PART II

FEASIBILITY STUDY
ON
SABO AND FLOOD CONTROL

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CHAPTER I PROJECT AREA AND BASIC DESIGN CRITERIA

1.1 Objective Projects and Target Flood Protection Areas

The Master Plan Study proposed an integrated long-term sabo and flood control plan to protect 12 inundation sub-districts with a total inundation area of 15,300 ha and to relieve a population of 57,600 from flood menace. The proposed structural master plan consists of eight (8) sabo dams and twelve (12) river improvement sub-projects.

The target flood protection districts, areas and existing population of the proposed sub-projects are shown below. Location of the target flood protection districts and proposed structural measures are shown in Fig. II.1 and Fig. II.2, respectively.

Protection District	Proposed Project	Area (ha)	Population
Tangit, Laoag	Tangit Laoag River Improvement	600	3,945
Suyo, Laoag	Suyo Laoag River Improvement	200	1,054
Poblacion, Laoag	Poblacion Laoag River Improvement	130	5,149
Camangaan, Laoag	Camangaan Laoag River Improvement	480	2,039
Poblacion, San Nicolas	Poblacion San Nicolas River Improv.	230	5,835
San Manuel, Sarrat	San Manuel Sarrat River Improvement	550	1,339
Suyo, Dingras	Suyo Dingras River Improvement	200	2,317
Poblacion, Dingras	Poblacion Dingras River Improvement	550	4,228
Cura/Labugaon River	Cura Sabo Dam No. 1 / No. 2 Labugaon Sabo Dam No. 1 / No. 2 Cura/Labugaon River Improvement	3,900	11,115
Solsona River	Solsona Sabo Dam No. 1 / No. 2 Solsona River Improvement	2,280	7,152
Madongan River	Madongan Sabo Dam Madongan River Improvement	4,180	8,764
Papa River	Papa Sabo Dam Papa River Improvement	1,950	4,651
Total		15,250	57,588

From the above eight (8) sabo dams and 12 river improvement projects, five (5) sabo dams and seven (7) river improvement projects were selected during the Master Plan Study as objective projects for the Feasibility Study. The objective projects are listed below along with their target flood protection districts, areas and existing population. For location and target flood protection areas, see Fig. II.1 and Fig. II.2.

River	Objective Project	Protection District	Area (ha)	Population
Laoag	Pob. Laoag R/I	Pob. Laoag	130	5,149
Laoag	Pob. San Nicolas R/I	Pob. San Nicolas	230	5,835
Laoag-Bongo	Pob. Dingras R/I	Pob. Dingras	550	4,228
Cura/Labugaon	Cura Sabo Dam No.1 Labugaon Sabo Dam No.1 Cura/Labugaon R/I	Cura/Labugaon River	3,900	11,115
Solsona	Solsona Sabo Dam No.1 Solsona R/I	Solsona River	2,280	7,152
Madongan	Madongan Sabo Dam Madongan R/I	Madongan River	4,180	8,764
Papa	Papa Sabo Dam, Papa R/I	Papa River	1,950	4,651
Total			13,220	46,894

Note: Pob. means poblacion and R/I means river improvement.

1.2 Existing River Conditions

The rivers related to the above projects are Laoag, Lower Bongo, Cura/Labugaon, Solsona, Madongan and Papa. Their existing morphological and hydrological features are summarized below.

River	Length (km)	Slope (%)	Width (m)	Carrying Capacity (m^3/s)	Return Period (year)	Remarks
Laoag	31.6	0.021-0.090	400-1,000	2,000-5,000	2-4	no dike
Lower Bongo	11.0	0.151-0.200	300-600	500-2,000	5	no dike
Cura/Labugaon	17.0	0.331-1.08	100-1,000	500-2,000	1-10	no dike
Solsona	11.5	0.137-1.54	230-330	1,000-1,300*	25**	with temporary dikes
Madongan	9.5	0.452-1.35	300	2,000*	25**	with temporary dikes
Papa	7.5	0.540-1.85	223	1,000-1,500*	100**	with temporary dikes

* 1.0m freeboard capacity of temporary dike ** return period of temporary dike capacity

As shown in the above table, the Laoag, Lower Bongo and Cura/Labugaon rivers are flooded frequently due to their small flow capacities. Although the calculated flood carrying capacities of the Solsona, Madongan and Papa rivers are large, these rivers are also exposed to high flood risk because the existing temporary dikes are insufficient in structural strength and are easily breached. For details of the existing river morphological and hydrological features, see Master Plan Study, Main Report, Chapter IV.

1.3 Design Flood Discharge

The structural master plan was prepared for a design flood of 25-year return period. The design discharge distribution is shown in Fig. II.3. Based on this design flood discharge distribution, the objective river improvement projects for the Feasibility Study are designed to meet also a 25-year flood discharge as shown below.

River	Project	Design Discharge (m^3/s)
Laoag	Pob. Laoag R/I	10,900
	Pob.San Nicolas R/I	10,900
Laoag-Lower Bongo	Pob. Dingras R/I	8,700-6,500-3,220
Cura/Labugaon	Cura Sabo Dam No. 1	850
	Labugaon Sabo Dam No. 1	1,260
	Cura R/I	2,360-850
	Labugaon R/I	1,260
Solsona	Solsona Sabo Dam No. 1	1,030
	Solsona R/I	3,490-1,120-1,030
Madongan	Madongan Sabo Dam	1,970
	Madongan R/I	1,970
Papa	Papa Sabo Dam	690
	Papa R/I	690

Note: Pob. means Poblacion and R/I means river improvement.

1.4 Design Sediment Control

A sabo dam controls sediment runoff from the watershed to the downstream rivers. The balance of sediment inflow to and outflow from the sabo dam is accumulated in the sedimentation basin. As a result, the slope of the sedimentation basin rises with the lapse of time. On the other hand, the sediment outflow from the sabo dam increases according to the rise of the sedimentation basin slope. The rising rate of the sedimentation basin slope varies, depending on the sedimentation basin volume which is determined by its dam crest elevation. For details of the sediment control of a sabo dam, see Chapter VII, Part I of this Report.

The proposed sabo dams are designed to control the sediment outflow below the allowable sediment transport capacity of the downstream rivers for a flood with a 25-year return period. In the Master Plan Study, the design sedimentation basin slopes of the proposed sabo dams were set at three-fourths of the original riverbed slopes. Further, the design sedimentation volumes were set so that their sedimentation basin slopes will not exceed the design ones until the target year (after 20 years). The design slopes and sedimentation volumes of the sabo dams proposed in the Master Plan are summarized below.

River	Sabo Dam	Catchment Area (km^2)	Design Sedimentation Slope (%)	Design Sedimentation Volume (m^3)
Cura	Cura No. 1	68.2	0.81	391,000
	Cura No. 2	63.1	0.81	150,000
Labugaon	Labugaon No. 1	100.5	0.86	1,043,000
	Labugaon No. 2	90.9	0.86	511,000
Solsona	Solsona No. 1	72.2	1.94	233,000
	Solsona No. 2	68.2	1.94	233,000
Madongan	Madongan	153.8	1.14	2,192,000
Papa	Papa	51.4	1.56	707,000
Total				5,460,000

The heights of the objective sabo dams for the Feasibility Study; namely, Cura No. 1, Labugaon No. 1, Solsona No. 1, Madongan and Papa, are designed to have the sedimentation capacities shown above.

CHAPTER II SEDIMENT ANALYSIS

2.1 Design Sabo Dam Crest Elevation and Sedimentation Capacity

The design sabo dam crest elevation is determined to meet the required sedimentation volume estimated in the Master Plan Study based on the detailed longitudinal and cross sectional surveys in the sedimentation basin. In calculating the sedimentation volume, the design sedimentation slope is set at three-fourths of the original riverbed. The determined design dam crest elevation, sedimentation slopes and sedimentation capacities of the five (5) objective sabo dams are as follows. The plans and longitudinal profile of the sabo dams and sedimentation basins are shown in Fig. II.4(1) to Fig. II.4(5).

Sabo Dam	Dam Crest Elevation (EL. m)	Sedimentation Slope (%)	Sedimentation Capacity (m^3)
Cura No.1	118.0	0.75	422,000
Labugaon No.1	125.0	0.82	1,197,000
Solsona No.1	143.0	1.29	242,000
Madongan	133.0	0.98	2,207,000
Papa	145.5	1.38	794,000
Total			4,862,000

Note: Some design dam crest elevations and sedimentation slopes were revised from those of the Master Plan, based on the detailed topographic survey.

2.2 Sediment Transport Analysis

Sediment transport analyses were performed for the whole river stretch of the objective sedimentation basins of sabo dams and the objective alluvial fan river channels. The analyses aim to verify the sediment control effects of the proposed sabo dams and to predict the riverbed variation of the proposed river channels.

2.2.1 Calculation Methodology

Sediment transport in the river sections of the sedimentation basins and alluvial fan rivers was simulated by combining the following three basic calculations.

(1) *Hydraulic Calculation*: The non-uniform flow calculation method is adopted to calculate flow velocity, water depth and hydraulic gradient in the river sections.

(2) *Sediment Transport Rate Calculation*: Ashida-Michiue's formula widely used in Japan is applied for the calculation of bed and suspended loads transport.

(3) *Riverbed Variation Calculation*: Riverbed variation in a certain river section is obtained by calculating the balance between sediment inflow from the upstream boundary and sediment outflow from the downstream boundary.

For the above calculations, the data on hydrology, river cross sections, riverbed materials, and sediment runoff from the mountain valley and its grain size distribution obtained in the course of the Master Plan and Feasibility Studies are necessary.

As for the hydrological data, the flood discharge series in an hydrological average year (the year of 1968 is assumed in this Study) is used. The average annual sediment inflow from the mountain valley (average annual sediment inflow to sabo dam) in each river is assumed as follows.

River	Sediment Inflow (m^3/year)
Cura	54,600
Labugaon	154,700
Solsona	114,500
Madongan	223,100
Papa	99,600

2.2.2 Sediment Control Effects of Sabo Dam

(1) Riverbed Variation of Sedimentation Basin

The riverbed of the sedimentation basin gradually aggrades with the lapse of time. The riverbed aggradation in the proposed sabo dams were simulated as shown in Fig. II.5(1) to Fig. II.5(5).

In the Master Plan, a series of two (2) sabo dams are proposed in the Cura, Labugaon and Solsona rivers. The downstream sabo dams, Cura No. 1, Labugaon No. 1 and Solsona No. 1 will be constructed in the first phase and the upstream sabo dams, Cura No. 2, Labugaon No. 2 and Solsona No. 2 will be constructed 10 years after the construction of the downstream sabo dams.

The riverbed variation in the downstream sabo dams is complicated. The riverbeds continue aggrading for 10 years. However, they degrade after 10 years due to the sediment control of the upstream sabo dams and, thereafter, again begin to aggrade. Finally, the sedimentation slopes of the sabo dams reach or approach the respective design slopes after 20 years.

On the other hand, the riverbed variation of the upstream dams is simple. The riverbeds continue the gradual aggradation after the construction and their slopes reach or approach the design ones after 20 years.

In the Madongan and Papa rivers, only one (1) dam each is proposed. The riverbeds of the sabo dams continue aggradation after construction and their slopes reach or almost attain the design slopes after 20 years.

(2) Variation of Annual Sediment Outflow from Sabo Dam

The sediment outflow from a sabo dam increases according to the rise of its sedimentation slope. The average annual sediment outflow from the proposed sabo dams were simulated as shown in Fig. II.5(1) to Fig. II.5(5).

The sediment outflow from the downstream sabo dams in the Cura, Labugaon and Solsona rivers shows complicated variations corresponding to the changes of the sedimentation slopes. The sediment outflow from the downstream sabo dams gradually increases until 10 years after construction. It decreases for some time after 10 years due to the sediment control of the upstream sabo dams and, thereafter, again begins to increase.

On the other hand, the sediment outflow from the upstream sabo dams gradually increases in a simple manner after construction. However, the total sediment control effect of the upstream and downstream sabo dams are measured by the sediment outflow from the downstream sabo dam.

