6. MASTER PLAN FOR STRUCTURAL MEASURES

6.1 Structural Master Plan for the Bucao River Basin

Components of the Master Plan

The conceivable development plan of the structural measures for the Bucao River basin consists of 1) countermeasures at the Pinatubo Crater Lake, 2) sabo dam plan, 3) consolidation dam/sand pocket in the middle reaches, 4) dike heightening and strengthening for the downstream reaches, 5) re-construction of the Bucao Bridge, and 6) channel work in the downstream reaches. The objectives of the plan are to protect the vulnerable downstream areas and to secure the safety of the Bucao Bridge from flood and mudflow damage for floods up to the design flood through stabilization of the riverbed movement. From the conceivable developmet plan, some components were selected to formulate the master plan. A general overview of the structural master plan on the Bucao River basin is shown in Figure 6.1. In addition, purpose of each structure for sabo and flood control is described in Table 6.1.

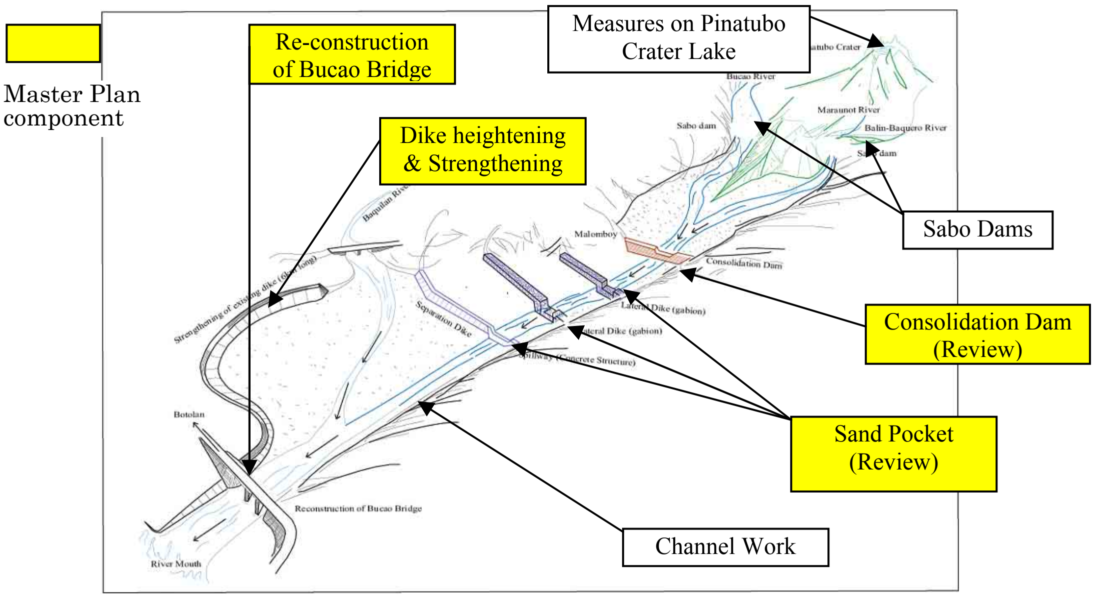


Figure 6.1 Conceivable Plan including Master Plan on the Structural Measures of the Bucao River Basin

Table 6.1 Purpose of Structures for Sabo and Flood Control

Structures	Purpose
Sabo Dam	To trap sediment from reaches and to stabilize unstable lahar deposits
Channel Work	To prevent erosion of sediment deposition in channel by controlling riverbed gradient
Sand Pocket	To trap remobilized lahar deposit
Consolidation Dam	To stabilize in-channel deposition by preventing riverbed erosion
Dike	To protect inland from flood and mudflow

Countermeasures at the Pinatubo Crater Lake

The Pinatubo Crater Lake was formed in June 1991 following the eruption, and the lake water level rose every year thereafter by impounding rainfall; it started to overflow at the Maraunot Notch from September 2001. On 10 July 2002, the Maraunot Notch collapsed and the water level at the crater lake suddenly dropped by 23 m, the outflow from which caused lahar flow in the downstream of the Bucao River basin; such lahar flows had not been experienced for seven years prior to that event since 1995.

A detailed geological investigation was conducted after the collapse of the notch, and it was found that almost all the unstable material was washed out by the breach and solid rock foundation was exposed at the overflow section and along the downstream slope. Electric resistivity test at the notch portion revealed that there was no significant permeable geological layer inducing further collapse.

Based on the above, it was concluded that at this stage no structural measures to protect the notch against further erosion would be required. Instead, it is recommended an observation system for rainfall, lake water level, and ground water level at the notch be provided for monitoring the condition of the Pinatubo Crater Lake and the Maraunot Notch to secure the safety of the downstream areas.

Sabo Dam Plan

The annual sediment yield in the Bucao River basin is estimated at 20.1 million m^3 in the year 2001. Although the sediment yield is expected to reduce year by year in future, a series of sabo dams is planned to mitigate sediment delivery to the downstream.

Eight potential sabo dam sites were selected as shown in Figure 6.2, and the priority ranking study for the development was conducted as shown in Table 6.2.

