社会開発調査部報告書

No. 52

REPUBLIC OF THE PHILIPPINES

STUDY ON ILOG - HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT

MASTER PLAN REPORT

VOLUME I : MAIN REPORT

JULY 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

REPUBLIC OF THE PHILIPPINES

STUDY

ON

ILOG - HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT

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JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to a request from the Government of the Republic of the Philippines, the Government of Japan decided to conduct a study on Ilog-Hilabangan River Basin Flood Control Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Philippines a survey team headed by Mr. Katsuhisa Abe, Director of the Board, CTI Engineering Co., Ltd., Tokyo, Japan, which was composed of members from CTI Engineering Co., Ltd., I. N. A. Civil Engineering Consultants Co., Ltd. and PASCO International Inc., three times between February 1990 and June 1991.

The team held discussions with officials concerned of the Government of the Philippines and conducted field surveys at the study area. On each occasion, after the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of the Philippines for their close cooperation extended to the team.

July 1991

Kensuke Yanagiya

KENSUKE YANAGIYA
President

JICA STUDY TEAM
ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT

July 19, 1991

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir:

LETTER OF TRANSMITTAL

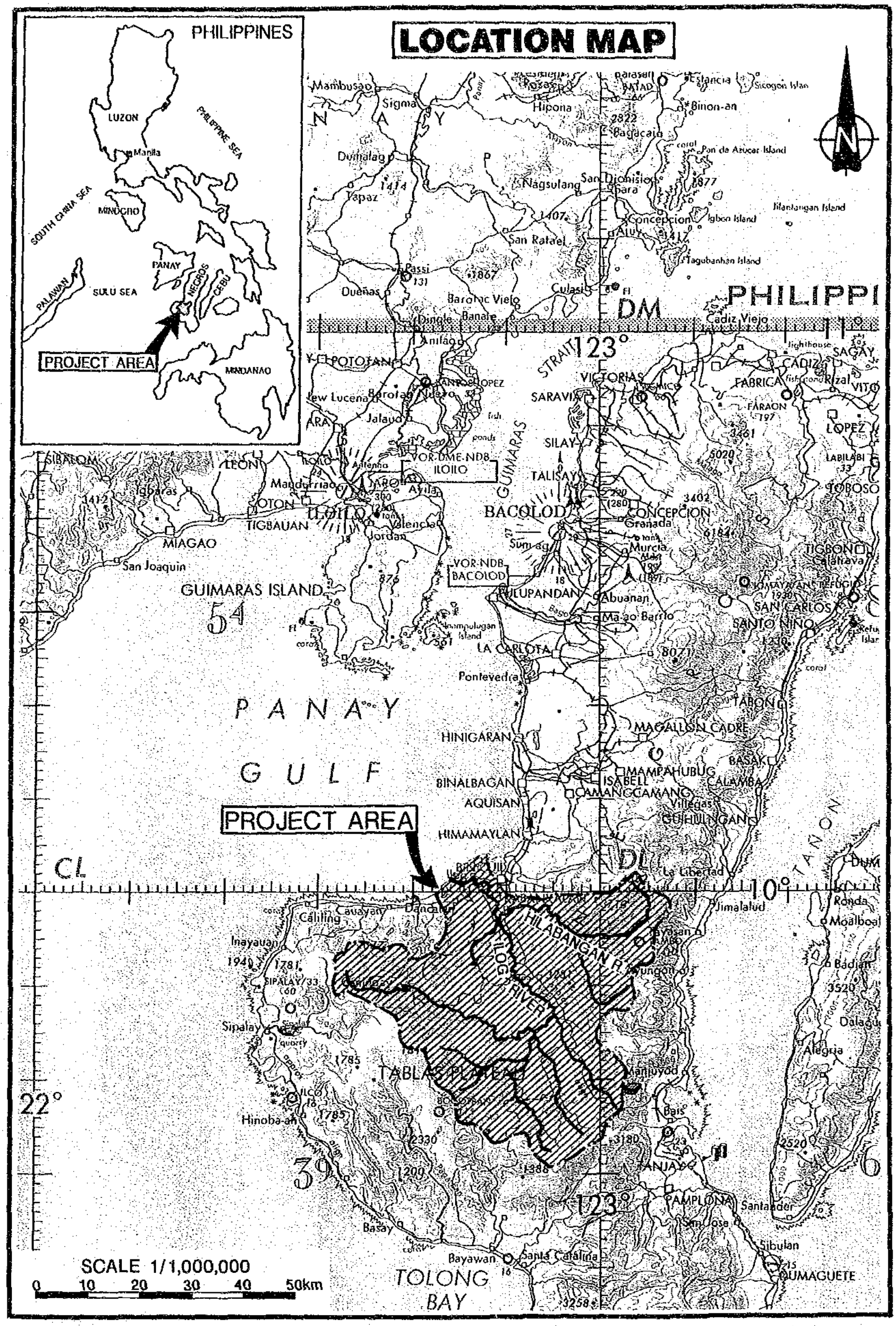
We are pleased to submit herewith the Master Plan Report on the Study on Ilog-Hilabangan River Basin Flood Control Project which includes the selection of priority projects.

The Master Plan Report consists of three (3) volumes. Volume I is the main report presenting the summary of all the study results, details of project formulation and recommendations. Volume II is the Supporting Report discussing sectorwise technical details. Volume III (Data Book) includes hydrological data, the results of geological investigations, survey works and interview survey on flood damage caused by Typhoon Ruping in November 1990.

We wish to express our grateful appreciation to the officials of the Japan International Cooperation Agency, the Advisory Committee, the Ministry of Foreign Affairs, the Ministry of Construction, the Embassy of Japan in the Philippines, and the officials concerned of the Government of the Philippines for their assistance and advice to the Study Team. We sincerely hope that the study results would be useful for the succeeding study stage to work out solutions towards the socioeconomic development of the Ilog-Hilabangan River Basin.

Very truly yours,

KATSUHISA ABE
Team Leader


LOCATION MAP
PHILIPPINES
LUZON
Manila
PHILIPPINE SEA
SOUTH CHINA SEA
MINDORO
PANAY
NEGROS
CEBU
PALAWAN
SULU SEA
MINDANAO
PROJECT AREA
PANAY GULF
GUIMARAS STRAIT
GUIMARAS ISLAND
ILOILO
BACOLOD
VOR-DME-NDB ILOILO
VOR-NDB BACOLOD
HINIGARAN
BINALBAGAN
AQUISAN
HIMAMAYLAN
ISABELA
MAMPAHUBUG
GUIHULNGAN
HILABANGAN R.
ILOG RIVER
TABLAS PLATEAU
Sipalay
Hinoba-an
Basay
Bayawan
Santa Catalina
TANJAY
PAMPLONA
DUMAGUETE
TOLONG BAY
SCALE 1/1,000,000
0 10 20 30 40 50km

SUMMARY

1. INTRODUCTION

1.1 Study Area and Objectives of the Study

The study area covers the Ilog-Hilabangan River Basin of 2,162 km^2. The objectives of the study are to formulate the master plan of flood control for the Ilog-Hilabangan River Basin and to identify priority projects.

1.2 Background of the Project

Regional development is one of the main strategies of the national development policy emphasized in the Medium-Term Philippine Development Plan for 1987-1992. It is proposed to solve the problem disturbing the desired favorable development.

Inhabitants of the Ilog-Hilabangan River Basin have been enjoying abundance in agricultural production and fish culture. Poverty and insurgency problems have, however, increased due to floods which bring about damages resulting in low productivity and thus hampering development of the region. The maximum flood, recorded in November 1949, inundated the landside area for 4 days, causing 730 casualties and about 5.1 million pesos of damage at 1954 prices. Another example is the flood in September 1984 which inundated the municipalities of Kabankalan and Ilog, as well as the surrounding flat land, resulting in 48 dead and 29 missing. Then, on November 13, 1990, Typhoon Ruping hit the Visayas Region and caused flooding in the lower reaches of Ilog-Hilabangan River, which was more severe than the 1984 flood. DPWH has painstakingly made efforts to mitigate flood damage; however, this is expected to increase in the future due to further agricultural development and population increase.

In consonance with government policy, therefore, it is essential to provide flood control works to mitigate flooding problems and improve the livelihood of the inhabitants. The necessity of providing more effective countermeasures has been recognized, and a study was commenced to formulate a master plan of flood control for this river basin.

1.3 Flood Inundation Condition in the Basin

Flood damage in the Ilog-Hilabangan River Basin is most conspicuous in the flat land in the lower reaches, and this is caused mainly by overflow water from the river. The flow capacity of the river channel presently ranges from from 500 m^3/s to 2,000 m^3/s, while the probable discharge of a 2-year return period is 920 m^3/s. Discharge over the flow capacity widely spreads over the flat land, inundating an estimated area of 125 km^2 in the lower reaches.

In terms of area, sugarcane plantations are the most dominant in the flat land, followed by fishponds, paddy fields, coconut/nipa grooves, and residential areas. Floods cause, accordingly, damages on the agricultural/aquacultural products as well as residential properties.

2. MASTER PLAN

2.1 Planning Conditions

The Master Plan has been studied on the basis of the following conditions.

Project Scale

The project scale for the Master Plan was selected in consideration of those of other major rivers in the Philippines and the magnitude of recorded maximum flood in the basin. A 100-year return period was adopted.

Target Year

Since the Master Plan is envisioned to provide an ideal flood control plan, the target year for completion could not be specified aside from its enormous fund requirement and work volume. To examine the economic viability, however, a tentative project completion year is required, and the year 2020 is employed as the target year.

2.2 Optimum Plan

A comparative study was made among several alternative measures for flood control, which include river improvement, diversion channels, dam/reservoir, and their combinations. A river improvement plan along the present river channel was selected from the economic and technical aspects.

2.3 Implementation Schedule

Implementation ofthe Master Plan is assumed to span a long period of 30 years from 1991 to 2020, including the feasibility study stage.

Since the Master Plan is to be formulated on the condition that an Urgent Project be included in the early stage, a phased implementation schedule was studied according to safety degree. Eventually, flood control works for a 25-year return period flood is proposed to be completed in the first phase, and it will be consecutively upgraded to the design scale of a 100-year return period until the target year 2020.

2.4 Construction Cost

The construction cost of the Master Plan is estimated at 1,253 million pesos at the price level of November 1990 and the conversion rates of currencies are US$1.00 = ¥130 =₱28.00 (₱1.00 = ¥4.64). This cost consists of main construction cost, engineering services and administration cost, physical contingency and compensation cost, excluding price contingency, as follows:

Item	Cost (mil. ₱)
1. Construction	893
2. Administration	45
3. Engineering Services	143
4. Physical Contingency	108
5. Compensation	64
Total	1,253

2.5 Project Evaluation

Annual Average Benefit

The annual average benefit which was calculated under the land use condition of the year 2020 is 126.6 million pesos, including direct and indirect benefit.

Economic Viability of the Master Plan

The economic viability of the Master Plan was assessed by means of IRR, B/C and NPV. The results are as follows:

IRR : 12.6 %
B/C* : 1.266
NPV* : 68.55 million pesos
* Discount rate = 10%.

Project Justification

In general, the borderline in this kind of infrastructure project is around 10% and therefore the Master Plan with an IRR of 12.6% has an adequate economic viability. Further, this project will bring about intangible benefits such as saving of invaluable human life that may possibly be lost by flooding, protection of possible injuries and mitigation of occurrence of diseases. The Master Plan should then be put into implementation in the near future.

3. SELECTION OF URGENT PROJECT

The urgent project was selected within the framework of the Master Plan by narrowing down the area to be protected and/or by lowering the project scale, as follows:

Flood Control Measure : River channel improvement for the same river stretch as the Master Plan

Project Scale : 25-year return period

The economic viability of the Urgent Project was preliminarily calculated at 15.2% in IRR. The Urgent Project is thus acceptable enough from the economic viewpoint, although it is necessary to confirm its viability in the feasibility study stage.

4. RECOMMENDATION

(1) Early Conduct of a Feasibility Study

Under the present situation in the study area, the Study has to be terminated after the completion of the Master Plan Study Stage. The Master Plan shows a relatively high economic viabiliy of 12.6 % in the economic internal rate of return (EIRR). It is, therefore, recommended to conduct a feasibility study as soon as possible for the implementation of the project.

(2) Considerations for the Feasbility Study

The following considerations should be taken into account in the feasibility study stage:

(a) Typhoon Ruping hit the study area on November 13, 1990 and caused a tremendous flood damage. In this regard, the data on flooding condition and flood damage by this typhoon have been collected. (These data are compiled in Volume III, Data Book of the Master Plan Report.)