The sediment outflow of the sabo dams in the Madongan and Papa rivers gradually increases, corresponding to the riverbed aggradation of their sedimentation basins.

The average annual sediment runoff control effects of the proposed sabo dams for 20 years are summarized below.

Annual Sediment	Cura	Labugaon	Solsona	Madongan	Papa
Average Annual Inflow (m^3/year)	54,600	154,700	114,500	223,100	99,600
Average Annual Outflow for 20 Years (m^3/year)	20,900	57,300	69,700	51,900	36,200
Control Rate (%)	62	63	39	77	64

2.2.3 Prediction of Riverbed Variation

The riverbed variations of the Cura, Labugaon, Solsona, Madongan and Papa rivers were simulated under the conditions with and without sabo dam for the following river reaches.

River	Simulated River Reaches	Length (km)
Cura	Confluence to Laoag - Improvement End	11.85
Labugaon	Confluence to Cura - Improvement End	2.0
Solsona	Confluence to Bongo - Irrigation Dam	10.5
Madongan	Confluence to Solsona - Irrigation Dam	9.0
Papa	Confluence to Bongo - Irrigation Dam	7.0

In both simulation cases of with and without sabo dam, the Cura and Labugaon rivers were assumed to confine flood waters within the channels as well as the other rivers although they are provided with no dikes at present.

According to the above simulations, the entire stretches of the above five (5) rivers are predicted to gradually aggrade in the case without sabo dam. The aggradation rate is considerably large in the lower reaches. In the case with sabo dam, the riverbed aggradation is reduced by the sediment control of the proposed sabo dams. Some degradation is expected in the upper/middle reaches of Cura River, in the middle reaches of Madongan River and in the whole stretch of the Labugaon River.

The average riverbed aggradation or degradation of the rivers after 20 years are predicted as shown below.

(unit: m)

River	Without Sabo Dam			With Sabo Dam		
	Lower Reach	Middle/Upper Reach	Entire Reach	Lower Reach	Middle/Upper Reach	Entire Reach
Cura	0.36 (0-6.0K)	0.25 (6.0-11.85K)	0.31 (0-11.85K)	0.16 (0-6.0K)	0.00 (6.0-11.85K)	0.09 (0-11.85K)
Labugaon	-	-	1.47 (0-2.0K)	-	-	-0.35 (0-2.0K)
Solsona	1.48 (0-3.0K)	1.33 (3.0-10.5K)	1.38 (0-10.5K)	0.96 (0-3.0K)	0.47 (3.0-10.5K)	0.62 (0-10.5K)
Madongan	2.24 (0-4.0K)	0.85 (4.0-9.0K)	1.51 (0-9.0K)	0.24 (0-4.0K)	0.04 (4.0-9.0K)	0.06 (0-9.0K)
Papa	1.11 (0-3.0K)	1.28 (3.0-7.0K)	1.20 (0-7.0K)	0.47 (0-3.0K)	0.12 (3.0-7.0K)	0.28 (0-7.0K)

Note: Positive figures show aggradation, while negative figures show degradation.

Even in the case with sabo dam, some riverbed aggradation is predicted in the lower reaches of each river after 20 years. However, the riverbed elevation at that time is expected to be still lower than the inland elevation. For the simulation results on the riverbed variations with and without the sabo dam at each river section, see Volume III-2, Appendix A, Sediment Analysis, Table A.2.1.

The difference of the existing average riverbed elevation and future average riverbed elevation with sabo dam (after 20 years) from the inland elevation are summarized below.

(unit: m)

River	Existing			Future		
	Lower Reach	Middle/Upper Reach	Entire Reach	Lower Reach	Middle/Upper Reach	Entire Reach
Cura	-0.72 (0-6.0K)	-1.01 (6.0-11.85K)	-0.91 (0-11.85K)	-0.65 (0-6.0K)	-1.01 (6.0-11.85K)	-0.88 (0-11.85K)
Labugaon	-	-	-0.90 (0-2.0K)	-	-	-1.26 (0-2.0K)
Solsona	-2.13 (0-3.0K)	-1.65 (3.0-10.5K)	-1.80 (0-10.5K)	-1.17 (0-3.0K)	-1.18 (3.0-10.5K)	-1.18 (0-10.5K)
Madongan	-1.44 (0-4.0K)	-1.81 (4.0-9.0K)	-1.61 (0-9.0K)	-1.20 (0-0.40K)	-2.01 (4.0-9.0K	-1.58 (0-9.0K)
Papa	-1.51 (0-3.0K)	-1.83 (3.0-7.0K)	-1.68 (0-7.0K)	-1.04 (0-3.0K)	-1.71 (3.0-7.0K)	-1.40 (0-7.0K)

Note: Negative figures show riverbed is lower than inland elevation.

The existing and future average riverbed elevations and inland elevation at each river section are compared in Fig. II.6(1) to Fig. II.6(2). Further, the existing dike elevation of the Solsona, Madongan and Papa rivers are compared in these figures for reference. In these figures, the ordinates of the riverbed elevation, inland elevation and dike elevation are presented in height difference from the design high water level.

2.2.4 Riverbed Variation at Design Flood

A considerably large sediment runoff is expected at the design flood even after completion of the sabo dams. This large sediment runoff may cause imbalanced sediment transport in the downstream river channel, resulting in an excessive sediment deposition in some river sections, especially in the river sections where the riverbed makes a large change.

Hence, the sediment balance in the alluvial fan rivers at the design flood time is checked. In this analysis, the slope of the sedimentation basin of the sabo dams are all assumed to be the respective design slopes (3/4 of original slope) for a greater factor of safety.

The sediment balance in each river at the design flood time is shown in Fig. II.7. The location and height of maximum riverbed aggradation in each river are estimated as follows.

River	Stretch	Sediment Deposit (m^3)	Maximum Riverbed Aggradation Height (m)
Cura	4.0 - 4.55K	30,200	0.18
Labugaon	2.87 - 3.53K	26,500	0.25
Solsona	10.5 - 10.84K	17,400	0.45
Madongan	9.0 - 9.1K	19,700	0.50
Papa	7.0 - 7.27K	30,000	0.53

As shown in the above table, most of the sections having maximum aggradation are located at the fan apexes, the uppermost sections along the channels. The maximum riverbed aggradation height is within the range of 0.45 to 0.53 m in the Solsona, Madongan and Papa rivers. The existing cross-sections at the apexes, however, have enough capacity to absorb the sediment deposits because of the prevailing channel incision caused by the sediment control effect of the irrigation diversion dams.

2.3 Sandbar Characteristics

2.3.1 General

In the river channel in the alluvial plain, sandbars are generally formed in the bed and, as a result, water convergence and divergence sections appear alternately in the longitudinal direction. Bank erosion usually occurs at the water convergence section.

The forms of sandbar are roughly classified into three (3) types: single-row bar, double-row bar and scale-like bar. Size of the sandbar becomes larger in the order of scale-like, double and single.

Generally, larger size sandbars cause larger bank erosion. The size of sandbar is usually measured by its wavelength and wave height.

Further, the sandbar moves downward during floods, being accompanied by the movement of stream convergence point. The movement of stream convergence point brings about a new bank erosion at the downstream. Finally, the movement of sandbar causes bank erosion at every river section. However, if the movement of sandbar is restricted by some river morphological characteristics, bank protection works can be concentrated on some limited river sections.

2.3.2 Field Survey of Sandbar

Floods of the Solsona, Madongan and Papa rivers have been confined comparatively well by the temporary dikes for four (4) years since 1993, although the dikes were breached at many locations during the same period. The existing sandbar formation of the above rivers are considered to show the characteristics of the improved river channels in the alluvial fan areas.

In the course of the Feasibility Study, the following salient features of sandbar were surveyed, as shown in Fig. II.8(1) to Fig. II.8(3):

(1) sandbar formation (sandbar frontlines);

(2) main flood stream lines during Typhoon Gloring; and,

(3) wave height of sandbar (height difference between sandbar crown and lowest riverbed at floodwater convergence point).

2.3.3 Sandbar Formation

Single bars predominate in the following river sections.

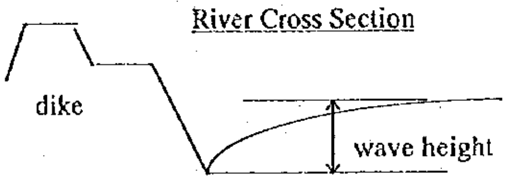
River	Total River Section	Single Bar Section
Solsona	0-11.5K	0-5K; 8-11.5K
Madongan	0-9.5K	7-9.5K
Papa	0-7.5K	0-7.5K

The single sandbars in the above river sections hardly move downward during floods and as a result, location of the flood convergence points is almost fixed. Bank protection works may generally be concentrated around the existing floodwater convergence points in the above river sections.

On the other hand, double sandbars are formed in the remaining river sections of the Solsona and Madongan rivers. These sandbars easily move downward during flood, being accompanied by the movement of floodwater convergence points. Hence, continuous bank protection works may be necessary for both banks of these river sections.

2.3.4 Wave Height of Sandbar

The wave height of sandbar is defined as height difference between sandbar crown and lowest riverbed at floodwater convergence point as shown below.



In general, the heavy scouring occurs along the flood convergence bank during large floods and the scoured portion is partially refilled again at their tail ends. The maximum scouring depth, which is most important for the toe protection designing, can be hardly observed during floods. The only measurable one on the site is the scoured trace which was partially refilled. Considering the limitation of the study period , the measured scouring depths are used for the structural design in the feasibility study. In this context, further study on local scouring and its proper protection is necessary through the hydraulic model test in the detailed design stage.

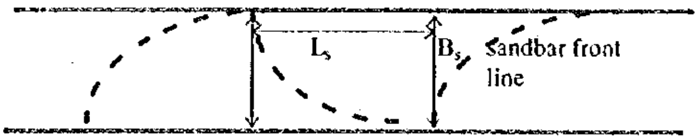
The wave heights have a tendency to increase in proportion to the increase of riverbed slope, as shown in Fig. II.9. From the above figure, the local scouring depths measured from the sandbar crown elevation at floodwater convergence point are estimated as follows, corresponding to the riverbed slope.

Riverbed Slope (%)	Scouring Depth (m)
$S < 0.8$	<1.5
$0.8 < S < 1.3$	<1.8
$1.3 < S < 1.5$	<2.4
$1.5 < S$	<2.8

The foundation depth of bank protection structures will be determined, based on the above scouring depth.

2.3.5 Direction of Sandbar Front Line

The sandbar front lines alternately change direction towards right and left as shown in Fig. II.8(1) to Fig. II.8(3). Main flood flow of the river generally runs along the sandbar front lines. Hence, the tangent of the sandbar front lines is considered to be one of the important indexes for the bank protection design, especially for the design of spur dikes/groins. The tangent of the sandbar front lines defined as shown below are also calculated from the Fig. II.8(1) to Fig. II.8(3).



The tangent of the sandbar front lines (L_s/B_s) is larger in the river sections with gentle slope and smaller in the river sections with steep slope, as shown in Fig. II.10. From the above figure, the tangent of the sandbar front lines is classified by riverbed slope as shown below.

Riverbed Slope (%)	Tangent (L_s/B_s)
S < 0.8	4.0 - 5.0
0.8 < S	2.0 - 3.0

The ratio of length and interval distance of spur dikes will be determined based on the above tangents of sandbar front line.

CHAPTER III LAOAG-BONGO RIVER IMPROVEMENT PLAN

3.1 Location and Length of Flood Protection Dikes

The proposed Master Plan will protect eight (8) flood protection districts by constructing flood protection dikes with bank protection works and related river structures, if necessary. No river dredging and widening are proposed. The target flood protection areas are Tangit-Laoag; Suyo-Laoag; Poblacion-Laoag; Camangaan-Laoag; Poblacion-San Nicolas; San Manuel-Sarrat; Suyo-Dingras; and Poblacion-Dingras.

The alignment and longitudinal profile of the river improvement are shown in Fig. II.11.

