No.

JAPAN INTERNATIONAL COOPERATION AGENCY

DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE REPUBLIC OF THE PHILIPPINES

THE STUDY ON COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES

FINAL REPORT

VOLUME IV: SUPPORTING REPORT (2)

(PART II: FEASIBILITY STUDY)

October 2000

NIPPON KOEI CO., LTD.

KRI INTERNATIONAL CORPORATION

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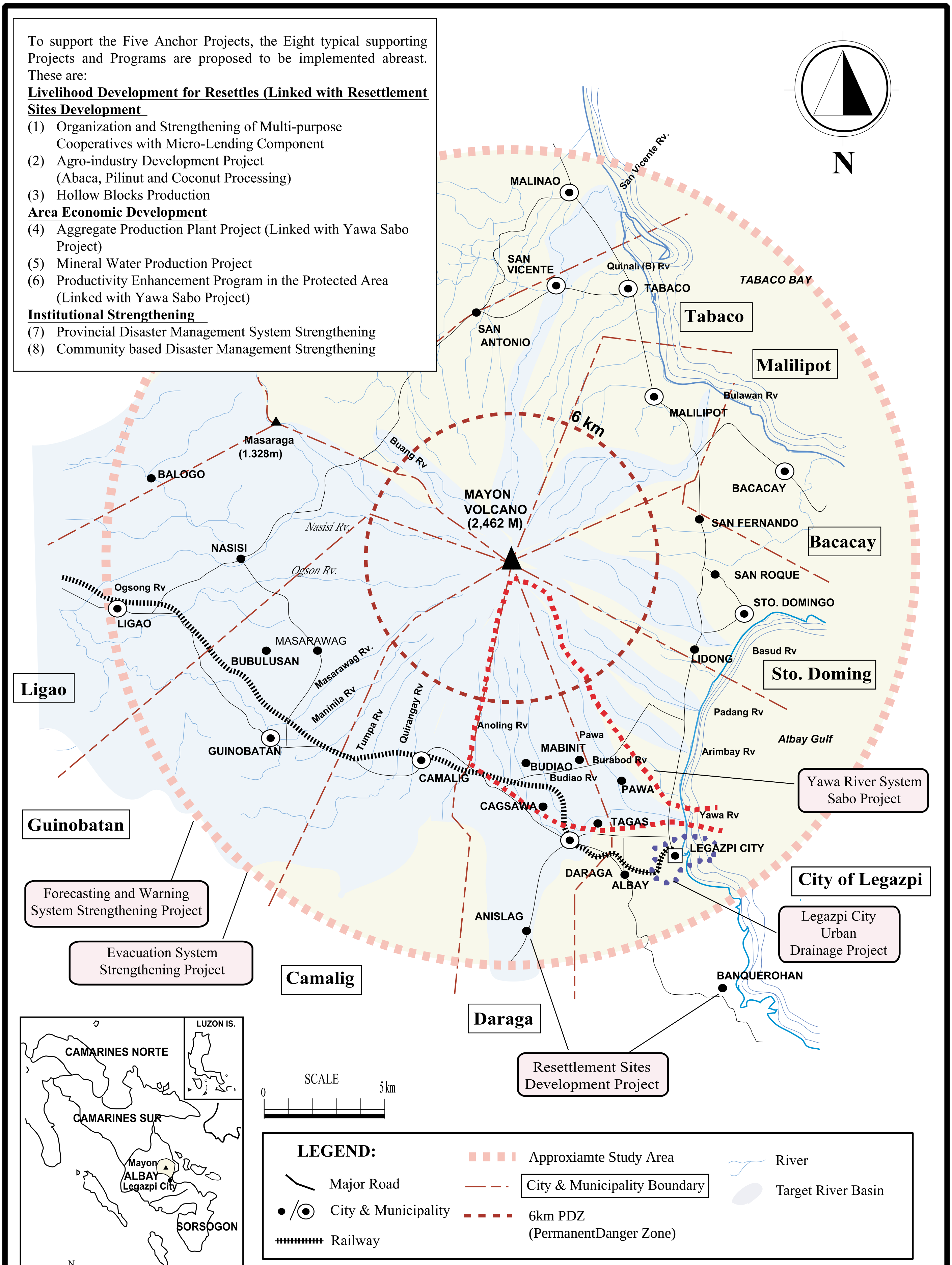

LOCATION MAP OF THE STUDY AREA
(Proprity Projects & Programs Proposed in Feasibility Study)

List of Acronyms

A&D	Alienable and Disposable Land
ADB	Asian Development Bank
AFP	Armed Forces of the Philippines
Agromet	Agro-meteorological Station, PAGASA
AIT	Asian Institute of Technology
ALECO	Albay Electric Cooperative
ALERT	Albay Legazpi Emergency Rescue Team
APDMC	Asia Pacific Disaster Management Centre
ARCs	Agrarian Reform Committees
ASEAN	Association of Southeast Asian Nations
BAS	Bureau of Agricultural Statistics
BCCARD	Bicol Consortium for Agricultural Resources and Research and Development
BDCC	Barangay Disaster Coordinating Council
BFP	Bureau of Fire Protection
BMG	Bureau of Mines and Geo-science
BOI	Board of Investment
BOT	Bureau of Telecommunication
BRAIC	Bicol Regional Agri-Industrial Center
BRBFCIDP	Bicol River basin Flood Control and Irrigation Development Project
BRS	Bureau of Research and Standard, DPWH
BSBI	Bicol Small Business Institute
BSWM	Bureau of Soils and Water Management
BU	Bicol University
BUCA	Bicol University College of Agriculture
BWAD	Bacacay Water District
CARP	Comprehensive Agrarian Reform Program
CASF	Composite Air Support Force
CBIS	Community-Based Information System
CDA	Cooperative Development Authority
CDCC	City Disaster Coordinating Council
CLUP	Comprehensive Land Use Plan
CNDR	Corporate Network for Disaster Response
CSG	Cemented Sand and Gravel

DA	Department of Agriculture
DA-BFAR	Department of Agriculture – Bureau of Fisheries and Aquatic Resources
DAR	Department of Agrarian Reform
DBM	Department of Budget and Management
DCC	Disaster Coordinating Council
DECS	Department of Education, Culture and Sports
DENR	Department Environment and Natural Resources
DFA	Department of Foreign Affairs
DILG	Department of the Interior and Local Government
DOE	Department of Energy
DOH	Department of Health
DOLE	Department of Labor and Employment
DOST	Department of Science and Technology
DOT	Department of Tourism
DOTC	Department of Transportation and Communication
DPWH	Department of Public Works and Highways
DSWD	Department of Social Welfare and Development
DTI	Department of Trade and Industry
EIA	Environmental Impact Assessment
EMB	Environmental Management Bureau
FIDA	Fiber Industry Development Authority, DA
GA	Government Agency
GDP	Gross Domestic Product
GOJ	Government of Japan
GOP	Government of the Philippines
GRDP	Gross Regional Domestic Product
GVA	Gross Value Added
HLURB	Housing and Land Use Regulatory Board
HUDCC	Housing and Urban Development Coordinating Council
IANDR	Inter-Agency Network for Disaster Response
IBRD	International Bank for Reconstruction and Development
IEE	Initial Environmental Examination
IRA	Internal Revenue Allotment
JBIC	Japan Bank for International Cooperation (Ex-OECF & EXIM)
JICA	Japan International Cooperation Agency
LARC	Local Amateur Radio Club

LBP	Land Bank of the Philippines
LGUs	Local Government Units
LINDGC	Legaspi – Iriga – Naga – Daet Growth Corridor
LTO	Land Transportation Office
LWD	Local Water District
LWUA	Local Water Utility Agency
M/D	Minutes of Discussion
MDCC	Municipal Disaster Coordinating Council
MLUC	Municipal Land Use Committee
MM	Minutes of Meeting
MMSL	Meters above Mean Sea Level
NAAD	Network of Areas for Agricultural Development
NAMRIA	National Mapping and Resource Information Authority
NAPHIRE	National Post Harvest Institute for Research and Extension
NCDPP	National Calamities and Disaster Preparedness Plan
NDCC	National Disaster Coordinating Council
NEDA	National Economic and Development Authority
NFA	National Food Authority
NGAs	National Government Agencies
NGOs	Non-Government Organizations
NHA	National Housing Authority
NIA	National Irrigation Administration
NIPAS	National Integrated Protected Areas System
NPC	National Power Corporation （or NAPOCOR）
NPAAD	Network of Protected Areas for Agricultural Development
NSCB	National Statistical Coordination Board
NSO	National Statistics Office
NTC	National Telecommunication Commission
OCD	Office of Civil Defense
O&M or O/M	Operation and Maintenance
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PAMB	Protected Area Management Board
PCA	Philippine Coconut Authority
PCM	Project Cycle Management
PCBTSDP	Presidential Commission on Bicol Tourism Special Development Project

PCG	Philippine Coast Guard
PD	Presidential Decree
PDCC	Provincial Disaster Coordinating Council
PDMO	Provincial Disaster Management Office
PDZ	Permanent Danger Zone
PFDA	Philippine Fishery Development Authority
PHIVOLCS	Philippine Institute of Volcanology and Seismology
PHO	Provincial Health Office
PIA	Philippine Information Agency
PNRC	Philippine National Red Cross
PMO	Project Management Office
PMS	Presidential Management Staff
PNP	Philippine National Police
PNR	Philippine National Railways
PPA	Philippine Port Authority
PPDO	Provincial Planning and Development Office
PPFP	Provincial Physical Framework Plan
PRA	Participatory Rural Appraisal
PSWDO	Provincial Social Welfare and Development Office
PTA	Philippine Tourism Authority
RA	Republic Act
RDC	Regional Development Council
RDCC	Regional Disaster Coordinating Council
RRA	Rapid Rural Appraisal
SIADs	Sub-Integrated Area Development Units
SRA	Social Reform Agenda
SW	Scope of Works
TESDA	Technical Education and Skills Development Authority
TLRC	Technology Livelihood Resource Center
TOR	Terms of Reference

Measurements

Length

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

Area

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

Volume

cm^3	=	cubic centimeter
l	=	liter
kl	=	kiloliter
m^3	=	cubic meter

Derived Measures

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

Weight

g	=	gram
kg	=	kilogram
ton	=	metric ton

Currency

PHP	=	Philippine Peso
¥	=	Japanese Yen
US$	=	US Dollar

Time

s	=	second
min	=	minute
hr	=	hour
d	=	day
y	=	year

Other Measure

%	=	percent
º	=	degree
ºC	=	degree(s) Celsius
10^3	=	thousand
10^6	=	million
10^9	=	billion
kmph	=	kilometer per hour

Energy

W	=	Watt
kw	=	kilowatt

Fiscal Year

January 1 to December 31

Exchange Rate
(As of December 1999)

US$ 1 = PHP40.0

US$ 1 = ¥105

The Study on Comprehensive Disaster Prevention around Mayon Volcano

SUPPORTING REPORT (2)

(Part II: Feasibility Study)

XIV : Hydrology, Hydraulics/River Planning

SUPPORTING REPORT (2) – XIV
HYDROLOGY, HYDRAULICS/RIVER PLANNING

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HYDROLOGY, HYDRAULICS/RIVER PLANNING

1. PHYSICAL PROFILE OF LEGAZPI CITY

1.1 Location

Legazpi City is situated at approximately 123°45' Longitude East and 13°19' Latitude North, approximately 554km southeast of Manila.

1.2 General Land Use

Legazpi City has an area of 20,420ha (204km^2). The area spans 29km from north to south and 19.5km east to west.

The present land use of Legazpi City is divided into urban area and rural area as shown below.

Land Use of Legazpi City

Total Area of Legazpi City	20,420ha	100%
Urban Area	1,382ha	6.8%
Rural Area	19,038ha	93.2%

Note: Urban Area is defined as an area of Legazpi Port and Albay Districts, and Rural Area is defined as an area of Rural North and South Districts of four Districts in Legazpi City.

Open space covers a total estimated area of 4,486ha (22.0% of total land area of Legazpi City), including parks, public recreational areas, cemeteries, river/creeks, swamps and grasslands.

Build-up area of the city covers approximately 1,420ha (7.0% of total land area of Legazpi City), being used for residential, commercial, institutional, industrial and transportation. More than half (53.4%) of the total build-up area is in the urban area while the rest (46.6%) is in the rural area.

1.3 Community Units

According to the Engineer's Office of Legazpi City, Legazpi City has 70 barangays of which 41 barangays are in the urban area and 29 are in the rural area. There are four city political districts, namely, Rural North (13 barangays), Legazpi Port District (23 barangays), Albay District (18 barangays), and Rural South (16 barangays).

An administrative map definitely indicating four districts of Legazpi City is not available from Legazpi City.

1.4 Growth Centers

The urban area composes of Albay District and Legazpi Port District. The Albay District is an area of provincial and city government administrative centers and other institutional facilities.

The Legazpi Port District is a hub of business and trade and center of financial and commercial activities in the region.

The Legazpi satellite market and bus terminal area, which is located on the boundary of Albay and Legazpi Port Districts, is an immerging commercial district that holds the spillovers of sprawling commercial establishments in the central commercial district.

2. PRESENT CONDITIONS AND PROBLEMS

2.1 Flood Damage

(1) Hazard Area

Flood inundation records in Albay and Port districts are not available from Engineer's Office of Legazpi City for the Study. However, a map of flood prone areas in Legazpi City obtained from Engineer's Office of Legazpi City (Figure XIV 2.1) shows areas regularly flooded and occasionally flooded.

According to the Engineer's Office of Legazpi City, flooded areas shown in Figure XIV 2.1 are roughly defined as follows.

a) Areas regularly flooded	:	Approx. 70ha Floods occur 3-5 times per year by 1-day storm rainfall (Approx. 60mm/day estimated by JICA Study)
b) Areas occasionally flooded	:	Approx. 180ha Flood occurs once in year by 3-day storm rainfall (Approx. 200mm/day estimated by JICA Study)

Rainfall amounts for these defined floods are not mentioned by Engineer's Office. The flood prone areas defined by Engineer's Office of Legazpi City are briefed below.

a) Low-lying area along the Tibu River
b) Low-lying area along the Macabalo River
c) Low-lying area along the Panal River
d) City center in the Legazpi Port District

Legazpi Port District is situated in a low-lying area and some areas in the central commercial area of Port District are below sea water level. The central area of Albay District is not affected by flood inundation.

