5.6 Flood Damage Analysis

5.6.1 General

In order to re-assess and review the effect of the proposed river improvement plan and Sabo plan of the Master Plan, the flood damage reduction amount is estimated for the Quinali (A) River basin, the Quinali (B) River basin and the Yawa River basin. The flood damage analysis is made based on the same condition and method of the Master Plan. The direct damage caused by typhoons between 1980 and 1982 is taken into account in this study.

The flood damages are estimated for the infrastructure, houses, crops and irrigation facilities under different flood magnitude with a return period of 2-, 10-, 20-, 50- and 100-years.

The mud/debris flow damage analysis is made on the basis of the damage caused by typhoon "Daling" and the return period of rainfall due to the typhoon which played the role of triggar of mud/debris flow, because no other data are available on mud/debris flow damages. According to the hydrological analysis, the rainfall at Legazpi due to typhoon "Daling" is estimated at about 5-year return period. Supposing mud/debris flow occurs by the rainfall of 5-year return period and it will continue in the future, annual damage value is estimated at 1/5 of total damage value per one mud/debris flow. As for its one damage value which will occur in the future, it is estimated at the same value as the damage caused by typhoon "Daling".

5.6.2 Damage to Infrastructure

(1) Damage to Houses

In estimating the flood damages caused by typhoon and heavy rain, only the damage to private houses is taken into consideration, since the damage data for the public buildings such as schools, churches, government buildings and factories were not obtained. For the estimation of the flood damages, effect of the wind and rainfall is not included and the damages to household effects are not taken into account. Inundation area and inundation depth caused by typhoon "Pepang" in 1979 were obtained from the field survey in 1980 and those of the other magnitude of flood are based on the flood analysis in the Master Plan study. These basic data are also reviewed considering the recent typhoon "Daling" in 1981.

The damage to houses is estimated by multiplying the number of houses by the value of house and flood damage rate based on inundation depth. The damage to commercial establishments is estimated at about 10 percent of the damage to houses. The damage at 1982 price level is estimated as follows.

- Quinali (A) River basin: The damage is estimated at P 15.78 million, P 26.78 million, P 32.19 million and P 39.50 million and P 46.90 million for the flood magnitude of 2-year, 10-year, 20-year, 50-year and 100-year probable flood respectively as shown in TABLE-5.6.1.

- Quinali (B) River basin: The damage is estimated at P 1.09 million, P 2.23 million, P 2.71 million, P 5.26 million and P 6.07 million for 2-year, 10-year, 20-year, 50-year and 100-year probable flood respectively as shown in TABLE-5.6.1.

- Yawa River basin: The damage is estimated at P 1.81 million, P 6.49 million, P 11.76 million, P 18.39 million and P 22.04 million for 2-year, 10-year, 20-year, 50-year and 100-year probable flood respectively as shown in TABLE-5.6.1.

With regarding the damage to houses due to mud/debris flow caused by typhoon "Daling", it is estimated at P 0.18 million for the Quinali (A) River basin and P 0.69 million for the Yawa River basin. Details are shown in TABLE-4.3.1. The annual damages of the Quinali (A) River and the Yawa River basins are estimated at P 36 thousand and P 138 thousand, respectively.

(2) Damage to Government Infrastructure

i) Damage to Road Structure

Damage to road structure can be approximately measured by the estimated damage cost (calamity fund) of each typhoon between 1975 and 1981. The damage revalued at 1982 price level is estimated as follows.

- Quinali (A) River basin: P 2.98 million (1975), P 0.46 million (1976), P 3.92 million (1977), P 1.11 million (1978), P 1.20 million (1979) and P 3.16 million (1981) as shown in TABLE-5.6.2.

- Quinali (B) River basin: P 0.30 million (1975), P 0.18 million (1976), P 0.62 million (1977), P 0.33 million (1978), P 0.68 million (1979) and P 0.40 million (1981) as shown in TABLE-5.6.2.

- Yawa River basin: P 0.49 million (1975), P 0.22 million (1976), P 0.36 million (1977), P 0.56 million (1978), P 0.57 million (1979) and P 0.37 million (1981) as shown in TABLE-5.6.2.

ii) Damage to Railway Structure

Damage to railway structure can be measured by the estimated damage costs (calamity fund) between 1975 and 1981. The damage revalued at 1982 price level is estimated as follows.

- Quinali (A) River basin: P 1.49 million (1975), P 0.46 million (1979), P 0.26 million (1980) and P 1.70 million (1981) as shown in TABLE-5.6.2.

iii) Damage to River Facilities

Damage to river facilities can be measured by the estimated damage cost of each typhoon between 1975 and 1981. The damage revalued at 1982 price level is estimated as follows.

- Quinali (A) River basin: P 1.07 million (1975), P 0.21 million (1977), P 0.53 million (1978), P 1.16 million (1979), P 3.65 million (1980) and P 8.41 million (1981) as shown in TABLE-5.6.2.

- Quinali (B) River basin: P 0.11 million (1975), P 0.22 million (1978), P 0.12 million (1980) and P 0.17 million (1981) as shown in TABLE-5.6.2.

- Yawa River basin: P 0.14 million (1975), P 0.10 million (1976), P 0.16 million (1978) and P 0.25 million (1979) as shown in TABLE-5.6.2.

iv) Damage to Government Infrastructure

Flood damage to government infrastructure between 1975 and 1981 is listed in TABLE-5.6.2. The damage revalued at 1982 price level is estimated as follows.

- Quinali (A) River basin: P 5.55 million (1975), P 0.46 million (1976), P 4.13 million (1977), P 1.64 million (1978), P 2.82 million (1979), P 3.91 million (1980) and P 13.95 million (1981) as shown in TABLE-5.6.2.

- Quinali (B) River basin: P 0.40 million (1975), P 0.18 million (1976), P 0.62 million (1977), P 0.54 million (1978), P 0.68 million (1979), P 0.12 million (1980) and P 1.13 million (1981) as shown in TABLE-5.6.2.

- Yawa River basin: P 9.34 million (1975), P 0.32 million (1976), P 0.36 million (1977), P 0.73 million (1978), P 0.81 million (1979) and P 0.76 million (1981) as shown in TABLE-5.6.2.

(3) Total Damage to Infrastructure

The total damage to infrastructure are calculated for the five flood cases of 2-year, 10-year, 20-year, 50-year and 100-year probable flood respectively by aggregating the damages in the preceeding clauses. These damages are estimated on the following assumption:

i) Damage to infrastructure is the actual estimated damage for 2-year to 20-year probable flood. The base damage for 2-year probable flood is taken as the greatest damage cost between 1976 and 1981, since the damage of the period between 1976 and 1981 is assumed to be around 2-year probable flood from the flood analysis.

ii) The damage to infrastructure for 10-year, 20-year, 50-year and 100-year probable flood is estimated on the assumption that the damages will be affected mainly by the inundation depth obtained from the flood analysis. Therefore, these damages are estimated by multiplying the actual flood damage of 2-year by the flood damage rate of 1.2 for 10-year, 1.28 for 20-year, 1.3 for 50-year and 1.4 for 100-year respectively as shown in TABLE-5.6.3.

The total damage to infrastructure at 1982 price level is summarized in the following table:

(Unit: million pesos)

River Basin	Return Period				
	2-year	10-year	20-year	50-year	100-year
Quinali (A) River	29.73	43.57	50.05	57.64	66.44
Quinali (B) river	2.21	3.58	4.15	6.73	7.64
Yawa River basin	2.46	6.86	11.73	17.78	21.18

5.6.3 Damage to Irrigation Facilities

(1) Quinali (A) River Basin

The estimation method of flood damage to irrigation facilities is considered to be the same as that to infrastructure. Therefore, the biggest amount among the damages by typhoons between 1975 and 1981 is picked up and is regarded as the flood damage caused by the probable flood with a return period of 2-year. By applying the same flood damage rate as the infrastructure, the damage for 2-year, 10-year, 20-year, 50-year and 100-year probable flood is estimated at P 0.62 million, P 0.75 million, P 0.80 million, P 0.81 million and P 0.87 million respectively as shown in TABLE-5.6.4.

(2) Quinali (B) River Basin

Damage to the irrigation facilities in the Quinali (B) River basin is estimated in the same way as in the Quinali (A) River basin. The results are shown in TABLE-5.6.4. The estimated flood damage is P 0.11 million, P 0.13 million, P 0.14 million, P 0.14 million and P 0.15 million for 2-year, 10-year, 20-year, 50-year and 100-year probable flood respectively.

(3) Yawa River Basin

The estimated flood damage is P 0.04 million for 2-year and 10-year, P 0.05 million for 20-year to 100-year probable flood respectively.

5.6.4 Damage to Crops

(1) Flood Damage

Quinali (A) River Basin

The annual record of flood damage to crops in the project area is not kept systematically in the relevant offices. The flood damage to rice is therefore estimated by applying the standard for the estimation of inundation damages prepared by the Ministry of Agriculture, Forestry and Fisheries in Japan. The obtained amount of flood damages to rice is regarded as the crop damages taking into account the present land use condition in the flooded area.

The rice field in the project area is classified based on the inundation area by flood of typhoon "Pepang" as illustrated in FIG.-3.3.2 and the inundation depth and period for different return period as shown in TABLE-5.6.5. The result of classification is summarized in TABLE-5.6.6. Out of 9,400 ha of the existing rice field in the Quinali (A) River basin, 7,500 ha is flooded. The flooded rice field consists of 6,320 ha of irrigated area and 3,080 ha of rainfed area.

