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THE REPUBLIC OF THE PHILIPPINES

RE-STUDY OF MAYON VOLCANO SABO AND FLOOD CONTROL PROJECT

SUPPORTING REPORT I

MARCH 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

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SUMMARY

A. General

This report presents the re-study of Mayon Volcano Sabo and Flood Control Project and covers the following studies:

1. To re-assess and review the Master Plan for Mayon Volcano Sabo and Flood Control Project submitted by JICA in March 1981, taking account of the recent disaster due to typhoon "Daling" in June and July 1981.

2. To conduct a risk analysis and identify the zoning area for the disaster preparedness.

3. To make a study of disaster prediction and warning system covering the area of Mayon Volcano and its surrounding area and to establish measures for disaster preparedness and prevention.

4. To prepare and identify a Sabo project including an immediate phased implementation plan of urgent Sabo facilities, and to formulate the implementation arrangement of the Sabo project.

5. To prepare the detailed engineering design of the emergency Sabo/erosion control facilities at the selected work sites determined by the field survey. Several Sabo facilities on the Anuling River and the Pawa-Burabod River were selected, taking into account the budget of the Philippine Government. The results are presented in "DESIGN REPORT".

B. Re-assessment and Review of the Master Plan

1. The Master Plan was re-assessed and reviewed considering changes in such key factors as hydrological analysis, river planning, Sabo planning, flood damage analysis, costs and benefits, etc.

2. The hydrological analysis made in the Master Plan was reviewed adding meteo-hydrological data after 1980 which include the ones during typhoon "Daling". However, the 50-year probable flood peak runoff estimated this time is almost the same as the previous one. Thus, the design discharge for Sabo and river improvement plan, which is taken as 50-year probable flood, was not revised.

3. Sabo plan for the rivers of the Quinali (A) and the Yawa River basins was changed after the field survey and aerophoto interpretation, considering the disaster and the devastation area due to typhoon "Daling".

4. River improvement plan was not basically changed in this study, since the design discharge was not revised.

5. Aside from the re-assessment and review of the Master Plan, urgent river improvement works and facilities at several places were identified through the field investigations in 1980 and 1982. They are Oas diversion, Tagpo-Cavaci shortcut, Guinobatan improvement and the Tagas River. However, the construction cost and implementation schedule for the works are not included in this study due to insufficient data. Therefore, the works should be implemented after further and relevant studies.

6. Agricultural development plan and irrigation development plan in the Master Plan were not changed in this study.

7. Provisional program for the implementation of the Master Plan was mainly changed on the Sabo plan, taking into account the importance, necessity and urgency of each Sabo facility.

8. Construction cost including physical and price escalation contingencies was changed based on the mid-1982 price level and modification of Sabo works in the Master Plan. Financial cost is summarized as follows:

(Unit: million pesos)

Item	River Basin			
	Quinali (A)	Quinali (B)	Yawa	Total
Whole Construction Period (years)	10	8	7	10
Sabo Works	167.5	11.6	138.3	317.4
River Improvement Works	1,311.3	414.0	57.8	1,783.1
Irrigation Works	120.8	51.3	-	172.1
Total Cost	1,599.6	476.9	196.1	2,272.6

9. The flood damage reduction benefit was obtained through execution of the proposed Sabo and river improvement works. The annual flood damage reduction benefit of the whole project totals P34.8 million comprising P29.0 million for the Quinali (A) River, P2.5 million for the Quinali (B) River and P3.3 million for the Yawa River basins.

10. The annual land enhancement benefit of the whole project was estimated at P33.7 million through the land use intensification, including P24.2 million gained from the irrigation development in the Quinali (A) River basin and P9.5 million from the irrigation development in the Quinali (B) River basin.

11. Economic evaluation was made on the basis of "With and Without project principle". The economic internal rate of return estimated is 4.7% for the whole project, 5.7% for the Quinali (A), 2.7% for the Quinali (B) and 1.64% for the Yawa.

C. <u>Re-study of the Sabo Project</u>

1. After completion of the re-assessment and review of the Master Plan, both a Sabo project on the southern slope of Mayon Volcano where the serious disaster occurred during typhoon "Daling" and a disaster prediction and warning system project were proposed.

2. Based on the field observation and interpretations of aerophotos taken in 1980 and 1982, the disastered zone by mud/debris flow at the foot of Mayon Volcano amounts to 1,329 ha in 1980 and 1,767 ha in 1982. By the results of risk analysis, zoning area such as danger zones and safety zones was identified in the project area. Shelter zones and emergency evacuation areas were selected by the risk analysis only based on the aerophoto interpretation.

3. The Sabo project will be performed by selected Philippine contractors through a competitive bidding. The construction period required for the proposed implementation program is to be 8 years including Stage-I Sabo works and Stage-II Sabo works considering the budget of the Philippine Government. The construction works are divided into eight (8) yearly programs considering the priority, effectiveness and urgency of the Sabo facilities in each river.

4. Disaster prediction and warning system plan was established to predict the occurrence of disasters and to avoid casualties and economic damages.

5. The total construction cost of the Sabo project was estimated at P305.9 million, of which P161.5 million (F/C P44.0 million, L/C P117.5 million) is Stage-I construction cost and P144.4 million (F/C P34.8 million L/C P110.0 million) is Stage-II construction cost.

6. The project cost of the disaster prediction and warning system was estimated at ¥2,070 million in foreign currency portion and P4,059 thousand in local currency portion.

7. Project implementation for the Sabo project was planned for items such as executing agencies, implementation schedule, mode of construction, operation and maintenance and consulting services.

8. The implementation program for the disaster prediction and warning system project is divided into three stages. The construction period of 3 years is required for the first stage, 2 years for the second stage and 2.5 years for the third stage.

9. Economic evaluation of the Sabo project was made in the same way as the re-assessment and review of Master Plan. Financial evaluation was also conducted. And benefits of the disaster prediction and warning system were assessed.

D. Principal Features of the Project

1. Hydrology and Geomorphology

1) General

Item	River Basin		
	Quinali (A)	Quinali (B)	Yawa
Drainage Area at River Mouth	524 km^2 (at Lake Bato)	158 km^2	74 km^2
River Length at River Mouth	57 km (at Lake Bato)	31 km	17 km
Average Annual Rainfall	2,400 mm (at Guinobatan)	4,200 mm (at Malinao)	3,300 mm (at Legazpi)

2) 1-Day Point Rainfall

Station	Master Plan (Period)	Review (Period)
Guinobatan	386 mm (1956 - 79)	394 mm (1956 - 81)
Legazpi	519 (1956 - 79)	510 (1956 - 81)
Allang	389 (1975 - 79)	344 (1975 - 81)
Sto. Domingo	350 (1956 - 79)	342 (1956 - 81)
Malinao	381 (1972 - 79)	382 (1972 - 81)
Quinali (A) River basin	358 (1972 - 79)	336 (1972 - 81)

3) 50-Year Probable Flood Peak Runoff

Name of River	Drainage Area	Master Plan	Review	Difference
Quinali (A) (A-59)	524.2 km	4,070 m^3/sec	4,170 m^3/sec	2.4 %
Nasisi (A-34)	84.2	1,697	1,656	2.5
Yawa (Y-14)	74.4	2,083	2,142	2.7
Pawa-Burabod (Y-12)	7.6	299	296	1.0
Anuling (Y-1)	9.4	377	373	1.1
Quinali (B) (B-21)	157.8	2,369	2,383	0.6

Remarks: The difference between the Master Plan and this study is negligibly small, so that the probable 50-year flood peak runoff in the Master Plan is not changed.

2. Sediment Volume for Sabo Works

Name of River	Sediment Runoff Volume (m^3)	Allowable Sediment Volume (m^3)	Excess Sediment Volume (m^3)
Quirangay	260,100	82,600	177,500
Tumpa	43,800	35,200	8,500
Maninila	94,000	36,700	57,300
Masarawag	276,800	77,600	199,200
Ogsong	140,500	32,700	107,800
Nasisi	992,100	270,900	721,200
Anuling	415,600	85,800	329,800
Budiao	234,600	58,100	176,500
Pawa-Burabod	252,000	69,500	182,500

Remarks: Sediment volume for the Buang River (Quinali (B)) is not changed in this study. They are 319,700 m^3, 143,700 m^3 and 176,000 m^3 respectively.

