Urgent Mitigation Works After Mt. Pinatubo Eruption, Philippines

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ABSTRACT: The 15 June 1991 eruption of Mt. Pinatubo in the Philippines caused millions of cubic meters of volcanic debris to fall within 50 kilometers of the volcano. Strong winds and heavy rains scattered lahar and mudflows all over the mountain surroundings. Hundreds of people were killed. Thousands more were injured or missing and hundreds of thousands of families were rendered homeless. Six years after the eruption, lahar flows still pose a great danger to life and property in low-lying areas. With the assistance of Japan International Cooperation Agency (JICA), the Philippine Government initiated a major follow-on study of the lahar problems in the Sacobia-Bamban and Abacan Rivers Basins. The study included monitoring the lahar problem through one rainy season, and developing designs for works to control sediment.

This paper presents the eruption of Mt. Pinatubo in 1991 and the urgent mitigation works conducted by the Department of Public Works and Highways (DPWH) in the Philippines. It highlights the accomplishment of the mitigation works and recommends further rehabilitation and development works in the future.

1 INTRODUCTION

Mt. Pinatubo is situated at approximately 15°08'N latitude and 120°21'E longitude. It erupted in 1991 after being dormant for nearly 600 years. The drainage system around Mt. Pinatubo is mainly controlled by a topography with a radial pattern. The Bucao, Marella and Sto. Tomas river systems drain from the western slope of Mt. Pinatubo into the South China Sea. Along the eastern slope of Mt. Pinatubo, the O'Donnell, Sacobia-Bamban, Abacan, Pasig-Portero and Porac-Gumain rivers radiate outwards to the Luzon Central Plain.

The 1991 eruption of Mt. Pinatubo, one of the largest eruptions of the century, produced remarkable volumes of pyroclastic flow and ash-fall deposits. The pyroclastic flow deposits covered thousands of square kilometers and the volume of deposits on Mt. Pinatubo's slopes was estimated at 6.7 billion cubic meters. Lahar generated by heavy rain falling on unstable pyroclastic flow deposits pose continuing and grave danger to human lives and property in the low-lying areas. Among the major rivers surrounding Mt. Pinatubo, the Abacan and Sacobia-bamban Rivers posed great danger to the outlying areas being used for residential, commercial and industrial/agriculture purposes.

1.1 Foreign Assistance

Following the eruption, aid was immediately offered by many countries including the US Government which funded relief efforts and studied the eruption to develop methods of mitigating its effects, USACE (1994). Later, the Government of the Philippines (GOP) requested technical assistance from the Government of Japan (GOJ) to study flood and mudflow control along the Sacobia-Bamban and Abacan river systems. In accordance with the scope of work for the technical assistance which was agreed upon between the JICA and the DPWH, the JICA master plan and feasibility studies were carried out for the period of November 1993 to May 1996.

On the basis of the results of the JICA feasibility study, the GOP decided to implement the recommended flood and mudflow control works in the Sacobia-Bamban river basin and requested for financial assistance from the GOJ in 1995.

2 THE PROJECT AREA

Mt. Pinatubo is situated approximately 100 km north-west of Manila in the Zambales Mountain Range in the west coast of Central Luzon. Mt. Pinatubo is a composite andesitic volcano constructed upon older sedimentary and ultramatic strata. Underlying older volcanic rocks consists mostly of andesitic agglomerates, tuff breccias, and tuffaceous sandstones interspersed with andesitic or basaltic flow rocks. Before its eruption, Mt. Pinatubo was among the highest peaks in west-central Luzon. Its former summit consisted of the crest of lava dome that rose about 700 m above a broad, gently sloping, deeply dissected apron of pyroclastic deposits. Older volcanic relics, including an ancestral Mt. Pinatubo, lay south, east and north east of the peak. As a result, Mt. Pinatubo was relatively inconspicuous. However, the mountain's lower flanks, composed mainly of thick pyroclastic deposits, were a testimony of past explosive episodes.

