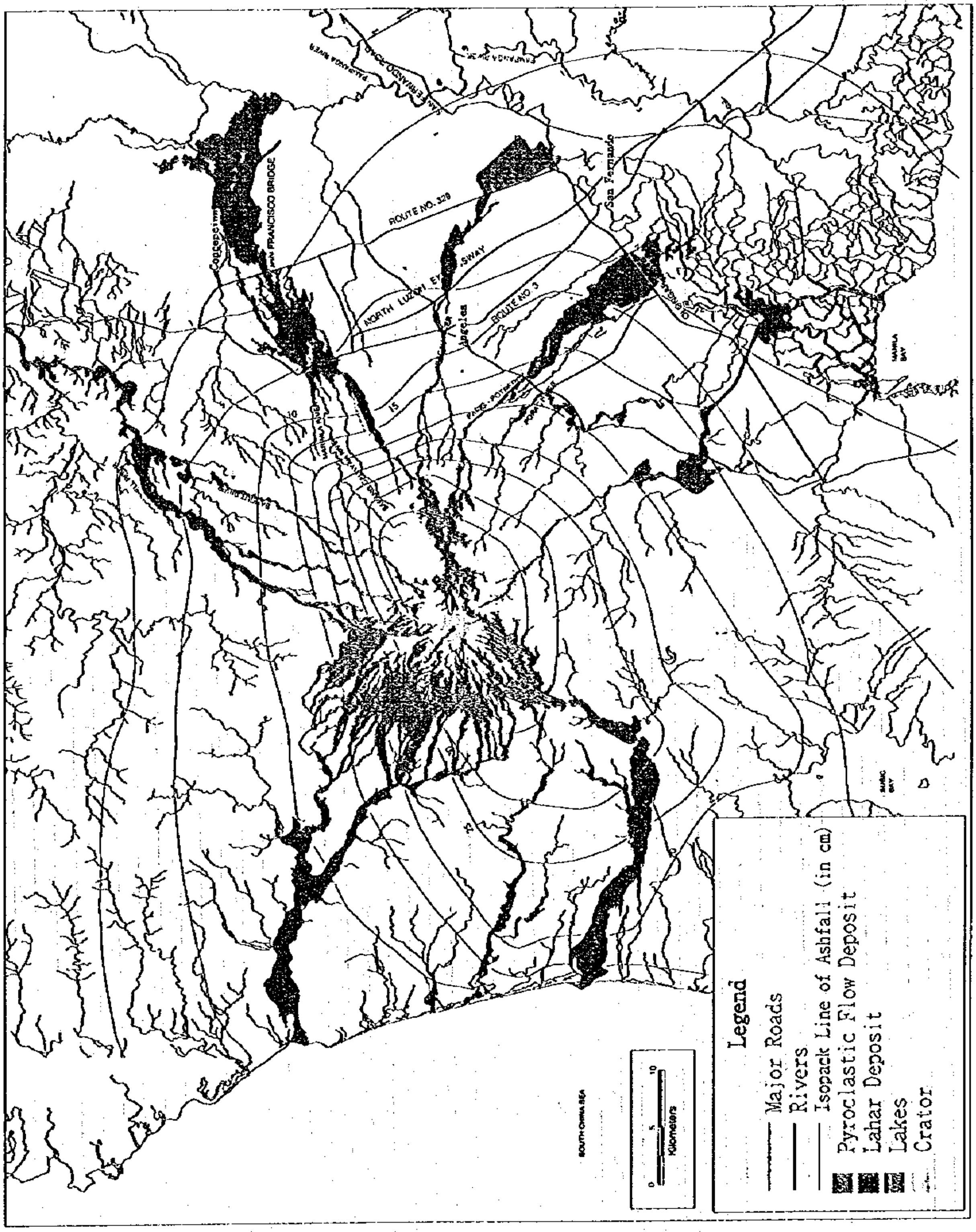


Figure 3.2
Pinatubo Volcano Disaster Map

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

Pyroclastic Flow Deposit Volume in the Eastern Slope of Mt. Pinatubo

River Basin	C.A. (km2)	Pyroclastic Flow Deposit Volume (million m3) and Remaining Ratio (%)								
		1991 June	1991 October		1992 October		1994 March		1994 October	
Sacobia-Abacan		968	768	79%	688	71%	303	31%	295	30%
Sacobia-Abacan upstream	18	550	400	73%	347	63%	303	55%	295	54%
Sacobia-Abacan Uppermost reach	22	418	368	88%	341	82%	Annexed to Pasig River 320	77%	252	60%
Pasig upstream	23	430	380	88%	340	79%	285	66%	223	52%
Pasig		430	380	88%	340	79%	605	141%	475	110%
Total	63	1,398	1,148	82%	1,028	74%	908	65%	770	55%

Piracy

Annual Lahar Delivered Volume in the Eastern Drainage of Mt.Pinatubo

River Basin		Lahar Delivered Volume (million m3)				
		1991	1992	1993	1994	Total
Sacobia-Bamban		150	80	65	8	303
Abacan		50	0	0	0	50
Pasig		50	40	55	130	275
TOTAL		250	120	120	138	628

Comments: The Pyroclastic Deposit volume for 1994 March was estimated using the GIS database created from the DTM for 1991,1992, 1994 with a contour interval of 5m mapped to a scale of 1:10,000 from Aerial photographs. The Sacobia uppermost stream was annexed to the Pasig in 1993 October. Lahar deposition volumes are based on PHIVOLCS for 1991 to 1993 and JICA for 1994.

Variation of Annual Pyroclastic Flow and Lahar Deposits

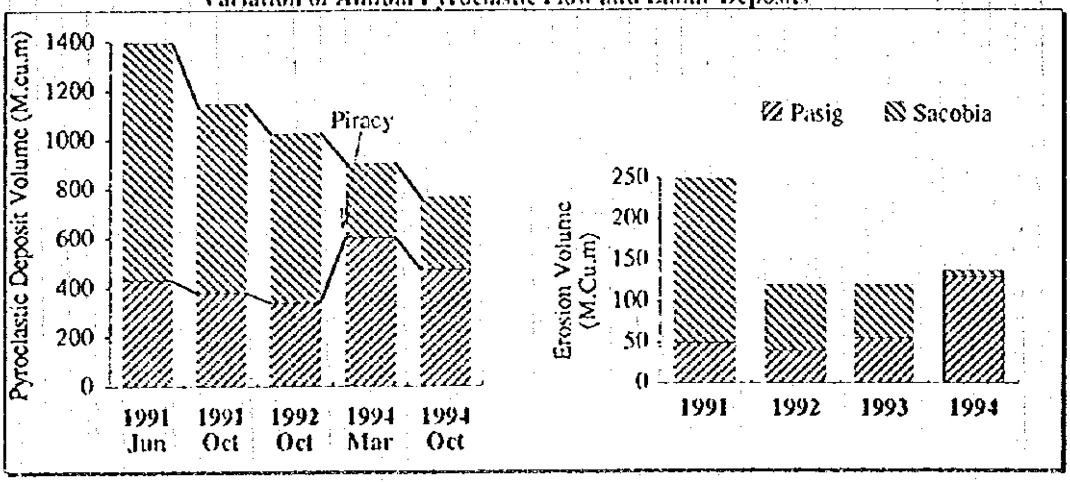
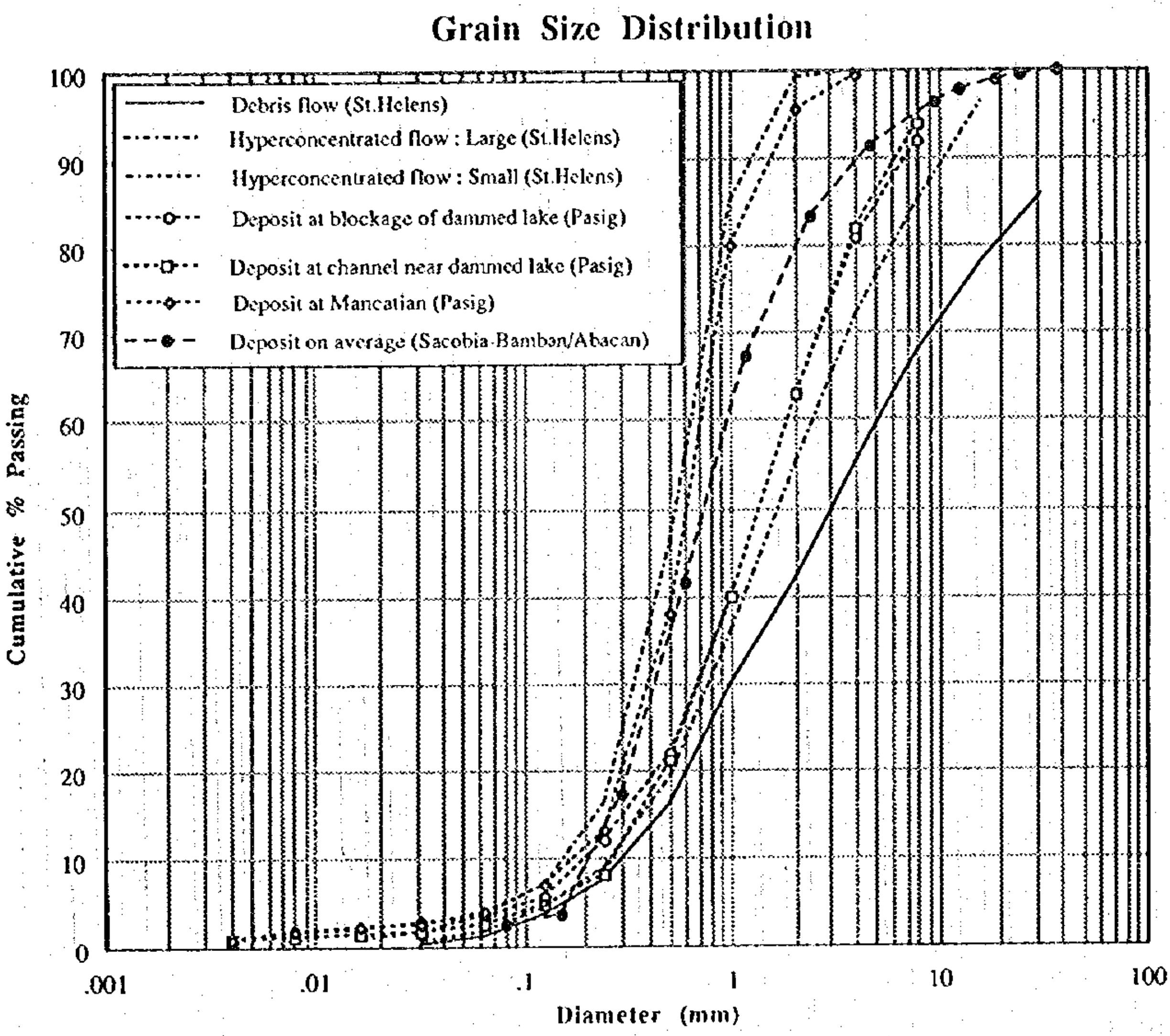


Figure 3.3 Pyroclastic Flow Deposits and Lahar Delivered Volumes

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



Source : Mount St.Helens (USGS)
Pasig River in 1992 (PHIVOLCS)
Sacobia-Bamban/Abacan River in 1994 (JICA)