3. Sabo Facilities

Name of River	Proposed Works	Scale of Works	Remarks
Quinali (A) River Basin			
Quirangay	Sabo Dam (Slit type)	Height: 10.0 m Length: 30.0 m	
	Training Levee	Length: 310 m	On the left bank
	Spur Dike (Type B)	At four (4) sites Total length: 990 m	On the left bank
Tumpa	Consolidation (with coconut fence)	At sixteen (16) sites Total length: 160 m	Drop: 1.0-2.0m
Maninila	Ground sill (Type B)	At nine (9) sites Total length: 450 m	
Masarawag	Sabo Dam (Slit type)	Height: 10.0 m Length: 120 m	
	Spur Dike (Type A)	At four (4) sites Total length: 910 m	
Ogsong	Spur Dike (Type A)	At six (6) sites Total length: 1,200 m	
	Jetty	At seven (7) sites Total length: 560 m	
	Ground sill (with crib)	At seven (7) sites Total length: 260 m	Drop: 2.0-3.0m
Nasisi	Consolidation dam	At two (2) sites Total length: 430 m	with spur dike
	Ground sill (Type A)	At three (3) sites Total length: 690 m	with spur dike
Yawa River Basin			
Anuling	Sabo Dam (Slit type)	Height: 10.0 m Length: 60.0 m	Anuling 1
	Ground sill (Type A)	At two (2) sites Total length: 210 m	One is attached with spur dike
	Training Levee	Length: 600 m	On the right bank Anuling 1

Name of River	Proposed Works	Scale of Works	Remarks
	Sabo Dam (Slit type)	Height: 10.0 m Length: 70.0 m	Anuling 2
	Spur Dike (Type A)	At two (2) sites Total length: 540 m	"
	Spur Dike (Type A)	At four (4) sites Total length: 860 m	Downstream of the confluence
	Spur Dike (Type B)	At one (1) site Total length: 480 m	"
Budiao	Sabo Dam (Slit type)	Height: 10.0 m Length: 90.0 m	
	Training Levee	Length: 400 m	On the left bank
	Spur Dike (Type A)	At three (3) sites Total length: 760 m	
	Spur Dike (Type B)	At one (1) site Total length: 400 m	
Pawa-Burabod	Sabo Dam (Slit type)	Height: 10.0 m Length: 80.0 m	
	Consolidation dam	Height: 4.0 m Length: 120 m	
	Spur Dike (Type A)	At four (4) sites Total length: 1,000 m	
	Spur Dike (Type B)	At three (3) sites Total length: 750 m	

Remarks: Sabo facilities comprising 1 Sabo dam and 4 Consolidation & Spur dike in the Quinali (B) River basin are the same as the Master Plan.

4. River Improvement Works

Item	River Basin		
	Quinali (A)	Quinali (B)	Yawa
Improvement Length	48.8 km	21.8 km	2.3 km
Design Discharge	920 - 4,260 m^3/sec	270 - 2,420 m^3/sec	2,150 m^3/sec
Proposed Riverbed Slope	1/130 - 1/1,550	1/80 - 1/1,200	1/300 - 1/1,000
Proposed River Width	80 - 450 m	42 - 270 m	150 - 190 m
Proposed Levee			
Slope	1 : 2	1 : 2	1 : 2
Top Width	4 - 5 m	4 - 5 m	5 m
Freeboard	1.0 - 1.2 m	1.0 - 1.2 m	1.2 m
Proposed River Cross Section	Simple and Compound	Simple and Compound	Compound
Sluiceway	7 sites (2m x 2m x 26 nos.)	-	-

Remarks: River improvement works established in the Master Plan are not changed in this Re-study.

5. Agricultural Development Scheme

Item	River Basin	
	Quinali (A)	Quinali (B)
Irrigation Area		
Existing (Net)	3,640 ha	1,370 ha
Proposed (Net)	6,350 ha	2,400 ha
Weir (New)	2	1
Intake (New)	3	1
Irrigation Canal		
Main	45 km	11 km
Secondary	80 km	41 km
Drainage Canal		
Main & Secondary	71 km	45 km
Field Drain	238 km	95 km
Sluiceway	7	4
Fertilization		
Existing	70 kg N/ha	70 kg N/ha
Proposed		
Dry Season	100 kg N/ha	100 kg N/ha
Wet Season	80 kg N/ha	80 kg N/ha
Palay Yield		
Present		
Dry Season	3.8 tons/ha	3.8 tons/ha
Wet Season	3.5 tons/ha	3.5 tons/ha
Proposed		
Dry Season	5.0 tons/ha	5.0 tons/ha
Wet Season	4.5 tons/ha	4.5 tons/ha

Remarks: Agricultural development schemes established in the Master Plan are not changed in this Re-study.

6. Stagewise Development for the Disaster Prediction and Warning System

Stage	Stations for Prediction	Stations for Warning	External Information Stations
First Stage	Legazpi weather station (R) Mayon Rest House Mabinit Quirangay Tabaco (EL. 300 m) San Roque Legazpi Golf Micericoraia	OCD Legazpi Office, Matanag Ligao Libon	PAGASA Legazpi, PAGASA Manila
Second Stage	(R) Ligao, Nasisi Libon, Balaigang, Masarawag (W) Bato	Barangays other than the above: Tabaco Micericordia	OCD Legazpi, OCD Manila PAGASA Legazpi, PAGASA Manila
Third Stage	Water level other than the above: (V) Micericordia	-	-

Note: (R) Rainfall observatories
(W) Water level observatories
(V) Volcanic observatories

In addition to the stations described above, 4 warning mobil units should be prepared in Legazpi and 2 units each in Ligao and Tabaco.

7. Construction Cost Updated by the Re-study of the Master Plan

(Unit: 1000 Pesos)

Description	Quinali (A) River		Quinali (B) River		Yawa River		Total	
	Foreign Currency Portion	Local Currency Portion	Foreign Currency Portion	Local Currency Portion	Foreign Currency Portion	Local Currency Portion	Foreign Currency Portion	Local Currency Portion
1. Contract Cost								
(1) Direct Cost	256,371	266,190	91,702	85,833	28,319	49,304	376,392	401,327
(2) General	25,637	26,620	9,171	8,584	2,832	4,931	37,640	40,135
(3) Supervision & Miscellaneous	16,920	17,568	6,052	5,664	1,868	3,254	24,840	26,486
(4) Profit	29,893	31,037	10,693	10,008	3,301	5,749	43,887	46,794
(5) Contractor's Tax	9,865	10,243	3,529	3,303	1,090	1,898	14,484	15,444
Sub total	338,686	351,658	121,147	113,392	37,410	65,136	497,243	530,186
2. Right of Way/Site Acquisition	-	17,688	-	3,606	-	410	-	21,704
3. Resettlement	-	24,293	-	878	-	1,134	-	26,305
4. Engineering Cost	27,950	41,084	10,605	12,849	1,224	9,030	39,779	62,963
5. Project Management Cost	-	34,516	-	11,727	-	5,128	-	51,371
6. Contingency								
(1) Physical Contingency	66,431	67,966	24,155	22,552	6,223	10,652	96,809	101,170
(2) Price Escalation	161,581	467,819	47,296	108,685	11,164	48,625	220,041	625,129
Total	594,648	1,005,024	203,203	273,689	56,021	140,115	853,872	1,418,828

8. Construction Cost for Sabo Project

(Unit: 1,000 Pesos)