The flood damage to crops varies with the time of flood occurrence even the magnitude of flood is quite the same. From this viewpoint, the ratio of planted area during the growing period, the distribution of typhoon and the damage rate of rice are established monthly. The monthly flood damage is calculated by multiplying these factors by monthly production cost already spent and net income of each crop season respectively. The sum of the monthly flood damage obtained is considered as the total flood damage to crop. As given in TABLE-5.6.7, the total flood damage is estimated at P 3.48 million and P 5.07 million for the flood of 2-year and 10-year to 100-year respectively.

Quinali (B) River Basin

Crop damage by flood in the Quinali (B) River basin is estimated in the same way as that in the Quinali (A) River basin. The flooded area of rice field in the whole Quinali (B) River basin is estimated at 880 ha out of the total rice field of 3,210 ha. The flooded rice field consist of irrigated area of 810 ha and rainfed area of 70 ha. As shown in TABLE-5.6.8, crop damage is estimated at P 0.35 million and P 0.56 million for the flood magnitude of 2-year and 10-year to 100-year respectively.

(2) Damage due to Mud/debris Flow

The damages to crops due to mud/debris flow in the project area consist of re-transplanting cost of coconut, loss of net return for coconut and rehabilitation cost of palay field coverd by mud/debris. The total damage value caused by typhoon "Daling" is estimated at

P 8.82 million for the Quinali (A) River basin and P 7.31 million for the Yawa River basin as shown in TABLE-5.6.9 and TABLE-5.6.10. The annual damages of the Quinali (A) River and Yawa River basins are estimated at P 1.76 million and P 1.46 million, respectively.

5.7 Implementation Program and Cost Estimate

5.7.1 Implementation Program

Preceding chapters in this report describe a re-assessment and review of the Master Plan for the Sabo works, the river improvement works and the irrigation works in the Project area. This chapter presents a provisional program for the implementation of the Master Plan re-studied including necessary future studies and design.

The Sabo works are urgent in nature and consist of relatively simple structures that can be constructed independently based on the re-assessment and review of the Master Plan and the construction schedule considering the priority of each Sabo facility. They are recommended to be implemented as one of the public investment and will be required to be constructed urgently according to the Philippine's yearly budget. Therefore, it is possible to proceed with detailed survey and design for construction after the completion of the re-assessment and review of the Master Plan. For the river improvement works, on the contrary, it is first necessary to undertake feasibility study due to complexity and magnitude of their works. Then, it will be followed by detailed design for construction.

Regarding the construction, the following are taken into account:

(a) In accordance with the work quantities involved in the construction, adequate and reasonable pace of construction of each component work should be considered.

(b) Construction work will be executed by local contractors to be selected on a contract basis, which is a commonly used method in the Philippines.

(c) Preparatory work, such as right of way/site acquisition and resettlement of people to be removed, etc. should be undertaken before the actual construction starts.

This implementation program is provisional in nature and subject to further adjustment according to the future situations.

(1) Quinali (A) River

The construction works for the Quinali (A) River basin comprise the Sabo works for the Quirangay, the Tumpa, the Maninila, the Masarawag, the Ogsong and the Nasisi Rivers, the river improvement works for the Quinali (A), the Nasisi and the Talisay Rivers, and the irrigation works.

The construction period is assumed to be 10 years, of which 8 years for the Sabo works, 10 years for the river improvement works and 4 years for the irrigation works. The provisional construction time schedule is shown in FIG.-5.7.1.

(i) Sabo Works

The Sabo facilities comprise mainly Sabo dam, consolidation dam, spur dike, jetty, ground sill and training levee. The Sabo works for the major 6 tributaries are assumed to be constructed in parallel with the river improvement works.

(a) Further Investigations and Detailed Design

Before proceeding to the actual construction, it is necessary to undertake further investigations and detailed design as stated below.

. Detailed Investigations

To perform boring as detailed geological investigations for the Sabo dam and consolidation dam site if required. To perform detailed topographic survey, plane survey map of scale 1/1,000, for all proposed structural areas.

. Detailed Design

To perform detailed design of the Sabo facilities on the basis of the re-study and review of the Master Plan and the above geological investigations and topographic survey.

. Tender Documents
To prepare tender documents for the Sabo works.

. Detailed Design Schedule
The detailed investigations and detailed design including preparation of tender documents are proposed to be finished within every 1 year considering the construction time schedule and Philippine's yearly budget.

(b) Construction Schedule
The preparatory works such as access roads, temporary buildings and facilities, and right of way/site acquisition, will be implemented prior to the commencement of each Sabo work for each river.

The Sabo works of 6 tributaries are scheduled to be performed from the 2nd year to the 8th year in parallel as shown in the construction time schedule. Each Sabo facility will be constructed considering the priority and effectiveness of the facilities and the schedule of the Sabo works in the Yawa River basin.

Detailed construction schedule is described in Section 7.3.8.

(ii) River Improvement Works
The river improvement works for 3 major rivers comprise the enlargement excavation of the existing river channel, the excavation of Oas diversion channel, the levee embankment and the bridge construction including road and railway.

The river improvement works are divided into 10 work sections as shown in the construction time schedule of FIG.-5.7.1. There are 6 work sections for the Quinali (A) River, 1 for the Nasisi River and 3 for the Talisay River.

(a) Feasibility Study and Detailed Design

Before the actual construction, it is required to undertake the following feasibility study and detailed design.

. Feasibility Study

To perform additional hydrological observation.

Rainfall observation: The available rainfall record is a daily record except 3-hour rainfall record of Legazpi, so that the hourly rainfall observation is advisable for more reliable design. The observation is to be performed both in the plain area and in the mountainous area to assess the basin average rainfall.

Stream flow observation: The hourly observation of stream flow is necessary in order to analyze the relation between rainfall and runoff.

To review hydrological and hydrographical study.

The hydrological analysis made in the Master Plan and the hydrological study were re-assessed and reviewed in 1982. However, this study is to be reviewed when the new data becomes available.

To review the Master Plan in 1981 and the Re-study in 1982 by further investigations and to perform the detailed feasibility study for the Quinali (A) River basin. (Feasibility study should include the river improvement works including Lake Bato, the river improvement works downstream Lake Bato.)

. Detailed Design

To perform detailed geological investigations at the work sites for bridges, headworks and sluiceways.

To perform detailed topographic survey; plane survey map of scale 1/1,000, along the proposed river courses and profile and cross section survey of scale 1/1,000 is desirable.

To carry out detailed material investigations for embankment.

To perform detailed design of the civil structures on the basis of the above geological investigations, topographic survey, material investigations and additional hydrological observation.

To prepare tender documents for the river improvement works and the bridge construction.

. Feasibility Study and Detailed Design Schedule
The detailed feasibility study is proposed to be finished within 1.5 years. The detailed design including preparation of tender documents is proposed to be finished within 1.5 years.

(b) Construction Schedule
The construction schedule is planned in sequence of the Quinali (A) River, the Nasisi River and the Talisay River according to the priority of each river.

The excavation of river channel and the embankment of levees in all work sections are scheduled to be made from the downstream to the upstream.

The preparatory works such as access roads, temporary buildings and facilities, land acquisition and resettlement will be implemented prior to the commencement of the construction works.

Quinali (A) River

At first the levee construction of the reaches from Sta. 17+074 to 21+892 designed as Oas diversion is scheduled in the first and the second year to decrease the flood damage to Oas.

In the next stage, the levees of the reaches from Sta. 2+341 to 27+500 are scheduled to be constructed from the third to the sixth year.

The reaches from Sta. 0+000 to 2+341 located downstream the junction with the Talisay River is scheduled to be constructed at the last stage of the tenth year after the completion of the river improvement works for the Talisay River. This work section is to be planned considering the flooding from Lake Bato.

The new bridges located at each work section of the levees are executed in parallel with the river improvement works.

Nasisi River

River improvement works for the Nasisi River are scheduled to be implemented in the seventh year after the completion of the Quinali (A) River from Sta. 2+341 to 27+500, since the Nasisi River is the major tributary of the Quinali (A) River.

The new bridges are constructed in parallel with the river improvement works. Special attention will be paid to the reconstruction of Binatagan Bridge on the Daan Maharlika Highway and for Nasisi Bridge on Southline of the Philippine National Railway.

Talisay River

River improvement works for the Talisay River are scheduled to be implemented in the last stage of the eighth and the ninth year, since the inundation area due to the flood of this river is assumed to be limited only to the narrow area along this river and the flood damage to this area is not assumed to be serious compared with the area of the Quinali (A) and the Nasisi Rivers.

(iii) Irrigation Works

The integration of irrigation systems is proposed for about 6,350 ha in the project area comprising 4,350 ha for Agos Sta. Cruz - South Quinali scheme area, 600 ha for Quinali scheme area and 1,400 ha for Cabilogan scheme area.

The irrigation works are performed considering the progress and schedule of the river improvement works, and the construction period is assumed to be 4 years.

(a) Further Investigations and Detailed Design

Before the actual construction, it is required to undertake the following investigations and detailed design.

. Detailed Investigations

To perform additional hydrologic observation for the irrigation water availability.

To perform detailed topographic survey adding to the plane survey map, scale 1/5,000, prepared in 1979.

. Detailed Design

To perform detailed design of the irrigation facilities on the basis of the above topographic survey and additional hydrological observation.

. Tender Documents

To prepare tender documents for the irrigation works.

. Detailed Design Schedule

The detailed investigations and detailed design including preparation of tender documents are proposed to be finished within 1 year.