(b) It is necessary to examine the river channel improvement paln through the field investigation, focusing on land acquisition and house evacuation which may cause a social problem.

(3) Consideration in Case of Implementing River Improvement Works without the Feasibility Study

In case that river improvement works are to be partially carried out without implementing a feasbility study, reference should be made to the components of the proposed Master Plan in order to avoid double investment when the project is implemented.

(4) Continuation of Hydrological Observation in the Study Area

Several hydrological gauging stations have been installed in the study area by this Study. Since the hydrological data will be useful for conducting the feasibility study, it is desirable that data collection by these hydrological gauging stations shall be continued.

PROJECT FEATURES

(1) Design Flood

- Project Scale : 100-year return period
- Design Discharge : 5,450 m^3/s

(2) Target Year : Year 2020 (For project evaluation only)

(3) Flood Control Measure

- River Channel Improvement : 21.5 km in total length

(4) Structures and Works

- Embankment	:	966,700 m^3
- Excavation	:	6,701,800 m^3
- Dredging	:	2,723,700 m^3
- Revetment	:	153,150 m^2
- Sodding	:	530,200 m^2
- Sluice (Type A)	:	3 units (one box culvert)
- Sluice (Type B)	:	1 unit (three box culvert)
- Drainage Facility	:	6 units (one box culvert)

- Bridge

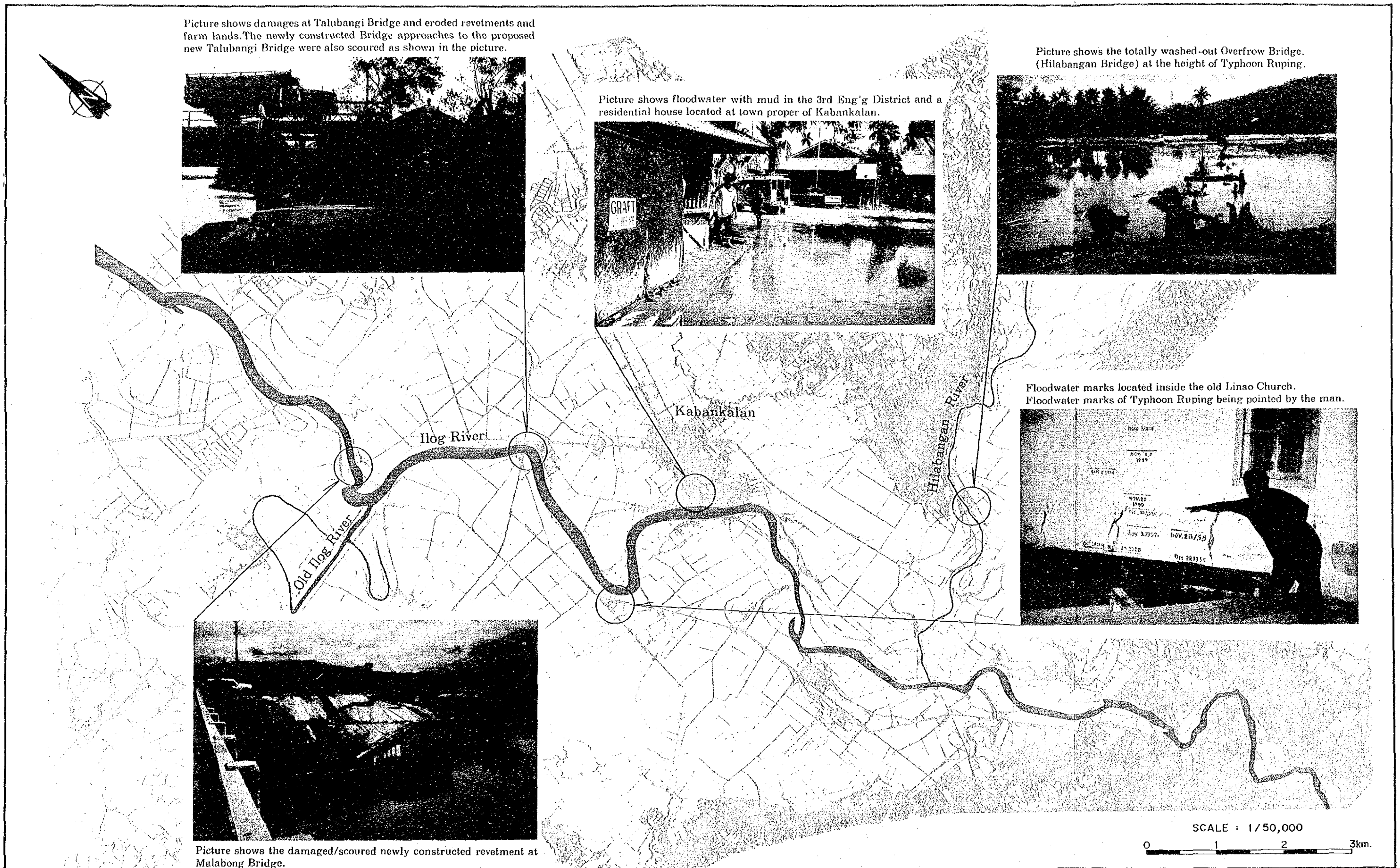
a. Talubangi Bridge : 10 m wide and 290 m long
b. Bungul Bridge : 4 m wide and 360 m long

(5) Compensation

- Land Aquisition

a. Fishpond : 38 ha
b. Sugarcane : 178 ha
c. Residential Area : 6 ha

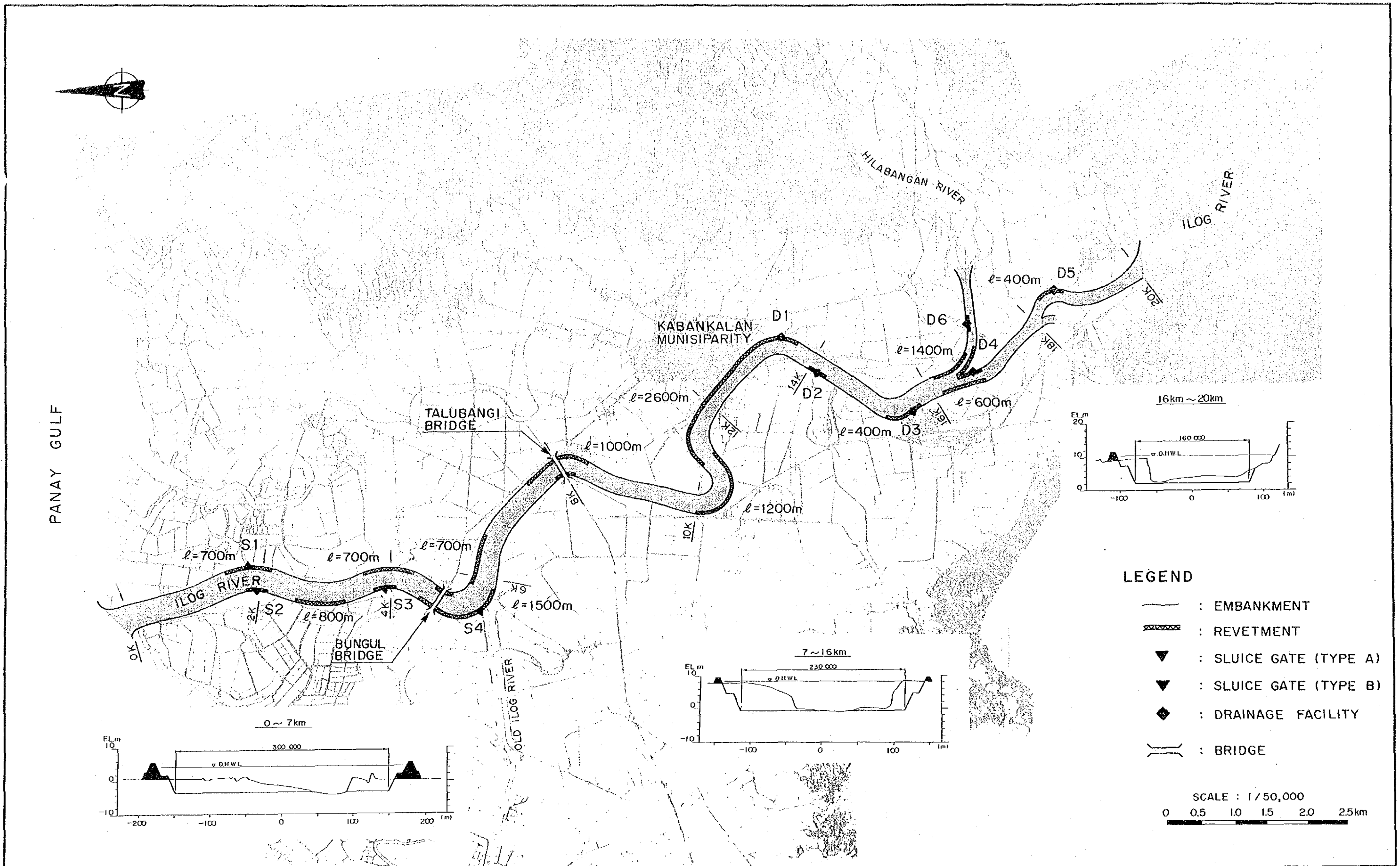
- House Evacuation : 354 units



THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

FLOOD DAMEGE BY TYPHOON RUPING



THE STUDY ON ILOG-HILABANGAN RIVER BASIN FLOOD CONTROL PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

FEATURES OF THE MASTER PLAN

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ABBREVIATIONS

(1) Organizations

ADB	:	Asian Development Bank
BREDCO	:	Bacolod Real Estate Development Corporation
BSWS	:	Bureau of Soils and Water Management
CENECO	:	Central Negros Electric Cooperative
DPWH	:	Department of Public Works and Highways
JICA	:	Japan International Cooperation Agency
LWUA	:	Local Water Utilities Administration
NAPOCOR/NPC	:	National Power Corporation
NCSO	:	National Census and Statistics Office
NEOCECO	:	Negros Occidental Electric Cooperative
NEDA	:	National Economic and Development Authority
NIA	:	National Irrigation Authority
NSCB	:	National Statistical Coordination Board
NWRC	:	National Water Resources Council
PMO	:	Project Management Office, DPWH
RWDC	:	Rural Waterworks Development Corporation
SONEDCO	:	Southern Negros Development Corporation
UNISTARCH	:	Universal Starch Industrial Corporation
VRESCO	:	Victorias Rural Electric Service Cooperative

(2) Others

CIS	:	Communal Irrigation System
GDP	:	Gross Domestic Product
GRDP	:	Gross Regional Domestic Product
NCR	:	National Capital Region
ITCZ	:	Intertropical Convergence Zone

(3) Measurement

Length

mm	=	millimeter
cm	=	centimeter
m	=	meter
km	=	kilometer

Area

m^2	=	square meter
ha	=	hectare
km^2	=	square kilometer

Volume

cm^3	=	cubic centimeter
l, ltr.	=	liter
kl	=	kiloliter
m^3	=	cubic meter
MCM	=	million cubic meter

Weight

g	=	gram
kg	=	kilogram
ton	=	metric ton
lb	=	pound
kVA	=	kilovolt ampere

Time

s	=	second
min	=	minute
h, hr	=	hour
d	=	day
mo.	=	month
y, yr.	=	year

Electric Measures

V	=	volt
A	=	ampere
W	=	watt
kW	=	kilowatt
MW	=	megawatt
GW	=	gigawatt
kV	=	kilovolt

Other Measures

%	=	percent
°	=	degree
'	=	minute
"	=	second
°C	=	degrees Centigrade
10^3	=	thousand
10^6	=	million
ppt	=	parts per trillion

Derived Measures

m^3/s	=	cubic meter per second
kWh	=	kilowatt hour
MWh	=	megawatt hour
GWh	=	gigawatt hour

CHAPTER 1. INTRODUCTION

1.1 Background of the Project

The Medium-Term Philippine Development Plan, 1987-1992, which was approved and adopted by the Government, is a blueprint aiming at economic recovery in the short run, as well as sustainable growth in the long run. Following a 3-year implementation schedule, updating works are are being undertaken by the authorities concerned.