The three (3) objective sub-projects for the Feasibility Study; namely, Poblacion-Laoag; Poblacion-San Nicolas; and Poblacion-Dingras river improvements aim to protect the respective poblacion (urban) areas. They consist of flood protection dikes with bank protection structures and related river structures such as sluice, etc., if necessary.

The location and length of the necessary dikes to protect the three (3) poblacion areas were determined based on the detailed field survey. The flood protection dikes of Poblacion-Laoag should be extended downward until the lower end of Suyo-Laoag to completely protect Poblacion-Laoag. Hence, the Suyo-Laoag River Improvement is integrated into the Poblacion-Laoag River Improvement.

The location and length of the necessary flood protection dikes, and the revised protected area and revised existing protected population are summarized below.

Project	Location (River Distance)	Dike Length (m)	Protected Area (ha)	Protected Population
Pob. Laoag R/I	4.9-8.3 km (right bank)	3,490	330*	6,203*
Pob. San Nicolas R/I	6.9-11.1 km (left bank)	4,200	230	5,835
Pob. Dingras R/I	27.6-33.3 km (left bank)	5,450	550	4,228
Total		13,140	1,110	16,266

Note: (1) Pob. and R/I mean poblacion and river improvement, respectively.
(2) * Includes Suyo Laoag flood protection district.

3.2 Design Standard of Flood Protection Dikes

The dike crown elevation and dike alignment are the most basic design elements of the proposed dikes.

(1) The design high water level is the same as proposed in the Master Plan. The crown elevation of the dikes is set at 1.0 m above the design high water level.

(2) The following two (2) types of dike construction are generally applicable for the above objective river sections.

(a) River wall with revetment works is constructed on the shoulder of the existing natural riverbank. The land required for the river wall construction must be acquired.

(b) Earth dike is constructed on a site some distance back from the shoulder of the existing natural riverbank. No bank protection works are provided. The minimum setback distance is set at 30-50 m, referring to the standards in Japan. The land necessary for earth dike construction must be acquired; however, land acquisition in riverside of dikes is not necessary. The dike construction will cause no adverse effects on such riverside land. The land can be used as they are at present.

The construction cost of the typical river wall in rural area is 3.7 times that of the typical earth dike as shown below.

(unit: peso/m)

Type	Construction Cost	Land Acquisition Cost	Total Cost
River Wall	28,400	none	28,400
Earth Dike	7,450	230	7,680

(3) Hence, earth dikes are generally applied in this study. However, river walls with revetment works are proposed for some special sections in Poblacion-Laoag and Poblacion-Dingras where a considerable number of buildings stand on the riverbanks.

3.3 Poblacion Laoag River Improvement

The river improvement works will include earth dike (2,250 m, 127,800 m^3), river wall (1,240 m), revetment (160 m) and drainage sluiceway (2 units).

The alignment of river walls and earth dikes, and the longitudinal profile and typical cross section of the improved river are shown in Fig. II.12(1).

The typical structural design of the proposed earth dikes, river walls and drainage sluiceways are shown in Fig. II.13.

The acquisition of urban land (0.8 ha) and farmland (5.3 ha) is necessary for the construction of the river walls and earth dikes. No house resettlement is necessary.

3.4 Poblacion San Nicolas River Improvement

The river improvement works will include earth dike (4,200 m, 232,500 m^3), spur dike (5 units), and drainage sluiceway (2 sites).

The alignment of earth dikes, longitudinal profile and typical cross section of the improved river are shown in Fig. II.12(2).

The typical structural design of the proposed river walls, earth dikes and drainage sluiceways are shown in Fig. II.13.

The acquisition of farmland/bush-land (9.9 ha) is necessary for the construction of the earth dikes. No house resettlement is necessary.

3.5 Poblacion Dingras River Improvement

The river improvement works will include earth dike (5,150 m, 321,700 m^3), river wall (300 m), revetment (300 m), spur dike (5 units) and drainage sluiceway (1 site).

The alignment of river walls and earth dikes, longitudinal profile and typical cross section of the improved river are shown in Fig. II.12(3).

The typical structural design of the proposed river walls, earth dikes, revetments, spur dikes and drainage sluiceways are shown in Fig. II.13.

The acquisition of farmland/bush-land (13.0 ha) is necessary for the construction of river walls and earth dikes. A few house resettlements (3 houses) are necessary.

CHAPTER IV SABO DAM PLAN

4.1 Design Criteria of Sabo Dam

(1) The design dam crest elevation, sedimentation slope and capacity of the five (5) objective sabo dams are determined,, as shown in Chapter II, 2.1.

(2) The geological structures of the objective sabo dam sites consist of two (2) layers of river deposits and rocks. For these sites, two (2) types of sabo dam structure are considered. One is a structure of which foundation is fixed on the rocks (fixed type). The other is a structure of which foundation is placed on the river deposits (floating type). The floating type is applicable only in case the bearing capacity of the river deposits is sufficient. The structural type of the proposed sabo dams will be determined through cost comparison.

4.2 Cura No. 1 Sabo Dam

The geological structures at the dam site consist of river deposits in the surface layer, altered/weathered andesite in the middle layer and diorite in the bottom layer. The thickness of the river deposits is 2-13 m, averaging 6 m. The geological section at the dam site is shown in Fig. II.14(1).

The river deposits of the dam site has a sufficient bearing capacity to support the proposed sabo dam. Hence, the sabo dams of fixed type and floating type are compared.

(1) Fixed Type

The sabo dam structure consists of main dam and sub-dam. Both main and sub-dams are fixed on the rocks by excavating the river deposits and, therefore, no apron is necessary. No side wall is proposed since both riverbanks are formed of hard rocks.

(2) Floating Type

The sabo dam structure consists of main dam and sub-dam. Both main and sub-dams are constructed on the river deposits as a floating structure and, therefore, a concrete apron is constructed between the main dam and sub-dam. No side wall is proposed since both riverbanks are formed of hard rocks.

(3) Cost Comparison

The dam height, concrete volume, excavation volume and required construction cost of the two (2) alternatives are compared as follows. As evident from the table, the floating type is recommendable.

Item	Fixed Type	Floating Type
Dam Height (m)	17.0	9.0
Concrete Volume (m^3)	31,700	15,100
Excavation Volume (m^3)	70,100	32,200
Rock (m^3)	13,300	1,800
River Deposits (m^3)	56,800	30,400
Construction Cost (million pesos)	101	46

The proposed sabo dam will be constructed on the river deposits as a floating structure. The design dam height, crest length, crest elevation, sedimentation slope and sedimentation capacity are set as shown below.

Dam Height (m)	Crest Length (m)	Crest Elevation (m)	Sedimentation Slope (%)	Sedimentation Capacity (m^3)
9.0	183	118.0	0.75	422,000

The plan and longitudinal profile of the sedimentation basin is shown in Fig. II.4(1). Salient features of the sabo dam structures are shown below. Their structural design is shown in Fig. II.15(1).

	Main dam	Sub-dam	Apron	Total
Height/Thickness (m)	9.0	4.0	1.2	-
Concrete Volume (m^3)	9,300	2,500	3,300	15,100

A paddy field of 0.4 ha must be acquired for the construction of the sabo dam. No house resettlement is necessary.

4.3 Labugaon No. 1 Sabo Dam

The geological structures at the dam site consist of river deposits, fractured weathered diorite and diorite in the descending order of layer. The thickness of the river deposits ranges from 1 m to 7 m with an average of 4 m. The geological section at the dam site is shown in Fig. II.14(1).

Fixed type is definitely recommendable since the thickness of the river deposits is small. Cost saving by the application of floating type is very small.

The foundation of the sabo dam will be fixed on the fractured weathered diorite by excavating the river deposits. The design dam height, crest length, crest elevation, sedimentation slope and sedimentation capacity are set as shown below. The plan and longitudinal profile of the sedimentation basin is shown in Fig. II.4(2).

Dam Height (m)	Crest Length (m)	Crest Elevation (m)	Sedimentation Slope (%)	Sedimentation Capacity (m^3)
17.0	118	125.0	0.82	1,197,000

The sabo dam structure consists of main dam and sub-dam. Both main dam and sub-dam will be fixed on the rocks and, therefore, no apron is proposed. No side wall is proposed since both riverbanks are formed of hard rocks. Salient features of the structures are shown below. Their structural design is shown in Fig.II.15(2).

	Main dam	Sub-dam	Total
Height (m)	17.0	7.5	-
Concrete Volume (m^3)	14,100	2,800	16,900

No land acquisition and no house resettlement are necessary for the construction of the sabo dam.

4.4 Solsona No. 1 Sabo Dam

The geological structures at the dam site consist of river deposits (surface layer), diorite with basalt and andesite (middle layer), and diorite (bottom layer). The depth of the river deposits is as shallow as 1-2 m. On the other hand, the height of the right side abutment is topographically limited. The geological section at the dam site is shown in Fig. II.14 (2).

A fixed type sabo dam is naturally proposed since the thickness of the river deposits is so small.

The foundation of the sabo dam will be fixed on the diorite with basalt and andesite by excavating the river deposits. The design dam height, crest length, crest elevation, sedimentation slope and sedimentation capacity are designed as shown below. The plan and longitudinal profile of the sedimentation basin is shown in Fig. II.4(3).

Dam Height (m)	Crest Length (m)	Crest Elevation (m)	Sedimentation Slope (%)	Sedimentation Capacity (m^3)
12.0	118	143.0	1.29	242,000

The sabo dam structure consists of main dam and sub-dam. Both main and sub-dams will be fixed on the rocks and, therefore, apron is not proposed. No side wall is proposed since both riverbanks are formed of hard rocks. Salient features of the structures are shown below. Their structural design is shown in Fig. II.15(3).

	Main dam	Sub-dam	Total
Height (m)	12.0	4.0	-
Concrete Volume (m^3)	4,500	700	5,200

Land acquisition of a small upland (0.1 ha) on the right side abutment is a must, however, no house resettlement is necessary for construction of the sabo dam.

4.5 Madongan Sabo Dam

The geological structures at the dam site consist of thick river deposits underlain by weathered basalt. The thickness of the river deposits is as deep as 26-37 m, averaging 32 m. The geological section at the dam site is shown in Fig. II.14(2).

The river deposits at the dam site are too deep to adopt a fixed type structure. On the other hand, the river deposits have a sufficient bearing capacity to support the proposed sabo dam. Hence, the sabo dam will be constructed on the river deposits as a floating structure.

The design dam height, crest length, crest elevation, sedimentation slope and sedimentation capacity are set as shown below. The plan and longitudinal profile of the sedimentation basin is shown in Fig. II.4(4).

Dam Height (m)	Crest Length (m)	Crest Elevation (m)	Sedimentation Slope (%)	Sedimentation Capacity (m^3)
10.5	183	133.0	0.98	2,207,000

The sabo dam structure consists of main dam, sub-dam and apron. The sub-dam will also be constructed as a floating structure. A concrete apron will be constructed between the main dam and sub-dam. No side wall is proposed since both riverbanks are formed of hard rocks.

Salient features of the structures are shown below. Their structural design is shown in Fig. II.15(4).

	Main dam	Sub-dam	Apron	Total
Height/Thickness (m)	10.5	4.5	2.2	-
Concrete Volume (m^3)	12,100	3,100	5,600	20,800

No land acquisition and no house resettlement are necessary for the construction of the sabo dam.

4.6 Papa Sabo Dam

The geological structures at the dam site consist of river deposits, weathered/altered fractured diorite and diorite in this order of layer. The thickness of the river deposits is 3-8 m, averaging 5 m. The geological section at the dam site is shown in Fig. II.14(3).

The river deposits at the dam site has a sufficient bearing capacity to support the proposed sabo dam. Hence, the sabo dam of fixed and floating types are compared in the same way as Cura No. 1.

(1) Fixed Type

The sabo dam structure consists of main dam and sub-dam. Both main and sub-dams are fixed on the rocks by excavating the river deposits and, therefore, no apron is necessary. No side wall is proposed since both river banks are formed of hard rocks.

