The Study on Comprehensive Disaster Prevention around Mayon Volcano

SUPPORTING REPORT (1)

(Part I : Master Plan)

II : Sabo Planning

SABO SUPPORTING REPORT (1) – II
SABO PLANNING

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SUPPORTING REPORT (1) – II
SABO PLANNING

1. PRESENT PHYSICAL CONDITION FOR SABO PLANNING

(1) Eruption

- Mayon Volcano erupted 45 times from 1616 to 1993 according to the existing records.
- Eruptive intervals of Mayon volcano average about 8 to 10 years until the 1993 eruption.
- Recent remarkable eruptions have occurred in Feb. 1993, Sep. 1984, May 1978 and April 1968.

(2) Ejecta

- Emission source of Mayon volcano has been ejected from the central crater.
- Ejecta of Mayon volcano have four major types: lava flows, air fall, pyroclastic flow, and lahar flow triggered by rainfall.
- Average volume of eject is estimated to be totally 43×106 m^3 in recent four (4) events from the 1968 eruption.

(3) Topography

- Mountain slope is divided by four segments as the below.
- There is a positive relationship between slope gradient and landform units on Mayon volcano.

Landform Classification of Mountain Slope

Elevation of Segment Masl (meter above sea level)	Slope Gradient	Landform	Material
From summit to 1000masl	1/1.6	volcanic dome	volcanic rock (mainly Andesitr rock)
From 1000masl to 500-300masl	1/3.3-1/7.8	pyroclastic, debris and lava plateau	primary or secondary pyroclastic and debris material primary lava flow
From 500-300masl, to 100-20masl	1/16.7-1/23	alluvial fan	secondary or thirdly pyroclastic and debris material
From 100-20masl to Tertialy mountain foot or ocean	more than 1/100	alluvial plain	sand and silt

(4) Distribution of Fan and its Development

- Fan landform formed by debris flow distributes widely around Mayon volcano.
- Major rivers in the Study Area form confluence fans on the foot of volcano slope. Cross-sectional landform on confluence fan has the flat surface. It is possible to change channel course frequently on fan surface.
- The Basud River and the Bulawan River form the alluvial fan with steep gradient at the estuaries as depositional section.

(5) Changes of Drainage Area by Lava Flow and Piracy

There occurred disappearance of the drainage area on the slope surface by lava flowing and piracy because of the high frequently eruption

- The drainage area of the Arimbay river was infilled by lava flowed down on the 1993 eruption.
- The drainage area of Tumpa river and Maninila river were infilled by lava flowed down on the 1968, 1978 and 1984 eruption.
- The drainage area of Budiao river was captured into the drainage area of Anoling river by displacement of channel course.
- Therefore these river bed condition on the downstream reach as depositional area are quite stable.

(6) Occurrence Record of Debris Flow

Recent occurrence of mud and debris flow can be grasped by analyzing comparison with air photographs. It can be considered that river bed where mud flow flowed down is unstable because of forming unequilibration slope. Occurrence record of debris flow in accompany with the eruption is shown in below.

Disaster Record of Mud and Debris Flow on the Recent Eruption

River Basin	The 1984 Eruption	The 1993 Eruption	The 1998 Typhoon Loleng
Yawa			
Pawa-Burabod	Mud Flow	Mud Flow	
Budiao	Mud Flow		
Anoling	Mud Flow		Downcutting of Riverbed
Quirangay			
Tumpa			
Maninila			
Masarawag	Mud Flow		Downcutting of Riverbed
Ogsong			
Nasisi			
Buang	Mud Flow		
Quinali (B)			
San Vicente	Mud Flow		
Arimbay	Mud Flow	Mud Flow	
Padang	Mud Flow	Mud Flow	Debris Flow
Basud	Mud Flow		Debris Flow
Bulawan	Mud Flow		Debris Flow

The 1984 eruption

Pyroclastic flow deposited widely around the top of volcano on the 1984 eruption. Mud flows are triggered by intense rainfall on slope covered with new pyroclastic materials. Most mud flow events occurred during and directly after the September 1984 eruption, in the Pawa-burabod River, the Budiao River, the Masarawag River, the Buang River, the San Vicente River, the Padang River, the Basud River, and the Bulawan River.

The 1993 eruption

The 1993 eruption was the extrusion of a small volume of lava, and the occurrences of pyroclastic flows generated from the collapse of this lava for the southeast slope. Mudflows, which originated pyroclastic flow field, occurred in Pawa-burabod River, Arimbay River, and Padang River after eruption.

The 1998 typhoon Loleng

The typhoon Loleng attacked the Albay area on October 1998. The probable one-day rainfall of Typhoon Loleng was suitable for two- (2) year probability. There occurred topographical changes on several rivers around Mayon volcano. Spot downcutting of riverbed with 1-2 m depth occurred on alluvial fan area in Anoling River and Masarawag River. Debris flows occurred on Padang River, Basud River and Bulawan River. Rock and sand materials were swept for alluvial fan area on estuary.

<u>The 2000 eruption</u>

Main eruption occurred on February 22, 2000. Lava flow flowed down widely around the top of volcano after the main eruption, especially in the Bonga gully on the southeast slope of volcano. The occurrence of pyroclastic flow and ash fall was also recorded by PHIVOLCS.

(7) Traction Force and Silting Slope

- Alluvial fan on the foot of volcano has formed by debris and mud flowing down.
- Debris and mud flow has the following geomorphologic character;
  Frequent changing in flowing course on the fan top
  Straight trace in debris flow

(8) Channel Profile and Cross Section

- Channel longitudinal profiles follows to landform profile of mountain slope.
- On pyroclastic and debris plateau area, channel forms deeply incised valley in cross section (maximum height: 50m).
- On alluvial fan area, lateral bank is very low (mean height: 1m).

(9) Mean Particle Diameter of Debris

- Mean D50 = 13.0 mm (debris flow portion)
- Mean maximum D50 = 180.0 mm (debris flow portion)

(10) Physical Property of Deposited Material

- Matrix size of deposited river bed material is relatively fine material (Mean D20:2.0 mm - 0.125 mm) in overall.
- Average gravel density is estimated to be 1.823 g/cc in target rivers.
- Gravel and sand on river bed are composed of 40% hard volcanic rock (Andesite) and 60% porous rock (Black and red scoria)

2. SABO PROJECT OF DISASTER PREVENTION PROJECTS AND THEIR IMPLIMENTATION STATUS

2.1 Review of Previous Studies

(1) Master Plan for Mayon Volcano Sabo and Flood Control Project on March 1981

Sabo works around Mayon volcano were planned to check and control the sediment runoff or debris flow against 50-year probable flood, and to take account of the importance of the affected area. The number of the proposed facilities is summarized in the following table.

Sabo master plan for the Quinali (A) River System

Sabo plan for the Quinali (A) River System was established for six rivers as the Quirangay, the Tumpa, the Maninila, the Masarawag, the Ogsong and the Nasisi which had been seriously devastated.

The Quirangay River

Six spur dikes and three ground sills were arranged in order to promote a sand retarding.

The Tumpa River

Fifteen consolidation works with coconut trunk fences were planned to mitigate the river bed and side erosion.

The Maninila River

Nine consolidation works with cribs were planned to mitigate the river bed and side erosion.

The Masarawag River

Thirteen spur dikes and three ground sills were arranged in the upper reaches to enlarge the function of existing natural sand retarding basin and also nine consolidation works were planned in the lower reaches to stabilize the river bed.

The Ogsong River

Six spur dikes and nine ground sills were arranged in the upper reach to enlarge the function of existing natural sand retarding basin, and two consolidation dams and three ground sills planned in the lower reaches to stabilize the river bed.

The Nasisi River

Two consolidation dams were proposed in the upper reach to check and control the sediment runoff and in the lower reaches of the dams, three spur dikes, 23 groins and levee of 2,350m long were arranged to form a big artificial sand retarding basin in the river course.

Sabo master plan for the Quinali (B) River

Sabo plan for the Quinali (B) River was established for the Buang river and the upper reaches of main course which had been affected by the Buang river.

The Buang River

Four consolidation works and two spur dikes which were attached to the consolidation works were planned to mitigate the erosion and to stabilize the river bed.

The upper reach of the Quinali (B) River

One (1) sabo dam with an effective height of 8m is planned to checked and control the sediment runoff.

Sabo master plan for the Yawa River System

Sabo plan for the Yawa River system was established for three rivers of the Anuling river, the Budiao river and the Pawa-burabod river.

The Anuling River

Five consolidation works were planned to check and debris production and sediment runoff.

The Budiao River

Eight spur dikes and six ground sills were arranged to make the best use of the vast existing natural sand retarding basin.

The Pawa-burabod River

One sabo dam for the upper reaches to check and control the debris runoff and the seven consolidation works for the just lower reach to stabilize the river bed. In the next downstream reaches, seven spur dikes were arranged to check and control the sediment flowing into the existing canal and the lower river channel.

Proposed Facilities on the Master plan for Mayon Volcano Sabo and Flood Control Project on March 1981

River	Sabo Dam	Consoli-dation Dam	Spur Dike	Ground Sill	Jetty	Sediment Run-off Volume (m^3)		
						Without Facilities	With Facilities	Sediment Volume Reduction Ratio (%)
Yawa								
Pawa-Burabod	1	7	7			252,000	69,500	72%
Budiao			8		6	234,600	58,100	75%
Anoling		5				415,600	85,800	79%
Quirangay			6		3	260,100	78,200	70%
Tumpa		15				43,700	26,900	38%
Maninila		9				94,000	36,700	61%
Masarawag		9	13		3	276,800	65,300	76%
Ogsong		2	6	3	9	140,500	28,500	80%
Nasisi		2	3	23		992,100	270,900	73%
Buang		4	2			211,800	67,800	68%
Quinali (B)	1					319,700	119,700	63%
San Vicente								
Arimbay								
Padang								
Basud								
Bulawan								

(2) Re-study of Mayon Volcano Sabo and Flood Control Project on March 1983

The typhoon "Daling" in 1981 caused serious mud and debris flow damage on the slope of Mayon volcano. The mud and debris flow due to typhoon "Daling" caused loss of lives more than fifty and the affected area was mainly in the Sabo project area, which was submitted in the 1981 master plan. The master plan for the Mayon volcano sabo and flood control project in March 1981 was re-assessed and reviewed, taking account of the disaster in the June and July 1981 typhoon "Daling". The following items were changed on the sabo facilities planned after the re-study of the master plan.

- Zoning areas such as danger zones and safety zones was identified in the project area.
- Subject rivers of the re-study were streams of the Quinali (A) rivers and Yawa river system.
- Design of consolidation dam was changed the slit dam type.

- Continuous consolidation dams attached on long spur dikes on both side were proposed to increase the capacity of retarding basin.
- Design run off volume of Nasisi river and Pawa-burabod river was changed.

(3) Difference between the this sabo master plan and 1981 & 1983 Master plan

The 1981 and 1983 master plans were the urgent projects and submitted even detail design of sabo and flood facilities to be implemented immediately. Phenomenon to be treated by the 1981 and 1983 master plan were assumed to be mud and debris flow caused by the 1979 eruption. Therefore sediment yield was measured comparative easily. This master plan considers being able to adapt disasters with changes of topographical and hydrological condition by the future eruption. As the result of that, there are basically differences of TOR between this Master Plan and the past Master Plans.