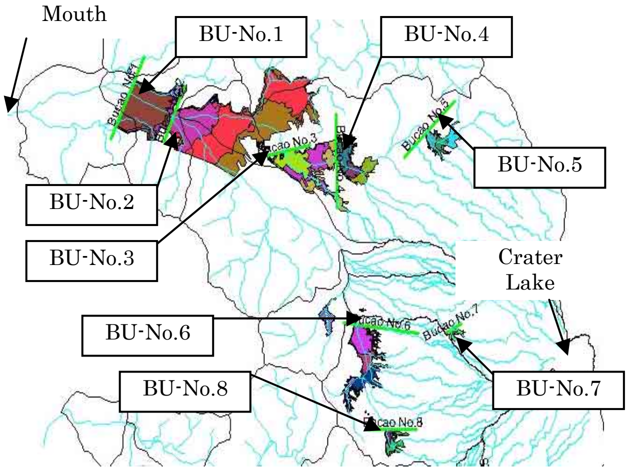


Figure 6.2 Location of Identified Sabo Dam Sites in the Bucao River Basin

All the identified sabo dam sites have a rather small capacity for sediment storage, of which the maximum capacity is only 5 million m^3, just 25% of the annual sediment yield in the basin. The accumulated sediment storage capacity of all the sabo dams is estimated at 14.2 million m^3, which is just 70% of the annual sediment yield of the basin. This means that all the proposed sabo dams may be full of sediment within a year after completion. As the basin sediment yield is still too large to control by sabo dams, it was concluded that the plan for sabo dams in the upstream basin would not yet be effective at controlling sediment delivery to the middle and downstream reach of the river.

Table 6.2 List of Identified Sabo Dams

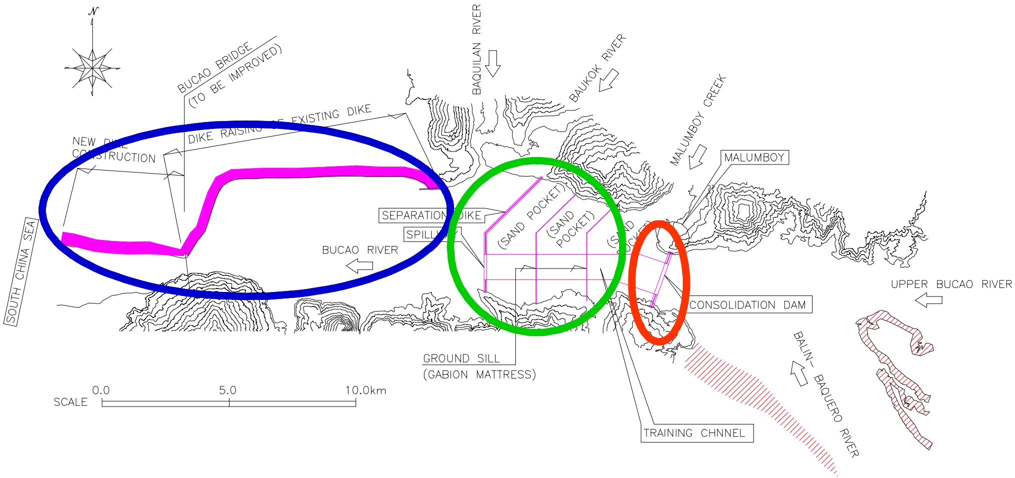
Priority	Dam Site	Dam Height (m)	(C) Dam Volume (10^6 m^3)	(B) Sediment Storage (10^6 m^3)	Development Efficiency (B)/(C)	Sediment Trap Capacity (10^6 m^3)
1	No.6	5.0	0.007	3.895	556.4	22.1
2	No.3	5.0	0.021	5.040	240.0	32.6
3	No.4	5.0	0.022	3.250	147.7	11.4
4	No.5	22.0	0.011	1.157	108.2	2.8
5	No.8	5.0	0.006	0.528	88.0	3.1
6	No.7	5.0	0.006	0.307	51.2	0.2

Note: No.1 and No.2 are consolidation dams for sand pocket and not included in the list.

Consolidation Dam, Sand Pocket at the Middle Reach and Dike Heightening and Strengthening at the Downstream Reach

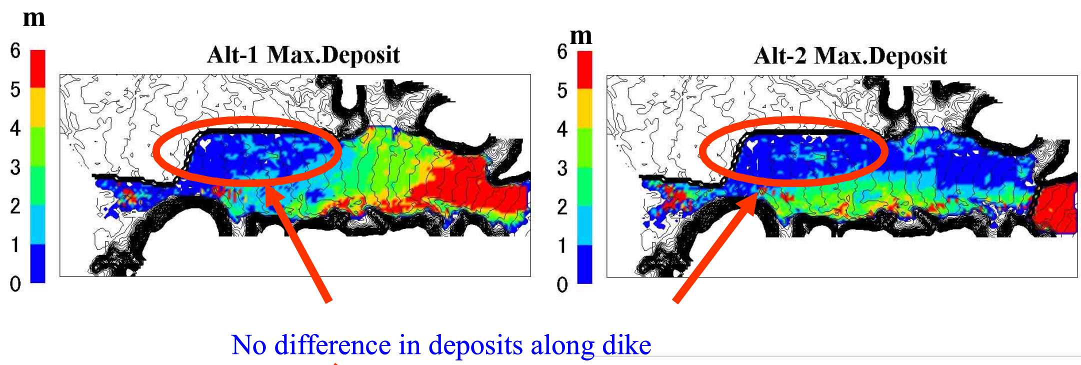
The target protection area of these works is the mudflow prone area on the right side and the national highway No.7 crossing over the Bucao River, both in the downstream reach. Future riverbed aggradation and the occurrence of mudflow are the target events to control by the structural measures to secure the safety of the target protection areas. Three alternatives, 1) dike heightening and strengthening in the downstream reach, 2) consolidation dam at the middle reach, and 3) sand pocket at the middle reach are considered as the countermeasures. The mitigation effects on the riverbed aggradation were compared by the proposed three alternatives.