The agricultural and rural sectors are expected to lead the development process in the national development plan. With a public investment program supportive of employment in the rural areas, agricultural productivity would rise, and incomes in turn would increase. As a result, demand would increase not only for food and other agricultural products, but also for industrial goods and services. Increased incomes in the rural areas would stimulate investment, and change consumption patterns toward products of industries that are more labor-intensive and of enterprises that are small and medium scale. In the development plan, the following are indicated as obstacles to the regional development:

(1) Persistence of Poverty in the Regions

Poverty has been identified as a critical problem in some regions in the country. Despite the assistance and programs directed toward low-income groups, the situation has not remarkably improved in recent years.

(2) Low Productivity in the Regions

Low productivity characterizes some of the regions in the country. Productivity in agriculture is even lower, per worker, for the entire country.

(3) Insurgency Problem in the Regions

At present, some municipalities in the country face serious insurgency problems. The situation has created uncertainties in the business, economic and political climate and has disrupted the development and growth of communities.

In accordance with the national development plan, regional development plans for the respective regions were incorporated. These regional development plans present the specific problems, strategies and programs of the individual regions, thus establish the direction of their development.

Among these regional development plans, Region VI (Western Visayas) and VII (Central Visayas), where the Ilog-Hilabangan River Basin lies, show typical development problems mentioned in the national plan. In some cases, such problems seem to disturb Region VI and VII much more severely than the other regions.

As for the Ilog-Hilabangan River Basin, where inhabitants have been enjoying abundance in agricultural production and fish culture, one typical development problem is floods which brought about damages resulting in low productivity; thus, increasing poverty and insurgency problems in the region. DPWH has made every effort to mitigate the flood damage; however, this is expected to increase in the future due to further agricultural development and population increase. The maximum flood recorded in November 1949 inundated the landside area for 4 days, causing 730 casualties and about 5.1 million pesos of damage at 1954 prices. Another example is the flood in September 1984 which caused inundation to the municipalities of Kabankalan and Ilog, as well as the surrounding flat land, resulting in 48 dead and 29 missing. During the past study period, on November 13, 1990, Typhoon Ruping hit the Visayan Region and caused flooding in the lower reaches of Ilog-Hilabangan River, which was much more severe than the 1984 flood .

In consonance with the government policy, therefore, it is essential to provide flood control works to mitigateflooding problems and improve the livelihood of the inhabitants. The necessity of providing more effective countermeasures has been recognized and the study to formulate the master plan and carry out a feasibility study for a flood control project which should be urgently implemented in the basin has been conceived.

1.2 Study Area

The study area covers the Ilog-Hilabangan River Basin of 2,162 km^2.

1.3 Project History

In accordance with the backgroundof the project, the study was commenced under the following objectives:

(1) To formulate the master plan of flood control for the Ilog-Hilabangan Rive Basin and to identify priority projects; and

(2) To conduct a feasibility study on the flood control projects selected.

To achieve the objectives, the study period was broadly divided into three stages:

(1) The First Stage from February 1990 to May 1990 is to conduct the prelimi study for the formulation of the master plan including aerial photogrammetry, river survey, field investigation, data collection, etc.

(2) The Second Stage from July 1990 to March 1991 is to conduct the study for formulation of the Master Plan including basic analysis, preliminary design, cost estimate, project evaluation, selection of an urgent project, etc.; and

(3) The Third Stage from May 1991 to December 1991 is to conduct a feasibility study for the selected urgent project.

Although the first stage of the study which was conducted mainly at the jobsite has been successfully completed without any anxiety on the security of the Team, certain events have occurred at the end of the stage such as the kidnapping of members of volunteer groups from Japan and the United States of America in Negros Island which brought reservations on security at the jobsite.

Accordingly, the field works in the second stage such as hydrological observation, geological investigation, interview survey, data collection, etc., were entrusted to a local consultant with cooperation from government local counterpart personnel to avoid security risks to expatriates. The Master Plan was then formulated under such circumstances.

As for the third study stage which includes a feasibility study for the urgent project, it is required that Japanese experts should examine the field conditions by themselves at the site. Since the peace and order situation in the study area was still uncertain as of May, 1991, the Embassy of Japan issued a Note Verbale to the Philippine side informing that the project will be terminated after completion of the Master Plan Study, and this was agreed upon by the Philippine side.

1.4 Modification of Implementing Arrangement

Due to the termination of the Study, the Implementing Arrangement for this study which was originally agreed between the Japan and Philippine sides had to be modified mainly on the following items:

(1) Objective of the Study

One of the original objectives of the Study, i.e., to conduct a feasibility study on the flood control projects selected, was eliminated.

(2) Study Schedule

The study which was commenced in February, 1990 was scheduled to last until December, 1991. However, the study was terminated in July, 1991 as presented in Fig. 1.4-1.

(3) Reporting

After the Interim Report which was submitted in May, 1991, the Draft Final Report and the Final Report are to be submitted. These two reports are replaced by this Master Plan Report which includes the formulation of the Master Plan and selection of the Urgent Project.

1.5 Staffing Schedule

The study was carried out by the Study Team which consisted of fifteen (15) experts recruited from CTI Engineering Co. Ltd., I.N.A. Civil Engineering Consultants Co., Ltd. and PASCO International Inc., all of Japan, with CTI Engineering Co., Ltd. acting as the leading firm. The members of the Study Team are shown in Table 1.5-1, and the members of the Advisory Committee which was organized for the Study are presented in Table 1.5-2.

CHAPTER 2. PRESENT CONDITION OF THE STUDY AREA

2.1 Topography and Geology

The Ilog-Hilabangan River Basin, with a catchment area 2,162 km^2, is situated in the central and southern portions of Negros Island. It lies generally between 122° 30' to 123° 10' E longitude, and from 9° 30' to 10° 10' N latitude. The main drainage is the Ilog River whose headwaters originate in the northwestern tip of the basin. The river flows in the southeast direction until it turns to the northwest direction in the middle reaches and discharges into the Panay Gulf. On the other hand, the Hilabangan River originates in the easternmost part of the basin, flows generally westward in the upper reaches and then into a northwest direction, and joins the Ilog River at about 3 kilometers from Poblacion Kabankalan. The tributaries which follow a dendritic pattern, drain into the main river channel. The development of the dendritic pattern appears to have been controlled by the lithologic condition and by the geologic structures.

Topography

The Ilog-Hilabangan River Basin is enclosed by three (3) clusters of mountains; namely, Negros Central Mountains to the north, Negros Cordillera to the east and Southern Negros Mountains to the southwest. It faces Panay Gulf to the northwest. (Refer to Figs. 2.1-1 and 2.1-2.)

The Negros Central Mountains is a wide, middle degree of dissected mountain region having a dendritic valley with moderate to very steep slopes. The maximum elevation of the area is about 1,000 meters above mean sea level. (Refer to Fig. 2.1-3.)

The Negros Cordillera Mountain is of the same degree as the Negros Central Mountains. It is a long, north-trending mountain range, running along the eastern edge of Negros Island with a maximum elevation of around 700 meters above mean sea level.

The Southern Negros Mountains have a highly dissected northwest trending mountain range. The maximum elevation is nearly 700 meters above mean sea level.

The Ilog-Hilabangan Plain is situated in the middle part of the basin. It is characterized by an irregularly shaped depression and a dissected plateau that has an alluvial flat land and gently sloping hills. The highland of this plain has an elevation of less than 300 meters above mean sea level.

In the northwestern part of the plain, the delta along the Ilog-Hilabangan River faces Panay Gulf. From the micro-topographical viewpoint, the delta has a very gentle slope as it comes to the seashore, as shown in Fig. 2.1-4.

Geology

(1) Geological History of Negros Island

Negros Island is an uplifted igneous sedimentary basin, named as the Negros-Siquijor basin, believed to have originated during Cretaceous. The basin is considered a back-arc basin generated by an eastward moving subducted plate. The oldest volcanic rocks of the basin with their intercalated pyroclastic and clastic rocks are dated Cretaceous. Intrusion and partial metamorphism took place during the Paleocene.

Intermittent igneous activity and tectonic movement with sedimentation succeeded during the period of earliest Eocene to Recent. Coralline limestone was indicated during Eocene, Late Oligocene, Early to Late Miocene and Pliocene to Pleistocene.

The limestones generally overlie clastic rocks and/or igneous deposits. Diorite and gabbro intrusions took place during the period of Middle to Late Miocene. Sedimentary rocks of Early Miocene and older age are highly cemented.

(2) Distribution of Geology

Old volcanic rocks, partly covered by later sedimentary rocks and young volcanic rocks, are exposed in the interior of the Negros Central Mountains and the Negros Cordillera. The front and foothills are generally covered by these sedimentary rocks, which include sandstone, siltstone, conglomerate, shale, and limestone.

At the Southern Negros Mountain region, there is a series of old sedimentary rocks with younger sedimentary rocks and volcanic rocks. The region is dominated by old volcanic rocks with the basement complex of metamorphosed igneous and sedimentary rocks.

Ilog-Hilabangan plain is formed of young and old sedimentary rocks, volcanic rocks and limestone. (Refer to Figs. 2.1-5 and 2.1-6.)

(3) Geologic Structure

Numerous faults and folds are found in the river basin area. The main trend of the faults strikes northwest-southeast and northeast-southwest. Folds generally exist in older sedimentary rocks. The Ilog-Hilabangan plain and the Negros Central Mountains are bordered by faults having NNE-SSW strike and SSE dip.

2.2 Meteorology and Hydrology

The meteorological and rainfall stations in Negros Island and neighboring areas are listed in Table 2.2-1 and the streamwater gauging stations in the Ilog-Hilabangan River Basin are listed in Table 2.2-2. The location of these stations are presented in Figs. 2.2-1 and 2.2-2, respectively.

A chart of the available data at these stations is shown in Figs. 2.2-3 and 2.2-4. The data observed at these stations reveal the following meteorological and hydrological conditions.

Meteorology

The most important factors affecting the climate of the Philippines aside from geomorphological conditions are semi-permanent cyclones and anticyclones, air streams, ocean currents, linear systems and tropical cyclones. Global distribution of semi-permanent cyclones and anticyclones, e.g., a large anticyclone centered over Siberia in January, produce air streams and ocean currents which greatly affect the climate of the Philippines.

The principal air streams which significantly affect the Philippines are the Northeast Monsoon, the Southwest Monsoon and the North Pacific Trades. The Northeast Monsoon affects the area during the months of October to March; most dominant during January and February. The Southwest Monsoon occurs at the time of high solar altitude from May to October when the Intertropical Convergence Zone (ITCZ) moves over the area, and the air mass is warm and very humid.

The main ocean current affecting the Philippines is the North Equatorial Current moving westward across the North Pacific Ocean. Surface temperature in the vicinity of the Philippines is 27.3 degrees Centigrade, and this value is quite uniform.

The linear systems which significantly affect the climate of the Philippines are the ITCZ, a tail end of cold fronts, and easterly waves. ITCZ affects the Philippines from May to October and is usually characterized by distributed weather conditions of widespread cloudiness, convective type precipitation and moderate and strong winds.

Tropical cyclones largely contribute to the rainfall in the Philippines from June to December. Rainfall abnormalities such as prolonged flood conditions are mostly due to the occurrence of tropical cyclones, and draught conditions are also attributed to the occurrence of less than the expected number of tropical cyclones.

Since there is no significant change in meteorological conditions, i.e., temperature, relative humidity, etc., the climate of the Philippines is usually classified according to rainfall pattern. Fig. 2.2-5 shows the modified Corona's climate classification.

The basin falls in Type I and Type III of the modified Corona's climate classification. Type I in which the southwest portion lies, is characterized as two pronounced seasons, dry and wet; heavy rain period is from June to September during the prevalence of the southwest monsoon season. Type III is not characterized with a very pronounced heavy rain period and has a short dry season lasting only from one to three months.

Monthly variations of meteorological data such as temperature, relative humidity, pan-evaporation, cloudiness, etc., at Iloilo City are tabulated in Table 2.2-3, and some of these items are also illustrated in Fig. 2.2-6. There is no significant variation in temperature and relative humidity; monthly average temperature varies from 25.9 degrees Centigrade in January to 28.8 degrees Centigrade in May. Relative humidity varies from 74% in April to 85% in August.

Tropical cyclones that passed through Negros Island from 1948 to 1988 are presented in Table 2.2-4, while monthly frequency of tropical cyclones obtained from the same record are listed in Table 2.2-5. According to the tables, more than 60% of the tropical cyclones which hit Negros Island occurred in November and December.