(b) Construction Schedule

Cabilogan scheme is scheduled to be implemented first in parallel with the river improvement works for the reaches from Sta. 17+074 to 21+892 (Oas Diversion).

Agos Sta. Cruz - South Quinali and Quinali scheme will be completed by the 4th year, that is, the preceding year of the commencement of the reaches from Sta. 12+200 (near Quinali Bridge) to 17+074.

Relating structures such as headworks and sluiceways will be constructed in parallel with the levee embankment of the river improvement works.

(2) Quinali (B) River

The construction works for the Quinali (B) River basin comprise the Sabo works for the Buang River, the river improvement works for the Quinali (B), the San Francisco and the San Vicente Rivers and the irrigation works.

The construction period is assumed to be 8 years, of which 1 year for the Sabo works, 8 years for the river improvement works and 3 years for the irrigation works. The provisional construction time schedule is shown in FIG.-5.7.1.

(i) Sabo Works

(a) Further Investigations and Detailed Design

Before proceeding to the actual construction, it is necessary to undertake further investigations and detailed design as stated below.

- Detailed Investigations

  To perform boring as detailed geological investigations for the Sabo dam site of the Buang River, if required.

  To perform detailed topographic survey of all proposed structural areas.

- Detailed Design

  To perform detailed design of the Sabo facilities on the basis of the above geological investigations and topographic survey.

- Tender Documents

  To prepare tender documents for the Sabo works.

- Detailed Design Schedule

  The detailed investigations and detailed design including preparation of tender documents are proposed to be finished within 6 months.

(b) Construction Schedule

Sabo works for the Buang River is scheduled to be implemented in the 8th year. The consolidation dam located at Buang Bridge should be constructed first to protect the bridge piers. Next, the consolidation dam located upstream will follow. Afterward the Sabo dam located at EL. 155 will be commenced.

(ii) River Improvement Works

(a) Feasibility Study and Detailed Design

Before the actual construction, it is required to undertake the following feasibility study and detailed design.

. Feasibility study

To perform additional hydrological observation.

- Rainfall observation
- Streamflow observation (The Quinali (B) River, main course, at Balza Bridge)

To review hydrological and hydrographical study.

To review the Master Plan prepared in 1981 by further investigations and to perform the detailed feasibility study for the Quinali (B) River basin.

. Detailed Design

To perform detailed geological investigations at the bridge site.

To perform detailed topographic survey along the proposed river courses.

To carry out detailed material investigations for embankment.

To perform detailed design of the civil structures on the basis of the above geological investigations, topographic survey, material investigations and additional hydrological observation.

To prepare tender documents for the river improvement works and the bridge construction.

. Feasibility Study and Detailed Design Schedule

The detailed feasibility study is proposed to be finished within 1 year. The detailed design including preparation of tender documents is proposed to be finished within 1 year.

(b) Construction Schedule

The construction schedule is planned in sequence of the San Francisco River, San Vincente River and the Quinali (B) River. The river improvement works are scheduled to be commenced in the first year and to be completed by the eighth year.

The works for the San Francisco River is scheduled to be commenced in the first year and the works for the San Vicente River is scheduled to be commenced in the third year. Especially, the construction works of this stage are to be performed in parallel with the irrigation works.

The works for the Quinali (B) River is scheduled to be constructed from the fifth year after the completion of the works for the San Vicente River.

The construction works of the new bridges located at each work section will be performed in parallel with the river improvement works.

(iii) Irrigation Works

The integration of irrigation systems, namely Bantayan scheme area, is proposed for about 2,400 ha.

(a) Further Investigations and Detailed Design

The necessary items in detailed investigations and detailed design are the same as the irrigation works for the Quinali (A) River basin.

(b) Construction Schedule

Bantayan headworks are scheduled to be constructed in the second year in parallel with the irrigation works.

The irrigation works are to be performed in parallel with the river improvement works for the San Vicente River. The construction period is assumed to be 3 years.

(3) Yawa River

The construction works for the Yawa River basin comprise the Sabo works for the Anuling, the Budiao and the Pawa-Burabod River and the river improvement works. The construction period is assumed to be 7 years, of which 7 years for the Sabo works and 4 years for the river improvement works. The provisional construction time schedule is shown in FIG.-5.7.1.

(i) Sabo Works

The Sabo facilities comprise mainly Sabo dam, consolidation dam, ground sill, spur dike and training levee. The Sabo works for the major 3 tributaries are assumed to be constructed in parallel with the river improvement works.

(a) Further Investigations and Detailed Design

Before proceeding to the actual construction, it is necessary to undertake further investigations and detailed design as stated below.

. Detailed Investigations

To perform boring as detailed geologic investigations for the Sabo dam and consolidation dam site, if required.

. To perform detailed topographic survey, plane survey map of scale 1/1,000, for all proposed structural areas.

. Detailed Design

To perform detailed design of the Sabo facilities on the basis of the re-assessment and review of the Master Plan, the above geological investigations and topographic survey.

. Tender Documents

To prepare tender documents for the Sabo works.

. Detailed Design Schedule

The detailed investigations and detailed design including preparation of tender documents are proposed to be finished within every 1 year considering with the construction time schedule and Philippine's yearly budget.

(b) Construction Schedule

The Sabo works of 3 tributaries are scheduled to be performed from the 1st year to the 7th year in parallel as shown in the construction time schedule. Each Sabo facilities will be constructed considering the priority and effectiveness of the facilities and the schedule of the Sabo works in the Quinali (A) River basin.

Detailed construction schedule is described in Section 7.3.8.

(ii) River Improvement Works

The river improvement works for the Yawa River comprise the levee embankment and the reconstruction of Yawa Bridge.

(a) Feasibility Study and Detailed Design

Before the actual construction, it is required to undertake the following feasibility study and detailed design.

. Feasibility Study

To perform additional hydrological observation.

Rainfall observation

Stream flow observation

To review hydrological and hydrographical study.

To review the Master Plan in 1981 and the Re-study in 1982 by further investigations and to perform the detailed feasibility study for the Yawa River basin.

. Detailed Design
To perform detailed geological investigations at the bridge site.

To perform detailed topographic survey along the proposed river course.

To carry out detailed material investigations for embankment.

To perform detailed design of the civil structures on the basis of the above geological investigations, material investigations and additional hydrological observation.

To prepare tender documents for the river improvement works and the bridge construction.

. Feasibility Study and Detailed Design
The detailed feasibility study is proposed to be finished within 1 year. The detailed design including preparation of tender documents is proposed to be finished within 1 year.

(b) Construction Schedule
The river improvement works are scheduled to be commenced in the second year in parallel with the Sabo works and to be completed by the fifth year. The construction of Yawa Bridge is to be performed in the third and the fourth year.

5.7.2 Cost Estimate

Construction costs for each river basin are estimated considering local conditions of the Philippines, available equipments and materials, suitability of construction method, working rules, etc. These costs are estimated on the follwing conditions and on the basis of the Government estimate procedure.

(i) Construction cost (Financial) comprises Contract cost, Right of way/site acquisition, Resettlement, Engineering Cost, Project management cost and Contingencies.

(ii) Contract cost components are Direct cost, General, Supervision & miscellaneous, Profit and Contractor's tax.

(iii) Direct cost is estimated as the unit price including materials, labor and equipment expenses.

(iv) General cost includes mobilization and demobilization, vehicles, field offices and other temporary works, and it is taken as 10 per cent of Direct cost.

(v) Supervision & miscellaneous is taken as 6 per cent of the sum of Direct cost and General.

(vi) Contractor's profit is the cost of 10 per cent of the sum of Direct cost plus General and Supervision & miscellaneous.

(vii) Contractor's tax is estimated at 3 per cent of the sum of Direct cost, General, Supervision & miscellaneous and Profit.

(viii) Engineering cost which is 10 per cent of Contract cost includes topographic survey, design, soil testing prior to and during construction, construction surveys and construction management.

(ix) Project management cost is 5 per cent of Contract Cost.

(x) Physical contingency is estimated at 20 per cent of Contract cost for the river improvement works and the irrigation works, since these works are studied at the Master Plan level. While, Physical contingency of the Sabo works is taken as 15 per cent of Contract cost.

(xi) Price escalation contingency is estimated based on disbursement schedule and price escalation rate. The price escalation rate is taken as 7 per cent for the foreign currency portion and 13 per cent for the local currency portion.

(1) Quinali (A) River

The estimated construction cost including physical and price escalation contingencies in the Quinali (A) River basin is P 1,599.6 million which comprises P 167.5 million for the Sabo works, P 1,311.3 million for the river improvement works and P 120.8 million for the irrigation works as shown in TABLE-5.7.1. The foreign and local currency portion of the construction cost is estimated in TABLE-5.7.4 and the construction cost disbursement schedule is shown in TABLE-5.7.13. In addition, the economic cost is also presented in TABLE-5.7.7 and TABLE-5.7.10.

Annual operation and maintenance cost for the Sabo works and the river improvement works is taken as 0.5 per cent of the construction cost uniformly in this re-study. Annual O/M cost for the irrigation works is estimated at P 320 per hectare. The estimated annual O/M cost is P 477 thousand, P 3,900 thousand and P 2,032 thousand for the Sabo works, the river improvement works and the irrigation works respectively after the completion of all the project works.

(2) Yawa River

The estimated construction cost including physical and price escalation contingencies in the Yawa River basin is P 196.1 million which comprises P 138.4 million for the Sabo works and P 57.8 million for the river improvement works as shown in TABLE-5.7.2. The foreign and local currency portion of the construction cost is estimated in TABLE-5.7.5 and the construction cost disbursement schedule is shown in TABLE-5.7.13. In addition, the economic cost is also presented in TABLE-5.7.8 and TABLE-5.7.11.