2.2 Present Condition of Sabo Works

Based on the sabo planning which are proposed by the JICA Study Team on 1981 and 1983, DPWH Region Ⅴ has constructed sabo facilities around the Mayon volcano, following the past study. In the result of that, the number of the existing facilities is summarized at the present as the following Table;

Existing Facilities for Each River in the Study Area

River	Existing Facilities (Total Number and Total Length)
Yawa	Boulder Dike (7 dikes, 3,078m)
Pawa-Burabod	Spur Dike , Training Levee (13 dikes, 6,496m) Consolidation Dam (1)
Budiao	Spur Dike , Training Levee (6 dikes, >5,135m)
Anuling	Spur Dike , Training Levee (7 dikes, 1,850m) Ground Sill (1)
Quirangay	Spur Dike , Training Levee (10 dikes, 3,305m) Consolidation Dam (1)
Tumpa	None
Maninila	Ground Sill (3)
Masarawag	Spur Dike , Training Levee (8 dikes, 1,700m)
Ogsong	Spur Dike (2 dikes, 80m)
Nasisi	Ground Sill (3 dikes, 565m) Consolidation Dam (2)
Buang	None
Quinali (B)	None
San Vicente	Spur Dike (6 dikes, >770m)
Arimbay	Spur Dike (8 dikes, 2,680m) Consolidation Dam (1)
Padang	Spur Dike (7 dikes, 2,340m)
Basud	Spur Dike (15 dikes, 2,913m) Consolidation Dam (1)
Bulawan	Spur Dike (9 dikes, 3,493m) Consolidation Dam (1)

It can be observed that a part of training dikes, consolidation works and riverbed girdles were damaged or destroyed. In the case of training dikes failure, it may be considered that some foundations for training dikes with stone pitching structure are damaged or destroyed by erosion or bump of boulders. And in the case of failure of spur dikes failure, training dikes in outside of river bend and training dikes constructed with a certain angle with respect to running water appear clearly to be damaged or destroyed.

The whole overflow section of the consolidation work in the Basud River was destroyed, which failed to function properly.

3. BASIC DISASTER MANAGEMENT STRATEGIES FOR SABO PLANNING

3.1 Objectives of Sabo Planning

Objectives for sabo structural plan to take countermeasure is debris flow and mud flow during and soon after eruption.

In additional, it is impossible to predict large-scale collapse on mountain slope as catastrophic phenomenon. Countermeasure by normal sabo structure can not treat large-scale collapse like that.

Debris flow - A high density mud flow with abundant coarse-grained materials such as rock, tree trunks, etc.

Mud flow - A form of mass movement consisting of the down-slope flow of a mixture of water and earth material, usually following a natural drainage line or stream channel.

3.2 Basic Concept for Sabo Planning

Sabo works around Mayon Volcano are aimed at preventing the sediment-related disasters that are caused by the erosion phenomena accompanied with the eruption. In this study, sabo works for preventing disaster means the hardware-related measures that consist of the construction of such works as the dams, dikes, etc. When sabo plan of Mayon Volcano is proposed, it is first of all important to consider of not only hydrological analysis of sediment but also natural characteristics of the Study Area to be object of the preventive measures. The said characteristics of the Study Area consist firstly of the primary natural factors related to the area in such as natural features, the volcanic activities, topography, geology and its changes and development. Flow chart of Sabo structural planning around Mayon volcano is shown in Figure II 3.1.

Basic concept for Sabo planning around Mayon Volcano is itemized as the below:

- Phenomenon to be treated by a Sabo facility is assumed to be debris flow and mud flow.
- Eruptive magnitude to be treated by a Sabo facility is assumed one in the 1984 eruption.
- Existing structure and aliment of Sabo facility (limited to be hard and strong structure only) should be considered and utilized positively in this planning.
- Natural undulation on slope landform shall be considered. For example on southeast to south slope of volcano, lava flow mound can be utilized as natural barrier to perform in part of large dike.
- Sabo planning should adapt to changeable river course, landform changes and increase of runoff volume by the future eruption.
  - Changeable channel course will develop on fan surface
  - New channel will form by deposition of pyroclastic flow or lava flow

3.3 Selection Criteria for Sabo Planning

Selection criteria and protection area for sabo planning on each rivers are summarized below:

Criteria for Sabo Planning

River	Area and Object to be Protected	Criteria for Sabo Planning
Yawa river system	Legazpi City area, Yawa main river, rail way, Cagsawa ruins, National road	All debris material must be trapped by structure measure in upstream area to main river.
Arimbay river	No action plan since the drainage area disappeared by lava flow occurred the 1993 eruption	
Padang river, Basud river	National road, Barangay	There are some parallel tributaries next to target rivers. Debris material should be converged into one channel and flowed out the ocean or deposit field safely and directly.
Bulawan river	National road, Malilipot	Countermeasure concept for the downstream area is same to Padang river and Basud river. On the upstream area, it is possible that one tributary of Bulawan river will capture Tabigyan river. Facility planning should protect this piracy phenomenon.
San vicente river, Buang river	National road, Barangay, River improvement in plain area	All debris material should be trapped by structure measure in upstream area from the national road. Or only property of Barangay shouldbe protected by another structure.
Nasisi river, Ogsong river	No action plan is contemplated since protection area located far away for downstream area. Fan area should be utilized as natural retarding basin.	
Quinali (A) river	National road, Barangay, Paddy field-	Debris material should be gathered into main channel and flowed down between barangayes and the paddy field safely.

4. PREVENTIVE STRUCTURAL PLAN FOR MUD AND DEBRIS FLOW

4.1 Design Sediment Volume

(1) Sediment Yield

Sediment Yield (The Pyroclastic Deposition Volume Estimation Based on the Current Deposition Distribution and its Depth)

The volume of pyloclastic deposition was estimated. It is to know the total volume of the deposition which has a potential to move. The distribution of pyroclastic deposition is surrounding the summit. The lowest elevations of the pyroclastic deposition area and the maximum and average depth of the deposition were estimated based on field survey, river cross sectional survey and aerial photograph interpretation at each 7 basins and 16 subbasins. The area was extracted from digital elevation model and the depths were multiplied. The lava area was excluded from the calculation because the erosion is not expected from lava area. The result is shown below.

Sediment Yield

Basin	Lowest Elevation of Pyroclastic Area (m)	Pyroclastic Area (sq.km)	Lava Area (sq.km)	Pyroclastic minus Lava (sq.km)	Maximum Depth (m)	Average Depth (m)	Volume for Maximum Depth (Million cubic m)	Volume for Average Depth (Million cubic m)
Yawa	300	14.323	0.914	13.409	50	30	670	402
Pawa Burabod	340	5.098	0.441	4.658	37	16	172	75
Budiao	330	1.613	0.017	1.596	28	24	45	38
Anoling A	300	4.313	0.102	4.211	28	20	118	84
Anoling B	300	2.876	0.545	2.331	33	23	77	54
Anoling C	240	3.055	0.285	2.770	40	23	111	64
Quinali(A)	300	38.747	1.295	37.452	50	30	1,873	1,124
Quirangay	330	3.641	0.733	2.908	24	24	70	70
Maninila	400	3.812	0.186	3.626	31	11	112	40
Masarawag	360	4.702	0.002	4.700	36	31	169	146
Ogsong	360	3.179	0.000	3.179	20	14	64	45
Nasisi	280	8.640	0.000	8.640	48	30	415	259
Buga	300	4.052	0.000	4.052	48	30	194	122
Buang	240	19.646	0.003	19.644	24	19	471	373
Quinali(B)	300	28.904	0.010	28.894	50	30	1,445	867
San Vicente	260	15.089	0.003	15.086	45	33	679	498
Arimbay	300	5.576	1.196	4.379	50	30	219	131
Padang	320	5.996	0.917	5.078	36	22	183	112
Basud	460	5.366	1.915	3.451	52	39	179	135
Bulawan	220	15.771	0.709	15.061	47	29	708	437

(2) The Probable Runoff and Design Runoff of Mud and Debris Flow

<u>The probable runoff volume formula as the estimation model</u> (Technical Standard for the Measures against Debris Flow (Draft), 1988, Ministry of Construction)

The quantitative relationship between rainfall and the magnitude of mud and debris flow is not available in the Study Area since no measurement of mud and debris flow had been conducted.

The empirical probable runoff volume formula is applicable to estimate the magnitude of mud and debris flow on the basis of a rainfall depth.

The formula reflects the topographic and geologic conditions of the site and have yielded satisfactory results in Japan. The following explain the formula:

$$Vec = (10^3 \times R \times A) / (1-\lambda) \times (Cd/(1-Cd)) \times fr \quad \text{.......} \quad (1)$$

Where;

Vec	:	Sediment Flow Volume (m^3)
Rt	:	Provable one day rainfall (mm)
A	:	Catchment area (km^2)
λ	:	Void ratio of unstable material
C*	:	Sediment concentration of stable sediment material (0.6)
Cd	:	Sediment concentration of flowing debris material In case of Cd>0.9 C*; Cd = 0.9 C* In case of Cd<0.3 C*; Cd = 0.3
fr	:	Calibration coefficient runoff $A<0.1km^2$; fr = 0.50 $1km^2$ $A \times 10.0km^2$; fr = 0.05 (logA × 2.0) + 0.05 $A>10.0km^2$; fr =0.10

The concentration of following debris material is obtained by the following equation:

$$Cd = (\rho \times \tan\theta) / \{(\sigma - \rho) \times (\tan\phi - \tan\theta)\} \quad \text{.......} \quad (2)$$

Where;

Cd	:	Sediment concentration of flowing debris material
σ	:	Density of gravel ($2.6t/m^3$)
ρ	:	density of water ($1.2t/m^3$)
ϕ	:	Angle of internal friction in sediment material (30°)
θ	:	Slope gradient (from base point to 200m upstream)

The probable runoff volume formula was adopted to estimate sediment runoff.

(3) Estimation of sediment runoff soon after eruption

The probable runoff volume formula was developed analysing the sediment runoff of volcanic material. Most of materials analyzed were ones ejected several years before and fresh debris of ejecta are very few. Fresh debris of ejecta is easy to flow because it is not consolidated and have a higher λ of formula (1) as compared with those old debris. Another reason of this might be the smaller cohesion as compared with an old debris. Void ratio of unstable material (λ) has had gradual and continuous increase after deposition of pyroclastic flow. As the result of that, λ changes in the formula (1) is accompanied with passing of time. In this connection a special consideration is necessary for the estimation of sediment runoff for the fresh debris because the Mayon Volcano have erupted with an interval of approximately 10 years.

The deposit of mud and debris flow at October 18, 1985 was 260,000m^3 according to the measurement carried out in the Pawa-Burabod river. The daily rainfall of this occasion was 59.8mm of which is recorded at the Buang rain gauge station on October 18, 1985 and correspond to under the 2-year design rainfall. The estimated sediment runoff the proposed model is 28,308m^3 assuming the following parameters:

Basin area	:	5.1km^2
River bed slope	:	1/10.6
Internal friction angle	:	30.0 degree
Specific gravity	:	2.60 (t/m^3)
C*	:	0.17
Cd	:	0.30
fr	:	0.13

This big difference between the measured and the estimated might be due to the eruption that just occurred one year before on October 6, 1984. In this accord, it is concluded that the multiplier of 9.19 or rate of 260,000m^3 is to be applied to the estimation of the sediment runoff within one year

(4) Expectation of sediment runoff within the design flow

The expectation of sediment runoff due to the probable (n) year rainfall in a year is obtained by the product of sediment run off be estimated and the probability density. Where the probability density for (n) year event is approximated by following formula:

$$Pd(n) = 1/(n-1)(n+1) \qquad (3)$$

Where :

Pd : Probability density for n-year event
n : Return period of exceedence in year

Meanwhile the probability of a year to fall on the period within 10 year is 0.1 because the eruption takes place once 10 years. On the contrary the probability not to fall on the critical period is 0.9 because 9 years out of 10 there is no eruption.