Hydrology

(1) Annual and Monthly Rainfall

Annual rainfall for stations in Negros Island and neighboring areas are compared in Table 2.2-6. An annual rainfall isohyetal map for the 1981-84 period is shown in Fig. 2.2-7. The said map shows that the higher rainfall zone is around Bacolod and annual rainfall amount decreases to the south, though annual variation is too large to characterize the annual rainfall distribution in this area.

Average monthly rainfall distribution of the same stations are presented in Table 2.2-7 and illustrated in Fig. 2.2-8. The characteristics of the modified Corona's climate classification are seen in the illustration, and rainfall pattern at Kabankalan presents the intermediate characteristics of Type I and Type III.

Monthly rainfalls observed at Kabankalan are presented in Table 2.2-8. The monthly rainfall correlation coefficient between Kabankalan and other stations are presented in Fig. 2.2-9. As shown in the figure, the correlation coefficient is low for all stations, and it is difficult to supplement the lacking rainfall data of Kabankalan from the other stations.

(2) River Discharge

The monthly average discharges of the Ilog and Hilabangan rivers at the following stations are shown in Tables 2.2-9 and 2.2-10.

River	Station	Catchment Area (km^2)
Ilog	Pandan, Orong	1,453
Hilabangan	Pangsud	431

The average annual runoff height of the rivers at these stations is around 1,400 mm, and this amount seems appropriate in consideration of the annual rainfall and the presumed evapotranspiration amount. This value corresponds to the specific discharge of 4.5 $m^3/s/100\ km^2$.

The average flow duration curve of the Ilog River at Pandan, Orong for the 1956-79 period has been drawn as shown in Fig. 2.2-10. This duration curve has been developed based on the available daily discharge basis duration curves for years in the following table and considering adjustment by the annual average discharge for 24 years for the 1956-79 period. Discharges with 95-day, 185-day, 275-day and 355-day probability and the minimum discharge for years with available daily discharge basis duration curves are as follows:

Unit: m^3/s

Year	95-day	185-day	275-day	355-day	Min.	Ave.
1970	80.0	33.8	21.5	15.2	14.1	68.1
1972	78.8	48.9	29.1	14.7	11.5	68.7
1973	24.0	13.4	8.30	6.35	6.15	44.2
1976	23.0	8.20	6.75	5.40	5.15	45.2
1977	10.4	7.80	6.45	5.75	5.20	46.1
1978	20.0	9.70	6.10	4.80	4.80	37.0
Ave.	39.4	20.3	13.0	8.70	7.80	51.5
Adjusted 1956-79 period Ave.	50.6	26.1	16.7	11.2	10.0	66.2

2.3 River Condition and Existing River Structure

River Condition

(1) General Features

The Ilog-Hilabangan river system is composed mainly of two major rivers; namely, the Ilog River with a length of about 120 km, the principal drainageway of this basin and the Hilabangan River with a length of 35 km, one of the main tributaries of the basin, although the Ilog River diversifies into several branch rivers in the flatland of the lower reaches. (Refer to Fig. 2.3-1 and 2.3-2.)

The riverbed gradient of the Ilog River ranging from 1/140 to 1/3,100 is relatively gentle compared with that of the Hilabangan River. The change is not gradual from the upper to the lower reaches, i.e., the gradient in the lower reaches is sometimes steeper than that of the upper reaches. This means that the sediment produced in the upper reaches is transported rapidly in the steeper stretch, while some sediment is deposited in the gentle gradient stretch. On the other hand, the riverbed gradient of Hilabangan River ranging from 1/80 to 1/240 gradually changes from the upper to the lower reaches.

The width and depth of the Ilog River, which are related to the flow capacity of the river, are variable in the upper reaches. In the lower reaches, the river width ranges between 100 m and 230 m and the river depth, between 5 m and 15 m. The branch rivers diversifying from the Ilog River such as Bagacay, Bungul, Old Ilog River, etc., have the river width ranging between 30 m and 150 m and river depth ranging between 2 m and 5 m, while the Hilabangan River has the river width of about 150 m and river depth of about 3 m (Refer to Fig.2.3-3). Likewise, the Binicuil River, which may serve as a diversion channel of Ilog River, has the river width of between 10 m and 100 m and the river depth between 2 m and 5 m.

(2) Change of River Course

Changes in the Ilog river course at the delta area can be identified by comparing various information such as aerophotographs, topographic maps and river surveying results. In the study area, aerophotographs taken in 1970 and 1990 and topographic maps developed in 1956 and 1990 are available, although the river surveying results of the same section are not available. As per comparison of these aerophotographs and topographic maps, the following points were identified (refer to Fig.2.3-4).

(a) Major river changes in 34 years are visible at two (2) points in the Hilabangan River, three (3) points in the Ilog River and two (2) points in Old Ilog River, and the extent of change is within 750 m. The other portions do not show any remarkable change.

(b) The change of the Ilog River at the diversion point to Bungul diversion channel is remarkable and the shift in its course is continuing.

(c) The Old Ilog river basin which had once changed the river course has been reducing the river width and depth after the Bungul diversion channel, and cut-off channels have been constructed. Since then, the change of river course has not been severe due to the reduced water discharge.

(3) Meandering of River Course

In the alluvial plain, the river naturally meanders because of the imbalance between the sediment flow capacity of the river and the friction with riverbed and bank materials, and river meandering is also influenced by obstacles to prevent the smooth flow of discharge. The behavior of the river on this matter could not be determined because of the compound elements involved.

As the general condition on meandering of the Ilog-Hilabangan River, the ratio of river length to the length of meander axis is referred. In comparison with the ratio of other rivers in the Philippines, the ratio of the Ilog-Hilabangan River is about 1.3 which is in the middle range of those of the other river basins (refer to Fig. 2.3-5). Judging from this fact, the meandering condition of the Ilog-Hilabangan River is not so severe.

<u>River Structures</u>

In the Ilog-Hilabangan River, river structures have been provided according to purpose as follows (refer to Fig. 2.3-6). The location of river structures is shown in Fig. 2.3-6.

(1) For Flood Control

(a) Embankment of Bungul diversion channel in the stretch of 1,500 m at the left side and 500 m at the right side started in 1957 and completed in 1959.

(b) Embankment of cut-off channel with the total length of 3,500 m at both sides started 1974 and completed 1975.

(c) Revetment of Ilog River at Talubangi in a total stretch of 425 m; 168 m constructed in 1968 and 257 m extended in 1979.

(d) Revetment of Bungul diversion channel in a length of 65 m in 1979.

(e) Revetment of Ilog River at Kabankalan in the stretch of about 700 m started in 1980 and completed in 1984.

(f) Revetment of Bungul diversion channel in a stretch of 25 m started in 1990 and still ongoing as of October 10, 1990.

(2) For Transportation

(a) Wooden bridge crossing the Hilabangan River at Barangay Overflow, with the length of 83 m (year of construction is not clear).

(b) Steel bridge at Barangay Talubangi, with the length of 126 m constructed in 1927.

(c) Bungul concrete bridge with the length of 80 m crossing the Bungol diversion channel started in 1977 and completed in 1979.

(d) New bridge at Barangay Talubangi proposed at immediate downstream of the existing Talubangi bridge.

(e) New bridge crossing the Hilabangan River at Barangay Overflow, which was started in 1990 and still ongoing.

(3) For Irrigation

(a) Intake facilities with three intake pumps at Ilog River for SONEDCO (sugar milling company) at Kabankalan Municipality.

(b) Intake facilities with two intake pumps at the Tablas River, a tributary of Ilog River, for Dacong Cogon Sugar and Rice Milling Company at Kabankalan Municipality.

(4) For Water Supply

(a) A bridge with water supply pipe crossing the Hilabangan River.

2.4 Sedimentation

Although the data to specify the sedimentation condition in the Ilog-Hilabangan river basin is not available, sediment yield in the mountainous areas seems to be not severe because of the fairly good vegetation (refer to Fig. 2.4-1). Correspondingly, the sediment produced in the upper reaches does not severely affect the stability of the river channel in the lower reaches as stated below:

(1) The sediment transport capacity in the upper reaches of the Ilog River is not so big judging from the gentle riverbed gradient.

(2) River mouth expansion in the 34 years from 1956 to 1990 is 500 m in maximum and 200 m on an average in the stretch of 1,500 m along the shoreline, which are considered as moderate.

(3) The riverbed has not remarkably changed, judging from the longitudinal profile of the riverbed surveyed in 1982 and 1990 and the riverbed elevation based on discharge measurement notes by NWRC. (Refer to Figs. 2.4-2 and 2.4-3.)

2.5 Inundation and Flood Damage

Inundation

According to the results of the interview-survey conducted in this study period, the lowland area of this basin is habitually inundated (refer to Table 2.5-1). The inundation condition in the lowland area is summarized as follows:

(1) Inhabitants in most parts of the lowland area have suffered from flood damage every year or once in every few years, and even in the relatively high land of Poblacion Kabankalan, they suffer from flood damage once in every ten years.

(2) The main causes of flood are typhoons and heavy rainfalls causing rivers or drainage canals to overflow.

(3) Inundation sometimes continues more than a day and the inhabitants have to evacuate to higher places.

(4) The inundation water depth sometimes reaches more than 1 m in case of a severe flood like in 1984 and the water usually flows down with a relatively high velocity.

(5) The highest inundation depth which was marked in 1949 can be identified from the flood mark at the church of Barangay Linao. (Refer to Fig. 2.5-1.)

(6) The flood inundation area in 1984 flood roughly covers the area of 125 km^2 in the lower reaches. (Refer to Fig. 2.5-2.)

Flood Damage

The interview-survey results indicate that the worst flood occurred in 1949 when the lower reaches was inundated for four days. A total of 730 lives perished, and half of the sugarcane plantation was damaged.

Typhoon Nitang which was considered to be the most powerful storm to batter the country since 1970, hit Western Visayas on September 2, 1984. In this region, lost were a total of 156 lives, of which 140 deaths were reported in Negros Occidental areas. Persons affected in the province amount to more than 227,000, and properties and economic activities were seriously damaged. According to a report by the NEDA Regional Office IV, Typhoon Nitang's total direct damage in the province was estimated in monetary terms to have reached more than 600 million at the 1984 price level. The breakdown is presented in Table 2.5-2.

During the past study period, Typhoon Ruping, which was more powerful than Typhoon Nitang, hit the Visayan Region on November 13, 1990 and inflicted severe damage on the Ilog- Hilabangan river basin. In the lower reaches, several portions of the river bank were eroded by floodwaters, washing away a wooden bridge, suspending operation of a sugar mill, and damaging agricultural crops and other properties, as presented in Fig. 2.5-3. DPWH estimated the cost for repair/rehabilitation works of various infrastructures in Region VI and VII at ₱220 million and ₱184 million, respectively.

2.6 Water Utilization

2.6.1 Water Balance

Available Water Resources

The water balance of the Ilog-Hilabangan River Basin which has a drainage area of 2,162 km^2 is assumed as follows based on the hydrological data:

Item	Amount of Water (mm)	(MCM)
Surface Runoff	1,400	3,030
- Flood Runoff	1,140	2,470
- Base Flow	260	560
Evapo-transpiration	1,000	2,160
Percolation	100	210
Total	2,500*	5,400

* Average annual rainfall for 20 years.

Some portions of percolation come out into the river as groundwater. Assuming that 50% of percolation retrieves as groundwater, the total available water including flood runoff of 2,470 MCM, base flow of 560 MCM and percolation of 105 MCM (210 MCM/2) is estimated at approximately 3,100 MCM. (Refer to Fig. 2.6-1.)

Present Water Utilization

There are ten (10) communal irrigation systems for paddy fields in the study area. Irrigation water for paddy and sugarcane cultivation is obtained from many tributaries using intake weirs or portable pumps. There is no water intake facility in the main stream of the Ilog River. For domestic water supply, many wells are operated in the lower basin which is estimated to be plentiful in groundwater. There are many brackishwater fishponds in the estuary. The prawn farms have pump stations to draw brackishwater from the tidal river and the others have facilities for natural intake. Additionally, there are two (2) sugar plants in the area that use much water for their cooling system.

The present water utilization is estimated at 52 MCM/year as tabulated in the following table. The water use ratio is only 2% of the total usable water of about 3,100 MCM (i.e., 52 MCM/ 3,100 MCM x 100 = 2%), which means that 98% of the water resources flow out into the sea without being used.