The estimated annual O/M cost is P 472 thousand and P 209 thousand, for the Sabo works and the river improvement works respectively after the completion of all the project works.

(3) Quinali (B) River

The estimated construction cost including physical and price escalation contingencies in the Quinali (B) River basin is P 476.9 million which comprises P 11.6 million for the Sabo works, P 414.0 million for the river improvement works and P 51.3 million for the irrigation works as shown in TABLE-5.7.3. The foreign and local currency portion of the construction cost is estimated in TABLE-5.7.6 and the construction cost disbursement schedule is shown in TABLE-5.7.13. In addition, the economic cost is also represented in TABLE-5.7.9 and TABLE-5.7.12.

The estimated annual O/M cost is P 26 thousand, P 1,382 thousand and P 768 thousand for the Sabo works, the river improvement works and the irrigation works respectively after the completion of all the project works.

5.8 Project Evaluation

5.8.1 General

Economic evaluation is made on the basis of "with- and without-project principle". The net incremental benefit attributable to the project is defined as the change of the economic and socio-economic conditions under the conditions of with- and without-project. The benefit attributable to the proposed plan consists of such direct benefits as the flood damage reduction benefit and the land enhancement benefit as well as indirect and intangible benefits incidental to the project implementation.

In order to evaluate the project benefit from the flood damage reduction benefit for the crops and the land enhancement benefit, the economic price of crops and farm inputs in 1990 by 1982 constant value is estimated on the basis of the international market price forecasted by the World Bank in 1982. The economic prices of palay and coconut (copra) are estimated at P 1,610/ton and P 3,290/ton. Details are shown in TABLE-5.8.1 and TABLE-5.8.2.

The economic cost is obtained through deducting the taxes levied on the construction materials and machinery, the profits of contractors, contractor's tax, land compensation cost and the price escalation from the financial project cost estimated in Section 5.7. Internal rate of return of the project is estimated from these economic benefit and cost assuming that the evaluation period of the project is 50 years from the commencement of the Project.

All the benefits and costs are valued as of mid-1982. Exchange rate of US$ 1 = P 8.0 is used in this study.

5.8.2 Project Benefit

(1) Direct Benefit

The flood damage reduction benefit is obtained through execution of the proposed Sabo and river improvement works. It is quantified as the sum of average annual flood damages to houses, infrastructures, crops and irrigation facilities caused by the flood with the magnitude of 2-year to 50-year under the condition of without-flood control. The annual flood damage reduction benefits for the flood with the magnitude between 50-year and 100-year are estimated in both cases of with- and without-irrigation development under the condition of with-flood control. But, the balance between the two benefits are too small compared with the above-mentioned sum. In this context, this balance, which should theoretically be deducted, is not taken into account in estimating the flood damage reduction benefit in this report.

The proposed improvement plan of the Quinali (A) River requires to convert 550 ha of existing rice field to the new river bed resulting in the occurrence of production foregone. The annual production foregone is estimated at P 1,315,000 based on the net income of rice cultivation.

In the proposed river improvement plan, no surface drainage measure is taken into consideration for pumping out of the inundation due to heavy rainfall from the newly protected lowland. According to the hydrological analysis, some damages caused by the inundation due to rainfall excess will still remain when probable rainfall with a return period of 100-year occurs. This annual average inundation damage is estimated at P 708,000 for the Quinali (A) project, P 81,000 for the Quinali (B) project and P 197,000 for the Yawa Project. Thus the flood reduction damage benefit in this report is obtained by deducting the prospective amounts of the remaining inundation damage and annual production foregone from the average annual flood damage.

The water level of Lake Bato is considered to rise to some extent through implementation of the proposed improvement plan of the Quinali (A) River. This will have an adverse effect on the inundation depth and period on the lowest part of the Agos-Sta. Cruz irrigation development scheme of the Quinali (A) project, resulting in accruement of negative benefit. Therefore, this negative benefit is excluded from the total project benefit in undertaking the project evaluation. The estimated negative benefit totaling P 284,000 annually will have increased in line with the progress of river improvement works and attain to the full amount at the 11th year.

The annual flood damage reduction benefit of the whole project totals P 34.8 million comprising P 29.0 million for the Quinali (A) project, P 2.5 million for the Quinali (B) project and P 3.3 million for the Yawa project as shown in TABLE-5.8.3. This benefit is assumed to increase in proportion to the flooded area recovered by the flood control works which will be constructed in stage-wise in each project area. The benefit from the whole project will attain its maximum in the 11th year from the start of construction for the proposed flood control works.

The land enhancement benefit accrues through the land use intensification and is defined as the increment of the net income between with- and without-irrigation development under the condition of with-flood control. The annual land enhancement benefit of the whole project is estimated at P 33.7 million as shown in TABLE-5.8.4, including P 24.2 million gained from the irrigation development in the Quinali (A) River basin and P 9.5 million from the irrigation development in the Quinali (B) River basin. The full land enhancement benefit is expected to be attained after 3 year development period. For estimation of the land enhancement benefit, typical farm budgets for rice cultivation under rainfed, present irrigated and future irrigated conditions are made as shown in TABLE-5.8.5 (1) (2) (3) in which the budget of coconut cultivation is also given in TABLE-5.8.6.

The annual direct benefit under full development stage is estimated at P 54.7 million for the Quinali (A) River basin, P 12.0 million for the Quinali (B) River basin and P 5.0 million for the Yawa River basin as shown in TABLE-5.8.7.

(2) Indirect and Intangible Benefit

Besides the direct benefits estimated, various indirect and intangible benefits are obtained through the implementation of the project. These benefits are as follows:

i) Most of the casualties in the project area have been brought about by mud/debris flow and flood caused by the past typhoons. The great number of life will be secured by the Project. The recent records on the casualties are shown in TABLE-5.8.8.

ii) Avoidance of impairment to public health by epidemic prevalence contamination of well providing with drinking water.

iii) Prevention of the interruption of the national and regional road by flood or debris, which will result in smooth transportation and increase in the production of goods and services in the region.

iv) Raising agricultural potential of alluvial plain and fan by stabilizing the agricultural land through elimination of the flood and sediment damage, which will contribute greatly to the food industrial crop production of the project area, and also to strengthen regional and farmers economy.

v) Reduction of erosion at the foot of Mayon Volcano resulting in realization of reforestation and afforestation which will have a marked effect upon soil conservation and watershed management.

vi) Increase in employment opportunities for regional people during the construction period.

vii) Transfer of knowledge to the Philippine staff through the project execution, paticularly in the field of Sabo and river improvement works.

viii) For the beneficial area of the World Bank project, Nasisi-Hibiga Irrigation Scheme, the proposed Quinali (A) project can secure the stable irrigation water supply and expect increase in the anticipated yield of palay by 0.5 ton/ha for the wet season rice and 1.0 ton/ha for the dry season rice in combination with more fertilizer input.

5.8.3 Project Cost

The total economic cost for the whole project amounts to P 1,095.2 million consisting of Sabo and river improvement costs of P 991.0 million and irrigation development cost of P 104.2 million. The economic cost for the Quinali (A) project is estimated at P 742.4 million allocating P 668.5 million to the proposed Sabo and flood control works and P 73.7 million to the proposed irrigation development works. To the Quinali (B) project, P 244.5 million are allotted, among which P 213.9 million is used by Sabo and river improvement works and P 30.6 million are shared by irrigation works. The economic cost of Yawa project is estimated at P 108.6 million. TABLE-5.8.9 shows the economic disbursement schedule of the project cost.

5.8.4 Project Evaluation

The economic feasibility of the project are assessed on the basis of the current value of 1982. The analysis is carried out in terms of benefit-cost ratio and internal rate of return. For estimation of the economic internal rate of return, the benefit and cost stream is prepared for the project as presented in TABLE-5.8.10 to TABLE-5.8.13. As the results of estimation are given in TABLE-5.8.14, the economic internal rate of return is estimated at 4.9% for the whole project.

The sensitivity analysis is carried out to see the economic variability of the project under the several adverse circumstances, i.e. 20% cost up, 10% benefit down, 1 year delay and the conbined condition of 10% benefit down and 1 year delay. The analysis is made in terms of the internal rate of return and the results are shown in TABLE-5.8.15 and FIG.-5.8.1 (1) (2).

The estimated economic internal rate of return is 4.9% for the whole project. As for the economic internal rate of return of individual projects, it is 5.9% for the Quinali (A), 2.7% for the Quinali (B) and 2.8% for the Yawa. The whole project and each project are not always justifiable economically as a result of the above IRR calculated by the tangible benefit. However, the implementation of the project shall be seriously considered as a social project, since it can be expected to a large extent that the project will bring about such indirect and intangible benefits as social and mental stabilization, protection of human life, promotion of the regional economy, increase in the employment opportunity, elimination of the social unrest, etc. In conclusion, the project shall be immediately executed by using public financial resources to heighten the standard of living of the Bicol Region, which is lower than the national standard.

5.9 Urgent River Improvement Works and Facilities

5.9.1 General

Aside from the re-assessment and review of the Master Plan, urgent river improvement works and facilities at several places are identified. The identification is based on the field investigations in 1980 and 1982 as well as the Master Plan. However, the construction cost and implementation schedule for the following river improvement works are not included in this re-study due to insufficient data. It is noted, therefore, that these river improvement works and facilities should be implemented after further and relevant studies including topographic survey.