Description	Stage - I		Stage - II		Total		Grand Total
	Foreign Currency Portion	Local Currency Portion	Foreign Currency Portion	Local Currency Portion	Foreign Currency Portion	Local Currency Portion	
1. Contract Cost							
(1) Direct Cost	23,622	43,926	15,207	27,838	38,829	71,764	110,593
(2) General	2,363	4,392	1,520	2,784	3,883	7,176	11,059
(3) Supervision & Miscellaneous	1,559	2,899	1,004	1,837	2,563	4,736	7,299
(4) Profit	2,755	5,122	1,773	3,246	4,528	8,368	12,896
(5) Contractor's Tax	910	1,689	584	1,072	1,494	2,761	4,255
Sub total	31,209	58,028	20,088	36,777	51,297	94,805	146,102
2. Right of Way/Site Acquisition	-	25	-	15	-	40	40
3. Resettlement	-	-	-	-	-	-	-
4. Engineering Cost	-	8,923	-	5,687	-	14,610	14,610
5. Project Management Cost	-	4,462	-	2,843	-	7,305	7,305
6. Contingency							
(1) Physical Contingency	4,681	8,704	3,013	5,517	7,694	14,221	21,915
(2) Price Escalation	8,074	37,390	11,708	58,710	19,782	96,100	115,882
Total	43,964	117,532	34,809	109,549	78,773	227,081	305,854

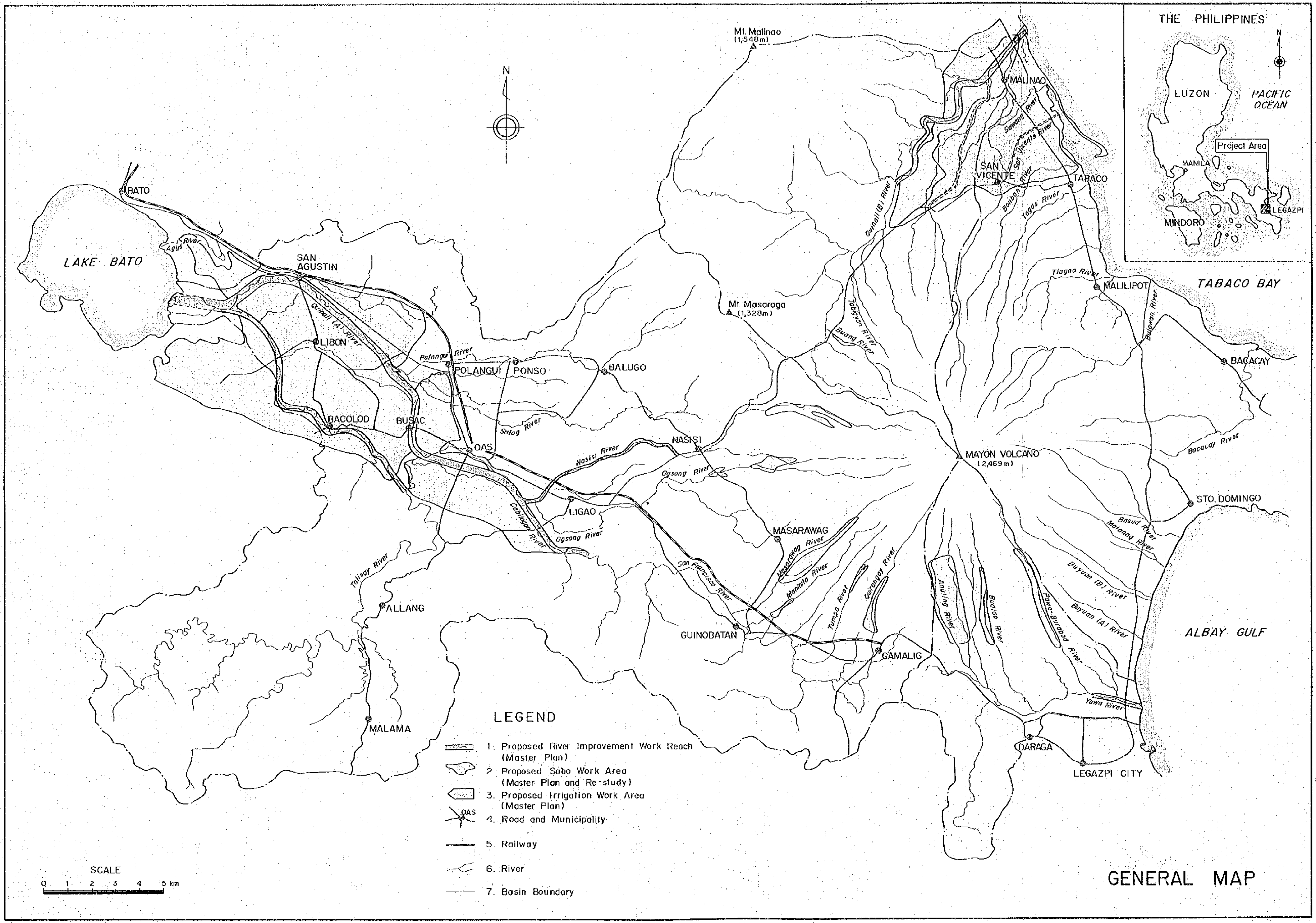
9. Construction Cost for Disaster Prediction and Warning System

(Unit: 1000 Yen & 1000 Peso)

Description	Stage-I		Stage-II		Stage III		Total	
	Foreicn Currency Portion	Local Currency Portion	Foreign Currency Portion	Local Currency Portion	Foreign Currency Portion	Local Currency Portion	Foreign Currency Portion	Local Currency Portion
1. Telemetry System by 150 MHz Radio System	156,802	-	55,874	-	86,944	-	299,620	-
2. Warning System by Multi-Access Radio System	300,083	-	86,275	-	5,075	-	391,433	-
3. Multiplex Radio Communication System	249,348	-	83,102	-	-	-	332,450	-
4. HF Communication System	9,800	-	17,980	-	-	-	27,780	-
5. Installation Materials	93,560	-	36,700	-	19,210	-	149,470	-
6. Installation Works	211,803	2,048	111,600	1,185	23,746	456	347,149	3,689
7. Training	27,000	-	-	-	-	-	27,000	-
8. Maintenance Service (One Year)	73,000	-	-	-	-	-	73,000	-
9. Sub total (1. to 8.)	1,121,396	2,048	391,531	1,185	134,975	456	1,647,902	3,689
10. Consultancy Service	145,676	-	50,116	-	38,000	-	233,792	-
11. Basic Construction Cost	1,267,072	2,048	441,647	1,185	172,975	456	1,881,694	3,689
12. Contingency	126,707	205	44,164	119	17,298	46	188,169	370
13. Total Construction Cost	1,393,779	2,253	485,811	1,304	190,273	502	2,069,863	4,059

10. Economic Cost and Benefit

Item	River Basin			
	Quinali (A)	Quinali (B)	Yawa	Total
Whole Construction Period (years)	10	8	7	10
Sabo Works (million pesos)	76.3	4.2	75.8	156.3
River Improvement Works (million pesos)	592.2	209.7	32.8	834.7
Irrigation Works (million pesos)	73.7	30.5	-	104.2
Total Cost (million pesos)	742.2	244.4	108.6	1,095.2
Annual Flood Reduction Benefit (million pesos)	29.0	2.5	3.3	34.8
Annual Negative Benefit by River Improvement (million pesos)	-0.3	-	-	-0.3
Annual Mud/debris Flow Reduction Benefit (million pesos)	1.8	-	1.7	3.5
Annual Land Enhancement Benefit (million pesos)	24.2	9.5	-	33.7
Total Annual Benefit (million pesos)	54.7	12.0	5.0	71.7
Internal Rate of Return (%)	5.9	2.7	2.8	4.9


THE PHILIPPINES
LUZON
PACIFIC OCEAN
Project Area
MANILA
MINDORO
LEGAZPI
Mt. Malinao (1,548m)
MALINAO
SAN VICENTE
TABACO
TABACO BAY
MALILIPOT
BACACAY
Mt. Masaraga (1,328m)
MAYON VOLCANO (2,469m)
STO. DOMINGO
ALBAY GULF
BATO
LAKE BATO
SAN AGUSTIN
LIBON
POLANGUI
PONSO
BALUGO
BACOLOD
BUSAC
OAS
NASISI
LIGAO
MASARAWAG
GUINOBATAN
CAMALIG
DARAGA
LEGAZPI CITY
ALLANG
MALAMA
Agus River
Quinali (A) River
Quinali (B) River
Polangui River
Salog River
Nasisi River
Ogsong River
Cabilogan River
Talisay River
San Francisco River
Masarawag River
Maninila River
Tumpa River
Quirangay River
Anuling River
Budiao River
Pawa-Burabod River
Buyuan (A) River
Buyuan (B) River
Matanag River
Basud River
Bacacay River
Bulawan River
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Tobigon River
Buang River
Bonbon River
San Vicente River
Sawang River
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RE-STUDY