Figure 3.4 Comparison of Grain Size Distribution of Lahar Materials

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

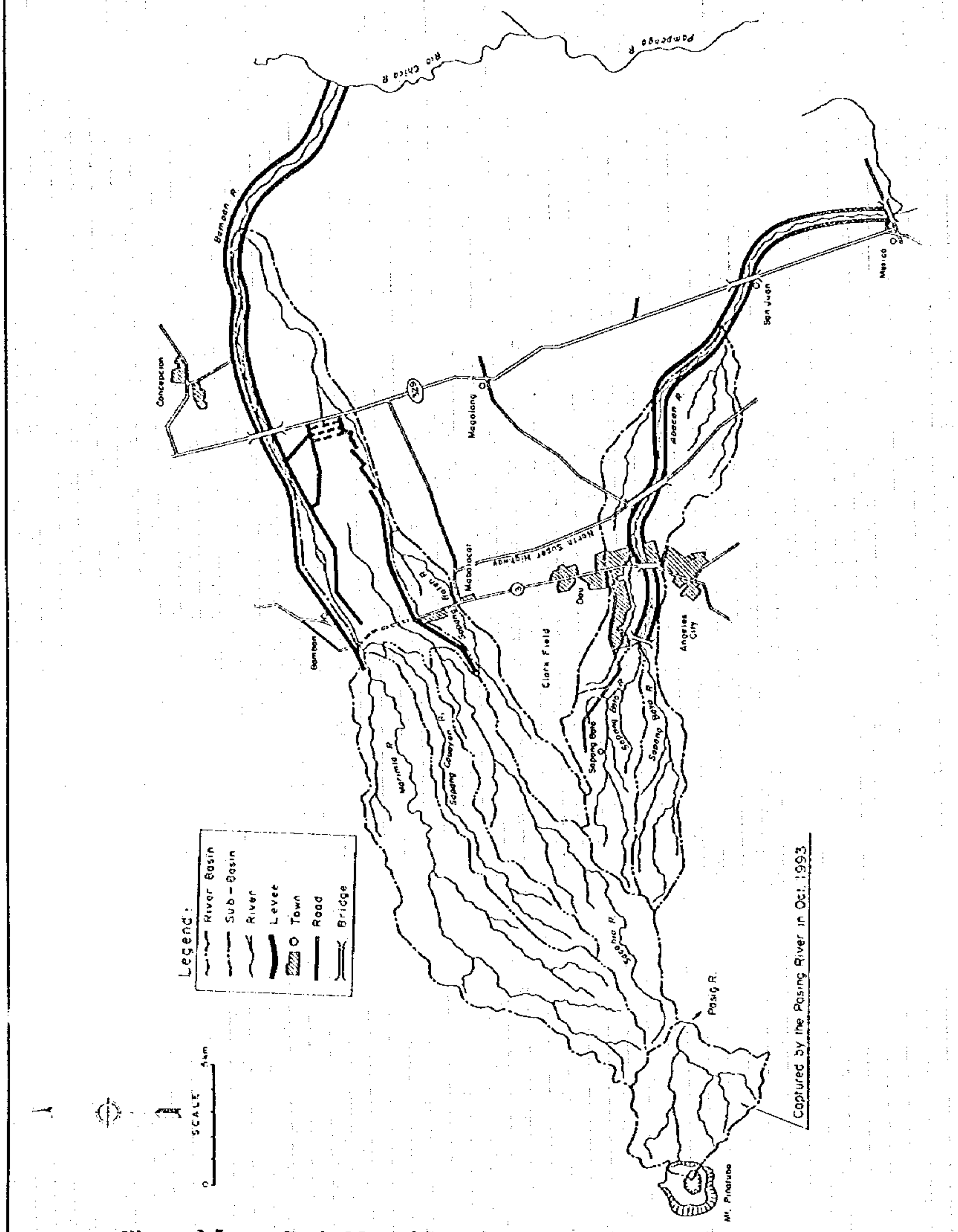


Figure 3.5 Basin Map of Sacobia-Bamban and Abacan Rivers

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

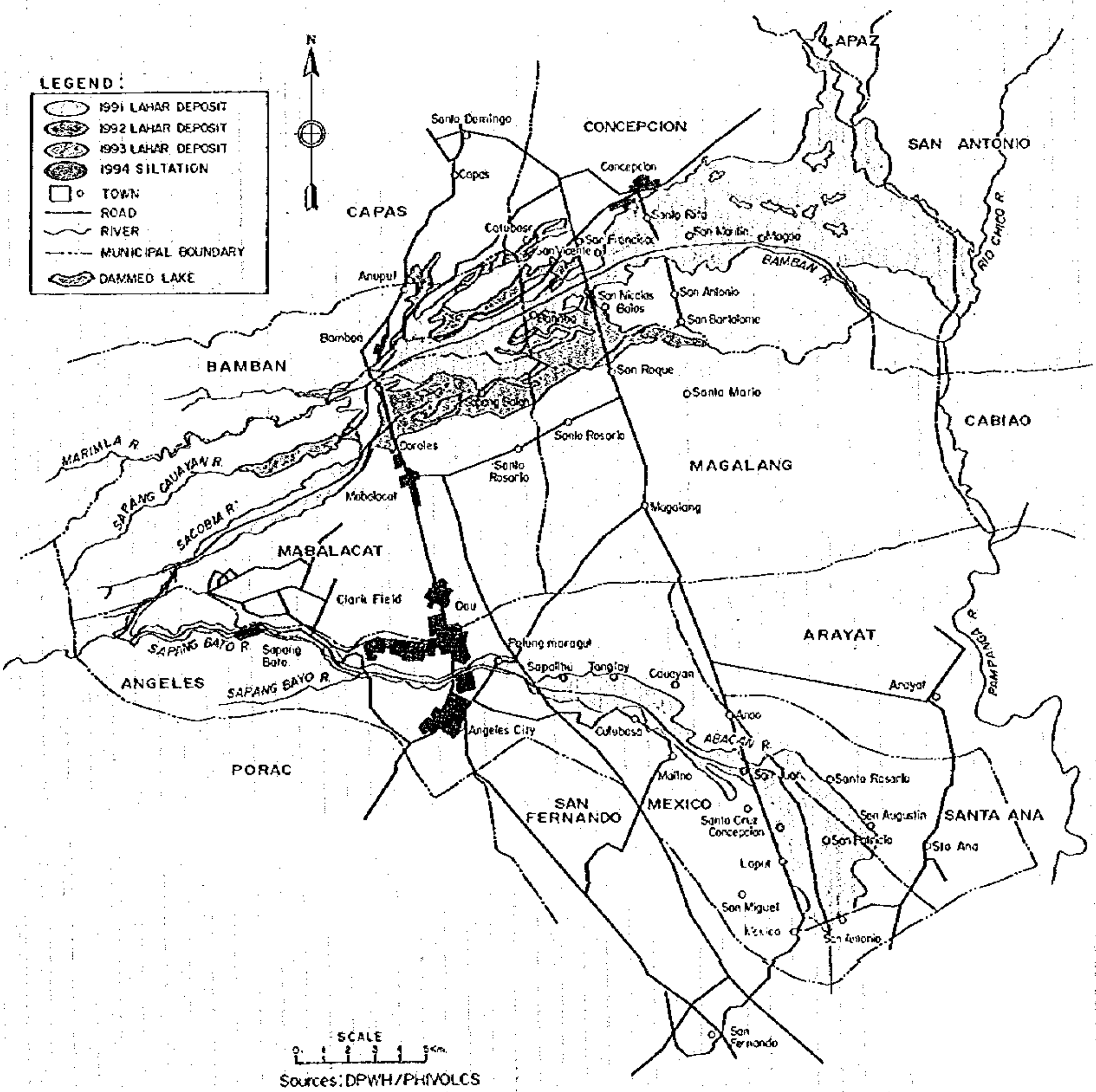


Figure 3.6 Lahar Disaster Area

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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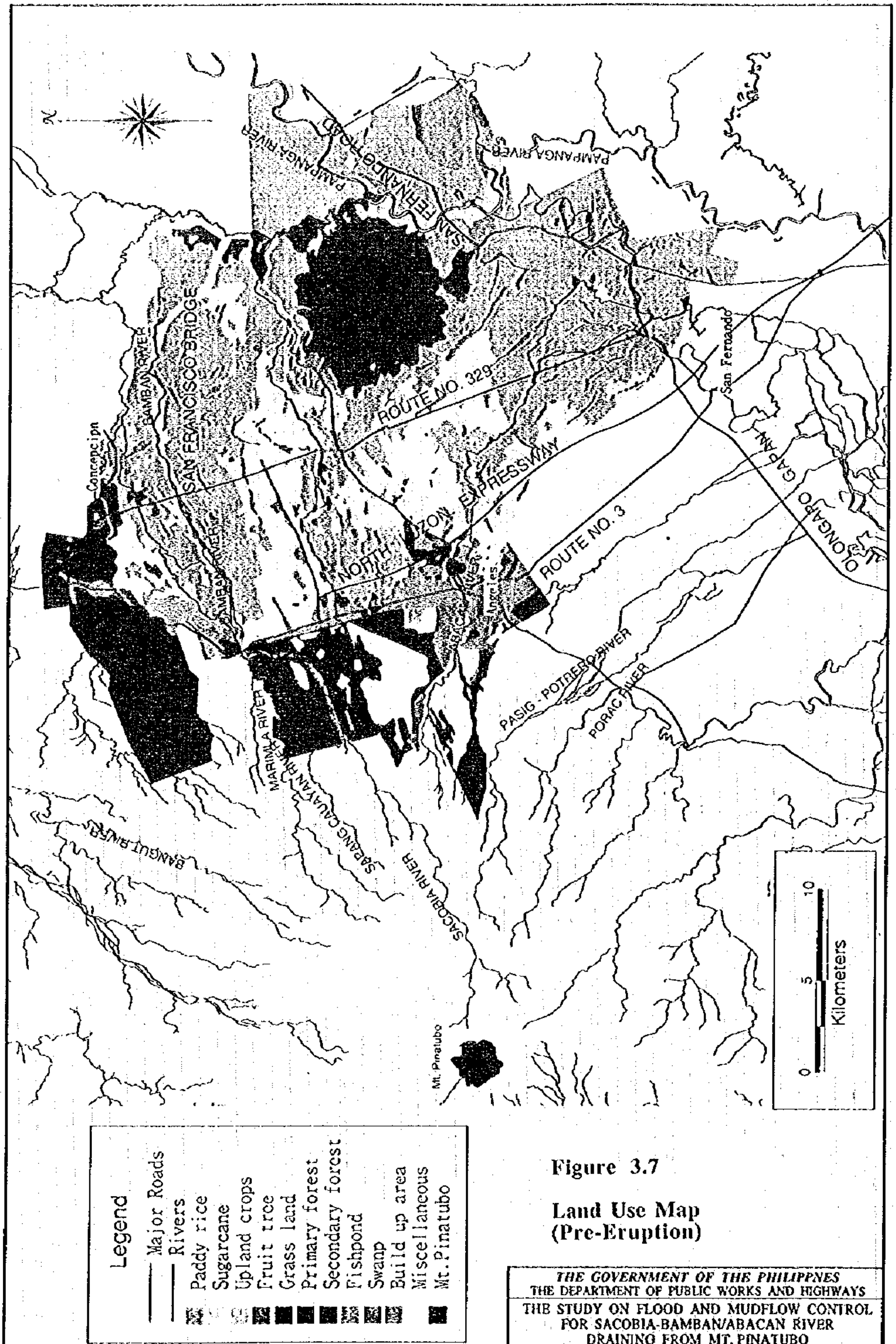


Figure 3.7

Land Use Map (Pre-Eruption)

THE GOVERNMENT OF THE PHILIPPNES 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

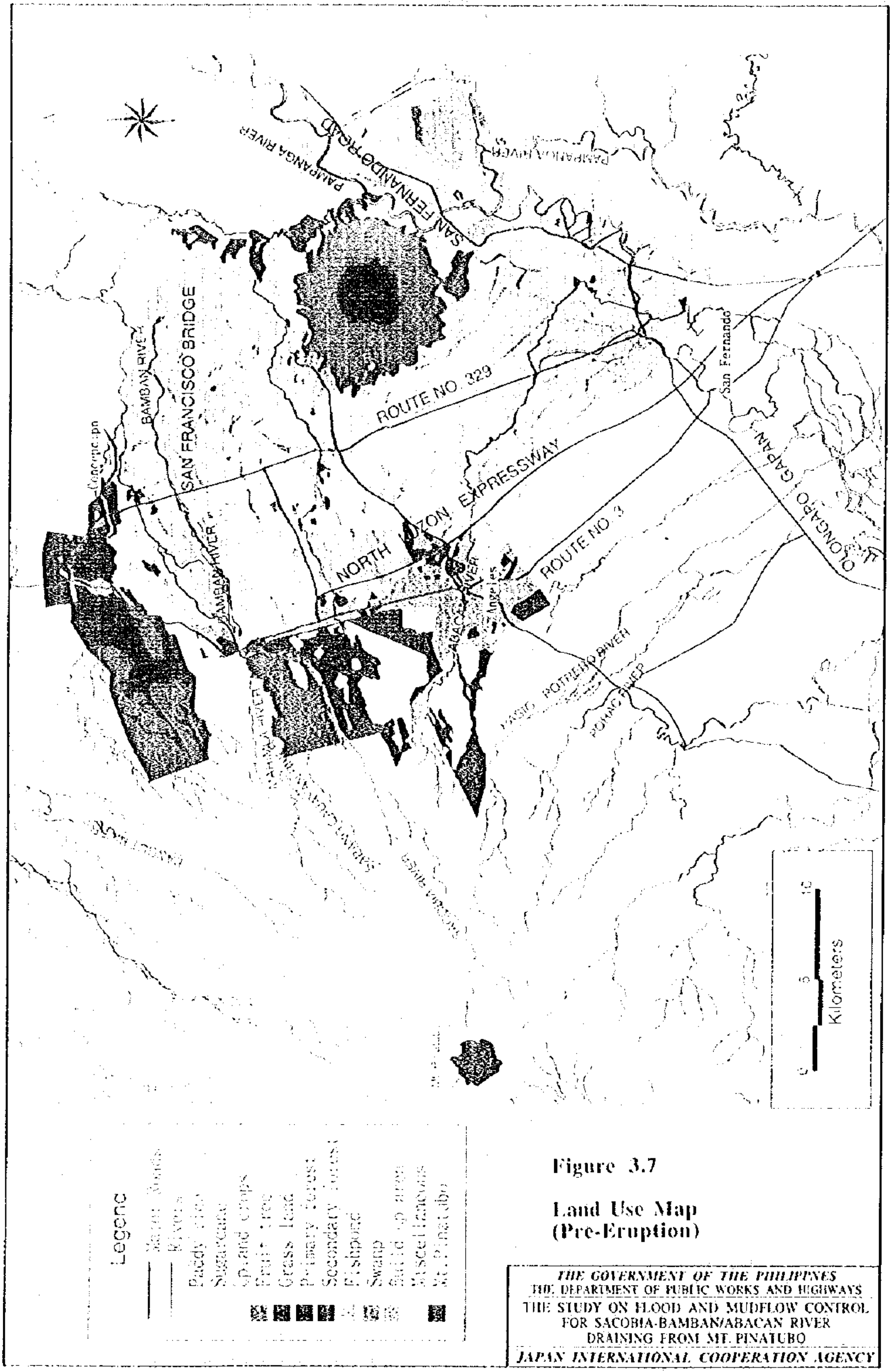
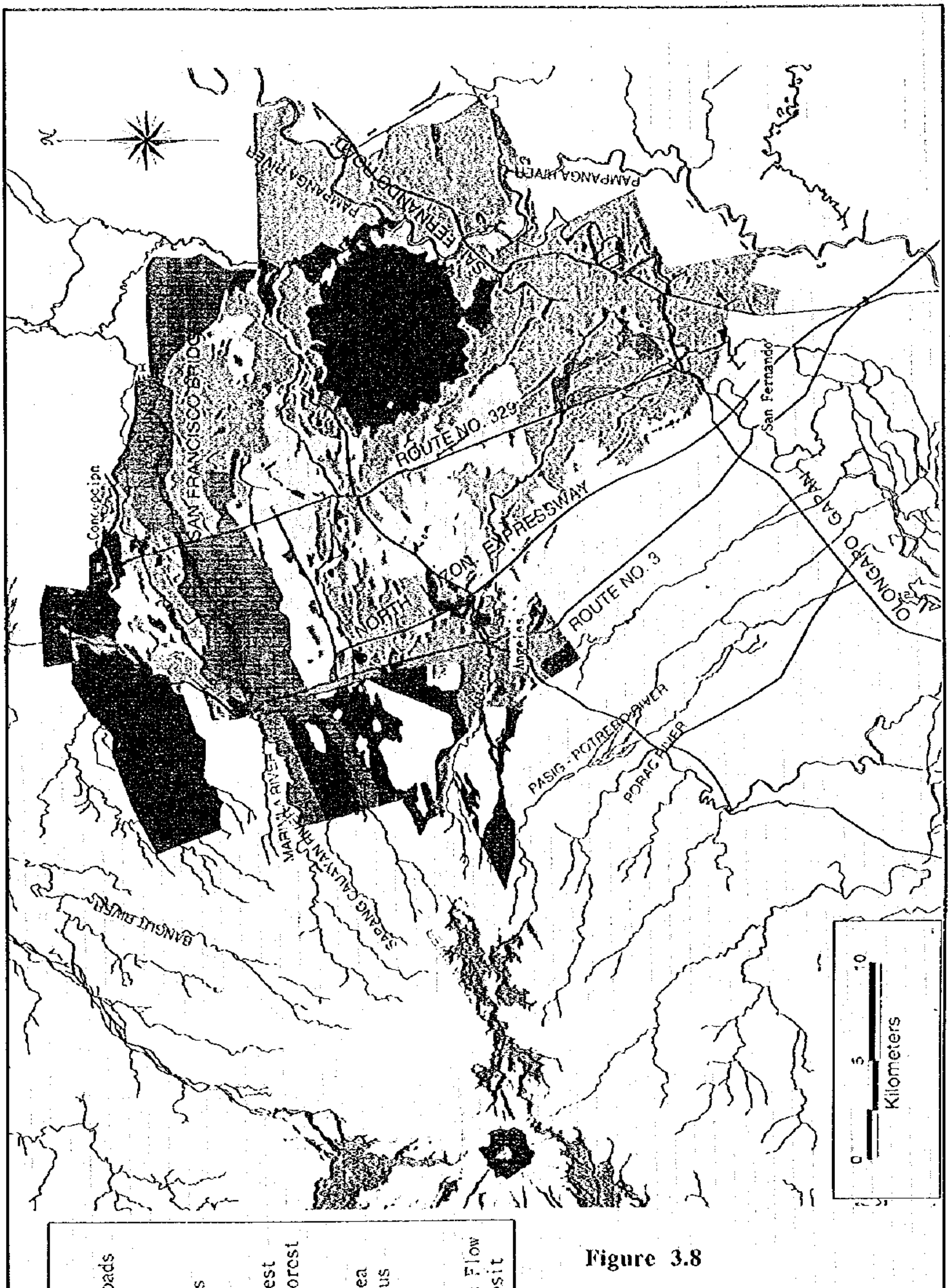


Figure 3.7

Land Use Map (Pre-Eruption)

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



Legend

- Major Roads
- Rivers
- Paddy rice
- Sugarcane
- Upland crops
- Fruit tree
- Grass land
- Primary forest
- Secondary forest
- Fishpond
- Swamp
- Build up area
- Miscellaneous
- Mudflow
- Crator
- Lakes
- Pyroclastic Flow Deposit

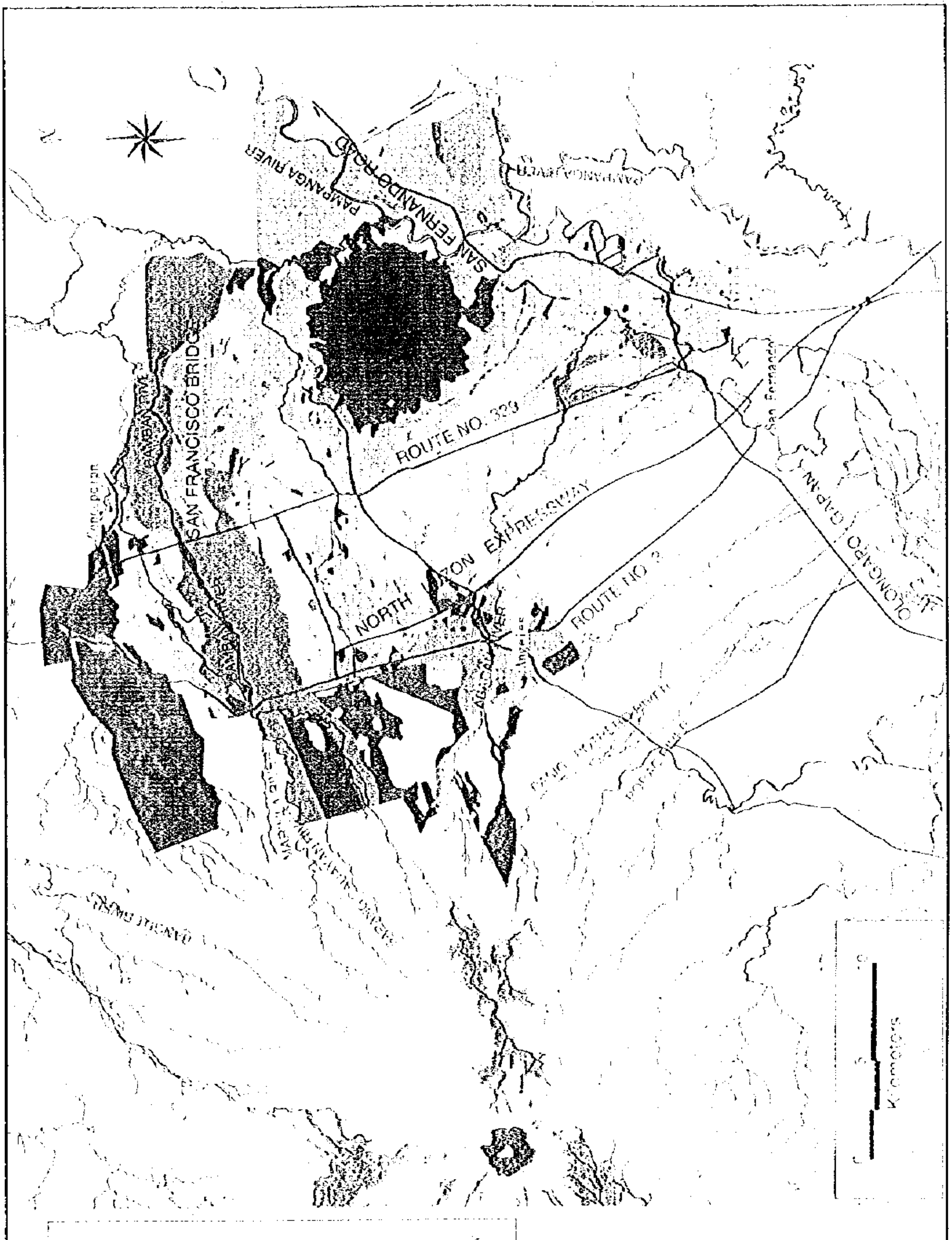
Figure 3.8

Land Use Map (Post Eruption)

THE GOVERNMENT OF THE PHILIPPNES
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



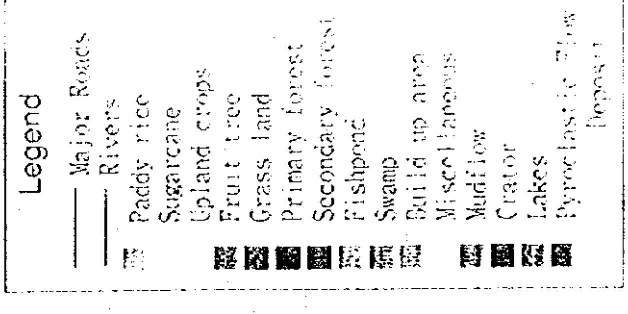


Figure 3.8

Land Use Map (Post Eruption)