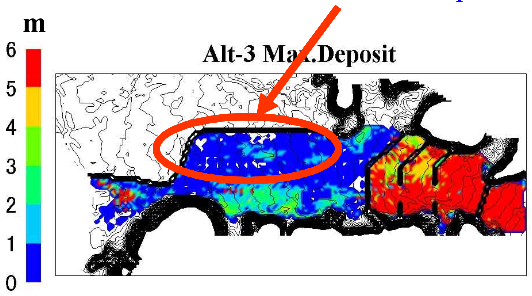
The simulated results are presented in Figures 6.3 and 6.4. The results indicate that both measures 2) consolidation dam, and 3) sand pocket would not be effective to mitigate future riverbed aggradation. This is because the secondary erosion from the middle reach of the Bucao River is not yet the main sediment source to the downstream but the upper basin is still the main source. The proposed measures 2) and 3) are therefore not recommended to be implemented at this stage. Alternative 1) dike heightening and strengthening along the downstream reach is hence selected as the priority measure for which the design dike height needs to be determined based on the expected increases in riverbed level over the next 20 years.



Alt-1	Dike Improvement	
Alt-2	Dike + Consolidation Dam	
Alt-3	Dike + C. Dam + Sand Pocket	

Figure 6.3 Alternative Structural Measures for the Bucao River





Note: As of Sep. 2002

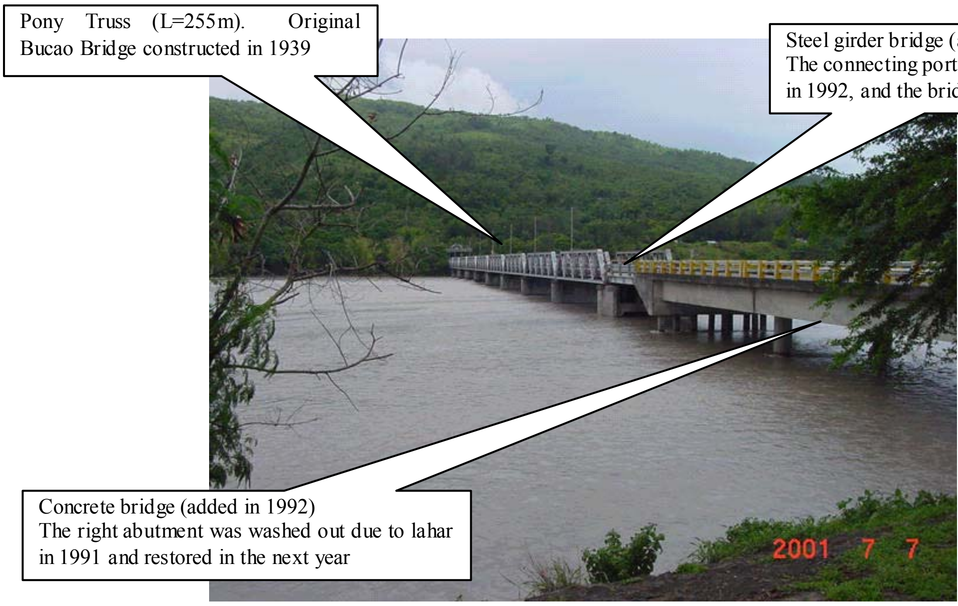
Alt	Cost (10^9 Pesos)	EIRR (%)
1	1.0	15.2
2	1.7	6.7
3	3.3	NA

Alternative-1 was selected for feasibility study

Figure 6.4 Results of Two-Dimensional Mudflow Analysis

Re-construction of the Bucao Bridge

It is estimated that the future riverbed aggradation at the Bucao Bridge portion would be 4 m at the most over the next 20 years based on the long-term riverbed movement analysis. On the other hand, the present clearance of the bridge is insufficient for even a 5-year probable flood as shown in Figure 2.7 in Chapter 2, which is currently 2.5 m at the pony truss portion, and only 1.5 m at the concrete girder bridge portion from the existing riverbed. Accordingly, it is required to heighten the bridge to provide sufficient clearance taking into account the future riverbed aggradation. It is judged that the re-construction of the Bucao Bridge is quite important and an urgent issue to secure the safety of National Highway No.7, the only arterial route in Zambales and on which the provincial economy fully depends.



Bucao Bridge during Flood

Figure 6.5 Damage Record of the Bucao Bridge after 1991

Channel Work in the Downstream Reach

It is recommended that no channel work in the downstream reach should be taken under the present condition of the sediment balance. Based on the riverbed movement analysis, it is estimated that the sediment inflow is excessive to the sediment transport capacity in the downstream reach and riverbed aggradation will continue for the next 20 years. Accordingly, continuous dredging activity would be required if channel work were to be conducted. Channel work could be considered in the future when the sediment inflow becomes balanced with the sediment transport capacity in the downstream reach.

6.2 Structural Master Plan for the Maloma River Basin

Components of the Master Plan

In the Maloma River basin, lahar due to the eruption of Mount Pinatubo was observed only in 1991. There is no particular source of sediment in the upstream at present, and no remarkable riverbed aggradation is observed. Considering the above, the master plan formulation for the Maloma River is focused on flood control only.