Demand	Annual Volume
Irrigation Sugarcane	10.4 MCM (20%)
Paddy	8.9 MCM (17%)
Aquaculture (Prawn Pond)	8.3 MCM (16%)
Domestic Water	5.0 MCM (9%)
Industrial Water	19.5 MCM (38%)
Total	52.1 MCM (100%)

Water utilization under each category of water use is discussed in the following subsections.

2.6.2 Agriculture and Irrigation

Production of Sugarcane and Rice

Negros Island is the region leading in sugar production in the Philippines, producing 59% of the total sugar production in the country (cropping year 1988-1989). Sugar price, however, stagnated for a very long period. Furthermore, alternative starch based and low calorie sweeteners had steadily invaded the sugar market. To get over such difficulties of the sugarcane industry, the following countermeasures are to be taken:

(1) To increase the unit yield per hectare with the construction of irrigation systems and improvement of cultivation techniques; and

(2) To lower production cost by rationalization management.

Presently, the study area is extensively cropped with sugarcane, with palay ranking second, followed by corn, coconut and some root crops. The present unit yield of sugarcane in the basin is estimated at 43 tons per hectare. This is below the country's average of 67 tons in 1989 and only 50% of sugar producing countries like Indonesia and Peru. On the other hand, the unit yield of palay is estimated at 2.5 tons per hectare.

The self-sufficiency rate of rice in this island is at a low level. The total demand of palay is calculated at 523,000 tons based on per capita consumption of 100 kg of rice. Since the production of palay is 274,700 tons based on average production in 1984-1986, the self-sufficiency rate is 53%. Shortage was supplemented by other grains such as corn and importation from other provinces. If this scenario will not change, the self-sufficiency rate is estimated at 38% by 2020 due to the increase of population. (Refer to Tables 2.6-1 and 2.6-2.)

Present Condition of Irrigation

Based on the land use and vegetation map shown in Fig. 2.6-2, present land use in the basin is roughly estimated as shown in Table 2.6-3. The areas of sugarcane and paddy are 36,900 ha and 13,800 ha, respectively.

Most of the farms are under rainfed condition. At present, sugarcane plantations in some areas are served by irrigation systems. The actual irrigated sugarcane is estimated at about 730 ha and most of them are in the Ilog lower basin.

There are ten (10) communal irrigation systems (CIS) for paddy in the entire basin. The total potential paddy area for these CIS is 640 ha, but the actual irrigated area is estimated at 410 ha only. The rate of irrigated area is 2.0% for sugarcane and 3.0% for paddy. (Refer to Fig. 2.6-3.)

Water Quality

The streamflow of the Ilog River has long been used for irrigation purposes in some parts of the lower basin. Results of water quality tests executed in 1974 to 1975 indicate that the water of the Ilog River is suitable for irrigation purposes. (Refer to Table 2.6-4.)

Cropping Pattern and Water Requirement

Sugarcane is planted from October to February and harvested from September to January. Water consumption for sugarcane is estimated according to four (4) different stages of crop management; namely, land preparation, planting or replanting (ratoon), crop management and harvest. In case of paddy, farmers have a double cropping per year. The first cropping is in the month of May to September and the second cropping is in October to February (refer to Fig. 2.6-4). Rice has six (6) stages of development, i.e., land soaking, land preparation, nursery, transplanting, crop maintenance, drainage and harvest. The water requirement for sugarcane is estimated at 14,200 m^3 while paddy is about 21,600 m^3 per ha per year. (Refer to Table 2.6-5.)

Present Water Utilization

Irrigation water for sugarcane and paddy are obtained from the stream in the foot of a hilly land, from portable pumps in its middle reaches and from water used in cooling system (refer to Sec. 2.6.5). There are no water utilization facilities to divert water from the main stream of the Ilog River. Based on the actual irrigation area, the present water demand is estimated as follows:

Sugarcane	:	14,200 m³/ha x 730 ha	= 10.4 MCM/year
Paddy	:	21,600 m³/ha x 410 ha	= 8.9 MCM/year
Total			= 19.3 MCM/year

2.6.3 Aquaculture

Present Condition of Brackish Fishery

Since the situation of the sugar industry had worsened in mid-1980's, fishpond operators had rapidly increased in number. At present, the total fishpond area is 15,800 ha and 1,330 operators engage in brackishwater aquaculture in Negros Occidental. The largest concentration of fishpond production and development was in the Ilog lower basin which had about 2,400 ha for fishpond or 15% of the aggregate fishpond area in the province. (Refer to Table 2.6-6.)

As of December 1988, the areas in the basin for bangus (milkfish) fishpond is 2,273 ha, while prawn is 124 ha. A brackishwater fishery, particularly prawn, needs much amount of freshwater to control the water quality of the ponds. Operators are depending on river water withdrawal by the use of pumps. To date, there are nine (9) pump stations in this area. (Refer to Fig. 2.6-5).

Present Water Utilization

To attain optimum growth during the culture period, brackishwater fishponds should be maintained with salinity ranging from 15 ppt to 25 ppt, transparency of pond water at 35 to 45 cm, and pH at 7.0 to 8.5 (neutral to alkaline). To maintain these conditions, old pond water should be changed regularly or diluted with good quality brackishwater, that is, 50% of pond water should be replaced. Change of water in pond is 20 times in one culture for four (4) months (prawn). About 1,670 m^3 of freshwater is needed per change per hectare. The present water utilization is estimated as follows:

1,670 m^3/ha x 20 changes x 2 cultures/year x 124 ha = 8.3 MCM/year

2.6.4 Domestic Water

Present Condition of Water Supply

(1) Water Supply System

There are three (3) categories of potable water supply system in Negros Occidental; namely, Level I (a point source or a well), Level II (a communal water system serving five to six households per faucet), and Level III (individual household connections).

At present about 49% of the provincial population avail themselves of the Level I water system, through assistance of the Local Water Utilities Administration (LWUA), the Department of Public Works and Highways (DPWH), and the former Rural Waterworks Development Corporation (RWDC). Water consumption under the Level I system in rural and urban areas is about 30 and 60 liters per capita, respectively. The ratio of population served by the Level II system is small in the province and in the study area. Level III or individual household connection in the basin serve 14% of the population.

There are two (2) water districts constructed by LWUA, the Kabankalan and Ilog. These water districts have deep wells and springs for water sources with withdrawal capacity of 1,956 liters per second. The annual production volume is 0.7 MCM (refer to Tables 2.6-7 and 2.6-8).

(2) Water Sources

The source of water supply is groundwater extracted through wells, springs and infiltration galleries. To date, there are 44 wells for domestic use in the Ilog lower basin, and the area is estimated to be plentiful of groundwater. Most of them are dug/ artesian wells.

Present Water Utilization

Judging from the present situation, the present amount of domestic water is estimated at about 5 MCM/year in the whole basin as follows:

Area	Population*	Water Utilization (lpcd**)	Water Utilization (MCM/yr)
Lower Basin:	152,400		2.4
1. Urban Area	30,800		1.1
Water District	12,500	-	0.7
Others	18,300	60	0.4
2. Rural Area	121,600	30	1.3
Upper Basin:	194,300		2.6
1. Urban Area	39,200	60	0.9
2. Rural Area	155,100	30	1.7
Total	346,700		5.0

* Projected population of 1990
** Liter per capita per day

2.6.5 Industrial Water

Present Condition

There are two (2) major industrial establishments in the study area; namely, the Southern Negros Development Corporation (SONEDCO) and the Dacongcogon Rice and Milling Company (DACONGCOGON). SONEDCO and DACONGCOGON are the sugar centrals in the municipality of Kabankalan with the former located in the lower basin. They need much water for cooling the sugar production plants.

SONEDCO has an intake facility in the Calasa River, a left bank tributary of the Ilog River. The pumping station is located in Sta. Isabel, about 3 kms away from the plant, and equipped with 3 pumps. During the milling season from the middle of October to the middle of April (6 months), these pumps operate simultaneously with the total output of 60 m^3/min. Used water is drained partly to the Ilog River downstream of the pumping station and partly to the Salong Creek which is used for agricultural purposes.

DACONGCOGON has an intake facility installed with two (2) pumps in the Tablas River, a tributary of the Ilog River. During the milling season (middle of October to middle of May) these pumps operate with the capacity of 27 m3/min.

Additionally, there is another industrial plant near the Ilog lower basin, the Universal Starch Industrial Corporation (UNISTARCH). UNISTARCH produces raw materials for glucose syrup from cassava and water for its processing plant depends on the Suay River which is outside the Ilog River Basin.

Present Water Utilization

The amount of industrial water utilization depends on the above two sugar centrals. Total water utilization is estimated as follows:

(60 + 27) x 60 min. x 24 hrs. x 155 days = 19.5 MCM

Note: Since the pump is operated 6 days a week, the total operation days is 155 days for 6 months.

2.6.6 Issue of Water Utilization

Drought Damage

Drought in the last 30 years occurred three (3) times: in 1966, 1979 and 1989. Damages to rice and corn crops in Negros Occidental in 1989-1990 were estimated at 3,318 ha and 791 ha, respectively, of which 57% for rice land and 87% for corn land were in the study area. Southern Negros suffered much due to the lack of irrigation system (refer to Table 2.6-9).

Water Source for Domestic Water

In the Ilog-Hilabangan river basin, shallow and deep well areas cover only about 6% (or 130 km2) and 74% (or 1,600 km2), respectively, because the remaining area is difficult for digging wells. As a result of water balance, available groundwater withdrawal is estimated at about 105 MCM. This amount of groundwater is enough for the estimated future demand of domestic water. (Refer to Table 2.6-10 and Fig. 2.6-6.)

On the other hand, utilization of surface river water as the source of water supply would require an intake structure, a treatment plant and transmission pipelines. From the technical and economical aspects, the utilization of surface water may not be justified as potential source of domestic water supply in the future.

River Water for Navigation and Environmental Preservation

The Ilog-Hilabangan River is used for river navigation. In the downstream, rafts made of bamboo and motorized boats are used by the farmers living in the area in transporting rice and other farm products. River transportation will continue in the future.

The extent of saltwater intrusion has been studied under the Nationwide Flood Control Plan. The study shows that intrusion from the estuary reaches up to 11 km of 95% dependable discharge. There are few intake works, wells or pumps, within the stretch affected by saltwater. (Refer to Fig. 2.6-7)

For the past ten (10) years, red tide occurred three (3) times in the Philippines. Negros Occidental suffered from red tide in 1986. The main causes are still unknown up to this time, but the fact that it occurred easily during the dry season/drought years should be considered.

2.7 Land Use

The Ilog-Hilabangan river basin is mostly covered by hilly and mountainous lands, according to the terrain slope classification as presented in the following table (refer to Fig. 2.1-3).

Category	Slope Degree	Area (km^2)	Share
Slope Category 1	0 to 3%	245	11%
Slope Category 2	3 to 8 %	346	16%
Slope Category 3	8 to 15%	780	36%
Slope Category 4	15% and more	791	37%
Total		2,162	100%

Slope categories 1 and 2 are made up of almost level and gently sloping areas, which are, in general, suitable for irrigation and cultivation of agricultural crops. Areas under the other categories hardly produce agricultural crops continuously without losing surface soil.

In the Ilog-Hilabangan river basin as presented in the above table, the land suitable for cultivation of crops in the lower reaches has a share of only 27%. The bulk of the basin, the remaining 73%, has difficulties in intensive agricultural production. Intensive utilization of land is thus concentrated in the lower reaches, which is covered mainly by lands cultivated for sugarcane, palay and some other grain crops, including fishpond. In the upper reaches of the river, dominantly situated are forests, pasture/grassland and upland grain crops.

The land use and vegetation map prepared by BSWM (refer to Fig. 2.6-2) indicates that about one-fourth of the land area is used for paddy and sugarcane cultivation, one-fourth for upland crops and about one-half is covered by forest and pasture. Land use is summarized as follows (refer to Table 2.6-3 for details):

Generalized Land Use Item	Areas (km^2)	Share
Lowland/upland paddy area	138	6%
Area planted to sugarcane	369	17%
Diversified upland grain crops	545	25%
Predominantly coconut	20	1%
Pasture and grassland	537	25%
Forest area (primarily second growth)	448	21%
Fishpond, marshes and mangrove	27	1%
Residential	35	2%
River reservation	43	2%
Total	2,162	100%

Mapping of the flood-prone areas in the down-reaches (lower than the confluence between the Ilog and Hilabangan rivers, including a part of the Binicuil river basin) has been conducted by JICA at the scale of 1:5000. These maps indicate the land use classifications that have been actually measured as summarized in the following table. The land use generalized by mesh unit is presented in Fig. 2.7-1.