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY

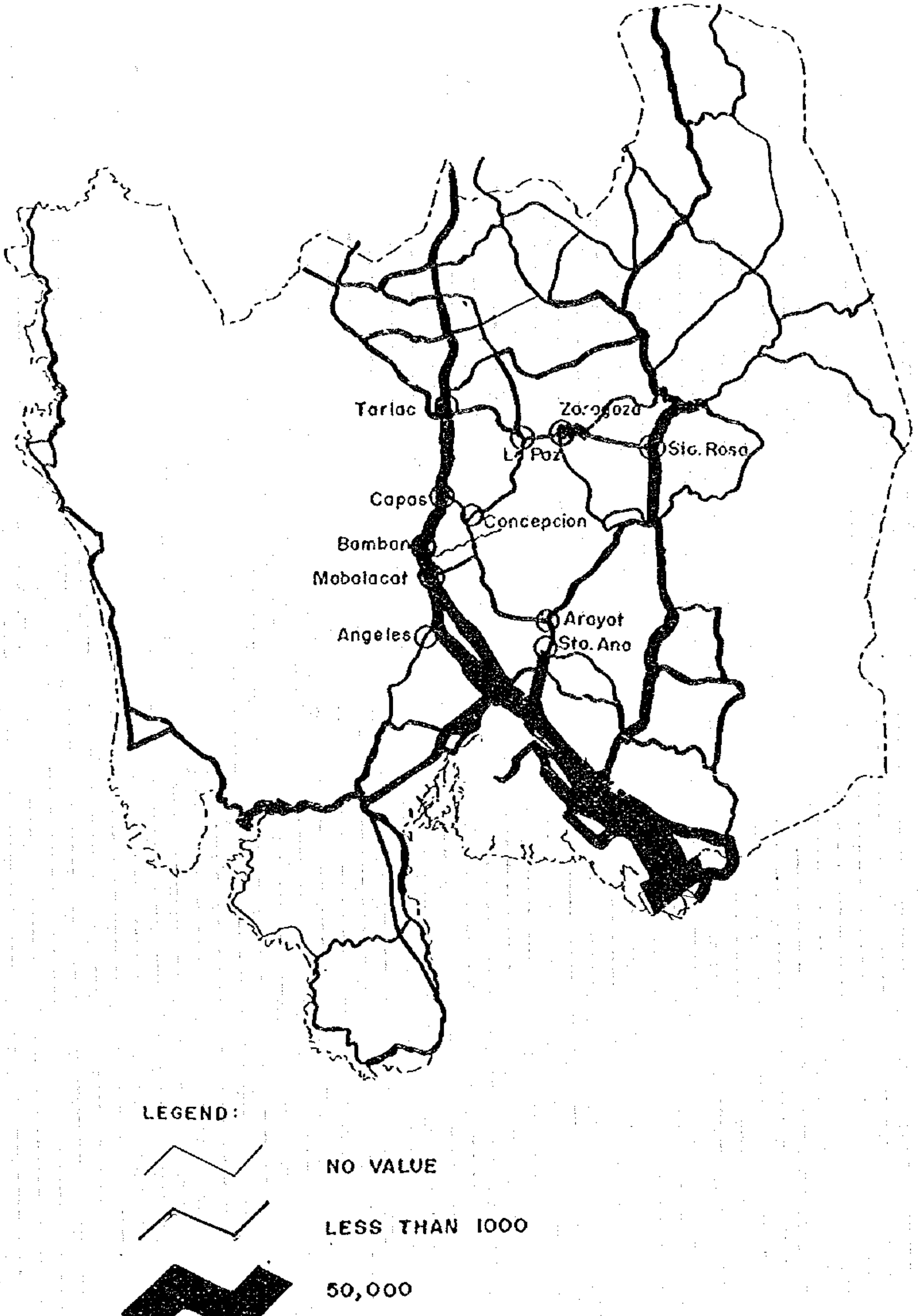


Figure 3.9
Estimated Traffic in Region III in 1993
Source : CLDP

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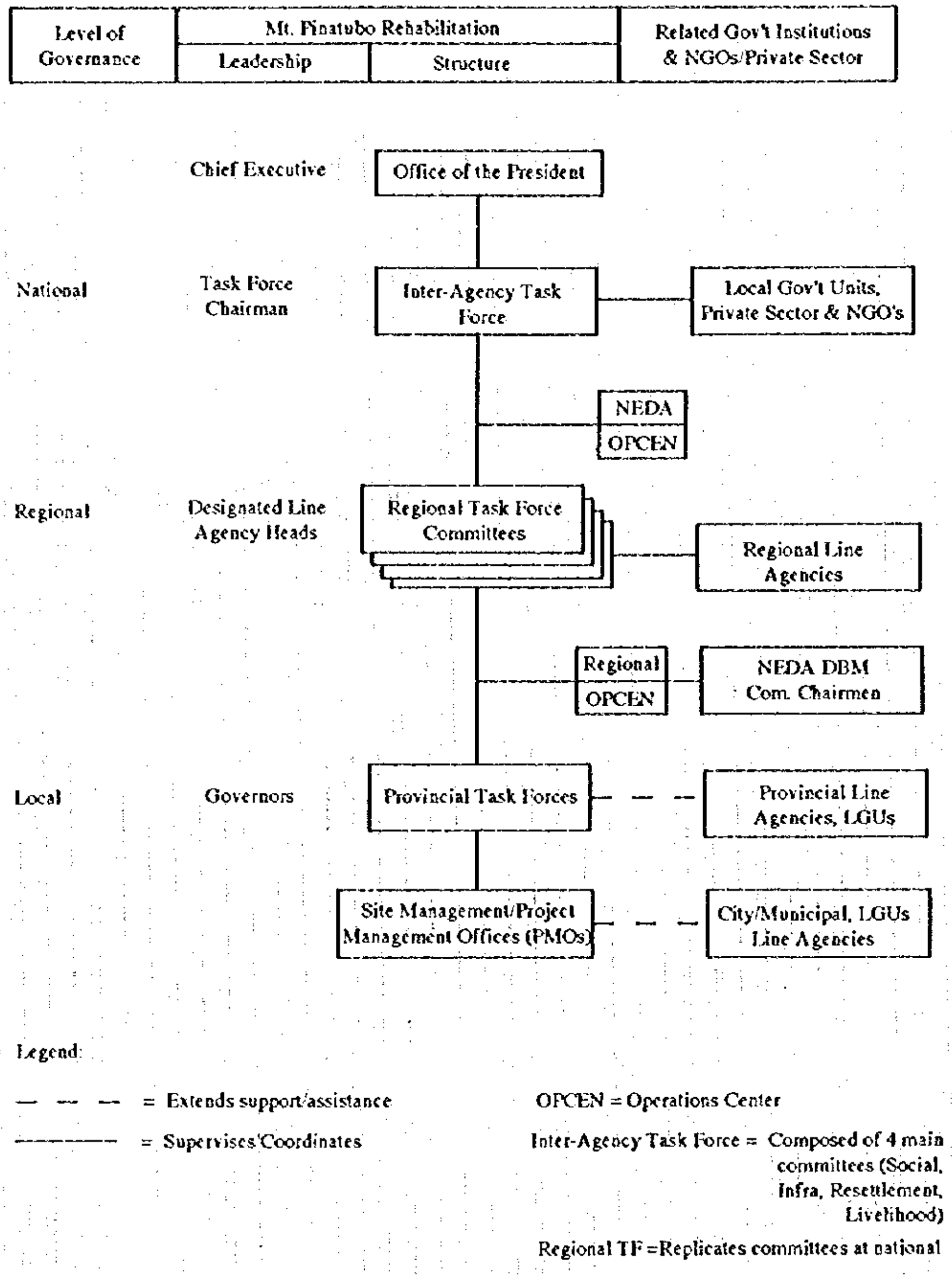
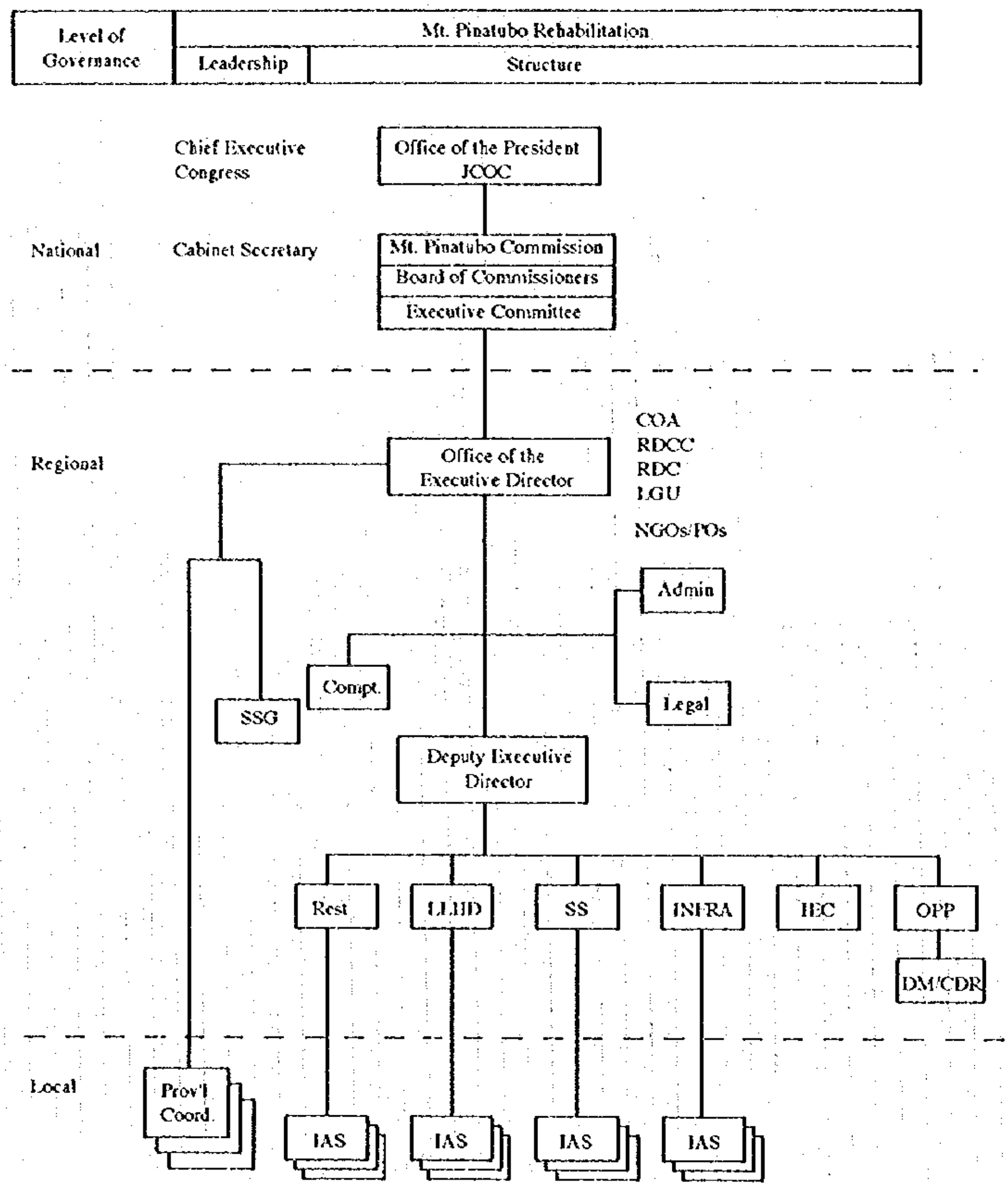


Figure 3.10 Organizational Structure of Task Force Mt. Pinatubo (1991-1992)



Legend:
SSG/TC = Special Services Group/Technical Consultants
Prov'l Coord. = Provincial Coordinators
Rest = Resettlement Administration
LLHD = Livelihood Administration
SS = Social Services Administration
INFRA = Infrastructure Administration
IEC = Information, Education & Communication
OPP = Office of Plans and Programs
DM/CDR = Data Management/Central Data Repository
Compt. = Comptroller
Admin = Administrative Services
Legal = Legal Services

Figure 3.11 Organizational Structure of the Mt.Pinatubo Commission

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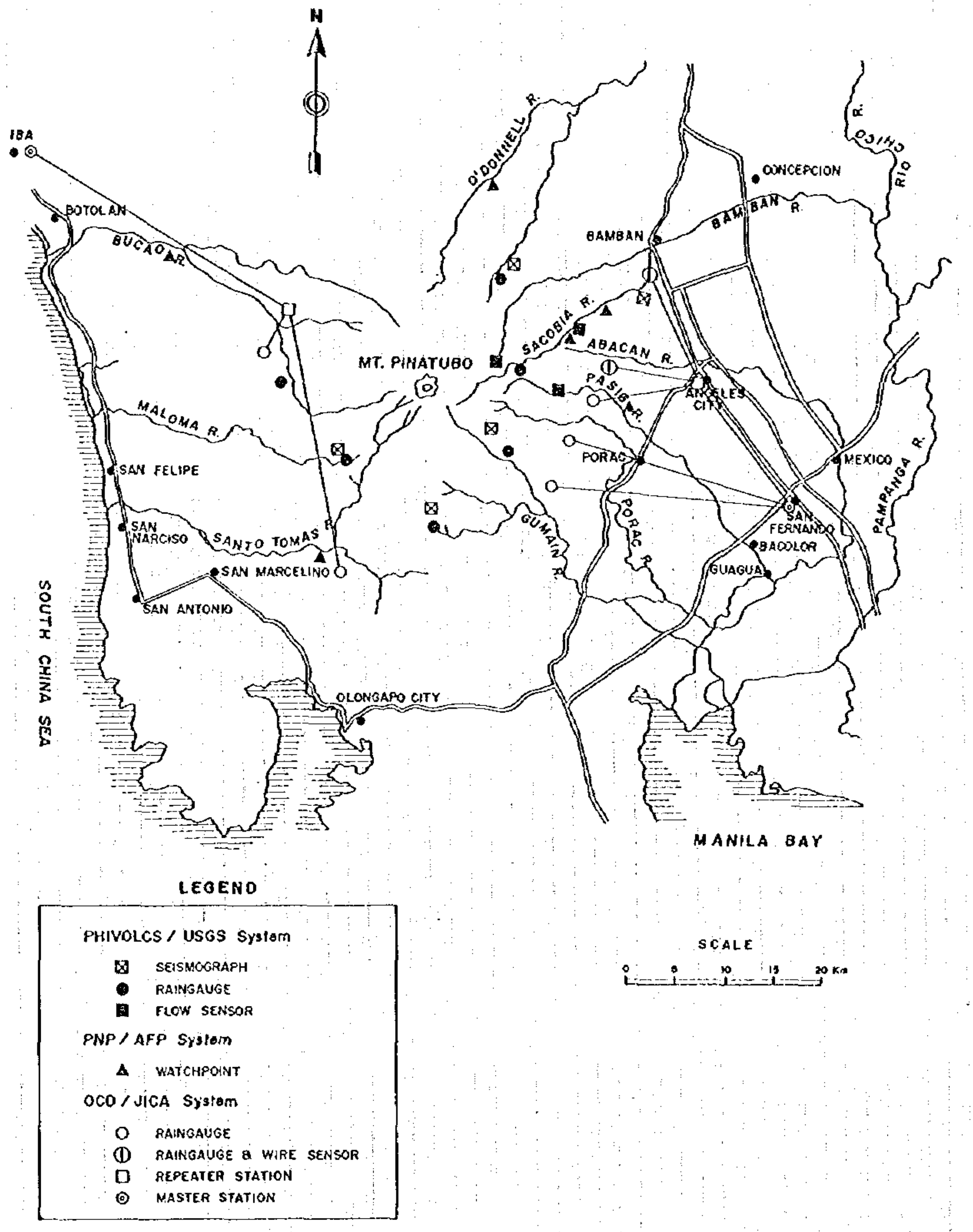

Figure 3.12 Location Map of Lahar Warning System

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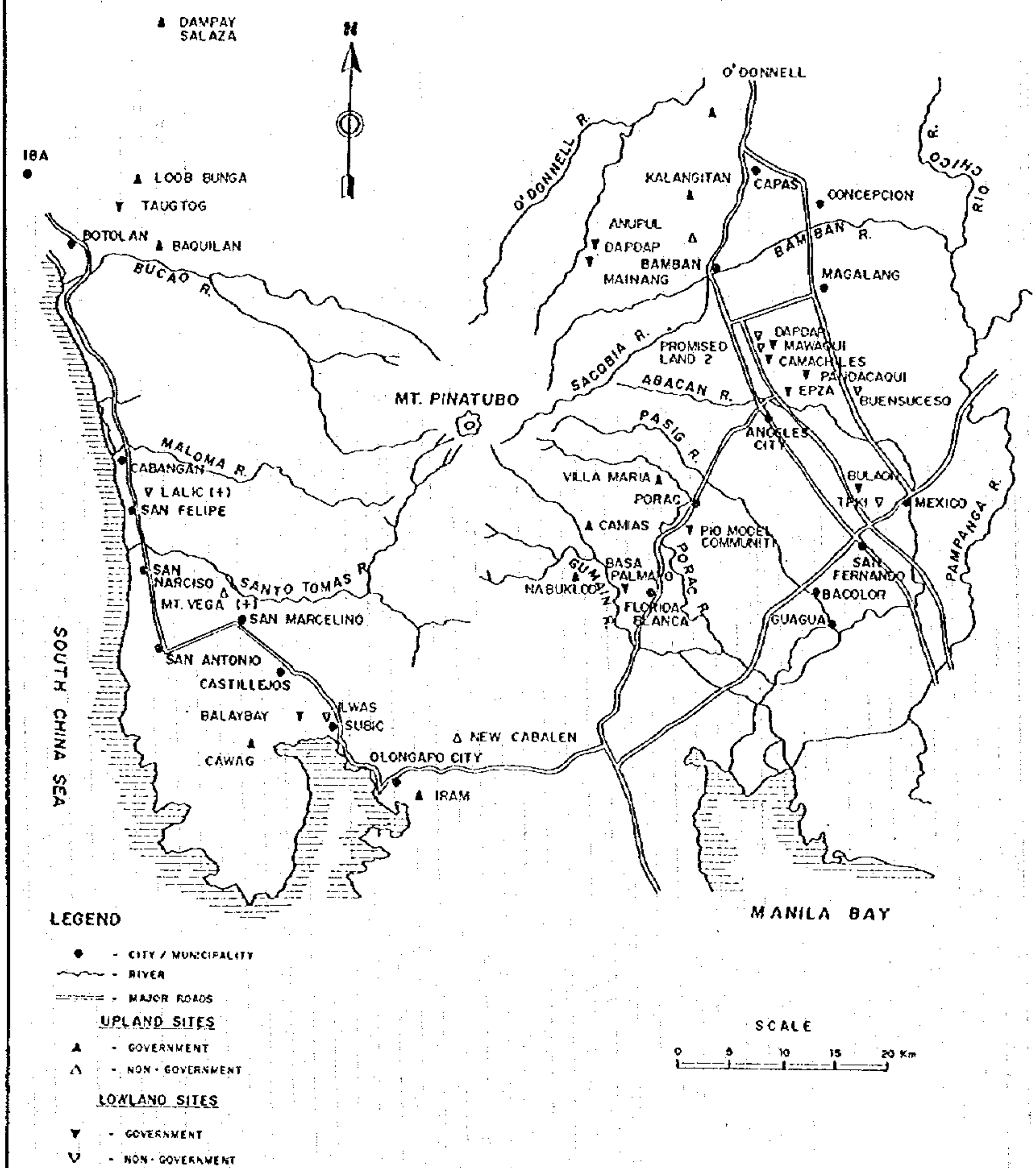

Figure 3.13 Location Map of Resettlement Area

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 4

BASIC CONCEPT OF THE STUDY

CHAPTER 4 BASIC CONCEPT OF THE STUDY

4.1 OBJECTIVE OF THE STUDY

4.1.1 OBJECTIVE

The Master Plan will provide an overall plan of mudflow/flood control works for the achievement of reconstruction and further development plan in the affected areas on the basis of the studies of projection of sediment delivery volume to low lying areas, forecast of potential mudflow/flood hazard areas, and formulation of structural measures to minimize further disasters due to mudflow/flood in the region.