The target protection area of the Maloma River basin is the downstream reach from the confluence of the Maloma and the Gorongoro Rivers as shown in Figure 6.6. The area is flooded yearly due to the flood over-banking and breaching the dike. National Highway No.7 is another important asset to protect from flood damage. The master plan is therefore composed of 1) Channel widening and dike construction in the downstream reach, and 2) Re-construction of the Maloma Bridge.

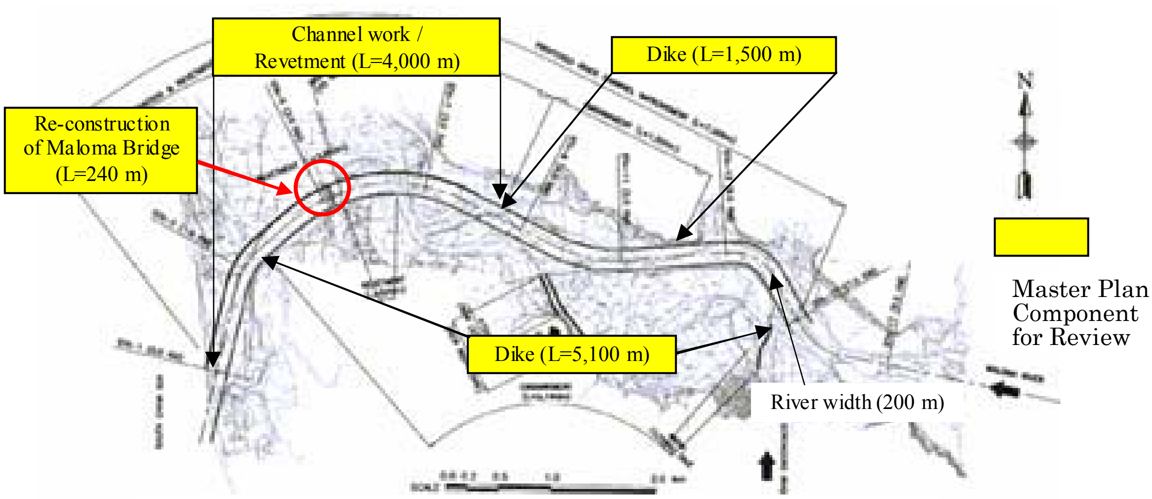


Figure 6.6 Structural Master Plan for the Maloma River Basin

Channel Widening and Dike Construction

Based on detailed field investigation, it was found that the flooding occurs due to insufficient flow capacity at the Maloma Bridge portion. The flood flow is retarded at the bridge portion, backs up on the upstream section, and then overflows from the right bank. The sediment deposition is therefore accelerated in the upstream reach. As a result, the river is meandering and the flood flow direction fluctuates and directly threatens the existing dike.

Channel widening and straightening at the downstream portion is proposed to solve the current problems. The river width is proposed at 200 m considering the design flood of 20-year return period, which under present conditions widens the river from 90 m to 240 m at the Maloma Bridge. At the river mouth portion, a short-cut channel was also considered to induce the flushing of sediment and to lower the flood water level. But it is concluded that the river mouth short-cut channel is not feasible from a technical viewpoint. The coastal sediment flow direction is from the north to the south, and the proposed river-mouth area would be easily buried due to the coastal sediment transportation to the mouth.

Re-construction of the Maloma Bridge

Maloma Bridge is currently becoming the bottle-neck of the river for flood flow as the present river width is only 90 m. Because of the river improvement plan, the bridge needs to be reconstructed with a bridge length of 240 m. It would be possible to consider re-constructing the bridge prior to the river improvement due to the importance of upgrading security of the National Highway No.7. In this case, however, the channel widening in the stretch of river for 200 m downstream from the bridge should be carried out together with the re-construction of the Maloma Bridge.

6.3 Structural Master Plan for the Sto. Tomas River Basin

Components of the Master Plan

The conceivable development plan on structural measures for the Sto.Tomas River basin consist of 1) Sabo dam plan, 2) Channel work and sand pocket in the Marella River, 3) Flood regulation at the Mapanuepe Lake, 4) Dike strengthening in the middle reach, 5) Dike heightening and strengthening in the downstream reach, 6) re-construction of the Maculcol Bridge, 7) Channel work in the downstream reach, and 8) Diversion channel for the Gabor River. The target protection area is the left side mudflow prone area on the middle reach, the mudflow/flood prone areas on both sides of the river in the downstream reach, and the National highway No.7, particularly at the Maculcol Bridge. From the conceivable development plan, some components were selected to incorporate into the master plan. The conceivable plan and master plan for the Sto.Tomas River basin is shown in Figure 6.7. The design flood for the master plan is defined at the 20-year return period based on the optimization study.