(2) Floating Type

The sabo dam structure consists of main dam and sub-dam. Both are constructed on the river deposits as a floating structure and, therefore, a concrete apron is constructed between them. No side wall is proposed since both river banks are formed of hard rocks.

(3) Cost Comparison

The dam height, concrete volume, excavation volume and required construction cost of the two (2) alternatives are compared as follows. As evident from the table, the floating type is recommendable.

Item	Fixed Type	Floating Type
Dam Height (m)	17.0	9.0
Concrete Volume (m^3)	34,800	16,900
Excavation Volume (m^3)	63,400	23,600
Rock (m^3)	11,000	3,100
River Deposits (m^3)	52,400	20,500
Construction Cost (million pesos)	108	51

The proposed sabo dam will be constructed on the river deposits as a floating structure. The design dam height, crest length, crest elevation, sedimentation slope and sedimentation capacity are set as shown below.

Dam Height (m)	Crest Length (m)	Crest Elevation (m)	Sedimentation Slope (%)	Sedimentation Capacity (m^3)
9.0	233	145.5	1.38	794,000

The plan and longitudinal profile of the sedimentation basin is shown in Fig. II.4(5). Salient features of the sabo dam structures are shown below. Their structural design is shown in Fig. II.15(5).

	Main dam	Sub-dam	Apron	Total
Height/Thickness (m)	9.0	3.5	1.0	-
Concrete Volume (m^3)	11,900	2,600	2,400	16,900

Land acquisition of a paddy field (0.75 ha) and upland (0.24 ha) is necessary, however, no house resettlement is needed.

CHAPTER V ALLUVIAL FAN RIVER IMPROVEMENT PLAN

5.1 Design Criteria of River Channel

(1) Alignment

The existing river alignments of the Solsona, Madongan and Papa are smooth and considered hydraulically adequate as experienced in the recent floods. Hence, their design alignments are set at the present conditions.

The alignment of the Cura/Labugaon River is designed as proposed through the comparative study of alignments in the Master Plan. The Cura and Labugaon rivers are designed to join at the fan apex and thereafter, to run along the existing main course of the Cura River.

(2) River Width

The existing river width of the Solsona, Madongan and Papa were evaluated as hydraulically stable ones, based on the Regime Theory in the Master Plan Study. Hence, their design river widths are set as they are at present.

Similarly, the river width of the Cura/Labugaon is designed as proposed based on the Regime Theory in the Master Plan Study.

(3) River Profile

According to the sediment transport analysis in Chapter II, the riverbed profiles of the objective four (4) rivers are predicted to be comparatively stable in the future. No large aggradation or degradation is expected throughout the entire river sections. Hence, no riverbed dredging is proposed for the Solsona, Madongan and Papa rivers and dredging will be limited to some river sections of Cura/Labugaon.

The design high water level is determined to envelope the calculated river water levels under the existing and future predicted riverbed conditions for a greater factor of safety.

(4) River Mouth

Sediment loads from the alluvial fan rivers of Cura, Solsona and Papa are easily washed away to the Bongo River since the Bongo River is wide and its backwater effect on the alluvial fan rivers is small. In fact, no significant sediment deposits are identified at their river mouths.

Possible sediment deposition at the river mouths of the alluvial fan rivers also is not large. Sediment deposition at the river mouths in design flood time is estimated to be in the range of 1 cm in the Papa River and 8 cm in the Cura River. The long-term riverbed aggradation at the river mouths after 20 years is predicted to be nil in the Cura River and 100 cm in the Solsona River. For details, see Chapter II, Sediment Analysis.

Hence, no special sediment control device is proposed for the river mouths. The river alignment at each river mouth is designed to follow the existing one.

5.2 Study on Alternative Bank Protection Works

The existing temporary earth dikes in the Solsona, Madongan and Papa rivers were breached at many locations in the entire stretches of the rivers by Typhoon Gloring in 1996. This dike breaching was caused by local scouring at the foot of the dikes in the floodwater convergence points. No overflow of the dikes occurred. Hence, foot protection of the dikes is considered essential.

Bank protection works get the largest chunk in the improvement of the alluvial fan rivers. The following three (3) typical measures are considered for protection of the proposed earth dikes in the alluvial fan rivers.

(1) Revetment
(2) Spur Dikes
(3) Ground-sill with Small Spur Dikes

These three (3) types are technically and economically compared as follows.

5.2.1 Revetment

(1) General

Wet masonry revetment with toe protection concrete blocks is proposed. The revetment must be thick and strong enough to cope with severe striking of gravel and pebbles. The toe protection concrete blocks must be heavy enough to resist the movement force of flood flow. The foundation of the revetment must be deep enough to cope with the local riverbed scouring caused by sandbar at floodwater convergence points.

(2) Foundation Depth

The design foundation depth of revetment is determined based on the possible local riverbed scouring depth measured from the average riverbed. The possible local scouring depths measured from sandbar crown in the objective alluvial fan rivers are estimated in Chapter II, Subsection 2.3.4. They vary depending on the riverbed slope, as shown below.

Riverbed Slope (%)	Scouring Depth below Sandbar Crown (m)	Scouring Depth below Average River Bed (m)
S < 0.8	1.5	1.5 x 0.8 = 1.2
0.8 < S < 1.3	1.8	1.8 x 0.8 = 1.5
1.3 < S < 1.5	2.4	2.4 x 0.8 = 2.0
1.5 < S	2.8	2.8 x 0.8 = 2.3

The elevation of sandbar crown is usually 20% higher than that of the average riverbed. Therefore, the local possible scouring depths measured from the average riverbed elevation in the objective rivers are estimated as shown in the above table.

The average riverbed elevation of the objective rivers in the future is predicted in Chapter II, 2.2.3. Hence, the foundation depth of the revetment will be determined by lowering the above possible local scouring depth from the lower average riverbed elevation between the existing and future ones, and further providing some allowance.

Hence, the standard design foundation depth of the revetment works is proposed, considering 1.0 m allowance as follows.

Riverbed Slope (%)	Foundation Depth below Existing or Future Average Riverbed (m)
S < 0.8	2.2
0.8 < S < 1.3	2.5
1.3 < S < 1.5	3.0
1.5 < S	3.3

(3) Typical Structural Design and Cost

The typical revetment structures for the upper reaches of Madongan River are designed as follows. The upper Madongan river sections are regarded as the representative ones of the objective alluvial fan rivers. The design hydraulic conditions are as follows:

Design discharge $Q = 1,970\ m^3/s$; *riverbed slope* $S = 1/75$; *river width* $B = 300\ m$; *water depth* $H = 2.5\ m$

The revetment is placed on the surface of both banks and it is provided with toe protection concrete blocks. The slope length and thickness are assumed to be 10.1 m and 0.35 m, respectively.

For the designed revetment structures, see Fig. II.16.

The volumes of the wet masonry revetment and toe protection concrete block per 1,000 m river distance (river bank distance = 2,000 m) are estimated at 7,060 m^3 and 12,000 m^3, respectively. The construction cost per 1,000 m river distance is estimated to be 48.6 million pesos.

5.2.2 Spur Dike

(1) Objective Function

Spur dikes are generally constructed to prevent the main flood stream from striking the dikes and to keep a safe distance between the main flood stream and dikes. In alluvial fan rivers, a series of impermeable spur dikes with a comparatively short length are usually constructed to push the main flood stream toward the river center up to a line connecting the heads of the spur dikes.

(2) Length of Spur Dike

Too long spur dikes may disturb flood stream and make it difficult to maintain the river course. Further, the spur dike structure itself is susceptible to damage. In alluvial fan rivers, it is generally recommended to place a series of short spur dikes at close intervals than to construct single long spur dikes.

Length of the existing spur dikes in Japan is mostly less than approximately 10% of the river width.

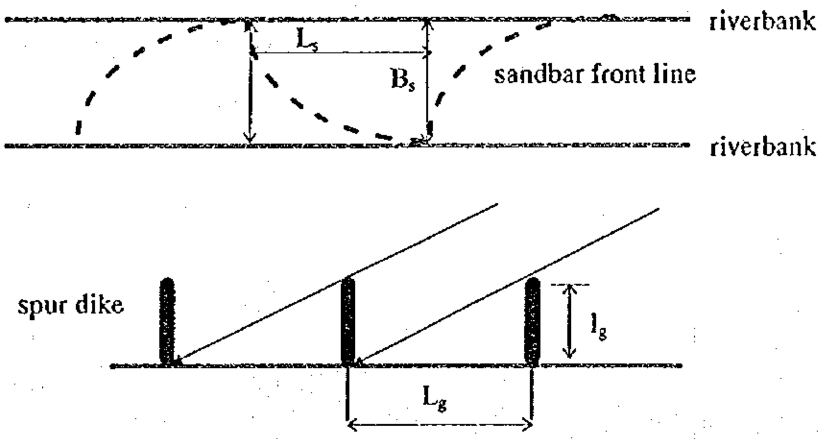
Hence, the design length of spur dikes is set at 10% of the river width. The length of spur dikes is calculated to be 15 m by assuming the average river width as 300 m since the spur dikes are provided along both side banks in principle.

(3) Interval of Spur Dikes

The interval of spur dikes is designed based on experiences in similar projects. No practical calculation method is available at present. Generally, the interval of spur dikes (L_g) is determined in relation to their length (l_g).

According to the inventory survey by the Ministry of Construction in Japan, the ratio of interval distance and length of the existing spur dikes in Japan mostly fall within the range of L_g/l_g = 1.0-4.0, averaging 3.0. Many of them have a ratio of 2.0-3.0.

On the other hand, the spur dikes are expected to prevent the main flood stream from striking against the dikes. Therefore, the interval of spur dikes is determined taking into account of the direction of main flood stream. Main flood flow generally runs along the sandbar front lines. To prevent the striking of the main flood stream against the dikes, the ratio of the length and interval of spur dike (L_g/l_g) should be less than the tangent of sandbar front lines (L_s/B_s) as shown in the following figure.



Where,

L_s = sandbar length, B_s = sandbar width, L_g = spur dike interval, l_g = spur dike length

Tangent of the existing sandbar front lines (L_s/B_s) in the Solsona, Madongan and Papa rivers varies depending on the river bed slope (S). It is summarized as follows.

Tangent (L_s/B_s)	Riverbed Slope(S)
2 - 3	S > 0.8 %
4 - 5	S < 0.8 %

From the above, L_g/l_g is set at 2 for the river sections of steeper than 0.8% and 4 for the river sections of gentler than 0.8%. The proposed L_g/l_g of 2 or 4 falls within the main range of the existing spur dikes in Japan.

Hence, the design interval distance of spur dikes (L_g) is determined as follows.

(a) For upper reaches (S > 0.8 %) : L_g = 30 m
(b) For lower reaches (S < 0.8 %) : L_g = 60 m

(4) Local Scouring Around Spur Dikes

Apart from the local riverbed scouring caused by sandbar, another local scouring occurs around spur dikes by the flow disturbance of the spur dikes. The maximum scouring usually appears at the head of spur dikes. The scouring depth is estimated based on the previous hydraulic laboratory tests or field surveys of similar projects.

The Ministry of Construction in Japan conducted several hydraulic model tests and field surveys on the scouring around spur dikes in the past. From these tests and surveys, the scouring depth of a series of spur dikes of impermeable submerged type is roughly estimated to be 50-60% of river water depth except for the upstream end spur dike. For details, see Appendix C, River Improvement Plan.

(5) Foundation Depth

The design foundation depth of spur dikes is determined in consideration of the riverbed scouring caused by sandbar and by the flow disturbance of spur dikes.

The maximum scouring depth caused by the flow disturbance of spur dikes is estimated at 1.3-1.5 m when the design flood water depth is assumed as H = 2.5 m. For the riverbed scouring depth by sandbar, see the previous Section 5.2.1.

(6) Typical Structural Design and Cost

The typical spur dikes for the upper Madongan river reaches are designed as follows under the same hydraulic conditions as revetment.