According to Final Report of the Master Plan in 1981, flood inundation area by flood of Typhoon "Daling" in 1981 was widely spread in Legazpi City as briefed below and shown in Figure XIV 2.2. Legazpi rainfall station measured a 1-day rainfall of 220mm (approximately 5-year probable rainfall). Duration of inundation was about one to two days with maximum depth of 50cm. The inundation area is approximately 450ha.

a) Low-lying area along the Tibu River
b) Low-lying area along the Macabalo River
c) Low-lying area along the Ruran River
d) Low-lying area along the Sagumayon River
e) Low-lying area along the Panal River
f) Whole Legazpi Port District
g) Southeast area of Legazpi Airport

It was actually observed by the Study Team that the above areas were also inundated by Typhoon "Loleng" in 1998. The Legazpi rainfall station measured a 3-day rainfall of 266mm (approximately 2-year probable rainfall). Duration of inundation was approx. one day with maximum depth of 30cm.

(2) Hazard map

Available data to construct a flood hazard map of Legazpi City are limited to the following.

a) Flood inundation records (only available for Typhoon "Daling" in 1981)
b) Brief flood inundation survey conducted by the Study Team for Typhoon "Loleng" in 1998
c) Map of flood prone areas in Legazpi City obtained from Engineer's Office of Legazpi City
d) General hearings from resident people and City Engineers (The hearings are unsystematic and limited in number.)

e) Topography (only available from Legazpi City Map of NAMRIA with 10m contour line and river system)
f) Land use such as road network, paddy fields, and existing and planned urban drainage system in the city

Therefore, flood hazard map of Legazpi City is preliminarily constructed by the following assumptions.

As explained previously, the recorded flood inundation area by Typhoon "Daling" in 1981 as shown in Figure XIV 2.2 is measured to be one caused by 5 year probable rainfall.

The Study Team also observed that almost the same area was inundated by Typhoon " Loleng" in 1998. The inundation area is assumed to be one caused by 2 year probable rainfall.

The comparison between two flood inundation events is tabulated below.

Comparison of Flood Events in 1981 and 1998 in Legazpi

Flood Event	Flood Inundation Area (ha)	Storm Rainfall Amount at Legazpi (mm)	Duration and Depth of Inundation
Typhoon "Daling" in 1981	450	220mm (1 day rainfall) Approx. 5 year probable rainfall	One to two days 50cm (maximum)
Typhoon " Loleng" in 1998	450 (almost the same as above area)	266mm (3 day rainfall) Approx. 2 year probable rainfall	One day 30cm (maximum)

Figure XIV 2.2 indicates that the flood inundation areas caused by Typhoon "Daling" are confined within the low-lying areas east of Washington Drive in Albay District which is laid between the Legazpi Airport and Legazpi City Hall.

On the other hand, 10-year probable 1-day rainfall at Legazpi is estimated to be around 300mm which is 1.2 times that of 5-year probable 1-day rainfall.

Therefore, it is preliminarily assumed that flood hazard area caused by 10-year probable 1-day rainfall in Legazpi City for the purpose of urban drainage plan will also be confined within the low-lying areas east of Washington Drive in Albay District.

Figure XIV 2.3 shows the hazard map of 10-year probable flood in Legazpi City.

(3) Historical Flood Damages

According to the Planning Office of Legazpi City, no official data of historical flood damages were compiled in Legazpi City.

The JICA Study Team is presently under investigation on historical flood damages of Legazpi City in collaboration with the Planning Office of Legazpi City. Results of the survey will be compiled in Draft Final Report and used for economic evaluation of the proposed urban drainage project.

2.2 Physical Setting in Project Area

(1) Present Drainage System

The drainage system in Legazpi City is aided by its topography and rivers which dissect the urban area and meander towards the shoreline. Storm water drains from the southern hills and those from the western and northern sides of the urban districts and flows eastwardly to the Albay Gulf.

Two rivers serves as a main storm drainage outlet such as Tibu River for the Legazpi Port District and Macabalo River for storm water coming from the Albay District. Macabalo River collects storm water from its upstream branch rivers such as Ruran, Sagumayon and Panal Rivers in the Albay District.

Both Tibu and Macabalo rivers have an independent drainage basin which has no interrelation with Yawa River as shown in Figure XIV 2.1.

The catchment area of Tibu and Macabalo Rivers is briefed below:

Catchment Area of Tibu and Macabalo Rivers

River	Sub-Basin	Catchment Area (km^2)
Tibu	Tibu	2.4
Macabalo	Ruran	3.5
	Sagumayon	3.6
	Panal	3.0
	Macabalo	2.8
	Total	12.9

Note: Tentatively measured by Legazpi City Map of NAMRIA (Scale: 1/10,000, Contour Line: 10m). This map is only available for the Study.

The river length and river slope of Tibu and Macabalo rivers are summarized below:

River Length and River Slope of Tibu and Macabalo Rivers

River	Sub-Basin	River Length (m)	River Slope
Tibu	Tibu	1,700	0.0018
Macabalo	Ruran	4,500	0.0037
	Sagumayon	5,250	0.0032
	Panal	3,312	0.0051
	Macabalo	2,000	0.0015

Note: Tentatively measured by Legazpi City Map of NAMRIA (Scale: 1/10,000, Contour Line: 10m). This map is only available for the Study.

The drainage capacity of the existing river channels is preliminarily estimated by site surveys as follows. Present river system diagram of Tibu and Macabalo rivers with flow capacity of each section is shown in Figure XIV 2.4. Back data for calculation of flow capacity of existing river channel in Tibu and Macabalo rivers are tabulated in Data Book.

Drainage Capacity of Tibu River

Distance from River Mouth (m)	Drainage Capacity (m^3/s)
125	263.0
203	33.2
440	20.2
510	20.2
696	9.5
786	9.5
834	30.0

Drainage Capacity of Macabalo River

River	Location of Section	Drainage Capacity (m^3/s)
Ruran	65m upstream of National Road	3.7
Sagumayon	Upstream of confluence with Ruran River	5.7
Sagumayon	Downstream of confluence with Ruran River	18.9
Panal	100m upstream of confluence to Macabalo River	19.6
Macabalo	Downstream of confluence with Panal River	17.0
Macabalo	1,600m upstream of river mouth	3.8
Macabalo	1,000m upstream of river mouth	149.6

The present condition of the existing river channels in the Tibu and Macabalo rivers is summarized below.

Present Condition of Existing River Channels

River	Dike Condition	Dike Height	Channel Width
Tibu	Heavily damaged. Needs to be newly reconstructed for all sections.	Suitable for 10-year flood peak, except for section (696 to 786m from river mouth).	Suitable for 10-year flood peak for all sections (0 to 834m from river mouth.
Macabalo and its tributaries	Heavily damaged. Needs to be newly reconstructed for all sections.	Suitable for 10-year flood peak only for section (1000m from river mouth). Other sections are to be raised.	Suitable for 10-year flood peak only for section (1000m from river mouth). Other sections are to be widened.

(2) Insufficient maintenance for urban drainage system

Insufficient maintenance for urban drainage system in Legazpi City worsens flooding and inundation as described below.

a) Absence or inadequacy of drainage structures to properly train or guide the flow of rain water to natural receptacles or water bodies
b) Siltation or clogging in some drainage pipes because of inadequate maintenance
c) Dumping of solid and liquid waste in natural and man-made channels which lessen their conveyance capacity
d) Construction of subdivisions or housing developments in nearby areas without adequate drainage outflow connection

3. ALTERNATIVE STUDY

3.1 Conceivable Alternatives

(1) Basic Concept

Basic concepts for urban drainage plan in Legazpi City are:

a) to mitigate flood damage in the flood prone areas
b) to upgrade the function of river as an estero in urban district
c) to take into consideration social and environmental aspects such as land use, land acquisition, water quality and garbage disposal, etc.
d) to protect the low-lying areas from the intrusion of tidal flood
e) to facilitate the operation and maintenance of drainage system
f) to propose technically sound and economically viable urban drainage plan

(2) Conceivable Alternative Solutions

Conceivable alternative solutions for Legazpi Urban Drainage are composed of the structural measures such as river improvement, pump station and retention pond to mitigate flooding and inundation in Legazpi City.

a) River improvement of main river channels (Tibu and Macabalo Rivers) to enlarge river flow capacity suitable for 10-year probable flood

The main river channels such as the Tibu and Macabalo rivers are to be enlarged if design flood discharge is larger than flow capacity of the present river channels. Riprapping of the channels is properly installed along the water course.

b) Installation of pumping station to compulsorily drain interior flood inundation

Pump drainage system is considered as an effective measure to minimize inundation damage in the low-lying areas of the city. Suitable size and type of pumping station is to be determined to minimize the total project cost.

c) Installation of floodgate to protect tidal flood into the rivers

Suitable size and type of floodgate is to be installed in the Macabalo and Tibu rivers to protect the low-lying areas from the intrusion of tidal flood in the city. Proper gate operation should be made in parallel with a pumping station.

d) Installation of retention pond to regulate flood peak discharge

Installation of retention pond is considered as an effective measure to regulate flood peak and to minimize the size of pumping station if installed with a pumping station.

(3) Alternatives

Based on the basic concepts and conceivable alternative solutions for urban drainage plan, only one alternative is selected as follows.

The alternative is selected as the combination of all components such as river improvement, pump station and retention pond for each river. All three components are necessary for the purpose of flood and inundation mitigation in each river basin.

3.2 Case Study on Alternative

(1) Definition of Alternative

The Alternative is composed of river improvement works for the Tibu and Macabalo rivers and an integration of a pump station and a retention pond to regulate flood water, also operated with a floodgate at a river mouth.

Installation of a retention pond will reduce the pumping capacity of a pump station if the required area for a retention pond is available in those rivers.

(2) Preliminary Facility Plan and Design for Alternatives

The alignment and hydraulic design of the proposed river improvement for Alternative Plan for the Tibu and Macabalo rivers are briefly described below.

Alignment

The alignment of the proposed dike for Alternative in the Tibu and Macabalo rives is shown in Figure XIV 3.1 and 3.2.

The channel alignment is chosen to reduce the potential flood and inundation prone areas and to minimize the social and environmental impacts by following the existing river channel wherever possible.

The length of the dike for each river is summarized below.

Length of Dike for Tibu River and Macabalo River and Its Tributaries

River Name	Length of Dike (m)	Location
Tibu	834	From the river mouth
Ruran	95	From the confluence to the Sagumayon
Sagumayon	50	From the confluence with the Ruran
Sagumayon after Ruran	70	From the confluence with the Panal to the confluence with the Ruran
Panal	100	From the confluence to the Macabalo
Macabalo	1,700	From the river mouth

Hydraulic Design

The proposed river section is a single trapezoid for the Tibu and Macabalo rivers so as to flash out debris and garbage being stuck in the rivers. The typical cross section of the proposed dike is shown in Figure XIV 3.3. The riverside slope is set at 1v:1.2h and protected by grouted riprap.

The common hydraulic design of the dike for each river is summarized below.

Hydraulic Design Standard for Urban Drainage Plan

Free Board	1.0m
Channel gradient	0.001
Roughness coefficient	0.030

Design discharge, design depth and channel width for each river are summarized below.

Back data for determination of design depth and channel width are tabulated in Data Book.

List of Hydraulic Design Parameters

River Name	River Length to be Improved (m)	Deisgn Discharge (m^3/s)	Design Water Depth (m)	Deisgn River Width (m)	River Width to be Wien (m)
Tibu	834	17	1.10-4.00	4.8-39.0	-
Ruran	95	34	2.00	10.5	6.5-7.0
Sagumayon	50	35	2.00	11.0	5.0
Sagumayon after Ruran	70	70	2.50	15.0	10.0
Panal	100	39	2.00	12.0	2.0
Macabalo	1,700	105	2.00-2.50	26.0-32.0	0.0-28.0

Note : Design peak discharge is 10 year probable flood, which occurs at a time of concentration.

The alignment and hydraulic design of the proposed pump drainage for the Tibu and Macabalo rivers are briefly described below.

Alignment

The pump drainage is composed of a pump station, retention pond and floodgates at the river mouth of each river.

The pump station is installed in the existing river channel without an inlet to the pump station. The floodgate is installed at the other side of the river channel separated from the pump station with an island revetment.

Hydraulic Design

The design pumping capacity for each river is equivalent to the estimated design flood peak for pump drainage facilities with retention pond condition, derived from 10-year return period rainfall as described below.

Design flood peak is also calculated by Modified Rational Method as follows.

Design Flood Peak for Pumping Station

River Name	tc (min)	Q (m^3/s)
Macabalo	58	105
Tibu	14	17

Steel gates are furnished in the floodgate for each river to prevent the design high water sea level (EL. + 1.61m) from intruding into the drainage areas.

Design discharge for the floodgate and its number of gates for each river are briefed below.

Design Discharge of Floodgate and No. of Gates

River Name	Design Flood Discharge (m^3/s)	No. of Gates
Macabalo	105	5
Tibu	17	3

The floodgates will drain the design flood of each river. The freeboard of 1.00m is set above HWL of river channel.

Several combinations of a pump station and a retention pond are prepared for those rivers as shown below.

The physically maximum land available for a retention pond in the Tibu and Macabalo river is firstly checked and shown below.

Available Area for Retention Pond

River Name	Available Areas for Retention Pond
Macabalo	(1) 3.0ha at river mouth (2) 6.3ha at Lap-Lap Barangay (500m upstream of the river mouth, left bank) (3) 12ha between Macabalo and Bagumbayan Bridges (1.5km upstream from river mouth)
Tibu	(1) 0.5ha at river mouth (2) No other available areas along river channel

Note : The area is measured by 1/5,000 City Map.

The relationship between a pump capacity and required retention pond volume is calculated by simulation of flood inflow hydrograph, outflow by pump station and required retention pond volume. Results of calculation are shown below.

Relationship between Pump Capacity and Required Retention Pond Volume

For Macabalo River

Pump Capacity (m^3/s)	Pump Operation Time (hr)	Required Retention Pond Volume (m^3)	Depth of Retention Pond (m)	Area of Retention Pond (ha)
20	7.9	367,200	3.1	12
15	10.5	405,000	3.4	12
10	15.8	444,600	3.7	12

Note : Total flood volume is estimated to be 567,000m^3.