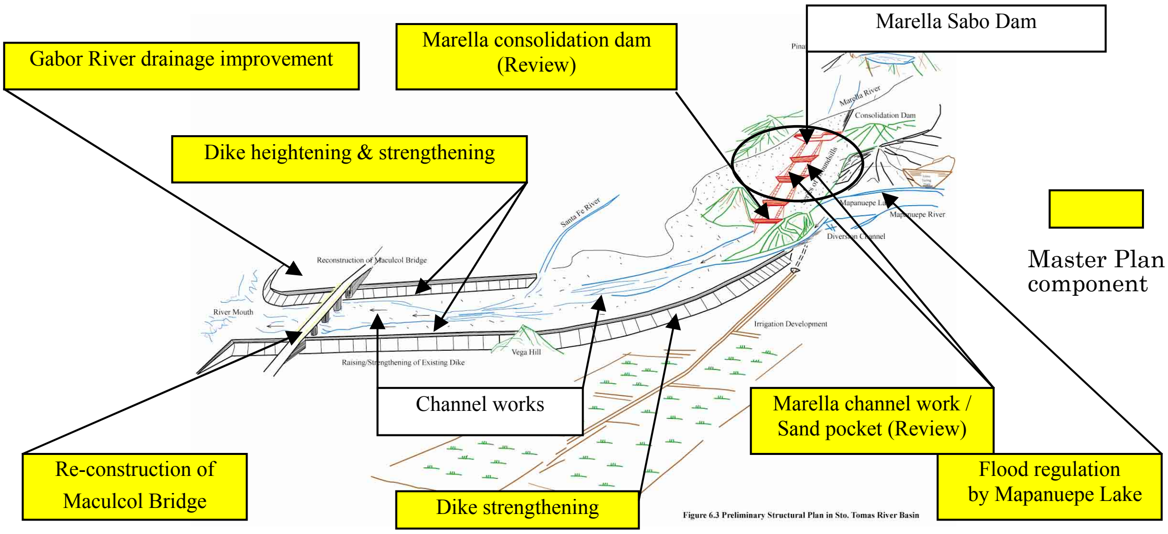
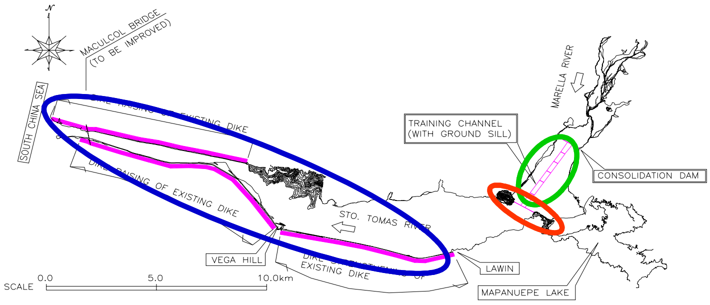


Figure 6.7 Conceivable Plan including Master Plan for the Sto.Tomas River Basin

Marella Channel Work, Sand Pocket, and Sto.Tomas Dike Improvement

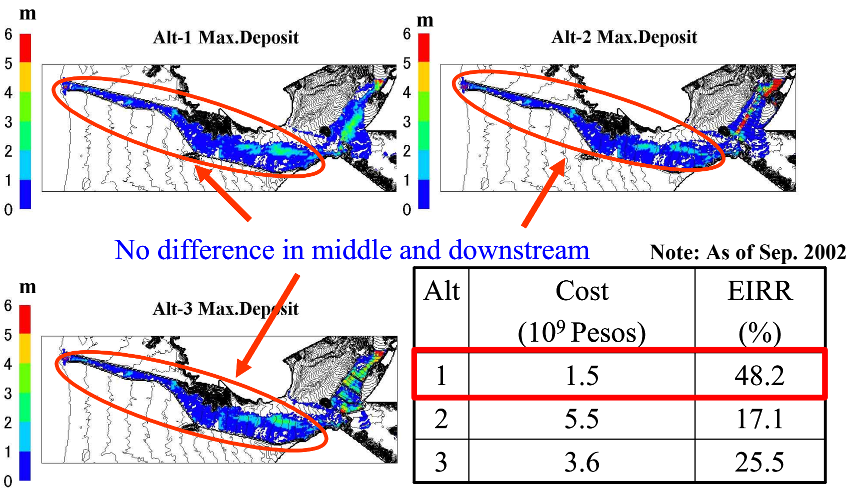
A key issue for the master plan for the Sto.Tomas River basin is how to mitigate the effects of riverbed aggradation. The options are to decrease sediment yield and secondary erosion in the Marella River, or to improve the existing dike taking into account further riverbed aggradation. The alternative countermeasures are therefore identified as shown in Figure 6.8. They are 1) Dike heightening & strengthening along the Sto.Tomas River, 2) Channel work in the Marella River, and 3) Sand Pocket in the Marella River.

Figures 6.9 and 6.10 show the results of the study of alternatives in terms of the mitigation effects on the future riverbed aggradation. Based on the analysis, it was found that both of 2) Marella channel work, and 3) sand pocket are not so effective to mitigate the downstream riverbed aggradation because the proposed channel work is limited to 4 km in the downstream reach over the whole 25 km of the Marella River. The major sediment source is the upstream part of the Marella River, and it is required to extend the channel work to the whole river to decrease the sediment delivery to the Sto.Tomas River. Also the sand pocket would require a high dam as the present gradient of the Marella River is 1/60, and the difference in the riverbed elevation at the downstream end to the 4 km upstream is 120 m. The above measures would be quite costly and may have unacceptable environmental impacts. Based on the above, 1) dike heightening and strengthening of the Sto.Tomas River considering further riverbed aggradation was selected as the priority scheme from economic and environmental viewpoints.