OF

MAYON VOLCANO SABO AND FLOOD CONTROL PROJECT

SUPPORTING REPORT I

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ABBREVIATION

BAEcon	Bureau of Agricultural Economics
BAEx	Bureau of Agricultural Extension
BFCD	Bureau of Flood Control and Drainage
BPI	Bureau of Plant Industry
BRBDP	Bicol River Basin Development Program
COMVOL	Commission on Volcanology
DCC	Disaster Coordinating Council
EEA	Emergency Economic Administration
FAO	Food and Agriculture Organization of the United Nations
JICA	Japan International Cooperation Agency
MATELCO	Mayon Telephone Cooperation
MPWH	Ministry of Public Works and Highways
MSSD	Ministry of Social Services and Development
NCSO	National Census and Statistics Office
NEDA	National Economic and Development Authority
NIA	National Irrigation Administration
NWRC	National Water Resources Council
OCD	Office of Civil Defence
PAGASA	Philippine Atomospheric Geophysical and Astronomical Services Administration
PLDTS	Philippine Long Distance Telephone Services
PNR	Philippine National Railway
UNDP	United Nations Development Program
mm	millimeter
cm	centimeter
m	meter

km	kilometer
in.	inch
m^2	square meter
km^2	square kilometer
ha	hectare
$mile^2$	square mile
m^3	cubic meter
m/sec	meter per second
l/sec	liter per second
m^3/s	cubic meter per second
$m^3/sec/km^2$	cubic meter per second per square kilometer
$m^3/year/km^2$	cubic meter per year per square kilometer
mm/hr	millimeter per hour
lit/sec/ha	liter per second per hectare
m/ha	meter per hectare
kg/ha	kilogram per hectare
kgN/ha	kilogram nitrogen per hectare
kgP_2O_2/ha	kilogram phosphate per hectare
kgK_2O/ha	kilogram potassium per hectare
mg/l	miligram per liter
yr	year
%	percent
^oC	degree centigrade
EL.	elevation above mean sea level
Mt.	Mount
GNP	Gross National Product
GDP	Gross Domestic Product
GRDP	Gross Regional Domestic Product

FOB	Free on Board
P	Philippine peso
US$	United States dollar
¥	Japanese yen
CY	Calendar Year
FY	Fiscal Year
SSS	Social Security System
GSIS	Government Security and Insurance System
palay	paddy

CHAPTER I

I. INTRODUCTION

1.1 Historical Background

Mayon Volcano with an elevation of 2,469 m which is located in the southeast of Luzon, the Republic of the Philippines, has erupted periodically about once every 10 years. In the surrounding area of Mayon Volcano and the Quinali (A) River basin, the ejecta as lava, volcanic ashes, etc. from the volcano has run out as an avalanche of earth and rocks or a debris flow with heavy rain and thus has caused such serious damages as burying of houses, paddy field, and washing away of railway, road, dike, etc. In the plain area of the Quinali (A) River basin, flooding has brought about much sediment deposition and thus caused a serious damage due to flood inundation. Sabo works for the surrounding area of the volcano have been a long-cherished desire of the inhabitants in this region and also an outstanding problem of the Philippine Government.

In August, 1977, the Philippine Government officially requested the Japanese Government to study the Project. In response to the request of the Philippine Government, the Japanese Government despatched three experts during the period from January 16 to January 19 in 1978. They examined a course of cooperation by the Japanese Government, necessity of preliminary study, and possibility of the project implementation. As a conclusion, they were convinced of the necessity of countermeasures against debris extrusion and recommended the urgent despatch of a preliminary study team.

In response to the above recommendation and the request of the Philippine Government, a preliminary study team consisting of six experts was despatched to the field during the period from May 29 to June 17 in 1978. The team confirmed the urgent necessity of the proper study and possibility of the project implementation based upon the results of site reconnaissance and its examination, hearing of the situation from and the consultation with the Philippine Government. The team then proposed the basic principle, work items and work schedule of the study of the Project.

The Project was studied by two (2) phases. The Study Team for the first phase was despatched to the field during the period from September 17 to December 18 in 1979, and performed detailed design of Sabo facilities in the Pawa-Burabod River, a tributary of the Yawa River according to the request of the Philippine Government. And the Team submitted the Design Report to the Philippine Government in March 1980.

The Study Team for the second phase was despatched to the field during the period from June 23 to August 30 in 1980, and established the Master Plan for the Project. And the Team submitted the Master Plan Report to the Philippine Government in March 1981. The study covered the area of Mayon Volcano and its surrounding area, which is directly or indirectly affected by the mud/debris flow and flood flow. The study included the Sabo works, the river improvement works and the irrigation works.

After the disaster due to typhoon "Daling" in June 1981, the Philippine Government officially requested the Japanese Government to provide a technical assistance for the re-study of the Project in August 1981. In response to the request of the Philippine Government, the Japanese Government despatched a preliminary survey team in February 1982. The team comfirmed a necessity of re-study of the Master Plan and a disaster prevention program, taking into account the recent disaster that occurred in the area.

The Study Team was despatched to the field during the period from June 1 to July 31 in 1982, and conducted the re-study of the Project. The Team also prepared detailed engineering design of Sabo facilities for urgent projects in the first year program after further study in Japan.

1.2 Objectives of the Re-Study and Scope of Work

The study is conducted to protect human life and property and promote the living standard of the population in the Mayon Volcano area. The objectives of the study are to re-assess and review the Master Plan, to re-study and formulate the Sabo Project and to prepare a detailed engineering design of the emergency Sabo/erosion control facilities. The study aims in detail:

To re-assess and review the Master Plan for the Mayon Volcano Sabo and Flood Control Project submitted by JICA in March 1981, taking account of the recent disaster occurred in the Mayon Volcano area in June and July 1981 among others.

To conduct a risk analysis and identify the zoning area for the disaster preparedness.

To make a study of the disaster prediction and warning system covering the area of the Mayon Volcano and its surrounding area and to establish measures for disaster preparedness and prevention.

To prepare and identify the Sabo project including an immediate phased implementation plan of urgent Sabo facilities, and to formulate the implementation arrangement of the Sabo project.

To prepare the detailed engineering design of the emergency Sabo/erosion control facilities at the selected work site determined by the field survey, i.e. several Sabo facilities located in the Anunling River and the Pawa-Burabod River, taking into account the first year budget of the Philippines.

1.3 Acknowledgement

Throughout the period of this investigation, the Study Team has maintained close cooperation with the Philippine Government for all engineering and administrative matters. Many data and informations required for the study were provided by the Philippine Government.

The Study Team takes this opportunity to express its sincere thanks to the Ministry of Public Works and Highways(MPWH), MPWH Regional Office, No. V, Rawis, Legazpi City and all other Authorities concerned for their kind cooperation and assistance to the Study Team during its stay in the Philippines. The Study Team feels it particularly happy to be able to contribute with this study to the development of the Philippines.

CHAPTER II

II. NATIONAL AND REGIONAL SOCIO-ECONOMIC BACKGROUND

2.1 National Socio-economic Condition

The Philippines is located between latitude 5° and 21° north and between longitude 117° and 127° east with an area of 300 thousand km^2. The natural conditions of the Philippines are very favorable for agricultural production. Total population of the country was about 47.9 million in 1980 with the population density of about 160 persons per km^2, which increased at an average rate of 2.7% per annum during the period of 1970-1978.

The gross domestic product (GDP) in 1980 was P270 billion or the equivalent of US$34 billion, and per-capita GDP was approximately P5,640 (US$710). About 39% of GNP is occupied by service sector followed by 37% of industrial sector. The agriculture sector has relatively lower share in GNP compared with other non-agricultural sectors, which accounts for 23% of GNP. During the past five years from 1975 to 1980, GNP in real terms increased by 6.3% per annum.