Relationship between Pump Capacity and Required Retention Pond Volume

For Tibu River

Pump Capacity (m^3/s)	Pump Operation Time (hr)	Required Retention Pond Volume (m^3)	Depth of Retention Pond (m)	Area of Retention Pond (ha)
3	1.4	10,800	2.0	0.5
2	2.1	11,880	2.4	0.5
1	4.3	13,536	2.7	0.5

Note : Total flood volume is estimated to be 15,300m^3.

(3) Cost Estimate

The preliminary cost estimate is made for Cases 1, 2, and 3 conceived for the Macabalo and Tibu rivers as follows. The estimate is based on the direct construction cost of each case.

Preliminary Cost Estimate among Cases for Macabalo River

Case	River Improvement	Pump Station	Flood Gate	Retention Pond
1 (Qmax=20m^3/s) Grand Total 294.3 Million peso	Excavation : 36,400m^3 x 120 peso/m^3 = 4.4 Million Peso Embankment : 4,840m^3 x 200 peso/m^3 = 1.0 Million peso Riprapping : 23,750m^2 x 330 peso/m^2 = 7.8 Million peso Total : 13.2 Million peso	Conventional Type 5 (m^3/s) x 4 = 20 (m^3/s) Total : 211.7 Million peso	5 units (3m x 3m) Total : 24.0 Million peso	Area : 12ha Depth : 3.1m Excavation : 340,760m^3 x 120 peso/m^3 = 43.6 Million peso Embankment : 4,022m^3 x 200 peso/m^3 = 0.9 Million peso Riprapping : 2,508m^2 x 330 peso/m^2 = 0.9 Million peso Total : 45.4 Million peso
2 (Qmax=15m^3/s) Grand Total 266.9 Million peso	(same as Case1) Total : 13.2 Million peso	Conventional Type 4 (m^3/s) x 3 = 12 (m^3/s) 3 (m^3/s) x 1 = 3 (m^3/s) Total : 180. 3 Million	5 units (3m x 3m) Total : 24.0 Million peso	Area : 12ha Depth : 3.4m Excavation : 395,721m^3 x 120 peso/m^3 = 47.5 Million peso Embankment : 4,671m^3 x 200 peso/m^3 = 0.9 Mill'on peso Riprapping : 2,913m^2 x 330 peso/m^2 = 1.0 Million peso Total : 49.4 Million peso
3 (Qmax=10m^3/s) Grand Total 240.5 Million peso	(same as Alt 1) Total : 13.2 Million peso	Conventional Type 3 (m^3/s) x 2 = 6 (m^3/s) 2 (m^3/s) x 2 = 4 (m^3/s) Total : 149.1 Million	5 units (3m x 3m) Total : 24.0 Million peso	Area : 12ha Depth : 3.6m Excavation : 434,413m^3 x 120 peso/m^3 = 52.1 Million peso Embankment : 5,127m^3 x 200 peso/m^3 = 1.0 Million peso Riprapping : 3,198m^2 x 330 peso/m^2 = 1.1 Million peso Total : 54.2 Million peso

The least cost alternative for the Macabalo River is Case 3, composing river improvement of the Macabalo river and pump drainage (Pumping Capacity = 10m^3/s) with a retention pond with grand total direct cost of 240.5 Million pesos.

Preliminary Cost Estimate for Alternative for Tibu River

Case	River Improvement	Pump Station	Flood Gate	Retention Pond
1 ($Qmax=3m^3/s$) Grand Total 84.84 Million peso	Excavation : $1,500m^3$ x 120 peso/m^3 = 0.2 Million peso Embankment : $437m^3$ x 200 peso/m^3 = 0.1 Million peso Riprapping : $9,180m^2$ x 330 peso/m^2 = 3.0 Million peso Total : 3.3 Million peso	Submersible Type 1 (m^3/s) x 1 = 1 (m^3/s) 2 (m^3/s) x 1 = 2 (m^3/s) Total : 65.3 Million peso	3 units (3m x 3m) Total : 15.0 Million peso	Area : 0.5ha Depth : 2.0m Excavation : $10,056m^3$ x 120 peso/m^3 = 1.2 Million peso Embankment : $119m^3$ x 200 peso/m^3 = 0.02 Million peso Riprapping : $74m^2$ x 330 peso/m^2 = 0.02 Million peso Total : 1.24 Million peso
2 ($Qmax=2m^3/s$) Grand Total 76.08 Million peso	(same as Case 1) Total : 3.3 Million peso	Submersible Type 1 (m^3/s) x 1 = 1 (m^3/s) 1 (m^3/s) x 1 = 1 (m^3/s) Total : 56.2 Million peso	3 units (3m x 3m) Total : 15.0 Million peso	Area : 0.5ha Depth : 2.4m Excavation : $12,067m^3$ x 120 peso/m^3 = 1.5 Million peso Embankment : $239m^3$ x 200 peso/m^3 = 0.05 Million peso Riprapping : $89m^2$ x 330 peso/m^2 = 0.03 Million peso Total : 1.58 Million peso
3 ($Qmax=1m^3/s$) Grand Total 67.16 Million peso	(same as Case 1) Total : 3.3 Million peso	Submersible Type 0.5 (m^3/s) x 1 = 1 (m^3/s) 0.5 (m^3/s) x 1 = 1 (m^3/s) Total : 47.2 Million peso	3 units (3m x 3m) Total : 15.0 Million peso	Area : 0.5ha Depth : 2.0m Excavation : $13,576m^3$ x 120 peso/m^3 = 1.6 Million peso Embankment : $161m^3$ x 200 peso/m^3 = 0.03 Million peso Riprapping : $100m^2$ x 330 peso/m^2 = 0.03 Million peso Total : 1.66 Million peso

The least cost alternative for the Tibu River is Case 3, composing river improvement of the Tibu river and pump drainage (Pumping Capacity = $1m^3/s$) with a retention pond with grand total direct cost of 67.2 Million pesos.

(4) Selection of Optimum Scheme

a) Selection Criteria

Since related project evaluations based on environmental and social surveys for the alternative plan of urban drainage are presently under investigation, the optimum scheme can be selected by the least cost alternative method.

b) Optimum Scheme

Cases 1, 2 and 3 will similarly reduce flood damage in the flood prone area and inundation damage in the low-lying areas in the Port District with the same reducibility.

Expected land acquisition and resettlement costs of Cases 1, 2, and 3 will be the same since the equivalent area will be used for a retention pond.

Therefore, Case 3 is economically more feasible than Cases 1 and 2, with the least cost and the same reducibility of flood and inundation damages.

4. BASIC PLAN OF URBAN DRAINAGE

4.1 Purpose of the Project

Flood and inundation in the Legazpi City are caused by the occurrence of high tide level in the Albay Gulf and by the inadequate capacity of drainage channels and rivers discharging into the sea. Flood and inundation damage have become more serious and more severe since early the 1990s because of the increasing presence of urban dwellings and other damageable developments in low-lying port district.

In order to solve the flood and inundation problems in Legazpi City, The City Engineer's Office - Legazpi City Drainage Task Force (CEO-LCDTF) prepared "Legazpi City Urban Districts Drainage and Flood Control Master Development Plan" in 1998. The Master Plan provides technical data for urban drainage system and formulates a strategic plan and effective design for secondary and tertiary drainage system in the city. Actual rehabilitation of the existing drains and expansion of new drains along the main road system are partially under way by the City Engineer's Office of Legazpi City with financial support of LGU. The Master Plan briefly suggested needs for suitable river improvement and pump drainage plan for the Macabalo and Tibu rivers, but no planning and design were made for river improvement and pump drainage plan.

Therefore, the scope of work for JICA Study is to study the river improvement and pump drainage plan for the Macabalo and Tibu rivers, dealing with a completed urban drainage system planned by Legazpi City as a prerequisite condition.

The purpose of the Project is to control or mitigate flooding and inundation in Legazpi City through effective river structural measures that will result in reduction of losses due to flood.

The Feasibility Study aims to confirm the economic and technical viability of the priority structural projects identified in the master plan, to assess their social and environmental impact, and to come up with final recommendations on the most appropriate type of structure to be constructed.

4.2 Design Flood

(1) Probable Rainfall

Considering that two rivers are located in the vicinity of Legazpi City, Legazpi rainfall station was selected as a representative rainfall station to estimate probable storm rainfall.

According to the Hydrometeorological Investigations and Special Studies Section of Flood Forecasting Branch, PAGASA, the intensity-duration relationships were analyzed by the above section using 40 years of rainfall graph records from 1951 to 1990 at Legazpi, which is explained in detail in Supporting Report (1) I : Hydrology, Hydraulics and River Planning of Master Pan.

The past rainfall graph records used for the above analysis and latest records from 1991 to the present at Legazpi Station are requested by the JICA Study Team, but are not available from PAGASA for the purpose of update and evaluation by the Study Team.

Therefore, the following probable rainfall intensity-duration relationships estimated by PAGASA were adopted not only to the runoff study for river improvement plan but also for urban drainage plan.

Adopted Probable Rainfall Intensity-Duration Relation at Legazpi

(unit : mm/hr)

Return Period (yr)	10 (min)	20 (min)	30 (min)	60 (min)	120 (min)	3 (hr)	6 (hr)	12 (hr)	24 (hr)
2	129.6	95.1	78.4	52.4	36.8	29.2	19.2	11.7	6.8
5	186.0	136.8	113.2	76.6	55.3	44.4	31.1	19.0	10.6
10	223.8	164.4	136.2	92.7	67.6	54.5	38.9	23.8	13.2
20	259.8	191.1	158.2	108.1	79.3	64.2	46.5	28.4	15.6
50	306.0	225.3	186.8	128.0	94.6	76.7	56.2	34.4	18.7
100	341.4	251.1	208.2	143.0	106.0	86.1	63.5	38.8	21.1

Note : Obtained from PAGASA.

(2) Probable Design Flood

The design flood protection level of 10-year return period was adopted as a protection level of each river, based on the recommendation by BOD of DPWH as a design criteria for urban drainage plan in the Philippines.

The rational formula was adopted to the runoff analysis for the following reasons:

- The catchment area of the drainage basin is comparatively small and concentration time to the peak discharge is quite short.
- Generally, as a design scale of urban drainage plan, 5 to 10 year return period flood is adopted.
- Construction of drainage facilities in the build-up urban area is quite costly and adoption of large scale of protection level is not feasible.

The runoff formula adopted for determination of flood peak discharge is explained below :

$$Q = 1/3.6\ Cs\ C\ I\ A$$

where,
- Q = Peak discharge (m^3/s)
- I = Intensity of rainfall (mm/hr)
- A = Catchment area (km^2)
- C = Runoff coefficient
- Cs = Storage coefficient

  $Cs = 2\ tc / (2\ tc + td)$

  where,

  tc = Time of concentration

  td = Time of flow in the main drain

The application of a rational formula modified by a storage coefficient is preferable in the project area which mainly consists of flat and low-lying areas.

Results of calculation for 10-year probable flood peaks in the Tibu and Macabalo Rivers are tabulated below.

Results of Flood Peak Calculation (10-Year)

River Name	Catchment Area (km^2)	River Length (m)	Tc (min)	Td (min)	Cs	C	Q (m^3/s)
Tibu	2.4	1,700	14	123	0.19	0.70	17
Ruran	3.5	4,500	36	117	0.40	0.70	34
Sagumayon	3.6	5,250	42	105	0.44	0.70	35
Panal	3.0	3,312	26	60	0.46	0.70	39
Macabalo	12.9	7,250	58	117	0.44	0.70	105

Note : Ruran, Sagumayon and Panal are upstream branch rivers of Macabalo River.

(3) Tide Levels in the Albay Gulf

According to the City Engineer's Office of Legazpi City, Legazpi City is experiencing a mean high tide of 1.8m recorded, while some places within the City Central Commercial/Business District are identified to be at below sea level.

This tidal level variation is evident in most places along floodway fringe or primary dunes of two main outlet rivers (Tibu and Macabalo Rivers) near the seashores. Actual observation was conducted and found that water levels in these rivers rise to a tremendous height during high tide though there is an absence of rain.

With this tidal condition against the present ground elevation of the City Central Commercial/Business District, storm water from the drainage canals will hardly flow towards these two rivers that serve as the main drainage receptacles for the City Urban Districts.

Tide levels at Port of Legazpi are measured by Philippine Ports Authority. The measurement records of tide levels at Port of Legazpi are not available from the Philippine Ports Authority.

However, the design tidal levels at Port of Legazpi are obtained from "Design Manual for Port and Harbour Facilities in the Philippine Ports Authority (1995)" as summarized below.

List of Tides at Port of Legazpi

(unit : m)

HHWL	HWL	MHHW	MHW	MTL	MLW	LWL	DLT	LLWL
Highest High Water Level	High Water Level	Mean Higher High Water	Mean High Water	Mean Tide Level	Mean Low Water	Low Water Level	Design Low Tide Level	Lowest Low Water Level
-	+1.61	+1.40	+1.33	+0.75	+0.17	-0.25	-0.35	-0.70

Note : HHWL is not available at Port of Legazpi.

The deviation between HWL and LWL at Port of Legazpi is approximately 1.9m. High Water Level (HWL) of 1.61m observed at Port of Legazpi is adopted to the design high tide level.

4.3 Alignment of Drainage System

(1) Basic Plan

Basic Plan of Urban Drainage for Legazpi City is selected as the least cost alternative plan (Case 3) by case study as described in Section 3.

The selected alternative plan has the following subprojects.

Basic Plan of Legazpi City Urban Drainage

SubProject	River	Composition of Structural Measures
River Improvement	Tibu	1. Construction of new dike (L=834m) 2. Raising dike height (L=277m)
	Macabalo	1. Construction of new dike (L=1,700m) 2. Raising dike height (L=616m) 3. Widening river channel (L=616m)
	Ruran	1. Construction of new dike (L=95m) 2. Raising dike height (L=95m) 3. Widening river channel (L=95m)
	Sagumayon	1. Construction of new dike (L=50m) 2. Raising dike height (L=50m) 3. Widening river channel (L=50m)
	Sagumayon after Ruran	1. Construction of new dike (L=70m) 2. Widening river channel (L=70m)
	Panal	1. Construction of new dike (L=100m) 2. Raising dike height (L=100m) 3. Widening river channel (L=100m)
Pump Drainage	Tibu	1. Pump station (4 units) 2. Floodgate (5 units) 3. Retention Pond (0.5ha)
	Macabalo	1. Pump station (2 units) 2. Floodgate (3 units) 3. Retention Pond (12ha)

Dimensions of composition of river improvement for Tibu and Macabalo rivers are tabulated in Data Book.