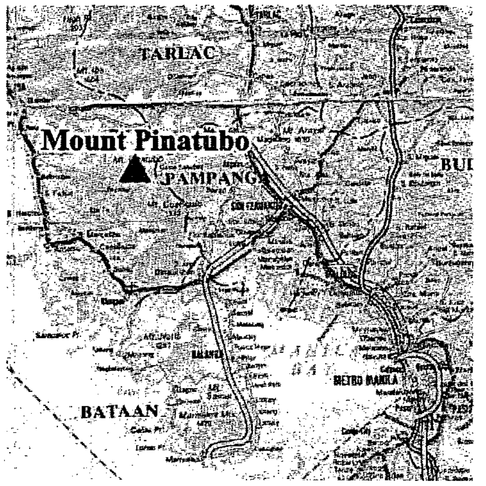

Figure 1. Location Map of Mount Pinatubo

2.1 *Pyroclastic Flow Deposits*

The total volume of pyroclastic flow deposits at the eastern slope of Mt. Pinatubo where Sacobia-Bamban, Abacan and Pasig-Portrero rivers originate was 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 explosions. In October 1993, the relatively large-scale landslide that was triggered by a secondary explosion had occurred in the pyroclastic flow deposits-filled valley. As a result, the Pasig-Portrero River captured the Sacobia upstream catchment of 23 km^2. The catchment areas including the tributaries of Sacobia-Bamban river basin after the said piracy are enumerated below:

Table 1 Catchment Areas

Sacobia River (after piracy)	39.5 km^2
Sapang Cauayan River	20.8 km^2
Marimla River	67.5 km^2
Sapang Balen River	21.7 km^2
Residual Basin	57.4 km^2
Total for Sacobia-Bamban River Basin	206.9 km^2

Lahar, generated by heavy rain falling on erodable pyroclastic flow deposits, pose continuing and grave danger to human lives and property both in low-lying and outlying areas being used for residential, commercial and industrial purposes. The lahar disaster areas in Sacobia-Bamban river basin for the period from 1991 to 1996 are summarized below. The lahar disaster area has not expanded since 1996.

Lahar Disaster Area in Sacobia-Bamban River Basin

Year	1991	1992	1993	1994	1995	1996	Total
Area (ha)	8,125	2,183	1,267	118	60	negligible	11,753

The above table shows that the lahar disaster area had rapidly reduced since the river piracy has occurred in October 1993 and no lahar was observed since 1996. Annual volume of lahar delivered from the Sacobia upper catchment was reduced remarkably after a piracy from 65 million m^3 to 8 million m^3 occurred in 1994.

The Mt. Pinatubo Commission (MPC) established "The Integrated Plan for Mt. Pinatubo Affected Area" in July 14, 1994. The said program for the Sacobia-Bamban River was formulated primarily in accordance with the plan proposed by the US Army Corps of Engineers (USACE) in 1994 such as construction of 6 m - 13 m high dike along the right bank of Bamban River and 10 m – 13 m high dike connecting to the old dike along the right bank of Sacobia River. However, the river piracy of Pasig-Portrero River in the uppermost reaches of Sacobia River drastically changed the condition of sediment transport.

The condition after the said piracy was considered in the Philippine Institute of Volcanology and Seismology (PHIVOLCS) and JICA sediment forecasts, but not in the USACE forecast. The recommended flood and mudflow control structures in the Integrated Plan by the Mt. Pinatubo Commission (MPC) were updated in accordance with the sediment forecasts done by the PHIVOLCS and by JICA.

Since the likelihood of re-capture of upper catchment by Sacobia River is negligibly small in near future, it was appropriate timing to proceed with the construction of flood control structures with proper scale for restoring socio-economic condition before the eruption.

3 OBJECTIVES

The objectives of the Project are:

(1) To rehabilitate/restore the Sacobia-Bamban river basin which was damaged due to the eruption of Mt. Pinatubo in order to prevent further destruction of life and property,

(2) To rehabilitate/improve the major road link between Pampanga and Tarlac (Manila North Road or Route 3 Highway) in order to ensure ease of transport, strengthen inter-regional linkages, and to support the growth of agricultural, industrial, finishing, commercial and tourism activities in Central Luzon, and

(3) To protect the vast agricultural land from flood.