Design discharge $Q = 1{,}970\ m^3/s$, *riverbed slope* $S = 1/75$, *river width* $B = 300\ m$, *water depth* $H = 2.5\ m$

The spur dike made of stone concrete (boulders/pebbles filled with concrete) is placed in front of both side dikes at an interval of 30 m. The size of one (1) unit spur dike is length : 15 m, height : 4 m and width : 2 m at crown, 6 m at bottom (see Fig. II.16). The stone concrete volume per 1,000 m river distance (2,000 m riverbank distance) is estimated to be 15,460 m^3.

The construction cost of the spur dikes per 1,000 m river distance is estimated at 28.4 million pesos.

5.2.3 Groundsill with Small Spur Dikes

(1) Objective Function

Groundsills are generally constructed for the following purposes.

(a) Excessive sediment control in the mountains may cause an imbalanced sediment transport, resulting in a riverbed degradation in the upper reaches of the alluvial fan rivers. Some sediment will be yielded from the riverbed in the process of the riverbed degradation. On the other hand, the yielded sediments from the riverbed in the upper reaches may create a riverbed aggradation in the lower reaches, especially in the river sections where the riverbed slope makes a large change. Groundsills will prevent such a riverbed degradation in the upper reaches and minimize the riverbed aggradation in the lower reaches.

(b) Sandbars of a large scale are generally formed in the alluvial fan rivers. They create floodwater convergence and divergence points alternately in the longitudinal direction of river channel. As a result, local riverbed scouring is caused at the floodwater convergence points. A larger scale sand bar generally cause a deeper riverbed scouring. Groundsills will disturb the formation of sandbars in the river channel and as a result, mitigate the local riverbed scouring.

No significant riverbed degradation is predicted in this project except for the Labugaon River (2 km). Even the riverbed degradation in the Labugaon River is not large and therefore, its contribution to the aggradation in the lower reaches is considered small (see, Chapter II, Subsection 2.2.3). Hence, the control of riverbed degradation by groundsills is considered unnecessary.

From the above, the groundsill construction in this project only aims to disturb the formation of sandbar in the river channel and as a result, to minimize the local riverbed souring depth along the riverbanks.

(2) Interval of Groundsill

The Ministry of Construction in Japan has conducted several hydraulic model tests on the groundsills in the river channels with a steep slope in recent years. According to the above tests, the space between groundsills must be shorter than the existing sandbar length in principle to disturb the formation of sandbar by dividing a sandbar into sections.

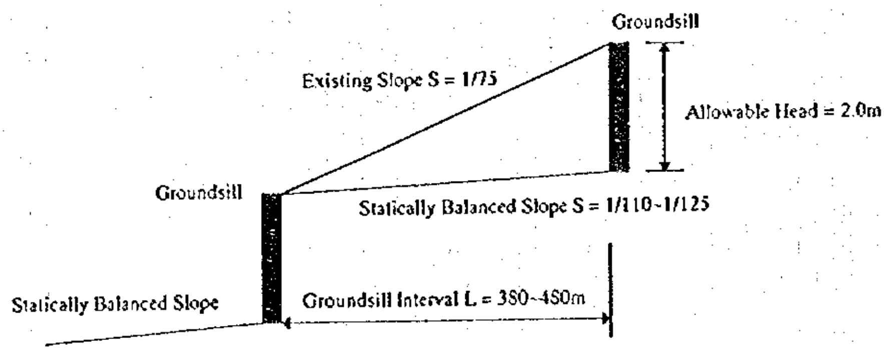
The ratio of the existing sandbar length and river width in the objective alluvial fan rivers are summarized as follows, where, L_s : sandbar length, B : riverbed width, S : riverbed slope.

Ratio (L_s/B)	Riverbed Slope (I)
2 - 3	S > 0.8 %
4 - 5	S < 0.8 %

Hence, the interval distance of groundsill (L) must be L < 2B for the river sections of S > 0.8% and L < 4B for the river sections of S <0.8%.

If the riverbed continues degradation in the future, the riverbed surface will be covered with armor coat and as a result, the riverbed slope will reach a certain statically balanced one. The armor coat is formed out of the selected riverbed materials. Its grain size is generally larger than 90% of the size of existing riverbed materials. On the other hand, the 90% size (diameter) of the existing riverbed materials in the typical river reaches of the project (Upper Madongan River reaches) is in the range of 20 cm and 30 cm. The statically balanced slope of the riverbed consisting of gravel/pebbles with a size of 20-30 cm is estimated to be 1/110 to 1/125.

Groundsills must control or compensate a head (difference of riverbed elevation) created by the riverbed degradation from the existing slope (1/75) to the future slope (1/110 - 1/125). The head to be controlled varies depending on the interval distance of the groundsills. The maximum interval of groundsills is estimated to be 380 - 480 m assuming the allowable head is 2.0 m.



Further, an empirical formula of L = (1.5 - 2.0) B is widely used for small rivers in Japan. According to this formula, the interval of groundsills is estimated to be 450 - 600 m for the upper Madongan River reaches of 300 m river width.

From the above discussions, the interval of groundsills for the typical river reaches (Upper Madongan River reaches) is set at L = 1.5B = 450 m.

(3) Hydraulic Control of Groundsill

A groundsill of single section is usually employed and its crest elevation is set at the design riverbed elevation. However in this project, a groundsill of double section is proposed to converge the flood flow into the center of river channel (see Fig. II.16).

From the above-mentioned model tests in Japan, the following hydraulic effects are generally assumed.

(a) The low water channel section of a groundsill is determined to flow a 2-3 year flood discharge.

(b) Although main flood streams converge into the center of river channel, sub-streams with a certain velocity run down along the riverbanks. The flow velocity along the riverbanks is roughly estimated at half of that of the river center.

(c) The local scouring depth along the riverbanks is also roughly estimated at half of the scouring depth of without groundsill.

Hence, small spur dikes will be provided between groundsills.

(4) Foundation Depth

The design foundation depth of groundsills is determined in due consideration of the riverbed scouring by the flow disturbance of groundsill. The immediately downstream riverbed in the low water channel section is susceptible to severe scouring due to a high speed flood flow. The design riverbed scouring depth is determined, referring to that of the existing irrigation dams.

The design foundation depth of small spur dikes is determined according to the design criteria of the spur dikes discussed in the previous Section 5.2.2. The riverbed scouring depth by sandbar will be decreased to half of the existing one due to the effects of groundsill. For the existing riverbed scouring depth by san bar, see the previous Section 5.2.1.

(5) Typical Structural Design and Cost

The typical groundsill with small spur dikes for the upper Madongan river reaches is designed under the same hydraulic conditions as revetment and spur dikes as follows:

Design discharge $Q = 1{,}970\ m^3/s$, *riverbed slope* $S = 1/75$, *river width* $B = 300\ m$, *water depth* $H = 2.5\ m$

The double-section groundsill made of stone concrete is constructed at an interval of 450 m. The crest elevation of groundsill is set at the design riverbed elevation for the low water cannel section and 1.25 m above the design riverbed elevation for the high water channel section.

The size of one (1) unit groundsill is length : 306 m, height : 3.0 m at central section (see Fig. II.16). The groundsill concrete and riverbed protection block per 1,000 m river distance are estimated to be 2,330 m^3 and 4,060 m^3, respectively.

Between the groundsills, small stone concrete spur dikes are placed in front of both side dikes at an interval of 30 m. The size of one (1) unit spur dike is length : 15 m, height : 3.0 m and width : 2 m at crown, 5.0 m at bottom (see Fig. II.16). The volume of concrete per 1,000 m river distance (2,000 m riverbank distance) is estimated to be 8,900 m^3.

The construction cost of the groundsill with small spur dikes per 1,000 m river distance is estimated at 53.3 million pesos.

5.2.4 Comparative Evaluation

(1) The construction costs per 1,000 m river distance of the three (3) bank protection works for the representative river reaches in the alluvial fan rivers (Upper Madongan River reaches) are compared as follows. Spur dikes are economically most recommendable.

Works	Construction Cost (million peso/km)
Revetment	48.6
Spur Dikes	28.4
Groundsill with Small Spur Dikes	53.3

(2) The hydraulic control effect of groun-sills is large. However, it is considered too early to construct such groundsills that will fix the riverbed elevation and slope in this stage. Detailed and accurate prediction of the future riverbed elevation and slope is difficult at present. The groundsills will prevent the degradation of riverbed. However, the riverbed degradation in the upper reaches of the alluvial fan is considered more preferable for flood damage reduction.

It is considered preferable to construct groundsills in the future after the riverbed slope becomes stable.

(3) Construction of a perfect bank protection structure which requires no maintenance works is considered difficult in these alluvial fan rivers. However, the scale of individual structural damage and annually required maintenance cost must be below a certain level in view of the technical and financial limitations of the agency responsible for maintenance.

Each spur dike unit is structurally independent. Damage of one unit will not cause chain reacting damages of other units and its adverse effect on the river hydraulic condition will be limited within a local area. Hence, the scale of structural damage of spur dikes at one site is considered smaller than those of the other alternatives.

In fact, the major maintenance problem of the spur dikes is only at their heads which are susceptible to damage by local scouring exceeding the design criteria, especially at the upstream end of a series of spur dikes. However, the spur dike will function as planned for the time being even if its head is broken as far as the broken head is not carried away by flood flow. Even if the proposed spur dike body is broken at 2.0 m from the tip, the broken head will not move under a flood flow of less than 9.0-10.0 m/s (see Volume III-2, Appendix C, River Improvement Plan).

Therefore, the maintenance requirement of the proposed spur dike is considered smaller than the other alternatives.

From the above discussions, spur dikes are recommended for the dike protection of the project.

5.3 Design Criteria of Proposed Bank Protection Works

Spur dikes are employed for the bank protection works. The design criteria for spur dikes are summarized as follows:

(1) Length and Interval Distance

The length of all the spur dikes is set at 15 m. The interval distance of spur dikes is designed to vary according to the riverbed slope as follows:

(a) 30 m for the river sections with a riverbed slope steeper than 0.8%
(b) 60 m for the river sections with a riverbed slope gentler than 0.8%

(2) Foundation Depth and Crown Elevation

The foundation depth of super dikes is designed in consideration of the riverbed scouring caused by sandbar and by the flow disturbance of spur dikes.

The riverbed scouring by sandbar varies depending on the riverbed slope as mentioned before. The average design foundation depth of spur dikes is set as shown below by assuming that the riverbed scouring depth by the flow disturbance of spur dikes varies from zero near the riverbank to 1.5 m at the spur dike head, averaging 1.0 m.

Riverbed Slope (%)	Foundation Depth below Existing or Future Average Riverbed
S < 0.8	2.2
0.8 < S < 1.3	2.5
1.3 < S < 1.5	3.0
1.5 < S	3.3

The crown elevation of spur dikes is set at 1.0 m below the design high water level in principle.

(3) Location of Spur Dike Construction

The spur dikes will be arranged according to the following principle.

(a) Both banks will be protected in the river section with double sandbars where floodwater convergence point is not fixed. The interval distance of spur dike will be set at 30 m or 60 m, depending on the riverbed slope.

(b) The bank of floodwater convergence side will mainly be protected in the river section with single sandbars where floodwater convergence point is almost fixed. The interval will be set at 30 m or 60 m, depending on the riverbed slope. The opposite side bank will be provided with spur dikes of long interval (60 m) to meet secondary flood water streams as required.

(c) The banks in the following river sections will be protected as required.

(i) River section with no dike.

(ii) River section where background inundation area is comparatively small or high in elevation.

(iii) River section which is affected by backwater of the Laoag-Bongo River.

Due to uncertainties on hydraulics, however, a further hydraulics study is recommended during the detailed design stage. A hydraulic model test is necessary to check the hydraulic effects of sandbar formation on the riverbanks, to estimate the possible scouring around the spur dikes and to determine the detailed dimensions of the spur dike system. The test is to be carried out by (1) using movable and mixed gravel beds; (2) adjusting various similitudes to the site such as shearing stress, specific gravity of riverbed materials and sandbar formation; and (3) installing two types of channel models, straight and bending channels.