The government of the Philippines has embarked on the five-year plan (1983-1987). The plan envisages to raise GNP at an average annual growth rate of 7.7% for the five-year plan period. The major national goals of the plan envisage to attain; i) sustainable economic growth, ii) more equitable distribution of the fruits of the development and iii) total human development.

2.2 Regional Socio-economic Condition

The project area is located in the Bicol Region consisting of six provinces (Albay, Camarines Norte, Camarines Sur, Catanduanes, Masbate and Sorsogon), three cities (Iriga, Legazpi and Naga) and 113 municipalities. The Bicol Region has the total area of 17,633 km^2 and the total population of 3,467 thousand in 1980. Annual population growth rate of the Bicol Region was about 1.6% on an average from 1970 to 1980 and population density was 197 persons per km^2 in 1980.

Gross regional domestic product (GRDP) of the Bicol Region between 1975 and 1980 grew by 4.6%, or, in absolute terms, from P2,554 million in 1975 to P3,195 million in 1980 at 1972 constant prices. Per-capita GRDP was about P920 in 1980, which was lower than the national level.

Agriculture sector including fishery and forestry is the region's largest economic sector, producing about 52% of the total regional product in 1980. In 1979, there were 1,271 thousand persons employed compared with 911 thousand in 1970 and the employment has increased by 3.8% annually. Agriculture remains to be the main source of livelihood as indicated by about 739 thousand workers, or 58% in agriculture activities, and industry's share was approximately 176 thousand or 14%, while the rest of the economy accounted for 356 thousand or 28% of total employed in 1979.

All the consumer price indices in the Bicol Region indicate price increase during the period from 1972 to 1980, and especially higher price increase during the period from 1972 to 1974 was caused due to quadruple increase in oil price. The consumer price increased by 12.9% annually on the average from 1975 to 1980.

To contend with the problems of the region, the development plan for 1983-1987 is formulated. For the years from 1983 to 1987, an average growth rate of 7.4% is aimed to lift the GRDP from P3,829 million in 1983 to P5,094 million by 1987 for an increase of 33% over the five-year span. Among subsectors, agriculture will increase production by 7.4% annually, industry by 5.2%, and services by 8.7%. Valued at 1972 prices, output-per-person in the region will increase from P1,035 in 1982 to P1,290 by 1987.

CHAPTER III

III. PRESENT CONDITIONS OF THE PROJECT AREA

3.1 Geomorphology, Geology and Land Classification

3.1.1 Geomorphology

An environment of the Mayon Volcano in Albay Province in southeastern Luzon and the Quinali (A) River basin between Mayon Volcano and Lake Bato are studied for the project area. Mayon Volcano is one of the world famous mountains for its picturesque conical form of symmetry. It is an active volcano of typical konide stratovolcano with an elevation of 2,469 m. There are an extinct volcano of Masaraga (EL. 1,328 m) in the west side and a dormant volcano of Malinao (EL. 1,548 m) in northwest side of the Mayon Volcano.

A low hill area lower than EL. 400 m is extending in the south of the project area, comprising sandstone, shale, limestone and volcanic rocks of Pleistocene and Tertiary. The surveyed area can be divided into two geomorphological areas, Mayon Volcano area and alluvial plain area.

(1) Mayon Volcano

Mayon Volcano is a typical stratovolcano consisting of alternation of lava and pyroclastic materials, showing younger stage of geomorphic cycle. Contour line is concentric around its crator. Characteristic drainage pattern is radial and consequent valleys have been formed. Rivers above EL. 200 m - 300 m are intermittent streams which flow only in heavy rainfall time or in rainy season, because most of the ground is covered with well-permeable pyroclastic flow deposits. Between summit and mid slope of EL. 1,500 m, the Mayon slope is extending barren ground with talus covers and grass land of Cogon dissected with dry gullies. These gullies develop into V-shaped at EL. 1,500 m down to 600 m, into U-shaped at lower than EL. 600 m, and finally diverge into unsettled shallow channels over the alluvial fan at EL. of 200 m - 300 m. River deposits below EL. 600 m are mostly debris flow deposit in recent age and gravelly, accompanying big blocks. Especially, between EL. 200 m and 300 m, debris flow deposits are covering the gentle slope. The riverbed of the lower Basud River is raised up close to the girder of the San Isidro-Lidong Bridge on the eastern slope. On the other hand at the Buang Bridge on the lower Buang River on the western slope, the riverbed is scoured and bridge piers are exposed at the foot. Slope gradient of Mayon Volcano can be classified at clear transition points as follows.

Slope section	Gradient (degree)
Below elevation of 200 m - 300 m	less than 3°
" 500 m - 600 m	around 5°
" 900 m - 1,000 m	15° - 20°
" 1,600 m - 1,700 m	25° - 27°
above 1,600 m - 1,700 m	30° - 42°

Thus, difference of slope gradient is more than 10 degrees around EL. 600 m, where very sharp transition of gradient appears. It shows that the upper slope of the transition point is covered with debris and volcanic ejecta on the surface and lava flow underneath, and that the lower slope mostly comprises pyroclastic materials. It means that debris flow comes into existence and runs on the upper slope and runs through or deposits on the lower slope.

There are several small hills of cinder cone, dacitic volcanic spine with an elevation lower than 300 m, such as Tagontong Hill of Kilicao, Mt. Quituinan of Bublusan and Tancalao Hill in the southwest of Malinao.

(2) Alluvial Plain

There are developing alluvial plains around Legazpi City, south of the Yawa River along the Albay Gulf, and plain along the Quinali (B) River, which rises in Malinao Volcano and Masaraga Volcano and debouches into the Tabaco Bay. These alluvial plains are extension of alluvial fans on the skirt of Mayon Volcano. North of the plain along the Quinali (A) River, debouched to Lake Bato abuts on the skirt of Masaraga Volcano with an elevation of 1,328 m. South of the plain abuts on the foot of hills with an elevation of about 400 m of sedimentary and volcanic rocks of Pleistocene - Tertiary period. The plain extends with a width of 6 km.

An active fault (San Vicente - Ligao Fault) is running along the boundary between the hills and the plain, showing very clear line extending to WNW - ESE direction.

Lake Bato where the Quinali (A) River debouches, is very shallow. Its bottom is about 1.5 m above mean sea level, its surface is 6 m in elevation and its surface area is 20 km^2, having low flat plain around the lake.

3.1.2 Geology

The Philippine Archipelago is located in the Circum-Pacific Islands arc or in the Circum-Pacific Active Zone, where volcanic and earthquake activities are concentrated. Bicol peninsula is located in a graben between Philippine Deep on the east and Philippine Fault Zone on the west. A big active fault (San Visente-Ligao Fault) of WNW-ESE is running in the south of Mayon Volcano.

A series of typical andesitic volcanic rocks has been developed around the Mayon volcanic group during the period from Tertiary to the Recent. According to the plate-techtonic theory, when the oceanic plate (Philippine Plate) thrusts underneath the Philippine archipelago to the depth of 100 - 200 km, the plate is metamorphosed and emitted hot fluid causes melting of mantle material to form andesitic magma which extrudes as volcanism. Geology of Mayon Volcano and its surroundings is classified as follows:

(1) Volcanic rocks of andesite and dacite (partly including phyolite) and sedimentary formations of sandstone, shale and conglomerate of Oligocene to Miocene Tertiary.

(2) Andesitic volcanic rocks of upper Miocene Tertiary to Pleistocene Quaternary (partly including phyolitic volcanic spine and cinder cone).

(3) Limestone and limestone-bearing sandstone, mudstone and conglomerate of Pliocene Tertiary to Pleistocene Quarternary.

(4) Lava, ash fall deposits, pyroclastic rocks, debris flow deposits, and mud flow deposits formed directly from Mayon activity during the period of Pleistocene Quaternary to the recent.

(5) Alluvium consisting of gravel, sand and silt deposited in Holocene (partly including littoral deposits).