As for the long term development plan in the region, the regional development plan in Central Luzon by JICA and Integrated Plan by MPC are being formulated. The plans foresee to meet the development strategy of the "Philippine 2000". As for the study area, the core for the development may be the Clark Base Conservation Program. The development of major urban centers such as Angeles, Tarlac and Concepcion may also be an important framework under the concept of national triad growth centers.

The strategy of the regional development plan will be formulated under the assumption that the mudflow/flood control works in the Master Plan would be achieved for the restoration of land resources which are now covered with lahar. The target of master plan for mudflow/flood control works are the following:

1) To minimize the potential of disastrous mudflow and flood inundation,

2) To limit the sediment deposition areas within the presently affected areas and to minimize the scale of structural measures on the basis of forecast of future development of alluvial fan in low-lying area,

3) To realize future land use plan to restore dislocated families to their original settlements which are now covered with lahar.

Although this Master Plan Study covers only Sacobia-Bamban and Abacan river basins, the overall development surrounding Mt.Pinatubo in collaboration with those in the other river basins draining Mt.Pinatubo will be crucial for the achievement of the regional development plan. The Basic Concept of Master Plan is shown in Figure 4.1.

4.1.2 BASIC ASSUMPTION

(1) Another Eruption of Mt.Pinatubo

According to the observation by USGS/PHIVOLCS, the likelihood of further large explosive events from Mt.Pinatubo during the next decades is apparently low, because the main magma body has apparently lost of its gas. This Master Plan Study, therefore, does not consider the further eruption of Mt.Pinatubo in the plan formulation of engineering intervention measures.

(2) Re-piracy between Pasig and Sacobia rivers

Since the headwater of the Sacobia River of 23 km^2 was annexed to the Pasig River in October 1993, the sediment delivery rate to the downstream reach of the Sacobia and Bamban rivers has been diminished drastically. On the contrary, a remarkable sediment deposition has been occurred in the Pasig River. The observation at piracy point between Sacobia and Pasig river shows that the downcutting of the Pasig river channel is developing, and the difference of riverbed elevation between Sacobia and Pasig rivers is recognized at about 50-60 m in October, 1995. Therefore, the likelifood of re-piracy of the headwater of Pasig River into Sacobia River during the next decades is apparently low. In the Master Plan Study, the design condition is established under the assumption that the pyroclastic flow deposits field might be hardened and the sediment derivery rate would be equivalent to that in pre-eruption period when the next re-piracy may occur after decades. Therefore, the design criteria for structural measure is prepared to cope with the magnitude of mudflow/flood on the basis of the catchment area before piracy.

(3) New San Francisco Bridge for Sacobia-Bamban River

In 1995, the most critical problem in the Bamban River is the safety of the San Francisco Bridge. The clearance of the San Francisco Bridge is about 72 cm on an average in October 1995. The flood flowing capacity of the river at the bridge would be about 220 m^3/s which is equivalent to a moderate flood peak discharge of the Bamban River. 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.

In October 1995, DPWH commenced a reconstruction works of new San Francisco Bridge at immediately upstream of the present one under the ADB loan. The clearance of the new bridge will be 5 m on an average. The new bridge will be completed after the rainy season in 1997. Therefore, the combination of structural measures in the Sacobia-Bamban River are formulated based on the assumption that the construction of San Francisco Bridge will be completed in 1997, and the flood flowing capacity at the bridge will be increased.

(4) Abacan Gap

The Abacan River produced lahar and large volume of eroded sediment through the Sapangbato River for the period of June to September 1991. Lahar damaged all of the bridges across the river, and caused the lateral erosion of river bank that has destroyed hundreds of houses in Barangay Sapangbato and in Angeles City. However, no lahar has occurred along the river ever since the piracy of the Sacobia River had occurred at "Abacan Gap" in 1992. The difference of riverbed elevation at Abacan Gap is observed at about 50 m since 1994, the likelihood of mudflow/flood entered from the Sacobia River is aparently low. In the Study, the remaining pyroclastic flow and fall deposit in the upstream reach is regarded as future sediment source for the Abacan River.

4.2 CONCEPT OF PHASED DEVELOPMENT

4.2.1 PHASED DEVELOPMENT

The Master Plan provided an overall mudflow/flood control plan. It would take time for implementation of the schemes while the remarkable sediment volume is being transported to low lying areas and the risk of mudflow and flood is still high in the study area. Many protection works have been conducted by the government and the people in the affected areas just after the eruption and the efforts are being carried out continuously.

Under the situation, the following works are essential in formulating the construction plan.

1) To forecast and monitor the volume of sediment transport to low lying areas.

   Engineering judgment should be made on the basis of historical development of landforms, sediment hydraulic analysis and annual sediment transportation. In particular, the response of the structures should be monitored diligently to clarify chronological variation of sediment deposition.

2) To elaborate the dimension of sabo/flood control structures

As well as the maintenance of existing sabo/flood control structures, the dimension and alignment of the structures in the Master Plan should be elaborated corresponding to the actual geomorphologic changes. The structures in the Master Plan would ensure the achievement of the schemes in the Regional Development Plan.

On the basis of the above consideration, the master plan of mudflow and flood control works should be organized into the following phased categories which include (1) urgent works which have been carried out by DPWH for the period from 1991 to 1993, (2) short term plan to be carried out for the period from 1994 to 1996 before the overall proposed study plan is implemented, (3) medium term plan which is composed of overall mud flow/flood control works and (4) long term plan of rehabilitation and reconstruction of the affected areas. The schematic implementation schedule of the phased development plan is shown in Figure 4.2.

4.2.2 URGENT WORKS

Rehabilitation works by DPWH for the period from 1991 to 1993 are regarded as the Urgent Works. Sabo dams and river dike system were constructed urgently in 1992 in the basin. The restoration works for the structures have been carried out by DPWH.

On the other hand, non-structural measures are also required against disastrous lahar/flood until the long term plan is completed. Warning system for disseminating the warning message to the people in lahar hazard area was operated by Regional Disaster Coordinating Council in Region III (RDCC III) while the resettlement plan for the people in lahar disaster area was put in operation by MPC.

4.2.3 SHORT TERM PLAN (TEMPORARY STRUCTURE)

Sand pocket structures at Bamban river basin were constructed by DPWH before the onset of rainy season in 1994. The objective of the structures was to protect the Route 329 against mudflow and to prevent mudflow from spreading outside the lahar disaster area in 1994.

The structure of the short term plan should be flexible to cope with the changes in natural condition because of uncertainties of producible volume of mudflow to low-lying areas. The condition of sediment deposition during the rainy season was monitored, and the rehabilitation works for short term plan were proposed.

4.2.4 MEDIUM TERM PLAN (PERMANENT STRUCTURES)

Medium Term Plan is formulated to ensure the safety against flood/mudflow for the accomplishment of schemes in the Long Term Plan. The alignment and combination of structural measures will be elaborated through the monitoring of geomorphologic changes while the dimension of structures will be revised corresponding to the actual response of sediment transport and deposition.

4.2.5 LONG TERM PLAN (RECONSTRUCTION PLAN)

The structures are planned to accelerate the development strategy of Regional Development Plan. The structural measures may be required to ensure the transportation system connecting with national triad growth centers and the agricultural productivity in the Study Area. The structural measures should be carried out in compliance with environmental conservation in the Study Area.

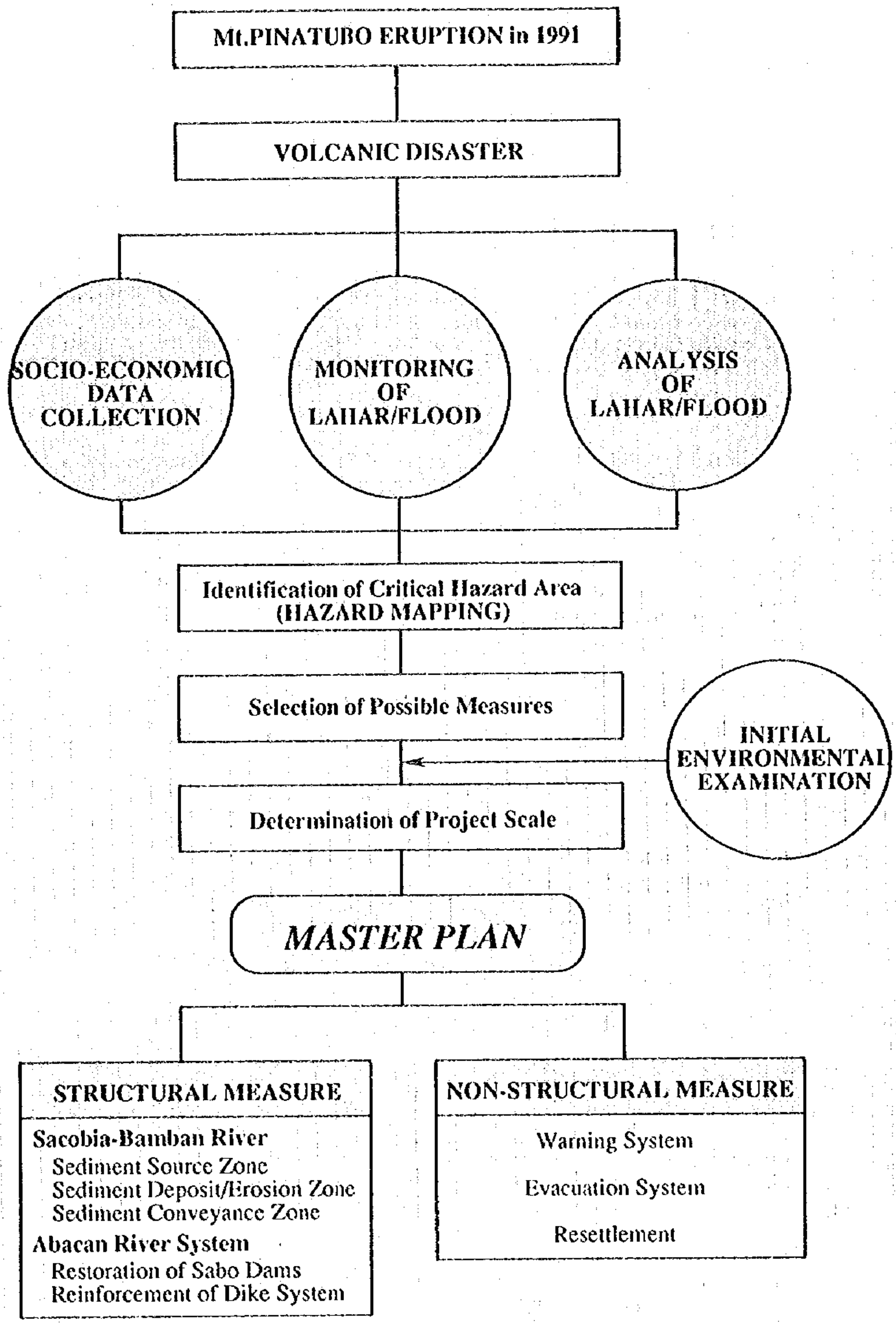

Figure 4.1

Basic Concept of Master Plan Study

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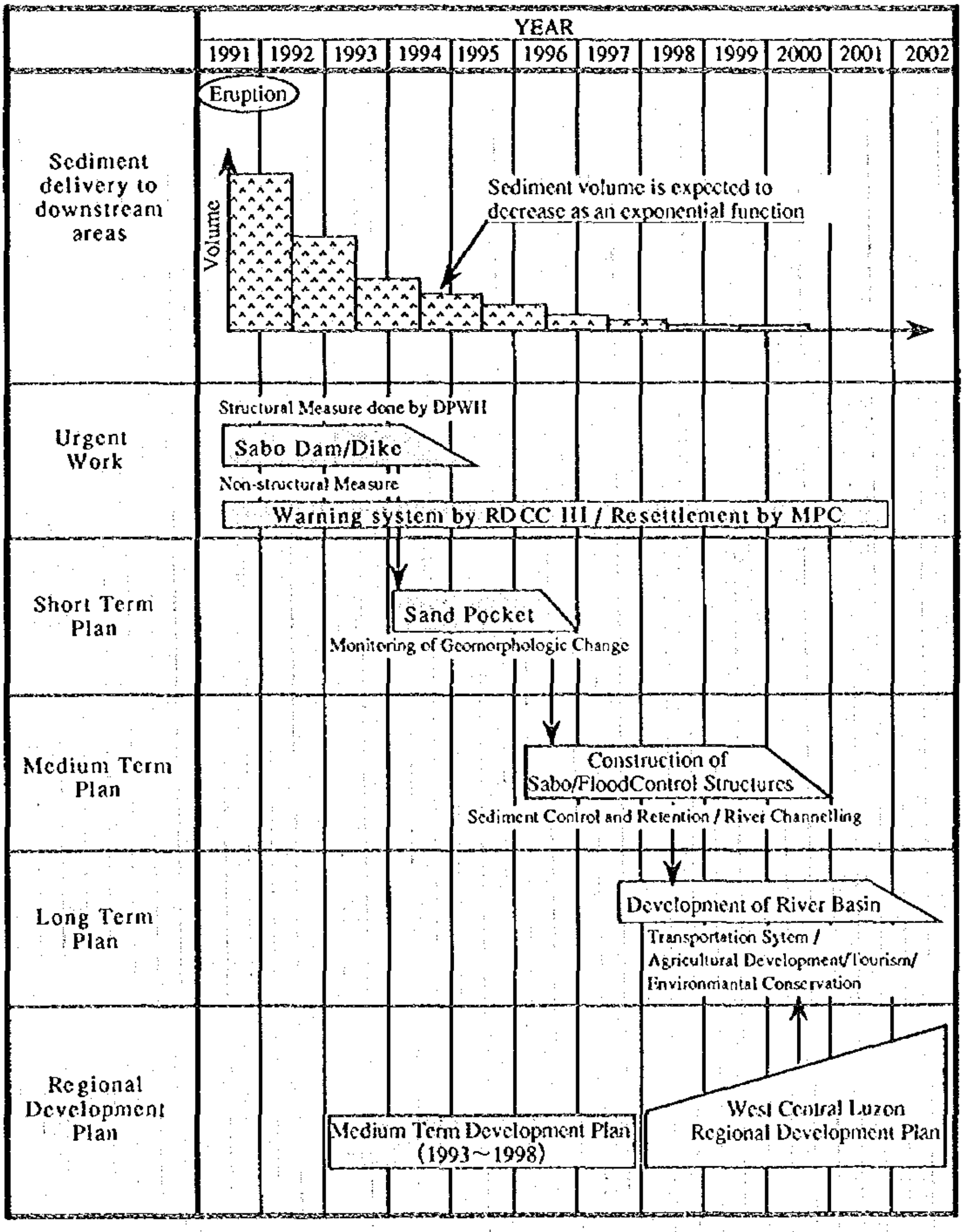

Remarks : [ ]: Put into operation [ ] : Planned

Figure 4.2 Implementation Schedule of Flood/Mudflow Control Works

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

CHAPTER 5

GEOMORPHOLOGIC CHANGES

CHAPTER 5 GEOMORPHOLOGIC CHANGES

5.1 SACOBIA AND ABACAN RIVERS

5.1.1 GEOMORPHOLOGIC MAPPING

Geomorphologic change in the East Pinatubo Pyroclastic Flow Field (EPPFF : after PHIVOLCS) where Sacobia, Abacan and Pasig rivers originate was studied in detail on the basis of four (4) sets of aerophotographs. The geomorphologic maps are shown in Figures 5.1 to 5.2.

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). Figure 5.3 shows the cross sectional data of pyroclastic flow depositional area in EPPFF. The cross sectioning at an interval of 200 m was carried out by GIS, and the volume of pyroclastic flow deposit was estimated at 1.40 billion m^3 in EPPFF.

While, the longitudinal profiles of Sacobia and Abacan rivers in Figure 5.4 and Pasig River in Figure 5.5 show the riverbed profile of pre- and post eruptions, surface elevation of pyroclastic flow deposit and the point of stream piracy. The pyroclastic flow deposit in 1991 was about 180 m thick in maximum in the Sacobia River and about 210 m thick in maximum in the Pasig River.

The longitudinal profile of pre-eruption shows that the riverbed elevation of the Pasig River is lower than that of Sacobia River although the catchment area of the Pasig River was smaller than that of the Sacobia River before the 1991 eruption. Since a river with wider catchment area forms generally a lower riverbed elevation, the Pasig River may have connected with the headwater of the Sacobia River before the Buag Eruption of 400-500 years ago, and connected again with its original headwater in October 1993, where was recognized as the headwater of the Sacobia River for 500 years.

The variation of catchment area and the balance of pyroclastic flow deposits are also shown in Figure 5.6. A number of river piracies were occurred between Sacobia and Abacan rivers in 1991 until the Abacan Gap was developed, while the Pasig River gradually added its catchment area and finally connected with the headwater of the Sacobia River in October 1993.

The chronological changes of riverbed elevation in Sacobia and Pasig rivers are shown in Figure 5.7. The riverbed in the Sacobia River is degrading rapidly in the upstream reach, while in the middle reach between Mactan and Maskup the riverbed elevation is rather stable. In the Pasig River, the river piracy in October 1993 caused remarkable riverbed aggradation. However, the riverbed is degrading rapidly in the rainy season in 1995.