Generalized Land Use Item	Areas (km^2)	Share
Lowland paddy area	15.6	12.5%
Area planted to sugarcane	56.6	45.3%
Fishpond	25.4	20.3%
Coconut, Nipa	9.6	7.7%
Orchard	0.4	0.3%
Forest	0.5	0.4%
Residential	5.9	4.7%
River reservation	5.6	4.5%
Unused (marshes, mangrove)	5.4	4.3%
Total	125.0	100%

2.8 Socioeconomy

2.8.1 Regional Economy

Gross Regional Domestic Product

The gross regional domestic product (GRDP) in Region VI and VII where the Ilog-Hilabangan River Basin is located figured at ₱7,155 and ₱8,085 million (at 1972 constant price) in 1989, respectively. These regions show a contrast in annual growth rate of GRDP as summarized below:

Region	1972-1982	1982-1989
Philippines	5.79%	0.78%
Region VI	3.56%	-1.60%
Region VII	5.72%	1.45%

Region VII shows a growth rate equivalent to or higher than the national average in any period, probably because this Region contains Cebu Province, the second biggest in the Philippines in terms of population. Meanwhile, Region VI has achieved only low or negative economic growth; especially in the agricultural sector, which has not recovered the highest production of ₱3,387 million (at 1972 constant prices) achieved in 1982, although it has increased from the bottom of ₱2,766 million hit in 1987. The industrial sector decreased by more than ₱1,100 million from 1983 to 1987 (47.6% decline). Only the service sector recorded a new high of ₱2,969 million in 1989 after the recession. In Region VII, each sector has gained the new high in 1989 after the recession. (Refer to Table 2.8-1.)

Economic Framework

The economic framework in these two regions also presents a contrast in terms of GRDP share by industrial sector. In Region VI, the agricultural sector has been keeping a dominant position, having a share of more than 40% in the GRDP, which is much higher than the national average of 27% (in 1988 and 1989). On the contrary, the share of the industrial sector figured at only about 18% (in 1988 and 1989), much lower than the national average of 33% for the same period. The GRDP in Region VII is, however, dependent on the services sector, sharing around 46% in these years, even higher than the national average of 40%, and this difference of 6% is shared by the agricultural sector. (Refer to Table 2.8-2.)

The breakdown of GRDP share by more detailed industrial origin shows the following important facts. The subsector of fishery (in the agricultural sector) and mining/quarrying (in the industrial sector) in both regions contribute much to the national economy on the subsectoral basis. The fishery subsector has a share of 15% and 11%, while the mining/ quarrying subsector has 11% and 33% in Region VI and Region VII, respectively. These figures are much higher than the contribution ratio of the whole GRDP to the GDP of the country; 6.7% in Region VI and 7.5% in Region VII in 1989. (Refer to Table 2.8-3.)

Per Capita Gross Domestic Product

Per capita gross domestic product (GDP) of the Philippines in 1989 reached ₱16,040 at current prices and ₱1,783 at 1972 constant prices, but it has not surpassed/equalled yet the highest amount of ₱1,949 achieved in 1982. During the period from 1983 to 1986, per capita GDP of all regions continued declining, but most of them rebounded slightly in 1987 after hitting the bottom in 1986. No region has as yet regained their highest level reached in 1981 or 1982. (Refer to Table 2.8-4.)

Per capita GDP of Region VI, though not the lowest among all the regions, figured at only ₱1,288 in 1989, while that in Region VII, ₱1,785 in the same year, kept the same level as the national average. In the past, however, both regions have been below the national average, even less than half of that in NCR, especially the decrease between 1982 and 1986 in Region VI, which was 28.8%, the largest in percentage. It is believed that the drastic fall of international prices of agricultural commodities and the political disorderly situation have knocked out the regional economy severely.

Average Annual Family Income

Both Region VI and VII gained an average annual family income of ₱31,164 and ₱27,972 at current prices in 1988, respectively, which were lower than the national average of ₱40,408 and far less than even a half of that in NCR. (Refer to Table 2.8-5.)

Although the family income in Region VI exceeds that of Region VII, its saving ratio stands at the lowest level (12.8%) among all the regions, while Region VII shows a saving ratio of 20.8% which is higher than the national level of 19.5%.

2.8.2 Demography

Population in the River Basin

The Ilog-Hilabangan River Basin lies administratively in nine (9) and six (6) municipalities in Negros Oriental and Negros Occidental provinces, respectively, as shown in Fig. 2.8-1, though some are only partially covered by the basin. According to the census results in 1970 and 1980 (recent demographic data are not yet available although census was held in 1990), population in these 15 municipalities increased from 525,037 in 1970 to 676,155 in 1980 with an average annual growth rate of 2.6% that is almost the same as the national average of 2.7%.

Population density is calculated at 102 persons/km^2 in 1970 and 131 persons/km^2 in 1980 in these municipalities. These figures indicate that the basin is sparsely populated in comparison with the national average of 122 and 160 persons/km^2 in 1970 and 1980, respectively. Based on the density, population in the river basin with a catchment area of 2,162 km^2 is estimated at some 284,000 in 1980. (Refer to Table 2.8-6.)

Demographic conditions in and around the river basin are also characterized by a distribution ratio between the urban and rural population, which is much different from the national level as summarized in the following table (refer to Table 2.8-7):

Region	1970		1980	
	Urban	Rural	Urban	Rural
Philippines	31.8%	68.2%	37.5%	62.5%
The River Basin	12.5%	87.5%	15.5%	84.5%

The annual growth rates of population in the urban and rural areas in the basin-related municipalities in Negros Oriental were calculated at 2.93% and 2.30% during 1970 to 1980, and those of Negros Occidental side were at 6.45% and 2.10%, respectively.

Demographic Projection

Demographic projections on the regional basis have been provided until the year 2030 in the 1989 Philippine Statistical Yearbook, NSCB. Based on its medium assumption (moderate fertility and moderate mortality decline), future population in the river basin was estimated as presented in Table 2.8-8, and summarized below, together with a distribution ratio in urban and rural areas.

Year	Population (x 1000)			Distribution	
	Urban	Rural	Total	Urban	Rural
1990	69.99	276.71	346.70	20.2%	79.8%
2000	106.43	310.41	416.80	25.5%	74.5%
2010	126.12	345.88	472.00	26.7%	73.3%
2020	144.99	374.11	519.10	27.9%	72.1%
2030	160.77	400.66	561.40	28.6%	71.4%

Labor Force and Unemployment

The number of labor force or household population 15 years old and above accounts for about two-thirds of the total population in Regions VI and VII, slightly higher than the national level. It has increased at the average annual rate of 2.7% in the Philippines and 2.3% in both Regions VI and VII during the period 1980 to 1988. These figures nearly coincide with the population growth in any region. It is noted that in Region VI, labor force has been increasing in spite of a negative growth of its GRDP during the said period, and this brought about a rapid rise of unemployment.

Unemployment rates in these two regions figured at 5.6% and 4.4%, respectively, on the average during the same period, which are much lower than the national average of 7.1%. Unemployment rate in Region VI jumped up to 10.8% in 1986 due to the rapid fall of international prices of agricultural commodities such as sugar, and has maintained a high level since then (8.0% in 1987 and 7.3% in 1988). Meanwhile, Region VII peaked at 7.2% in 1987, but still less than the national average of 9.1% and rapidly decreased down to 5.7% in 1988. The difference between these regions is deemed to be due to their distinctive economic structures, that is, Region VI is dependent on the agricultural sector by about 40% and Region VII on the service sector by about 45% as discussed elsewhere in this Subsection 2.8.2. (Refer to Table 2.8-9.)

2.8.3 Infrastructure

Transportation

The road network of Negros Occidental Province has a total length of 4,670 km as of 1986, including concrete or cemented roads by only 5% and asphalted roads by 16% as presented in Table 2.8-10. This road network accounts for less than 60% of the requirement of 7,926 km, which was calculated on the basis of the national standard of 1 km for every 100 ha. The major national road, running in parallel to the shoreline around Negros Island, is considered to be in a generally good condition, at least from Kabankalan located in the lower reaches of Ilog River to Escalante in the north of the island. (Refer to Fig. 2.8-2)

In the Ilog-Hilabangan River Basin, Poblacion Kabankalan plays a junction point in the road network, connecting the coastal municipalities/cities in Negros Occidental and also Poblacion Bias in Negros Oriental by crossing the island through the mountainous areas. In its lower reaches exist three (3) bridges, the Malabong and Talubangui concrete bridges and the Hilabangan wooden bridge, as described in detail in Section 2.3.

The Southern Negros Development Corporation (SONEDCO) operates and maintains a railway system of about 40 km in the municipality of Kabankalan, which is used for transporting sugarcane from the fields to mill plants.

Negros Occidental Province has four (4) major seaports; namely, the Pulupandan Port, the Banago Port, the Bacolod Real Estate Development Corporation (BREDCO) Port in Bacolod City, and the San Carlos City Port, all of which serve and accommodate passenger-cargo movements.

Water Supply System

There exist two (2) water supply systems in the lower reaches, i.e., in the poblacions of Kabankalan and Ilog. The main water sources of the Kabankalan water supply system are two (2) deep wells and one (1) spring. The deep wells fill up one (1) elevated tank with a capacity of 75,000 gallons, and the spring water is stored in a ground reservoir of 117,000 gallon capacity. The total water production for the last seven (7) months (January 1990 to July 1990) amounted to 387,169 m^3, but only 61% of this amount was distributed because of leakage, meter tampering, illegal connection, etc. The number of concessionaires or users during the period were 1,687 households or a population of 11,809 distributed in Poblacion Kabankalan, Sitio Overflow, part of Binicuil and part of Sitio Naga.

The sources of water supply for Ilog Poblacion are spring developments in the sloping side of the mountain. Two (2) intake boxes were constructed and provided with a transmission pipeline (102 mm diameter) that transmits the water down by gravity flow to a reservoir with a capacity of 45,000 gallons at the foot of the mountain. At present the system is serving 128 households for five (5) hours a day, consuming 25,000 gallons per day, more or less. Water consumption of concessionaires are not metered yet, so that the water charge is on a flat rate basis of ₱30 per month per household.

Power Supply

The existing generating plants in Negros Island (as of June 1988) have an aggregate installed capacity of 156.3 MW as shown in the following table:

Plant Name	Installed Cap. (MW)
Bacolod CENECO Diesel 2-3	2 x 3.0 = 6.0
Bacolod CENECO Diesel 4	2 x 5.45 = 10.9
Talisay CENECO Diesel 1	1 x 3.6 = 3.6
Talisay CENECO Diesel 2-3	2 x 5.5 = 11.0
Amlan NPC Hydro 1-2	2 x 0.4 = 0.8
Amlan NPC Diesel	1 x 5.5 = 5.5
Palinpinon NPC Pilot Geo	4 x 1.5 = 6.0
Palinpinon NPC Geo I	3 x 37.5 = 112.5
Total	156.3

The major transmission lines of the National Power Corporation (NAPOCOR) installed in the island are (1) Mabinay - Bacolod 138 kV line, (2) Mabinay - Kabankalan 69 kV line, and (3) Bacolod - San Enrique 69 kV line (refer to Fig. 2.8-3). The bulk of electric power used in Negros Occidental Province is supplied from Bacolod and Mabinay Substations with capacities of 80,000 kVA and 10,000 kVA, respectively. These two substations derive power from the Palipion Geothermal Power Plant. The distribution of power to different parts of the province is being carried out by three (3) electric cooperatives; namely, the Central Negros Electric Cooperative (CENECO) in the central part of the province, Victorias Rural Electric Service Cooperative (VRESCO) in the north and the Negros Occidental Electric Cooperative (NOCECO) in the southern part.

In the municipalities of Kabankalan and Ilog, the number of residential consumers is 3,989 and 2,223 with diffusion ratios of 17% and 27%. The consumption per household is averaged at 46.6 KWH and 29.3 KWH per month, respectively.

Telecommunications

Telephone services in Negros Occidental are provided by the branch of Philippine Long Distance Telephone Company based in Bacolod City. Direct local calls reach as far as Silay City in the northern portion of the province. In the farther northern parts such as Victorias and Cadiz City, calls are considered long distance and are facilitated via microwave. In the southern portion, Kabankalan is the farthest municipality that can be reached via long distance call.

The province has a total of 34 radio/telegraph stations, consisting of eight (8) radio stations, four (4) radio telegraph stations and 22 telegraph stations. Messages from local stations intended for the province are relayed to the Provincial Communication Center (Bacolod Message Center) which assumes the responsibility of distributing the messages to their respective destinations.