Alt-1	Dike Improvement	
Alt-2	Dike + Channel Training + C. Dam	
Alt-3	Dike + C. Dam (with Sand Pocket)	

Figure 6.8 Alternative Measures in the Sto. Tomas River Basin

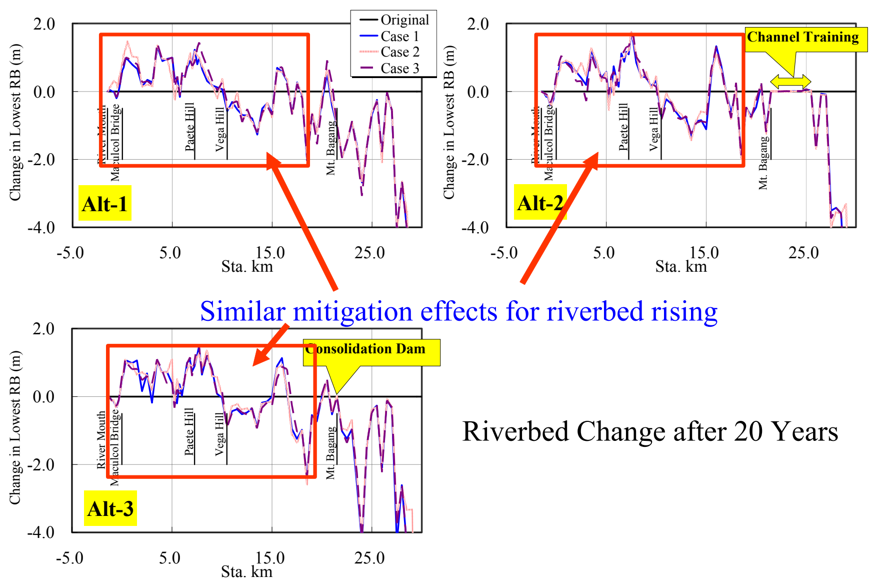


Note: As of Sep. 2002

Alt	Cost (10^9 Pesos)	EIRR (%)
1	1.5	48.2
2	5.5	17.1
3	3.6	25.5

Alternative-1 was selected for feasibility study

Figure 6.9 Results on Two-Dimensional Short Term Mudflow Analysis



Riverbed Change after 20 Years

Figure 6.10 Results on One-Dimensional Long Term Riverbed Movement Analysis

Flood Regulation by the Mapanuepe Lake

The catchment area of the Mapanuepe Lake basin is 90 km^2, about 35% of the whole Sto.Tomas River basin (262 km^2). The flood regulation effect of the lake is estimated at 700 m^3/s (1,900 m^3/s to 1,200 m^3/s) under a 20-year probable flood. In the master plan, the flood regulation effect by the Mapanuepe Lake was taken into account for the design flood for the downstream reach, as the dammed-up lake can be maintained for the next 20 years considering further riverbed degradation at the downstream reach of the Marella River, which was the dammed portion to form the natural lake. Based on the long-term riverbed movement analysis, the maximum riverbed degradation at the dammed-up portion is estimated at 3 m, by which the Mapanuepe Lake will not be breached and the lake has capacity to store the 20-year return period flood.