5.1.2 PRE-ERUPTION BEFORE 1991

The upstream reaches of Sacobia, Abacan and Pasig rivers was running deep into the eastern slope of Mt. Pinatubo. The flattish old pyroclastic flow deposit with numerous small-scale gullies developed in Crow Valley and/or Maraunot Period was formed at the center of EPPFF with an elevation of 500 - 700 m. While, at the upper reach of the Abacan River in the east of EPPFF, the plateau with an elevation of 300 - 400 m was developed by the old pyroclastic flow deposit in Inararo Period. According to the observation from the Clark Field, the depositional surface of old pyroclastic flow deposit in Inararo Period may be higher than that of Crow Valley and/or Maraunot Period. In fact, the old pyroclastic flow deposit in Inararo Period was identified in the valley slope with a height of 50 - 100 m of Sapangbayo (Taug) River. The old pyroclastic flow deposit might be developed by the intrusion of those in Crow Valley and/or Maraunot Period into the valleys which was formed by eroding those in Inararo Period.

The Sacobia and Pasig rivers flow down in the rather deep valley with 100 - 200 m high at the old pyroclastic flow deposit. When the riverbed is lowered to the bottom of old pyroclastic flow deposit, the lateral erosion of river channel was occurred, and a small-scale river terraces were developed. However, the old pyroclastic flow deposit in Buag Period (about 500 years ago) was not identified in the Sacobia and Pasig river basins.

Even before the 1991 eruption, there was a wind gap (so called "Abacan Gap") in the uppermost end of the Sapangbato River. In the prehistorical eruption period, the stream piracy used to occur, and the rather wide riverbed and river terrace were formed in the Sapangbato River. In the Sapangbato River, two (2) spindle-shaped valleys were identified before 1991 eruption with pyroclastic flow deposit and lahar deposition.

5.1.3 POST ERUPTION (JUNE TO OCTOBER, 1991)

Immediately after the eruption, pyroclastic fall deposit (tephra) was widely deposited on the slope of Mt. Pinatubo with 0.5 m thick in the upstream reach of Sacobia and Pasig rivers and 0.3 m thick in Abacan River. The total volume of pyroclastic fall deposit in the EPPFF was estimated at 42 million m^3 in total; 20 million m^3 in the Sacobia River, 11 million m^3 in Abacan River and 11 million m^3 in Pasig River.

Immediately after the 1991 eruption, the flattish EPPFF was formed by the hot pyroclastic flow deposit. A number of small-scale secondary explosions occurred every day due to water coming in contact with the hot pyroclastic flow deposits, predominantly in positions overlying the buried channels in the valleys. However, since the scale of 1991 eruption was smaller than those in Crow Valley and Maraunot Periods, and the old pyroclastic flow deposit was not covered wholly.

The basin boundary of pre-eruption among Sacobia, Abacan and Pasig rivers was disappeared by rather deep pyroclastic flow deposit with 220 m high at Bukbuc River and 160 m high at Sacobia River in maximum. The piracy of the drainage system between Sacobia and Abacan rivers occurred repeatedly. The Sacobia River produced lahar 183 times for the period from July 17 to September 4, 1991 as recorded at the lahar observation point in Mactan Gate. The Abacan River captured from time to time the upstream reach of the Sacobia River by connecting with the Sapangbato River, a tributary of the Abacan River.

Lahar in 1991 were organized mainly into the pyroclastic fall deposits with thinner fine-grained material of high concentration. The lahar deposition area was therefore observed along the river course down to 15 to 30 km from Mt. Pinatubo with 2 to 5 m thickness, and extended to 50 km downstream of Mt. Pinatubo with 0.1 to 0.5 m thickness.

Lahar and large volumes of sediment in the Abacan River through the Sapangbato tributary had reduced the storage capacity of the Abacan River. Increased flooding and sediment discharge destroyed or damaged all of the bridges across the Abacan River, and caused the lateral erosion of river bank resulting in the destruction of hundreds of houses in Barangay Sapangbato and in Angeles City. Since October 1991, no lahar was observed in Sacobia and Abacan rivers. Sabo dams were constructed for the period from November 1991 to March 1992.

In the upstream reach of the Pasig River, the Bukbuc River (16.9 km^2) was buried with pyroclastic flow deposit of 200 m high and rather deep depression was formed due to numerous secondary explosion. At last, the closed basin with 10.0 km^2 was formed in the Bukbuc River. While, the Timbu Creek ran deep into the upstream of primary pyroclastic flow deposit, and the catchment area expanded from 4.4 km^2 to 10.5 km^2. At the same time, the main stream of Sacobia River swerved to northward.

Dammed lake developed at the confluence between Bukbuc and Yangca rivers, and the large-scale of secondary explosion used to occur to contact lake water with the hot pyroclastic flow deposit. In case of breaking of dammed lake, the large-scale lahar avalanched to downstream areas of the Pasig River.

5.1.4 POST ERUPTION (NOVEMBER 1991 TO OCTOBER 1992)

On April 4, 1992, after a week-long heavy rainfall, a large secondary explosion with a 1.0 to 1.5 km high of grayish ash column on the eastern slope of Mt. Pinatubo had caused the aggradation of about 5 m in the Abacan and Sacobia rivers as shown in Figure C.12. Sabo dams (Nos. 1 to 3) in the Abacan River were completely buried while sabo dam (No.4) was partially buried. In the Sacobia River, sabo dam (No.1) was completely buried and sabo dam (No.2) was filled to the brim. However, the sabo dam (No.2) blocked completely the secondary pyroclastic flow.

The Taug (Sapangbayo) River, a tributary of the Abacan River, drained tephra-covered slopes not pyroclastic flow deposits. Three (3) sabo dams in the Taug (Sapangbayo) River were filled up with lahar composed of pyroclastic fall deposits.

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 and had facilitated the piracy by the Sacobia River. No lahar has occurred along the Abacan River ever since the piracy of the Sacobia River had occurred at Abacan Gap. In 1993, lahar deposition area in the Sacobia-Bamban River was relatively narrow compared with those in 1991 and 1992 and was limited in the upstream reach of San Francisco Bridge. The Abacan Gap formed a escarpment of 40 to 50 m deep in 1995.

In the Pasig river basin, a lot of secondary explosion occurred at the confluence between Bukbuc and Yangca rivers. Since the main stream of Pasig River returned to the Papatac River, a hot lahar flowed down through the valley along Papatac River. The Timbu Creek diminished its catchment to 5.6 km^2.

5.1.5 POST ERUPTION (NOVEMBER 1992 TO APRIL 1994)

In October 1993, the large-scale landslide which was triggered by secondary explosion had occurred in the pyroclastic flow deposits-filled river valley. The river channel of Sacobia River was buried with secondary pyroclastic flow deposit. As a result, the Pasig River captured the upstream reach of the Sacobia River. Comparing Figure 5.6 (d) with Figure 5.6 (e), the caldera with 1.0 km long, 0.5 km wide and 70 m deep (20 million m3) was developed at the point where large scale secondary explosion occurred on October 5, 1993.

After the above river piracy, the catchment area of Sacobia River was reduced from 38.8 km^2 to 18.5 km^2 while that of Pasig River was increased from 24.2 km^2 to 44.5 km^2.

As well as the rainy season in 1991, a dammed lake developed at the confluence between Bukbuc and Yangca rivers, and the large-scale of secondary explosion used to occur to contact lake water with the hot pyroclastic flow deposit. In case of breaking of dammed lake, the large-scale lahar avalanched to downstream areas of the Pasig River.

5.1.6 POST ERUPTION (MAY 1994 TO NOVEMBER 1994)

In 1994, only a few small-scale lahars were observed at Mactan Gate in Clark Field. However, several large-scale secondary explosions and lahar occurred in the Pasig River.

The secondary pyroclastic flow deposited with 50 to 100 m deep in the valley of the Pasig River, and the Pasig River swerved its flow into the Timbu Creek since June 1994. As repeating secondary explosion and secondary pyroclastic flow, the river channel of Timbu Creek-Pasig River was buried with a remarkable volume of sediment.

At the beginning of August 1994, the lahar in the Pasig River overtopped the left river bank at immediately downstream of Watch Point No.5. Some lahar avalanched to the direction to Taug (Sapangbayo) River. The primary protective dike was constructed at the left bank with 10 m high.

According to the field reconnaissance by helicopter on October 28 1994, no secondary explosion occurred in the upstream reach from the river piracy point of the Pasig River, while numerous thick smoke risings were observed in the secondary pyroclastic flow deposit-filled valley in the Timbu and Papatac rivers. As shown in Figure 5.6, the primary pyroclastic flow deposit in these area was washed out to the downstream reach in April 1994. Therefore, a secondary explosion may occur in the secondary pyroclastic flow deposit-filled valley which maintain high temperature although three (3) years have passed since the 1991 eruption.

5.2 BAMBAN RIVER

5.2.1 GEOMORPHOLOGIC MAPPING

Geomorphological change in the middle/lower reach of the Sacobia River and Upper reach of the Bamban River was studied in detail on the basis of four (4) sets of aerophotographs. The geomorphologic maps are shown in Figures 5.8 to 5.10.

5.2.2 PRE-ERUPTION

The Sacobia, Abacan and Pasig rivers which originate in the EPPFF and flow down through the old pyroclastic flow deposit in Inararo Period form a large alluvial fan in the Luzon central plain. The area of alluvial fan is estimated at 600 km^2 with a radius of 20 km although the catchment area in the upstream reach from apex of alluvial fan is only 87.4 km^2. A number of traces of old river channel on the surface of alluvial fan shows the fact of frequent stream piracies due to lahar and debris flow.

Assuming the sediment deposition of 50 m deep on an average in the alluvial fan for 50,000 years, the volume of sediment deposition is estimated at about 30 billion m^3 in total (10 million m^3/year) based on the topographic map with a scale of 1:50,000.

Figure 5.8 shows the geomorphological condition of pre-eruption in the Sacobia-Bamban River. The hilly mountain ridge from EPPFF which forms the basin boundary between Sacobia and Sapang Cauayan rivers runs into the alluvial fan. Although the crest elevation of mountain ridge is lower than the depositional surface of alluvial fan at Bamban, the alluvial fan is studded with islets (a diameter of 100 - 200 m) which are a part of hilly mountain ridge.

In the reach of the Sacobia River from Mactan Gate to Maskup, a river channel of 50m wide with a riverbed gradient of 14/1,000 was developed in the spindle-shaped river channel of 8.5 km long and 500 - 800 m wide and a terrace scarp with 10 - 20 m high was developed at the fringe of a flattish terrace surface which was developed in Maraunot Period of 2,500 - 3,000 years ago. The Clark Field is located on this terrace surface in the south of the Sacobia River.

Accompanying the previous volcanic activities of Mt. Pinatubo, the remarkable sediment discharge through the Sacobia River formed the alluvial fan in the vicinity of Dolores. The Sacobia River then changed its flow direction to the north, and joined the Marimla and the Sapang Cauayan rivers. The Sacobia River (Bamban River) changed the flow direction again to east-northeast with a riverbed gradient of 3/1,000 due to the blockage by small plateau at Bamban.

5.2.3 POST ERUPTION (JUNE 1991 TO OCTOBER 1992)

Lahar volume in the Sacobia River was estimated at 150 million m^3 in 1991 and 70 million m^3 in 1992. In the reach of the Sacobia River from Mactan Gate to Maskup, lahar deposition in the spindle-shaped river channel of 8.5 km long and 500 - 800 m wide was estimated at 70 million m^3 with a thickness of 7 - 10 m.

Since the Sacobia River flows down to the northward on the edge of an alluvial fan where Dolores is located, the lahar was deposited and dispersed along the river course with 10 - 15 m deep in 1991. In 1992, lahar deposits did not only pile up in previously affected areas in 1991 but also in the eastern and western sides.

Damming of Marimla and Sapang Cauayan rivers by the aggradation of the Sacobia River has led to the intermittent formation of lakes. Although the damming of Marimla River was breached in 1991, the dammed lake at Sapang Cauayan River remains with a storage of 7 million m^3.

5.2.4 POST ERUPTION (NOVEMBER 1992 TO APRIL 1994)

The volume of lahar deposition was estimated at 65 million m^3 in 1993. The narrow gorge at Maskup was buried wholly by lahar deposition and lahar flowed down along the dike of right bank and deposited between dike at right bank and the deposition in 1992. Since the construction of right bank dike was completed to 2.5 km downstream from Route 3, the lahar flowed down to the southward where Barangay Sapang Balen was located.

5.2.5 POST ERUPTION (MAY 1994 TO NOVEMBER 1994)

Although a few lahar were observed at Mactan Gate of Clark Field by PHIVOLCS in 1994, the volume of lahar was estimated at 8 million m^3 in total. Comparing the volume of lahar of 65 million m^3 in 1993 with those in 1994, the volume of lahar in 1994 is deemed to be very small even if the river piracy by the Pasig River is taken into account. As a result, riverbed degradation with secondary erosion of 3 million m^3 occurred in the spindle-shaped river channel from Mactan Gate to Maskup, and sediment of 11 million m^3 flowed down into the sand pocket area.

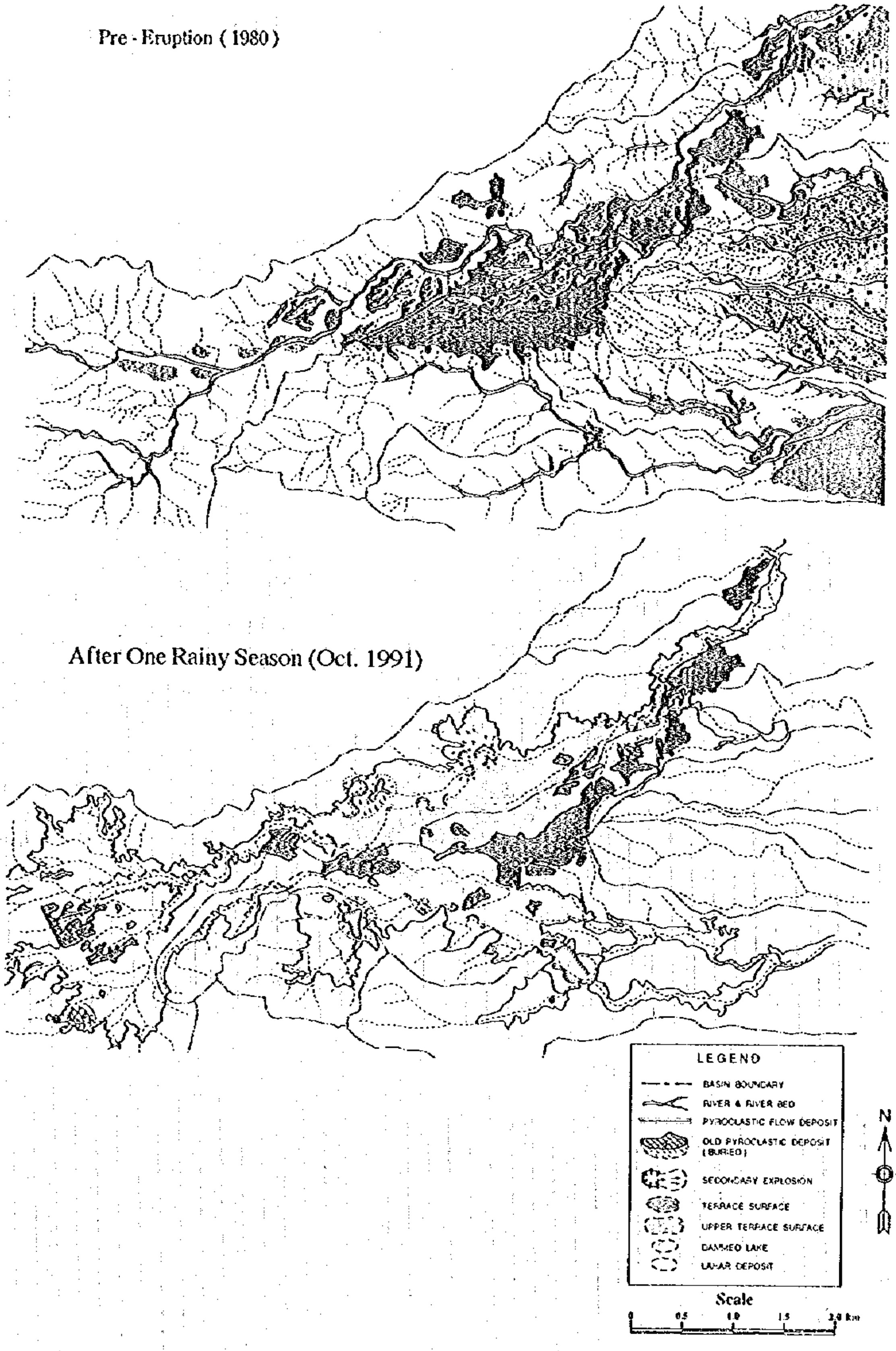

Figure 5.1 Geomorphological Map in EPPFF (Pre-Eruption and October 1991)