5.4 Proposed River Improvement Plan

5.4.1 Cura/Labugaon River Improvement

The existing Cura/Labugaon River consists of a number of distributaries with braided river streams. The proposed plan will construct one (1) improved channel by uniting the existing distributaries. The Labugaon River is designed to join the Cura River at the fan apex. The improvement length, design river width, and design high water slope are shown below. The alignment, longitudinal profile, and typical cross-section of the improved river are shown in Fig. II.17(1).

River	River Section	Design Discharge (m^3/s)	Improvement Length (km)	River Width (m)	High Water Slope
Cura	Lower/Middle	2,360	10.9	340	0.138-0.813
	Upper	850	-	200	-
Labugaon	Entire	1,260	1.8	250	0.864, 0.948

There exist six (6) irrigation intakes serving a total area of 775 ha in the objective river reaches in addition to INIP-I Labugaon diversion dam and Cura NIS intake. Location of the intakes, and their respective service areas and structures are shown in Fig. II.18(1).

The river improvement shall be designed to maintain the existing functions of the above intakes. Further, the existing Bagbag Bridge shall be extended to cross the improved river.

The proposed river improvement works will include river channel excavation (992,000 m^3), earth dikes (21,500 m, 992,000 m^3), spur dikes (349 units), groundsill (1 unit), intake sluiceway (4 units) and bridge extension (1 bridge, 90 m).

The typical structural design of the earth dikes, spur dikes, groundsill, intake sluiceway and bridge extension are shown in Fig. II.19(1) to Fig. II.19(3).

Farmlands/bush-lands (10.0 ha) must be acquired for the river improvement. No house resettlement is necessary.

5.4.2 Solsona River Improvement

The proposed plan will strengthen the existing dikes throughout the entire river reaches. The improvement length, design river width and high water slope are shown below. The alignment, longitudinal profile, typical cross-section of the improved river are shown in Fig. II.17(2).

River	River Section	Design Discharge (m^3/s)	Improvement Length (km)	River Width (m)	High Water Slope
Solsona	Lower	3,490	1.5	330	0.152
	Middle	1,120	5.5	230	0.071-0.879
	Upper	1,030	4.0	230	1.446, 1.542

There are three (3) irrigation intakes serving a total area of 120 ha in the objective river reaches other than INIP-I Solsona diversion dam. Location of the intakes, and their respective service areas and structures are shown in Fig. II.18(1). The river improvement shall be designed to maintain the existing functions of the above intakes.

The proposed improvement works will include heightening of the existing dikes (16,000 m, 202,000 m^3), repair of the existing dikes (5,000 m^3), spur dikes (302 units), groundsill (1 unit), and intake sluiceway (3 units).

The typical structural design of the spur dikes, groundsill and intake sluiceway are shown in Fig. II.19(1) to Fig. II.19(3).

Neither land acquisition nor house resettlement is necessary for the river improvement.

5.4.3 Madongan River Improvement

The proposed plan will strengthen the existing dikes over the entire river reaches. The improvement length, design river width and high water slope are shown below. The alignment, longitudinal profile, typical cross-section of the river improvement works are shown in Fig. II.17(3).

River	River Section	Design Discharge (m^3/s)	Improvement Length (km)	River Width (m)	High Water Slope
Madongan	Entire	1,970	9.0	300	0.233-1.372

There are eight (8) irrigation intakes with a total service area of 2,886 ha in the objective reaches other than INIP-I Madongan diversion dam. Location of the intakes and their respective service areas and structures are shown in Fig. II.18(2). The river improvement shall be designed to maintain the existing functions of the above intakes.

The proposed improvement works will include heightening of the existing dikes (10,000 m, 110,000 m^3), repair of the existing dikes (18,000 m^3), spur dikes (394 units), groundsill (1 unit) and intake sluiceways (8 units).

The typical structural design of the spur dikes, ground-sill and intake sluiceways are shown in Fig. II.19(1) to Fig. II.19(3).

Neither land acquisition nor house resettlement is necessary for the river improvement.

5.4.4 Papa River Improvement

The proposed plan will strengthen the existing dikes over the entire river reaches. The improvement length, design river width and high water slope are shown below. The alignment, longitudinal profile, typical cross-section of the river improvement works are shown in Fig. II.17(4).

River	River Section	Design Discharge (m^3/s)	Improvement Length (km)	River Width (m)	High Water Slope
Papa	Entire	690	7.0	223	0.496-1.854

There are two (2) irrigation intakes with a total service area of 179 ha in the objective river reaches other than INIP-I Papa diversion dam. Location of the intakes, and their respective service areas and structures are shown in Fig. II.18(2). The proposed river improvement shall be designed to maintain the existing functions of the above intakes.

The proposed improvement works will include heightening of the existing dikes (4,500 m, 20,000 m^3), repair of the existing dikes (6,800 m^3), spur dikes (283 units), groundsill (1 unit) and intake sluiceways (2 units).

The typical structural design of the spur dikes, ground-sill and intake sluiceway are shown in Fig. II.19(1) to Fig. II.19(3).

Neither land acquisition nor house resettlement is necessary for the river improvement.

CHAPTER VI CONSTRUCTION PLAN AND COST ESTIMATE

6.1 Construction Plan

6.1.1 Construction Work Volume

The volume of the construction works are summarized as follows.

(1) Laoag-Bongo River Improvement

Work Item	Unit	Pob. Laoag	Pob. San Nicolas	Pob. Dingras	Total
Embankment	m^3	127,800	232,500	321,700	682,000
Concrete Wall/Revetment	m^3	3,550	-	1,520	5,070
Spur Dike	unit	-	5	5	10
Drainage Sluiceway	unit	2	2	1	5

(2) Sabo Dam

Work Item	Unit	Cura No. 1	Labugaon No. 1	Solsona No. 1	Madongan	Papa	Total
Excavation	m^3	32,300	29,600	7,000	20,900	23,700	113,500
River Deposits	m^3	30,400	17,600	1,800	18,300	20,600	88,700
Rock	m^3	1,900	12,000	5,200	2,600	3,100	24,800
Stone Concrete	m^3	15,100	16,900	5,200	20,800	16,900	74,900

(3) Alluvial Fan River Improvement

Work Item	Unit	Cura/ Labugaon River	Solsona River	Madongan River	Papa River	Total
Channel Excavation	m^3	992,000	-	-	-	992,000
Embankment	m^3	992,000	207,000	128,000	26,800	1,353,800
Spur Dike	unit	349	302	394	283	1,328
Intake Sluiceway	unit	4	3	8	2	17
Bridge	unit	1	-	-	-	1
	(m^2)	(810)				(810)

6.1.2 Workable Days, Construction Materials and Labor Force

(1) Workable Days

Workable days per year are estimated at 190 days for earth works and 240 days for the other works such as concrete and masonry works, taking into account the suspension due to holidays and rainy days as follows.

	Holidays	Rainy Days	Workable Days
Earth Works	70	100	190
Others	70	50	240

(2) Construction Materials

The proposed construction works will require cement, reinforcing bar, soil, sand, gravel and boulder as summarized below.

Construction Works	Construction Materials
Earth Dike	Riverbed Soil, Selected Soil, Gravel
River Wall	Cement, Sand, Gravel, Re-bar
Revetment	Cement, Sand, Gravel, Boulder
Spur Dike in Alluvial Fan	Cement, Sand, Gravel, Boulder
Spur Dike in Laoag River	Boulder
Groundsill	Cement, Sand, Gravel, Re-bar
Sluiceway/Bridge	Cement, Sand, Gravel, Re-bar
Sabo Dam	Cement, Sand, Gravel, Boulder

The required quantities of the construction materials are summarized as follows.

Materials	Unit	Quantity
Cement	ton	69,940
Re-bar	ton	1,120
Riverbed Soil	m^3	2,046,000
Sand	m^3	76,100
Gravel	m^3	217,700
Boulder	m^3	410,000

Cement and reinforcing bar will be transported from Manila or its surrounding areas. On the other hand, soil, sand, gravel and boulder are available in the riverbeds nearby the construction site.

The grain size distribution of the riverbed materials are summarized below.

Sediment Size	Fan Apex/ Middle Fan Reaches	Lower Fan Reaches	Laoag River
Large Cobble/Small Boulder (128-512 mm)	8%	-	-
Very Coarse Pebble/ Small Cobble (32-128 mm)	21%	16%	10%
Medium/Coarse Pebble (8-32 mm)	29%	32%	22%
Very Fine/Fine Pebble (2-8 mm)	23%	25%	35%
Sand (0.125-2 mm)	19%	27%	33%

(3) Required Labor Force

The total required labor force for the period of 4-year construction is estimated as follows.

Kind of Labor	Labor Force (man-day)
Skilled Labor	515,000
Unskilled Labor	902,000
Total	1,417,000

6.1.3 Standard Construction Method

The following standard construction methods are assumed in this Study.

(1) Sabo Dam

(a) River water will be diverted by constructing a temporary cofferdam for half of the river width. The cofferdam will be constructed by using riverbed materials at the site and sandbags.

(b) Excavation of the river deposits will be executed by using backhoe (0.6 m^3) and the excavated materials will be transported to the nearby spoil banks by dump trucks (11-ton). The dumped materials will be leveled by bulldozer (15-ton).

(c) Spoil banks for Labugaon, Madongan and Papa sabo dams are assumed at the old river areas located one (1) km downstream from the dam sites. Dumping site for Cura sabo dam is planned within the upstream valley of the dam. No special spoil bank is necessary for Solsona sabo dam since the excavation volume is small.

(d) Concrete will be mixed in a batch plant to be installed nearby the dam site. The mixed concrete will be transported by a truck mixer to the site and placed by using a truck crane (25-ton).

(2) Channel Excavation and Embankment

All the embankment materials are available in the riverbeds nearby the site. On the other hand, the required embankment volume is larger than the required channel excavation volume. Hence, the whole river deposits dredged in the channel excavation works will be used for the embankment. These works will employ the following equipment: backhoe (0.6 m^3), dump truck (10-ton) and bulldozer (15-ton).

(3) Spur Dike Construction

Spur dikes in the Laoag River will be made by laying boulders by manpower. On the other hand, spur dikes in the alluvial fan rivers are made of stone concrete. The construction will include the following works: gathering of boulders from the nearby riverbed, transportation of mixed concrete from the plant installed for sabo dam, and concrete placing. The required equipment are backhoe (0.6 m^3), truck mixer (10-12 ton) and truck crane (15-ton).

6.1.4 Construction Schedule

A 4-year period is proposed for the construction. The project will be implemented from 1997 to 2003 assuming the following time schedule.

(1) Loan application and agreement to/between foreign financing organization, and other preparations from 1997 to 1998

(2) Detailed design in 1999

(3) Construction from 2000 to 2003

The implementation schedule including the time schedule of the construction works is proposed as shown in Fig. II.20.

6.2 Project Cost Estimate

6.2.1 Cost Estimation Criteria

The project cost is estimated based on the following assumptions and conditions.

(1) Constitution of Project Cost

The project cost is composed of construction cost, compensation cost, administration cost, engineering service cost and physical contingency cost. The construction cost includes cost for preparatory works, main works and miscellaneous works. The compensation cost includes land acquisition cost and house resettlement cost.

(2) Price Level

Price level is as of June, 1997.

(3) Currency Conversion Rate

Currency conversion rates among US Dollar (US$), Philippine Peso (₱) and Japanese Yen (¥) are as follows.

US$1.00 = ₱26.00 = ¥115

(4) Currency of Cost Estimate

The construction cost is estimated at foreign currency and local currency. Their portions by cost item are assumed as follows.

Items	Foreign Currency Portion	Local Currency Portion
1. Materials		
Cement	0.7	0.3
Re-bar	0.8	0.2
Soil, Sand, Gravel, Boulder	0.4	0.6
Fuel, Lubricant	0.8	0.2
2. Construction Equipment	0.7	0.3
3. Labor	0.0	1.0
4. Compensation Cost	0.0	1.0
5. Administration Cost	0.0	1.0
6. Engineering Cost	0.9	0.1

(5) Construction Cost

Construction cost consists of labor cost, materials cost and equipment cost.