2.9 Projects Related to the Study

Flood Control

Public works authorities have made efforts to mitigate flood damages such as the ones inflicted by the flood of 1949. Examples of the projects undertaken are as follows:

(1) In 1957, public works authorities conducted six (6) alternative studies including those for the Bungul diversion channel and cut-off channel Nos. 1, 2 and 3. Eventually, the construction of Bungul diversion was started in 1957 and completed in 1959.

(2) In 1974, public works authorities started the construction of a cut-off channel to increase the flow capacity of the Ilog River. The construction was completed in 1975, though the old Ilog River was naturally clogged afterwards.

(3) Revetment along the Ilog river course at Talubangi and Kabankalan were provided in 1979 and 1984, respectively.

(4) In 1988, the proposal for expansion of the existing cut-off channel was accepted and the project will start as soon as funds become available. The construction cost of this cut-off channel is estimated at 26 million pesos at 1989 prices.

Power Supply

(1) Expansion of Transmission Lines

The National Power Corporation (NPC) constructed the Negros-Panay interconnection project which was started in late 1988 and completed in late 1989. The project includes the installation of 18 kms of submarine cables (138 kV). The new transmission line of 167 kms was installed in line with the expansion of the Mabinay and Bacolod substations.

(2) Bago Hydroelectric Plant

To cope with the future demand in consonance with the expansion of transmission lines, NPC is planning to develop the Bago Hydroelectric Plant, of which feasibility study was terminated in 1982 and detail design works is ongoing, proposing the maximum installed capacity of 183 MW. Based on the feasibility study, the outline of the project is given as follows:

(a) Main structures include a 125 m dam with a catchment area of 402 km^2 and a 5 km power tunnel to a 3 x 53 MW power facility.

(b) The reservoir has a total storage volume of 168 MCM and an active storage volume of 134 MCM above minimum drawdown elevation.

(c) Average annual energy generated by the project is 410 Gwh.

(d) The capital cost at end 1981 price level including contingencies and engineering but excluding interest is ₱1,463 million.

(e) Construction period is scheduled for 6 years including detail design works.

Water Resources Development

To develop water resources in this basin, the study on the Hilabangan Irrigation Project for the lower basin was carried out in 1975. The Tambolan Communal Irrigation Project for the upper basin is under study by the National Irrigation Administration (NIA).

(1) Hilabangan River Irrigation Project

The development plan of the project envisages irrigation of about 5,900 ha in both the dry and wet seasons. The proposed development area along the Ilog River is divided into the left bank area of 3,000 ha and the right bank area of 2,900 ha. The diversion dam site with a drainage area of approximately 430 km^2 is located at Barrio Lupni, 4 km upstream of the confluence with the Ilog River . The proposed diversion dam will be concrete gravity overflow with a height of about 2.5 m above the riverbed and 140 m long. Although the study was once reviewed in 1983, this project has not progressed to the further stage as of 1990.

(2) Tambolan Communal Irrigation Project

In this project, it is proposed that intake facilities be provided at Barangay Casoloning with the catchment area of 30 km2 upstream of the Hilabangan River. The irrigation area to be covered by this project is approximately 600 ha.

Road Improvement

DPWH is currently implementing the Improvement and Reconstruction of the Southern Negros Roads Project (between Kabankalan and Maaslom; refer to Fig. 2.8-2) financed under ADB loan. The road is around 74 km in total length and the construction schedule is approximately three (3) years. In the Ilog-Hilabangan river basin, the route of this road is generally aligned along the right bank of the artery of the Ilog River up to Mabinay from Kabankalan.

The bridge which is proposed to cross the Hilabangan River at Barangay Overflow is a permanent concrete bridge with the design live load of HS-20-44. The bridge length is 170 m, and the width is 6 m in the first stage and 10 m in the second stage.

CHAPTER 3. BASIC STUDY AND ANALYSIS

3.1 Hydrology

3.1.1 Rainfall Analysis

Rainfall Data

As explained in the preceding chapter, there is only one (1) rainfall station in Kabankalan in the river basin and thirteen (13) rainfall stations outside the basin with relatively long periods of daily rainfall data. Of these daily rainfall stations, Kabankalan has been selected as a representative station for estimation of the probable value, because other stations are located far from the river basin. Hourly rainfall data observed at automatic rainfall stations installed by the Study Team were used to develop the rainfall intensity - duration curve.

Duration of Design Rainfall

Duration of design rainfall for the present study has been determined at two (2) days, considering the following items: (a) scale of the catchment area, (b) duration of flood and (c) rainfall characteristics.

Annual Maximum Rainfall

Based on the daily rainfall record at Kabankalan, the annual maximum 2-day continuous rainfall from 1971 to 1989 has been picked up and presented in Table 3.1-1. The annual maximum 1-day rainfall which will be used to develop the model hyetograph is also shown in the table. The maximum observed 2-day rainfall is 233.8 mm in 1982. Monthly occurrences and rate of the annual maximum 2-day rainfall are tabulated in Table 3.1-2.

Probable Rainfall

Probable rainfall for the Ilog-Hilabangan River Basin was obtained on the basis of the probable point rainfalls, considering areal and altitude adjustment.

(1) Point Rainfall

The annual maximum rainfall was plotted on a log-probability chart, and the probable 2-day point rainfalls were obtained as follows:

Return Period	Rainfall (mm)
100-year	324
50-year	291
25-year	258
10-year	214
5-year	178
2-year	122

(2) Conversion of Point Rainfall to Areal Rainfall

Probable rainfalls were obtained in the form of point rainfalls. These point rainfalls were converted into areal rainfall for probable hydrograph calculation. The Holton's formula, the most popular one, was applied. Constants which were determined for the neighboring area, the Panay River Basin, were also applied. The formula is:

$$P = P_o \cdot EXP[-0.1 \cdot (0.386 \cdot A)^{0.31}]$$

where,

P : Areal Rainfall

P_o: Point Rainfall

A : Area (km^2)

(3) Adjustment of Rainfall by Altitude

Since the calculated probable rainfall is based on the data at Kabankalan (altitude is approx. EL 10 m), this value was adjusted by altitude (7.5% per 100m) to the rainfall in mountainous areas.

(4) Probable Rainfall in the Ilog-Hilabangan River Basin

Two-day probable rainfall in the Ilog-Hilabangan River Basin was accordingly calculated as follows:

Return Period	Rainfall (mm)
100-year	202
50-year	181
25-year	161
10-year	133
5-year	111
2-year	76

Model Hyetograph

The actual rainfall pattern during a flood is commonly used for rainfall pattern to obtain the probable hydrograph. Hourly rainfall data in the Study Area is available only after May 1990, and there is no sufficient data; hence, a model hyetograph was applied.

Rainfall intensity - duration curve which will be used to develop a model hyetograph was prepared from the data of rainfall which exceeded 100 mm per 24 hours. The curve is presented in Fig. 3.1-1. The centralized model hyetograph was accordingly developed as shown in Fig. 3.1-2.

3.1.2 Runoff Analysis

Runoff Model

The storage function model is applied as a runoff model for this study. This storage function model is commonly used for major river systems in the Philippines and is also widely used in Japan. Constants for the Ilog-Hilabangan River Basin were determined through simulation.

The storage function model was developed to express the non-linear characteristics of runoff phenomena, introducing the following function between the storage volume (S_l) of a basin and the discharge (Q_l) from the same.

$$S_l = K \cdot Q_l^P$$

where,

K and P : constants

Runoff calculation was performed in combination with the following equation of continuity for basin.

$$\frac{dS_l}{dt} = \frac{1}{3.6} \cdot f \cdot r_{ave} \cdot A - Q_l$$

where,

S_l : apparent storage volume in the basin ($m^3/s/hr$)

f : inflow coefficient

r_{ave} : basin's average rainfall (mm/hr)

A : area of the basin (km^2)

$Q_l(t) = Q(t+T_l)$: direct runoff height with lag time (m^3/s)

T_l : lag time (hr)

The storage function of the channel is expressed as follows:

$$S_l = K \cdot Q_l^p - T'_l \cdot Q_l$$

where,

K and p : constants

T'_l : lag time for river channel

Division of Basin

The entire Ilog-Hilabangan River Basin was divided into 25 subbasins as shown in Fig. 3.1-3. Division was made on 1/50,000 topo-map considering factors, e.g., area of subbasins, shape of basin, topography and other conditions. It was also made considering possible structures, i.e., dams and a retarding basin.

Based on this division of the basin, a river system diagram was developed as shown in Fig. 3.1-4. The model is composed of 25 subbasins, 13 river channels and 4 dams. The characteristic features of each subbasin and channel are presented in Tables 3.1-3 and 3.1-4, respectively.

Verification of Model

(1) Summary of Parameters

Summaries of parameters for the storage function model for river basins and river channels determined through the verification are presented in Tables 3.1-5 and 3.1-6, respectively.

(2) Objective Flood for Verification

(a) Objective Flood

The objective flood for verification of the runoff model was selected from a series of hydrographs observed by an automatic water level gauge. The following floods were selected for verification.

	Peak Discharge (m^3/s)		
Date	Orong	Talubangi	Overflow
May 20-22	1,000	1,028	–
Aug. 12-15	838	1,152	178
Sep. 30 - Oct. 2	1,039	1,039	–
Oct. 10-1	437	473	–

(b) Verification Point

Verification of the model was conducted at the following points where water level record is available.

River	Point	Catchment Area (km²)
Ilog	Orong	1,432
Hilabangan	Overflow	445
Ilog	Talubangi	1,960

(3) Conformity Degree

The adequacy of the model can be verified through the calculation of conformity degree (S2) which is expressed by the following formula.

$$S^2 = \frac{1}{n} \sum_{i=c_1}^{n} \left(\frac{Q_o(i) - Q_c(i)}{Q_{op}} \right)^2$$

where,

$Q_o(i)$: observed discharge at time (i)

$Q_c(i)$: calculated discharge at time (i)

Q_{op} : peak value of observed discharge

n : calculation time

It is generally said that if S2 is smaller than 0.03, conformity degree is good. On the other hand, the value of S2 for the said floods are in the range between 0.013 and 0.009, and thus the adequacy of the model was verified. (Refer to Fig. 3.1-5.)

Probable Flood Hydrograph

Probable flood hydrograph is obtainable using the model hyetograph and runoff model. The following table shows peak discharges by return period at reference points.

Unit: m³/s

Reference Point	Return Period (year) 100	50	25	10	5	2
Talubangi	5,430	4,540	3,690	2,630	1,880	920
Orong	4,270	3,510	2,920	2,090	1,510	750
Overflow	2,900	2,380	1,930	1,410	980	460

3.2 Flood Inundation

Inundation by floods in the Ilog-Hilabangan River Basin was analyzed to estimate the probable flood water level in the inundation area for the study on the effect of project execution. For the analysis, some factors as described hereinafter are involved.

3.2.1 Flow Capacity

The flow capacity of the Ilog River, its tributary and branches such as the Hilabangan River, the Old Ilog River, the Bagacay River, etc., was examined under the following conditions:

(1) Non-uniform calculation is applied to the examination of flow capacity.

(2) The roughness coefficient of 0.03 which is usually applied to rivers in flat plane, was employed judging from the present river condition.

(3) As the initial condition at the river mouth, the water stage of 1.5 m which corresponds to the mean high water spring observed at the gauging station of Banago, Bacolod was adopted.

(4) The cross-sections of the river channel taken from the surveying results in this study period were used for the calculation.

Non-uniform calculation results are shown in Fig. 3.2-1. Based on the above considerations and by comparing the water stage and the ground height along the river course, it was determined that the bankful flow capacity of the Ilog River ranges between 300 m^3/s and 2,000 m^3/s, and it is over 1,000 m^3/s in most stretches (refer to Case 1 in Fig. 3.2-2).

In the stretch between 6.0 km and 16.0 km from the river mouth, it is presumed that the bankful flow capacity, which is estimated at about 1,000 m^3/s, would become about 2,000 m^3/s if the inundation in the small area along the river course is considered (refer to Case 2 in Fig. 3.2-2).

In the same manner, the bankful flow capacity of 300 m^3/s would become 500 m^3/s in the stretch between the river mouth and the 6 km point, considering minor inundations along the river course. Fig. 3.2-3 shows the flow capacity of a tributary and branch rivers.