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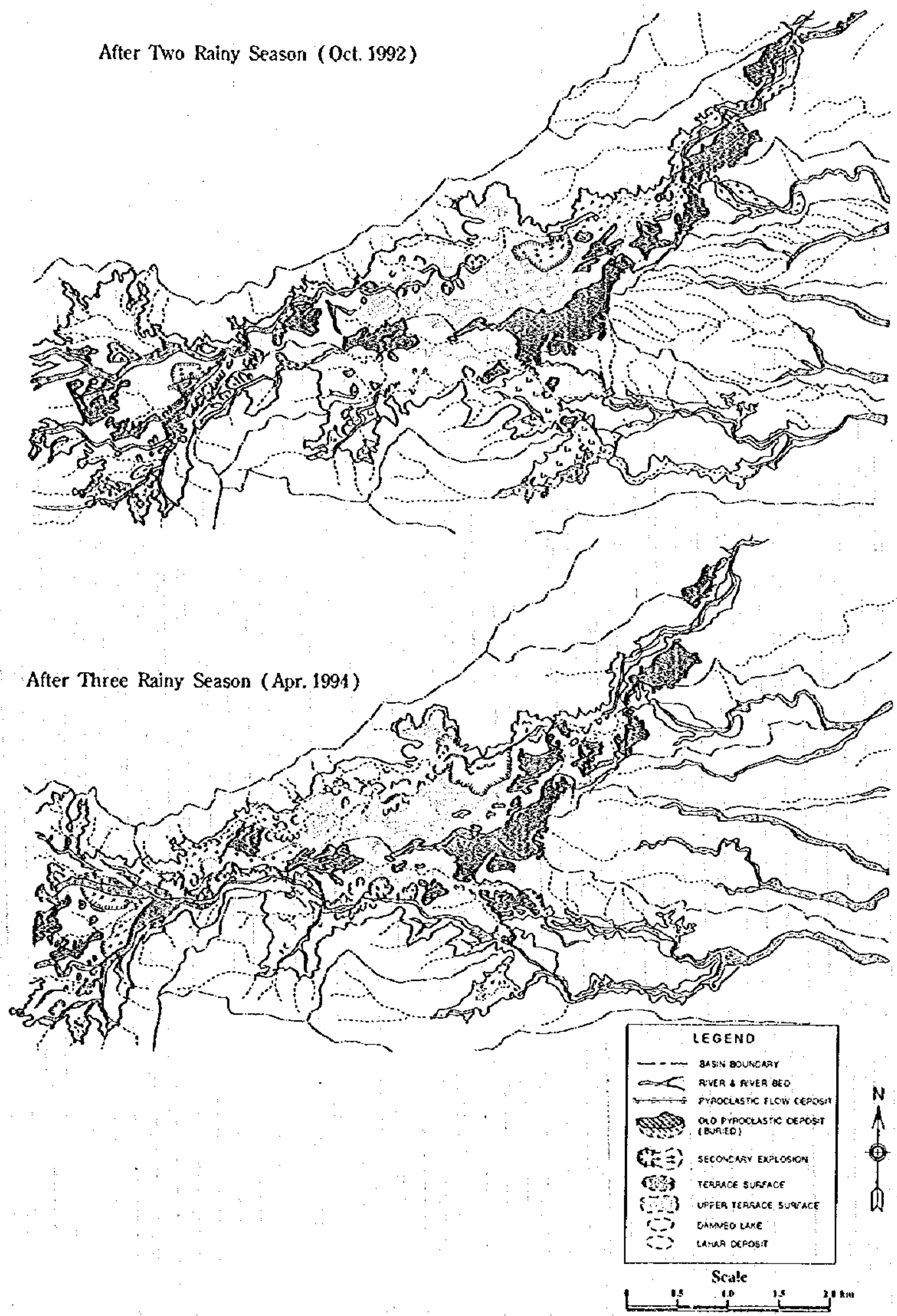

Figure 5.2 Geomorphological Map in EPPFF (October 1992 and April 1994)

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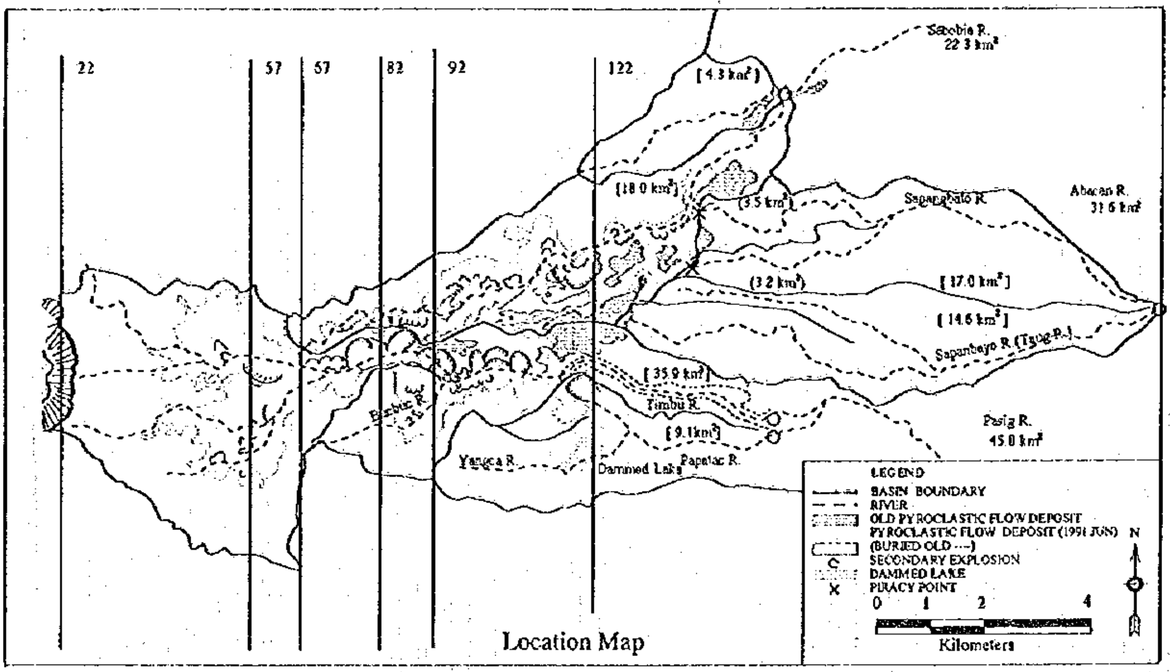
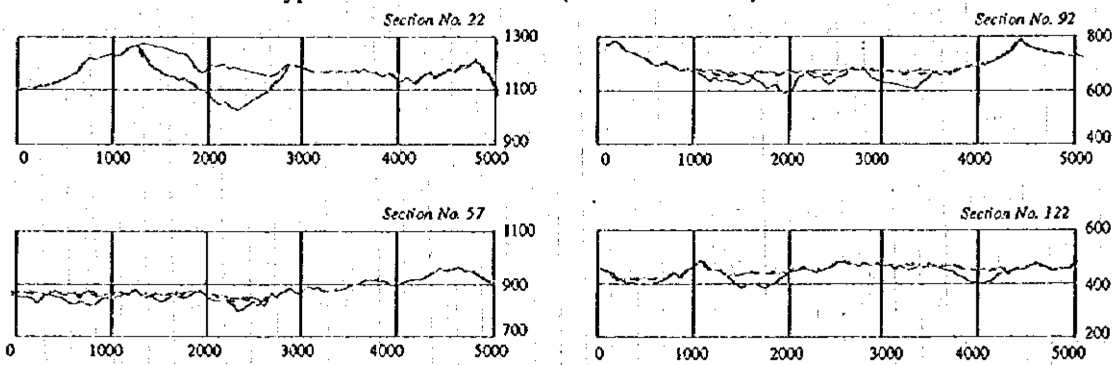
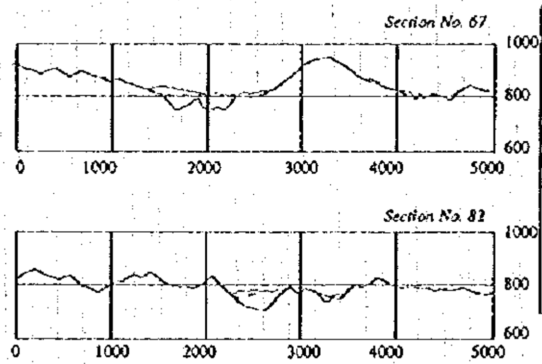


Location Map

Typical Cross Section Data (distance in meters)





Legend :
( ) Section Number
Before Eruption (1980)
After 2 Rainy Seasons (1992 Oct.)
After 3 Rainy seasons (1994 Apr.)

Comments : The analysis was performed using the GIS database created by JICA Study Team from the DTM for 1980, 1992 and 1994 with a contour interval of 5m mapped to scale of 1:10000 from Aerial Photographs of varying scales. The data has been modelled with a spatial resolution of 10m. The volume analysis was performed by estimating the area along sections at every 200m near the Crater and every 500m at other locations. The Pyroclastic flow area was identified by the Team Experts by Aerial Photo Interpretation.

Figure 5.3

Geomorphologic Sectional Analysis for Pyroclastic flow Deposits

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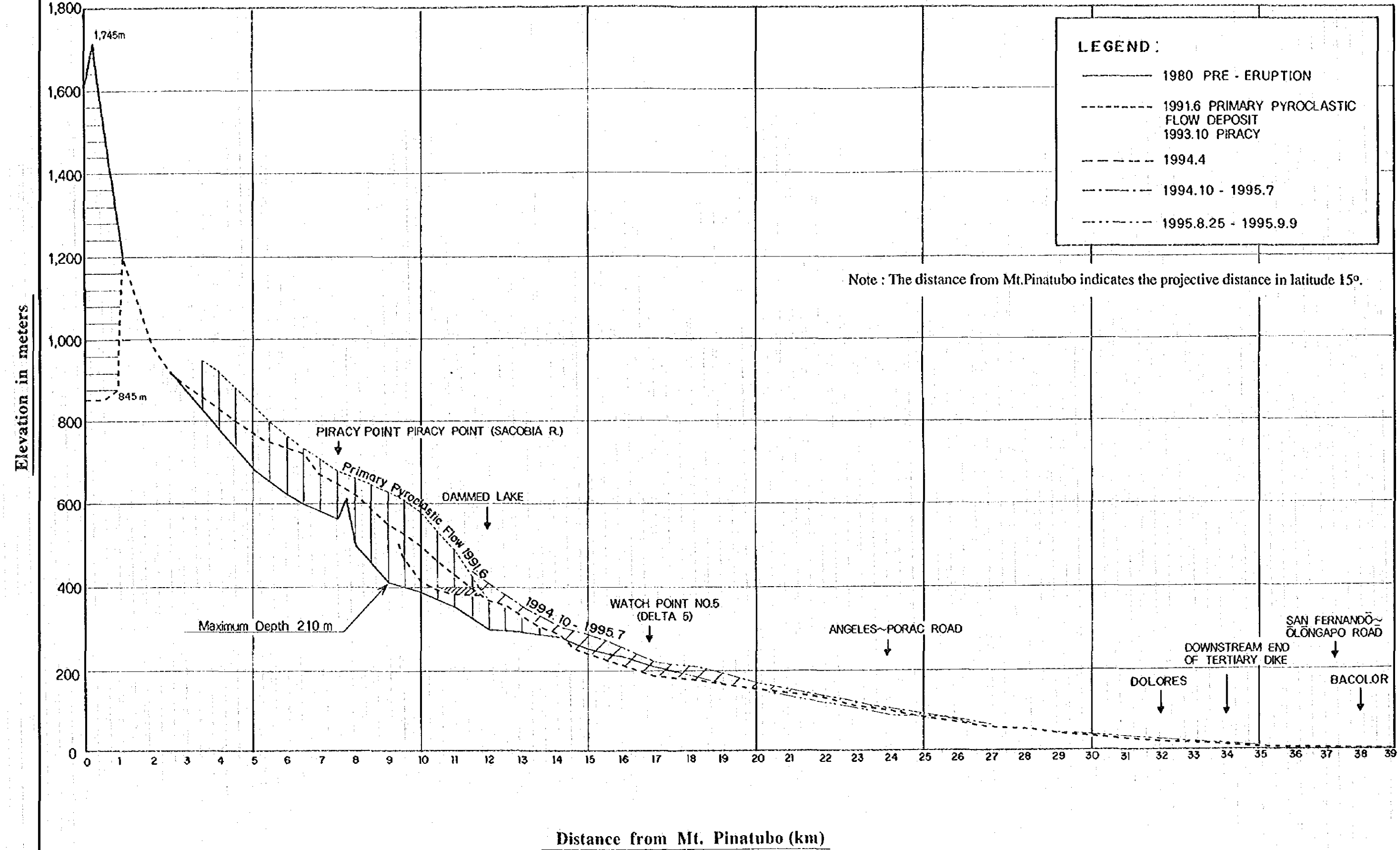

Figure 5.4 Longitudinal Riverbed Profile in Sacobia and Abacan Rivers

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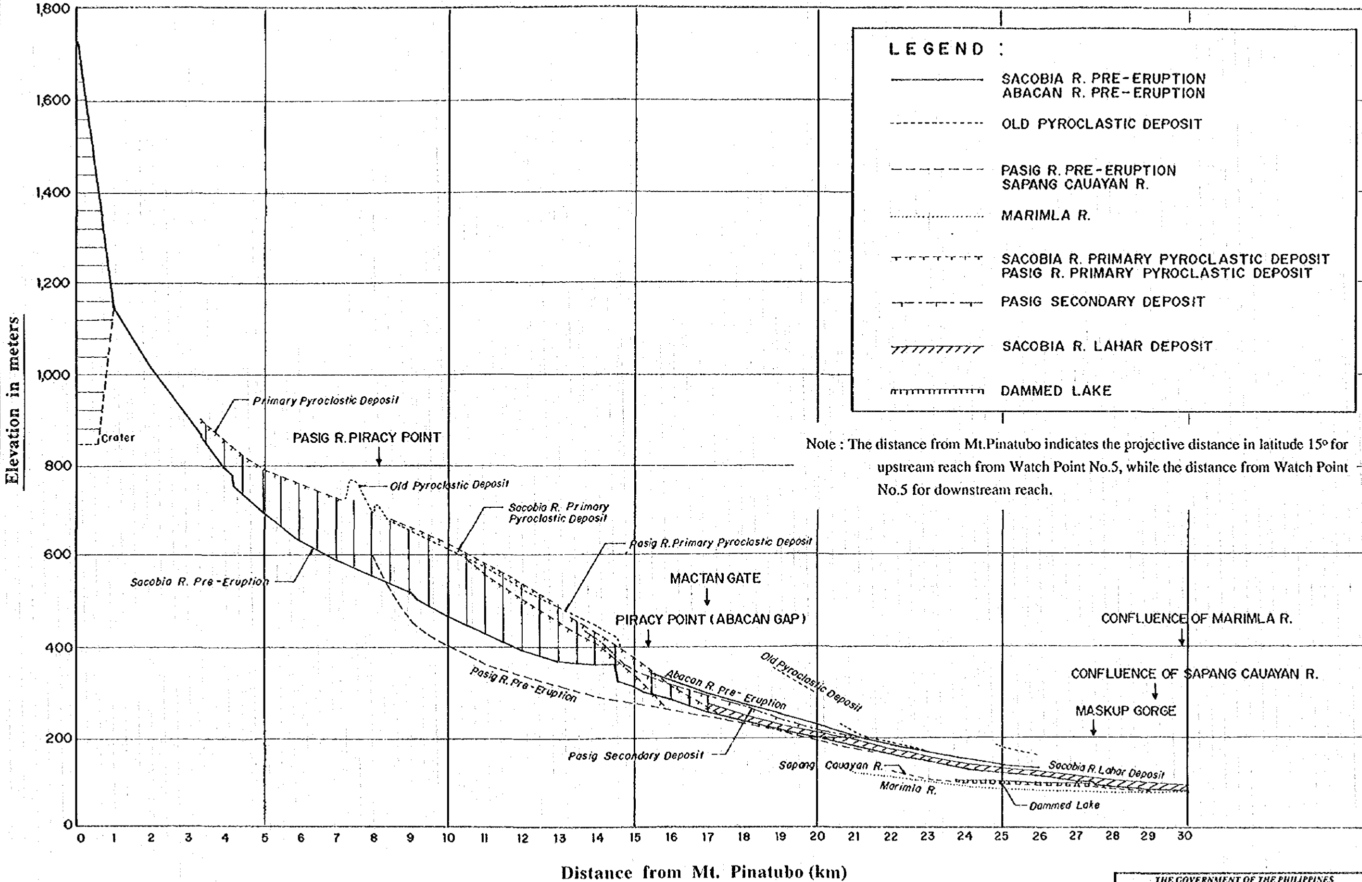

Figure 5.5 Longitudinal Riverbed Profile of Pasig River

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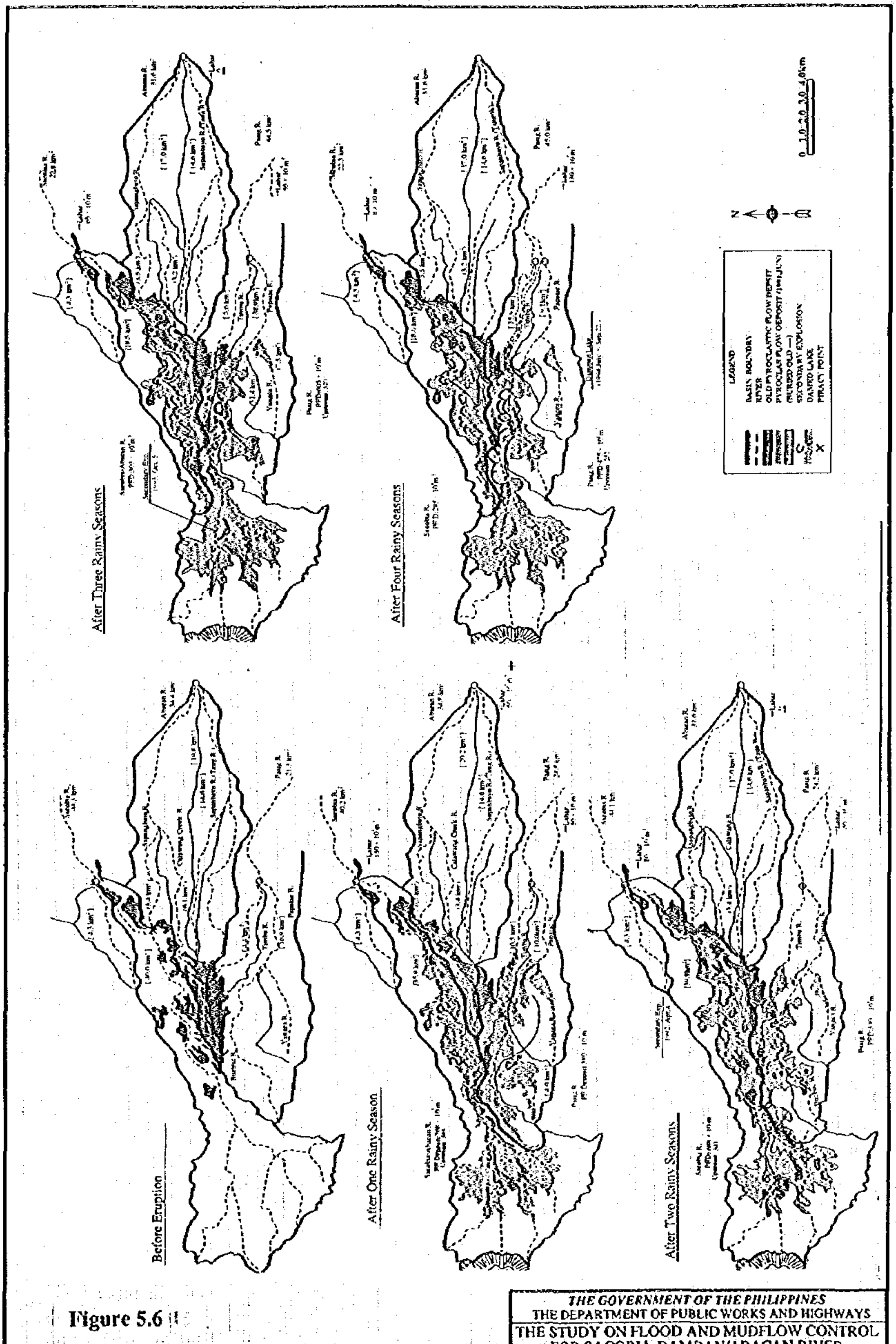