(2) Design Capacity of River Channels

Design capacity of river channels of Tibu and Macabalo and its tributaries to be improved to reduce the flood and inundation damages in those river basins is calculated as shown below.

Design Capacity of River Channels (10-Year)

River Name	River Length To be Improved (m)	Design Capacity (m^3/s)	Present Capacity (m^3/s)
Tibu	834	17	10 - 263
Ruran	95	34	4
Sagumayon	50	35	6
Sagumayon after Ruran	70	70	19
Panal	100	39	20
Macabalo	1,700	105	4 - 150

(3) Design Capacity of Pumping Station

a) Design flood

Design flood for the determination of a pumping capacity is derived from 10-year return period rainfall as described in Section 3.

Design Flood Peak for Pumping Capacity

River Name	Q (m^3/s)
Macabalo	105
Tibu	17

b) Design capacity

Design capacity of pump station is determined as follows.

Design Pump Capacity

River Name	Design Pumping Capacity (m^3/s)
Macabalo	10
Tibu	1

(4) Design Capacity of Retention Pond

a) Design flood

Design flood for the determination of a retention is also derived from 10-year return period rainfall as described in Section 3.

Design Flood Peak for Retention Pond

River Name	Q (m^3/s)
Macabalo	105
Tibu	17

b) Design capacity

Design capacity of retention pond is determined as follows.

Design Retention Pond Capacity

River Name	Design Retention Pond Capacity (m^3)	Design Retention Pond Area (ha)	Design Retention Pond Depth (m)
Macabalo	444,600	12	3.7
Tibu	13,536	0.5	2.7

5. PRELIMINARY STRUCTURAL DESIGN OF SELECTED SCHEME

Preliminary facility designs are prepared for the selected structures of the selected Alternative plan described in Section 3. The design of urban drainage structures is based on the results of hydraulic calculation, incorporating relevant design criteria as described in Section 4.

5.1 Channel Improvement

(1) Constitution of Works

The constitution of channel improvement works is composed of the following works.

a) Channel works
b) Dikes and revetments

(2) Alignment and Profile

The alignment of river channel is based on the following design considerations.

a) The channel alignment generally follow the existing ones to minimize land acquisition.
b) In case of widening of the existing channels, the optimum design alignment is determined in order to minimize house evacuation and consequently, reduce cost.
c) The design alignment should be as smooth as possible to attain uniform channel flow.

The alignment of the proposed river channel improvement works is shown in Figure XIV 3.1 and 3.2.

The profile of the river channels is designed on the following aspects.

a) The design gradient of the channel bed approximately follows the slope of the ground line.
b) The design channel bed is determined to start from the channel mouth which has the same elevation as that of the sea.
c) The slope of the design high water level also approximately follows the adjacent ground and as much as possible not higher than the predominant elevation of the adjoining ground.

(3) Drainage Capacity

The design discharge capacity of the proposed river channel for the Tibu and Macabalo rivers is summarized below.

Drainage Capacity of Proposed River Channels

River Name	River Length to be Improved (m)	Design Discharge (m^3/s)	Design Water Depth (m)	Design River Width (m)	River Width to be Widen (m)
Tibu	834	17	1.10-4.00	4.8-39.0	-
Ruran	95	34	2.00	10.5	6.5-7.0
Sagumayon	50	35	2.00	11.0	5.0
Sagumayon after Ruran	70	70	2.50	15.0	10.0
Panal	100	39	2.00	12.0	2.0
Macabalo	1,700	105	2.00-2.50	26.0-32.0	0.0-28.0

Note : Design peak discharge is 10 year probable flood.

(4) Preliminary Design

a) Channel works

A single trapezoid section for the river channels is adopted with a single slope of 1v:1.2h for all the sections to be improved in the Tibu and Macabalo rivers, considering highly congested land use along those rivers.

The dimensions of the adopted cross-section of the channels are tabulated below.

Dimensions of Adopted Cross Section of Macabalo River

River Name	Distance (m)	Top Width (m)	Bottom Width (m)	Water Depth (m)	Velocity (m/s)	Actual Capacity (m^3/s)	Design Capacity (m^3/s)
Macabalo	197	30.7	26.0	2.3	1.7	107	105
	155	30.4	26.0	2.3	1.7	106	105
	504	30.4	26.0	2.3	1.7	106	105
	300	36.0	32.0	2.5	1.8	150	105
	100	37.0	32.0	2.0	1.6	105	105
	323	37.0	32.0	2.0	1.6	105	105
	123	37.0	32.0	2.0	1.6	105	105
	70	37.0	32.0	2.0	1.6	105	105
Sagumayon plus Ruran	70	20.8	15.0	2.5	1.6	71	70
Ruran	95	15.5	10.5	2.0	1.4	34	34
Sagumayon	50	16.0	11.0	2.0	1.4	36	35
Panal	100	17.0	12.0	2.0	1.4	39	39

Dimensions of Adopted Cross Section of Tibu River

Distance (m)	Top Width (m)	Bottom Width (m)	Water Depth (m)	Velocity (m/s)	Actual Capacity (m^3/s)	Design Capacity (m^3/s)
125	40.0	39.0	4.0	1.7	263	17
78	40.0	39.0	1.1	0.8	33	17
237	14.0	4.8	2.5	1.0	20	17
70	14.0	4.8	2.5	1.0	20	17
186	11.7	10.4	1.8	0.9	18	17
90	11.7	10.4	1.8	0.9	18	17
48	10.3	9.3	2.8	1.1	30	17

b) Dikes and revetments

The dikes are designed to have several functions/uses such as for maintenance and repair works, flood defense activities during high water stage of the river channels.

The channel revetments are provided for all the sections to be improved with a side slope of 1v:1.2h to prevent the channel banks from being eroded and widened, hence, protecting the houses from possible damages as shown in Figure XIV 3.3

The type of revetment is selected on the basis of the channel design requirement and conditions in the area in relation to the side slope. The selected type of revetment is shown below.

a) Side slope : Single section

b) Revetment : Grouted wet masonry

(5) Construction Work Volume

The construction work volume for the proposed river improvement of the Tibu and Macabalo rivers is tabulated below.

Construction Work Volume for Proposed River Improvement

River Name	Excavation (m^3)	Embankment (m^3)	Riprapping (m^2)
Macabalo	36,400	4,840	23,750
Tibu	1,500	437	9,180

5.2 Pump Drainage

(1) Constitution of Works

The constitution of pump drainage works is composed of the following works.

a) Pump stations
b) Floodgates
c) Operation building and appurtenances

(2) Alignment

The alignment of the proposed pump drainage in the Tibu and Macabalo rivers is shown in Figure XIV 3.1 and 3.2.

(3) Pump Capacity

The design pump capacity of the proposed pump drainage in the Tibu and Macabalo rivers is summarized below.

Design Pump Capacity

River Name	Design Flood Peak (m^3/s)	Design Pumping Capacity (m^3/s)
Macabalo	105	10
Tibu	17	1

(4) Preliminary Design

a) Pump stations

The selection of a suitable pump type for the proposed pumping stations in the Tibu and Macabalo rives is made for the Study.

Pump Type

The basic conditions for the selection of a pump type are as follows:

- The required pump capacity for future extension is not considered.
- Total pump head is approximately 1.5m.
- Actual pump head is variable.

Generally, the following two types of pump, consisting totally of six kinds, are applicable for use in storm water drainage considering the basic conditions given above:

- Conventional type
  - Horizontal shaft axial flow pump
  - Horizontal shaft mixed flow pump
  - Vertical shaft axial flow pump
  - Vertical shaft mixed flow pump
  - Screw pump
- Submersible type
  - Submersible motor pump

Among these pump types, the following are chosen on preliminary selection.

Selected Pump Type for Pump Stations

River Name	Pump Type	Reasons
Macabalo	Horizontal shaft axial flow pump	Most economical among conventional types of pump for large pumping capacity (= 10.0m^3/s) required for Macabalo river.
Tibu	Submersible motor pump	Most suitable for small pumping capacity (= 1.0m^3/s) required for Tibu river.

Unit Capacity and Number of Pumps

The unit capacity and number of pumps are generally determined on the basis of the following premises.

- At least two units shall be installed in each pumping station against breakdown of a pump unit
- For easy maintenance, variations of a pump size and number of pump units shall be kept to a minimum
- The ON-OFF operation shall be as rare as possible

Taking into consideration these premises, the following unit capacity and number of pumps are proposed.

Unit Capacity and Number of Pumps

River Name	Unit Capacity	No. of Pumps
Macabalo	3.0	2
	2.0	2
Tibu	0.5	2

Design of Pumping Station

The main structure of a pumping station is typically composed of the following as shown in Figure XIV 5.1 to 5.3 and 5.5 to 5.7.

- Sand basin
- Intake canal
- Pump pit
- Surge tank

Structural Features of Pumping Station

River Name	No of Bay	Total Width (m)	Total Length (m)	Maximum Height (m)	Width of Surge Tank (m)
Macabalo	4	35	105	7.0	19.0
Tibu	2	22	105	7.0	9.0

b) Floodgates

Type and Basic Structure

The type and basic structure of the floodgates are determined in accordance with the following concepts.

In common practices, two types of floodgates are properly used in compliance with the site condition: namely, the open channel type and box culvert type.

Since there is nearly 0.7m difference of the design high water levels between the sea side and river side, the box culvert type requires smaller gate height resulting in less construction cost.

Moreover, no navigation of large vessels is expected through the floodgates. It is therefore recommended to apply to the sites the box culvert type of floodgate for the Project.

Dimensions of Opening

The opening of a box culvert in each floodgate is designed so that the flow velocity can be around 1.0m/s to avoid both sedimentation and abrasion through the culvert.

The dimensions of opening is presented below.

Dimensions of Floodgates

River Name	Design Discharge (m^3/s)	Gate Height (m)	Gate Width (m)	No. of Gates
Macabalo	105	3.5	3.0	5
Tibu	17	3.5	3.0	3

Design of Floodgates

The Macabalo and Tibu Floodgates have the following structural components as shown in Figure XIV 5.1 to 5.3 and 5.5 to 5.7.

- Box culvert
- Gate pier
- Operation deck
- Shed
- Gate equipment
- Breast wall
- Cut-off wall
- Wing wall
- Apron and riprap

c) Operation building and appurtenances

The proposed pumping station and floodgate will be arranged together in the layout of facilities, particularly such as:

- Main structure comprising intake canals, pump pits, pump bay, surge tank, etc.
- Operation building
- Pavement and parking lot
- Walled-in area with an entrance/exit gate

The layout is preliminarily determined on the basis of the following considerations.

The proposed pumping station will be provided on the existing ground in order to protect the mechanical/electrical equipment from being submerged under the design high water level of the sea, even when the dikes are breached and to ensure accessibility from the public road.

Operation building will be separately built from the main structure of pumping station taking into account no mechanical requirements, unrestrained design layout, convenience of construction work, etc. It will be located adjacent to main structure to save cable cost.

Oil tank will be placed far from operation building and main structure to avoid the danger. Some spaces will be needed beside the hopper to keep the garbage temporarily. Working space in front of operation building and parking lot will be needed.

The required lot for each pumping stations in the Tibu and Macabalo rivers is briefed below.

Required Lot for Pumping Station

River Name	Required Lot (m^2)
Macabalo	3,700
Tibu	2,300

(5) Construction Work Volume

The construction work volume for the proposed pump drainage of the Tibu and Macabalo rivers is tabulated below.

Construction Work Volume for Proposed Pump Drainage

Work Item	Macabalo	Tibu
Embankment	16,000m^3	4,600m^3
Reinforced Concrete	6,700m^3	3,200m^3
R C Pile	3,900m^3	560m^3
Pump	Horizontal Shaft Pump 4 sets	Submersible Pump 2 sets
Diesel Engine	4 sets 325ps-1,000rpm	
Mechanical Rake	1 set	1 set
Electrical Facilities for Auxiliary	L.S.	
Diesel Engine for Auxiliary Equipment	2 sets	
Low-tension Distribution Panel		3 sets
Auxiliary Pump and Auxiliary Facilities	L.S.	L.S.
Cable and Miscellaneous Materials	L.S.	L.S.
Diesel Generator		1 set
Control Panel	1 set	1 set
Day Oil Tank	2.0 ton	1.5 ton
Track Crane	1 set	1 set
Gate	5 sets	3 sets

5.3 Retention Pond

(1) Constitution of Works

The constitution of retention pond works is composed of the following works.

a) Excavation works
b) Embankment works
c) Riprapping works

(2) Alignment

The alignment of retention pond is selected, based on the following design considerations.

a) Unused open space or paddy fields is used for retention pond to minimize land acquisition.
b) Design alignment is determined in order to minimize house evacuation and consequently, reduce cost.

The alignment of the proposed retention pond works is shown in Figure XIV 3.1 and 3.2. The plan and profile of retention pond for the Tibu and Macabalo rivers are shown in Figure XIV 5.4 and 5.8, respectively.

(3) Design Capacity

The design capacity of the proposed retention pond for the Tibu and Macabalo rivers is summarized below.

Design Retention Pond Capacity

River Name	Design Retention Pond Capacity (m^3)	Design Retention Pond Area (ha)	Design Water Depth (m)
Macabalo	444,600	12	3.7
Tibu	13,536	0.5	2.7

(4) Preliminary Design

a) Excavation works

A single trapezoid section for the slope of retention pond is adopted with a single slope of 1v:1.5h for all the sections

The dimensions of the adopted cross-section of the slope are tabulated below.

Dimensions of Adopted Cross Section of Retention Pond

River Name	Length of Retention Pond (m)	Width of Retention Pond (m)	Free Board (m)	Water Depth (m)
Macabalo	400	300	1.0	3.7
Tibu	100	50	1.0	2.7

b) Dikes and revetment

The dikes are designed to have several functions/uses such as for maintenance and repair works, flood defense activities during high water stage of the river channels.

The revetments are provided for all the slopes with a side slope of 1v:1.5h to prevent the banks from being eroded.