Pe = 0.1 for erupted year and 0.9 for not erupted year

Since the 20-year mud and debris flow was adopted as the design flow, the expectation of sediment run off not exceeding the design flow for a year is given by the following formula:

$$V = \sum_{n-1}^{20} (k.V(n).Pd(n).Pe)$$

Where :

V	:	Expectation of sediment runoff in m^3
(n)	:	Index for return period of exceedence
K	:	Amplifier, 9.19 for erupted year, 1.0 for not erupted year
V(n)	:	Sediment runoff corresponding to (n)-year rainfall obtained by formula (1)
Pd	:	Probability density, obtained by formula (2)
Pe	:	Probability density, obtained by formula (3)

The results of the calculation are presented in Table II 4.1. The applicability of the method was confirmed on the basis of the recorded rainfall and the estimated runoff volume on Typhoon Sailing on 18 Oct. 1985 (260,000 m^3/1day, 59.8mm in 18th).

(5) Comparison Ejecta Volume and Sand Pocket Capacity Volume

Comparison Ejecta Volume and Sand Pocket Capacity Volume is shown in following table. Sediment yield for each river in the Study Area is a seven-digit number. Ejecta Volume on the 1984 Eruption and the 1993 Eruption for each river in the Study Area is a six -digit number. Sediment Runoff Volume on 20 years for each river is a five -digit number. And proposed sand pocket capacity is a six and seven -digit numbers.

Comparison Ejecta Volume and Sand Pocket Capacity Volume

River System	River	Sediment Volume				Sand Pocket Volume	
		Sediment Yield (1000m^3)	Ejecta Volume on the 1984 Eruption (1,000 m^3)	Ejecta Volume on the 1993 Eruption (1,000 m^3)	Sediment Runoff Volume on 20 years (1,000 m^3)	Pocket Capacity (H = 3m) (1,000 m^3)	Pocket Capacity (H = 4m) (1,000 m^3)
Yawa River System	Yawa						
	Pawa-Burabod	74,528	4,667	3,000	209	3,960	5,280
	Budiao	38,304	3,111	2,000	107	17,340	23,120
	Anoling	201,543	6,222	4,000	493		
Quinali (A) River System	Quirangay	69,792	3,306	2,125	156	1,373	1,830
	Tumpa	0	0	0	0		
	Maninila	39,886	2,722	1,750	168	3,324	4,432
	Masarawag	145,700	5,250	3,375	186		
	Ogsong	44,506	6,222	4,000	133		
	Nasisi	259,200	5,444	3,500	230		
Quinali (B) River System	Buang	373,236	5,444	3,500	539	1,823	2,430
	Quinali(B)		0	0			
	San Vicente	497,838	6,222	4,000	306	9,011	12,015
Arimbay River System	Arimbay	0	0	0	0		
Padang River System	Padang	111,716	4,278	2,750	211	10,125	13,500
Basud River System	Basud	134,589	7,000	4,500	198	12,825	17,100
Bulawan River System	Bulawan	436,769	10,111	6,500	445	5,130	6,840
Total		2,427,607	70,000	45,000	3,381	64,910	86,547

(6) Comparison Run Off Volume and Sand Pocket Capacity Volume

Comparison Runoff Volume and Sand Pocket Capacity Volume is shown in following table. The proposed sand pocket capacity for each river in this area is 24 times the run off volume on the average (in case of Dam Height 4m and provable one day rainfall 20 year).

Runoff was estimated at the top of fun as the reference section. The capacity of a pocket is estimated assuming the debris deposits, forming the surface with slope with a half gradient of the original ground line.

Comparison Runoff Volume and Sand Pocket Capacity Volume

Pawa-Burabod	V3 : Pocket Capacity (H=3m) 3,960,000	V3/V10,20,50	V4 : Pocket Capacity (H=4m) 5,280,000	V4/V10,20,50
Run Off Volume V V10:10year (m^3)	188,620	21	188,620	28
Run Off Volume V V20:20year (m^3)	208,554	19	208,554	25
Run Off Volume V V50:50year (m^3)	218,095	18	218,095	24
Anuling, Budiao	V3 : Pocket Capacity (H=3m) 17,340,000	V3/V10,20,50 32	V4 : Pocket Capacity (H=4m) 23,120,000	V4/V10,20,50
Run Off Volume V V10:10year (m^3)	542,599	32	542,599	43
Run Off Volume V V20:20year (m^3)	599,826	29	599,826	39
Run Off Volume V V50:50year (m^3)	627,219	28	627,219	37
Quirangay, Tumpa	V3 : Pocket Capacity (H=3m) 1,372,500	V3/V10,20,50	V4 : Pocket Capacity (H=4m) 1,830,000	V4/V10,20,50
Run Off Volume V V10:10year (m^3)	141,170	10	141,170	13
Run Off Volume V V20:20year (m^3)	155,610	9	155,610	12
Run Off Volume V V50:50year (m^3)	162,336	8	162,336	11
Masarawag, Maninila	V3 : Pocket Capacity (H=3m) 3,324,000	V3/V10,20,50	V4 : Pocket Capacity (H=4m) 4,432,000	V4/V10,20,50
Run Off Volume V V10:10year (m^3)	320,896	10	320,896	14
Run Off Volume V V20:20year (m^3)	353,733	9	353,733	13
Run Off Volume V V50:50year (m^3)	369,040	9	369,040	12
Buang	V3 : Pocket Capacity (H=3m) 1,822,500	V3/V10,20,50	V4 : Pocket Capacity (H=4m) 2,430,000	V4/V10,20,50
Run Off Volume V V10:10year (m^3)	473,215	4	473,215	5
Run Off Volume V V20:20year (m^3)	538,935	3	538,935	5
Run Off Volume V V50:50year (m^3)	574,462	3	574,462	4
San Vicente	V3 : Pocket Capacity (H=3m) 9,011,400	V3/V10,20,50	V4 : Pocket Capacity (H=4m) 12,015,200	V4/V10,20,50
Run Off Volume V V10:10year (m^3)	274,082	33	274,082	44
Run Off Volume V V20:20year (m^3)	305,837	29	305,837	39
Run Off Volume V V50:50year (m^3)	321,755	28	321,755	37
Padan	V3 : Pocket Capacity (H=3m) 10,125,000	V3/V10,20,50	V4 : Pocket Capacity (H=4m) 13,500,000	V4/V10,20,50
Run Off Volume V V10:10year (m^3)	192,694	53	192,694	70
Run Off Volume V V20:20year (m^3)	210,736	48	210,736	64
Run Off Volume V V50:50year (m^3)	219,091	46	219,091	62
Basud	V3 : Pocket Capacity (H=3m) 12,825,000	V3/V10,20,50	V4 : Pocket Capacity (H=4m) 17,100,000	V4/V10,20,50
Run Off Volume V V10:10year (m^3)	180,945	71	180,945	29
Run Off Volume V V20:20year (m^3)	197,896	65	197,896	27
Run Off Volume V V50:50year (m^3)	205,745	62	205,745	26
Bulawan	V3 : Pocket Capacity (H=3m) 5,130,000	V3/V10,20,50	V4 : Pocket Capacity (H=4m) 6,840,000	V4/V10,20,50
Run Off Volume V V10:10year (m^3)	406,904	13	406,904	17
Run Off Volume V V20:20year (m^3)	445,015	12	445,015	15
Run Off Volume V V50:50year (m^3)	462,675	11	462,675	15

4.2 Alternative Plan for Sabo Project

(1) Selected Project

Candidate sabo projects in this Study Area are selected by the conditions and criteria for this Study as follows.

- Yawa River System Sabo Project (SF-1)
- Quinali (A) River System Sabo Project (SF-2)
- Buang River Sabo Project (SF-3)
- San Vicente Sabo Project (SF-4)
- Padang River Sabo Project (SF-5)
- Basud River Sabo Project (SF-6)
- Bulawan River Sabo Project (SF-7)

The Arimbay River, the Ogsong River the Nasisi River sabo projects have not been proposed because of the cause as shown in Table II 4.2 to II 4.8.

(2) Proposed Alternative Plan

Phenomenon to be treated by the Sabo facility is assumed to be debris flow and mud flow, which is including the sediment run off by the eruption.

Probable one-day rainfall as design magnitude will be examined as follows:

- 10 year
- 20 year
- 50 year

Alternative Plan of Rivers in the Study Area

River Name		Case	
Pawa-Burabod River		1	S/P (Present River Course)
		2	P/D
Anoling Rivers	Anoling Rivers, Budiao River	1	S/P (Upper, 160 masl)
		2	S/P (Middle, 145 masl)
		3	S/P (Lower, 120 masl)
Masarawag River	Upstream on Masarawag River	1	S/P (T/D, C/D), T/D
		2	T/D
	Downstream on Masarawag River	1	T/D, G/S
		2	T/D, G/S, C/D
	Maninila River	1	T/D
		2	D/C
Quirangay River	Quirangay River	1	Two S/Ps (T/D, C/D)
		2	S/P (T/D, C/D) on the New Channel
	Tumpa River	1	No Action
		2	T/D
Buang River		1	S/P
		2	P/D, G/S
		3	No Action
San Vicente River	San Vicente River (Upper)	1	D/D
		2	No Action
	San Vicente River (Lower)	1	Twin S/Ps (Westside Type)
		2	Twin S/Ps (Eastside Type)
		3	P/D
Bulawan River	Upper Stream in Bulawan River	1	D/D, Tabigyan River C/D
		2	D/D, D/C, Tabigyan River No Action
	Fan Area in Bulawan River	1	T/D
		2	No Action
Basud River	Upper Stream on Basud River	1	BR, S/P, T/D
		2	S/P, C/D, Rehabilitation
	Fan Area in Basud River	1	S/P, C/D, Rehabilitation
		2	S/P, G/S, Widening
Arimbay River		1	No Action

Note: C/D: Cross Dike, C/D: Consolidation Dam, D/C: Diversion Channel, D/W: Dredging Work, F/W: Flood Way, P/D: Protection Dike, R/I: River Improvement, S/P: Sand Pocket, T/W: Training Work

The basic components of each alternative plan for sabo planning are as the below:

1) Sand pocket (Sabo dam + Long spur dike)

The proposed sand pocket alignment is composes of the long spur dikes and the Sabo dam. This alignment is designed to trap sediment material, and to protect houses and cultivate area widely.

2) Spur dike and training dike

The proposed spur dike and the training dike converge debris flows into the one channel, and flow the debris out the downstream safely and directly.

3) Protection dike

The proposed protection dike is designed to protect only houses as protected objects. Debris flow is dispersed for two direction by protection dike which has alignment of wedge type.

The table of alternative plans on each river is shown in the Data book.

(3) Facility design for Sabo Planning

The proposed facilities in the Study Area will be designed with the following structural conditions:

- Strong and large-scale facilities constructed in the past exist along Pawa-Burabod river, Budiao river, Quirangay river, Masarawag river and Nasisi river.
- A part of facility around Mayon volcano will need rehabilitation.
- In facility design for structural planning, CSG (concrete, sand and gravel) method was widely adopted to minimize the cost.
- CSG method was a kind of aggregate as the filling material for created embankment of spur dikes and consolidation. Sabo works in Pinatubo have already used it in Philippines and have shown its advantage.
- Advantage of CSG method is easy construction work, low cost and high local supplement.