4 IMPLEMENTATION STATUS

Briefly presented are the implementation programs for the three (3) contract packages under the Mt. Pinatubo Hazard Urgent Mitigation Project Phase I (PHUMP I) which is now on-going implementation.

PHUMP I concentrates on the Sacobia-Bamban River Channels. The Second Phase or PHUMP II, concentrates more on the Pasig-Potrero River Channel and its tributaries. Both PHUMP I and II zero in on the eastern side of Mt. Pinatubo. Being proposed is PHUMP III (Feasibility Study on-going) that will identify priority projects on the western side of Mt. Pinatubo.

4.1 Contract Package I

Flood control works under Contract Package I were organized into the following major items:
(1) Slope protection works for Bamban River;
(2) Channel Excavation;
(3) Spur dikes at the mid-stream of Bamban River; and
(4) Dike raising at downstream end of Sapang-Balen River

Slope Protection Works

During the finalization of the Loan Agreement between the DPWH and the OECF in 1996, only 9.0 kilometers of slope protection works were considered for inclusion under Package I, while other section which require slope protection works were to be implemented with GOP funding. However, the slope protection works supposed to be implemented under GOP funding failed to materialize. To remedy the situation, other components such as the Road Dike along Route 329, originally included for implementation under the Loan Agreement, were no longer required as a matter of change in priority. As a result, Packages 3 and 2 were implemented ahead of Package 1 (Package 3, 2 and 1, instead of the usual order of Packages – as in Package 1, 2 and 3.). Savings from Packages 3 and 2 were transferred to provide additional slope protection works for Package 1. Thus, an additional 20 kilometers of slope protection works had been included in the contract for Package 1.

Channel Excavation

Channel excavation was executed for a stretch of 12 kilometers from the downstream end of Bamaban River in order to achieve sufficient flow capacity. The total volume of excavated material reached 2.66 million m^3.

Spur Dikes

Permeable spur dikes with reinforced concrete piles were provided at the meandering portions of Balutu and Lilibangan. These were meant to reduce the velocity of river flow, protecting the banks from local erosion.

Dike Raising

Because the old dikes downstream of the Bamban River were eroded by river flow and rainwater, the raising and rehabilitation of these old dikes were done to provide sufficient flow capacity.

Sapang-Balen River Improvement

Structural measures (Dike Raising) along the downstream end of Sapang-Balen River was made to reduce the backwater effect of the river channel as a result of the design flood water level of Bamban River.

4.2 Contract Package 2

Construction works of Contract Package 2 consists of the training works of the Sacobia River including Maskup Consolidation Dam, Groundsills and the Bamban river improvement from Bamban Town to the San Francisco Bridge.

Maskup Consolidation Dam

The Maskup narrow path is located at the downstream end of the lahar deposited area in spindled-shape valley at north perimeter of Clark Field. The volume of lahar deposition was estimated at 70 million m^3 in the valley in 1995. Major function of Maskup Consolidation Dam is to stabilize the said unstable lahar deposition of 70 million cub.m. in the valley and to avoid re-mobilization of the lahar deposition. However, the dam does not function to store the sediment from upper Sacobia catchment since further lahar deposition by the dam may pose grave danger of mudflow/flood to surrounding areas curently protected by an old existing dike. Wing embankment on the right terrace was provided to connect old dike with Maskup consolidation dam as part of protective dike. The crest elevation of wing embankment is set at 2m higher than that of non-overflow section of Maskup Consolidation dam.

Catchment Area	:	39.5 km2 (after piracy condition)
<u>Overflow Section</u>		
Design Discharge	:	370 m2/sec (100-year probable flood)
Sediment Concentration	:	20%
Mudflow Discharge	:	470 m3/sec (=370 m3/sec/(1-0.2))
Spillway	:	110m wide and 3.7 m high
Overflow Depth	:	2.0m
<u>Non-overflow Section</u>		
Dam Height	:	3.7 m (effective height)
<u>Wing Embankment</u>		
Length and height	:	520m of 5.0 m high and 8 m wide at crest

Sacobia Training Channel

The reconstruction work of Route No. 3 highway including Mabalacat and Bamban bridges under Contract Package 3 can be achieved as a permanent structure only when Maskup consolidation dam fixes the outlet of Sacobia river at downstream end of the spindle-shaped valley and Sacobia river channel is trained properly to the downstream of Mabalacat Bridge. The alignment of the Sacobia channel was designed straight taking into account the flow characteristics of lahar, which generally flows down straightly into downstream stretch.