3.2.2 Flood Inundation Analysis

Flood Inundation Model

From the inundation conditions on record as shown in Fig. 2.5-1, flood discharge beyond the river channel flow capacity widely spread over the low land. To express the hydraulic condition, two-dimensional models were employed under the following considerations:

(1) The whole inundation area is divided into mesh blocks of 500 m by 500 m.

(2) The average ground height of each mesh is obtained using the topographic map with a scale of 1/5,000 which was prepared in this study.

(3) Structures such as roads and railways which may hamper the smooth flow of inundation water are taken into consideration assuming them as weirs between the mesh blocks.

(4) Flood discharge overtop at points with low flow capacity and spread over the inundation area.

Basic Equation

The basic equations applied to the model were derived from the Euler's equation of motion and the equation of continuity:

(1) Equation of Motion

$$\frac{1}{gA_x}\frac{\partial Q_x}{\partial t} - \frac{Q_x B_x}{gA_x^2}\frac{\partial H}{\partial t} + \frac{\partial H}{\partial x} + \frac{|Q_x|Q_x}{F_x^2} = 0$$

$$\frac{1}{gA_y}\frac{\partial Q_y}{\partial t} - \frac{Q_y B_y}{gA_y^2}\frac{\partial H}{\partial t} + \frac{\partial H}{\partial y} + \frac{|Q_y|Q_y}{F_y^2} = 0$$

$$F_x = \frac{1}{n}R_x^{2/3}A_x$$

$$F_y = \frac{1}{n}R_y^{2/3}A_y$$

(2) Equation of Continuity

$$\frac{\partial (Bh)}{\partial t} + \frac{\partial Q_x}{\partial x} + \frac{\partial Q_y}{\partial y} = 0$$

where, Q_x, Q_y : discharge of x and y direction
A_x, A_y : current area of x and y direction
B_x, B_y : width of x and y direction
R_x, R_y : hydraulic depth of x and y direction
n : roughness coefficient
H : water level
h : water depth

Initial Condition for Computation

The maximum inundation depth and the inundation area were examined under the probable flood discharge of 2-, 5-, 10-, 25-, 50- and 100-year return periods. As for the initial condition for computation, it was necessary to give the overflow discharge to the inundation area as well as the overflow section. In this computation, the following initial conditions were considered:

(1) Two sections are selected as the overflow sections where the flow capacity is very poor compared with the adjacent stretches, i.e., between 17 km and 18 km of the Ilog River with a flow capacity of about 1,000 m^3/s and at 4 km point, with 500 m^3/s.

(2) It is assumed that in the probable flood hydrograph, the surplus discharge over the flow capacity of 1,000 m^3/s overflows at the section between 17 km and 18 km. In the flood hydrograph after subtracting the overflow discharge at the section between 17 km and 18 km, the overflow discharge at the section of 4 km is given by the surplus discharge over the flow capacity of 500 m^3/s.

Computation Results

The maximum inundation depths in each case are shown in Fig. 3.2-4 expressed in figures and Fig. 3.2-5 in patterns. Although the adequacy of the flood inundation model was not verified due to lack of information, this model seems to be applicable because the flood marks at the church from 1949, which are between 0.5 m and 1.7 m as described in Section 2.5, broadly correspond to the calculated inundation depth. (Refer to Fig. 2.5-1.)

3.3 Study on Dam Sites

3.3.1 Preliminary Selection of Dam Sites

Dam sites in the river basin were examined through the topographic maps (1:250,000, 1:50,000 and 1:10,000), geological maps (1:1,000,000 and 1:250,000), aerial photographs and previous studies. Further, the following points were considered for preliminary selection of dam site:

(1) Flood Control Effect

It is desirable that dam sites are located close to the objective area to assure a more flood regulation effect by the dam.

(2) Water Resources Development

It is desirable that the dam sites can assure a sufficient storage capacity to meet the water resources requirement in the basin.

(3) Geological Condition

In the basin where a high dam may not be practical because of widespread limestone, it is necessary to examine the possibility of low dams with a bigger storage capacity.

Five possible dam sites were preliminarily selected as follows (refer to Fig. 3.3-1):

(1) Ilog No.1 upper site
(2) Ilog No.1 lower site
(3) Ilog No.2 site
(4) Hilabangan No.1 site
(5) Hilabangan No.2 site

The storage capacity curve of each site was worked out based on the topographic map of 1:10,000 and shown in Fig. 3.3-2.

3.3.2 Screening of the Selected Dam Sites

To narrow down the number of dam sites for further study, geological surface survey on the five (5) dam sites was carried out, focusing on investigating the limestone.

The Ilog No.1 lower, Ilog No.1 upper and Hilabangan No.1 dam sites are underlain by volcanic clastic rocks composed of tuff breccia interbedded with sandstone, siltstone and tuff. Meanwhile, Ilog No.2 and Hilabangan No.2 dam sites are underlain by hard, porous limestone. (Refer to Fig. 3.3-3.)

Since dam sites on limestone zone generally cause leakage problems, it is not recommendable to propose dams at the Ilog No.2 and Hilabangan No.2 sites, and thus these dam sites were eliminted.

3.3.3 Geological Investigation for Possible Dam Sites

To clarify the planning condition from the remaining three dam sites, the following geological investigations were carried out.

Dam Type

Among the remaining three dam sites, exploratory core drilling was conducted only at the Ilog No.1 upper and Hilabangan No.1 dam sites where high dams are expected, in order to select the suitable dam type.

It was clarified that the bedrock that is widely distributed around the dam sites is composed largely of hard to moderately hard, low permeable volcanic clastic rocks including soft consolidated or extraordinary high permeable portion.

The unconfined compressive test results indicate that the strength of volcanic clastic rocks is relatively low, and the bedrocks are classified as "Low" to "Very Low" strength class. Judging from this geological condition, the dam type suitable for these sites is to be fill type.

Geological Surface Survey of Reservoir Areas

Geological surface survey was mainly conducted to confirm the following conditions: (1) the existence of landslide area which may inflict damage on the dam body when it occurs and (2) the geological condition which may have water leakage in the reservoir.

Through the surface survey, the following geological conditions were clarified;

(1) No remarkable landslide area can be found in the reservoir area of the three dam sites.

(2) As for the geological condition of the Ilog No.1 upper and lower dam sites, of which reservoir areas largely overlap, bedrock is composed of volcanic clastic rocks and limestone. Although the volcanic clastic rocks have no serious water leakage problem, the limestone which is soft to moderately hard, high porous coralline or marly rock and has several sinkholes and caves may cause a serious water leakage problem. The limestone area is distributed higher than EL 25m and extends from the south (upper reaches) to the north (lower reaches) as shown in Fig. 3.3-4.

(3) The bedrock of Hilabangan No.1 reservoir is mainly composed of volcanic clastic rocks, and limestone which is crystalline to sandy, containing a few marly limestone lendes, is partially found. Although this limestone is generally harder than that spreading at the Ilog No.1 lower and upper reservoir areas, solution cavities may be formed judging from the existence of sinkholes in the area and thus, it may cause water leakage problem. The limestone is distributed higher than EL 150m as shown in Fig. 3.3-5.

3.4 Water Resources Development

In the case of formulation of the Master Plan, dams and reservoirs with multi-functions such as irrigation, municipal water supply and hydropower generation may be included in the optimum measures for flood control. In this connection, the potential study on water resources development through the dams and reservoirs was incorporated in the Study.

Future water demand in the Ilog-Hilabangan River Basin consists of irrigation, aquaculture, domestic water and industrial water. Of these future demands, domestic water will be supplied from groundwater and industrial water will depend mainly on the river water from some tributaries of the Ilog-Hilabangan River. Further, aquaculture will use the brackish water in the estuary, and consequently, only irrigation will depend on the river water directly from the main stream of the Ilog-Hilabangan River.

In this connection, water resources development in this study is emphasized for irrigation water in the lower reaches.

Objective Irrigation Area

In the previous irrigation project, the irrigation area of 5,900 ha consisting of 1,200 ha of paddy and 4,700 ha of sugarcane was proposed with the water source from the low water of the Hilabangan River by constructing a diversion dam in the Hilabangan River. In this study, the same irrigation area was adopted as the objective area of water resources development.

Proposed Irrigation Project

According to the water discharge data, the river water cannot meet the water requirement in the lower reaches when the river maintenance water is assured. Therefore, it is required that river flow regime is regulated by the dam and reservoir.

It is proposed in this study to apply the Ilog No.1 lower dam site, because this dam site is expected to be the most economical among the three possible dam sites as discussed in Chapter 4.

Required Storage Volume

The volume to be stored in the proposed reservoir was calculated from the monthly mean discharge data at the Orong Station which has a catchment area of 1,453 km^2. In this calculation, the river maintenance flow of 0.33 $m^3/s/km^2$ was considered as the minimum flow of the Ilog River, i.e., 4.83 $m^3/s/1,453\ km^2 \times 100 = 0.33\ m^3/s/100\ km^2$. In accordance with the result of water balance analysis for 24 years from 1956 to 1979, the required storage volume of 48.6 MCM (about 50 MCM) will be applied to reservoir planning, assuming that the irrigation areas of paddy and sugarcane are 1,200 ha (about 20% of the total irrigation area) and 4,700 ha (about 80%), respectively.

The volume of about 50 MCM which is the second largest volume, is equivalent to a drought with a 10-year return period. (Refer to Tables 3.4-1 and 3.4-2.)

Dam Scale (Tentative Plan)

Using Ilog No.1 lower dam site, the proposed dam dimensions for the above water utilization volume of 50 MCM are roughly estimated at 30 m of dam height and 21.5 m of normal water surface elevation.

CHAPTER 4. THE MASTER PLAN

4.1 Basic Concept of Formulation of the Master Plan

Flood damage in the Ilog-Hilabangan River Basin is most conspicuous in the flat land in the lower reaches as shown in Fig. 2.5-2. Therefore, the master plan of flood control in the Ilog-Hilabangan River Basin is formulated for the mitigation of flood damage in this lower reaches.

Project Scale and Target Year

The appropriate project scale for the master plan was selected in consideration of the following:

(1) The project scale applied to the other major rivers in the country; and,

(2) The scale of the recorded maximum flood in the basin.

The master plan is sometimes named framework plan or basic plan which provides an ideal flood control plan, and the target year for completion of the plan is unspecified due to the enormous fund requirement and work volume. Since it is necessary to examine the economic viability of the master plan in this study, a tentative project completion year is assumed considering the availability of basic data.

Flood Control Measures

In general, two approaches can be employed to attain flood mitigation in a basin, i.e., structural and non-structural measures. These are discussed as follows:

(1) Structural Measures

The major structural measures generally applied for flood control include dam and reservoir, retarding basin, river improvement and diversion channel. Several cases of structural measures were studied applying the measures individually or in combination with each other, and the appropriate combination of structural measures was selected from the economic and technical aspects.

(2) Non-structural Measures

Non-structural measures mainly include land use regulation, afforestation and reforestation, flood forecasting and flood warning. However, these measures may not be applicable in this river basin at present for the following reasons:

(a) In this river basin, most of the available land for agriculture are fully utilized and urbanization is not severe judging from the growth of population in the basin. Therefore, land use regulation on future land development is presumed not necessary.

(b) Afforestation and reforestation are useful to detain flood runoff from the aspect of land conservation. However, it takes a long time and enormous funds to fully generate the function, and therefore, this measure is not usually employed for flood control purposes but for other purposes such as forest development, environmental conservation, etc.

(c) A flood forecasting and warning system which can be introduced with less funds and within a short period of time is expected to be useful for flood damage mitigation. The system consists of sensitive equipment, and appropriate maintenance is necessary for efficient operation, together with trained operators/engineers and the spare parts to be provided from time to time. Judging from the present condition, the hydrological data necessary to formulate the flood forecasting system is not enough. Besides, it may be difficult to obtain knowledgeable operators/engineers and to timely provide the spare parts. Therefore, the installation of a flood forecasting and warning system seems to be still premature, though only this measure may be conditionally applicable among the said non-structure measures. To proceed to the establishment of the flood forecasting in the future, it is necessary to first prepare the hydrological data base in parallel with the arrangement of the organization and staff for the purpose. A model flood forecasting and warning system is shown in Supporting Report V, Flood Control, for reference when applied in this basin.

Project Evaluation

Project evaluation was made by calculating the Internal Rate of Return (IRR), as well as the Cost-Benefit Ratio and the Net Present Value, on the basis of the project benefit and economic project cost for the structural measures. Since the assets in the flood prone area are