Items (1) - (3) are developing around Mayon Volcano and hilly area on both sides of the Quinali (A) River Plain.

No sedimentary rock formations such as limestone, sandstone, conglomerate and mudstone are developing on the north side of the San Vicente-Ligao Fault, but all is covered with volcanic rocks. Sedimentary rocks and volcanic rocks that formed before Mayon activity are rather hard and compact, resistive against corrosion and sound enough for foundation of heavy structures, though their distribution is very limited.

There are several low hills in the skirt of Mayon Volcano, which are thoroughly or partly covered with volcanic ejecta from Mayon Volcano. Most of them are andesitic and dacitic lava dome, volcanic spine and cinder cone as mentioned above, in item (2). Volcanic rocks on a hill, north of Sto. Domingo and Mt. Bulakawan, south of Malilipot, is the same series of andesitic and dacitic lava, intercalated with agglomerate, and both belong to the volcanic rock in item (1). There are many exposures of hard andesitic rocks along the Bulawan River and the Tabigyan River around Mt. Bulakawan. Exposures of andesitic rock in item (2) are also found on Tankalao Hill, north of Bantayan on the Quinali (B) River and in southwest area of Tabigyan.

The first explosion of Mayon Volcano, ever recorded in history is in the year 1616. The active volcano has been erupted periodically about once a 10-year since the year 1928. Magma in Mayon Volcano is andesite or andesitic basalt with lower viscosity. Destructive explosion as in the case of dacite or rhyolitic magma did not take place in Mayon Volcano. But drastic damages caused by mud and pyroclastic flow will be a matter of deep concerns.

Slope forming materials of Mayon Volcano are classified into: (a) debris flow, (b) ash fall deposits, (c) pyroclastic flow, (d) mud flow, and (e) lava flow. Items (a) - (d) are unconsolidated to some extent and may have enough bearing strength for foundation of small Sabo structures, but they are less resistive against erosion.

Alluvium is developed on the plain lower than EL. 100 m and composed of gravel, sand and silt. Most of the alluvium is extending along the Quinali (A), the Quinali (B) and the Yawa Rivers and littoral sediment of gravel and sand is deposited along coast of Albay Gulf and Tabaco Bay.

3.1.3 Eruptions of Mayon Volcano and Their Recorded Calamities

Mayon Volcano is a stratovolcano of augite-hypersthene andesite accompanied with olivin-augite-hypersthene basalt. Its eruptions are not so violent, but subsequent pyroclastic flow and mud flow often cause calamities. The oldest eruption ever recorded in history is that of 1616; eruption records since then are as follows:

July 1766, Feb. 1814, June 1897, Mar. 1900, 1902, June 1928, 1938, Aug. 1939, Sep. 1941, Jan. 1947, Apr. 1968 and Jan. 1978.

Big eruptions among them are in 1814, 1897, 1928 and 1968.

Causes of eruption calamities are generally classified as follows:

Activities	Outcoming calamities
(a) hot blast (nuees ardentes)	growing cloud
(b) rolling incandescent material	pyroclastic flow
(c) earthquake	earthquake
(d) mud flow	mud flow
(e) lava flow	lava flow
(f) ash shower	ash fall

In the case of Mayon activity, no big calamity of (a), (c), (e) and (f) occurs. Big calamities with a loss of life are in the case of pyroclastic flow (b) and mud flow (d). According to past records, big calamities in the Mayon eruption has been limited in eastern, southern and southwestern slopes. Pyroclastic flow occurs at the time of eruption, but mud flow usually occurs after eruption and spread over wide area. Several records on big eruption and its calamities are described in the following paragraphs.

(1) Oct. 1766

An eruption took place in July 1976, and mud flow occurred in Oct. 1966 due to heavy rain caused by big typhoon. Malinao was thoroughly destroyed and coconut trees were burried in the mud flow up to their top. Nearby villages of Cagsawa, Budiao, Guinobatan, Ligao and Polangui were heavily damaged. The 30 deads in Malinao and the 16 deads in Legazpi were reported.

(2) Feb. 1814

Heavy cloud accompanied with a big eruption caused torrential rainfall and mud flow attacked the village of Bublusan, Cagsawa and Budiao with the depth of 10 - 12 m. The total deads in these villages reached to 1,200.

(3) 1875's disaster

No eruption occurred in this year. But mud flow was caused by heavy rainfall, recording the 1,500 deads.

(4) 1897's disaster

A big-scale eruption took place. Pyroclastic flow attacked Libog, 212 lives were lost in a day. Hot mud flow also flowed down along the Basud River, just after the eruption.

(5) 1915's disaster

There was no eruption happened in the year 1915. Nevertheless, big mud flow was caused by heavy rain, attacking most of the town of Camalig, Bongabong and Tabaco. No life was lost by the mud flow, but Railroad between Legazpi and Libog was burried.

(6) Jan. - Aug. 1928

A big-scale eruption took place. A lava flow reached down to an elevation of 300 m on the Libog side. Growing cloud occurred. The one dead was reported at San Antonio.

(7) Apr. and May 1968

Large scale eruption took place. Lava flow reached down to a low elevation on Camalig side slope. Growing cloud and mud flow occurred without any serious damage.

3.1.4 Land Classification

The land in the project area is largely classified into the mountainous area and lowland. The mountainous area is classified into three types, i.e. lava flow, volcanic fan and Tertiary mountain.

Lava flow is subdivided into new and old ones and it is distributed around Mayon Volcano and consists mainly of andesite lava flow and pyroclastics. Volcanic fan is distributed in the skirt of Mayon Volcano, consisting mainly of unconsolidated sediments. Tertiary mountain is distributed in the surrounding area of Mayon Volcano and subdivided into Volcanics, limestone - sandstone - volcanics and diorite.

Lowland is classified into high terrace plain, natural levee, alluvial plain, fan-like lowland, bar, old river trace, existing river and lake.

High terrace plain is distributed in northeast of Lake Bato. Natural levee is distributed in such major cities and municipalities as Legazpi City, Ligao, Oas and Libon. Alluvial plain is subdivided into low and high fan. It is widely distributed in the lowland. Fan-like lowland has a slight slope. Bar is distributed in Albay Gulf and Tabaco Bay. Old river trace is partly swampy. Existing river and lake indicate the main river such as the Quinali (A) River, the Yawa River, Lake Bato, etc.

The land classification in the project area is summarized as follows: 1) The land form in the project area is largely classified into two types, i.e. mountainous area and lowland, 2) In the mountainous area, volcanic fan is distributed on the foot of Mayon Volcano, indicating the transportation and sedimentation of a large volume of sediment. Lava flow is distributed in the upper half of Mayon Volcano, 3) In the lowland, alluvial plain has an extensive distribution, which is generally susceptible to flood.

3.1.5 Land Use

The land use is largely classified into populated area, public facility, cultivated land, forest and others.

Populated areas are classified into the concentrated and scattered ones. The former represents the major cities and municipalities such as Legazpi City, Tabaco, Ligao and Libon. The latter indicates barangays, etc. Public facilities are classified into school, church, airport and golf course. Cultivated lands are classified into rice field, field (Soy beans, cassava, corn, sweet potato, etc.), coconuts, abaca, citron and fish farms. Coconut farms are subdivided into dense and sparse ones. Forests are classified into natural tree schrub (Dipterocarp, Vitex parviflora) and nipa. Other land uses represented are grassland (Cogon, Parang), bare land, developed land and waters.

The land use in the project area is summarized as follows: 1) The lowland is almost used for rice field. Such major cities and municipalities as Legazpi City, Tabaco, Ligao and Libon are located in the lowland, 2) The lower half of Mayon Volcano is used for coconut plantation. In this plantation, the villages are scattered. The higher area than coconut plantation is covered with natural forest. Natural forest is well preserved rather on the northern side than southern side. From summit down to the 1,600 m level, the slope of Mayon Volcano remains bare.

3.2 Meteorology and Hydrology

3.2.1 Meteorology

(1) Climate

The project area has a tropical climate, affected by two air stream systems which produce distinctive variation in the climate. These air streams are monsoons and Pacific Trade Winds.