Typical cross section of facilities are as follows (in case of the probable one day rainfall 20 year):

<u>Sabo dam (All CSG method):</u>

Dam height = 6.0m (Effective height = 4m), Cut off height = 2m, Crown width=5.0m

<u>Spur Dike:</u>

Type A (All CSG method): Height=6.5m, Crown width=4.0m
Type B (CSG method + Embankment): Height=6.5m, Crown width=6.0m
Type C (Embankment): Height=6.5m, Crown width=6.0m
Type D (Raising)

Training Dike (CSG method):

In case of water depth 1.5m, Height=4.5m, Crown width=3.0m

5. RECOMMENDATIONS FOR MASTER PLAN

Profiles of recommended Sabo Facility Construction Project are itemized below:

The maps of alternative plans are shown in Figure II 5.1 to II 5.7.

SF-1: Yawa River System Sabo Project (Alternative Plan 1-1-2)

(1) Objective

All debris material must be trapped by structure measure in the upstream area to the main river. Alternative plan 1-1-2 for Yawa river system is able to keep an extensive land for enhanced landuse.

(2) Component

- Site : Anuling River and Pawa-Burabod River
- Sabo facility : Sand pocket alignment to be used for depositing the debris flow material
- Probable1 day rain fall : 20 year
- Proposed runoff volume : 808,000 m^3
- Sand pocket capacity : 28,400,000 m^3
- Protection area : Legazpi city area, Yawa main river, Rail way, Cagsawa ruins, National road
- O&M work : 23,600 m^3/year

(3) Work Volume

- Consolidation dam (C.S.G) : Length 1,100m, Height 4.0m (Anuling River 600m, Pawa-Burabod River 500m)
- Spur dike
  - C.S.G (Type-A) : Length 1,900m, Height 5.0m (Anuling River 1,900m)
  - Combined (Type-B) : Length 5,100m, Height 5.0m (Anuling River 1,730m, Pawa-Burabod River 3,370m)
  - Embankment (Type-C) : Length 600m, Height 5.0m (Pawa-Burabod River 600m)

- Training dike : Length 5,100m, Height 2.3m (Anuling River 4,750m, Pawa-Burabod River 350m)

SF-2: Quinali (A) River System Sabo Project (Alternative Plan 2-1-1-2)

(1) Objective

Debris flow material should be gathered into main channel and flowed down between barabgayes and the paddy field safely. Alternative plan 2-1-1-2 for Quinali (A) river system is able to keep an extensive land for enhanced landuse.

(2) Component

- Site : Masarawag River and Quirangay River
- Sabo Facility : Sand pocket alignment with ground sill to be used for dispersing and depositing the debris flow material. Guiding dike to confluence the Maninila river channel with the Masarawag river channel artificially.
- Probable 1 day rain fall : 20 year
- Proposed runoff volume : 510,000 m^3
- Sand pocket capacity : 6,262,000 m^3
- Protection area : Barabgay, Rail way, National road, Paddy field
- O&M work : 79,600 m^3/year

(3) Work Volume

- Consolidation dam (C.S.G) : Length 450m, Height 4.0m (Masarawag River 100m, Quirangay River 350m)
- Spur dike

  C.S.G (Type-A) : Length 2,200m, Height 5.0m (Masarawag River 1,250m, Quirangay River 950m)

  Combined (Type-B) : Length 2,750m, Height 5.0m (Masarawag River 2,050m, Quirangay River 700m)

  Embankment (Type-C) : Length 1,050m, Height 5.0m (Masarawag River 1,050m)

  Ground sill (Type-D) : Length 900m, Height 1.5m (Masarawag River 900m)

  Raising dike (Type-E) : Length 1,700m, Height 2.0m (Quirangay

River 1,700m)

- Training dike : Length 3,050m, Height 2.3m (Masarawag River 2,100m, Quirangay River 950m)

SF-3: Buang River Sabo Project (Alternative Plan 2-2)

(1) Objective

Only property of Barangay along the Buang River should be protected by the protection dike, which is proposed by Alternative plan 2-2. The Quinali (B) River section where located the downstream to the Buang River has the function of natural sediment control with the continuous alternation of narrow valley and wide river floor.

(2) Component

- Site : Buang River
- Sabo facility : Protection Dike to protect the spot area
- Probable 1 day rain fall : 20 year
- Proposed runoff volume : 539,000 m^3
- Protection area : Barabgay, National road
- O&M work : Basically no need

(3) Work Volume

- Spur dike
  Combined (Type-B) : Length 1,150m, Height 5.0m

SF-4: San Vicente Sabo Project (Alternative Plan 2-2)

(1) Objective

Debris flow material should be gathered into main channel and flowed down between barabgayes and the paddy field safely. Alternative plan 2-2 for the San Vicente River is able to confirm an avulsion of debris flow.

(2) Component

- Site : San Vicente River
- Sabo facility : Sand pocket alignment with huge sub-pocket to be used for converging and depositing the debris flow material.

- Probable 1 day rain fall : 20 year
- Proposed runoff volume : 306,000 m^3
- Sand pocket capacity : 12,015,200 m^3
- Protection area : Barangay(San Vicente), National road, Paddy field, River improvement in the plain area
- O&M work : 16,200 m^3/year

(3) Work Volume

- Consolidation dam (C.S.G) : Length 600m, Height 4.0m
- Spur dike

  C.S.G (Type-A) : Length 2,400m, Height 5.0m

  Combined (Type-B) : Length 2,700m, Height 5.0m

SF-5: Padang River Sabo Project (Alternative Plan 1-1-2)

(1) Objective

There are some tributaries next to the target rivers. Debris material should be converged into one channel and trapped by the structure measure. Alternative plan 1-1-2 for the Padang River is able to trap the sediment material on the upstream area to the National road.

(2) Component

- Site : Padang River and Golf course channel
- Sabo facility : Sand pocket alignment to be used for depositing the debris flow material.
- Probable 1 day rain fall : 20 year
- Proposed Runoff Volume : 211,000 m^3
- Sand pocket capacity : 13,500,000 m^3
- Protection area : Barangay, National road
- O&M work : 5,300 m^3/year

(3) Work Volume

- Consolidation dam (C.S.G) : Length 350m, Height 4.0m
- Spur dike

  C.S.G (Type-A) : Length 3,950m, Height 5.0m

  Combined (Type-B) : Length 600m, Height 5.0m

SF-6: Basud River Sabo Project (Alternative Plan 2-1-2)

(1) Objective

There are some tributaries next to the target rivers. Debris material should be converged into one channel and trapped by the structure measure. Alternative plan 2-1-2 for the Basud River is able to trap the sediment material on the upstream area to the National road in the similar design.

(2) Component

- Site : Basud River and one parallel channel
- Sabo facility : Sand pocket alignment to be used for depositing the debris flow material.
- Probable 1 day rain fall : 20 year
- Proposed runoff volume : 198,000 m^3
- Sand pocket capacity : 17,100,000 m^3
- Protection area : Barangay, National road
- O&M work : 4,300 m^3/year

(3) Work Volume

- Consolidation dam (C.S.G) : Length 350m, Height 4.0m
- Spur dike

  C.S.G (Type-A) : Length 2,500m, Height 5.0m

  Combined (Type-B) : Length 500m, Height 5.0m

SF-7: Bulawan River Sabo Project (Alternative Plan 2-1-2)

(1) Objective

Countermeasure concept for the downstream area is same to the Padang River and the Basud River. On the upstream area, it is possible that one tributary of the Bulawan River will capture the Tabigyan River. Facility planning should protect this piracy phenomenon. Alternative plan 2-1-2 for the Bulawan River is able to protect such a channel movement by reasonable planning.

(2) Component

• Site	:	Bulawan River
• Sabo facility	:	Continuous spur dike alignment to be used for confirming the debris flow material in the downstream. Deflection dike to protect the piracy.
• Probable 1 day rain fall	:	20 year
• Proposed runoff volume	:	445,000 m^3
• Protection area	:	Malilipot City, National road and Bridge
• O&M work		Basically no need

(3) Work Volume

• Spur dike

Combined (Type-B)	:	Length 1,350m, Height 5.0m
Combined (Type-C)	:	Length 3,050m, Height 5.0m

Table II 4.1 Run Off Volume

Basin	Probable Rainfall 2year (mm/day)	Run Off Volume 2year (1000 m^3)	Probable Rainfal 5year (mm/day)	Run Off Volume 5year (1000 m^3)	Probable Rainfal 10year (mm/day)	Run Off Volume 10year (1000 m^3)	Probable Rainfall 20year (mm/day)	Run Off Volume 20year (1000 m^3)	Probable Rainfal 50year (mm/day)	Run Off Volume 50year (1000 m^3)
Pawa Burabod	229	99	326	155	394	189	463	209	554	218
Budiao	229	50	327	79	394	96	463	107	554	112
Anoling A	227	89	323	140	390	170	458	188	548	197
Anoling B	227	72	323	113	390	138	458	152	548	159
Anoling C	227	72	323	113	390	138	458	152	548	159
Quirangay	209	74	296	116	353	141	407	156	474	162
Tumpa	213	0	303	0	361	0	416	0	485	0
Maninila	215	80	305	125	363	152	419	168	488	175
Masarawag	207	88	294	139	351	169	404	186	471	194
Ogsong	191	63	271	99	322	120	372	133	433	138
Nasisi	177	109	252	172	300	209	346	230	403	240
Buang	172	220	297	371	400	473	515	539	696	574
San Vicente	141	138	213	222	267	274	324	306	406	322
Arimbay	236	0	308	0	356	0	403	0	467	0
Padang	226	106	295	161	341	193	386	211	447	219
Basud	219	99	286	151	330	181	374	198	433	206
Bulawan	218	223	284	340	328	407	372	445	431	463
Run Off Volume		1,583		2,495		3,050		3,379		3,539

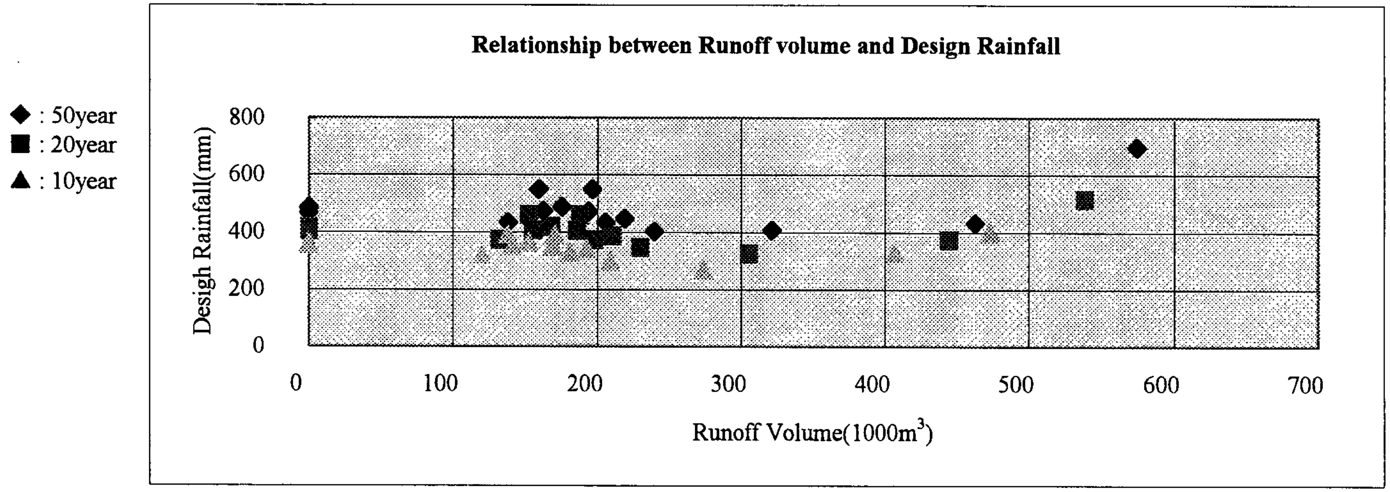


Table II 4.2 Alternative Plan - Yawa River System-Yawa River, Pawa-Burabod River, Budiao River, Anoling River