The type of revetment is selected on the basis of the design requirement and conditions in the area in relation to the side slope. The selected type of revetment is shown below.

a) Side slope : Single section
b) Revetment : Grouted wet masonry

(5) Construction Work Volume

The construction work volume for the proposed retention pond of the Tibu and Macabalo rivers is tabulated below.

Construction Work Volume for Proposed Retention Pond

River Name	Excavation (m^3)	Embankment (m^3)	Riprapping (m^2)
Macabalo	434,413	5,127	3,198
Tibu	13,576	161	100

6. OPERATION AND MAINTENANCE

6.1 Required Operation and Maintenance Works

The operation and maintenance works are required for the following structures and facilities .

a) River channels
b) Pumping stations
c) Retention ponds

In particular, it is of extreme importance that the emergency drainage equipment of pumping station starts and is operable in situations such as during floods and heavy rain.

Therefore, the operation and maintenance works for pumping station extend to the following categories to achieve the proper operation of pump drainage.

a) Facilities : Sustaining the reliability
Easiness of operation

b) Operation : Assured operation
Sustaining capability of operators

c) Check and repair : Sustaining function of facilities
Prevention of malfunction
Repairing parts

d) Environmental conservation : Reduction of noise and vibration
Reduction of air pollution
Disposal of garbage
Harmonious facility to the surroundings

6.2 Operation of Pumping Facilities

The operation of Tibu and Macabalo Pumping Stations with floodgates, in case of storm rainfall, high tide or in combination is summarized hereafter.

When the sea water level reaches El. +1.61m which is HWL (High Water Level) measured at Legazpi Port, Tibu and Macabalo Floodgates are closed to prevent backwater from the sea into the those rivers.

After closing the floodgates, the following procedures are applied to the pump stations.

If the river side water level is higher than the sea water level, the pump stations start operation until the sea water level becomes lower than HWL. The operation periods of pumps at Tibu and Macabalo rivers is not set for certain months because no clear line can be drawn between rainy season and dry season in Albay Province. The pump stations are to be operational all the year round.

6.3 Organization and Staffing for Operation and Maintenance

a) Organization

After completion of the project construction works, all the drainage facilities, including the Tibu and Macabalo Pumping Stations, will be transferred to DPWH, Region V which is designated the agency responsible for operation and maintenance of the completed project facilities.

DPWH, Region V will remain an important organization, coordinating other agencies concerned and making higher level decisions.

For operation and maintenance, coordination with the Engineer's Office of Legazpi City is important, particularly for the Tibu and Macabalo Pumping Stations and their floodgates and retention ponds.

A telemeter or radio communication system is proposed to be established to achieve drainage operation using an integrated operation system.

Main activities for operation and maintenance are:

- Operation of the pumping station, floodgates and their operation
- Seasonal maintenance/rehabilitation of dikes, revetments, retention pond, etc.

- Daily patrol along the rivers, drainage channels
- Measurement and monitoring of rainfall, water level, flow discharge and water quality
- Compilation of data and information regarding flood and flood damage

b) Staffing

For the operation and maintenance of the Project, the required number of staff will be as shown below.

Required Number of Staff at Tibu and Macabalo Pumping Stations

Personnel	Macabalo Pumping Station	Tibu Pumping Station
General Manager	1	-
Administrator	2	-
Technician (Electric)	2	1
Technician (Mechanical)	2	1
Operator	3	3
Office boy, Dump truck driver	4	2
Guard	3	3
Total	17	10

Note : General Manager and administrators are responsible for both pumping stations.

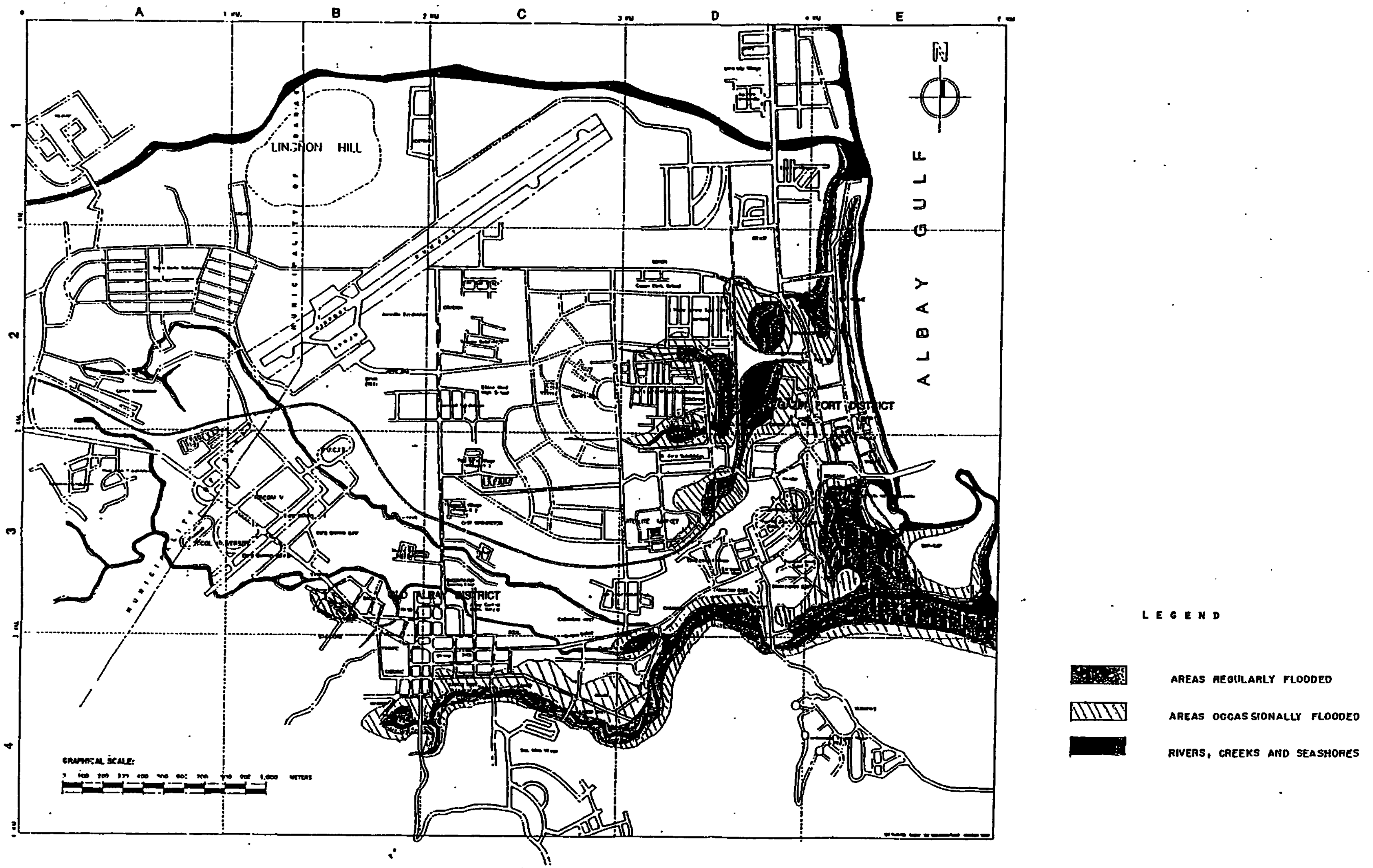
6.4 Operation and Maintenance Cost

The operation and maintenance costs and economic life for the project are considered in terms of economic cost as shown below.

Operation and Maintenance Cost and Economic Life for the Project

Item	Rate for O/M Cost (%)	Annual O/M Cost Maintenance/ Repairing	Annual O/M Cost Operation/ Administration	Economic Life
1. Civil Works	0.3	30%	70%	50 yr
2. Gate Facilities	1.0	40%	60%	30 yr
3. Pump Facilities	2.0	50%	50%	15 yr

Note : Replacement cost is the same amount as initial investment cost.



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES

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Figure XIV 2.1
Map of Flood Prone Areas in Legazpi City Defined by City Engineer's Office

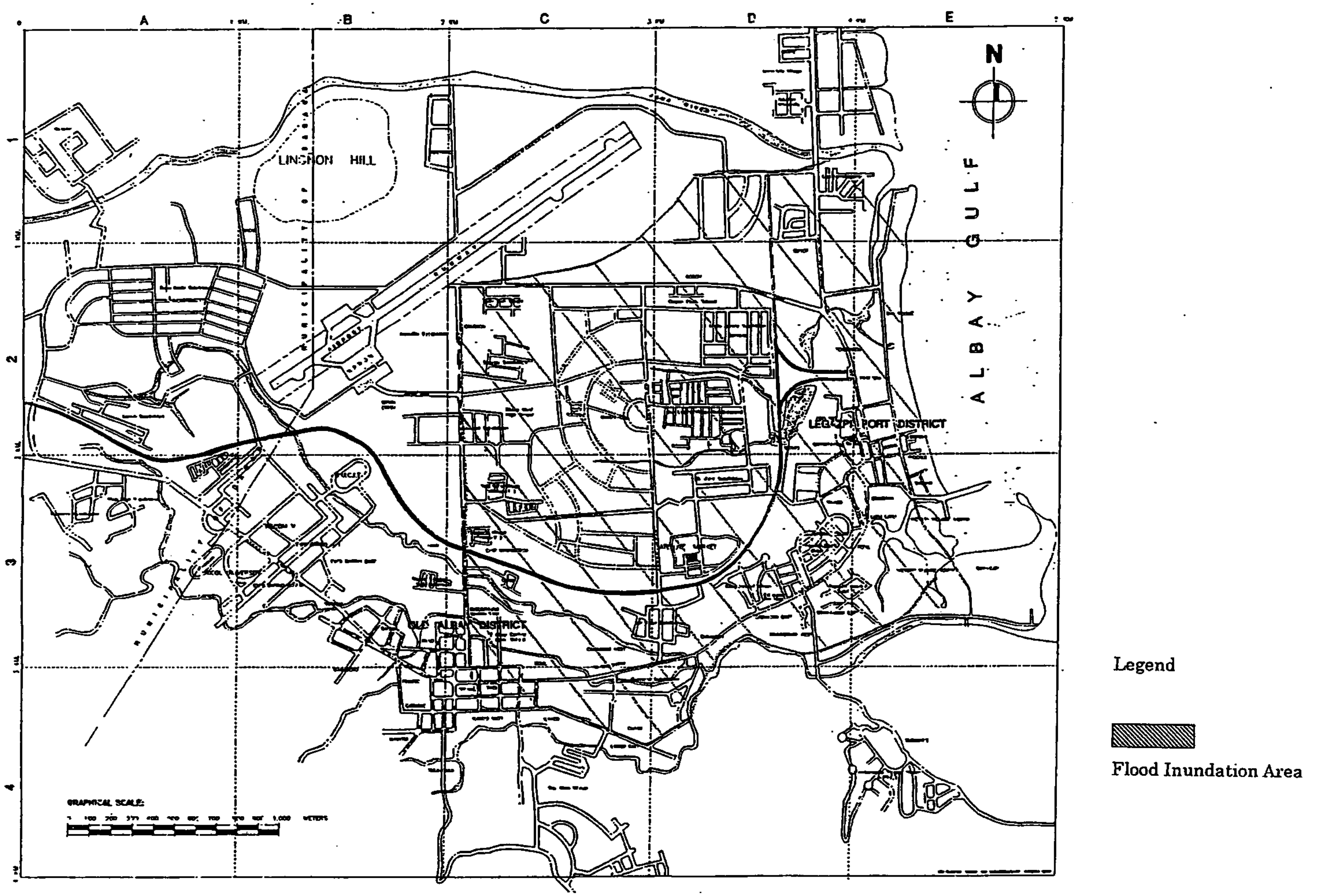

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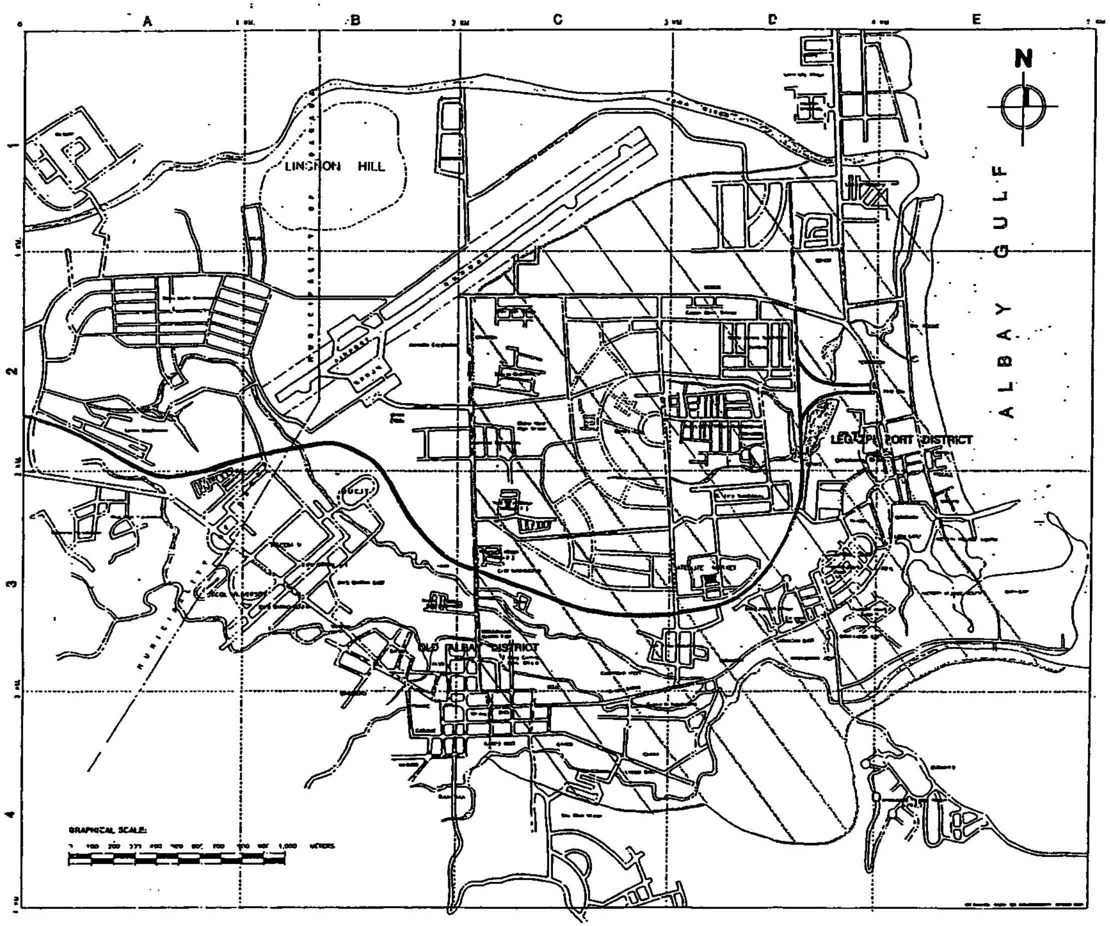
Figure XIV 2.2
Flood Inundation Area by Flood of Typhoon "Daling" in 1981