(6) Compensation Cost

Compensation cost is estimated based on past records, land/house tax and market prices.

In this project, the following lands will be acquired.

(a) Land on the construction sites of the proposed structures
(b) Land in the proposed sedimentation basins
(c) Farm land/bush-land confined by the proposed dikes in Cura/Labugaon River

However, the following lands need not be acquired.

(a) Riverside land of the proposed dikes in Poblacion Laoag, San Nicolas and Dingras River Improvements. The land can still be used as it is by the owners.

(b) Existing riverbed area confined by the proposed dikes in Cura/Labugaon River since it is considered as public land as stipulated in the Civil Code of the Philippines.

(7) Government Administration Cost

The cost of project management or administration by the government is assumed as 3% of the construction cost and compensation cost.

(8) Engineering Services Cost

Detailed design and construction supervision are to be carried out by an engineering consultant. The cost of engineering services is assumed as 16% of the construction cost.

(9) Physical Contingency

Physical contingency is estimated as 10% of the construction cost, compensation cost, administration cost and engineering services cost.

(10) Price Contingency

Price escalation rate is assumed as 7% per annum for local currency and at 2% per annum for foreign currency.

(11) Value Added Tax

Value added tax is estimated as 10% and it is included in the construction cost, except direct foreign currency.

6.2.2 Project Cost

The total cost of the proposed priority project is estimated to be 1,911.3 million pesos at 1997 prices and 2,333.1 million pesos including price contingency. These are broken down by work item and currency portion as follows. For details, see Table II.1.

(Unit: million peso)

Item	Foreign Currency Portion	Local Currency Portion	Total
1. Construction Cost	654.1	800.5	1,454.6
1.1 Preparatory Works	59.4	72.8	132.2
1.2 Main Works	540.6	661.6	1,202.2
(1) Sabo Dam	105.4	126.7	232.1
(2) Alluvial Fan River Imp.	358.6	478.1	836.7
(3) Laoag-Bongo River Imp.	76.6	56.8	133.4
1.3 Miscellaneous Works	54.1	66.1	120.2
2. Compensation Cost	0.0	6.4	6.4
2.1 Land Acquisition	0.0	6.0	6.0
2.2 House Resettlement	0.0	0.4	0.4
3. Administration Cost	0.0	43.8	43.8
4. Engineering Service Cost	209.4	23.3	232.7
5. Physical Contingency	86.4	87.4	173.8
Sub-total	949.9	961.4	1,911.3
6. Price Contingency	83.2	338.6	421.8
Total	1,033.1	1,300.0	2,333.1

Note : River Imp. means River Improvement

6.2.3 Disbursement Schedule

The annual disbursement schedule of project cost is summarized below. For details, see Table II.2.

(Unit : million peso)

Year	Foreign Currency Portion	Local Currency Portion	Total
1999	86.4 (89.9)	16.9 (19.3)	103.3 (109.2)
2000	219.4 (232.8)	245.9 (301.3)	465.3 (534.1)
2001	225.7 (244.2)	241.8 (317.0)	467.5 (561.2)
2002	221.6 (244.6)	238.0 (334.0)	459.6 (578.6)
2003	196.8 (221.6)	218.8 (328.4)	415.6 (550.0)
Total	949.9 (1,033.1)	961.4 (1,300.0)	1,911.3 (2,333.1)

Note: Figures without parentheses are costs at 1997 prices; with parentheses are costs including price contingency

6.2.4 Operation and Maintenance Cost

The total annual operation and maintenance cost of the project is assumed as 0.5% of the construction cost for the river improvement. It amounts to 7.3 million pesos after the project is completed in 2003.

CHAPTER VII PROJECT EVALUATION

7.1 Project Benefit

7.1.1 General

Two (2) major benefits will accrue from this project. One is flood mitigation benefit and the other is land use enhancement benefit.

The flood damage consists of direct damage and indirect damage. The direct damages include the damages on the following products and properties.

(1) Agricultural production from irrigated and rainfed fields.

(2) Housing units and their household effects.

(3) Commercial establishments and factories including buildings, machinery, equipment and inventory stocks.

(4) Social infrastructures including educational and medical facilities, and physical infrastructures including roads, water supply, electricity, telephone, irrigation and river facilities.

Indirect damages comprise the costs for the following activities.

(1) Opportunity losses of business and production activity
(2) Emergency activities
(3) Medical care and cure for flood victims
(4) Preventive activities against crimes

The direct damages except for physical infrastructures are estimated as a product of the number of facilities inundated by flood in an affected area, the economic value of inundated property and damage rate in accordance with inundation depth. The physical infrastructure damage is assumed as 20% of the above direct damages, referring to similar projects in the Philippines.

The indirect damage is assumed as 10% of the above direct damages.

The benefit of land use enhancement consists of land loss prevention benefit and land use restoration benefit. Cultivated lands have been washed out every year by floods in the alluvial fan areas. These land loss will be prevented by the project. On the other hand, the project is expected to restore the present devastated lands to cultivated land for agricultural production.

7.1.2 Flood Mitigation Benefit

Flood mitigation benefits of the project in financial terms under the present socio-economic situation are discussed below.

(1) Inundated Property by Flood Return Period

The possible inundation area, affected population and quantity of damageable property by each flood return period under the present socio-economic conditions were estimated by flood simulation in the Master Plan Study. Those for the objective project are excerpted from the above study and summarized below. For the inundated property by each sub-project area, see Appendix E.

Return Period (year)	2	5	10	25	50	100
Inundation Area(ha)	10,900	12,200	12,900	13,400	14,300	15,000
Affected Population	30,095	37,640	40,403	47,948	54,413	57,743
Agricultural Land (ha)	6,880	7,930	8,275	8,600	9,300	9,758
Number of Buildings	6,125	7,678	8,248	9,833	11,181	11,873
Housing Unit	5,943	7,440	7,995	9,515	10,803	11,459
Shopping Store	116	144	150	187	218	232
Factory	20	24	26	44	62	76
School	39	57	63	71	80	85
Hospital	7	13	14	16	18	21

Note: Hospital includes barangay health stations and rural health units.

(2) Estimated Flood Damage

The existing unit values of the damageable crop production and properties in financial terms are assumed as follows.

Property	Unit	Production, Durable Assets	Movable Assets	Total
Irrigated Field	Peso/ha	18,000	-	18,000
Rainfed Field	Peso/ha	13,700	-	13,700
Housing Unit	Peso/Unit	50,000	38,000	88,000
Shopping Store	Peso/Unit	15,000	210,000	225,000
Factory	Peso/Unit	53,000	65,000	118,000
School	Peso/Unit	1,500,000	250,000	1,750,000
Hospital	Peso/Unit	15,700,000	3,800,000	19,500,000
Brgy. Health Station	Peso/Unit	362,500	300,000	662,500
Rural Health Unit	Peso/Unit	1,040,000	600,000	1,640,000

The flood damage is estimated by multiplying the quantity of the damageable property by its unit value and damage rate. For the damage rate, refer to the Master Plan Study, Supporting Report, Appendix C.

The flood damage by each item corresponding to each flood return period under the present socio-economic conditions are estimated as follows.

(Unit: million peso)

Return Period (year)	2	5	10	25	50	100
Direct Damage	252.5	403.0	495.2	613.0	728.6	793.6
Agriculture Production	67.0	87.4	95.8	105.9	115.4	124.8
Housing Units	95.1	159.6	197.0	251.4	300.5	333.0
Industry	10.7	16.1	18.3	21.6	24.6	26.6
Infrastructure	79.6	139.9	184.1	234.1	288.1	309.2
Indirect Damage	24.6	36.7	43.5	52.2	61.0	66.8
Total	277.1	439.7	538.7	665.2	789.6	860.4

The total flood damage by each flood return period in the above table are broken down into each sub-project area as follows.

(Unit: million peso)

Return Period (year)	2	5	10	25	50	100
Pob. Laoag	11.8	69.5	119.0	179.2	237.1	252.2
Pob. San Nicolas	1.0	7.7	19.4	27.1	43.9	53.9
Pob. Dingras	2.9	13.7	21.7	28.6	41.1	46.0
Cura/Labugaon River	94.9	137.2	150.0	163.8	176.0	185.9
Solsona River	66.7	82.8	88.7	102.9	112.1	126.9
Madongan River	67.7	93.7	103.6	117.7	128.8	143.2
Papa River	32.0	35.1	36.3	45.9	50.6	52.2
Total	277.1	439.7	538.7	665.2	789.6	860.4

(3) Average Annual Flood Damage

The average annual flood damage is calculated by using the following formula.

$$D = \sum 1/2[D(Qi\text{-}1) + D(Qi)][P(Qi\text{-}1) - P(Qi)]$$

where;

D : average annual flood damage

D(Qi-1), D(Qi) : flood damage caused by flood with Qi-1 and Qi discharge, respectively

P(Qi-1), P(Qi) : probabilities of occurrence of Qi-1 and Qi discharge, respectively

The average annual flood damage of each sub-project area under the present socio-economic situation is calculated for floods below various return periods as shown below.

(Unit: million peso)

Return Period (year)	2	5	10	25	50	100
Pob. Laoag	1.3	7.1	11.7	16.1	18.1	19.3
Pob. San Nicolas	0.2	1.5	2.9	4.3	5.0	5.5
Pob. Dingras	0.7	3.2	5.0	6.5	7.2	7.6
Cura/Labugaon River	23.7	58.6	72.9	82.3	85.7	87.5
Solsona River	16.7	39.1	47.7	53.4	55.6	56.8
Madongan River	16.9	41.1	51.0	57.6	60.1	61.5
Papa River	8.0	18.1	21.6	24.1	25.1	25.6
Total	67.6	168.7	212.8	244.4	256.8	263.8

(4) Annual Flood Mitigation Benefit

The proposed project is planned to prevent all floods below 25-year return period. Hence, the project will produce an average annual flood mitigation benefit of 244.4 million pesos in financial terms under the present socio-economic situation. Breakdown by each sub-project area is also shown in the above table.

7.1.3 Benefit of Land Use Enhancement

(1) Land Loss Prevention

Farmland of 1,031 ha were lost in the alluvial fan areas during the past 20 years, broken down as follows: 584 ha in Cura/Labugaon River, 241 ha in Solsona River, 142 ha in Madongan River and 64 ha in Papa River. Therefore, about 51.6 ha of farmland will be washed out every year if no countermeasures are taken. The project will prevent this land loss. The amount of project benefit is obtained by calculating the agricultural production loss to be caused by this land loss.

The average annual land loss area and land loss prevention benefit in financial terms by each sub-project area are summarized below. For details, see Appendix E. The annual land loss prevention benefits will be accumulated from year to year.

Sub-project Area	Annual Land Loss Area (ha)	Annual Land Loss Prevention Benefit (thousand Peso)
Cura/Labugaon River	29.2	2,098
Solsona River	12.1	864
Madongan River	7.1	518
Papa River	3.2	231
Total	51.6	3,710

(2) Benefit of Land Use Restoration

There is a total devastated land (river wash area and bush/grass land) of 3,106 ha in the alluvial fan area at present. After the completion of the project, these areas will also become flood free and hence, the farmers could be motivated to restore a considerable portion of the existing devastated land for agricultural production.

Out of the existing devastated land of 3,106 ha, 1,830 ha is expected to be recovered and developed into the following: 820 ha for grazing, 510 ha for upland crop production and 500 ha for rice cultivation. The agricultural yield from these restored lands is considered the land use restoration benefit.

The estimated recovered land area and annual benefit in financial terms by each sub-project area are summarized below. For details, see Appendix E.