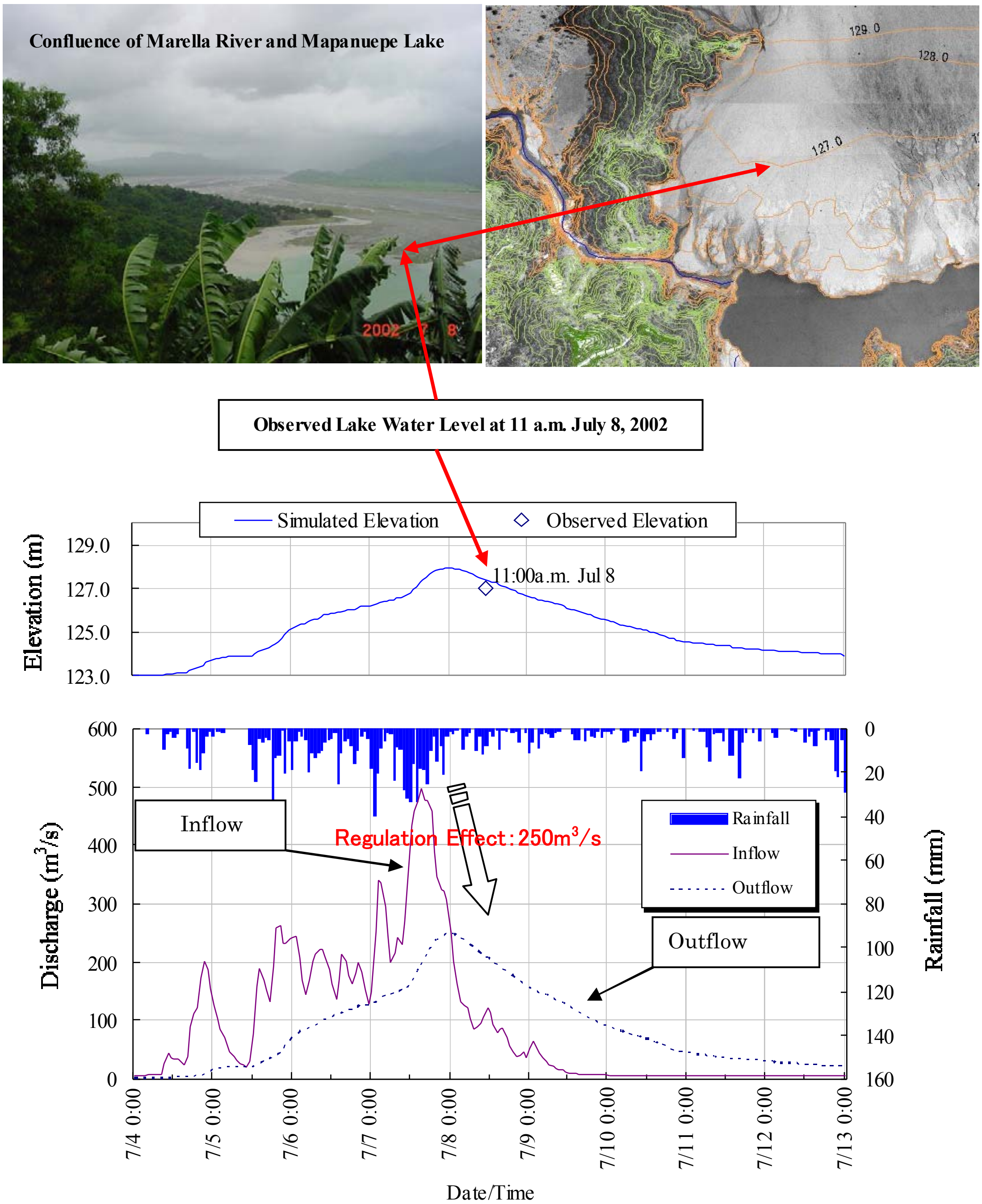


Figure 6.11 Observed Flood Regulation Effect by Mapanuepe Lake during the Flood of July 2002

Re-construction of the Maculcol Bridge

As shown in the following photographs, there is no more clearance below the Maculcol Bridge, which crosses over the Sto.Tomas River in the downstream reach. The flow capacity at the bridge portion is 0 m^3/s during the rainy season, and the flood directly hits the concrete girder–the flood flows by scouring the riverbed to the downstream. This bridge is judged as being in the most critical condition of all the bridges along the National Highway No.7. The route was identified as the most important infrastructure in Zambales, and the upgrading the security of the route is recognized as the most important and urgent issue. Re-construction of the bridge is therefore identified as the most urgent project in the master plan. The DPWH has conducted the detailed design for the bridge re-construction and is waiting for the financial arrangement for implementation.

During Flood 2002/7/7

After Flood 2002/7/8

Channel Work for the Sto.Tomas River

It is concluded that the channel work in the middle and downstream reaches of the Sto.Tomas River should not be taken as the countermeasures under the present sediment balance conditions. Based on the riverbed movement analysis, it is estimated that the sediment inflow is excessive to the sediment transport capacity in the downstream reach, and the riverbed aggradation would continue for the next 20 years. Accordingly, continuous dredging activity would be required to maintain the channel if channel work was carried out in the downstream. Channel work should therefore be considered in future when the sediment inflow reaches a balance with the sediment transport capacity of the downstream reach.

For the middle reach of the Sto.Tomas River, it is estimated that the sediment inflow and transport capacity is almost balanced and no remarkable sediment deposition may occur. Even though the channel may be maintained without intensive dredging work at the middle stream, it is recommended that no channel work shall be provided to fix the river channel of the middle reach at this stage except for channel training work. The reason for this is that the riverbed elevation in the middle reach is abnormally higher than the mudflow prone area on the left bank, so it is required to degrade the riverbed elevation by flood flow in the river.

7. MASTER PLAN FOR NON-STRUCTURAL MEASURES

Roles of the Non-Structural Measures under the Overall Master Plan

As explained in Chapter 3, the roles of the non-structural measures of the overall Master Plan are defined as follows:

1) to mitigate immediately flood and mudflow damages, particularly for the protection of human life,
2) to mitigate the damage from floods that exceed the design flood of structural measures,
3) to reduce natural hazard and social vulnerability in the flood/mudflow prone areas.

Non-structural measures are particularly focused on safeguarding human life against further disasters. The overall plan of the non-structural measures is then composed of 1) Flood/mudflow monitoring and warning system, 2) Evacuation system and 3) Watershed management. Table 7.1 describes the roles of the respective measures.

Table 7.1 Roles of Overall Non-structural Measures

No.	Non-structural measures	Roles under Flood/mudflow control master plan		
		To mitigate damage immediately	To mitigate damage exceeding the design flood	To reduce natural hazard and social vulnerability
1	Flood/mudflow monitoring & warning system	◎	◎	×
2	Evacuation system	◎	◎	○
3	Watershed management	×	×	◎

Notes: ◎: Main role, ○: Applicable role, ×: Non-applicable role

Flood/Mudflow Monitoring and Warning System

Taking into account the existing warning system in the study area, it was found that the key issue to improve the system is **<u>"to determine the best timing and reliable criteria for issuing warning to achieve effective evacuation"</u>**. The present system has no reliable warning criteria based on hydrological data. Accordingly, accumulation of hydrological information during typhoon/flood is essential to establish reliable warning criteria.

Figure 7.1 shows the proposed monitoring and warning system, which consists of seven (7) raingauges, and six (6) water level gauges, and one (1) monitoring station at Provincial Disaster Coordinating Council (PDCC) at Iba, Zambales. Data transmission system is proposed through GSM (Global System for Mobile Communication) to reduce the cost of the initial installation and system operation. Real time data transmission is technically possible by the proposed system.