Legend

Probable Flood Inundation Area (10 Year)

COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES

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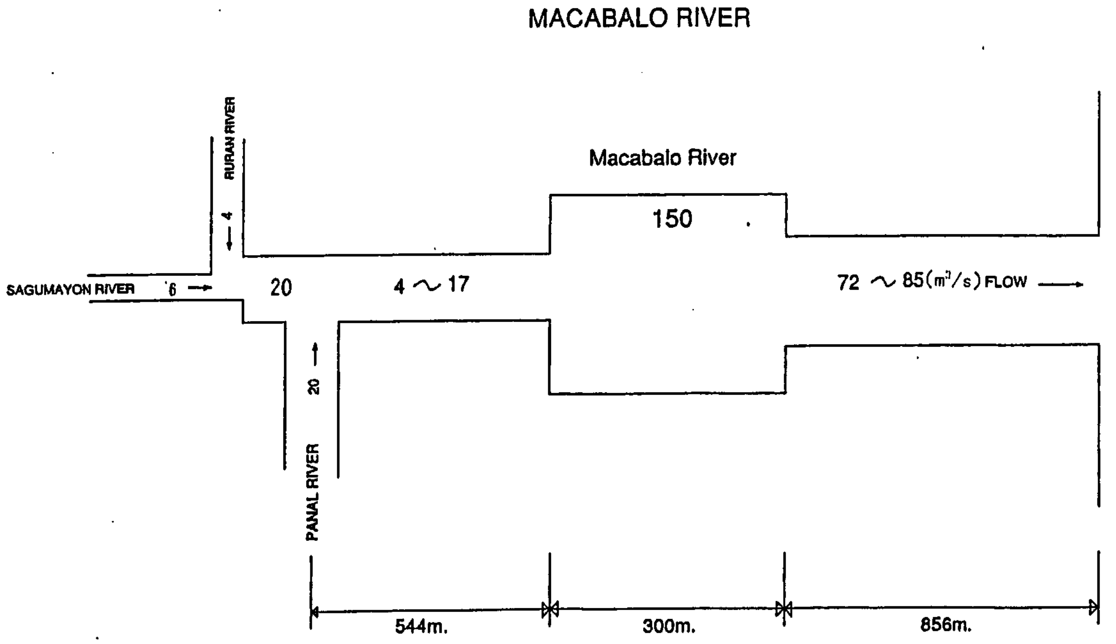
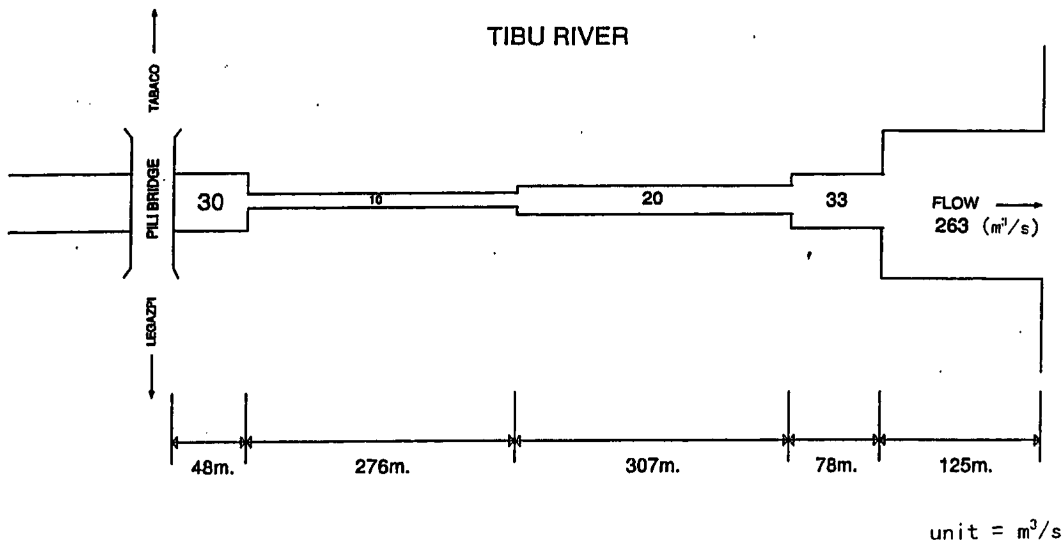
Figure XIV 2.3
Probable Flood Inindation Area in Legazpi City (10 Year)





COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	**Figure XIV 2.4** **Present Flow Capacity of Macabalo and Tibu River**
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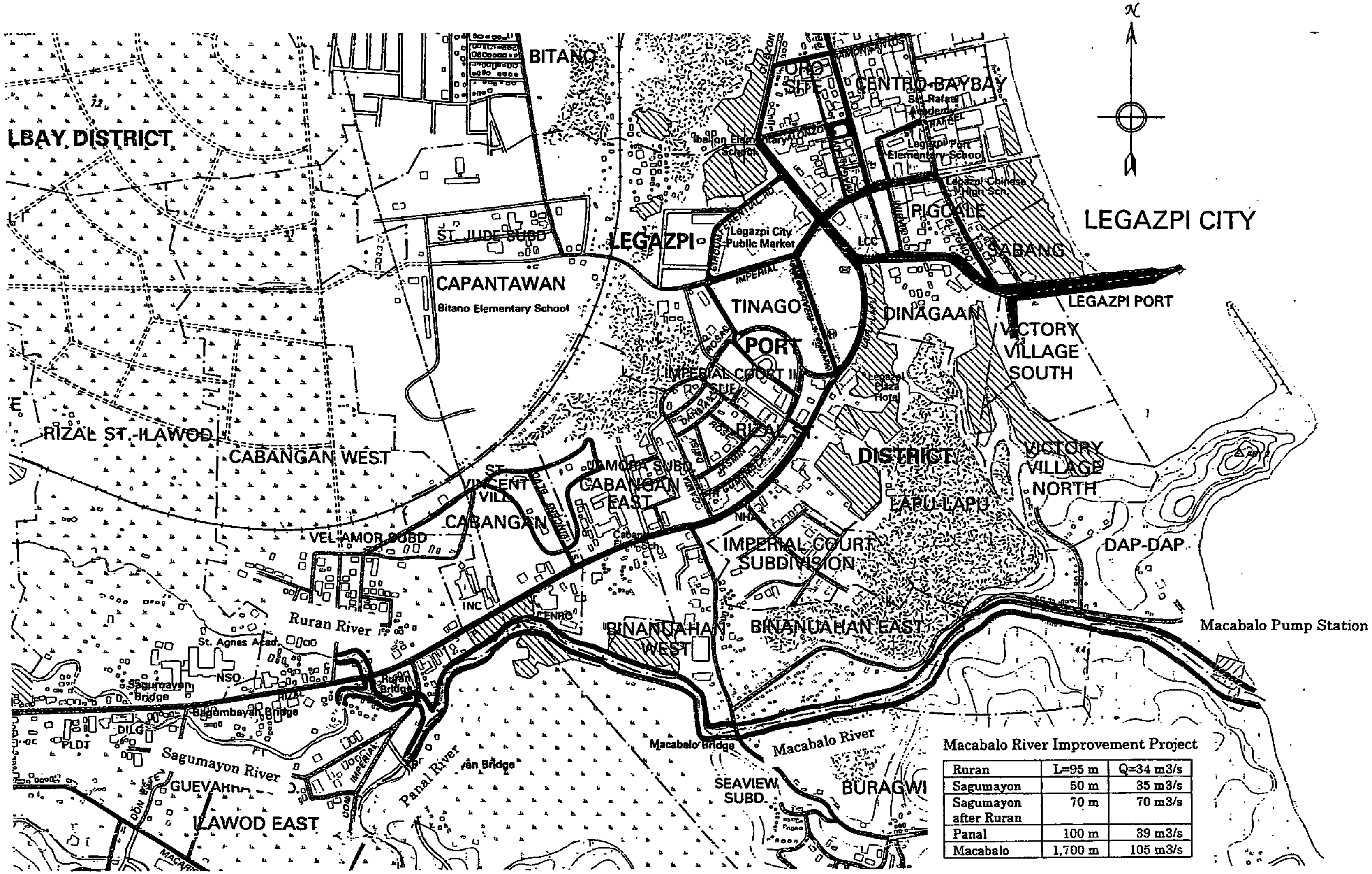

Macabalo River Improvement Project

Ruran	L=95 m	Q=34 m3/s
Sagumayon	50 m	35 m3/s
Sagumayon after Ruran	70 m	70 m3/s
Panal	100 m	39 m3/s
Macabalo	1,700 m	105 m3/s

COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES

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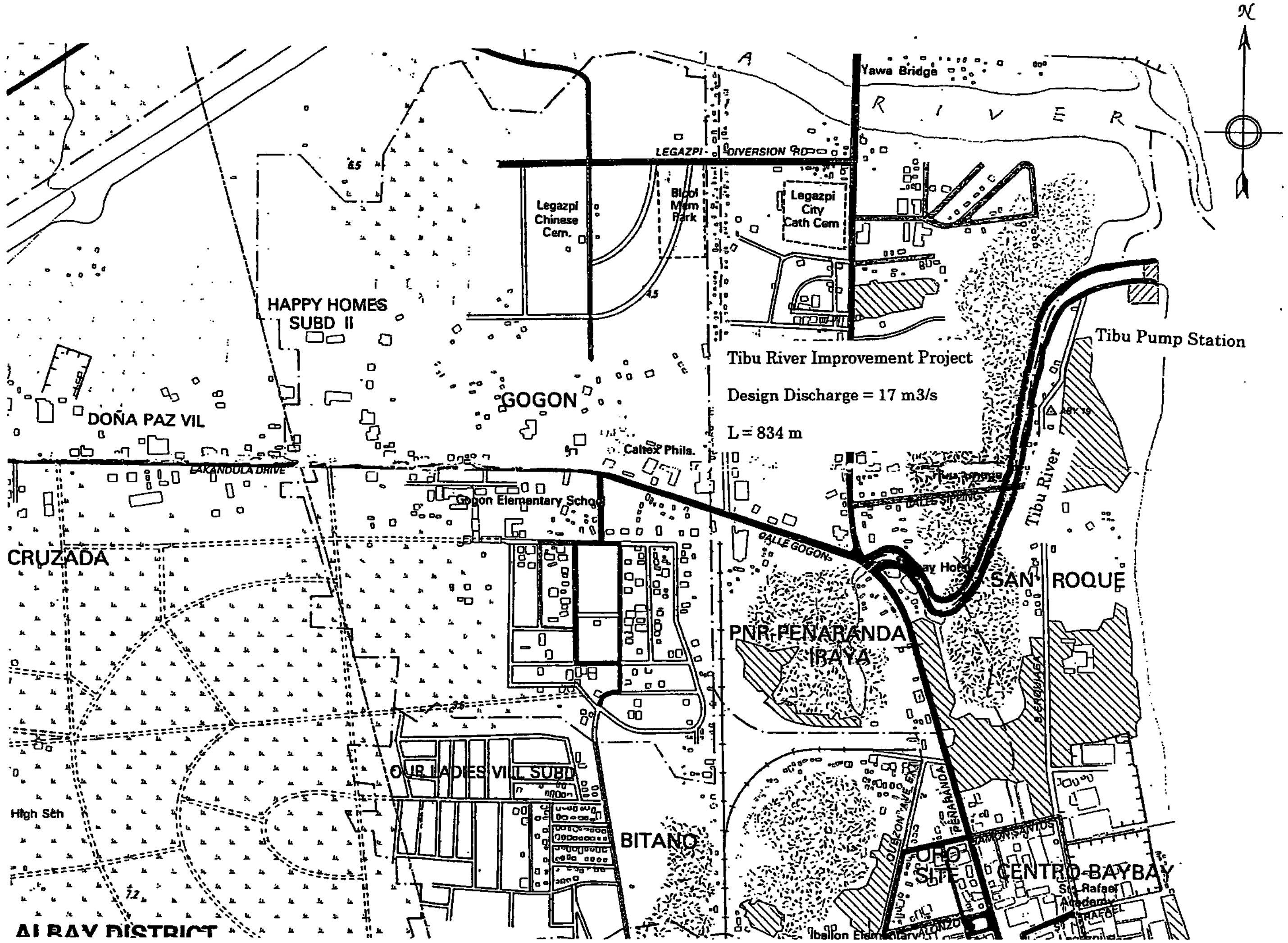
Figure XIV 3.1
Alignment of Proposed Dike and Pump Station for Macabalo River