No.	Basin	No. of Alt. A-B-C	Structural Component	A	Anoling Rivers, Budiao River	B	Pawa-Burabod River	C	Provable Basin 1 Day Rainfall	D/W (Anoling Rivers, Budiao River)	D/W (Pawa-Burabod River)	Railway (Anuling)
1	Yawa	1-1-1	Sand Pocket (2 pockets)	1	S/P(Upper, 160masl)	1	S/P(Present River Course)	1	10	O	O	O
2	Yawa	1-1-2	Sand Pocket (2 pockets)	1	S/P(Upper, 160masl)	1	S/P(Present River Course)	2	20	O	O	O
3	Yawa	1-1-3	Sand Pocket (2 pockets)	1	S/P(Upper, 160masl)	1	S/P(Present River Course)	3	50	O	O	O
4	Yawa	1-2-1	Sand Pocket+Protection Dike	1	S/P(Upper, 160masl)	2	P/D	1	10	O	×	O
5	Yawa	1-2-2	Sand Pocket+Protection Dike	1	S/P(Upper, 160masl)	2	P/D	2	20	O	×	O
6	Yawa	1-2-3	Sand Pocket+Protection Dike	1	S/P(Upper, 160masl)	2	P/D	3	50	O	×	O
7	Yawa	2-1-1	Sand Pocket (2 pockets)	2	S/P(Middle, 145masl)	1	S/P(Present River Course)	1	10	O	O	O
8	Yawa	2-1-2	Sand Pocket (2 pockets)	2	S/P(Middle, 145masl)	1	S/P(Present River Course)	2	20	O	O	O
9	Yawa	2-1-3	Sand Pocket (2 pockets)	2	S/P(Middle, 145masl)	1	S/P(Present River Course)	3	50	O	O	O
10	Yawa	2-2-1	Sand Pocket+Protection Dike	2	S/P(Middle, 145masl)	2	P/D	1	10	O	×	O
11	Yawa	2-2-2	Sand Pocket+Protection Dike	2	S/P(Middle, 145masl)	2	P/D	2	20	O	×	O
12	Yawa	2-2-3	Sand Pocket+Protection Dike	2	S/P(Middle, 145masl)	2	P/D	3	50	O	×	O
13	Yawa	3-1-1	Sand Pocket (2 pockets)	3	S/P(Lower, 120masl)	1	S/P(Present River Course)	1	10	O	O	O
14	Yawa	3-1-2	Sand Pocket (2 pockets)	3	S/P(Lower, 120masl)	1	S/P(Present River Course)	2	20	O	O	O
15	Yawa	3-1-3	Sand Pocket (2 pockets)	3	S/P(Lower, 120masl)	1	S/P(Present River Course)	3	50	O	O	O
16	Yawa	3-2-1	Sand Pocket+Protection Dike	3	S/P(Lower, 120masl)	2	P/D	1	10	O	×	O
17	Yawa	3-2-2	Sand Pocket+Protection Dike	3	S/P(Lower, 120masl)	2	P/D	2	20	O	×	O
18	Yawa	3-2-3	Sand Pocket+Protection Dike	3	S/P(Lower, 120masl)	2	P/D	3	50	O	×	O

D/C:Diversion Channel, D/W:Dredging Work, F/W:Flood Way, P/D:Protection Dike, R/I:River Improvement, S/P:Sand Pocket,

Table II 4.3 Altenative Plan - Quinali (A) River System-Quirangay River, Tumpa River, Maninila River, Masarawag River

No.	Basin	No. of Alt. A-B-C-D	Strucural Component	A	Upstream on Masarawag River	Downstream on Masarawag River	Maninila River	B	Quirangay River	Tumpa River	C	Countermeasure to Fan Area between Masarawag and Quiraqngay	D	Provable Basin 1 Day Rainfall	D/W
1	Quinali(A)	1-1-1-1	3 Sand Pocket	1	S/P (T/D, C/D), T/D	T/D, G/S	T/D	1	Two S/Ps(T/D, C/D)	-	1	-	1	10	O
2	Quinali(A)	1-1-1-2	3 Sand Pocket	1	S/P (T/D, C/D), T/D	T/D, G/S	T/D	1	Two S/Ps(T/D, C/D)	-	1	-	2	20	O
3	Quinali(A)	1-1-1-3	3 Sand Pocket	1	S/P (T/D, C/D), T/D	T/D, G/S	T/D	1	Two S/Ps(T/D, C/D)	-	1	-	3	50	O
4	Quinali(A)	1-2-1-1	2 Sand Pocket	1	S/P (T/D, C/D), T/D	T/D, G/S	T/D	2	S/P(T/D, C/D) on the New Channel	T/D	1	-	1	10	O
5	Quinali(A)	1-2-1-2	2 Sand Pocket	1	S/P (T/D, C/D), T/D	T/D, G/S	T/D	2	S/P(T/D, C/D) on the New Channel	T/D	1	-	2	20	O
6	Quinali(A)	1-2-1-3	2 Sand Pocket	1	S/P (T/D, C/D), T/D	T/D, G/S	T/D	2	S/P(T/D, C/D) on the New Channel	T/D	1	-	3	50	O
7	Quinali(A)	2-1-1-1	2 Sand Pocket	2	T/D	T/D, G/S, C/D	D/C	1	Two S/Ps(T/D, C/D)	-	1	-	1	10	×
8	Quinali(A)	2-1-1-2	2 Sand Pocket	2	T/D	T/D, G/S, C/D	D/C	1	Two S/Ps(T/D, C/D)	-	1	-	2	20	×
9	Quinali(A)	2-1-1-3	2 Sand Pocket	2	T/D	T/D, G/S, C/D	D/C	1	Two S/Ps(T/D, C/D)	-	1	-	3	50	×
10	Quinali(A)	2-2-1-1	1 Sand Pocket	2	T/D	T/D, G/S, C/D	D/C	2	S/P(T/D, C/D) on the New Channel	T/D	1	-	1	10	×
11	Quinali(A)	2-2-1-2	1 Sand Pocket	2	T/D	T/D, G/S, C/D	D/C	2	S/P(T/D, C/D) on the New Channel	T/D	1	-	2	20	×
12	Quinali(A)	2-2-1-3	1 Sand Pocket	2	T/D	T/D, G/S, C/D	D/C	2	S/P(T/D, C/D) on the New Channel	T/D	1	-	3	50	×
13	Quinali(A)	3-3-2-1	Training Dike	3	T/D	-	-	3	T/D	-	2	P/D	1	10	×
14	Quinali(A)	3-3-2-2	Training Dike	3	T/D	-	-	3	T/D	-	2	P/D	2	20	×
15	Quinali(A)	3-3-2-3	Training Dike	3	T/D	-	-	3	T/D	-	2	P/D	3	50	×

C/D:Cross Dike, Co/D:Consolidation Dam, D/C:Diversion Channel, D/W:Dredging Work, F/W:Flood Way, P/D:Protection Dike, R/I:River Improvement, S/P:Sand Pocket, T/W:Training Work

Table II 4.4 Alternative Plan - Buang River

No.	Basin	No. of Alt. A-B	Strucural Component	A	Channel Works on Buang River	B	Provable Basin 1 Day Rainfall	D/W	R/I	Bridge Rehabilitation
1	Buang	1-1	Sand Pocket	1	S/P	1	10	O	×	O
2	Buang	1-2	Sand Pocket	1	S/P	2	20	O	×	O
3	Buang	1-3	Sand Pocket	1	S/P	3	50	O	×	O
4	Buang	2-1	Protection Dike	2	P/D, G/S	1	10	×	×	O
5	Buang	2-2	Protection Dike	2	P/D, G/S	2	20	×	×	O
6	Buang	2-3	Protection Dike	2	P/D, G/S	3	50	×	×	O
7	Buang	3	No Action	3				O	×	O

C/D:Consolidation Dam, D/W:Dredging Work, G/S:Ground Sill, P/D:Protection Dike, R/I:River Improvement, S/P:Sand Pocket,

Table II 4.5 Alternative Plan - San Vicente River

No.	Basin	No. of Alt. A-B	Structural Component	A	San Vicente River (Lower)	B	Provable Basin 1 Day Rainfall	D/W	R/I	Bridge Rehabilitation
1	San Vicente	1-1	Twin Sand Pocket	1	Twin S/Ps(Westside Type)	1	10	O	O	×
2	San Vicente	1-2	Twin Sand Pocket	1	Twin S/Ps(Westside Type)	2	20	O	O	×
3	San Vicente	1-3	Twin Sand Pocket	1	Twin S/Ps(Westside Type)	3	50	O	O	×
4	San Vicente	2-1	Twin Sand Pocket	2	Twin S/Ps(Eastside Type)	1	10	O	O	×
5	San Vicente	2-2	Twin Sand Pocket	2	Twin S/Ps(Eastside Type)	2	20	O	O	×
6	San Vicente	2-3	Twin Sand Pocket	2	Twin S/Ps(Eastside Type)	3	50	O	O	×
7	San Vicente	3-1	Protectionj Dike	3	P/D	1	10	×	O	×
8	San Vicente	3-2	Protectionj Dike	3	P/D	2	20	×	O	×
9	San Vicente	3-3	Protectionj Dike	3	P/D	3	50	×	O	×

D/C:Diversion Channel, D/D:Deflection Dike, D/W:Dredging Work, F/W:Flood Way, P/D:Protection Dike, T/D:Training Dike, R/I:River Improvement, S/P:Sand Pocket

Table II 4.6 Alternative Plan - Padang River

No.	Basin	No. of Alt. A-B-C	Structural Component	A	Padan River	B	Cross Dike	Existing T/D	C	Provable Basin 1 Day Rainfall	D/W	R/I	Training Works (Padang Rv.) (m)	Bridge
1	Padang	1-1-1	Sand Pocket	1	S/P	1	C/D	Rehabilitation	1	10	○		-	
2	Padang	1-1-2	Sand Pocket	1	S/P	1	C/D	Rehabilitation	2	20	○		-	
3	Padang	1-1-3	Sand Pocket	1	S/P	1	C/D	Rehabilitation	3	50	○		-	
4	Padang	1-2-1	Spur Dike	1	S/P	2	G/S	Widening	1	10	×		1,250	○
5	Padang	1-2-2	Spur Dike	1	S/P	2	G/S	Widening	2	20	×		1,250	○
6	Padang	1-2-3	Spur Dike	1	S/P	2	G/S	Widening	3	50	×		1,250	○

C/D:Consolidation Dam, D/C:Diversion Channel, D/W:Dredging Work, F/W:Flood Way, G/S:Ground Sill, P/D:Protection Dike, R/I:River Improvement, S/P:Sand Pocket, T/D:Training