5.9.2 River Improvement Works and Facilities

The following river improvement works and facilities are identified in this study followed by those referred to as has been already identified by MPWH.

(1) Oas Diversion

Along the reaches of the Quinali (A) River taken up for improvement in the Master Plan, Oas Diversion Scheme seems most important. It aims at avoiding inundation of the densely populated municipality of Oas. It is modified as follows in accordance with the requirement of urgent implementation.

i) The reaches from STA. 17 + 074 to 21 + 892 is replaced by a newly constructed channel of 3.5 km in length, which passes across the rice field on the south of Oas as shown in FIG.-5.4.7.

ii) The design discharge is so selected as to conform with the discharge capacity of the present river upstream and downstream the reaches. As the present capacity is about 80 m^3/s as shown in FIG.-5.4.1, the design discharge selected is 200 m^3/s.

iii) The river bed slope is selected to be 1/550 to meet the present slope.

iv) The trapezoidal channel of 45 m in width is formed by excavation and/or embankment for dikes. The side slope of the channel is selected to be 1:2.

v) Widening of the main section and construction of side sections should be implemented as a part of the river improvement in the Master Plan in future.

(2) Tagpo-Cavaci Shortcut

The meandering reaches between Tagpo and Cavaci along the Cabilogan River has suffered from destruction of grouted riprap dikes to protect Tagpo by repeated floods caused by typhoons. It is recommended that a shortcut plan as shown in FIG.-5.4.7 is implemented to protect Tagpo and Cavaci.

(3) Guinobatan

Along the upstream reaches of the Quinali (A) River, main course, Guinobatan suffered most from flood damage including washing out of a National Highway bridge (San Francisco Bridge) and inundation. The reaches are partly provided with grouted riprap dike on the left bank at present. (The middle portion of 600 m in length is not provided with dike.) There seems to be three (3) major problems that hinder the smooth passage of flood flows downstream.

i) The alignment of the present river channel upstream the San Francisco Bridge is not smooth.

ii) Both of the bridges of Basod and San Francisco which are located downstream and upstream the town don't have adequate flow areas.

iii) The river reaches themselves don't have adequate discharge capacity as shown in FIG.-5.4.1.

To avoid these problems, the following are proposed.

i) River improvement works for the reaches from Basod Bridge (STA. 36+491) to San Francisco Bridge (STA. 37+673) of about 1.2 km in length and the reaches further upstream are to be implemented.

ii) The alignment is preferably selected to connect the cut-off channel at Travesia directly with the reaches in front of the Republic College Compound as shown in FIG.-5.9.1. This involves re-location of San Francisco Bridge and a road.

iii) To accommodate adequate flow areas for bridges, span and formation height of these bridges are so designed as to follow the river planning.

iv) Widening the river channel of right bank side is effective to increase the discharge capacity of the reaches provided that Basod Bridge is re-constructed.

v) To construct the left bank for 600 m reaches, and further to heighten the dike by about 1.5 m by parapet wall on top of dikes is effective for the same purpose provided that the formation height of San Francisco Bridge is raised as well. It is noted that proper design of foot protection should be made for dikes.

vi) Widening of river channel up to 60 m in width and 5 m in water depth results in increase of discharge capacity from 260 m^3/s at present to 890 m^3/s at the present river bed slope of 1/420, which corresponds to 10-year probable flood.

vii) The Masarawag River joins the main course almost perpendicularly at Basud Bridge. This hinders the smooth passage of flood flows which not only heightens the water level but also caused sedimentation at the junction.

Therefore, shifting the junction about 550 m downstream by canalization is effective to lower the water level and to avoid sedimentation at the junction. The alignment is shown in FIG.-5.9.1. (Sabo work section)

(4) Tagas River

Along the meandering reaches upstream the road bridge to Bliss Housing Project and the reaches downstream the National Highway bridge, right river bank was eroded during typhoon "Dinang" in 1981. This resulted in washing out of houses and inundation in adjacent areas. As the river passes across the densely populated area of Tabaco, the river improvement works seem urgently necessary.

i) The works along the downstream reaches of 2.2 km in length down to the river mouth is considered.

ii) The alignment of the river channel is selected, considering only widening of the river channel as shown in FIG.-5.9.2.

iii) The river width of 5 to 10 m at present is increased to 30 m to make full use of the flow area under the National Highway bridge. It becomes necessary to re-construct the road bridge to Bliss Housing Project and the one at the river mouth.

iv) The discharge capacity of the improved river channel increases to 140 m^3/s compared with the one at present of 50 m^3/s for the water depth of 2.0 m at the present river bed slope of 1/200. If confining dikes on both banks are constructed to allow the water depth of 2.7 m in future, it becomes 230 m^3/s which corresponds to 50-year probable flood.

(5) Binatagan Bridge

Binatagan Bridge which passes across the Nasisi River doesn't have an adequate flow area. And it is filled up with sedimentation. Due to the inadequate discharge capacity (FIG.-5.4.3), destruction of dikes as well as inundation is caused by floods during heavy rainfall. To avoid this situation, MPWH has taken up the Project to re-construct the bridge, the span of which is to be 60 m.

(6) Bridge of Ligao-Tabaco National Highway

The bridge of Ligao-Tabaco National Highway passing across the Nasisi River was completely washed out during typhoon "Daling". This is due to the improper structural design and maintenance. MPWH has taken up the Project to re-construct the bridge, the span of which is to be 60 m. (Sabo work section)

(7) Upper-most Reaches of the San Francisco River

Eastern tributaries of the Quinali (A) River pass across the Maharlika National Highway and join the San Francisco River. Most of the bridges don't have adequate flow areas for passage of flood water, thus, they have retarding effects. If such effects are avoided by enlarging the areas, inundation downstream is intensified. Therefore, re-construction of these bridges should not urgently implemented, as far as the discharge capacity of the reaches downstream, especially at the Mint Hill, is not adequate (FIG.-5.4.1.).

(8) Ogsong River

Downstream the Paulog Bridge of the Maharlika National Highway, the Ogsong River changed its course along 2 km reaches due to vast amount of sedimentation during typhoon "Daling". Dredging of the previous river channel by MPWH District Engineer's Office is underway to return the river flow as before.

(9) Yawa River

Flood inundation occurred during typhoon "Daling" due to inadequate discharge capacity (FIG.-5.4.18). But as far as the inundation is quite limited in area, depth and duration, no flood control works are found to be urgently necessary.

CHAPTER VI

VI. PROJECT FORMULATION OF MAYON VOLCANO SABO AND FLOOD CONTROL PROJECT

Mayon Volcano and its surrounding area is located in a region where typhoons are frequent and it often suffers from natural disasters such as eruptions, mud/debris flows, floods and storm surges. Furthermore, this project area is a fragile against such natural disasters because a scarcity of flat land has forced the economic and social activities to be conducted mainly on alluvial plains which are vulnerable to floods.

According to the present state of the project area, the basic issue seems to be concerned with conservation and use of land for the purpose of recovering pleasant lifestyles and securing safety and stability. It is necessary to enhance conservation and utilization of the land in conformity with the natural conditions of the land considering geographical and meteorological features and vegetation, and regaining contact with nature in daily life through conservation and recovery of the natural environment. At the same time it is necessary to plan and enforce land use under long term projection.

Therefore, besides the re-assessment and review of the Master Plan for Mayon Volcano Sabo and Flood Control Project, further implementation Plan of the project against floods and natural disasters except eruption should be established in close near future. The objectives of river system management in the project area are as follows.

- To conserve forests, rice field and retarding areas, and to promote the improvement of facilities for the conservation in mountainous area in order to secure stability of the river basins.

- For mountainous river basin, many barangays have been built on the slope of Mayon Volcano, and they are constantly threatened by mud/debris flow and flash flood. Therefore, countermeasures such as erosion control and forest conservation should be taken to protect mountainous slopes against mud/debris flow.

As most casualties are caused by mud/debris flow, the concentration of population and assets into dangerous areas should be avoided by diffusing information of areas which are menaced with mud/debris flow disasters and by enhancing conciousness of the people concerning disaster prevention. Also, casualties should be minimized by improving forcasting and warning and evacuation systems.

- Flat river basins such as Quinali (A), Quinali (B) and Yawa River basins have high potential of development for agricultural and urban land utilization. When floods occur at mountainous area, the force of the rushing water becomes increasingly powerful through the flat lands to the river mouth, receiving water from all the tributaries, and the river basins are always menaced by inundation. Once flood inundation occurs, the low level areas become easily subject to natural disasters and may suffer serious damage and casualties.

In considering the above mentioned objectives, the proposed project will be selected as a Sabo Project of the mountainous slopes of Mayon Volcano, since the recent disaster due to typhoon "Daling" in 1981 caused serious damages and casualties to the barangays located mainly on the southern slopes, and the project will prevent the disaster due to mud/debris flow directly. While, the river improvement works will require further a feasibility study after the completion of this study. However, the disaster prediction and warning system is desirable to be established in relation with the Sabo Project. Especially, the establishment of the disaster prediction and warning system is very effective to all disasters except the eruption of the volcano in the project area, both under with and without the Sabo project condition. Also, this system is very effective to produce a good result to social and mental stabilization of people.

The project for Sabo works and the disaster prediction & warning system project should be formulated as social projects as well as be established for social investment in the Province. Both of the projects will not be justified during the formulation stage either as each project or as combined project by an economic evaluation based on the tangible benefit. It is necessary and important to justify through the assessment of intangible and social benefits such as stabilization of people livelihood, protection of human life, social and mental stabilization, etc.