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	Figure XIV 3.2 Alignment of Proposed Dike and Pmp Station for Tibu River
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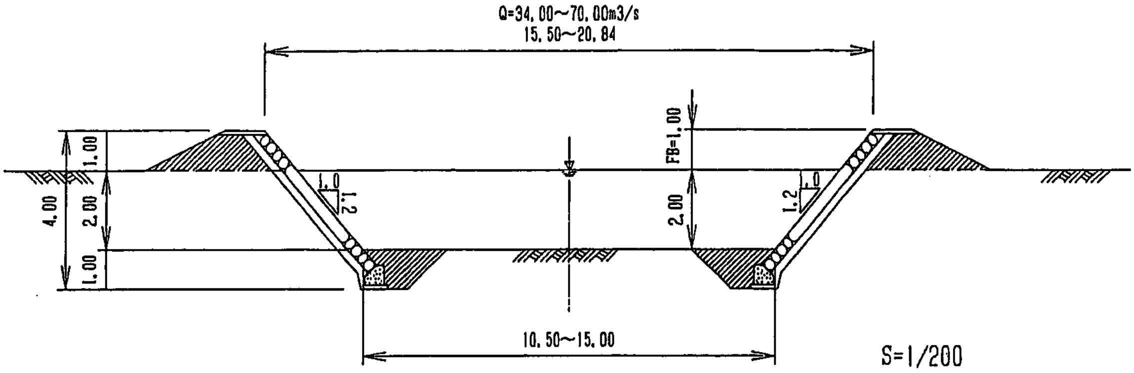
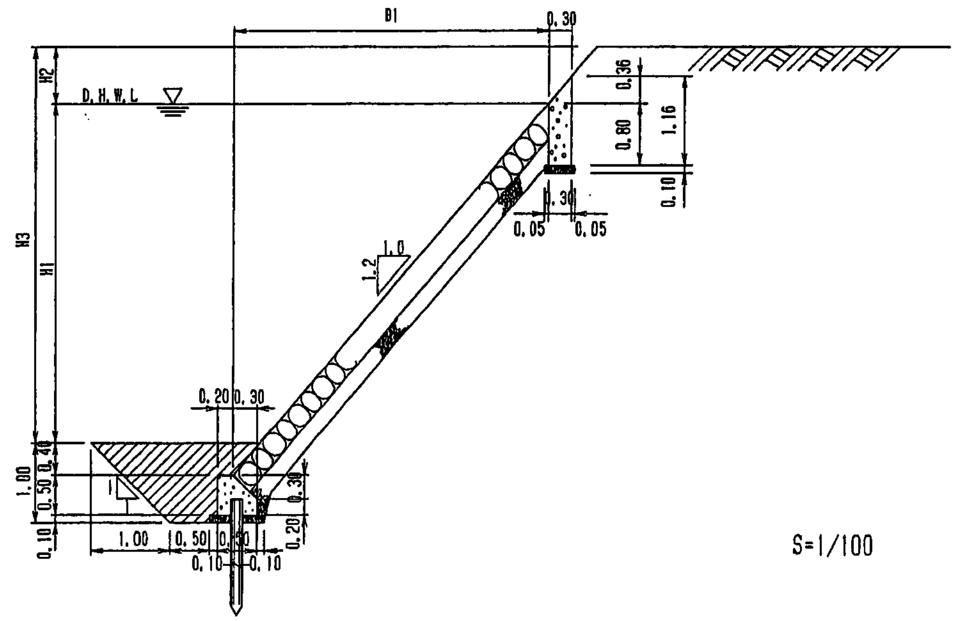


Macabalo upper



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	**Figure XIV 3.3** **Typical Cross-section of Proposed Dike**
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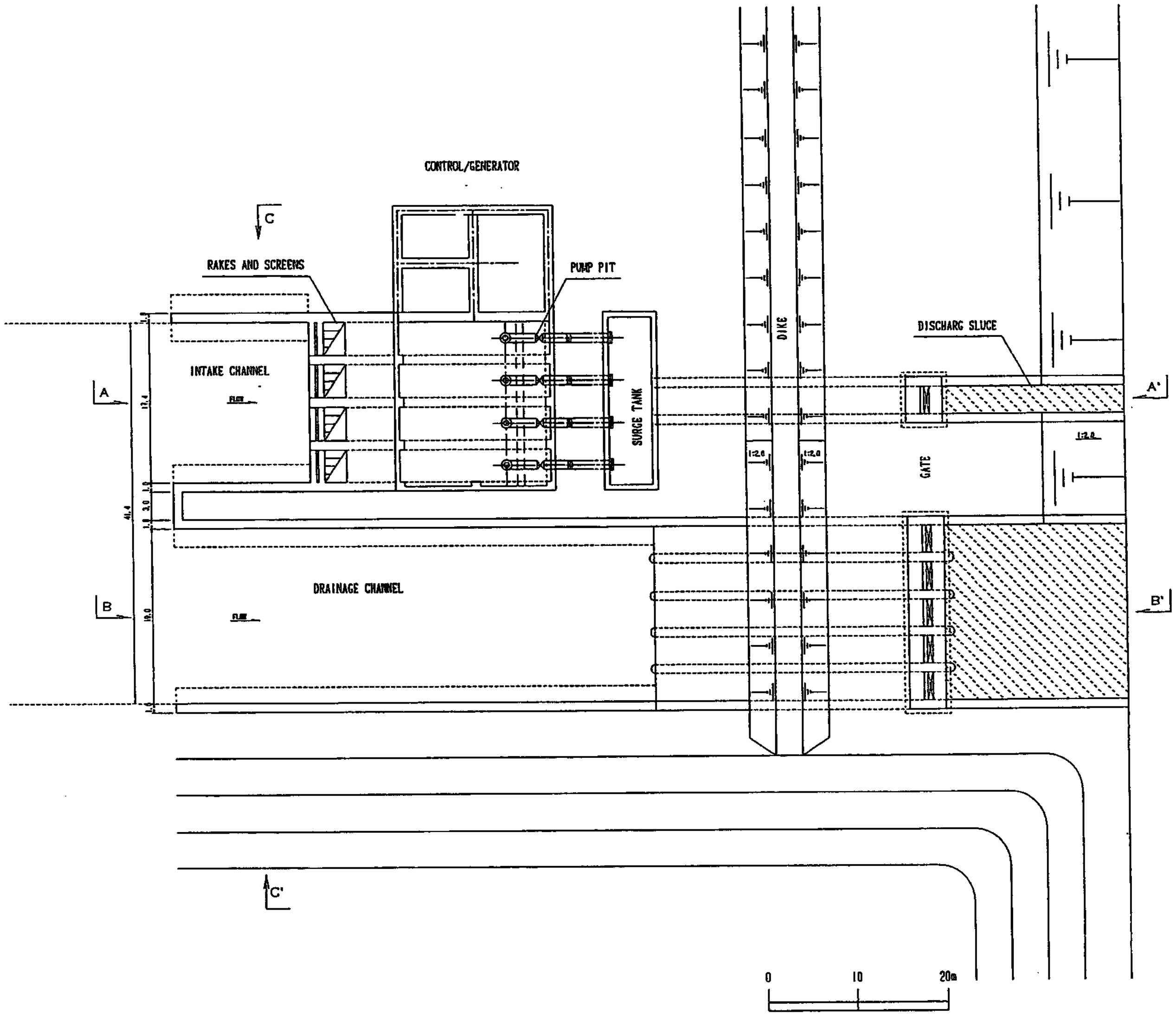

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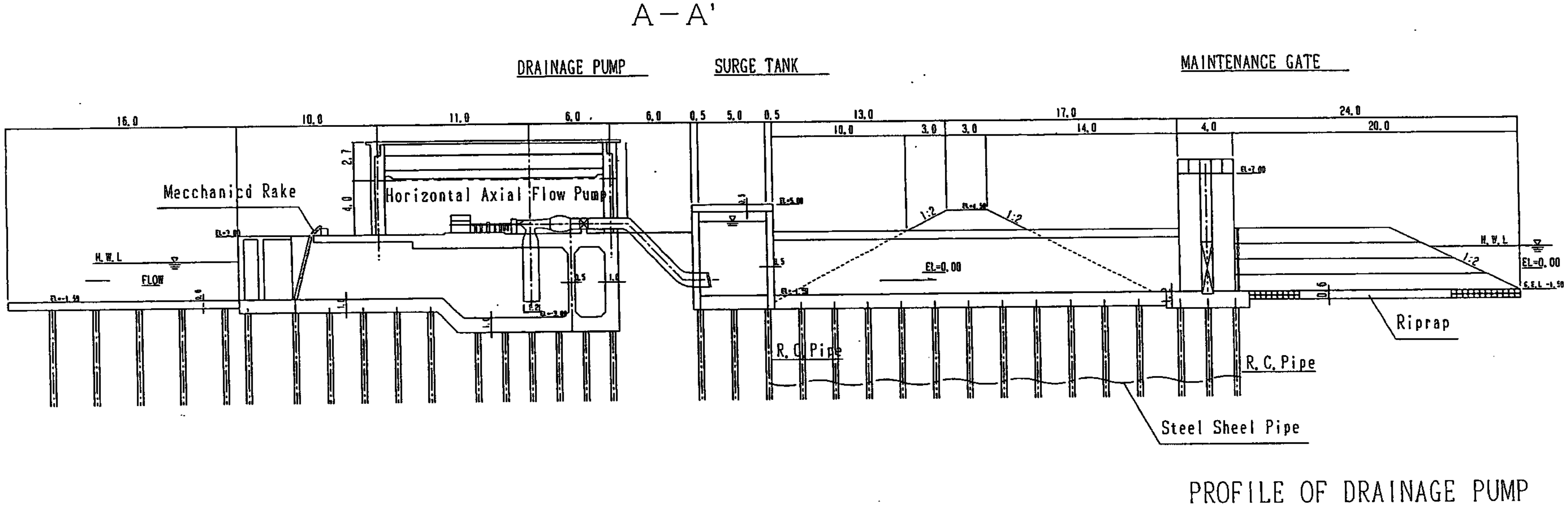
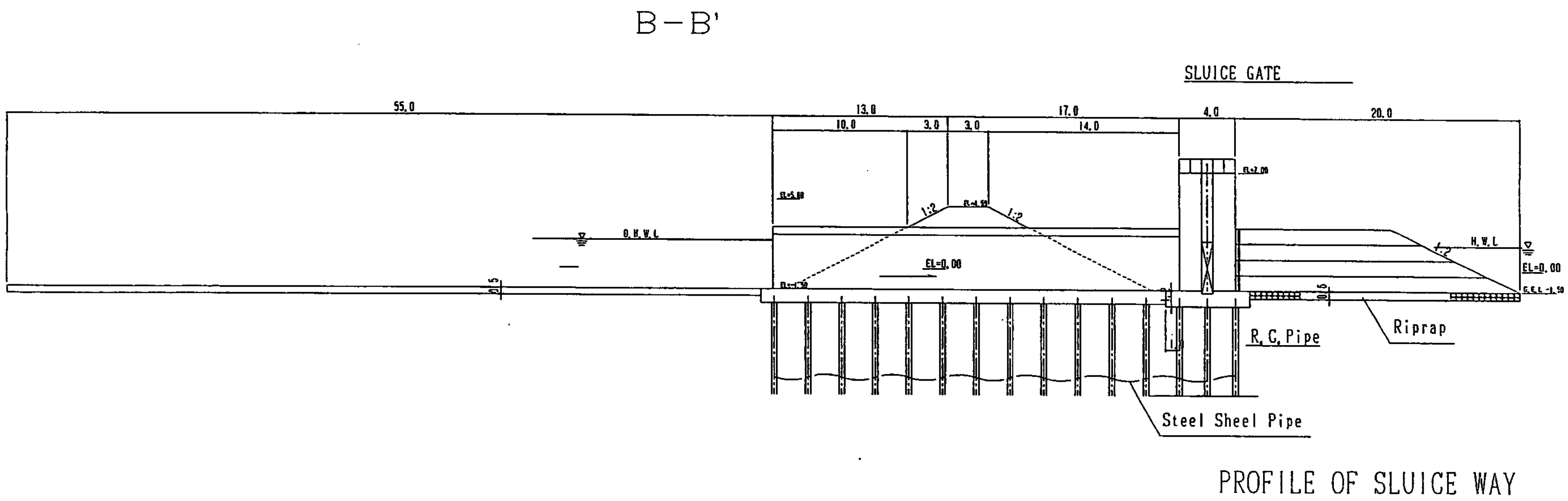
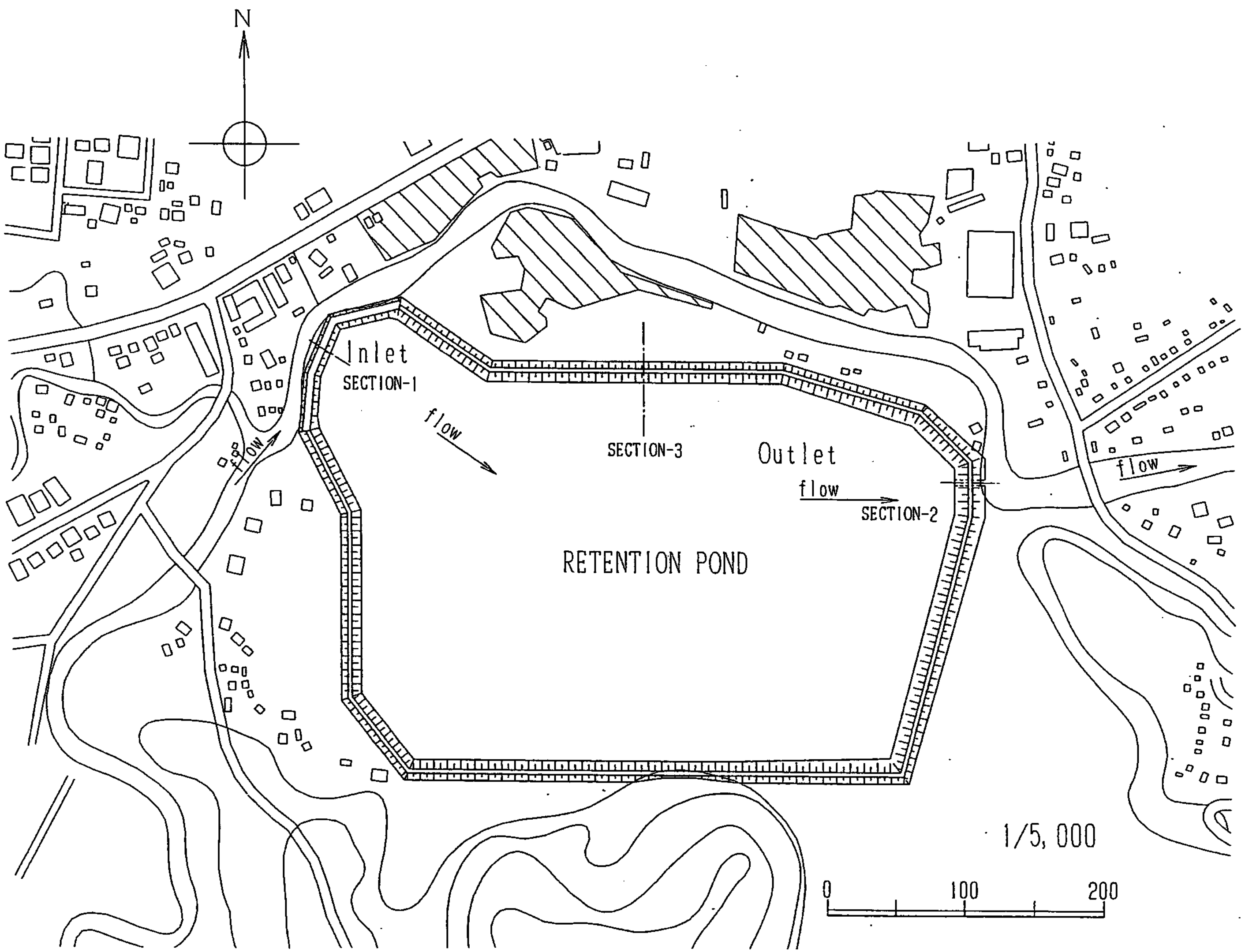
Figure XIV 5.1
Plan of Pump Station at Macabalo