According to the results of riverbed fluctuation analysis in the upstream stretch of Bambank River, the riverbed has a degradation tendency of 10m for the next decade after the completion of the Project. Hence, the location of confluence with the Bambank River was set at Sta. 21+600 (3.5 km downstream from Bambank Bridge) since the confluence should be settled as far downstream as possible to avoid riverbed degradation at confluence that may result to the erosion of at downstream face of groundsill. A 20-year return period of 380 m2/sec including sediment concentration of 10% was applied for design scale. Riverbed slope of 1/180 with an average water depth of 1.4 m was applied to the design.

Cross Section	:	Single trapezoid (1.0 V/2.0H)
Design Discharge	:	380 m3/sec (=340 m3/sec (1-0.1))
Design flow velocity	:	2.6 m/s
Riverbed slope	:	1/180
Design depth	:	1.4 m
Freeboard	:	0.8 m
Channel length	:	5.384 m from Maskup Dam to Bamban River
Channel width	:	110 m wide between bank crest and 102.8 wide at riverbed
Slope Protection	:	10,700 m long in total with rubble masonry and concrete footing (2.4 m high in minimum). Cemented Lahar and Gravel (CLG) with 4 m wide and 6 m high was provided at both banks for the upstream stretch between Masakup Dam to Groundsill No. 3

Groundsill

Six (6) groundsills of 2.0 m high with a slope of 1:3.0 were provided at an interval of 500 m. CLG was adopted for foundation covered with reinforced concrete of 50 cm thick. Three (3) horizontal rows and lateral row of steel piles of 5.0 m deep were provided to ensure the seepage length. Gabion mattresses were provided at both upstream and downstream ends. Seventh groundsill is composed of steel sheet piles of 7.0 m long. The seventh groundsill was provided to cope with riverbed degradation in the future.

Bamban River Improvement Work

The Upstream Stretch (Upstream End of Bamban to Sacobia Confluence) was designed with a 20-year flood probability. Design flood is 580 m3/sec for the stretch from upstream end to confluence with Sacobia Training Channel and 890 m3/sec from the confluence to San Francisco Bridge. River channel in upper stretch from upstream end to the Confluence with Sacobia River was designed under the condition that the design flow velocity should be smaller than 3.0 m/sec to avoid local scouring.

For the Downstream Stretch (from Scobia Confluence to San Francisco Bridge) a design flood of 890 m3/sec was applied. In this stretch, the protective dike with reinforced concrete at left bank and the dike with lahar embankment at right bank were constructed by DPWH in 1993-1995. However, the dike at right bank was seriously eroded by river flow and damages by rainwater. Hence, the bank protection works of rubble concrete with a slope of 1V:2H and concrete footing with gabion mattress embedded in riverbed at a depth of 2 m were provided for the right bank.

Sapang Cauayan River Improvement Work

Channel cross section was determined by non-uniform flow method on the basis of a 20-year flood probability. The bank protection works consists of rubble concrete with a slope of 1V:2H and concrete footing with gabion mattress embedded in riverbed at a depth of 1 m are provided for left bank, while CLG with 4 m wide and 5.0 m high was provided rubble concrete at right bank to restore the eroded bank.

4.3 *Contract Package*

The Manila North Road (Route 3) is one of major trunk highway system in Luzon connecting Manila with northern Luzon regions. It passes through San Fernando, Angeles, Mabalacat, Bamban, Capas and Tarlac in the project area. The traffic volume of Route 3 at Mabalacat before the eruption was over 9,500 vehicles per day in 1990 (Nationwide Traffic Count Program in 1990, DPWH). During the rainy season, most of the traffic made a detour through Route 329 (Magalang-Concepcion Road) crossing the Bamban River at San Francisco Bridge about 10 km downstream of the Route 3 and partially through Pan-Philippines Highway (Route 5 Highway because of frequent and heavy lahar flows.