The Sabo project and the disaster prediction & warning system project will be implemented separately. The Sabo project should be implemented urgently followed by the Philippine's budget as a part of the river system management for the Quinali (A) River and the Yawa River, because the disaster due to recent typhoon "Daling" in 1981 occurred mainly on the southern slope of Mayon Volcano from the Nasisi River to the Pawa-Burabod River and the Philippine Government also has a long-cherished desire for the implementation of the urgent Sabo project from the view point of social impact and stabilization in the project area. The disaster prediction & warning system project will be implemented considering the stagewise construction after further study. It will also be utilized very effectively to disseminate the information of the possibility of the unforeseen natural disaster in all the project area including flat area where flood inundation occurs, and to gather the hydrological data systematically for further study of the river improvement works.

CHAPTER VII

VII. RE-STUDY OF THE SABO PROJECT

7.1 General

This chapter presents the re-study of the Sabo project based on the additional data, the re-assessment and review for the Master Plan. The study covers the risk analysis and identification of zoning area, the preliminary engineering plan and design of Sabo facilities, and the disaster prediction and warning system plan. The study aims:

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

To conduct a study for disaster prediction and warning system in the area.

To study the establishment of measures for disaster preparedness and prevention.

To identify urgent Sabo works and facilities, and disaster prediction and warning system.

To prepare an immediate phased implementation program of urgent Sabo/river improvement works and facilities and disaster prediction and warning system.

To conduct preliminary engineering design of the selected development giving all basic dimensions and technical description of all components to facilitate preparation of specifications at a later stage.

To examine and formulate the implementation arrangement by appropriate and suitable technology and methodology, taking into account local conditions, implementing organization, budget, methods of construction.

To estimate project cost, the foreign and local currency components, including adequate information and supporting data for economic and financial analysis.

To justify the project based on the analysis of project evaluation considering changes in such key factors as costs and benefits, implementation schedule, and other relevant factors.

7.2 Risk Analysis and Identification of Zoning Area

7.2.1 General

Devastated conditions by mud/debris flow are studied by field observation and interpretations of aerophotos taken in 1980 and 1982. Based on these data, risk analysis and mud/debris flow zone identification are carried out. 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. Disastered zone by mud/debris flow even before 1980 is also abstracted by the microrelief and vegetation of the area.

Risk analysis is carried out by the results of the study for danger zone and safety zone. Also shelter zones up to 20 places are selected around the main villages. In addition to the shelter zones, emergency evacuation areas are selected temporally in the project area.

7.2.2 Present Condition of Devastation on the Slopes of Mayon Volcano

Outlined in this subsection are the results of aerophoto interpretations and field observations undertaken before and after the disaster caused by typhoon "Daling" in 1981, followed by descriptions of the conditions of individual rivers.

FIG.-7.2.1 to FIG.-7.2.10 are series of devastation map and microtopography map obtained from an aerophoto interpretation of the zone affected by mud/debris flows before the 1981 disaster in comparison with the one after the disaster, as determined through an aerophoto interpretation and field investigations.

(1) General Conditions in the Survey Area

i) Even before the 1981 disaster, the rivers running along the SE-SW side of the slopes of Mayon Volcano had suffered from devastation as a result of past mud/debris flows to a more marked degree than those running along the other sides. Aerophoto interpretations and field observations conducted this time coincide with the ones in the Master Plan.

ii) Similarly, large accumulations of mud and debris are observed in the beds of rivers running along the SE-SW side of the volcano's slopes even before the 1981 disaster. These seem to be caused by Mayon Volcano's eruptions in 1968 and 1978.

iii) There isn't significant change in the lava flow and pyroclastic deposits located above EL. 1,500 m on the slopes of Mayon Volcano. It is not conceivable, therefore, that these phenomena are attributable to the mud/debris flows which occurred in 1981.

iv) The following rivers were seriously affected by the 1981 mud/debris flows: (a) Anuling River; (b) Budiao River; (c) Pawa-Burabod River. The Ogsong River was affected to a moderately serious degree.

v) Mud and debris flowed and spread along each of the above rivers in areas below EL. 150 m (downstream the Provincial Road). However, areas upstream the Provincial Road were affected in the Anuling 2 and Ogsong Rivers. In addition, river channel excavation occurred along the Ogsong River below the Provincial Road.

vi) The following rivers were slightly affected by the 1981 mud/debris flows: (a) Quirangay River; (b) Maninila River; (c) Masarawag River; (d) Nasisi River.

vii) Large accumulations of mud and debris are observed in sections of these rivers between EL. 350 m and 500 m. The gradient of the river bed in each case is approximately 10 degrees.

viii) Ground water emerges as surface water between EL. 100 m and 200 m and gushes down the slopes across the Provincial Road. The gradient of the river beds is approximately 3 degrees.

ix) A feature of Mayon Volcano is its alternate accumulations of lava flows with a relatively high consolidation (average thickness: 2-3 m) and pyroclastics with a relatively low consolidation. Specifically, where pyroclastic material is deposited under a lava flow, the pyroclastic material is first washed out allowing the lava flow to slide downwards under its own weight. This results in deeper and more widespread devastation of the gullies.

(2) Conditions of Individual Rivers

i) Quinali (A) River

(a) Quirangay River

Although mud/debris flows attributable to typhoon "Daling" did occur, no significant change is observed in conditions of the affected zone before and after the disaster.

As shown in FIG.-7.2.1 and FIG.-7.2.6, there isn't significant alteration in conditions of the affected zone before and after the disaster.

In this river, significant accumulations of mud and debris start at EL. 400 m, where the gradient of the river bed is 6-8 degrees. Deep gullies are formed along reaches of the river above this level, but no large accumulations of mud and debris exist. Also, mud and debris deposits in the river bed were covered with new lava flows ejected by Mayon Volcano's eruption in 1978. This new lava flow is being weathered relatively quickly. Aero observations by helicopter during the survey indicate a marked degree of weathering.

An analysis of sediment transport conditions shows that the right tributary was excavated between EL. 400 m and 330 m after the disaster. Accumulations of mud and debris are observed below that level. Excavation occurred in the left tributary between EL. 400 m and 290 m, and accumulations are observed below that level.

The scale of excavation and accumulations due to mud/debris flows is smaller than the Budiao and Pawa-Burabod Rivers. This is attributable to the smaller mud/debris flows from reaches higher than the gullies, and to the shorter length of the excavated sections. An additional factor is the new lava flow ejected by the 1978 eruption. This seems to have prevented the pyroclastics from flowing downwards and providing impact for mud/debris flows. In this region attention should be paid to the possibility of secondary erosion in the middle and lower reaches of the river.

(b) Tumpa River

An aerophoto interpretation indicates no significant change in the upper reaches above EL. 200 m. Below EL. 200 m, however, the center of mud/debris flows shifted 50-100 m eastward as compared with observations made in 1980, indicating that the river bed is unstable. Reaches of the river down to EL. 160 m was affected by mud/debris flows which occurred in 1980.

In 1982, however, the affected zone extended down to the San Francisco River due to typhoon "Daling". Traces of mud/debris flows are also existing outside the areas affected by the flows which occurred in 1980 and 1982 in the vicinity of the Tumpa River. The river course during mud/debris flows is reticulated with adjacent rivers of the Quirangay and the Maninila.

(c) Maninila River

No significant change is observed in mud/debris flows after the 1981 disaster.

As shown in FIG.-7.2.1 and FIG.-7.2.7, there was no significant change in the zone affected before and after the disaster. However, slight accumulations of mud and debris are observed in the lower reaches below the Provincial Road. These seem to have been caused by secondary erosion in the upper and lower reaches above and below the Provincial Road, and attention should, therefore, be paid to this secondary erosion. Also, slight sliding of a lava flow in the uppermost reaches of the gullies seems to be causing small flows of mud and debris.

(d) Masarawag River

This river was slightly affected by mud/debris flows resulting from typhoon "Daling" in 1981.

As shown in FIG.-7.2.1 and FIG.-7.2.7, substantial flows and accumulations of mud and debris are existing in the lower reaches of the main stream below EL. 260 m. Particularly large accumulations of mud and debris are observed in paddy fields around the undercut slope along the lower reaches below the Provincial Road (i.e. below approx. EL. 180 m).

An analysis of sediment transport conditions shows that marked accumulations of mud and debris in the river start at EL. 500 m, where the gradient of the river bed is 8-9 degrees. No significant accumulations exist at higher points because of the formation of deep gullies and the steep gradient of the river bed.

(e) Ogsong River (Nabonton Creek)

The lower reaches of this river were affected by mud/debris flows resulting from typhoon "Daling" in 1981.

As shown in FIG.-7.2.2 and FIG.-7.2.8, significant amounts of mud and debris flowed into paddy fields down to EL. 180 m (river bed gradient: 2 degrees). However, only slight mud/debris flows are observed in the lower reaches below EL. 100 m. The front edge of mud/debris flows resulting from typhoon "Daling" seems to have extended down to the Provincial Road.

Substantial accumulations of mud and debris are observed at around EL. 500 m. The gradient of river bed is approximately 10 degrees.

A feature of this river is the marked destruction of gullies in its uppermost reaches. In many places, high-consolidation lava has crumbled as a result of the excavation of low-consolidation pyroclastics, and in future, attention should be paid to this phenomenon.

(f) Nasisi River

Slight mud/debris flows are observed in the middle and upper reaches after the 1981 disaster.