Figure 5.6

Chronogical Changes of Catchment Areas

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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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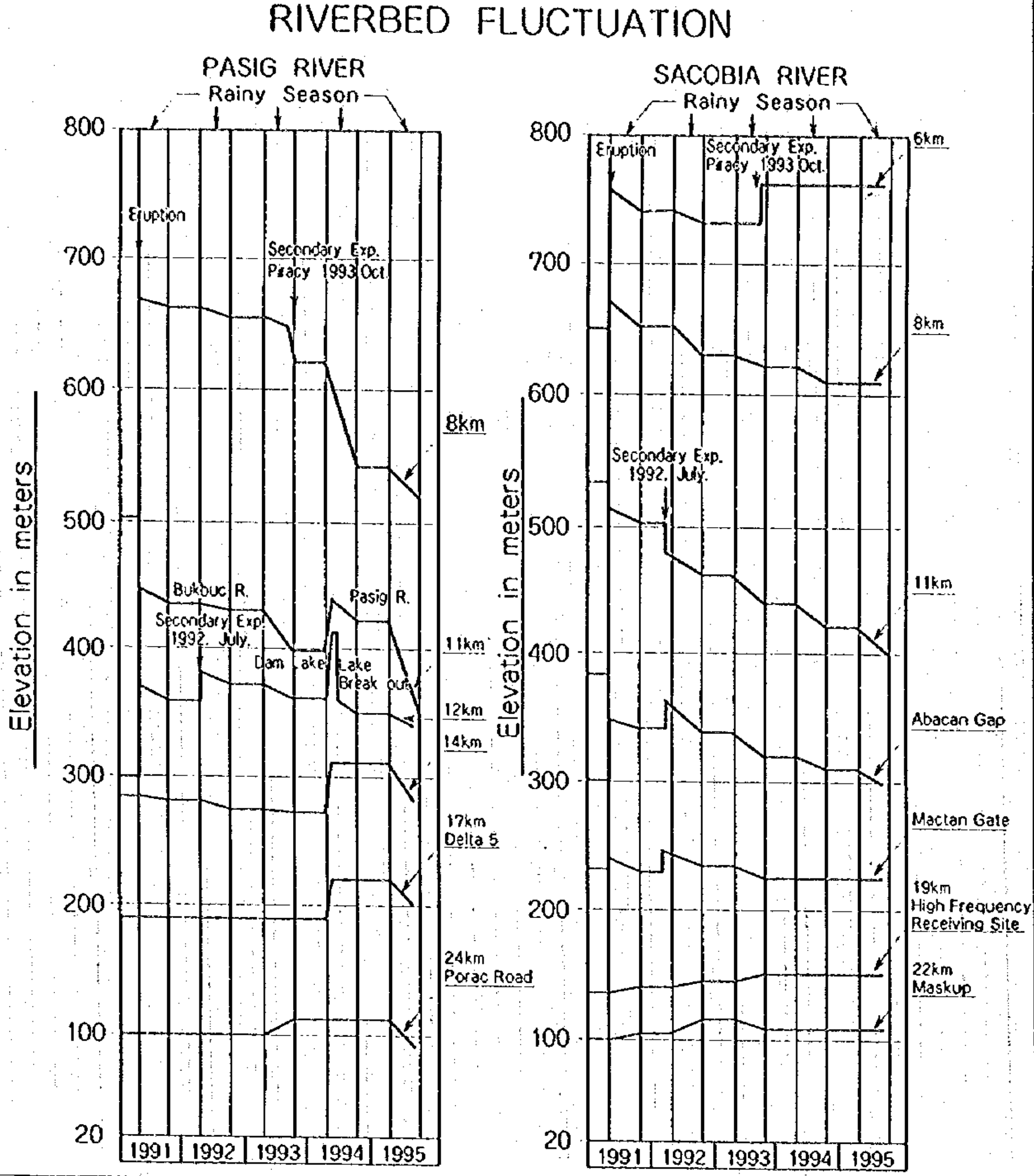

Pyroclastic Flow Deposit Volume (million m³)	450		400		360		725		595		550
Sediment Volume at Delta 5 (million m³)		50		40		55		130		45	
Drainage Area at Delta 5 (Km²)	21.3		24.5		24.2		44.5		45.0		

Pyroclastic Flow Deposit Volume (million m³)	1150		950		870		385		377		373
Sediment Volume in Sacobia River (million m³)		150		80		65		8		4	
Sediment Volume in Abacan River (million m³)		50		0		0					
Drainage Area at Mactan Gate (km²)	40.0		35.3		38.8		22.8		22.3		22.3

Remarks : Figures in km show the distance from Mt. Pinatubo.

Figure 5.7

Chronological Riverbed Fluctuation

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THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
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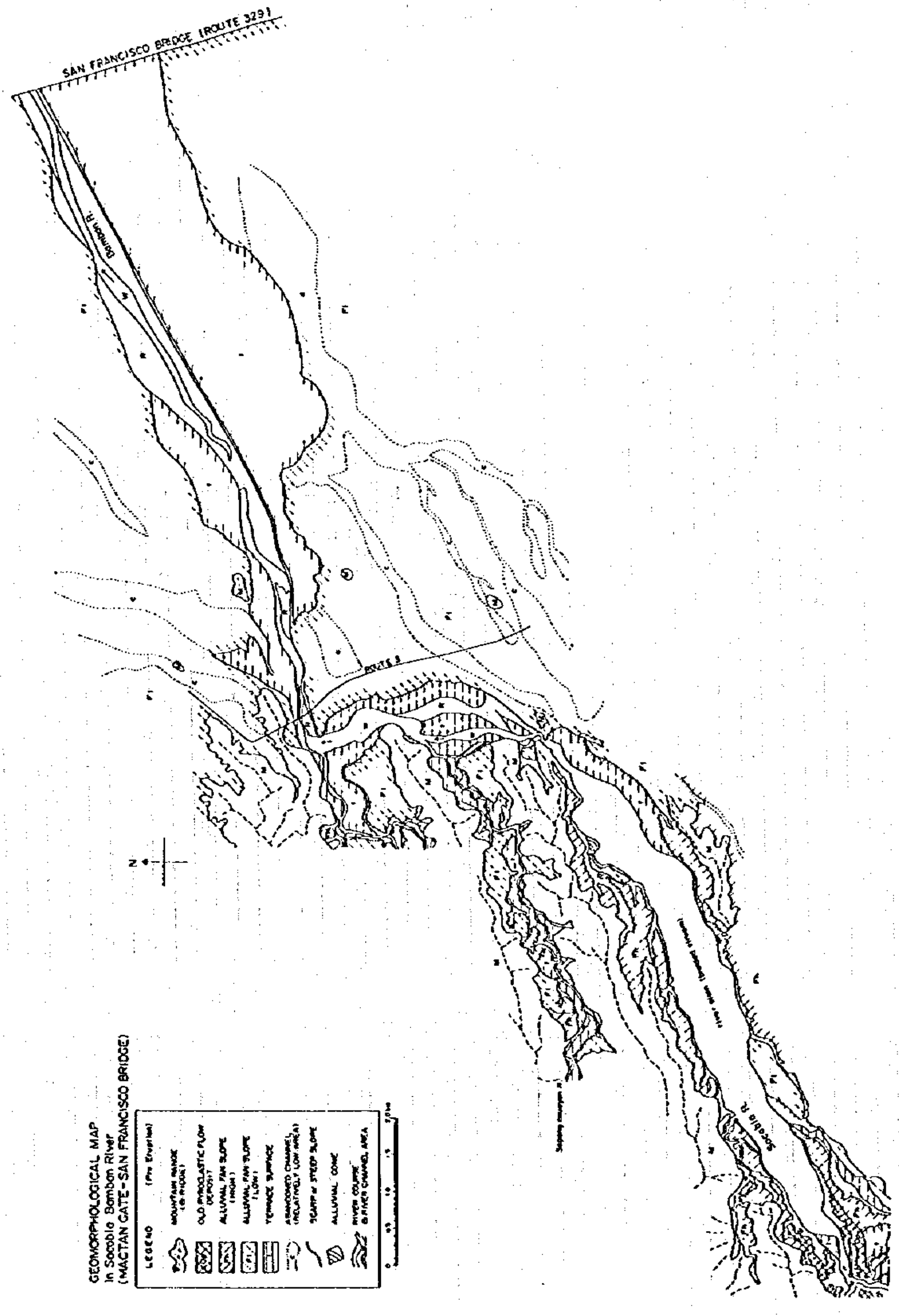

Figure 5.8 Geomorphologic Map in Sacobia River (Pre-Eruption, 1980)

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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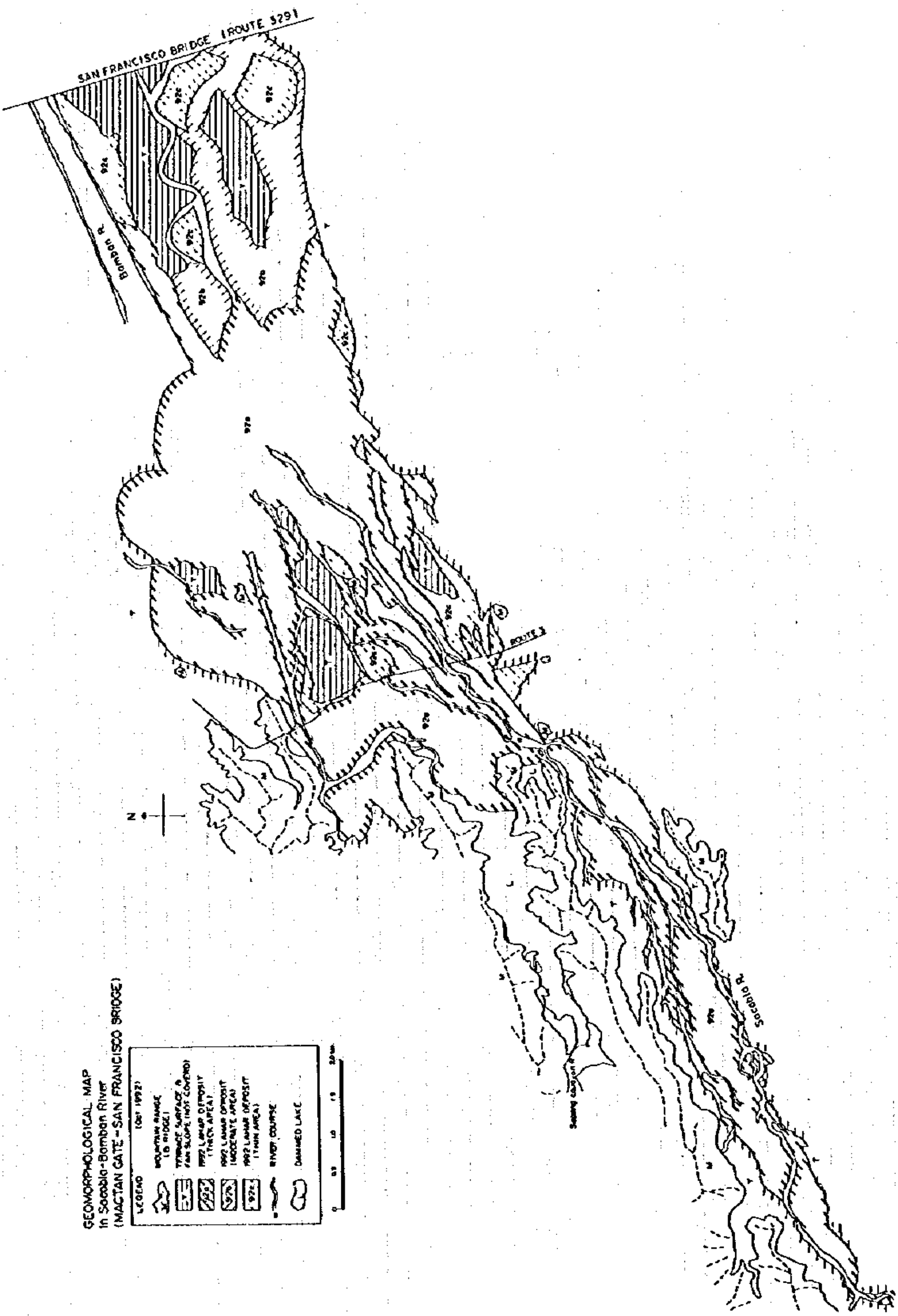

Figure 5.9 Geomorphologic Map in Sacobia River (October 1992)

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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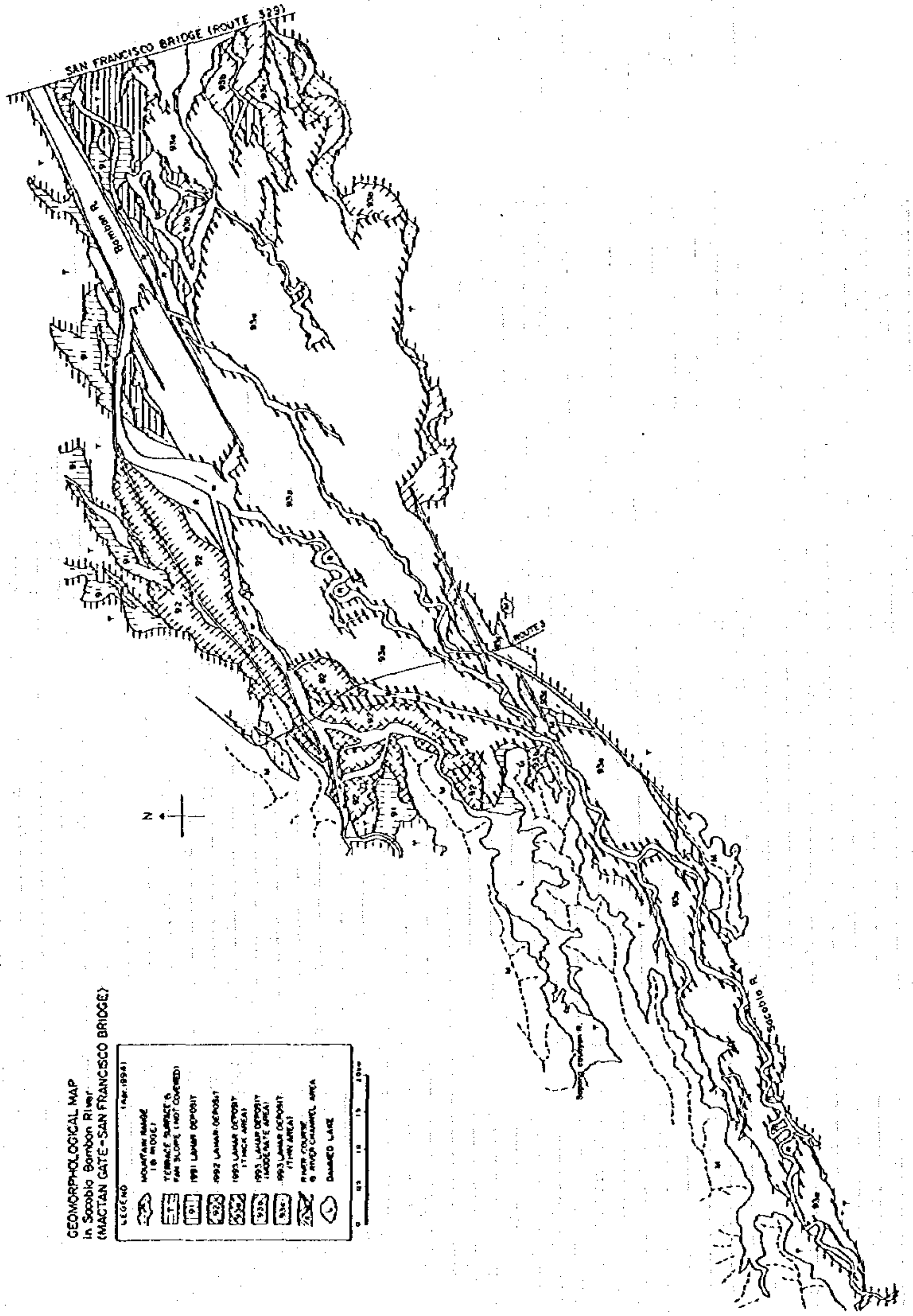

Figure 5.10 Geomorphologic Map in Sacobia River (April 1994)

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

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

JAPAN INTERNATIONAL COOPERATION AGENCY

CHAPTER 6

SEDIMENT BALANCE

CHAPTER 6 SEDIMENT BALANCE

6.1 SACOBIA-BAMBAN RIVER BASIN

6.1.1 SEDIMENT DELIVERY SYSTEM

Chronological changes in geomorphology occur gradually in accordance with a characteristics of sediment delivery to the downstream areas; namely, i) sediment source zone in the uppermost reach, ii) sediment deposition/secondary erosion zone in the middle stream and (iii) sediment conveyance zone in the downstream reach. The boundaries of sediment zones are generally settled with time, although the sediment zones are being shifted largely for a short duration. The approximate boundaries of sediment delivery zones are shown in Figure 6.1.

(1) Sediment Source Zone

The upstream reach of 17 km from the summit is defined as sediment source zone. The remarkable volume of ashfall and pyroclastic flow deposits were overburdened in the uppermost reach as sediment source. Although the ashfall deposit was one of the sediment sources immediately after the eruption in 1991, the pyroclastic flow deposit and sediment triggered by secondary explosion and heavy rainfall are regarded as a major sediment sources to the downstream areas since 1992.

(2) Sediment Deposition/Secondary Erosion Zone

Most sediment transported from the sediment source zone is being deposited in the sediment deposition/secondary erosion zone for the reach from 2 km upstream of Mactan to San Francisco Bridge. The spindle-shaped valley from Mactan to Maskup stored a remarkable volume of sediment and supplied sediment due to secondary erosion to downstream areas. The deposition and secondary erosion of sediment has occurred repeatedly in this zone. The sediment dispersed telescopically in the downstream reach of this transition zone.