Table II 4.7 Alternative Plan - Basud River

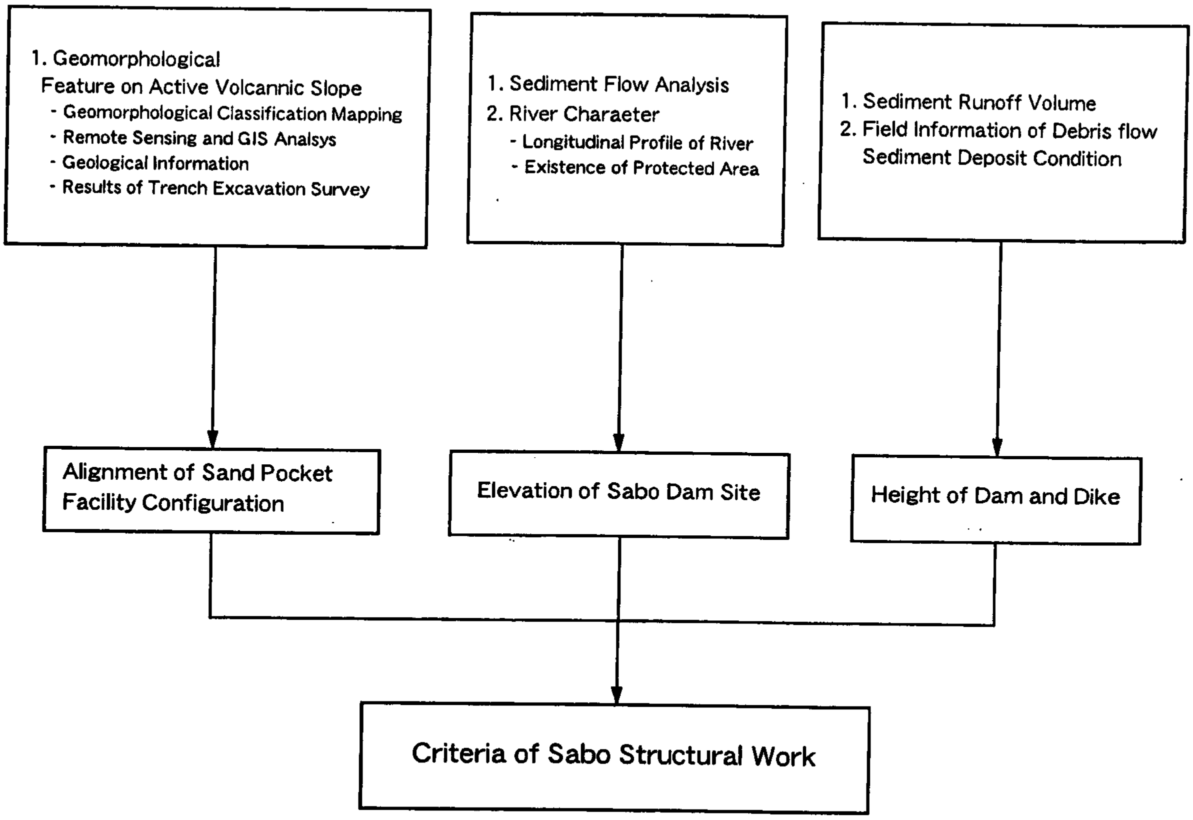
No.	Basin	No. of Alt. A-B-C	Structural Component	A	Around National Road	Upper Stream on Basud River	B	Fan Area in Basud River	C	Provable Basin 1 Day Rainfall	D/W	R/I	Bridge
1	Basud	1-1-1	Spur Dike+Bridge Construction	1	BR, S/P	T/D	1	T/D	1	10	×	×	○
2	Basud	1-1-2	Spur Dike+Bridge Construction	1	BR, S/P	T/D	1	T/D	2	20	×	×	○
3	Basud	1-1-3	Spur Dike+Bridge Construction	1	BR, S/P	T/D	1	T/D	3	50	×	×	○
4	Basud	1-2-1	Spur Dike+Bridge Construction	1	BR, S/P	T/D	2	-	1	10	×	×	○
5	Basud	1-2-2	Spur Dike+Bridge Construction	1	BR, S/P	T/D	2	-	2	20	×	×	○
6	Basud	1-2-3	Spur Dike+Bridge Construction	1	BR, S/P	T/D	2	-	3	50	×	×	○
7	Basud	2-1-1	Sand Pocket	2	S/P, C/D	Rehabilitation	1	T/D	1	10	○	×	×
8	Basud	2-1-2	Sand Pocket	2	S/P, C/D	Rehabilitation	1	T/D	2	20	○	×	×
9	Basud	2-1-3	Sand Pocket	2	S/P, C/D	Rehabilitation	1	T/D	3	50	○	×	×
10	Basud	2-2-1	Sand Pocket	2	S/P, C/D	Rehabilitation	2	-	1	10	○	×	×
11	Basud	2-2-2	Sand Pocket	2	S/P, C/D	Rehabilitation	2	-	2	20	○	×	×
12	Basud	2-2-3	Sand Pocket	2	S/P, C/D	Rehabilitation	2	-	3	50	○	×	×

BR:Bridge Construction, D/C:Diversion Channel, D/W:Dredging Work, F/W:Flood Way, P/D:Protection Dike, R/I:River Improvement, S/P:Sand Pocket, T/D:Training Dike

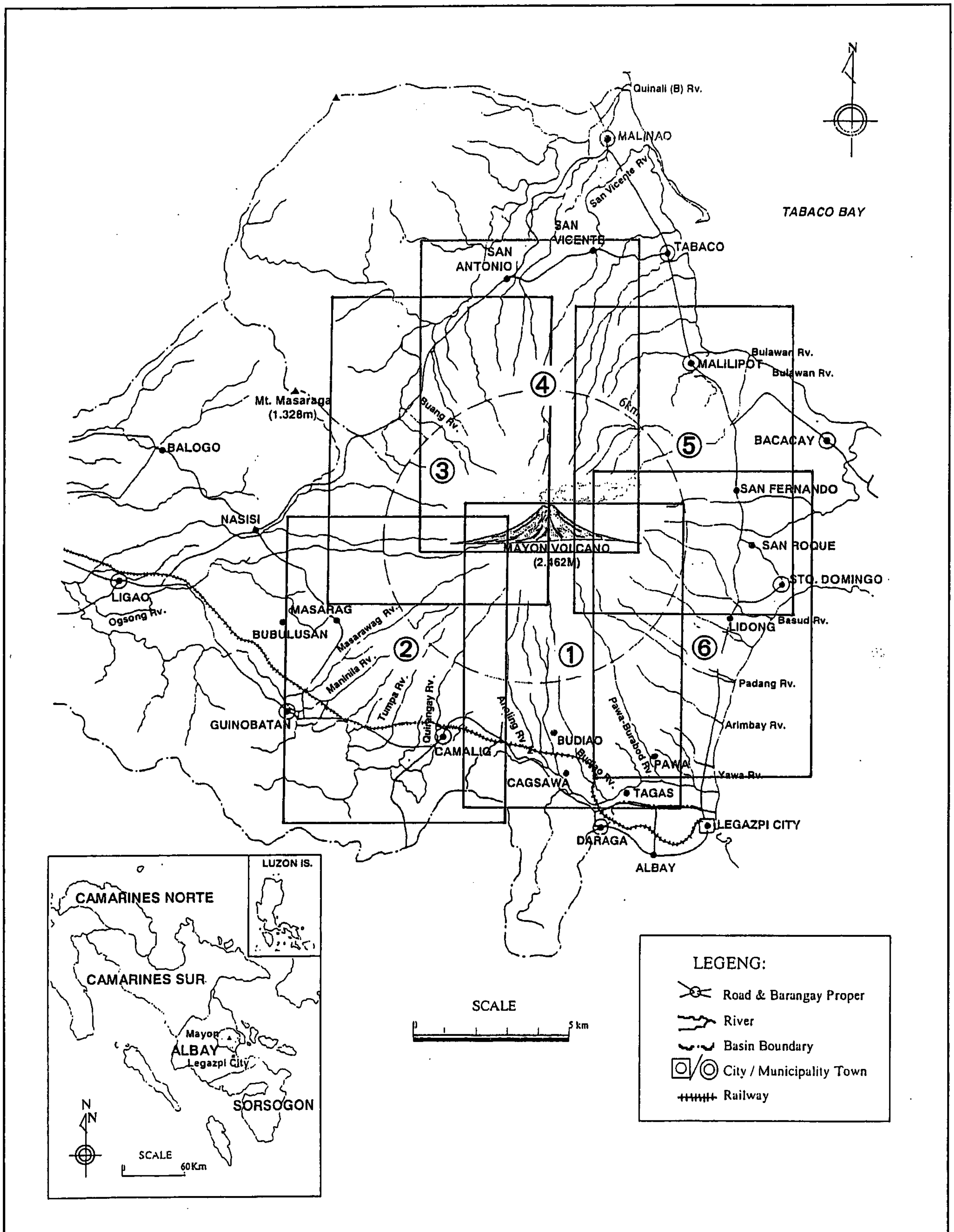
Table II 4.8 Alternative Plan - Bulawan River

No.	Basin	No. of Alt. A-B-C	Structural Component	A	Upper Stream in Bulawan River	Tabigyan River	B	Fan Area in Bulawan River	C	Provable Basin 1 Day Rainfall	D/W	R/I	Bridge Rehabilitation
1	Bulawan	1-1-1	Consolidation Dike+Training Dike	1	D/D	C/D	1	T/D	1	10	×	×	○
2	Bulawan	1-1-2	Consolidation Dike+Training Dike	1	D/D	C/D	1	T/D	2	20	×	×	○
3	Bulawan	1-1-3	Consolidation Dike+Training Dike	1	D/D	C/D	1	T/D	3	50	×	×	○
4	Bulawan	1-2-1	Consolidation Dike	1	D/D	C/D	2	-	1	10	×	×	○
5	Bulawan	1-2-2	Consolidation Dike+Training Dike	1	D/D	C/D	2	-	2	20	×	×	○
6	Bulawan	1-2-3	Consolidation Dike+Training Dike	1	D/D	C/D	2	-	3	50	×	×	○
7	Bulawan	2-1-1	Deflection Dike+Training Dike	2	D/D, D/C	-	1	T/D	1	10	×	×	○
8	Bulawan	2-1-2	Deflection Dike+Training Dike	2	D/D, D/C	-	1	T/D	2	20	×	×	○
9	Bulawan	2-1-3	Deflection Dike+Training Dike	2	D/D, D/C	-	1	T/D	3	50	×	×	○
10	Bulawan	2-2-1	Deflection Dike	2	D/D, D/C	-	2	-	1	10	×	×	○
11	Bulawan	2-2-2	Deflection Dike	2	D/D, D/C	-	2	-	2	20	×	×	○
12	Bulawan	2-2-3	Deflection Dike	2	D/D, D/C	-	2	-	3	50	×	×	○