The Northeast Monsoon prevails in a period from October to March, bringing significant amount of rainfall to the southern Luzon where the project area is located. The Southwest Monsoon prevailing from May to October originates in the Indian Ocean and affects the area. During this period the project area is warm and very humid with increasing rates of rainfall.

The North Pacific Trade Wind prevails during April and May, raising the temperature significantly. The South Pacific Trade Wind coincides with Southwest Monsoon from May to July.

The climate in the Philippines is classified into four types in terms of the rainfall pattern as shown in FIG.-3.2.1. Most of the area belongs to Type II climate which has no significant dry season with a very pronounced maximum rainfall under the influence of the Northeast Monsoon prevailing from November to January.

(2) Tropical Cyclone

Most of the tropical cyclones that affect the Philippines are formed in the Pacific Ocean between the Philippines and the Carolines-Marianes islands and move towards the west or northwest direction. They hit the project area any month of the year, especially from June to December.

The tropical cyclones which move along the eastern end of the Luzon Island or cross the southern most end of the Luzon have caused heavy rain and extensive damage to lives, crops and properties.

The tropical cyclones having brought damages to the project area after the year of 1970 are listed in TABLE-3.2.1. And TABLE-3.2.2 shows their monthly frequency.

(3) Rainfall

The observation network of rainfall is shown in FIG.-3.2.2. Ten stations exist in the project area and their record length is indicated in FIG.-3.2.3. All stations are located along the major roads lower than EL. 130 m. The observation is conducted on a daily basis with ordinary collector-type rain gages. Only Legazpi station, however, has 3-hour observation records, which are the ones of the shortest duration. The observed data of all the stations are gathered and compiled by PAGASA.

Another rainfall gaging station was just established in Ligao by the Bicol River Flood Forecasting System. It is telemetered and its operation began in December 1980. Hourly rainfall records since then are available.

The mean annual rainfall in the project area ranges from 2,000 mm to 4,000 mm. Dividing the area by Mayon Volcano, the western part located in the inland area has lower amount of rainfall than the eastern part facing to the sea. This may be due to sheltering effect of the surrounding hills and mountains.

On the mean monthly rainfall, the period from May to January is generally a rainy season and the large amount of rainfall occurs during the period from November to January. The relatively dry season appears from February to April. Monthly rainfall records of five stations in the area are listed in TABLE-3.2.3 to TABLE-3.3.7.

The recorded maximum rainfalls for the duration of 1-day, 1-month and 1-year are 484.8 mm at Legazpi in 1967, 1,528.8 mm at Legazpi in 1975 and 5,128.1 mm at Malinao in 1976, respectively.

(4) Temperature and Relative Humidity

FIG.-3.2.4 shows monthly fluctuation of temperature at the three principal stations in the project area. Mean temperature fluctuates monotonously within a small range from 25°C to 28°C throughout the year. The temperature rises during the period from January to May and after that goes down gradually until January. The highest temperature occurs in May or June. The extreme temperature within the area ranges from 21°C in January to 33°C in June.

Monthly relative humidity recorded from 1956 to 1977 at Legazpi is shown in Fig.-3.2.5. The relative humidity within the area is generally high and its fluctuation is very slight throughout the year. The driest period of the year occurs in May. The extreme relative humidity within the area varies from 79% to 91%.

3.2.2 Hydrology

(1) Streamflow Runoff

There are many streams in the project area originating in Mayon Volcano and other mountains. The largest river is the Quinali (A) River with a drainage area of 331 km^2 and a river length of 55 km. The second largest is the Talisay River with a drainage area of 194 km^2 and a river length of 50 km followed by the Quinali (B) and the Yawa Rivers.

The streamflow observation network in the project area is poor. Only two rivers of the Quinali (A) and the Talisay Rivers have gaging stations. Seven stations are located in the Quinali (A) River basin and one in the Talisay River basin as shown in FIG.-3.2.2. And their record length including a drainage area is listed in FIG.-3.2.6. Measurement of water level by a staff gage has been conducted on a daily basis by the BRBDP Office and the data observed are sent to the NWRC in Manila, where conversion from water level to runoff is made. In order to define a rating curve for each station, regular discharge measurement is conducted about once a month.

Monthly mean runoff of all the eight stations are listed in TABLE-3.2.8. The specific annual mean runoff ranges from 0.04 $m^3/sec/km^2$ to 0.1 $m^3/sec/km^2$. The runoff increases significantly in June and July, and continuously increases until December. The drought period appears from February to May. Especially, the drought of the Talisay River is severe due to low flow for its drainage area size. On the other hand, the runoff of the Nasisi River is stable throughout the year. Annual runoff coefficient is estimated at about 0.6 to 0.7 based on the mean annual runoff at the San Francisco River gaging station and the mean annual rainfall at Guinobatan.

Floods are caused frequently by typhoons and tropical cyclones. The flash floods coming down from the mountains have been somewhat controlled in recent years by construction of dike system in the Quinali (A) River basin. The area however is often flooded due to a failure of river dikes with inadequate discharge capacities. For this, the major floods have never been recorded accurately due to flooding as well as to the poor measurement method with neither self-recording nor flood mark investigation.

(2) Sediment

Many streams originate in the slope of Mayon Volcano, and some of them run down carrying plenty of debris. A portion of debris deposits along the low hills, and the remainings are transported further downstream through river channels. The sediment deposition in the middle and lower reaches raises the river bed. This results in the lack of discharge capacity of the river channel, which naturally leads to flooding. The quantitative analysis of debris production and sediment deposition over the area has not yet been made sufficiently.

According to the feasibility report prepared by TAMS-TAE in 1978 and subsequent study by ASIATIC in 1980, sediment inflow into Lake Bato, which is the outlet of the Quinali (A) River including the Talisay River, was estimated at 400,000 m^3 per year employing the sediment load of the Talisay River at Allang as a representative of sediment inflow into Lake Bato. Assuming the sediment flowing into the lake settled equally over the entire lake area of 20 km^2, the average lake bottom rising is estimated at about 2 cm per year.

(3) Hydrology of Lake Bato

Lake Bato is a natural reservoir having a drainage area of 874 km^2. The Quinali (A) River basin including the Talisay River occupies 60% of the above drainage area. The water surface area of Lake Bato changes from about 40 km^2 during rainy season to 6 km^2 during dry season. TABLE-3.2.9 shows recorded annual maximum, minimum and mean water level of Lake Bato. From this table, it is found that the recorded maximum water level is 10.45 m in December 1975 and that the minimum is 3.37 m in May 1969. The mean water level is about 6 m, which corresponds to the water surface area of 20 km^2. During flood time, the water level rises immediately within a few days and goes down very slowly extending more than a month as expressed in FIG.-3.2.7, which shows fluctuation of Lake Bato surface water level. It is because the only outlet of Lake Bato is the Bicol River. According to the discharge measurement data at Sto. Domingo, the Bicol River, located near the outlet of Lake Bato, the lake discharges about 38 m^3/sec in average. The discharge may range from 12 m^3/sec to 64 m^3/sec depending on the season.

3.3 Present River Conditions

3.3.1 Rivers in the Scope of Study

The rivers to be studied, divides of Sabo work section and flood control work section are summarized below.

The rivers to be studied are the following three (3) major rivers and eleven (11) small streams which originate in Mayon Volcano in accordance with the Inception Report submitted in June 1980 (July 1982 as well).

(1) Quinali (A) River including its tributaries
(2) Quinali (B) River including its tributaries
(3) Yawa River including its tributaries
(4) East and North-East Streams

Only for East and North-East Streams, necessity of Sabo and flood control works is also explained in this section.

Divides of Sabo work section and flood control work section are plotted off the following spots, where the river bed slope is approximately 1/100.

(1) Quinali (A) River - Bridges of Maharlika National Highway for eastern tributaries upto the Ogsong River
- The bridge site of Ligao-Tabaco National Highway for the Nasisi River

(2) Quinali (B) river - The contraction at Bantayan

(3) Yawa River - Banag Bridge of PNR

(4) East and North-East Streams
- Bridges of Legazpi-Malinao National Highway

The existing river structures and river control works underway are shown in FIG.-3.3.1. The inundation areas during typhoons "Pepang" in 1979 and "Daling" in 1981 are studied as shown in FIG.-3.3.2 and FIG.-3.3.3.