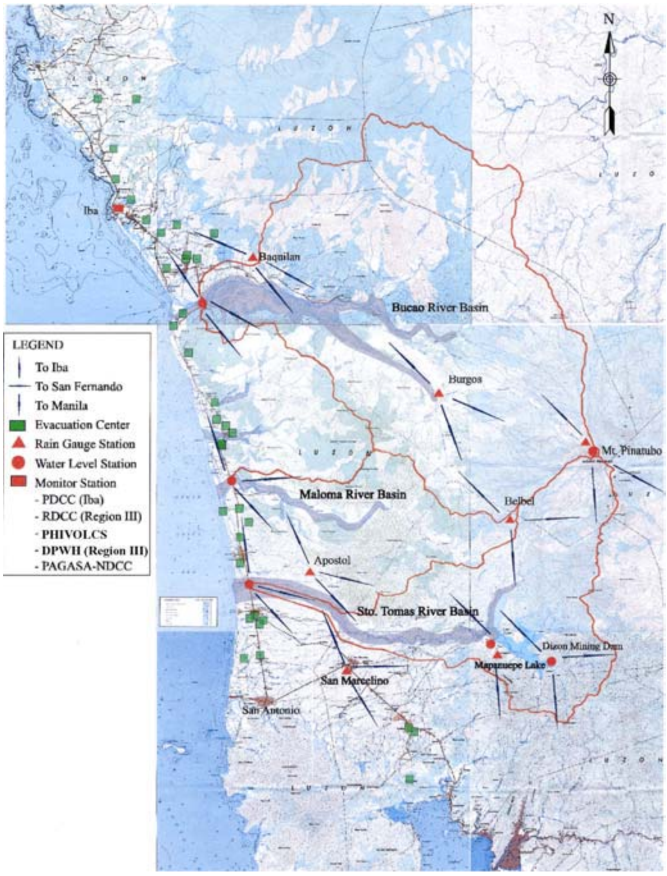


Figure 7.1 Proposed Monitoring and Warning System

The two ways for transmission of warnings from Iba central monitoring station to the respective municipal disaster coordinating council are through the Internet by access to the homepage of the PDCC, and through local radio broadcast at the provincial office direct to the people in the project area.

Evacuation System

There are 36 existing evacuation centers in the study area. All the centers are elementary schools or other public buildings. In this study, improvement of the evacuation system is proposed based on the locations and capacity of the existing evacuation centers. First of all, the distribution of existing centers was assessed. The areas where no evacuation centers are located within 2 km were initially identified based on the existing network of evacuation centers. Ten new evacuation centers were then identified to cover the whole hazard areas from which the evacuation center is available within 2 km. This is defined as the priority actions for the improvement. The evacuation distance of 2 km is based on the lead time of the peak flood after the peak rainfall.

In addition to the ten new evacuation centers, the 32 existing evacuation centers require renovation/improvement, such as repair of roof, floor, toilet, and elevating the ground level by filling where the inundation is possible during flood. The renovation works are also identified as priority activities.

As the next stage, increasing in the capacity of evacuation centers would be required where the number of evacuees is more than the capacity of the existing centers. Based on estimates, 50 additional evacuation centers would be required to contain all the people in the hazard area, which is proposed as the long-term actions after completion of the proposed priority activities.

Watershed Management

In the study area, the following five aspects of watershed management are identified as having the potential to contribute to disaster management: 1) Forest management, 2) Ancestral domain system for Aeta tribe at the skirt of Mount Pinatubo Area, 3) Sediment balance management, 4) Management of the Pinatubo Crater Lake, and 5) Environmental management of the mining area in the Mapanuepe Lake Basin. Figure 7.2 illustrates the relationship of the overall basin management.

Among them, 3) Basin sediment balance management is directly related to the structural measures, and the annual monitoring for sediment balance is recommended. For 4) Management of the Pinatubo Crater Lake, PHIVOLCS continues the efficient monitoring and warning activities to secure the safety of the downstream people. Item 5) Environmental management of the mining area was identified as an urgent issue in the study area. The current issues of water quality and the structural safety of the dam body should be well monitored by DENR, which is the agency responsible for mining management, and DENR is requested to provide proper guidance to the mining company to solve the issues to secure the safety of the downstream areas.

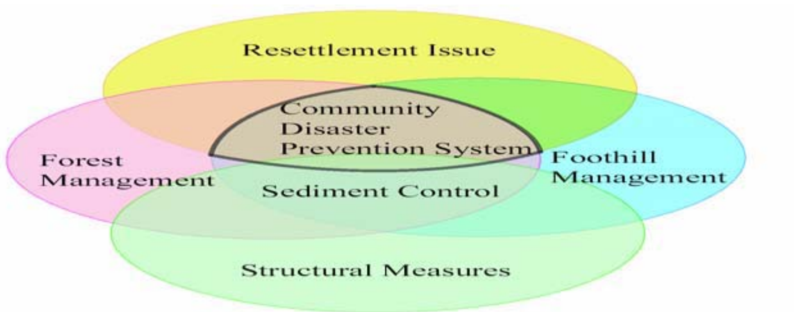


Figure 7.2 Five Categories under Watershed Management

Regarding 1) Forest management and 2) Ancestral domain system of Aeta tribe at the skirt of Mount Pinatubo, the condition is dependent on the activities of the people on the mountain. Proper guidance for forest management and development is therefore important and it is considered as a component of Community Based Disaster Prevention Programs mentioned in Chapter 8.