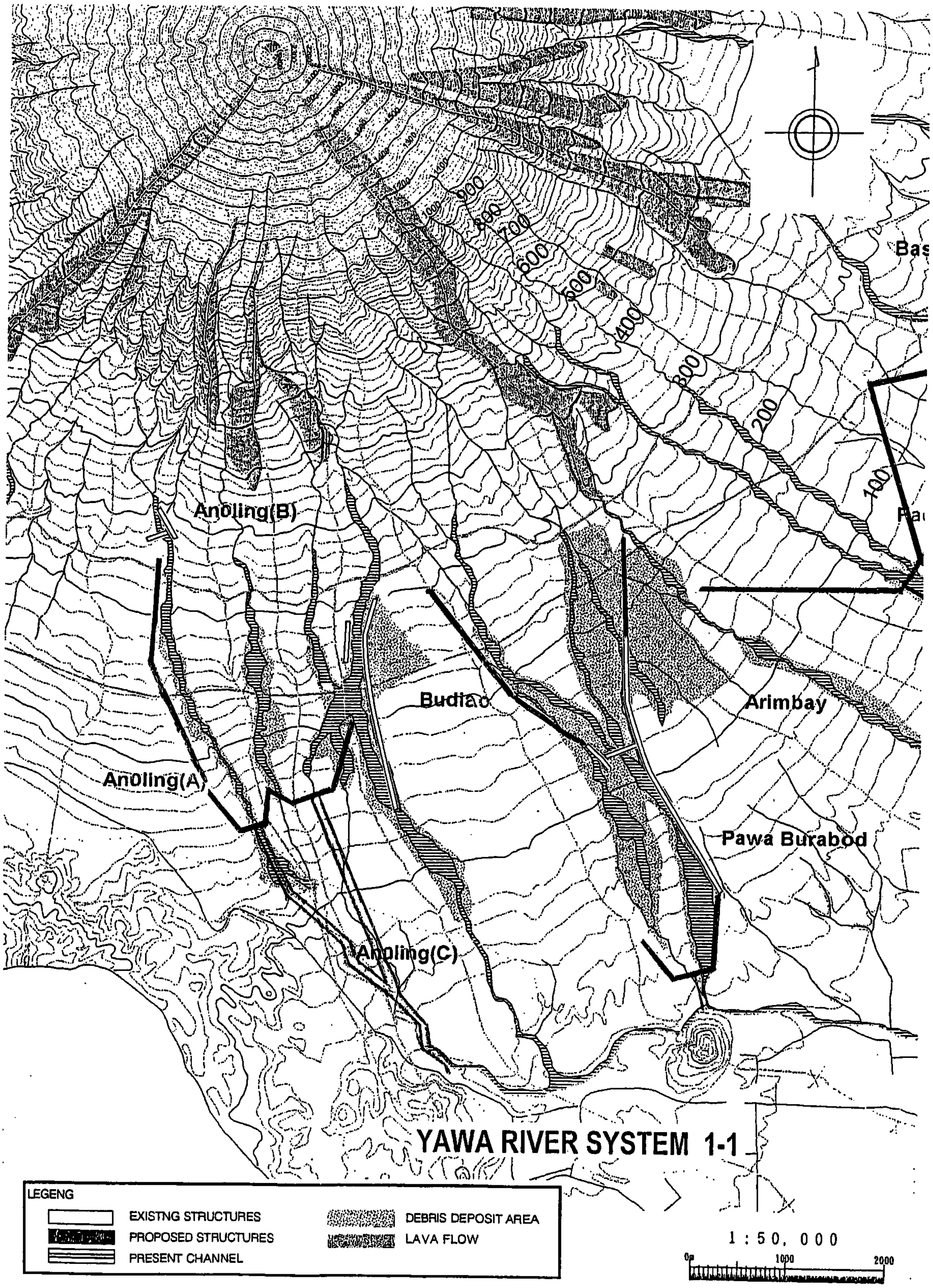
D/D:Deflection Dike, D/W:Dredging Work, F/W:Flood Way, P/D:Protection Dike, R/I:River Improvement, S/P:Sand Pocket, T/D:Training Dike



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	**Figure II 3.1** **Flow Chart of Sabo Structural Planning Around Mayon Volcano**
JAPAN INTERNATIONAL COOPERATION AGENCY	



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	**Figure II 5.1**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Location Map of the Study Area**



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	**Figure II 5.2** Selected Sabo Plan (Yawa River System)
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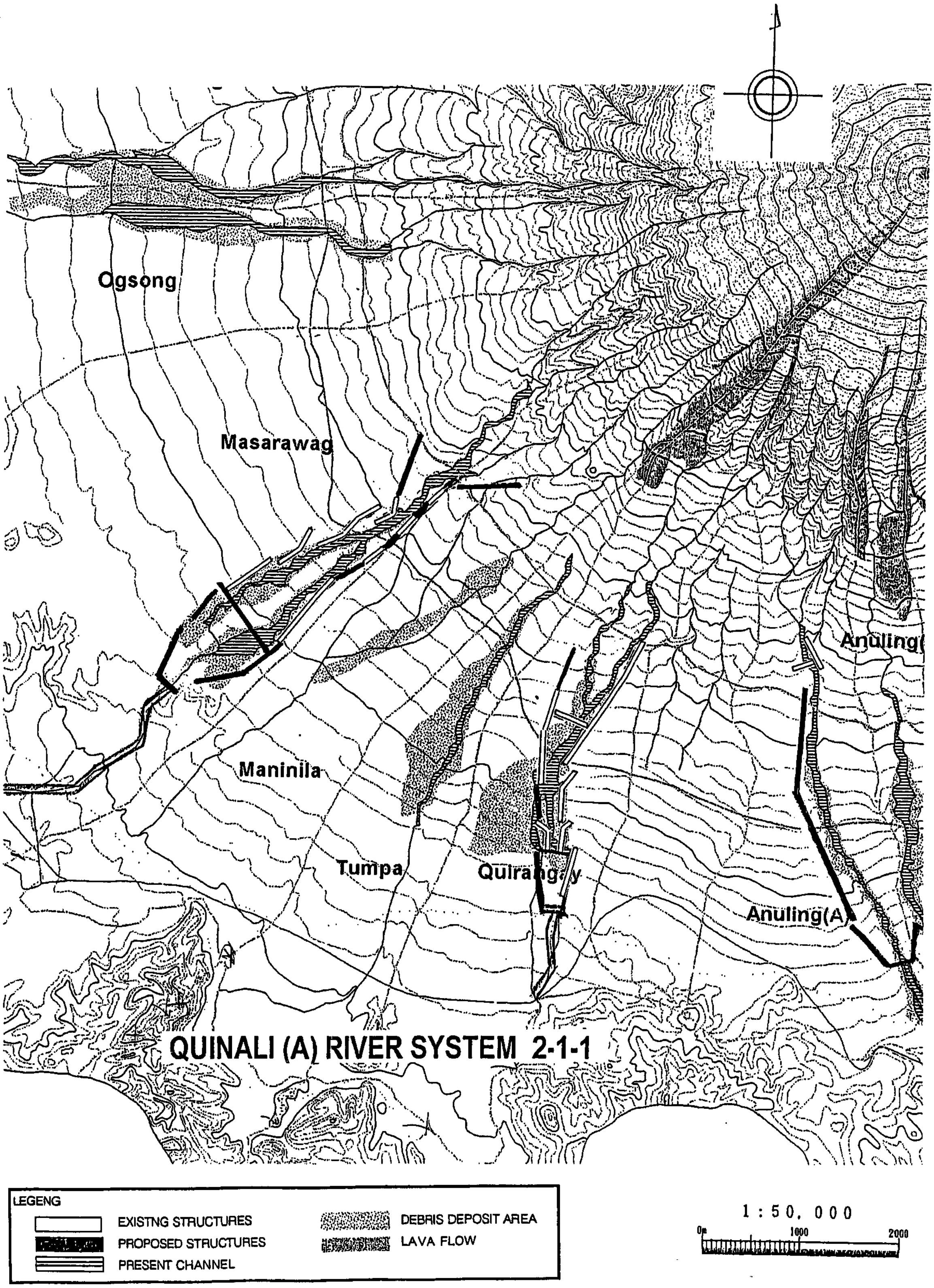

COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	Figure II 5.3 Selected Sabo Plan (Quinali (A) River)
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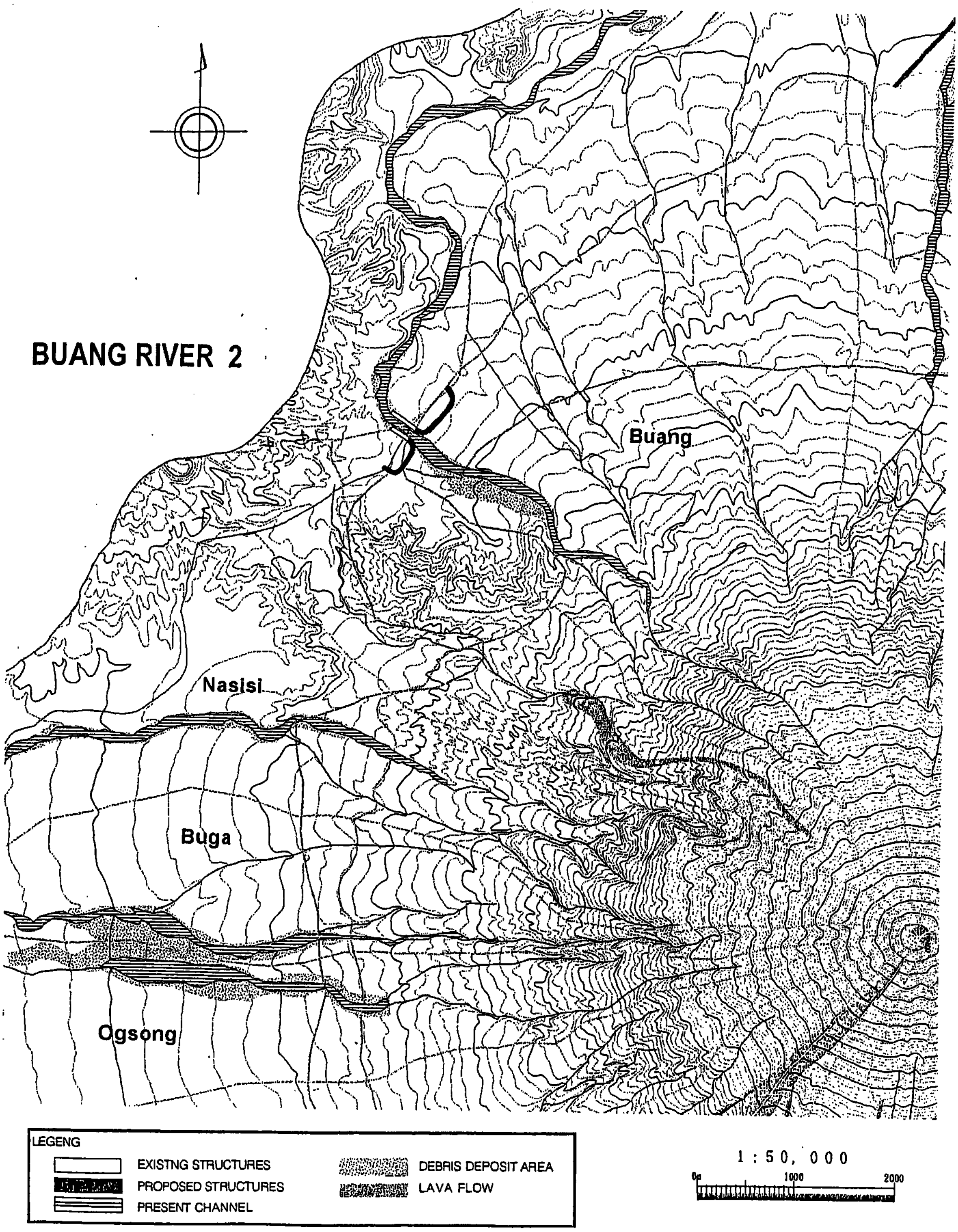
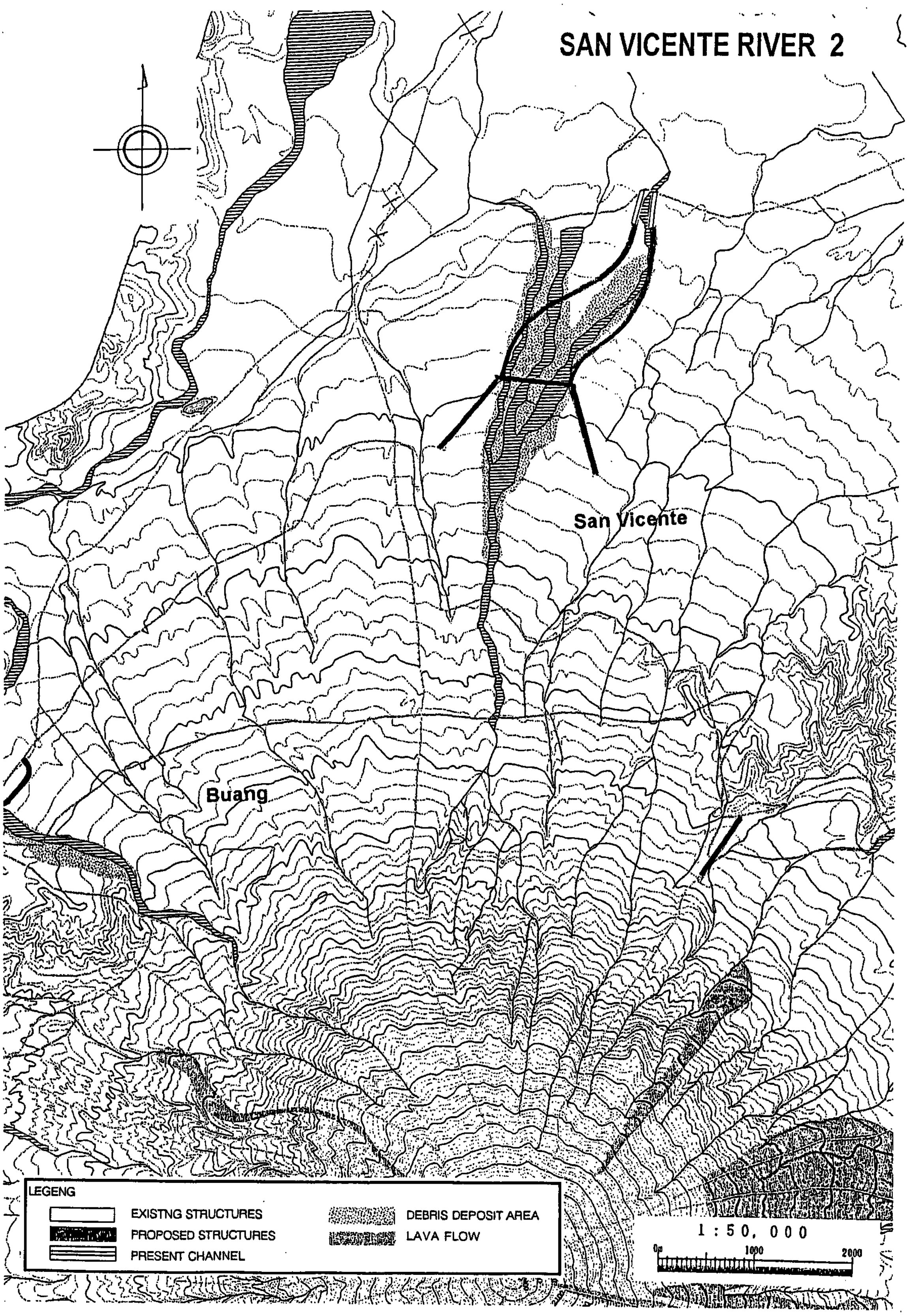


COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	Figure II 5.4 Selected Sabo Plan (Buang River)
JAPAN INTERNATIONAL COOPERATION AGENCY	



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	**Figure II 5.5** **Selected Sabo Plan (San Vicente River)**
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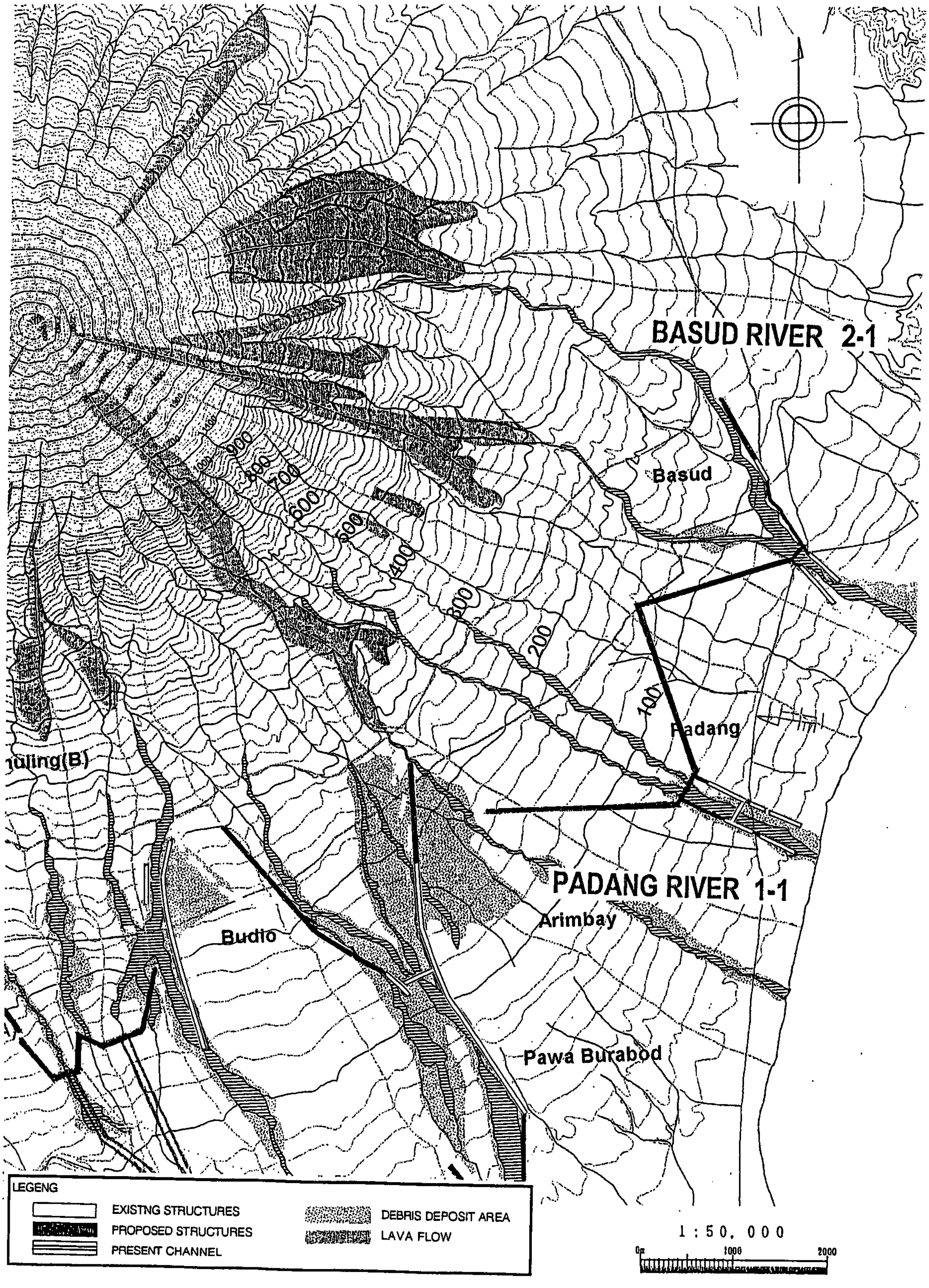
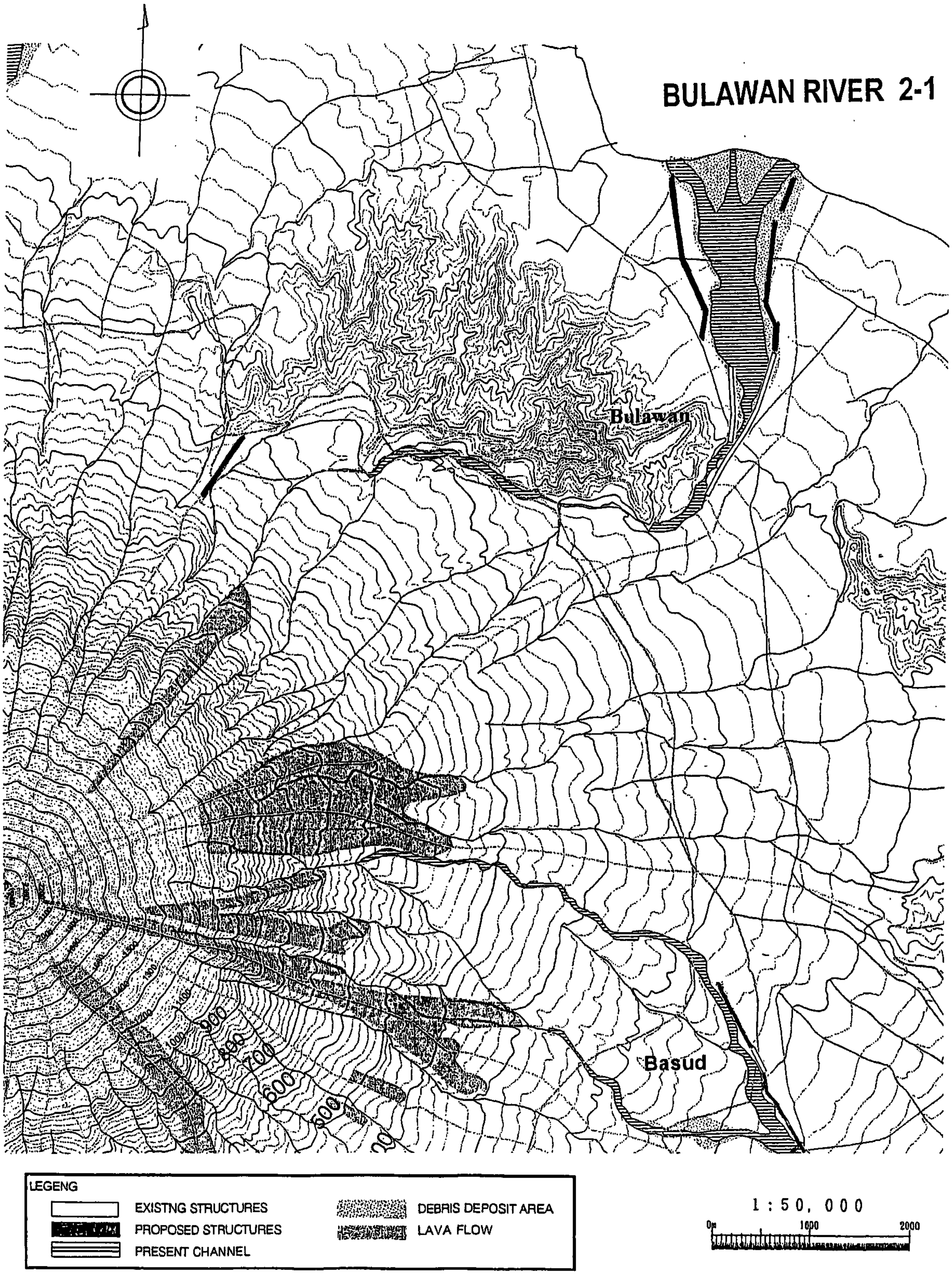


COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	**Figure II 5.6**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Selected Sabo Plan (Padang River and Busud River)**



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	**Figure II 5.7** **Selected Sabo Plan (Bulawan River)**
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