	Cura/ Labugaon	Solsona	Madongan	Papa	Total
Recovered Area (ha)	502	121	879	232	1,833
Grazing	181	57	360	220	819
Upland Crop	209	1	291	12	513
Rice	211	63	228	0	502
Annual Benefit (thousand Pesos)	3,532	784	4,106	52	8,474

7.2 Economic Evaluation

7.2.1 Basic Conditions of Economic Evaluation

(1) The economic viability of the proposed project is checked by calculating its economic internal rate of return (EIRR). Besides EIRR, net present value (NPV) and cost-benefit ratio (B/C) are presented as supplementary indices, for which costs and benefits are discounted at 15% per annum.

(2) In economic evaluation, the values of costs and benefits must be counted in real economic valuation. Economic costs and benefits are different from financial ones since the former is valued at real resource cost, while the latter is resource cost valued at market price. Therefore, the financial costs and benefits of the project are converted to the economic ones by using conversion factors.

The conversion factors of the material cost, machinery/equipment rental cost, labor cost, indirect cost, government expenditure and engineering cost are calculated by applying shadow wage rate and shadow exchange rate, and by eliminating national and local taxes as shown below. These conversion factors will be used in the calculation of the economic project costs and the economic values of the damageable properties and facilities.

Item	Local Portion	Foreign Portion
1. Materials		
Cement	0.53	1.04
Aggregate	0.68	1.06
Steel	0.24	1.06
Fuel/Lubricant	0.05	1.21
Lumber	0.80	1.04
Others	0.72	1.05
2. Machinery/Equipment Rental	0.26	1.11
3. Labor		
Skilled	0.93	-
Unskilled	0.60	-
4. Indirect Cost		
Overhead, Miscellaneous	0.86	-
Profit	0.65	-
5. Government Expenditure	0.95	-
6. Engineering Services	-	1.22

(3) The economic benefits of crop production are estimated based on international market prices.

(4) The value of the land to be used for the project is evaluated through crop production lost by the land acquisition as negative benefit.

(5) Economic life is 50 years.

(6) The basic price level for estimates is set at June, 1997. The prevailing exchange rate is set at US$1.00 = 26 Pesos = 115 Yen. The shadow exchange rate is assumed to be 1.20 times of the prevailing market rate.

(7) The economic benefits of the project are estimated for the present and future socio-economic conditions. The benefits are assumed to increase in the future in proportion to the increase of flood damage potential. The flood damage potential is further assumed to increase in proportion to the growth of population and GRDP. The average annual growth rates of the population and GRDP of the Basin are assumed as follows.

(a) Population: 0.9 % up to 2020
(b) GRDP: 6.2% up to 2000, 4.65% for 2000 to 2010 and 3.1% for 2010 to 2020

7.2.2 Economic Benefit

(1) Flood Mitigation Benefit

The flood mitigation benefits were estimated in financial terms in the previous Section 7.1.2. These benefits are converted into real economic values by applying the above-mentioned conversion factors. The integrated conversion factor of the damageable assets of housing unit, shopping store, factory, educational facility and medical facility ranges from 0.82 to 0.84, averaging 0.83.

Hence, the economic values of the above damageable assets are estimated by using a conversion factor of 0.83. On the other hand, the economic crop production values are estimated based on the international market prices.

The existing unit values of the damageable crop production and properties in economic terms are estimated as follows. For the estimation of the conversion factors of damageable properties, see Feasibility Study, Appendix E, and for the estimation of the economic values of agricultural production, see Master Plan Study, Appendix C.

Property	Unit	Production, Durable Assets	Movable Assets	Total
Irrigated Field	Peso/ha	17,200	-	17,200
Rainfed Field	Peso/ha	11,300	-	11,300
Housing Unit	Peso/Unit	41,500	31,500	73,000
Shopping Store	Peso/Unit	12,500	174,000	186,500
Factory	Peso/Unit	44,000	54,000	98,000
School	Peso/Unit	1,245,000	207,500	1,452,500
Hospital	Peso/Unit	13,031,000	3,154,000	16,185,000
Brgy. Health Station	Peso/Unit	301,000	250,000	551,000
Rural Health Unit	Peso/Unit	863,000	498,000	1,361,000

The average annual flood mitigation benefit by the proposed project is estimated in economic terms in the same way as the financial one. The benefits are assumed to accrue in proportion to the progress of construction works. The full benefits will accrue immediately after the completion of the entire works. The total full benefit of the project under the present socio-economic situation is estimated to be 203.8 million pesos and it is expected to accrue in 2004.

The above benefits include the full benefits of Cura No. 1/No. 2, Labugaon No. 1/No. 2, Solsona No. 1/No. 2, Madongan and Papa sabo dams, However, Cura No. 2, Labugaon No. 2 and Solsona No. 2 sabo dams are not included in this priority project. Further, even the proposed priority sabo dams will decrease their beneficial effects in the future due to the reduction of sediment control function. Hence, it is assumed from the conservative point of view on economic efficiency that:

(a) The function of Cura No. 1, Labugaon No. 1 and Solsona No. 1 sabo dams will terminate 10 years after completion of the project. Hence, the benefits of Cura No. 1/No. 2, Labugaon No. 1/No. 2 and Solsona No. 1/No. 2 sabo dams are subtracted from the above benefits after 10 years.

(b) The function of Madongan and Papa sabo dams will terminate after 20 years. Hence, the benefits of Madongan and Papa sabo dams are subtracted from the above benefits after 20 years.

Taking the above benefit reduction into account, the benefit rates of flood mitigation for the respective sub-project areas are calculated as follows.

	Pob. Laoag/ San Nicolas/ Dingras	Cura/ Labugaon River	Solsona River	Madongan River	Papa River
10 Years after Construction	100%	100%	100%	100%	100%
11th to 20th Year	100%	66%	80%	100%	100%
Beyond 21st Year	100%	66%	80%	79%	75%

From the above, the annual flood mitigation benefits in economic terms under the present socio-economic situation of each sub-project area are summarized below.

(unit: million pesos)

Sub-project Area	10 Years After Completion	11th to 20th Year	Beyond 21st Year
Poblacion Laoag	14.4	14.4	14.4
Poblacion San Nicolas	3.6	3.6	3.6
Poblacion Dingras	5.4	5.4	5.4
Cura/Labugaon River	68.3	45.0	45.0
Solsona River	44.3	35.4	35.4
Madongan River	47.8	47.8	37.8
Papa River	20.0	20.0	15.0
Total	203.8	170.8	154.9

The benefits under the future socio-economic condition are expected to increase in proportion to the economic growth and population expansion in the Basin, although they are assumed to keep constant after the target year of 2020.

(2) Land Use Enhancement Benefit

(a) Land Loss Prevention Benefit

The annual land loss prevention benefits in economic terms under the present socio-economic condition by each sub-project area are estimated as follows by converting the benefits in financial terms given in Section 7.1.3.

Sub-project Area	Annual Land Loss Prevention Benefit (thousand peso)
Cura/Labugaon River	1,658
Solsona River	683
Madongan River	410
Papa River	182
Total	2,933

The above annual benefits are expected to accrue immediately after completion of the project (2004) and they will be accumulated year by year thereafter.

The benefits under the future socio-economic condition are expected to increase in proportion to the economic growth in the Basin although they are assumed to keep constant after the target year of 2020.

(b) Land Use Restoration Benefit

The annual land use restoration benefits in economic terms under the present socio-economic condition by each sub-project are also estimated as follows by converting the benefits in financial terms given in Section 7.1.3. The benefits are fully matured ones and they are assumed to accrue 10 years after the project initiation.

Sub-project Area	Annual Land Restoration Benefit (thousand peso)
Cura/Labugaon River	2,188
Solsona River	511
Madongan River	2,515
Papa River	27
Total	5,241

The benefits under the future socio-economic condition are expected to increase in proportion to the economic growth in the Basin, although they are assumed to keep constant after the target year of 2020.

(3) Negative Benefit

Some farmlands will be appropriated for the site of river channels, dikes and sabo dams. The crop production in these areas will be lost as a negative benefit.

The total annual negative benefit of the project in economic terms under the present socio-economic situation is estimated at 0.04 million pesos. The benefit under the future socio-economic condition is expected to increase in proportion to the economic growth in the Basin, although it is assumed to keep constant after the target year of 2020.

7.2.3 Economic Cost

The financial project cost estimated in Chapter VI is converted into the economic cost by using the conversion factors assumed in Section 7.2.1. The integrated conversion factors of the respective work items are summarized as follows.

Work Item	Conversion Factor	Work Item	Conversion Factor
Sabo Dam	0.78	House Resettlement	0.83
Alluvial Fan River Imp.	0.79	Administration Cost	0.95
Laoag-Bongo River Imp.	0.83	Engineering Cost	1.10
Land Acquisition	0.00	Physical Contingency	0.83

The economic project cost is estimated to be 1,592.2 million pesos with the following breakdown in comparison with the financial one.

Item	Financial Cost	Economic Cost
		(Unit: million peso)
1. Construction Cost	1,454.6	1,149.5
1.1 Preparatory Works	132.2	104.5
1.2 Main Works	1,202.2	950.0
1.3 Miscellaneous Works	120.2	95.0
2. Compensation Cost	6.4	0.4
3. Administration Cost	43.8	41.6
4. Engineering Service Cost	232.7	256.0
5. Physical Contingency	173.8	144.7
Total	1,911.3	1,592.2

The disbursement schedule of economic cost is summarized below. For the detailed disbursement schedule of economic cost, see Appendix E.

Year	Annual Disbursement (million peso)
1999	104.4
2000	382.0
2001	384.9
2002	378.6
2003	342.3
Total	1,592.2

The total annual operation and maintenance cost (O&M cost) of the project is assumed to be 0.5% of the construction cost for river improvement. The annual O&M cost of the project amounts to 4.65 million pesos in economic terms after the project is completed in 2003.

7.2.4 Economic Evaluation

(1) Economic Viability

The economic internal rate of return (EIRR) of the project under the future socio-economic condition is calculated to be 20.3%. The cost-benefit ratio (B/C) and net present value (NPV) discounted at 15% under the future socio-economic condition are also calculated to be 1.43 and 442 million pesos. They are summarized below in comparison with those under the present socio-economic condition. The economic cost and benefit streams of the project under the present and future socio-economic conditions are shown in Table II.3 and Table II.4, respectively.

	EIRR (%)	B/C	NPV (million peso)
Under Future Condition	20.3	1.43	442
Under Present Condition	12.4	0.82	-190

(2) Sensitivity Test

The sensitivity test of the economic efficiency is performed for the following four (4) cases:

(a) 10% higher than the cost estimated

(b) 10% lower than benefits expected

(c) High economic growth scenario: 8.90% up to 2000; 6.68% in 2000-2010; 4.45% in 2010-2020

(d) Low economic growth scenario: 4.90% up to 2000; 3.68% in 2000-2010; 2.45% in 2010-2020

The results are summarized below. From the results, the proposed project is considered economically viable.

	EIRR (%)	B/C	NPV (million peso)
Base Condition	20.3	1.43	442
(a) 10% Cost Up	18.7	1.30	338
(b) 10% Benefits Down	18.5	1.28	294
(c) High Growth Scenario	22.9	1.69	716
(d) Low Growth Scenario	19.1	1.32	334

7.3 Social Evaluation

(1) Creation of Job Opportunity and Activation of Regional Economy

The proposed project creates opportunity for temporary jobs during the construction period. The requirement for temporary labor is estimated at 1.42 million man-days in total, i.e., 0.52 million man-days of skilled labor and 0.90 million man-days of unskilled labor during the four (4) years between 2000 and 2003.

Besides these temporary workers, a lot of support services for the construction works will be required in the Basin. These support services will create another job opportunity and it will contribute to activation of the regional economy.

(2) Enhancement of Land Use and Mitigation of Economic Disparity

There are many depressed areas along the Laoag River, especially in the alluvial fan area and large farmlands have been washed out in these areas. The proposed project will prevent these land losses and give people incentives to actively restore the lost farmlands. The project is expected to mitigate economic imbalance within the Basin.

(3) Improvement Social Amenity and Public Hygiene

People in the Basin are exposed to the danger of flood disasters and public hygiene after floods. The proposed project will relieve the people from the menace of floods and waterborne diseases and, as a result, they could enjoy their improved living conditions.