3.3.2 Sabo Work Section

(1) Quinali (A) River

There are six tributaries to be treated as the rivers for Sabo works in the Quinali (A) River basin. They are the Quirangay River which passes across Camalig, the Tumpa River, the Maninila River and the Masarawag River which pass across Maharlika National Highway between Camalig and Guinobatan, the Ogsong River (the Nabonton Creek) and the Nasisi River which passes across the Ligao-Tabaco National Highway.

The present condition of these rivers are explained below.

i) Quirangay River

The Quirangay River is the most upstream and devastated tributary among them. It forms a deep gorge between EL. 600 m and EL 400 m. Together with the Tumpa River, it forms a large alluvial fan between EL. 350 m and EL. 160 m. It is a wide area covered with cogon grass. Below EL. 160 m it flows at a gentle river bed slope and the river course becomes a ditch of several meters in width. Sandy soil dike upstream the PNR bridge was slightly damaged by typhoon "Daling", in 1981. Sediment runoff from the gorge does not seem to be notable, but considering the importance of Camalig, which is rather a large town, the priority of the Quirangay River is higher than others.

ii) Tumpa River

The Tumpa River does not have an erosive gorge upstream. A large alluvial fan exists on the mountain skirt. This proves a vast amount of sediment yield in the past. Secondary erosion upstream the fan seems to be a sediment source, but it is not violent. Below EL. 200 m, the river course becomes gentle, and below EL. 170 m, it disappears into rice fields.

iii) Maninila River

At the east of Maninila, the Maninila River passes across the Provincial Road, where the river course is not violent. But below EL. 150 m, new secondary erosion starts and the downstream river course goes down to Travesia. As far as the history of the formation of the river course, it seems that the devastated area due to secondary erosion becomes vast.

iv) Masarawag River

The Masarawag River bifurcates into two (2) course at EL. 270 m and combines again at about 1 km downstream the Provincial Road at EL. 160 m. The spindle-shape between two (2) course is 1 km in the maximum width and 3 km in length, and is functioning as a natural sand retarding basin. Along the left course, dike embanked with excavated sediment for 500 m in length disappeared because of mud/debris flow caused by typhoon "Daling".

v) Ogsong River (Nabonton Creek)

The upstream reaches of the Nabonton Creek are neighbouring with the Buga River, a left tributary of the Nasisi River. The border of the catchment of the Nabonton Creek and that of the Buga River around EL. 300 m is not clear. Therefore, sediment discharge flows into both of the rivers depending on the amount and characteristics of sediment.

The river bed slope upstream the Provincial Road is steep. One irrigation intake is existing which is now under repair. But the river bed slope downstream is about 1/40 and there exists deposit terrace of 2 - 3 m in height. The river course is winding, and secondary erosion of river bed is notable.

vi) Nasisi River

Upstream reaches of the Nasisi River is very much devastated and erosive, and it originates in Mayon Volcano running down on the western slope. It is the largest tributary of the

Quinali (A) River in Sabo work section. Along this river, there are such important structures as the Provincial Road Bridge, Nasisi Dam. And there was an overflow culvert type bridge of Ligao-Tabaco National Highway, but it was completely broken by scouring of its foot during typhoon "Daling". Other structures more or less suffered from flood damage.

Near Nasisi, the river course forms a contraction confined between hill foots. The contraction functions as a natural sand retarding basin. Five hundred (500) m downstream Nasisi, there is the Nasisi Dam of the National Irrigation Administration, which is an overflow type fixed weir with a small sand flush which also functions as consolidation works.

The river bed slope changes from 1/70 to 1/40 at the dam due to scouring. But as the bed material is composed of big gravels, lowering of river bed does not seem to occur further. About five hundred (500) m downstream the dam, as the Ligao-Tabaco National Highway bridge was washed out, a new bridge is under construction. Eight hundred (800) m downstream the bridge, where river bed slope becomes gentle (1/200), there exists a natural sand retarding basin of 100 m in width and 1,500 m in length.

(2) Quinali (B) River Basin

The Buang River which is one of the tributaries of the Quinali (B) River is the most violent ravine. This river flows on the northeastern slope of Mayon Volcano and then joins the main course of Buang. Three hundred (300) m upstream Buang, it passes across the Buang Bridge of the Ligao-Tabaco National Highway. The bridge piers were attacked and concrete suffered from abrasion, but before and after typhoon "Daling", there are no changes about these piers.

Downstream reaches of the Quinali (B) River after the confluence with the Buang River, about three (3) km in length, is a deep valley. The river width there is only 25 m, and the river bed slope is about 1/40, heap of boulders especially from the Buang River exists.

Other tributaries from Mayon Volcano are well covered with dense forest.

(3) Yawa River Basin

The Yawa River gathers three (3) main streams on the southern to southeastern slope of Mayon Volcano and other small streams from the southern hills which are outside of the scope of this study. The three (3) streams are the Anuling River which has two (2) torrents of the Anuling 1 River and the Anuling 2 River, the Budiao River and Pawa-Burabod River from the west to east.

i) Anuling 1 River

The mud/debris flow attacked Salvacion causing loss of lives of thirteen (13) during typhoon "Daling". After attacking the eastern side, it flowed and dispersed down the paddy fields and its front reached the left bank of the Yawa River. Not much unstable sediment deposit on river bed is found in the upstream reaches of this river above EL. 460 m, where the width of the gorge is narrow. The reaches between EL. 420 m (where the junction of two (2) torrents exists) and EL. 240 m are U-shaped gorge of 10 to 20 m in bank height, and there is a large volume of unstable sediment in the river bed, which is the source of sediment runoff.

ii) Anuling 2 River

This river flows east in parallel with the previous river. It is rather gentle, but unstable deposit mass on bank and river bed in the upstream reaches above EL. 280 m might lead to mud/debris flows.

iii) Budiao River

It is found that dense concentration of sediment flow was caused and runoff sediment volume was very large, during typhoon "Daling". However, the direction of the flow wasn't Budiao fortunately to count no loss of lives. The front of the sedimentation reached down to the PNR bridge site 1.5 km downstream the Provincial Road.

Lateral and longitudinal erosion are notable between EL. 430 m and EL. 330 m. There are even big boulders of several meters, and the reaches form V-shaped gorge of 40 to 50 m in bank height around EL. 400 m.

Along the reaches between EL. 200 m and the Provincial Road, the bank height is rather low and river course is in disorder. And lateral erosion is notable. Especially, erosion on the right bank around EL. 150 m is notable toward Budiao, and it is anticipated that the mud/debris flows in the future might cause vast damage to Budiao. The embankment of PNR downstream the Provincial Road was already damaged by the river flow, but it functioned as spur dikes to protect paddy fields.

iv) Pawa-Burabod River

The mud/debris flow caused the largest number of loss of lives of 18. The main reason of the disaster seems that the direction of the flow was not foreseen by the inhabitants.

It is found that the direction of mud/debris flow suddenly changed rightward around EL. 130 m, and that it hit Mabinit after destroying coconut trees for about 100 m in length. As the result, the river course bifurcated into two (2) streams at the point, and they remain at present.

Existing wet masonry type dike on the left bank was scoured and partly damaged, but it protected well enough Bonga, Burabod and surrounding cultivated areas. The one on the right bank is nothing but an island at present. The old river course near Burabod was filled with and it's river bed was raised up by sedimentation. The junction at present is about 750 m upstream the old one.

The upstream reaches above EL. 400 m, the bed slope is steep and longitudinal erosion is notable. The bank height is 20 to 30 m down to EL. 290 m, forming a gorge. The river bed is unstable with big boulders. The reaches between EL. 250 m and 190 m, river bed is exposed to repeated sedimentation and erosion which results in downward flow of sediment. And it seems that mouth of the gorge around EL. 250 m is the top of a fan and that river course may change to Buyuan.