Sediment accumulates generally at downstream end of mountainous area and its shape of deposition is governed by the topographic condition. An intersection point which is defined as the point of intersection between riverbed longitudinal profile and sediment depositional surface gradient is generally formed in the sediment deposition area when the excessive sediment delivery from the sediment source zone terminates and the riverbed degradates at the uppermost point of sediment depositional area.

In case that a remarkable pyroclastic flow deposit and subsequent secondary explosion occur in the sediment source zone, sediment delivery rate varies largely for short duration and the intersection point shifts broadly within the range of sediment deposition and/or secondary erosion zone. After the termination of excessive sediment delivery from sediment source zone, the intersection point shifts gradually to the downstream reach in accordance with the secondary erosion rate of sediment deposition. In the downstream reach from sediment deposition and/or secondary erosion zone, the river flow forms a braided river and a widespread sediment deposition is observed with shallow depth. In case that the sediment accumulation with relatively steep gradient is observed in the downstream reach, the intersection point shifts to the downstream and a form of natural river channel continues to downstream reach which is regarded as the sediment transportation zone.

(3) Sediment Transportation Zone

The sediment in the conveyance zone is transported gradually through the river channel to the Rio Chico River in proportion to the rate of river flow. Along the lower channel, aggradation systematically decreases in response to changes in stream gradient and channel morphology. Where gradients are fairly uniform, thickness of lahar deposits do not very much, changing drastically only at major breaks in the stream profiles. Aggradation rates are relatively high at constrict in the upstream channel, where repeated channel plugging causes flows to deposit.

6.1.2 MONITORING OF SEDIMENT DEPOSITION

(1) Chronological Changes of Sediment Deposition

The Sacobia river course has been changed frequently in a stretch of Maskup to Route 329 by floods and lahars in 1994. Lateral erosion and downcutting of the river channel were mainly observed in the upstream reach from Mactan to Maskup.

Figure 6.2 shows the changes of the river course in the Sacobia-Bamban and Marimla rivers in the rainy season of 1994. The chronological changes of river course of the Sacobia River from 1994 to 1995 are described below;

1) Before the onset of rainy season in 1994

Lahar had occurred frequently in the Sacobia River until its uppermost reach was annexed to the Pasig River on October 5-6, 1993. The 1993 lahar mainly rushed eastward from Maskup, an outlet of the spindle-shaped valley. As lahar deposits accumulated on the river terrace along the Mabalacat dike, the Sacobia active channel shifted toward the north-east direction from Maskup following the topographic gradient.

2) June 23, 1994

The river channel changed its direction eastward into the sand pocket during the relatively heavy rainfall of 76 mm recorded at the Sacobia rainfall gauge of PHIVOLCS on June 23, 1994.

3) July 10, 1994

The closing dike in the sand pocket was partially damaged by flooding when the PI2 rainfall gauge of PHIVOLCS recorded 106 mm on July 10, 1994. On July 15, a small-scale lahar of 1 m deep was observed at Mabalacat and a portion of the repaired closing dike was washed out when daily rainfall of 88 mm was recorded at the Upper Sacobia rainfall gauge of PHIVOLCS.

4) July 18, 1994

Daily rainfall of 222 mm was recorded at the Upper Sacobia gauge on July 18, 1994, it was the heaviest daily rainfall at this station in 1994. The moderate-scale lahar of 1.5 m deep was observed at Mabalacat. This lahar formed the 4 km long by 3-4 m high lobed deposition around Tabun Village which was buried by the 1992 lahars. The flood flow completely washed out the upper portion of the left sandbag dike in the sand pocket. After this event, the main stream of the Sacobia River shifted its course along the Bamban-Parua river dike and the San Nicolas Balas dike inside of the sand pocket.

5) July 23 to 25, 1994

Daily rainfall of 119 mm, 125 mm and 88 mm were recorded at the Upper Sacobia gauge for the three consecutive days from July 23 to 25, and the small-scale lahar of 1 m deep was observed at Mabalacat on July 25. During this flood, a remarkable volume of sediment from the Sacobia River were deposited over a 2 km long stretch on the Bamban River through the breached portion of the Bamban right dike 3.5 km upstream of the San Francisco bridge. The volume of sediment deposit was estimated at 600,000 m^3.

6) July 29 to 30, 1994

Relatively heavy daily rainfall of 34 mm and 72 mm were recorded at the Upper Sacobia gauge on July 29 and 30, respectively. During this storm, the Sacobia river course shifted down south and the flood water flowed along the Mabalacat-Magalang dike into the sand pocket area. The flood water washed out the lateral embankment at Mabalacat, which was constructed as a temporary transportation route to connect Mabalacat with Bamban, and formed the 1 km long by 2-3 m high lobed deposition along the Mabalacat-Magalang dike. After this event, the Sacobia River was flowing down along the dike to the sand pocket until October 22.

7) August 3, 1994

Daily rainfall of 67 mm was recorded at the Upper Sacobia gauge and the small-scale lahar of 1 m deep was also observed at Mabalacat on August 3. The confluence of the Marimla and Sapang Cauayan rivers was shifted northward, and the Bamban River followed down on its pre-eruption channel around Bamban town. At the same time, the Bailey bridge and the old Bamban river channel were completely buried with sediment.

8) October 22, 1994

No major morphologic change of the river channel was observed until October 22. The Malonzo-San Pedro Hill diversion dike (separation dike) was constructed by DPWH in October to prevent the heavy sediment inflow from the Sacobia River to the Bamban River and to store the sediment in the sand pocket.

Based on the field interview survey, Navaling, which is located at 1.5 km downstream from the sand pocket, was affected by siltation from September to October due to the dike breach of the Sapang Balen River. The volume of sediment deposited was estimated at 900,000 m^3. Paddy fields in the affected area were covered with sand and pumice, and were utterly damaged.

On October 22, the Sacobia River swerved again to the north-east. Several river channels were created from Maskup to the downstream end of the sand pocket. Based on the field observation in the 1994 rainy season, the river course had shifted frequently at many points after choking its old channel and flowed down on the another old channel.

9) Geomorphologic Changes in 1995

Figure 6.3 delineates the Sacobia river course based on the field investigation in the 1995 rainy season. From Mactan to Maskup, the river course did not significantly change except for riverbed aggradation. Before Typhoon Mameng on October 1, 1995, the riverbed had been gradually aggradated from the beginning of the 1995 rainy season. Then flood runoff triggered by the passage of the Typhoon Mameng heavily scoured the active riverbed by 3 to 4 m deep.

(2) Sediment Deposits in 1994 and 1995

1) Sediment Deposit Survey

As described in the preceding subsections, the sediment transport mechanism of the Sacobia River dramatically changed with river piracy occurred in October 1993 as a turning point. Quantitative survey of the actual sediment deposition and secondary erosion caused by lahar transported from the sediment source zone is indispensable in order to project the future sediment delivery with more accuracy. Thus, a simple cross-section survey and leveling were executed in the area from Mactan to Route 329, where sediment deposition and secondary erosion took place, to quantify the sediment delivery in 1994.

In the sediment accumulation area from Mactan to Maskup, a cross-sectional survey was carried out immediately after the 1994 rainy season at an interval of 1.0 km. Figure 6.4 shows the cross-sectional changes, and the volume of secondary erosion in the 1994 rainy season is estimated at 3.1 million m^3. This results show that the stretch of spindle-shaped valley from Mactan to Maskup changed in 1994 its characteristics from a sediment deposition area to a sediment source due to secondary erosion.

The results of leveling survey in the sand pocket area are also compiled as an isopach map in Figure 6.5. The volumes of the quarry and the embankment were estimated according to the data collected from the quarry checkpoint at Mabalacat and the DPWH. The depth and area of sediment accumulation in the downstream from Route 329 was based on the interview to the residents. A remarkable sediment volume of 10 million m^3 was accumulated in the sand pocket structure in 1994.

2) Sediment Deposits in 1994 and 1995

The sediment deposit survey shows a sediment volume of 11 million m^3 had accumulated in the area downstream of Maskup, while 3 million m^3 had been eroded in the area between Mactan and Maskup.

In comparison with those two figures, sediment of 8 million m^3 in volume was estimated as sediment yield in the sediment source zone in 1994. Compared with the sediment yield of 65 million m^3 in 1993, the sediment yield drastically diminished to one-eighth in 1994.

In addition, the sediment deposition of 4 million m^3 was estimated for the 1995 delivery based on the field observation to the deposit, as shown in Figure 6.6, by lahar during Typhoon Mameng on October 1, 1995. This lahar was the only one event which formed the sediment material as a lobed deposit along the Sacobia River during the 1995 rainy season.

6.1.3 SEDIMENT BALANCE AFTER ERUPTION

(1) Sediment Source Zone

Because of the remarkable geomorphologic changes in the uppermost reach due to movement of the pyroclastic flow deposits, the boundaries of the river basins have been shifted several times since the 1991 eruption. The change of catchment area of sediment source zone in the eastern slope of Mt.Pinatubo and the volume of pyroclastic flow deposits are summarized as shown below:

Geomorphological Changes in Sacobia-Pasig Headwaters

Time	Sacobia		Pasig		Total	
	C.A. (km^2)	P.F.D. (million m^3)	C.A. (km^2)	P.F.D. (million m^3)	C.A. (km^2)	P.F.D. (million m^3)
Pre-eruption	40.0	-	21.3	-	61.3	-
(Mt.Pinatubo Eruption in June 1991)						
Post-eruption	35.3	968 1)	24.5	430	59.8	1,398
(Sacobia Captures Headwaters of Abacan in April 1992)						
October 1992	38.8	688	24.2	340	63.0	1,028
(Pasig Captured Headwaters of Sacobia in October 1993)						
April 1994	18.5	303	44.5	605	63.0	908
October 1994	18.0	295	45.0	475	63.0	770

Note : C.A. : Catchment area for Sacobia River shows the upstream from Mactan, while those for Pasig River shows the upstream from confluence of Papatac and Timbu.
P.F.D. : Pyroclastic Flow Deposits
1) : Including P.F.D in Abacan Headwaters

The remaining pyroclastic deposits in the eastern slope of Mt.Pinatubo have been reduced to 55% in volume by the end of the 1994 rainy season. Although the pyroclastic flow deposits of 295 million m^3 still remain in the Sacobia headwaters, the lahar deposits have been observed only for a few times around Mabalacat in 1994. The reasons would be:

- The river piracy in October 1993 reduced catchment area of the Sacobia headwaters in half, and sediment yield and transportation rate were also reduced in proportion to the reduction of flood waters.
- In 1994, only a few small-scale secondary explosions were observed in the upstream reach of the Sacobia River, accordingly most of the sediment source materials in this area did not become loose.
- The pyroclastic flow deposit in the Sacobia River has already eroded deeply, and a series of narrow gorge which functions to retard the sediment outflow and flood discharge was formed in the upper reaches from Mactan.

(2) Sediment Deposition/Secondary Erosion Zone

The sediment deposition/secondary erosion zone is mainly divided into three (3) areas; namely, (i) the spindle-shaped valley from Mactan to Mascup, (ii) the Sapang Cauayan and Malimla-Bamban river channel, and (iii) the sand pocket. Of these areas, the spindle-shaped valley is regarded as the major sediment source in the succeeding rainy seasons.

The volume of sediment in the sediment deposition/secondary erosion zone is enumerated as below on the basis of GIS analysis. Sediment deposit of 83.5 million m^3 is observed in the spindle shaped valley between Mactan and Maskup so far after 1991 eruption, while sediment of 163.0 million m^3 dispersed and deposited from Maskup on the alluvial fan for the same period.

Deposition in Sediment Deposition/Secondary Erosion Zone

Segment	1991 - 1992	1993	1994	1995	Total
Mactan - Maskup	55	28	-3	-	80
Maskup - Route 3	125	40	10	4	174
Route 3 - Route 329	45	2	1	-	48
Total	220	70	8	4	302

Note : 1991 - 1992 indicates the volume for two rainy seasons in 1991 and 1992, while 1992 - 1994 indicates the volume for a rainy season in 1993.

In the rainy season of 1994, the secondary erosion was observed with lateral erosion of river bank, down-cutting of riverbed and shifting or short-cutting the meandering channel. Flood flow forms flat riverbed and some antidunes. Those phenomena are expected to continue in the succeeding rainy seasons.

While, the results of survey show that a remarkable sediment volume of 10 million m^3 was stored in the sand pocket structure in 1994. These structures were effective in preventing wide farm land such as sugarcane and paddy spreads from sedimentation.

The sediment balance in 1994 shows that 11 million m^3 of sediment was accumulated in the area downstream of Maskup, while 3 million m^3 of sediment was eroded in the area between Mactan and Muscup. Consequently, 8 million m^3 of sediment was delivered from the sediment source zone in 1994. Compared with sediment yield of 65 million m^3 in 1993, the sediment yield drastically diminished to one-eighth in 1994.

(3) Sediment Conveyance Zone

The sediment conveyance zone transports a sediment through the river channel of Bamban (Parua) River to the Rio Chico River in proportion to the rate of river flow. In the lower reach of the Bamban River, there is no additional inflow from the low-lying area along the river channel due to topographic conditions. Since the riverbed materials have not sorted yet, the rate of sediment transportation in lower reach of the Bamban River is governed by the riverbed gradient.

Figure 6.7 shows the freeboard and cross-sectional changes at San Francisco Bridge which is located at the uppermost point of the sediment conveyance zone. The riverbed aggradation has been identified slightly in this rainy season because of the secondary erosion of sediment deposition in the upstream channel. The riverbed aggradation tends to increase in sediment conveyance zone.

6.1.4 SEDIMENT YIELD

The normalized sediment yield which was adopted as the one of indexes in PHIVOLCS/USGS's forecast was estimated for Sacobia and Pasig rivers. Figure 6.8 shows that no distinctive decay rate is identified in the total volume of lahar deposition in Sacobia-Bamban and Pasig rivers, while that in Sacobia River are fitted with a regression line for the period of 1991 to 1994.

The sediment yield for the period of 1995 to 1997 is forecast on the assumption that the annual rainfall is 2,500 mm on an average and the catchment area is constant as of 1994, while the erosion rate of 50 mm/year is 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. It is noted that the re-capture of headwater by the Sacobia River is not expected in the estimation taking into account the following reasons:

1) Although the large to medium scale secondary explosion occurred frequently in the Sacobia river basin for the period of 1991 to 1993, those were not observed in 1994.

2) At the piracy point, the height difference of 50 m between the riverbed elevation of the Pasig River and that of the Sacobia River was observed by PHIVOLCS

and the Study Team in 1994. Thus, the re-capture by the Sacobia River is not expected to occur in the next decade.

6.1.5 SEDIMENT CONCENTRATION

On the basis of annual sediment deposits data and annual rainfall at Clark Field, chronological changes of average concentration of sediment delivered from the pyroclastic deposit field were roughly calculated as follows, in which annual runoff coefficient was assumed at 0.65.

Annual Average Sediment Concentration

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

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

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

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

6.1.6 SEDIMENT TRANSPORT CAPACITY

Sediment load was calculated by applying the Brown's equation at Maskup near outlet of Sacobia valley and outlet of the sand pocket in Sacobia river, at Malonzo, San Francisco bridge and Confluence of Rio Chico in Bamban/Parua river . In the study, the Bamban river system includes Marimla and Sapang Cauayang rivers but Sacobia River is separated from the Bamban river.

Table 6.1 shows the sediment load and concentration for selected flow rates between 10 m^3/s and 1000 m^3/s and they are summarized that the sediment concentration was estimated at 0.7 - 7 % at Maskup in the Sacobia river, 0.05-0.5 % at San Francisco bridge in the Bamban river.

6.1.7 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 in the following manner.

(1) Runoff

A long term daily rainfall record is not available in the study area. A short term daily rainfall record is available at Clark Field for three years, although annual rainfall data is available for more than 30 years. A long term daily rainfall data is available at Dagupan located 100 km northwest of the study area. Since the average annual rainfall depth of Dagupan (2,086 mm) is almost same, only 5 % higher than that of Clark Field (1,987 mm) and the daily rainfall data of Dagupan was used for generating runoff.

The average year of rainfall depth was selected as 1989 which was the 5th wettest year within the recent 10 years record. The maximum annual rainfall was recorded in 1972 during the observation period. Then, hourly runoff hydrograph was generated on the basis of 1989 rainfall record at Dagupan assuming runoff coefficient of 0.8 for daily rainfall depth larger than 20 mm. The effective rainfall was calculated at 1,567 mm and they were converted to runoff having triangular distribution for 5 hours a day.

On the other hand, rainfall pattern at Clark Field might be more reliable for the study area. The 1993 rainfall record gives approximately same annual effective rainfall of 1,560 mm as Dagupan assuming 0.85 of runoff coefficient for daily rainfall larger than 20 mm. Annual sediment was also estimated for the Clark Field rainfall in 1993.

(2) Annual Sediment Transport Capacity

Table 6.2 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 Field in 1993 is almost the same as that based on Dagupan in 1989.

6.1.8 SEDIMENT BALANCE FORECAST

Figure 6.9 shows the future sediment balance from 1995 to 2000 in the case of no-action in the future. The balance shows that secondary erosion will be the major sediment source in the future. The results are summarized as follows:

1) Sediment delivery from the sediment source zone is still considerable in a few years, and deposits will flow down the sand pocket area with incremental sediment yield due to secondary erosion in the reach from Mactan to Maskup.

2) The downstream from Route 329 will receive sediment discharge. Siltation and flooding with much sediment will continue every year.

3) Since a remarkable volume of sediment is still deposited in the upstream channel of the Bamban River, the downstream channel will gradually aggrade and San Francisco Bridge will confront the serious problem of insufficient freeboard.

In order to provide information on sediment balance for the alternative study in the flood and mudflow control plan, sediment balance is computed for the following cases:

Case 1: Permanent use of sand pocket (Figure 6.10)

Case 2: Provisional use of sand pocket and Maskup and Route 3 consolidation dams (Figure 6.11)

Case 3: Provisional use of sand pocket and series of consolidation dams from Maskup to Mactan (Figure 6.12)

Case 4: Provisional use of sand pocket, Maskup and Route 3 consolidation dams, and Upper-Bamban groundsills (Figure 6.13)