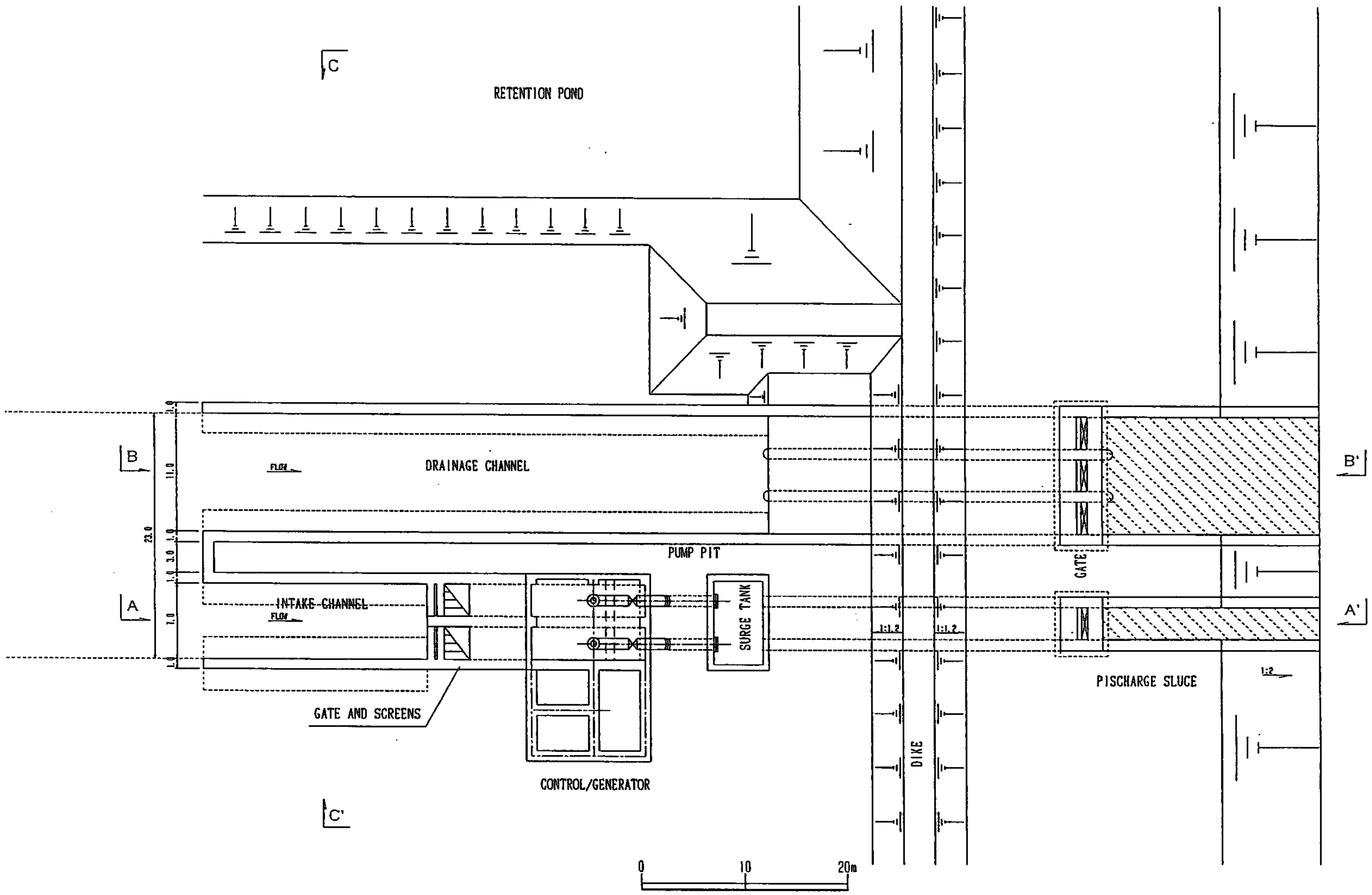
COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	**Figure XIV 5.2** **Profile of Drainage Pump at Macabalo**
JAPAN INTERNATIONAL COOPERATION AGENCY	



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	**Figure XIV 5.3**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Profile of Sluice Way at Macabalo**



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	**Figure XIV 5.4** **Plan of Retention Pond at Macabalo**
JAPAN INTERNATIONAL COOPERATION AGENCY	



COMPREHENSIVE DISASTER PREVENTION AROUND MAYON VOLCANO IN THE REPUBLIC OF THE PHILIPPINES	Figure XIV 5.5 Plan of Pump Station at Tibu
JAPAN INTERNATIONAL COOPERATION AGENCY	

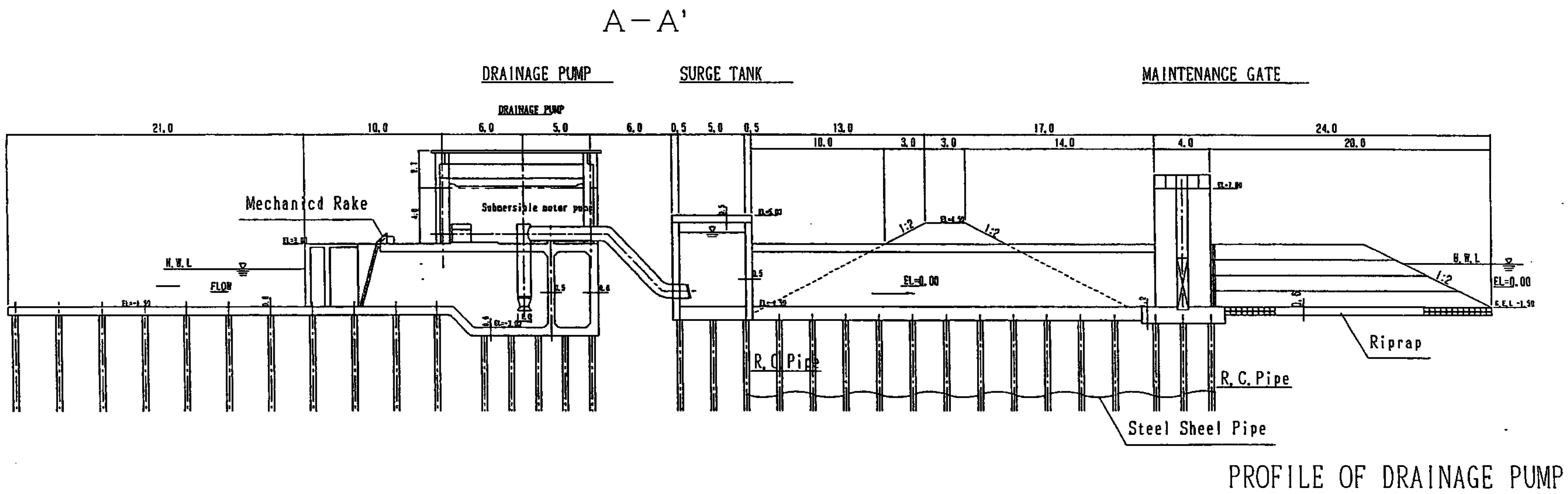


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Figure XIV 5.6
Profile of Drainage Pump at Tibu

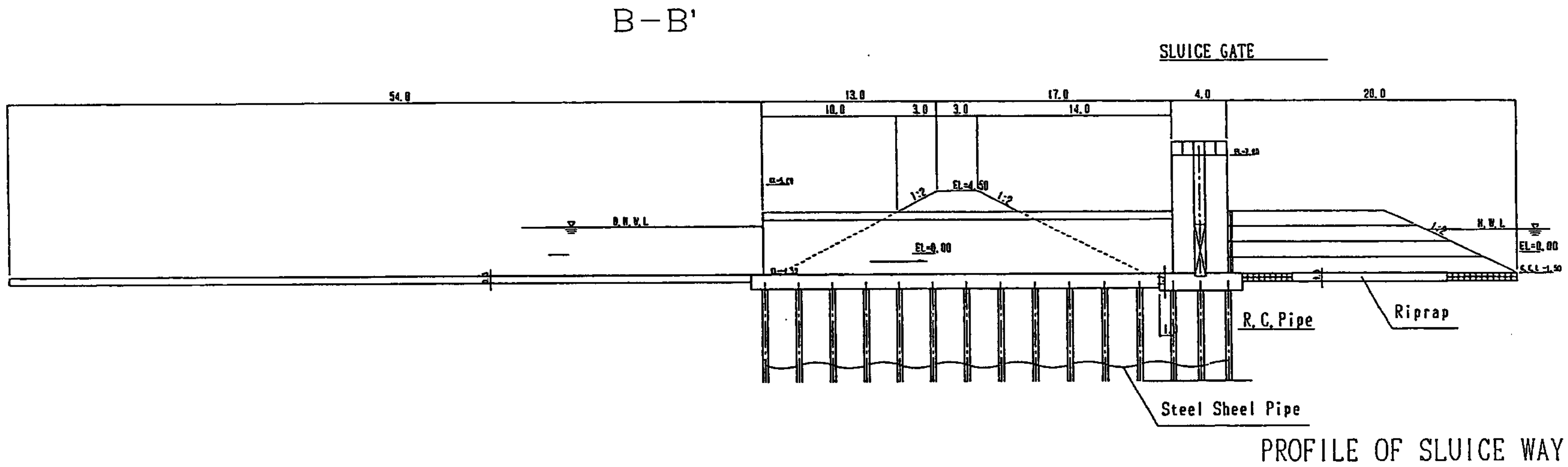

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Figure XIV 5.7
Profile of Sluice Way at Tibu

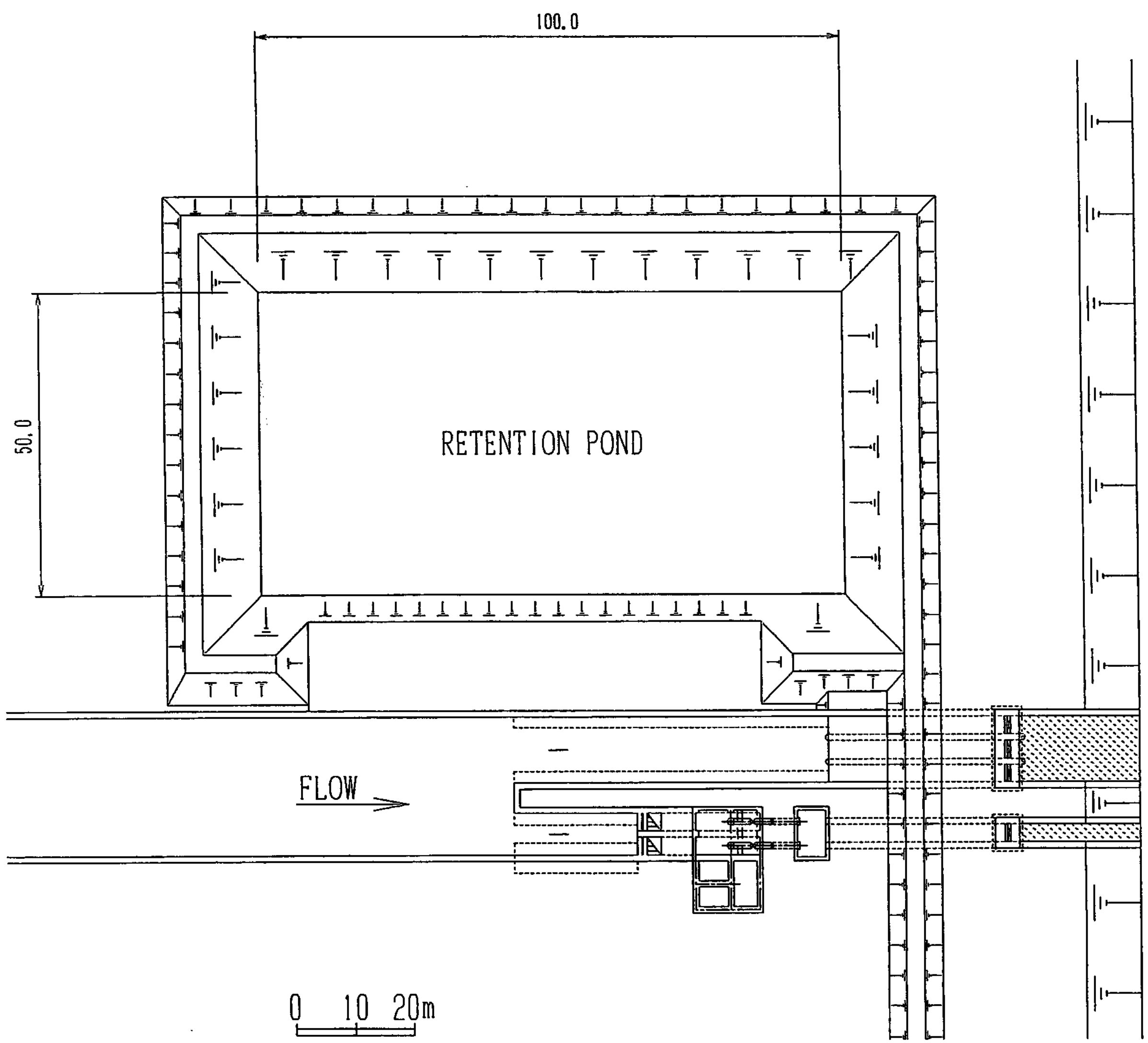

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Figure XIV 5.8
Plan of Retention Pond at Tibu