As shown in FIG.-7.2.2 and FIG.-7.2.8, considerable accumulations of mud and debris are observed in the river bed around EL. 500 m, where the gradient of the river bed is 10 degrees. Damage to the gullies is also observed in the uppermost reaches. As with the Ogsong River, the excavation of pyroclastics has caused the lava to crumble, and careful attention should be paid to this damage in the future.

ii) Quinali (B) River

(a) Buang River

As shown in FIG.-7.2.3, the volume of mud/debris flows during 1981 disaster was not much. The reason may be that the gullies on this side of slopes of Mayon Volcano suffered less devastation than the other sides. The middle reaches were sedimented. The Buang Bridge was partially damaged at that time, and is now under repair.

iii) Yawa River

(a) Anuling 1 River

The lower reaches of this river were affected by mud/debris flows resulting from typhoon "Daling" in 1981.

As clearly shown in FIG.-7.2.4 and FIG.-7.2.9, significant accumulations of mud and debris are observed around Salvacion. The accumulation and spreading start around EL. 150-160 m. Information obtained by field interviews reveals that the thickness of the flow at its leading edge near Salvacion was approximately 2.5 m, and that the average thickness in other parts was approximately 2 m. The results of our field observations indicate 10-50 cm thick deposit of mud/debris flows on paddy fields.

A study of sediment transport conditions indicates significant accumulations of mud and debris in the river bed around EL. 460 m. The gradient of the river bed at that level is approximately 10 degrees. Also, the andesite is exposed in the upper reaches of the right tributary immediately above that level. Only slight amounts of mud and debris have accumulated in the higher reaches. No significant exposure of the andesite is observed in the left tributary. However, larger amounts of mud and debris have been deposited in the river bed of the left tributary than the right tributary, where the accumulation seems to be slight.

On the other hand, there isn't significant change in the configuration of pyroclastic deposits in the gullies and in the upper reaches above the gullies before and after the disaster. The source of the mud/debris flows in this river seems to have been the material excavated and deposited in the river bed prior to the disaster.

The impact for the mud/debris flows seems to have been the crumbling and excavation of pyroclastic deposits in the gullies or in the upper reaches above the gullies. There is far more longitudinal erosion than lateral erosion.

(b) Anuling 2 River

This river was affected by the mud/debris flows which resulted from typhoon "Daling" in 1981. Since the accumulation and spreading of mud and debris occurred at relatively high elevations, damage to houses was not severe.

As shown in FIG.-7.2.4 and FIG.-7.2.9, the accumulation and spreading of mud and debris started at around EL. 300 m prior to the disaster, and since the river channel in the lower reaches was not clearly formed, the spreading occurred over a wide area. This is attributable to the low level of the ground water and the absence of springs. In addition, as even a large volumes of surface water can be penetrated into the ground, river channels have not been formed. And it seems that surface water flows down only during heavy rainfall.

The accumulation and spreading of mud and debris start at a lower level after the disaster than before. The starting point is now near the ford, about 2.2 km upstream the Provincial Road. As mentioned above, the spreading and accumulation of mud and debris occurred where a clear river channel wasn't formed, and not much direct damage to houses was caused because the material spread before reaching the houses. The area of spreading is shown in FIG.-7.2.4 and FIG.-7.2.9.

With regard to sediment transport, significant accumulations of mud and debris in the river bed start around EL. 460 m. The gradient of the river bed at that level is approximately 10 degrees. Deep gullies and a narrow river channel were formed in the upper reaches above that level, and no significant accumulations are observed. According to an aerophoto interpretation and field observations undertaken after the disaster, excavation starts in the area mentioned above and extends down to EL. 300 m. Also, there has been no marked change in the configuration of pyroclastics deposited in or above the gullies. The source of the mud/debris flows seems to have been the material deposited in the river bed prior to the disaster.

(c) Budiao River

Significant mud/debris flows are observed in the lower reaches of this river.

As clearly shown in FIG.-7.2.4 and FIG.-7.2.9 substantial amounts of mud and debris accumulated and spread in the lower reaches around EL. 140 m. In particular, paddy fields in the lower reaches below Provincial Road between Budiao and Banadero and the railway bridge are covered with coarse sand, though the volume of boulders is small.

Sediment transport is characterized by significant accumulations of mud and debris on the river bed starting around EL. 480-500 m. The gradient of the river bed in that area is approximately 10 degrees. Also, there is an andesite waterfall in the upper reaches immediately above that level. Deep gullies run along the slope, and no significant accumulation of mud and debris is observed, except in the area above the fall, where mud and debris are deposited. However, substantial amounts seem to have been deposited at the bottom of the waterfall. Alternate excavation and accumulation after the disaster are also observed between EL. 480-500 m and EL. 150 m. The accumulation and spreading of mud and debris start in the lower reaches below that level. FIG.-7.2.4 and FIG.-7.2.9 show the zone where mud and debris accumulated and spread. There isn't significant change in the configuration of pyroclastics deposited in or above the gullies before and after the disaster. The source of the mud/debris flows seems to have been the material excavated and deposited in the river bed prior to the disaster. The impact seems to have come from the crumbling and excavation of pyroclastics in the gullies or in the upper reaches above the gullies. The pattern of erosion seems to have been characterized more by longitudinal erosion than by lateral erosion. There was only slight lateral erosion, occurring on the undercut slope. As the catchment area of the Budiao River is extensive, it is likely that sediment transport will occur in significant volumes in the future.

An analysis of the accumulation of mud and debris after the disaster shows that river bed excavation starts around EL. 440 m and continues down to around EL. 180 m. The excavation of the right bank has been particularly severe, and the river channel is straight. Mud and debris excavated above EL. 160 m have accumulated and spread in the river bed in the lower reaches. FIG.-7.2.4 and FIG.-7.2.9 show the zone covered with mud and debris.

(d) The Pawa-Burabod River

Marked flows of mud and debris are observed in this river. As clearly shown in FIG.-7.2.4 and FIG.-7.2.10, significant changes occurred in the lower reaches where the gradient of the river bed is approximately 3 degrees. In particular, there occurred 200 m rightward shift of the river channel around the Provincial Road between Mabinit and Bonga. The channel, which previously curved to the left, became straight. In the lower reaches below that level, the river channel is divided into two, forming left (previously the main stream) and right tributaries. Substantial amounts of mud and debris accumulated in the river beds of both channels. A dike with a relative height of approximately 2 m runs along the left bank for a distance of 1.9 km. Although this dike has effectively prevented the mud and debris from spreading, it caused the river bed on the left side of the river to be raised to a level higher than the surrounding plain. At present, the right tributary forms the main stream of the river.

An outline description of sediment transport conditions in the Pawa-Burabod River is as follows:

Significant accumulations of mud and debris in the bed of this river start around EL. 480 m. The gradient of the river bed at that level is approximately 10 degrees. There are deep gullies in the upper reaches above that level, and andesite rocks are exposed at several places in the river bed. No significant accumulations of mud and debris are observed there.

On the other hand, the results of aerophoto interpretations and field observations undertaken before and after the disaster reveal that excavation occurred after the disaster within the area of mud and debris deposits, that is, between EL. 480 m and 150 m. Although detailed observations reveal some accumulation in this area, it is generally characterized as an excavation area. The accumulation and spreading of mud and debris start in the lower reaches below this area. FIG.-7.2.4 and FIG.-7.2.10 indicate the zone in which mud and debris have accumulated and spread.

As has already been mentioned, there isn't significant change in the configuration of volcanic ash and pyroclastic deposits in the upper reaches above the gullies before and after the disaster. In view of this fact, the source of mud/debris flows in this river seems to have been the material deposited in the river bed (probably as a result of the 1968 and 1978 eruptions of Mayon Volcano) and excavated by heavy rainfall. The impact was apparently provided by the crumbling and excavation of volcanic ash or pyroclastics in the gullies or in the upper reaches above the gullies. The pattern of erosion is characterized far more by longitudinal erosion than by lateral erosion.

The findings of aerophoto interpretations and field observations indicate that mud/debris flows may occur around EL. 280 m, where the gullies curve gradually to the right. Clear traces of mud/debris flows beyond the left bank walls of the gullies are observed in this area. As subsequent flows may follow a direct downward course, threatening the village of Bonga, appropriate erosion control measures should be taken to protect the village from this danger. Erosion control is also necessary at the inland side of the existing dike.

iv) East and North-East Streams

The Buyuan, Matanag and Basud Rivers run along the east slope of Mayon Volcano. Of these, the Buyuan and Basud were affected by mud/debris flows resulting from typhoon "Daling" in 1981. The area affected along the Buyuan River is growing at a much faster pace than the other two rivers, and an additional 68 ha has been covered since 1980. Also, the river channel has shifted southward and mud/debris flows reach down to Albay Gulf in the lowest reaches of this river. The area covered with mud and debris along the Basud River amounted to 110 ha in 1980 and 121 ha in 1982 as shown in FIG.-7.2.5.

TABLE-7.2.1 presents the devastation area along each river. According to this table, substantial devastation occurred along the Quirangay, Ogsong and Nasisi Rivers. Significant increases in the areas affected are observed in the Anuling, Pawa-Burabod and Buyuan Rivers, where the devastated areas increased by 60 ha or more between 1980 and 1982.