Construction works of Contract Package 3 consists of two (2) bridges: Mabalacat and Bamban bridges and reconstruction of a part of Route No.3.

Mabalacat Bridge

a) Total bridge length (between rear face of Backwall) 156.200 m

b) Type of Bridge
   - Superstructure Three (3)-Span Continuous Built-up Steel I-Section Girder
   - Pier T-Wall Type with Bored Pile of 1.2 m dia. and 27 m long
   - Abutment Reversed-T type with Bored Pile of 1.2m dia. and 22 m long

c) Width of Bridge
   - Total width 11.560 m
   - Clearance for roadway Two (2)-traffic lane 8.560 m
   - Sidewalk both sides 1.500 m each

d) Girder
   - Type Steel I-type girder
   - Length of girder 154.800 m
   - Span of girder 49.5 m + 55.0 m + 49.5 m 154.000 m in total

e) Facilities on bridge surface
   - Handrail made of cat-in-concrete

Bamban Bridge

a)	Total Bridge length		177.000 m
b)	Type of Bridge		
	Superstructure	Basket Handle Type Nielsen Rose Bridge	
	Abutment	Reversed-T type	
c)	Foundation (South Abutment)	Bored pile (1.2 m diameter with 16 m long)	
	(North Abutment)	Bored pile (1.2 m diameter with 18 m long)	
d)	Width of Bridge		
	Total width	12.440 m	
	Clearance for roadway	Two(2)-traffic lane of 8.560m wide	
	Sidewalk	both sides of 1.500 m wide each	
e)	Girder		
	Type	Steel I-type girder	
	Length of girder	175.600 m	
	Span of girder	174.000 m	
f)	Facilities on bridge surface		
	Handrail made of cat-in-concrete		
	Protect fence for cable		
	Steel guardrail		

Reconstruction of Route No. 3 Highway

Alignment of route traces the old alignment as much as possible in order to avoid right-of-way problem. Embankment of designated material, construction of drainage system, construction of hand-laid wet masonry and construction of Portland cement concrete pavement at the thickness of 250 mm.

Road Length	:	3,074 m
Land Width	:	3.65 m + 3.65 m (7.3 m in total width)
Shoulder Width	:	2.5 m (DBST)
Pavement	:	PCCP (250 mm thick)

5 RECOMMENDATION

The eastern side of Mt. Pinatubo had been the concentration of all previous studies and implementation works on flood and sediment mitigation brought about by the catastrophic eruption of the volcano in 1991. The detailed design and implementation of projects on the western side were deferred because of large-sale mudflow, resulting into topographical variation. In addition, the western side has a low priority compared with the eastern side where most of the developed centers of commerce are situated. However, because of the continued danger posed by the huge volume of sediment deposited material which is occasionally transported down the western slopes inducing secondary disasters, the complete implementation of the long-term flood and mudflow control plan for all of the eight major rivers surrounding Mt. Pinatubo (eastern and western) is recommended. Through the cooperation and support of the JICA, the Feasibility Studies for the western side of Mt. Pinatubo is now on-going (March 2002 – August 2003). It aims to rehabilitate and spur economic development in the study area by formulating a specific master plan for flood and mudflow prevention in the Bucao, Maloma and Sto. Tomas rivers and identify main priority projects for implementation.

6 CONCLUSION

After the completion of the Project, there were a total of 53,000 people (10,000 households) who have been relieved from inundation and 87 km^2 of land were saved from further inundation, including 4,300 hectares of farmland. Furthermore, about 16,000 vehicles per day are now being serviced by the reconstruction of Mabalacat-Bamban Road Section of Manila North Road (Route 3) instead of going through the circuitous Magalang-Conception-Capas Road (Route 329). Shortening the travel stretch from 21 kilometers to 15 kilometers, effectively shortening travel time by at least 25 minutes.

The benefit accrued from the implementation of the Project is defined as the reduction of the direct and indirect damages caused by flood/mudflow. The economic internal rate of return (EIRR) was estimated to be at 16.3 %.