7.2.3 Risk Analysis and Indentification of Zoning Area

(1) Method of Analysis and Zoning

The general procedure is schematically shown in FIG.-7.2.13. The extent of devastation of the survey area as the result of typhoon "Daling" in 1981 is ascertained by means of aerophoto interpretations and field observations. Aerophotos taken in 1980 and 1982 are first closely checked and devastation map (FIG.-7.2.1 to FIG.-7.2.5, scale: 1/25,000) is prepared. The areas covered with mud, debris and sand as observed from the 1980 and 1982 aerophotos are plotted on the devastation map. Areas affected by previous mud/debris flows prior to 1980 are also plotted through reference to such factors as drainage texture, topography and vegetation.

To determine the extent of mud/debris flows, the microtopography is studied in closer details and microtopography map is prepared. Vegetation around the river channels is also plotted on this map (microtopography map, see FIG.-7.2.6 to FIG.-7.2.10). The extent of devastation resulting from mud/debris flows is analyzed by superimposing areas affected in previous years over the areas affected in 1980 and 1982. On the basis of the findings of this analysis, the affected areas are classified into danger zones, safety zones, shelter zones and emergency evacuation areas, as follows:

i) Danger zones

These zones are defined to be the areas where the traces of mud/debris flows are clearly identified in and before 1979 and 1981. The areas extended from either the end point of gully or the top of fan down to the boundary with alluvial plain, even where the traces of mud/debris flows are not clearly recognized, are defined as danger zones. The railway, roads and river channels are also taken as boundaries.

ii) Safety zones

These zones are selected outside the above danger zones where gullies upstream are not developed. Furthermore, these zones are mainly selected based on the safety against mud/debris flows. However, the disasters due to volcanic activities are not considered in selection, since the forecasting of disaster due to lavas, volcanic ejecta, growing clouds, heat mud flows, etc. is very difficult.

iii) Shelter zones

These zones are selected mainly against mud/debris flows excluding volcanic activities, by the limited informations such as topographic conditions and interpretation of aerophotos. The selection of shelter zones is made under the following conditions;

- The shelter zone shall not be selected within the danger zones in principle.
- If the shelter zone is selected on hills within the danger zones, the safety is carefully studied and confirmed against disasters due to mud/debris flows, flood inundation and landslides.
- The shelter zones shall be selected at the places in and near the barangays and the municipalities to ensure the relief activities.

iv) Emergency evacuation areas

In addition to the shelter zones, emergency evacuation areas are selected temporally based only on interpretation of aerophotos. The selection of these areas is made under the following conditions;

- Areas are selected as temporary and emergent areas for the evacuation activity due to mud/debris flow.
- Areas are located in and near barangays, and are with road connection.

The zoning is carried out according to the above criteria, and a map showing these zones is prepared (See FIG.-7.2.11 and 7.2.12, scale: 1/50,000).

(2) Results of Risk Analysis and Identification of Zoning Area

As has already been mentioned in Subsection 7.2.2, significant mud/debris flows are observed along rivers on the south and southwest sides of Mayon Volcano. The rivers affected include the Anuling, Budiao, Pawa-Burabod, Ogsong and Nasisi.

Aerophotos taken in 1980 and 1982 show that the areas affected by mud/debris flows extend down to the lower terrain and alluvial plains. However, the incidence of damage as a result of mud/debris flows is apparently limited to the end of the fan areas, where the gradient is 2-3 degrees. Also, some alteration is observed in course of river channels within the fan area before and after the disasters.

The conditions described above are a further indication that similar danger exists throughout the area around Mayon Volcano. The lower reaches of rivers which have been subject to mud/debris flows and to devastation of gullies in their upper reaches, are particularly risky.

On the basis of the risk analysis described above, areas unaffected by mud/debris flows and where there is no devastation of gullies in the upper reaches of rivers are designated safety zones. In addition to areas around Mayon Volcano, other safety zones exist at the end of the north and east fans, around the Yawa River and Maharlika National Highway in the south, and in the mountainous area adjoining the SW-NW side of the volcano and within the reaches below approximately EL. 100 m of the Nasisi and the Ogsong Rivers.

In villages where devastation from mud/debris flows is likely, shelter zones and emergency evacuation areas are selected. As a rule, these must have suitable housing and facilities for refuge. Where such areas are too distant, however, tablelands free from the risk of mud/debris flows, flooding and devastation are selected instead even within the danger zones. The shelter zones and emergency evacuation areas should be finally established in due consultation with the relevant authorities and by further study for the above criteria.

7.3 Preliminary Engineering Design of Sabo Facilities

7.3.1 General

The objective of Sabo plan is ensure safety control on sediment discharge in the whole river basin. They are generally classified into two (2) categories, namely one (1) "River Basin Management of Sediment" and two (2) "Sabo Works for Preventing Direct Disaster due to Sediment". The classification is based only on the location and effect of the facilities. As mentioned in "Hydrological Analysis" in section 3.2, the daily or 3-hour rainfall during typhoon "Daling" was estimated at a return period of about 5 years. Howerver, as far as rainfall records are measured only in Legazpi in the Yawa River basin, heavier rainfall seems to have occurred during the typhoon in mountainous areas as far as the conditions of the mud/debris flows are studied. It should be note that the mud/debris flows due to the flood caused loss of lives more than thirty (30), and the area damaged is mainly in Sabo work section.

Since the planning scale of sediment amount is proposed at 50 year probable, it is probable that the amount of sediment runoff and disaster will be larger than the one in 1981. It is difficult that sediment runoff and yield are completely controlled by Sabo facilities arrangement, so that, the principles of this study are taken as follows.

(1) Control on the direction of mud/debris flows by arrangement of spur dikes, in order to ensure safety of objects to be protected from disaster. And to make the most use of spur dikes as the retarding basin.

(2) Prevention of mud/debris flows or dense sediment from entering the main river course in the lower reaches.

(3) Reduction of sediment yield in upstream reaches to the lowest minimum.

Sabo project should be implemented in a long term, and the proposed Sabo planning is made based on the present river conditions and the recent disaster due to typhoon "Daling". Therefore, the Sabo planning and design should be modified timely and properly prior to and during implementation period, taking into account the changes of topographic conditions due to heavy rain and unforeseen mud/debris flow.

7.3.2 Subject Rivers

Subject rivers of this study are streams of the Quinali (A) River and the Yawa River basins around the southern slope of Mayon Volcano. They are ten (10) rivers, namely, the Quirangay, the Tumpa the Maninila, the Masarawag, the Ogsong and the Nasisi Rivers in the Quinali (A) River basin, and the Anuling 1, the Anuling 2, the Budiao and the Pawa-Burabod Rivers in the Yawa River basin. For the respective rivers, present devastation conditions and importance of the objects to be protected are classified in TABLE-7.3.1 as well as the necessity of Sabo works.

7.3.3 Base Point and Sub-Base Point

For the above rivers, the base points and sub-base points for Sabo plan are set at the locations as shown in FIG.-7.3.1 and FIG.-7.3.2. The sediment control plan and Sabo facility arrangement plan are established estimating the quantity of sediment that passes through these base points.

7.3.4 Sediment Runoff Volume

In Sabo plan, it is important to estimate the sediment amount transported as mud/debris flows or dense sediment flows caused by major floods. In the Master Plan, the empirical formula proposed by Ashida and Okumura was employed to estimate the sediment runoff volume. The coefficient of the formula is re-studied because the sediment runoff volume during typhoon "Daling" is estimated by interpretation of the two (2) series of aerophotos. The sediment runoff volume at the base points is estimated for the design flood with a return period of 50 years as follows.

SEDIMENT RUNOFF VOLUME (50-yr Probable Flood)

Name of Basin	Name of River	Drainage Area (km2)	Sediment Runoff Volume (m3)	Specific Sediment Runoff (m3/km2)
Quinali (A)	Quirangay	10.0	260,100	26,000
	Tumpa	5.7	43,700	7,700
	Maninila	4.9	94,000	19,200
	Masarawag	9.7	276,800	28,500
	Ogsong	8.7	140,500	16,100
	Nasisi	35.7	992,100	27,800
Yawa	Anuling	9.4	415,600	44,200
	Budiao	7.5	234,600	31,300
	Pawa-Burabod	7.6	252,000	33,200

7.3.5 Allowable Sediment Volume

The allowable sediment volume is very closely concerned with river planning and conditions in the lower reaches, and it is controlled by the complicated factors. In this study, the bed load under the present river condition for the design flood with a return period of 50 years is taken as the allowable sediment volume supposing that the bed load is nearly equal to the allowable sediment volume in the lower reaches. This means that the sand deposition in the lower reaches is not so serious and the natural regulation of sediment in the river channel can also be expected. The bed load is calculated by employing Ashida, Takahashi and Mizuyama's formula.

On the other hand, the excess sediment volume is defined as the remainder of the sediment runoff volume minus the allowable sediment volume. Sabo plan is established for the excess sediment volume. Excess and allowable sediment volume estimated are listed as follows.

EXCESS SEDIMENT VOLUME

Name of River	Sediment Runoff Volume(m3)	Allowable Sediment Volume(m3)	Excess Sediment Volume(m3)
Quirangay	260,100	82,600	177,500
Tumpa	43,700	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

7.3.6 Effects of Sabo Facilities

Effects of Sabo Facilities is generally classified into three (3) categories as follows: reduction of sediment yield; check and retarding of sediment runoff; trapping of sediment runoff. Sabo facilities and their effects are described below.

(1) Sabo dam

Sabo dam is defined as a facility constructed across the river with an effective height more than 5.0 m, and it has all of the three effects mentioned above.

(2) Consolidation Work

A facility constructed across the river with an effective height not more than 5.0 m is called consolidation dam or ground sill. Especially, ground sill is defined as the one with no effective height.

They have the effects to fix unstable river bed sediment and to disperse mud/debris flows.